COSTRUZIONI STRUMENTI OFTALMICI

PHOENIX 3.6

USER'S MANUAL

COSTRUZIONE STRUMENTI OFTALMICI

Via degli Stagnacci 12/E | 50018 Badia a Settimo | Scandicci (FI) | ITALY
phone: +39 055 722191 | fax: +39 055 721557

cso@csoitalia.it | www.csoitalia.it

EN

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INTRODUTIONS | DISCLAIMER

Each device manufactured, marketed and / or otherwise placed on the market - directly and / or indirectly by CSO is made in accordance with the provisions and regulations in force in their user manuals contain the necessary information to ensure intended use and to identify the manufacturer, whilst taking into account the training / experience and knowledge of its intended users.

This information, including that contained in the accompanying manuals for our products and our technical advice, whether verbal, in writing or by way of demo and experiment, is provided on the basis of our best knowledge.

However, they must be considered as information without any binding effect, including those with respect to any industrial property rights of third parties, and do not exempt the customer from checking the current versions of our advice and suggestions, in particular of our material safety data sheets, instruction manuals and technical information, and products supplied by us, in order to estimate their suitability for the intended purpose and processes.

The application, use and processing of our products and the products manufactured by the customer on the basis of our technical advice and / or maintenance activities occur outside of our control and fall, therefore, entirely under the customer's own responsibility, for which CSO assumes no responsibility as set out below.

The technical results and / or data resulting from handling or use of our devices must be analyzed by experienced professionals in various fields of application of the specific product being otherwise compromised the correct reading and analysis of data.

The sale of our products is governed by our General Conditions of Sale and Delivery as amended.
The software provided by us in conjunction with our products or otherwise made available for download on your computer or for use online are the exclusive property of CSO which disclaims any responsibility for the accuracy of the results obtained with the programs or algorithms used by the programs themselves or liability resulting from the incorrect use of the software.

For data security, please refer to the management of Windows security. It is recommended to enter a password to access the account used.

Before performing an upgrade of the application or the archive, and / or at least before any maintenance operation, we advise to make a backup of the complete patient database. It is also recommended you periodically (every week at least) make a backup on a different medium of the one normally used (e.g. CD-ROM or DVD). CSO srl bears no liability for loss of data due to improper handling of the archive.

All measured data, calculated and interpreted and subsequently displayed to the user must be considered subject entirely to customer's responsibility. CSO remembers that any data and / or information arising from the use of the above software must necessarily be compared and verified with results from other devices in order to verify the exact calibration of the instruments and their proper functioning according to the specific parameters provided by the customer.

It should be noted, more specifically, that the indices of keratoconus screening provide mere indications which however are not sufficient for assessing either instrument calibration status nor the patient's clinical situation. Therefore, these indices are considered tools that the user can use to provide a diagnosis but cannot be considered themselves a diagnostic interpretation of keratoconus. Therefore, we recommend the user to exercise caution in evaluating these values and to correlate with other indices of screening tests and the clinical picture of the patient.

CSO does not assume any responsibility for damage of any kind howsoever arising and especially the application of the results of the Summary of Cataract in the software, including those arising from an incorrect calculation of the IOL. The user of the program must verify by plausibility considerations that the proposed values do not contain gross mistakes.

CSO assumes no responsibility and makes no guarantee of accuracy, calibration and / or exact measurements provided by the Products and / or software with which they operate even if provided by the CSO itself. Consequently, CSO will not and cannot be held responsible in any way or for any reason for any direct, indirect, consequential in general, of image, or profit loss, or moreover of any kind or species whether they are persons, property or other equipment or products that the customer complaints as a direct or indirect consequence of the use of our products and our software.

INTRODUTIONS | WHAT'S NEW

V. 3.4 (3.4.0073)

Application	3.4.0.73
Live	
	3.4.0.73

What's new

» Added favorite image on gallery
» Windows 10 Full support
» New instrument: AS-OCT (Anterior Chamber OCT)
» Enhanced instrument: Cobra "Plus"
» Tear-analysis eye blink missed detection fixed
» Optimized white balance in Keratoscope and Slit lamp
» Software activation fixed for SW upgrade ("P-?" in license field)
» Startup crash "Cannot draw overlay when LiveControl property is not set" fixed
» Improved movie recording for Slit Lamp and Keratoscope movie modes
» "Reprocess all acquisitions" feature introduced for Scheimpflug, Keratoscope, OCT, (Topo)Aberrometer
» Missed optical cup-disc detection fixed
» Updated online support
» Fundus Camera acquisition improved, max number of mosaic tiles was increased from 7 to 9
» Speed up mosaic creation
» Added function for "best image", contro-lateral navigation
» Tight integration with user manual (CHM format)
» Aligned statistical analysis for topographic acquisitions
» Quality indices for (Topo)aberrometer
» Epithelial indices OCT
» Toric IOL assistant (Topoaberrometer, Scheimpflug camera)
» Added NTSI on topographic and wavefront maps
» Visualize c40, K1ref, K2ref

V. 3.2 (3.2.1020)

Application	3.2.1.20
Live	
	3.2.1.20

What's new

» Web activation: simplified online registration
» Added smartcard support for data entry
» Pupillography contro-lateral comparison
» Lens DB update
» Schwind bugfixes
» Bugfixes (#775)
» Fundus Camera: Enhanced mosaic generation algorithm
» Fundus Camera: Added support 5Mpx USB3
» Slitlamp: Updated USB3 support
» Slitlamp: Re-introduced Cup-to-Disc measurement
» Topographers: Graphic for tearfilm Breakup time
» Topographers: Added mean BuT
» Topographers: Tear analysis comparison
» Topographers: added acquisition tear meniscus
» Topographers: Added scale steps
» Aberrometer: various enhancements
» Print: Enhanced report functionality (print update)
» Print: Customized print for various follow-up functions (keratoconus, refractive surgery, acquisition stats)
» New example DB
» Linear calibration onboard on device
» Enhanced ICRS

» Added PTI Graph
» Added indices for lens rise / lambda intercept
» Further PMS integration (external Phoenix GUI override)
» DICOM handling patient's without first name

V. 3.1 (3.1.1031)

Application	3.1.1.31
Live	3.1.1.26

What's new

» Slitlamp USB3 support
» Tearfilm analyzer adjustable timeline
» Quality statistics (Scheimpflug, Keratoscope, Aberrometer)
» Added follow-up for keratoconus and refractive surgery
» Updated statistics LSA / OPD Normality
» Optimized ZCS import (multiselect)
» Changed ordering main gallery (identifier X-Y)
» Configurable BCS Export
» Optimized visualization of high-res images
» Optimized measurements
» Optimized printing features Cobra
» Optimized color quality for Cobra
» Bugfixes (#744, #765, #766, #767, #768, #769)

Known issues

V. 3.0 (3.0.1021)

Application	3.0.1.21
Live	3.0.1.21

What's new

» New Instrument: (Topo-)Aberrometer (USB3)
» New Instrument: Color Keratoscope (USB3)
» New instrument: Tearfilm analyzer
» Advanced printing fundus
» A/V Ratio analysis on Cobra
» Toric IOL handling improved
» Enhanced handling of meibography
» Enhanced driver and firmware installation GUI
» Added exam description
» Enhanced main gallery performance
» Added layout functionality
» Added language Chinese
» Show refraction on main gallery
» Bugfixes (#704, #722, #730, #735, #736, #737, #738, #740)

Known issues

» It is not possible to configure storage commitment on the DICOM configuration (#745). It might lead to mis sed echo requests, when the configured partner actor tries to 'back-ping' on the local port. Workaround is to set the local port to 0.

V. 2.6 (2.6.4000)

Application	2.6.4.0
Live	2.6.4.0

What's new

» Changed PDF creation (using proprietary virtual PDF printer)
» Updated 64-bit drivers
» Enhanced mosaic handling on fundus acquisitions
» Auto-focus on Cobra acquisition
» Enhanced Web Service access
» Added Shortcut to calibration procedure for Keratoscope and Scheimpflug camera
» Bugfixes (#672, #677, #695, #697, #699, #700, #701, #703, #707)
» Capture 64-bit acquisition

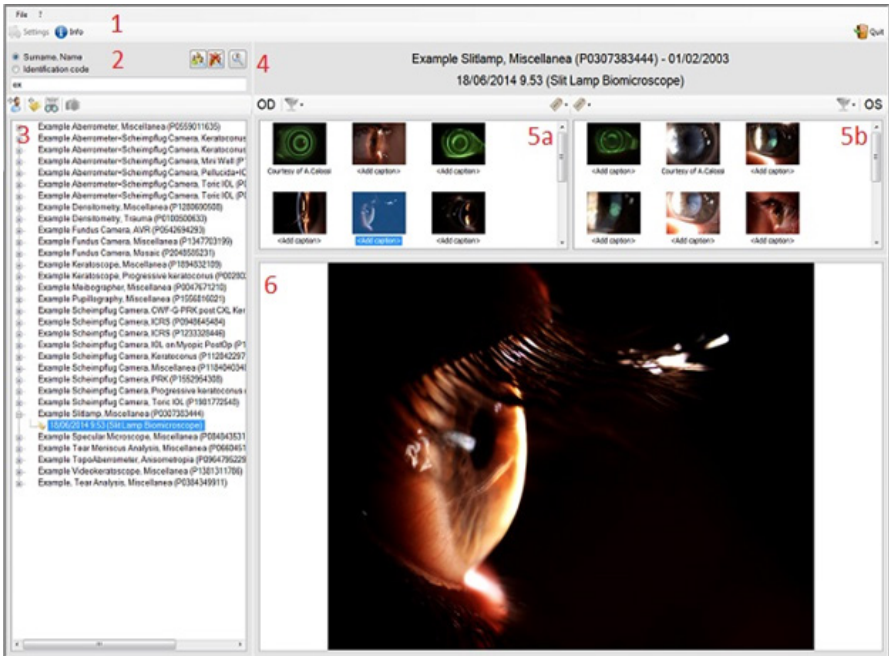
Known issues

» Install configuration for Capture, in combination with Sirius or Cobra:
- Install Capture, and disconnect once installed;
- Install Sirius / Cobra;
- Reconnect Capture

This is caused by a driver conflict between the Sirius/ Cobra driver and the Capture driver [Bug #694]

MANAGING PATIENTS AND EXAMINATIONS

When the program is launched, the **Main Screen** is shown.
This first screen allows the user to manage the database of patients and the examinations associated with each. It is made up of various sections and menus.



1 - Menu and Toolbar
2 - Patient Search panel
3 - Patients/Examinations list
4 - Patient/Examination information resume
5 - Right eye and Left eye gallery 5a - and 5b
6 - Acquisition preview

MENU AND TOOLBAR

A menu and a toolbar are displayed at the top of the screen: a short description of the functionalities and options associated to its items follows.

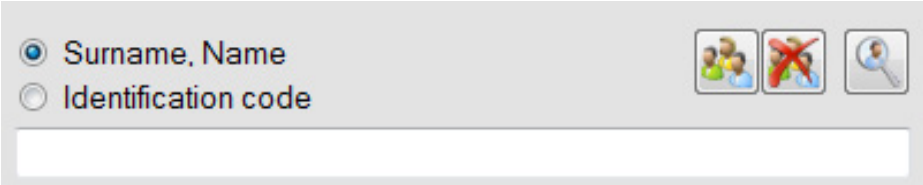
FILE

	SETTING	Allows the user to select the software language, manage groups, instruments and other settings. This menu may be accessed only if the patient list is not displayed. If patients are displayed in the list, click the **Clear Patient List** icon to enable the Settings function.
	IMPORT	Allows the user to import zcs file.
	QUIT	Exits the application after confirmation of the warning message.

INFORMATION

	ABOUT	Shows information on the software release.

PATIENT SEARCH PANEL



Each patient is identified by Surname (Last Name), First Name, and an Identification Code.
A patient already listed in the database can be selected in a number of different ways:

» Type a last name and first name in the Patient Text Box. In order to insert the last name and name correctly you must type: **Last Name, First Name**, without spaces (Eg **Smith, John**).
If the typed name does not correspond to any patient already present in the database, press Enter to open the win dow for entering a new patient.

» Type in a part of the Last Name, First Name string to display a list of patient names meeting the criteria. To select a particular patient, proceed as described in the previous point. For instance, you may display all the patients whose names begin with a given letter, or who have the same last name, or who have the same last name and the same first-name initial, etc.

As the letters or numbers are typed, the pull-down list will display patients meeting the criteria. If the typed characters do not yield any results, a warning icon will appear.
The warning icon is also displayed if an excessive number of results is returned.

» Click the  icon to fill the list and use the ↑↓ keyboard keys to scroll the patient list or select a patient directly from the list. With the Patient Box empty, press Enter or double-click the highlighted patient name.

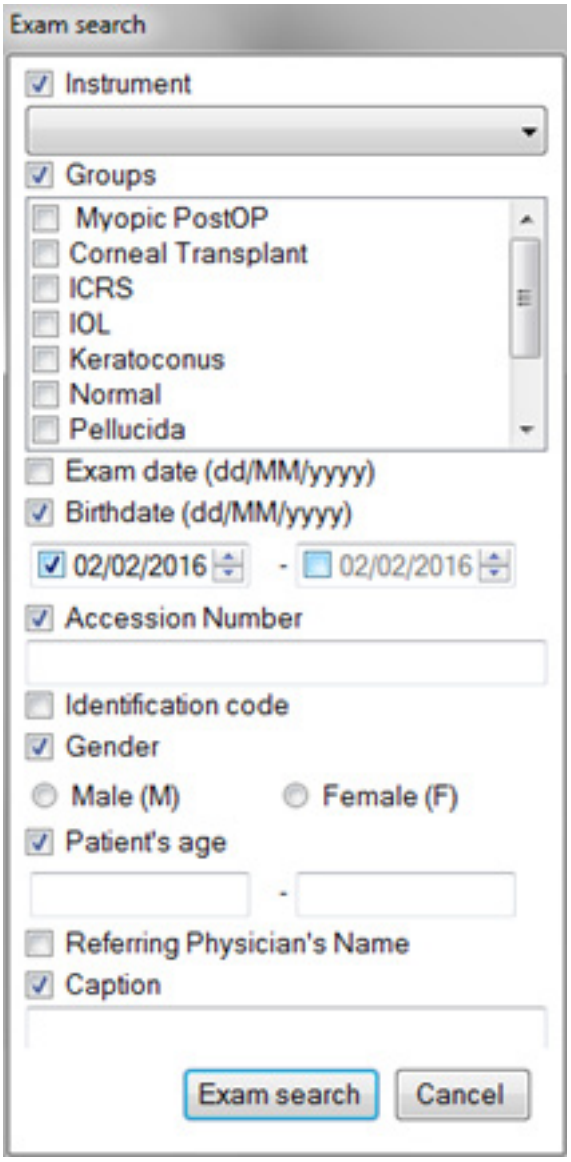
To select a search criterion, click the button alongside Last Name, First Name or alongside the Identification Code.
To view a patient, type his/her Last Name, First Name (or Identification Code) in the Patient Box. As the letters or numbers are typed, the pull-down list will display patients meeting the criteria.

Press the Empty Patient List  icon to empty the contents of the window in which the patient list is displayed (this will not delete the patients from the database) or the Advanced Search button  to perform a search by gender, date of birth, check-in number, examination date, patient age, referring physician, instrument, or group.

A patient archive may be expanded by clicking the + button to the left of the name in order to show the list of associated examinations. An unlimited number of examinations may be associated with each patient; the examinations are defined on the basis of the instrument used and the date of creation.

ADVANCED SEARCH

Click the icon in the Patient Search panel, to access the advanced search function.



For each of these categories, checking the button shows the boxes for entering search criteria:

» by gender: male or female

» by date of birth: start and end dates of the interval to be se arched

» by check-in number: a box for entering the number; this field features the automatic completion function

» by examination date: start and end dates of the interval to be searched

» by patient age: minimum and maximum age

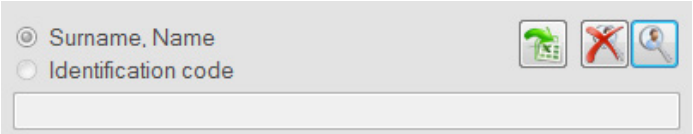
» by referring physician: a box in which to type the physician's name

» by instrument: a list of possible examination capture instruments (for example, Fundus camera, keratoscope, pupillo grapher, Scheimpflug camera, slit lamp biomicroscope)

» by group: a list of the groups created via the Settings function

» by caption: the caption added to a single acquisition is used as a search parameter

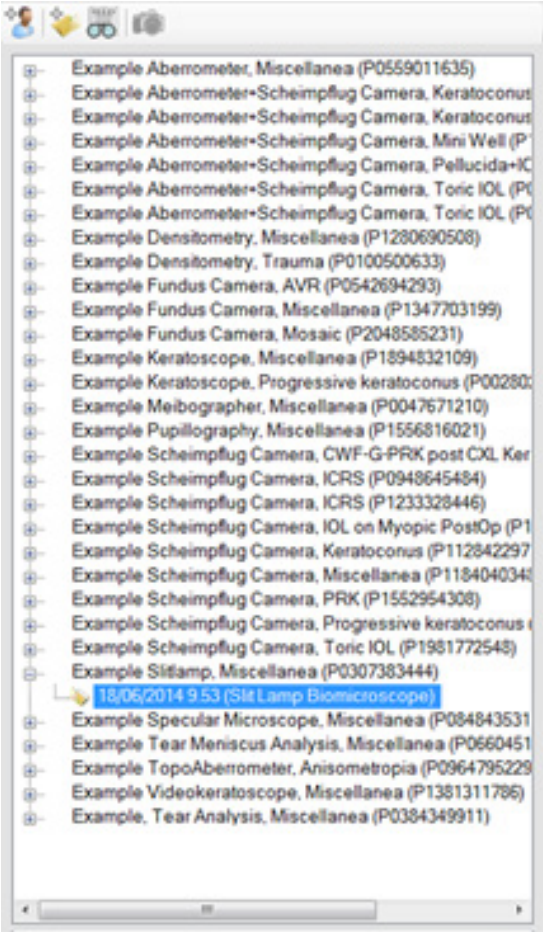
Once the Patients/Examinations list is filled according to the current search parameters the Patient Search panel changes as follows:



» The standard search for name or identification code is di sabled.
» Deletion or editing of Patient and Examination is not allowed as well as Patient and Examination creation.
» The software allows for an index export in csv format of the acquisitions belonging to the current examination list by pressing the icon.

» Click the icon to close the Advanced search mode and to return to the standard search mode.

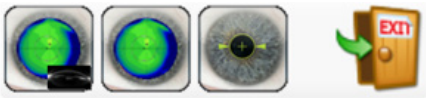
PATIENTS | EXAMINATIONS LIST



The Patient/Examination list shows every patient and examination matching a standard or an advanced search.
The fist level shows the patient list in the format Surname, Name (Identification code).
Once a patient has been selected, click the + button or press Enter or double-click with the mouse to expands the list of examinations associated or the – symbol to collapse the list.
Alternatively, the list can be expanded by pressing the → arrow key on the keyboard and collapsed by pressing the ← arrow key.
To select a previously-stored examination, use the mouse or scroll with the ↓↑ keyboard arrows to highlight one examination after another and, for each, view the relative images in the window on the right-hand side of the screen.

After an examination is created the Right eye and Left eye gallery is filled up with the acquisitions belonging to the current examination.

A toolbar is displayed at the top of the screen: a short description of the functionalities and options associated to its items follows

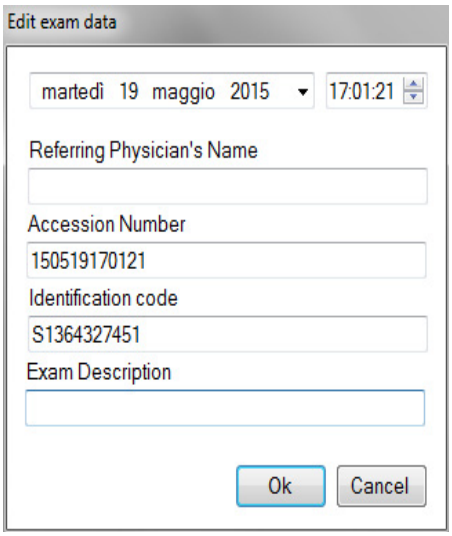
New Patient	Allows for the creation of a new Patient. After a new patient is created, an examination will also be created.
New Examination	Allows for the creation of a new Examination: if working with a single instrument, the image capture mode will be automatically accessed. Otherwise, if at least two instruments are used, the window shown below will open.  Select the instrument to be associated with the examination: after selection, the capture mode is accessed. Each examination is filed by date of creation and instrument type.
Edit refraction	It allows for the Refraction editing associated to a given examination. This becomes active when an examination is selected.
Acquire	It permits the selected instrument to capture the exam and accessing the capture environment. This icon becomes active when a new exam is created or when an empty exam is selected.

Contextually to what is selected (Patient or Examination) a menu is associated to the right click on the list:

PATIENT CONTEXTUAL MENU

Edit Patient	It reopens the patient data window for editing the last name, first name, date of birth, and/or gender.
Delete Patient	Allows for the patient deletion after confirmation of the warning message. **Warning:** deleting a patient also deletes all the examinations associated with that patient and the relative images.
Export	Save a zcs file containing the patient information and all the examinations belonging to the patient to be re-imported in another software program.

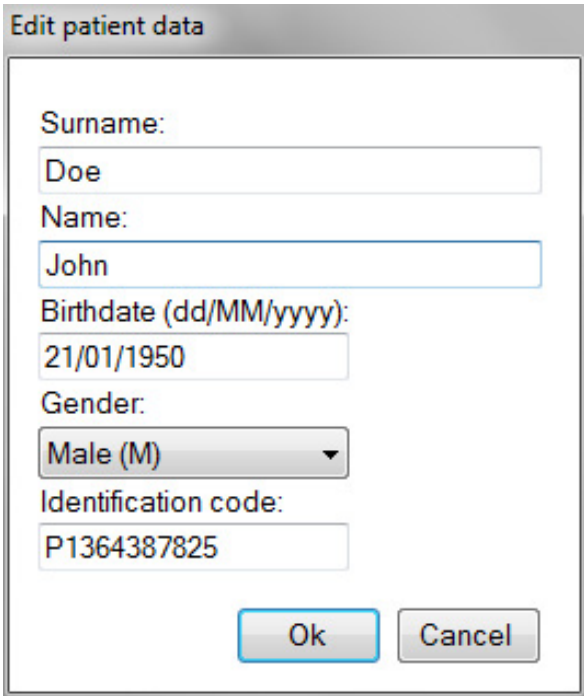
EXAMINATION CONTEXTUAL MENU

Edit Examination	Opens a window in which the user may edit the date and time of the exam, enter the name of a referring physician and add a description of the exam. 
Delete Examination	Allows for the deletion of the current examination from the database after confirming the deletion request warning message. **Warning:** deleting an examination also deletes all the images associated with it.
Send study	Send all the acquisitions belonging to the selected Exam to a PACS in DICOM format
Export	Save a zcs file containing the patient information and the current examination to be re-imported in another software program
Reprocess all measurements	This option is shown just in case of Topography or Aberrometry Exam. Allows to reprocess all the acquisitions belonging to the selected Exam.

PATIENTS CREATION

To enter a new patient in the database, click the  icon on the Patients/ Examinations list
Last name, First name, Date of birth, and gender mast be entered on the input window.

Date of birth must be entered in accordance with current windows settings: entering an invalid date will cause a warning icon to be displayed.
Entering a patient whose data are identical to those of another patient already contained in the database will likewise open a window containing a warning message.
The identification code is automatically entered by the system unless a different option is selected from the Settings menu.
To confirm new patient entry, press **OK** button. To cancel, click **Cancel.**
Whenever a new patient is created, an examination associated with that patient is also created.

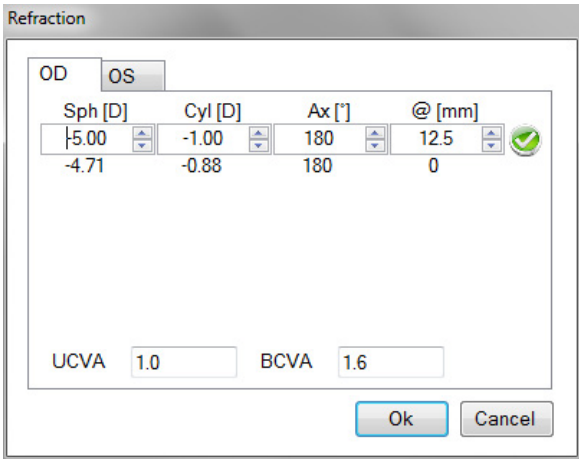


REFRACTION EDITING

Two labels permit opening the right eye (OD) or left eye (OS) chart.
Enter the values of the sphere in diopters (Sph), the cylinder in diopters (Cyl), the cylinder axis in degrees (Ax), and the distance to test eyeglass in mm (@) in the relative fields.
Once the refraction is a valid one the system calculates the refraction at the corneal vertex. If the data is incomplete, the warning icon will appear. If the data are correctly entered, the icon will be displayed.

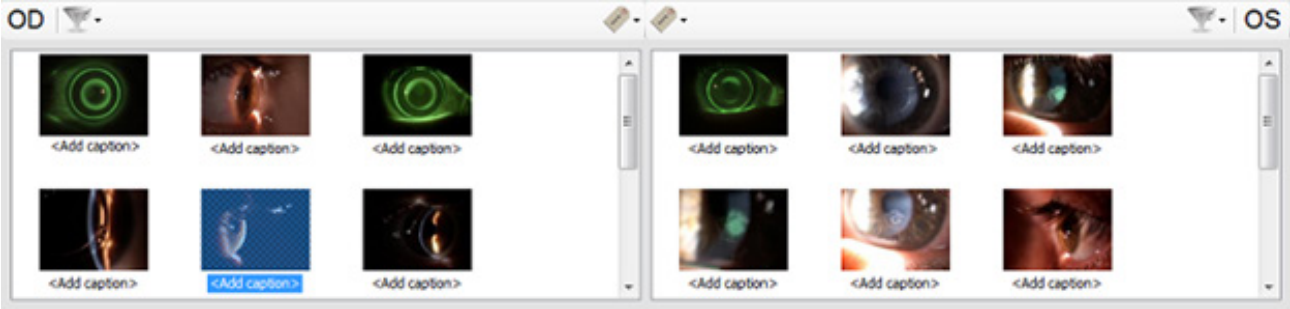
The patient's natural visual acuity is entered in the UCVA (Uncorrected Visual Acuity) box; the maximum visual acuity attainable with correction is entered in the BCVA (Best Corrected Visual Acuity) box.

The Cancel button closes the window without saving the changes. To save the entered data, click the OK button.



RIGHT AND LEFT EYE GALLERY

When an exam previously stored in the Gallery on the right-hand side of the main screen is selected the gallery will show the images relative to each exam as it is selected.
The images are subdivided by OD (right eye) and OS (left eye).



Images are browsable by selecting one of the thumbnail in the gallery: when selected it displays a preview of the summary of the selected examination in the lower portion of the screen.
The caption of the thumbnail can be edited in order to insert comments and notes.

Double-clicking an image opens the processed image summary, according to the exam type:

Groups
A type group may be associated to each eye of each examination: cataloging the examinations by homogeneous type groups is useful as a search aid.

Click the  icon to open the pull-down menu of the entered groups and select one of the existing tag.
To enter the eye being examined in a yet-to-be-defined group, select <new group>: it opens a box in which to enter the name of the new group.

The  icons permit associating current group to the follow eye (the right eye group with the left, and vice-versa).

Filters

You can filter the list of thumbnails in the gallery by selecting one of the filter elements from the dropdown menu  :
All (default choice), only images, only reports, only movie frames, only lenses or only mosaics.

SETTING

The Settings menu can be accessed only if the Patients List is not displayed on the main screen. Click the icon to empty the patients list. Then click or open the File menu and select Settings.

Language

Allows the selection of language to be used by the software.
Available choice are:

» Chinese
» German
» English
» Spanish
» French
» Italian
» Dutch
» Portuguese

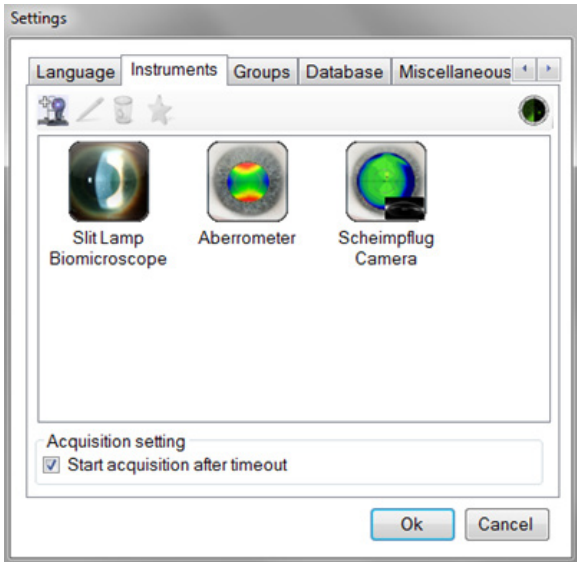
Settings: Language settings panel

Instruments
This section allows for managing the instruments to be used.

To proceed with an automatic setup of all the instruments to be used, connect all the instruments to the PC and press the Instruments wizard icon.
A window with the instruments to be installed will be shown. Check/uncheck the check-boxes to add/remove the exam from the list and press configure to start the procedure: after the system has automatically installed the instruments and, when necessary, the calibrations have been performed the examinations will be shown in the list.

To proceed with a manual setup of the instruments to be used press the icon: the Manual editing window will be shown.

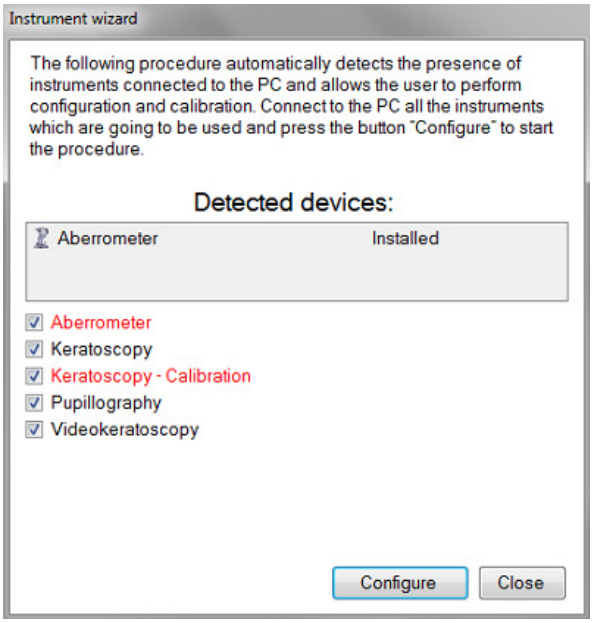
The device class has to be selected between: Aberrometer, Densitometer, External Camera, Fundus Camera, Keratoscope, Meibographer, OCT tomographer, OCT section, Pupillographer, Scheimpflug camera, Slit Lamp biomicroscope, Tear analysis, Video.
The Model Name has to be typed: this name will be reported alongside the exam.



Settings: Instruments settings panel

According to the device class the executable file to be associate have to be selected by the following table:

Aberrometer	**ALive.exe**
Densitometer	**SCLive.exe**
External Camera	**OpenFiles.exe**
Fundus Camera	**RMLive.exe**
Keratoscope	**SCLive.exe** for Modì **KLive.exe** for Antares **ALive.exe** for OsirisT and PERAMIS
Meibographer	**SCLive.exe** for Sirius **RMLive.exe** for Cobra **KLive.exe** for Antares
OCT tomgrapher OCT section	**OLive.exe**
Pupillographer	**CLive.exe** for Sirius and Modi **KLive.exe** for Antares **ALive.exe** for Osiris, OsirisT and PERAMIS
Scheimpflug camera	**SCLive.exe**
Slit Lamp biomicroscope	**SLLive.exe**
Tear analysis	**SCLive.exe** for Sirius **KLive.exe** for Antares
Video	**KLive.exe** for Antares **ALive.exe** for Osiris, OsirisT and PERAMIS



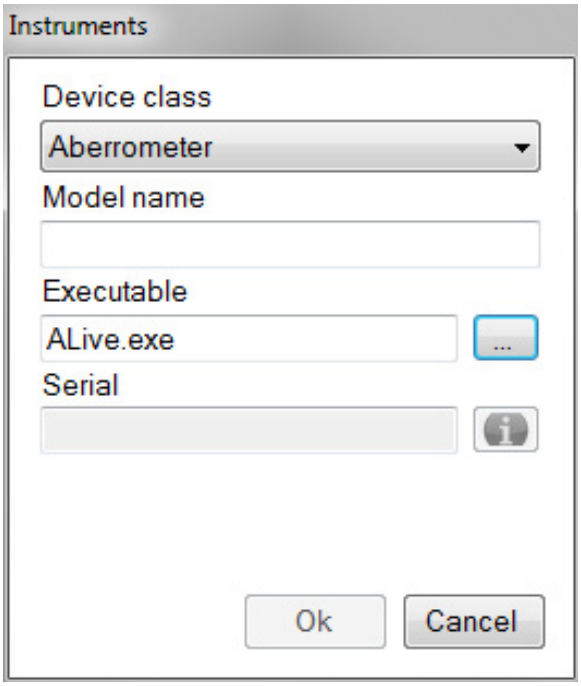
Instruments wizard

The icon permits editing an existing instrument.

To eliminate an instrument from the list, select it and click

If the device needs a calibration click the icon to start the calibration procedure.

If the Start acquisition after time out check-box is checked, the default examination live will be launched automatically after 5 seconds. When not checked, the acquisition choice screen will be shown until the user makes his choice. The icon allows the selection of the default exam.

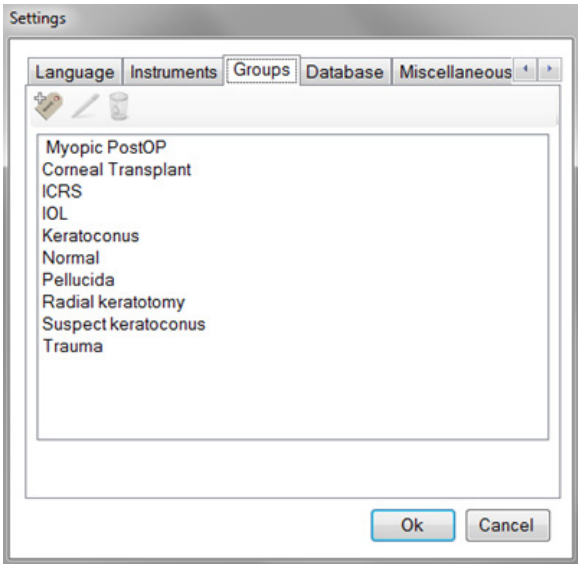


Manual editing for instruments

GROUPS

A type group may be associated to each eye of each examination: cataloging the examinations by homogeneous type groups is useful as a search aid.

Click the icon to add a new group, the icon to edit a pre-existing group or the icon to delete a group. and go active when a group in the list is selected.



Settings: Groups settings panel

DATABASE

Warning: this section should be handled with caution. Editing database management could result in loss of all patient data and existing examinations.

Default database path and options should never be changed unless there is a real need (for example connecting to a database file located on an remote server).

Click the  icon to unlock database paths editing.

Database: Sets the path for the Database .mdb file. This file contains all data related to patients, examinations, groups etc.

Image root: Sets the path for the image root file. Such file consists in a position-marker, meaning that the directory that contains this file is used to store all the images acquired by the software. Please note that images are not stored in the database .mdb file as they require a stand-alone directory in the hard drive.

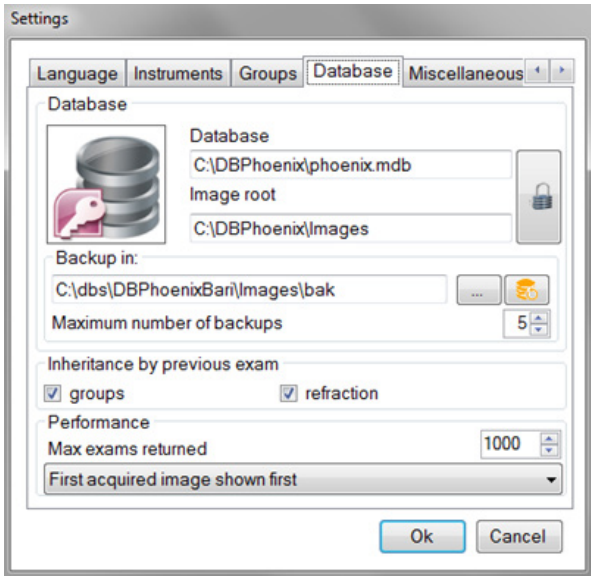
Backup in: Sets the path where to backup the .mdb file. Images will not be backed up automatically. Use the numeric counter to set the maximum number of backups allowed in the backup folder.

Backup now: Click the  icon to create an instant backup of the database.

Inheritance by Previous Exam: When the Groups and Refraction option boxes are selected, each new exam is attributed the group and the refraction data of the last exam created.

Performance: Sets the maximum number of examinations shown in the main patient list. Increasing this value could slow down the system.

The combo box below sets how the acquisition thumbnails are shown in the preview galleries when an examination is selected in the main patient list. By default, the first thumbnail is the oldest acquisition in the time line.



Settings: Database settings panel

MISCELLANEOUS

Patient Management

Deselecting *Who issues Patient IDs* also deselects the other two options (Phoenix and PMS) and it will be possible to insert the ID code at the moment a patient is created.
If this option box is instead selected, it will not be possible to enter the ID code manually. Select one of the following two options:

» Phoenix: the ID code is automatically assigned by Phoenix when a patient is created.

» PMS: The ID code and relative personal data will be cross loaded to Phoenix from an external database. The ID of the agency or institution providing the data must be entered in the field alongside the PMS item. Note that in the latter case, the patient entry icon is not active.

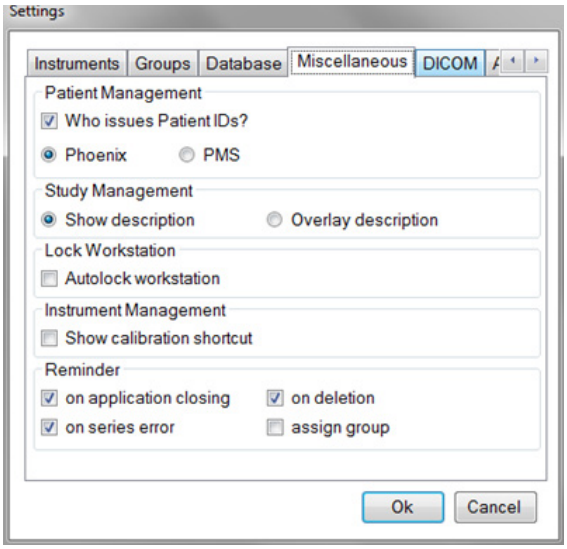
Study Management
When Show description is selected, the study description is shown in the main patient tree.
Otherwise the description is visible in overlay (meaning, that when the mouse passes over the examination, the description is visible as a tooltip.

Lock Workstation
Selecting Autolock workstation allows for an automatic lockdown of the workstation PC after a given number of minutes. Note that selecting this option Phoenix also returns to the main screen and empties the patient list.

Instrument Management
When Show calibration shortcut is selected, the main gallery shows shortcuts to the calibration procedure for both Scheimpflug camera as Topographer.

Reminder
The user may select among the following options:
Close application: displays the message requesting confirmation to close the application.
Delete: displays the message requesting confirmation to delete an image from the gallery
Series error: this warning is given when traces of images erroneously moved to other folders or files remain in the examination in question.

Assign group: after performing an acquisition a reminder is presented for classification (group assignment) of the assigned series



Settings: Miscellaneous settings panel

DICOM

DICOM is a medical computer standard adopted by many health agencies and hospitals in all parts of the world, which permits medical operators to exchange images and other information via computer systems adopting this standard. Deselect the “Suppress DICOM messages” box to show any errors that do not interfere with image capture.

If DICOM is instead selected, the remaining menus must be used.

Click the PACS or PMS button to open the following windows:

This window allows the user to identify the PACS system that will receive this information or the PMS system from which information may be requested.
In the relative fields, enter:

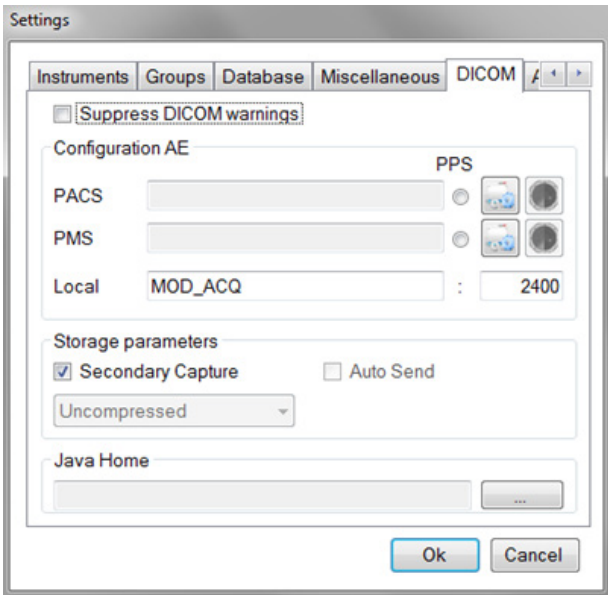
» Title: PACS/PMS ID.
» Host: PACS/PMS IP address.
» Port: PC port to which PACS/PMS is referred.
» Timeout(s): maximum waiting time before disconnecting a call.
» Limit: for PMS configuration only, identifies the maximum number of exams that may be received. If the field is left blank, any number of exams may be recei ved.

Clock [OK] to save the settings as entered; otherwise click [Cancel].
Click [Ping] to initiate a call to the PACS/PMS system.
Click [Reset] to remove PACS/PMS Setting

Under local you can configure the local Application Entity name and port.

The Storage Parameters allow the user to specify several data storage options:
» Secondary capture: by choosing this checkbox, the secondary capture will be sent, instead of the original acquisition. This is in fact the image that is shown in the gallery, created in a second moment, after original acquisition.
» Auto-send: by choosing this checkbox, Phoenix will be configured to send images immediately after acquisition. This option is not available when secondary capture is chosen.
» Lossless: select this box to select the type of compression used for sending, in a 5% to 100% ratio in 5% steps, in .jpeg format. Otherwise, the files are sent in the original, uncompressed format. Note that this principal is based on a best-first algorithm:
when images are originally acquired uncompressed, all compression options can be performed; when the image is acquired lossless, it can be forwarded also l ossless, but not uncompressed; finally, when the image is acquired lossless, it can’t be forwarded other than lossless. This option is not available when secondary capture is chosen.

This parameter, defining the environment required for using the functions offered by DICOM, is configured at end of software installation.



Settings: DICOM settings panel

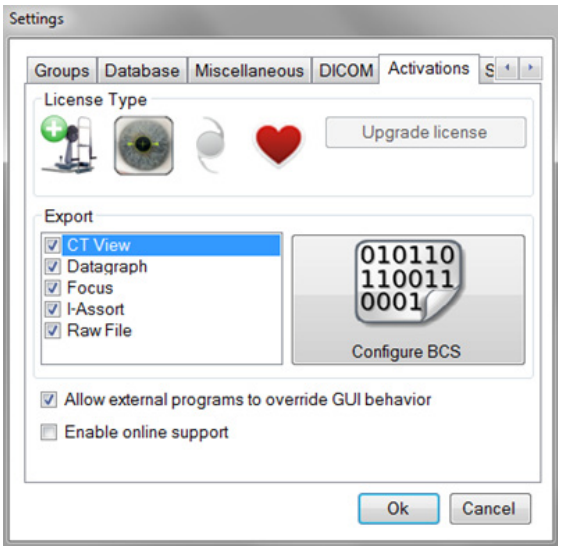
ACTIVATIONS

This section provides information about the current license type.

Also, it is possible to upgrade the current license module upon requesting your vendor or contacting support.
Click Upgrade license to start an upgrade request.
The upgrade procedure is faster when Internet access is provided, as described in the activation section.
When Internet access is available, make sure that the Enable online support checkbox is selected too.

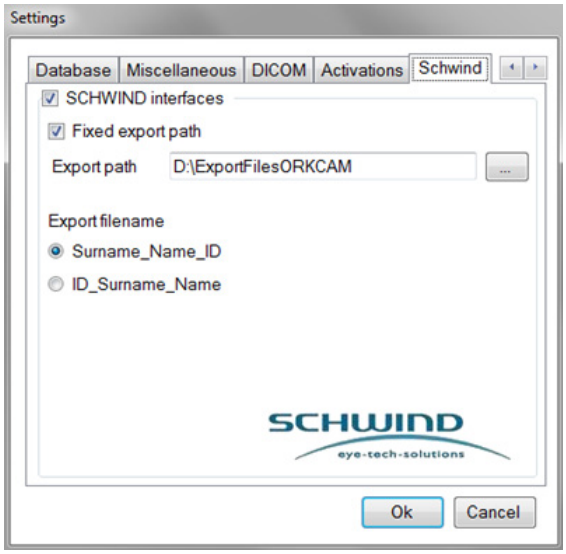
The Activations section also allows data export to external applications configuration.

For a number of external applications it is possible to configure the export on the main gallery. The default can be chosen from the combo box. Check the reminder if you want a reminder message for exporting both eyes contemporarily to the external application. BCS is a standard binary format, to which a growing number of contact lens manufacturers are conveying. Ask your vendor for a complete list of manufacturers.



Settings: Miscellaneous settings panel

SCHWIND

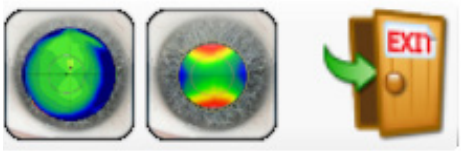


Settings: Schwind settings panel

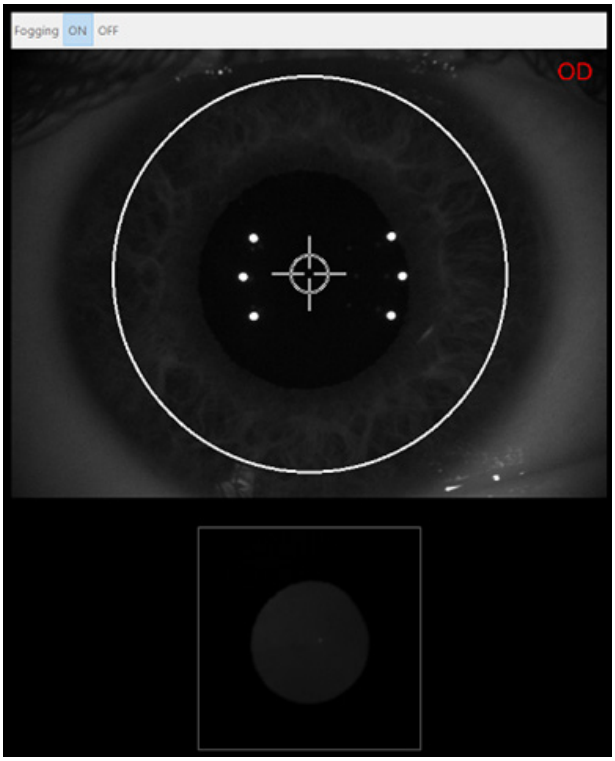
EXAMINATIONS | ABERROMETRY

ACQUISITION

The  icon on the main screen becomes active when a new examination is created or when an empty exam is selected.
Clicking the icon opens the window for selecting the instrument with which to capture an aberrometry.



To capture an aberrometry, select the icon  . The instrument will automatically set to the image capture mode and a live capture window opens.



Acquisition

CENTERING AND FOCUSING

To correctly center the instrument, position the cross-hair target between the reflected white spots. To obtain the correct position move the joystick right or left to perform horizontal movements, or turn the joystick clockwise-counterclockwise to perform vertical movements. Once the instrument is centered focus the image of the iris by moving the joystick back and forth.

ACQUIRE

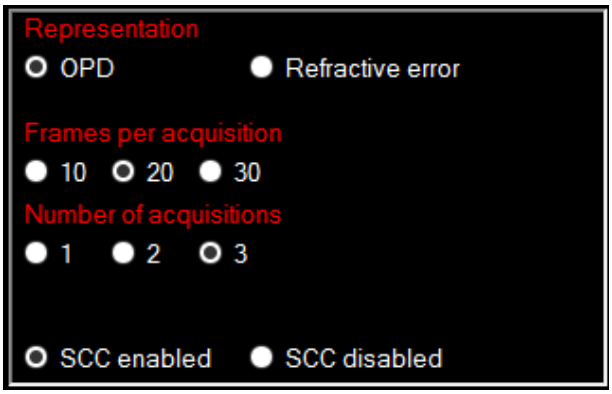
When the instrument is centered and focused at the correct distance, press the button on the joystick and wait the device to perform the full aberrometry capture. Once the images is captured a thumbnail is shown on the left or right side of the screen according to the acquisition laterality.
If the **Fogging buttons** was set as active the last step of the acquisition will be a fogging procedure else the fogging will be skipped.

CYCLOTORSION IMAGE CAPTURE

If the option SCC is activated, a cyclotorsion image capture will follow the aberrations measurement. Visible LEDs will light up in order to minimize the pupil diameter. Ensure the image remains focused while the time-lapse image capture process takes place: this will allow for the correct processing of the iris structure.
If the cyclotorsion acquisition succeeds, and the image turns out to be useful, no further images are required for the eye under examination. If the image does not correspond to minimal requirements for the acquisition of an image with cyclotorsion, the image capture process has to be repeated.
he program returns to the main screen.

IMAGE STORAGE AND PREVIEW

It is possible to manage the images in the gallery, by selecting whether an acquisition have to be saved or deleted. By right-clicking on the small thumbnail of the acquisition on the gallery a preview is shown instead of the live panel. A double left click on the thumbnail will set the relative acquisition as "to be deleted", the thumbnail will be marked with a litter bin, and will be not saved once the live session is over.



Aberrometry settings

OPTIONS

To access to the acquisition settings click on the  It will be possible to select between OPD and refractive error representation, or to chose the number of acquisitions per session and the number of frames per acquisitions. From this panel is also possible to activate/deactivate the cyclotorsion image capture.

To toggle in live press the settings icon back.

Once all the images needed have been captured, the capture environment may be closed pressing the  button; the program returns to the main screen.

Select one of the captured images to process it and access the Optical Analysis Summary.

ABERROMETRY MENU

A menu is displayed at the top of the screen: a short description of the functionalities and options associated with the icons follows.

FILE		
	Save screen-capture as image	Opens a window from which the current screen-capture can be saved in various image formats.
	Close	Closes the current analysis environment and returns to main page.
	Print screen-capture	Opens a window to set-up printing parameters and to print the current screen-capture.
	Print screen-capture (quick)	Directly prints the screen-capture.
	Export	Exports for external program.
	Quit	Exits the application after confirmation of the warning message.
EDIT		
	Edit Pupil/Corneal vertex	Opens the environment for pupil and corneal vertex editing. This displacement is shown on the right side of the screen of Optical Analysis Summary and is used as a reference for the calculation of the internal components of the wavefront.
ANALYSIS		
	Optical Analysis Summary	Opens up the default overview summary, containing information on aberrometry and refractive error.
	Optical Quality Summary	Opens up a summary report showing patient's quality of vision.
	Component Analysis	Opens up a screen where it is possible to analyze the effects of each single Zernike polynomial on visual quality.
	Images	Displays the image of the iris and pupil at acquisition time
	Comparison	Allows for a comparison of 2, 3 or 4 different acquisitions
	Differentials	Shows the difference-map between 2 acquisitions.
	Internal components	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.
OPTIONS		
	Options	Set-up user preferences for the display.
INFORMATION		
	About...	Shows information on the software release.

ABERROMETRY | TOOLBAR

A toolbar is displayed at the top of the screen: a short description of the functionalities and options associated with the Icons follows.

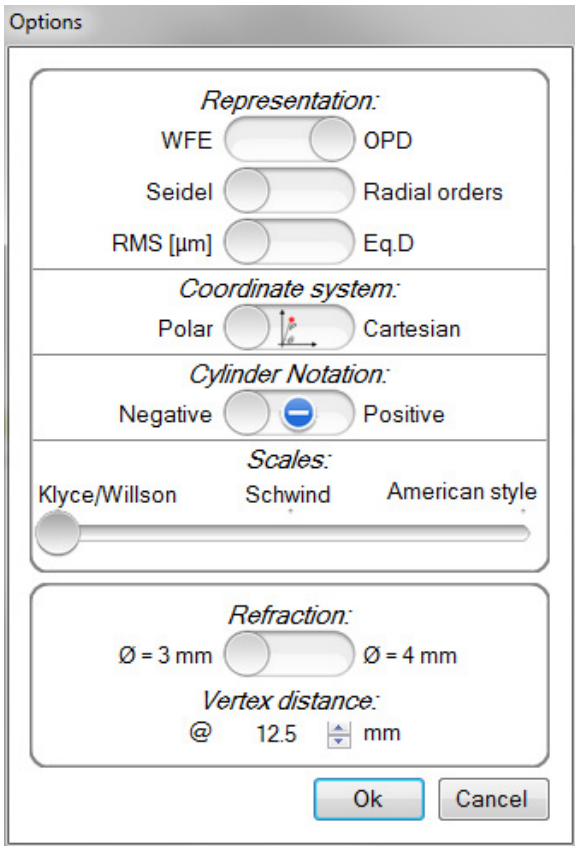
	**Optical Analysis Summary**	Opens up the default overview summary, containing information on aberrometry and refractive error.
	**Optical Quality Summary**	Opens up a summary report showing patient's quality of vision.
	**Component Analysis**	Opens up a screen where it is possible to analyze the effects of each single Zernike polynomial on visual quality.
	**Images**	Displays the image of the iris and pupil at acquisition time
	**Comparison**	Allows for a comparison of 2, 3 or 4 different acquisitions
	**Differentials**	Shows the difference-map between 2 acquisitions.
	**Internal components**	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.
	Export	Exports to external program.
	**Close**	Closes the current analysis environment and returns to main page.

ABERROMETRY | OPTIONS

The **Options** screen is displayed by:

» Choosing **Options** from the menu

User preferences for the way the representation of measured information is displayed can be changed here.



Optical Analysis Summary

REPRESENTATION

» **WFE/OPD:** displays the WFE (WaveFront Error) or the OPD (Optical Path Difference). OPD and WFE relate as follows: OPD(x,y) = -WFE(x,y)
» **Seidel/Radial orders:** displays the "Total Wavefront map", the "Higher Orders", "Astigmatism", "Coma-Like" (union of odd orders) and "Spherical-Like" (union of even orders).
» **RMS/Equivalent diopters:** RMS values for the aberrations will be shown in micron or in equivalent diopters. Coordinate system
» **Polar/Cartesian:** Each point position will be expressed in ρ (distance from center) and @ (position in degrees) or in x (horizontal distance from center) and y (vertical distance from center). Cylinder notation
» **Negative/Positive:** Negative or Positive notation will be used as cylinder notation.

SCALES

Three different color scales are available:

» Klyce/Willson

» Schwind

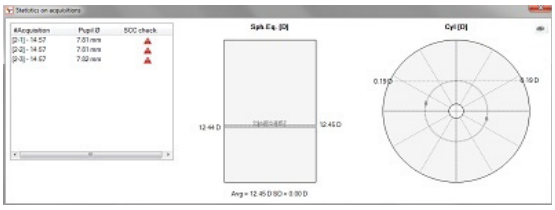
» American style

Refraction

The refraction will be evaluated using either a 3 or 4mm central pupil size. The refraction will be based on the selected **Vertex Distance.**

ANALISYS | STATISTICS ON ACQUISITION

Statistics on acquisition screen is displayed by pressing the Statistics on acquisition menu item of the Acquisition gallery contextual menu.



Statistics on acquisition

The aim of the form is to show quality and inter-reproducibility of acquisitions belonging to the same examination.

The screen is made up as follows:

» List of selected acquisitions: by selecting an item the corresponding map is shown and the corresponding index will
be highlighted. In the same row the pupil diameter and the SCC check result are shown as well.

» A scatter-box plot containing information on the Spherical Equivalent of the acquisitions.
» A radial scatter-chart containing information on the Cylinder and Axis of the acquisitions.

ANALISYS | OPTICAL ANALYSIS SUMMARY

Optical Analysis Summary is displayed by:

» Choosing **Optical Analysis Summary** from the Analysis menu

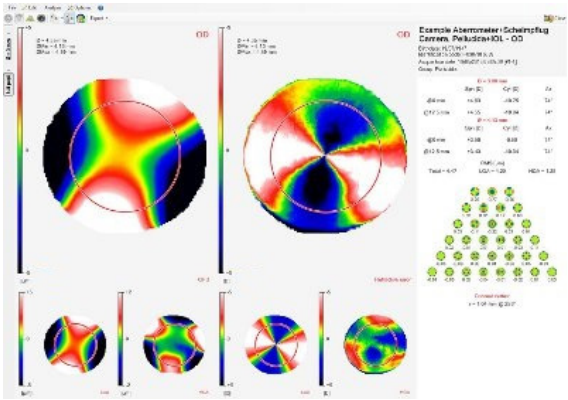
» Clicking the  icon on the toolbar

This display shows an overall analysis of the measured wavefront.
A OPD/WFE map is shown on the left side.
At the bottom left, aberrometric maps representing the LOA (Low Order Aberrations) and the HOA (High Order Aberrations): LOA correspond to polynomials of defocus and astigmatism (N = 2), HOA correspond to higher order polynomials from 3 to 7.

A Refractive error map is shown in the middle.
On the right panel from top to bottom are shown:

» Miscellaneous information on the patient and the acquisition.
» Refraction based on the selected pupil diameter and on the refractive diameter.
» The decomposition of the wavefront error in terms of Zernike polynomials on the Zernike pyramid is shown;
» The position of the corneal vertex respect to the pupil center.

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps.



Optical Analysis Summary

ANALISYS | VISUAL QUALITY SUMMARY

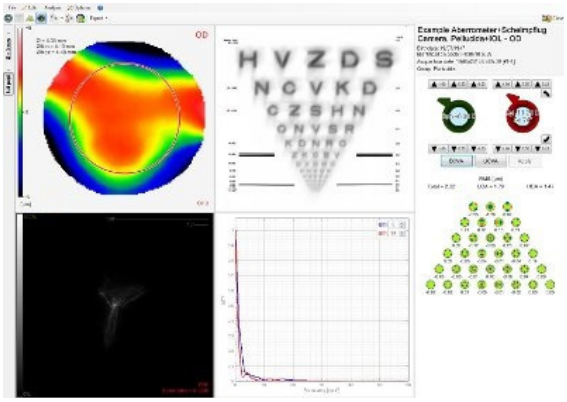
Visual Quality Summary is displayed by:

» Choosing **Visual Quality Summary** from the Analysis menu

» Clicking the  icon on the toolbar

This display shows an overall analysis of visual quality.
From top-left to the bottom-right are shown:

» OPD/WFE map;
» Vision Simulation;
» PSF;
» MTF.



Optical Analysis Summary

In the right panel above the Zernike pyramid it is possible to insert virtual corrective lenses, to simulate the vision with different types of sphero-cylindrical corrections.

» Selecting BCVA (Best Corrected Visual Acuity), the software automatically chooses the best lens to maximize the Strehl ratio of the current PSF. Lenses can be changed with variations of 1.00 D, 0.50 D or 0.25 D positive and negative, by pressing the appropriate buttons. The axis of the cylinder can rotated using the two arrows on the sides of the cylindrical lens.

» Select UCVA (Uncorrected Visual Acuity), to remove the virtual lenses.
» Select the Apply button to update the optical quality information using the current virtual lens configuration

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps.

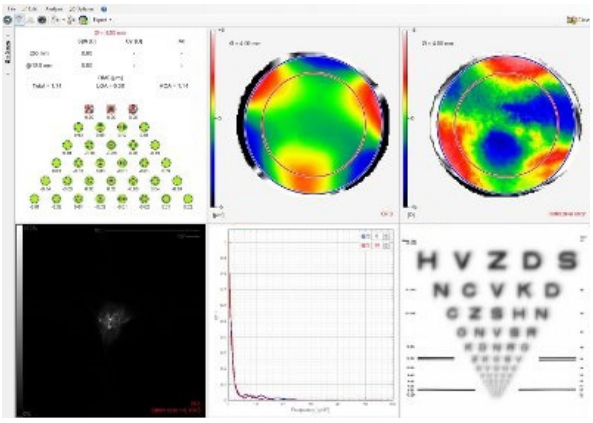
ANALISYS | COMPONENT ANALYSIS

Component Analysis is displayed by:

» Choosing Component Analysis from the Analysis menu

» Clicking the  icon on the toolbar

This display shows an overall analysis of visual quality by selecting or removing the effect on the vision of every single component of the Zernike pyramid.
From top-left to the bottom-right are shown:



Optical Analysis Summary

» Zernike pyramid: left-clicking on the polynomial image allows its effect to be included or excluded from the overall wavefront and the visual quality is updated. Right-clicking, via the context menu, groups of polynomials can be included or excluded. The available options are:
    - All polynomials
    - LOA (N=2): only low order
    - HOA (N≠2): only high order
    - N=3: only 3d order
    - N=4: only 4th order
    - N=5: only 5th order
    - N=6: only 6th order
    - N=7: only 7th order

» OPD/WFE map.
» Refractive error map.
» PSF.
» MTF.
» Vision Simulation.

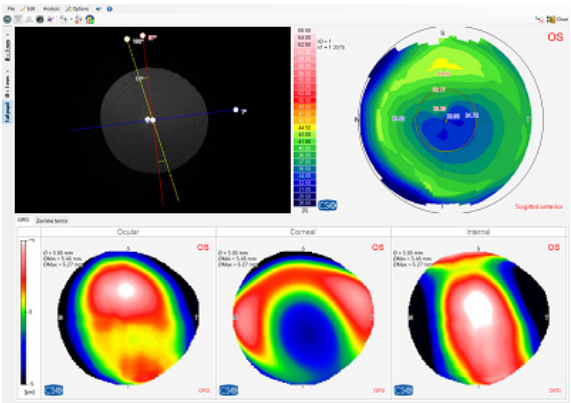
The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps.

ANALISYS | TORIC IOL ASSISTANT

Toric IOL assistant is displayed by:

» Choosing Toric IOL assistant from the Analysis menu

» Clicking the  icon from the toolbar.



Toric IOL assistant

To perform this type of analysis it is necessary to have acquired and stored in the software a corneal map (from a Corneal topographer or from a Scheimpflug camera) from which the program can take the corneal wavefront information and an aberrometry measurement from which the ocular wavefront information is obtained.

If topography and aberrometry came from different exams, select the acquisition to be used: as soon the second map is selected the Toric IOL assistant summary is shown.
In the lower part of the screen the Ocular, Corneal and Internal OPD/WFE maps are shown.
In the left-upper corner a Sagittal map is shown (in order to retrieve the corneal astigmatism axis)
In the right-upper corner a the back-lighted image of the post-cataract implant is shown: by adjusting the yellow line over the toric IOL marker the IOL axis will be determined. The displacement between this axis and the steepest axis of the corneal toricity (red axis) will measure the amount of rotation to be corrected.

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps.

To start a comparison/follow-up analysis image acquisitions need to be selected.

The first acquisition is chosen by default, based on which patient examination window is opened. Other images have to be manually chosen by the user.

If the acquisitions to be compared do not belong to the current patient/examination, patient examination search tools are provided: the  icon shows the complete patient database, whereas the  icon allows for an advanced search.

Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel.

The number of selected images may vary depending on the context of the follow-up operation. Click **OK** to continue, **Cancel** to cancel the comparison.

ANALISYS | COMPARISON/FOLLOW-UP IMAGE SELECTION

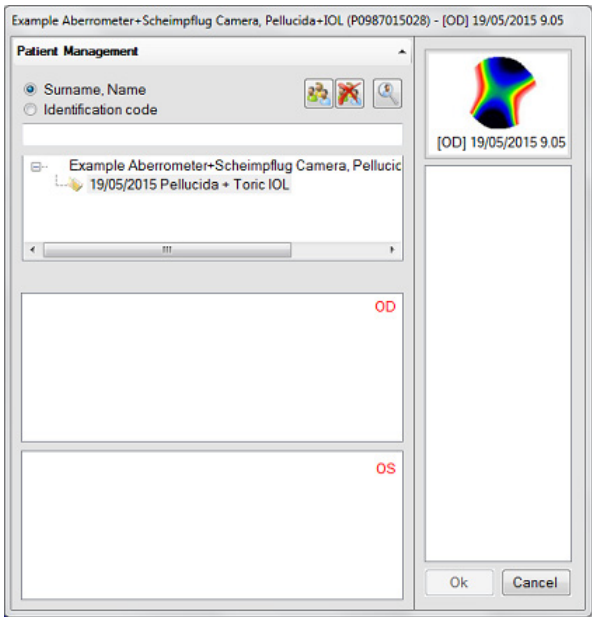
To start a comparison/follow-up analysis image acquisitions need to be selected.

The first acquisition is chosen by default, based on which patient examination window is opened. Other images have to be manually chosen by the user.

If the acquisitions to be compared do not belong to the current patient/examination, patient examination search tools are provided: the icon shows the complete patient database, whereas the icon allows for an advanced search.

Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel.

The number of selected images may vary depending on the context of the follow-up operation. Click **OK** to continue, **Cancel** to cancel the comparison.



Manual selection of the acquisitions to be compared

ANALISYS | COMPARISON

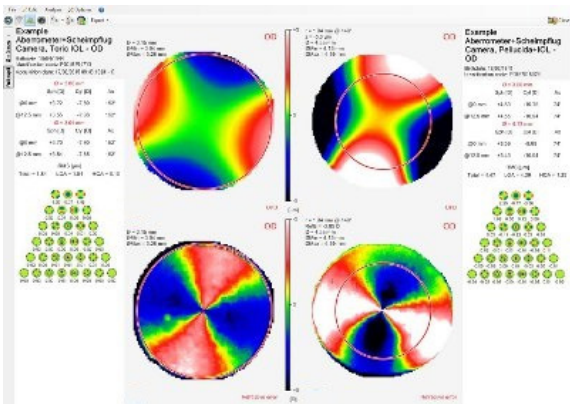
Comparison is displayed by:

» Choosing Comparison from the Analysis menu

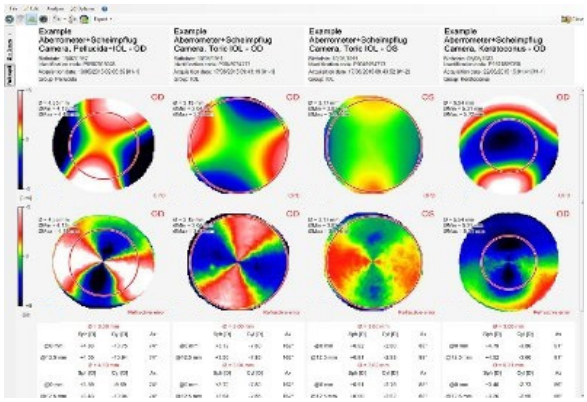
» Clicking the icon from the toolbar.

After completing the manual selection of images to be compared, a window with the selected images is shown. It's possible to select 2 , 3 or 4 maps (see figure). The comparison of two maps allows for the display of both sets of indices: Zernike pyramid, OPD/WFE map and Refractive error map are provided.

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the minimum full pupil size in 0.5 mm steps.



Comparison X2



Comparison X4

ANALISYS | COMPARE OD/OS

It is possible to compare the right and left eye without using the manual selection by:

» Choosing Compare OD-OS from the Analysis ► Comparison menu

» Clicking the  icon on the toolbar.

A comparison screen between the current eye and the fellow eye will be shown

ANALISYS | DIFFERENTIAL

Differential is displayed by:

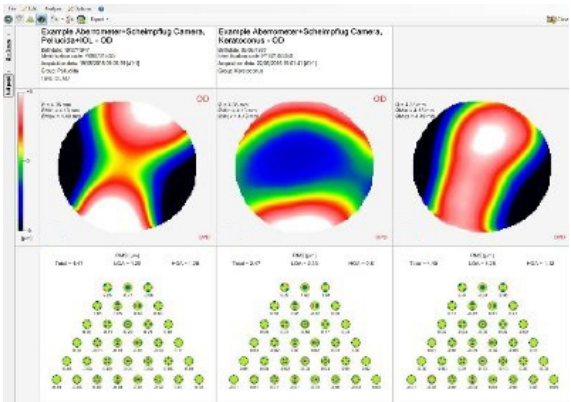
» Choosing **Differential** from the Analysis menu

» Clicking the  icon from the toolbar.

After completing the manual selection of the images to be compared, a screen with the Zernike pyramid, OPD/WFE map and their difference is shown.

It is possible to conduct a detailed analysis of the various components of the aberration, selecting only the polynomials of interest. Refer to Component Analysis section on how to do this.

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps



Differential

ANALISYS | INTERNAL COMPONENTS

Internal components is displayed by:

» Choosing **Internal components** from the Analysis menu

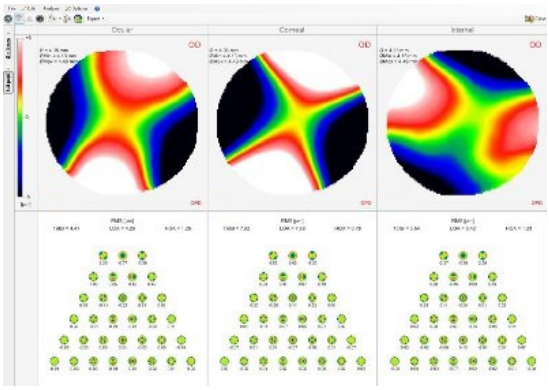
» Clicking the  icon from the toolbar.

To perform this type of analysis it is necessary to have acquired and stored in the software a corneal map (from a Corneal topographer or from a Scheimpflug camera) from which the program can take the corneal wavefront information and an aberrometry measurement from which the ocular wavefront information is obtained.

To start an internal components analysis select the acquisition to be compared: as soon as the second map is selected, the software creates a differential map which is the difference between the ocular wavefront and corneal wavefront. This is the amount of aberration that is internal to the eye, usually associated with the lens.

It is possible to conduct a detailed analysis of the various components of the aberration, selecting only the polynomials of interest. Refer to the Component Analysis on how to do this.

The pupil diameter can be selected on the left side of the screen using a range from 2 mm to the full pupil size in 0.5 mm steps.



Internal components analysis

OPTICAL PATH DIFFERENCE MAP (WAVE FRONT ERROR MAP)

The **OPD (Optical Path Difference) map** (or WaveFront Error according to the preferred setting) expresses in microns the difference in height between the wavefront measured in the eye being examined and a perfect spherical wavefront.

OPD and WFE relate as follows:
OPD(x,y) = -WFE(x,y)

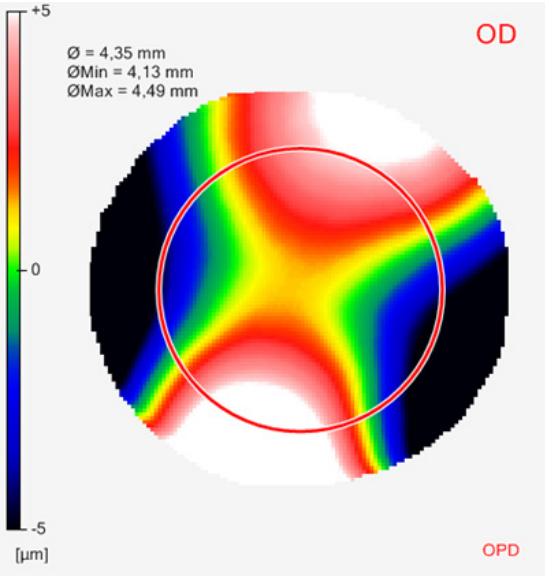
At the top left of the map are indicated:

» The average diameter of the pupil measured (the diameter of the circle having an area equal to that of the pupil measured)
» The minimum diameter of the pupil (the minimum distance from the center and the edge of the measured pupil)
» The maximum diameter of the pupil (the maximum distance from the center and the edge of the measured pupil)

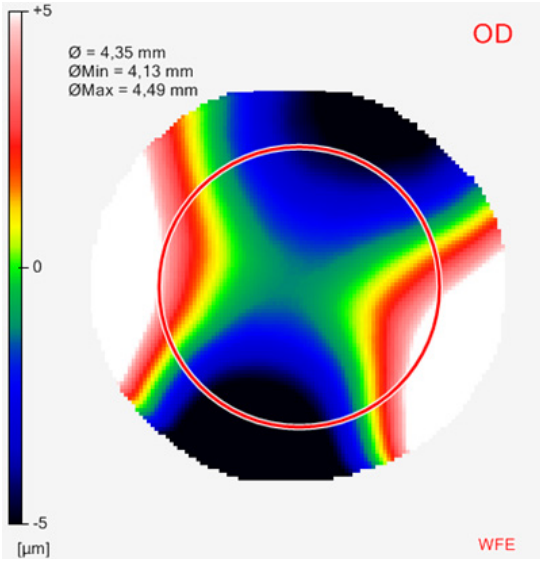
When the mouse cursor is moved around the map, the following will also be visible..

» The coordinates of the cursor expressed in Cartesian or Polar coordinates according to the preferred settings.
» The elevation Z error of the wavefront at the point where the cursor is positioned on the map.

	**Cursor**	When this item is selected, the coordinates and the numeric values of the map under the mouse pointer are displayed as it is moved. Left-click drops the cross, making it independent of the mouse pointer. A second click realigns the reference cross with the mouse pointer.
	**Distance**	Select this item to trace a segment on the map for measuring the distance between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The length of the segment thus defined will be displayed on the map, in millimeters.
	**Graph**	With this item selected the graphs representing the map profile along the meridian passing center of the map and the mouse pointer is displayed. The graph rotates during selection of the meridian: clicking on the desired orientation that particular meridian will be chosen and its chart will be shown horizontally.
	**Show/Hide value on cursor**	Shows or hides the numeric value over the map at the cursor position when a mouse movement occurs
	**Show/ Hide ruler**	Shows or hides the two perpendicular millimeter rulers (the shorter division corresponds to 0.5 mm; the longer division corresponds to 1 mm).
	**Show/ Hide meridians**	Shows or hides a polar grid.
	**Show/ Hide goniometer**	Shows or hides a goniometer.
	Show on map	Show or hide numeric values over the map:
		► **Nothing**: No numeric value is displayed over the map. ► **Numeric values:** The numeric values are shown on each map on a point grid.



Optical Path Difference map



Wave Front Error map

MAP | REFRACTIVE ERROR MAP

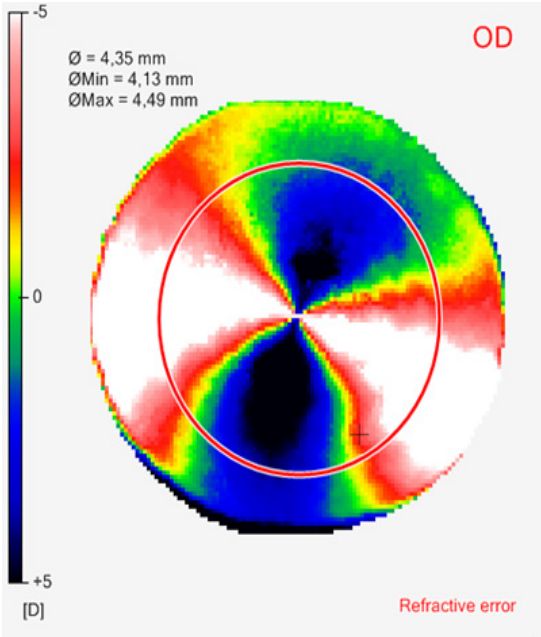
This map represents, point by point, the distribution of refractive error as measured by the instrument. The typical approach is to show the wavefront error as described in the OPD/WFE map: a second representation is based on assessment of the axial convergence and how it is calculated by the derivative of the wavefront. What results, is a representation very similar to the refractive power maps used in corneal topography and therefore more understandable from the clinical point of view, but that describes the entire ocular refractive state.

At the top left of the map are indicated:

» The average diameter of the pupil measured (the diameter of the circle having an area equal to that of the pupil measured)
» The minimum diameter of the pupil (the minimum distance from the center and the edge of the measured pupil)
» The maximum diameter of the pupil (the maximum distance from the center and the edge of the measured pupil)

When the mouse cursor is moved around the map, the following will also be visible:

» The coordinates of the cursor expressed in Cartesian or Polar according to the preferred settings.
» The refractive error at the point taken where the cursor is positioned on the map



Wave Front Error map

	Cursor	When this item is selected, the coordinates and the numeric values of the map under the mouse pointer are displayed as it is moved. Left-click drops the cross, making it independent of the mouse pointer. A second click realigns the reference cross with the mouse pointer.
	Distance	Select this item to trace a segment on the map for measuring the distance between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The length of the segment thus defined will be displayed on the map, in millimeters.
	Graph	With this item selected the graphs representing the map profile along the meridian passing center of the map and the mouse pointer is displayed. The graph rotates during selection of the meridian: clicking on the desired orientation that particular meridian will be chosen and its chart will be shown horizontally.
	Show/Hide value on cursor	Shows or hides the numeric value over the map at the cursor position when a mouse movement occurs
	Show/ Hide ruler	Shows or hides the two perpendicular millimeter rulers (the shorter division corresponds to 0.5 mm; the longer division corresponds to 1 mm).
	Show/ Hide meridians	Shows or hides a polar grid.
	Show/ Hide goniometer	Shows or hides a goniometer.
	Show on map	Show or hide numeric values over the map:
		► **Nothing**: No numeric value is displayed over the map. ► **Numeric values:** The numeric values are shown on each map on a point grid.

MAP | ZERNIKE PYRAMID AND REFRACTION PANEL

The panel shows the refraction and the terms of the Zernike decomposition of the wavefront error.
The notation of the cylinder (positive/negative) and the vertex distance can be set in the Options settings.

REFRACTION PANEL

The refraction is calculated on the preferred refractive diameter and on the analyized pupil diameter..For each pupil the refraction at the corneal vertex (@ 0 mm) and at the spectacle distance is shown. The notation of the cylinder and the vertex distance can be set in the Options settings.

ZERNIKE PYRAMID

In the first row Total RMS, LOA RMS (referring to the Zernike coefficients of order 2) and HOA RMS (referring to the Zernike coefficients of order greater than 2) are shown.
The Zernike Pyramid shows the value of the individual coefficients of the decomposition of the wavefront error in µm of RMS or in Equivalent Diopters according to the preferred setting.

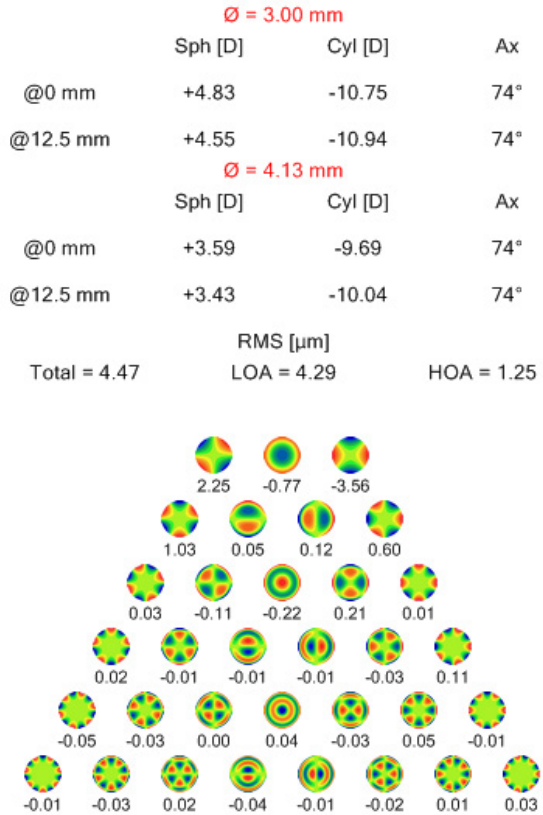
A drop down menu shows up by right-clicking on the panel, allowing configuration of the display in three different formats:

» **Zernike coefficients:** arranged in a pyramid, each aberration is represented by a pair of polynomials except the axis-symmetric ones.
» **Zernike coefficients** (amplitude/axis): Each aberration is given by an amplitude value and a direction (axis).
» **Pyramid Thibos:** The magnitude of the coefficients is indicated over a grayscale representation: they are arranged in a pyramid, and each corresponds to a rectangular area whose gray level is the coefficient value. Positive values are
identified by lighter shades of gray and negative values are in darker shades of gray. By moving the cursor over the table, the numerical values are shown.

The refraction values can be set between the values of 0.01D, 0.12D and 0.25D.

In some contexts the polynomial can be selected or deselected (ie. Component Analysis) including or excluding the polynomial on the overall wavefront error: in this case the context menu is enriched by following items:

» All polynomials
» LOA (N=2): only low order
» HOA (N≠2): only high order
» N=3: only 3d order
» N=4: only 4th order
» N=5: only 5th order
» N=6: only 6th order
» N=7: only 7th order
for the selection of set of coefficients.



Refraction panel and Zernike pyramid

MAP | PSF (POINT SPREAD FUNCTION)

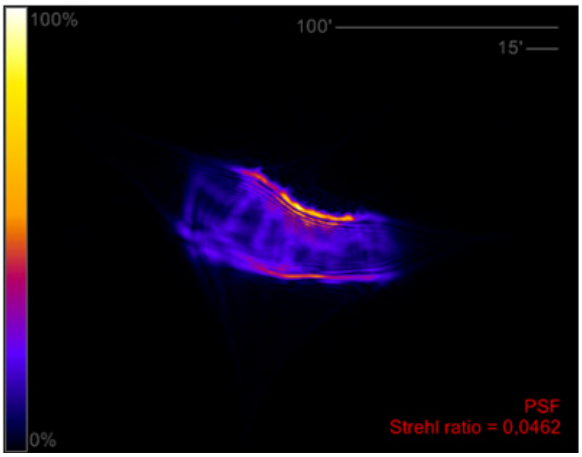
PSF (Point Spread Function) represents the light intensity on the retina, taking account the distortion created by the wavefront aberrations and diffraction. The PSF provides a representation of how a point of light would be seen (for example a star), through the patients eye

The Strehl Ratio value is shown at the bottom of the window. The Strehl Ratio is the ratio between the peak intensity of the PSF of the optical system under examination and the peak generated by a flat wavefront through the same pupil. An aberration-free PSF has a Strehl Ratio of 1; the ratio decreases as aberrations increase.

The upper portion of the window contains the scale factor, consisting of a segment representing the amplitude of 50' arc minute to provide an idea of the real dimension of the PSF.

By pressing the right mouse button you can select how the PSF is displayed:

- Black/white: white on black background.
- White/black: black on white background.
- Orange/Violet: color scale, areas with high energy are represented with yellow-white colors and areas with lower energy with purple-blue colors, on a black background.
- False color ZMX: color scale, where areas with high energy are represented in red and areas with lower energy in blue, on a blue background.
- With 100' and 200' you can change the width of arc, select 100' for small aberrations and 200' for highly aberrated eyes.



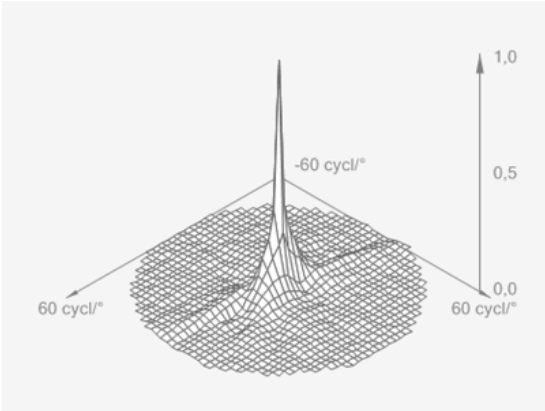
PSF (Point Spread Function)

MAP | MTF (MODULATION TRANSFER FUNCTION)

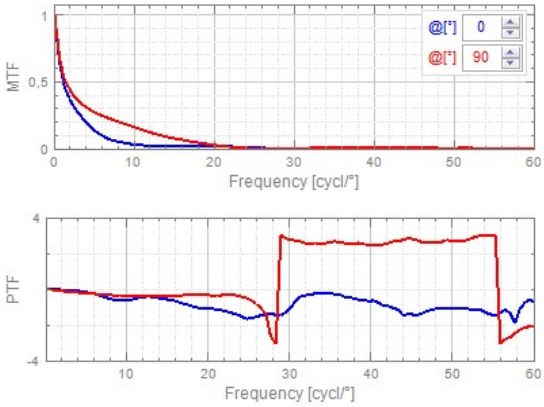
The Modulation Transfer Function (MTF) represents the ratio between image contrast and that of the object, as a function of spatial frequency. MTF assessment is a widely-used method for estimating optical system quality. The modulation, which represents the contrast ratio, is plotted on the y axis; the frequency (cycles/degree) is plotted on the x axis. The MTF graph represents the performance of an optical system at different contrast levels and for different spatial frequencies. The curve describes the manner in which the capacity of the system to perceive detail decreases as contrast decreases. At contrast equal to 1, the capacity to discriminate detail is maximum. On the other hand, high spatial frequencies are perceptible only at high contrast levels, while low spatial frequencies remain perceptible at low contrast levels. The MTF curves for good quality optical systems lie above curves for aberrated systems.

By pressing the right mouse button a drop down menu appears that allows you to choose different MTF displays.

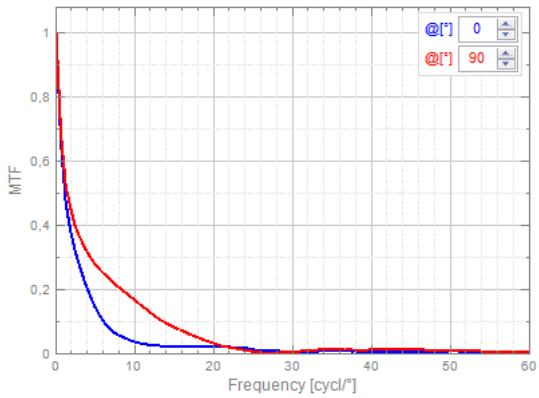
» MTF 3D
» MTF + PTF: The MTF chart + PTF (Phase Transfer Function) is how the OTF (Optical Transfer Function) varies, to vary spatial frequency, both in its component amplitude modulation, as in its phase component.
» MTF



3D MTF



MTF + PTF: The MTF + PTF graph represents the variation of the OTF (Optical Transfer Function) as the spatial frequency varies both in amplitude (Modulation Transfer Function) and in phase (Phase Transfer Function).

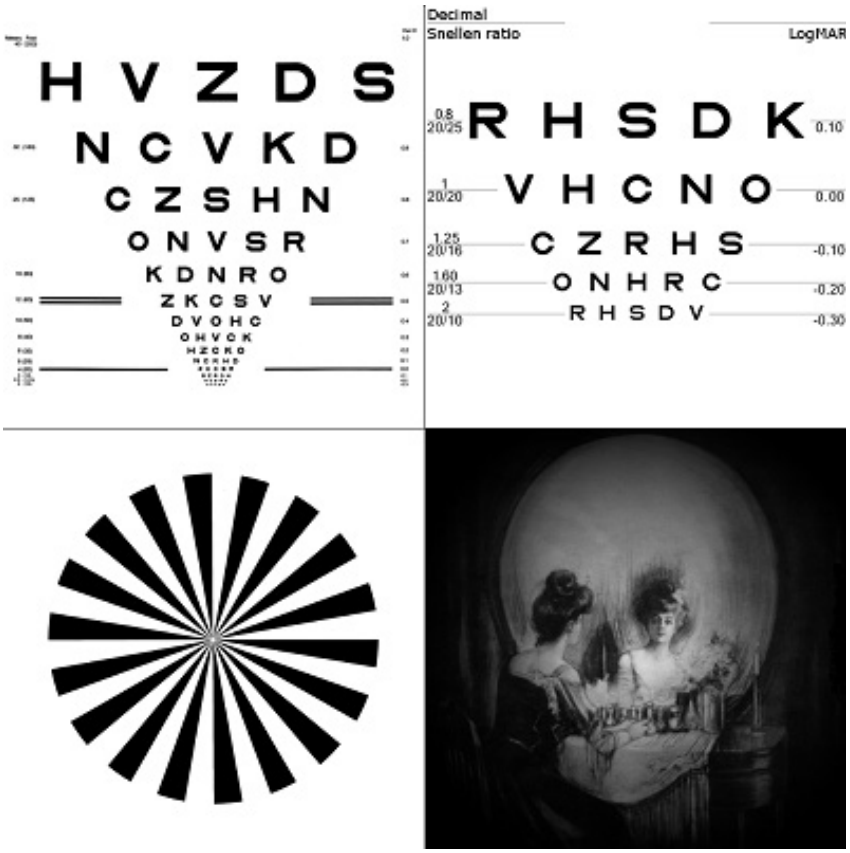


MTF for a normal eye. The x and y axis scales are linear. The red line represents the vertical meridian; the blue line represents the horizontal meridian.

MAP | VISION SIMULATION

A simulated visual acuity of the patient's eye can be shown. The simulation is obtained by a convolution with the PSF.
The drop down menu shown with a right-mouse click, offers four choices to view the simulated visual acuity

» ETDRS eye chart.
» ETDRS eye chart, higher Visual Acuity.
» Siemens Star.
All is Vanity – Charles Allen Gilbert.



Available images for the vision simulation

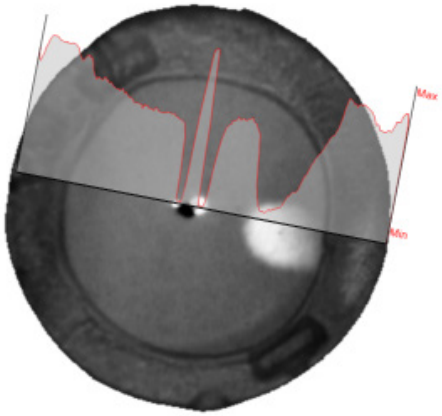
DENSITOMETRY

The purpose of Densitometry is to represent the back-scattering image of the acquired eye, highlighting all possible opacities that may be encountered though the path from the retina to the cornea.

Densitometry is provided as secondary examination by Scheimpflug camera.

First, the instrument needs to be calibrated in order to perform densitometry.

Then the densitometry image must be acquired in the Live environment before being processed in the main program.



Densitometry image

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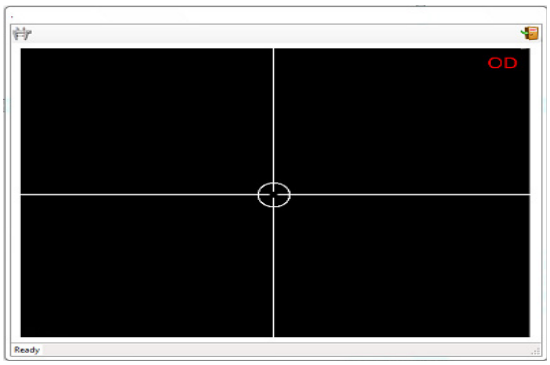
DENSITOMETRY CALIBRATION

The Scheimpflug camera needs to be calibrated the first time before operating densitometry examination.

The calibration procedure is automatically loaded the very first time a desitometry examination is started.

Once the Live environment has started, cover the central camera with a black paper or with an opaque object and press the calibration button in the top left corner of the calibration window in order to capture a black image.

The calibration procedure is now complete and acquisition is enabled.



Densitometry calibration window

DENSITOMETRY ACQUISITION

The scheimpflug camera needs to be calibrated the first time before operating densitometry examination.

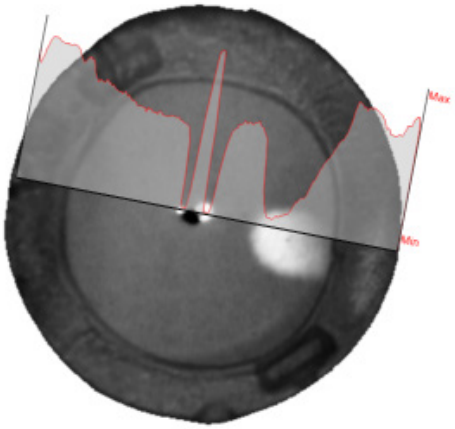
The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Densitometry icon
opens the acquisition environment.

Position the patient correctly, then focus the image and press the joystick button to acquire.
The captured image's thumbnail is then shown in the gallery. Select the image to view it.

DENSITOMETRY OPENING AND EDITING IMAGES

OPENING AND EDITING IMAGES

The acquired image is generally suitable for clinical diagnosis even without further graphical processing.Anyway it is possible to post-process the densitometry image in order to make it more suitable for examination. This section describes the advanced functions and tools that are available only for densitometry acquisitions. All other generic functions and tools are available for this instrument too.



Processed densitometry image with hisogram

DENSITOMETRY ENHANCEMENT

The original image is automatically elaborated and enhanced according to the following criteria:

» The lens is identified (that is the informative part of the exam) and is separated from the rest of the image, which usually contains useless noise and background disturbance.
» The lens is re-centered on image and on screen.
» Image background is drawn white to provide a more comfortable view.
» Various graphic filters are applied in order to improve gray-scale gamma and to smooth background noise on the lens. The resulting image provides more enhanced details and extremely dark areas are optimized to normal luminosity.

ADVANCED FEATURES

Mouse hovering over the lens produces a gray-scale histogram which is overlaid on the image. This is useful to underline lens abnormalities, if present. Left click locks the histogram with the current rotation angle, so it is possible to print a customized report of the exam with histogram evidence on it.
Patient data are shown on the top-right of the screen, along with a brief summary on the image acquisition quality:
» Pupil dilation: indicates whether pupil dilation is good enough for diagnostic purposes. If dilation is insufficient, it is advisable to repeat the acquisition minimizing room illumination and enhancing pupil dilation
» Acquisition quality: provides an evaluation on the overall image acquisition quality. If the image presents too much noise or quality is low (e.g. is too dark) it is suggested to recalibrate the instrument then proceed with a new acquisition

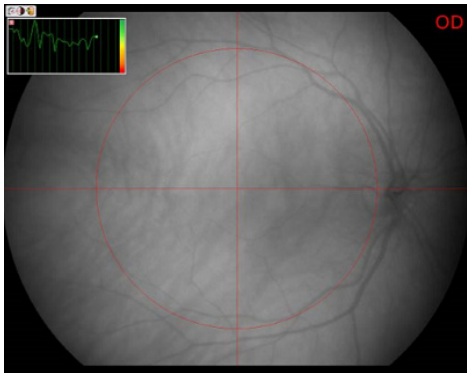
Patient data with acquisition quality summary

MENU OPTIONS

	Reprocess	Reprocesses an image that was previously restored to the original format.
	Restore	Restores an image to its original format, eliminating post-process enhancement.
	Invert Grayscale	Inverts grayscale on image.

FUNDUS CAMERA IMAGING | ACQUISITION

The  icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Fundus camera icon starts the image capture process.



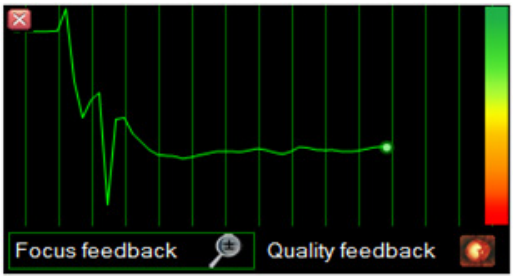
Optimal centered acquisition

IMAGE CAPTURE AND ALIGNMENT

Position the patient in the chinrest using the canthus mark to get them correctly postioned. Ask them to look directly at the orange fixation point inside the instrument. Then starting far away from the patient's eye, view the pupil on the screen, it appears as a very bright and clear spot. Move slowly towards the pupil, trying to keep it as centered as possible in the middle of the screen. Raise or lower the instrument if needed, using the joystick. Always make sure the patient is looking directly at the fixation.

Once the pupil is centered, continue to move in, very slowly, until the patient's retina becomes visible. If necessary, focus the image by turning the upper knob on the side of the instrument. If enabled, the focus assistant window will provide visual feedback showing improvement/worsening of the focus, as described in the section below.
Stabilize the image making sure the patient is steady and check that the light does not flicker. The image must be uniformly illuminated (see example image where is the image?). Do not move in further when the image is clear; too close a proximity could generate undesired reflections.

To capture the focused image press the white button on the joystick. The captured image will be saved in the OD (right eye) or OS (left eye) gallery, depending on which eye was photographed.

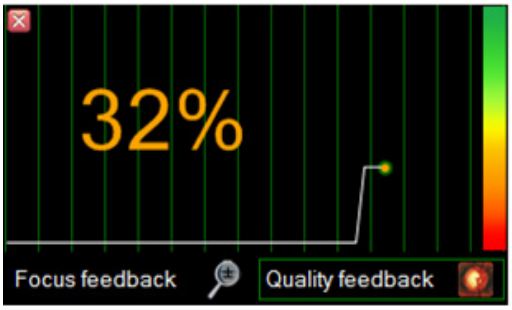


Focus assistant - *focus feedback mode*

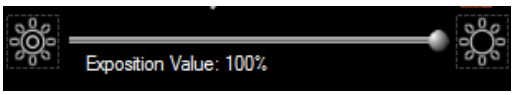
FOCUS ASSISTANT

The software provides two different approaches to provide support in determining when the image is optimally focused. The upper focus knob located on the side of the instrument should be used to adjust the focus once the fundus becomes visible during the alignment and centering phase.
When focus feedback mode is enabled the green line goes up when the focus is enhancing and goes down when it's getting worse. Keep adjusting the focus knob until the green line goes up, then stop as as soon as it begins to go down.
The focus assistant should be considered reliable only when the image is stable and bright and the patient is not moving.

When quality feedback mode is enabled the numeric value on screen provides a quality score (0-100%) for the image. The algorithm is more complex than the simple focus indicator implemented in the focus feedback mode as it continuously
evaluates various retina elements, for example the optical nerve's level of detail and the contrast of vascular vases.
Moreover, when this mode is enabled the image borders get colored in red, yellow and green depending on the numeric score so that is not necessary to keep looking at the focus assistant window while centering the retina.



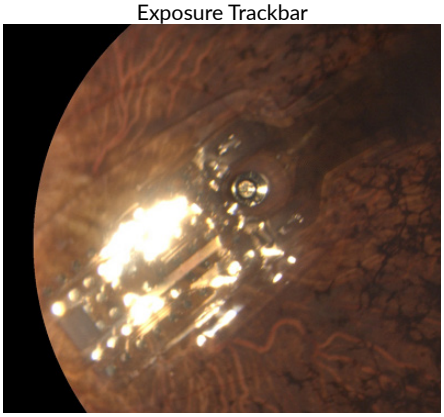
Focus assistant - Quality feedback mode



Exposure Trackbar

EXPOSURE TRACKBAR

Sometimes clinical conditions of the patient's fundus include hyper-reflecting areas which are over-saturated by the camera flash light of the instrument (i.e. implanted retinal microchips).
The result is an image where interesting details are over exposed as white saturated spots.
Lowering the exposure value using the Exposure Trackbar lowers the cameras response to the flash light, making such details perfectly visible while the rest of the fundus layer might become much darker.



Implanted microchip with hyper-reflecting metallic parts

CHECKING THE ACQUISITION

Once the image has been captured a thumbnail image pops-up in the respective OD/OS gallery. Click the thumbnail to view the image, then click anywhere in the screen to get back to the image capture process. Right click on the thumbnail to view the acquired infrared image, or choose Delete to cancel the image from the gallery.

MULTIFIX FUNCTIONS

Advanced MultiFix functions are available only on MultiFix Fundus Camera models.

FUNDUS CAMERA IMAGING | SETTINGS

Clicking on the icon on the toolbar brings up the settings window.
Program settings
Image format: any available image format can be selected here. Choose between Jpeg and other formats like PNG or TIFF.
The Quality setting adjusts the Jpeg compression level.

Acquisition mode: when One-shot is selected the instrument enters a stand-by mode after every acquisition and the acquired image is shown on the screen automatically.
When Non stop is selected the instrument will be ready for another acquisition and the previously acquired image can be reviewed by clicking the thumbnail on the OD/OS galleries.

STAND-BY TIME:
when this value is set the instrument will enter a stand-by mode after the selected number of seconds.

Settings window

FUNDUS CAMERA IMAGING | MOSAIC PREVIEW MODE

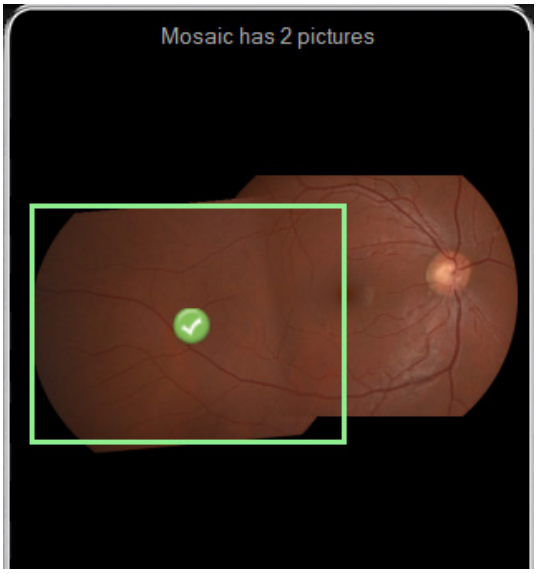
The icon on the toolbar activates Mosaic Preview Mode. Click it again to disable the preview mode. Mosaic preview mode will be automatically disabled after laterality change.

Please note that the purpose of *Mosaic preview mode* is to provide live support when acquiring images for mosaic construction. Any images can be used for mosaic creation later in the Mosaic creation window, even if they were taken with the Mosaic preview mode deactivated.

When *mosaic preview mode* is enabled, anytime a new retinal image is acquired the system tries to insert it in a mosaic preview. When the new picture matches correctly, a mosaic preview window pops-up at the bottom of the screen showing all the matching pictures merged together.

The purpose of *mosaic preview mode* is to show a preview of how the acquired images are currently matching a mosaic. When the examination is complete all the images are available for the final mosaic composition, so the mismatching pieces can still be inserted manually even if they don't currently match the mosaic in the live preview.

Tip: always compose the mosaic starting from the center (a retinal image with the optical nerve centered in the image, or at least present in the image), then acquire all the peripheral images in any order.



Mosaic preview window

FUNDUS CAMERA IMAGING | MULTIFIX FUNDUS CAMERA

MultiFix models provide extra functions in addition to the standard Fundus Camera features.

ASSISTED FOCUSING

Image focusing is controlled by the joystick, not by the upper focus knob as the standard model.
A focus slider is displayed in the control panel, providing visual feedback of the current focus position (neutral, myopia, hyperopia).

The instrument is reset to the neutral focus position with every new examination. Press 'N' anytime to reset the position, or mouse-click the neutral position on the slider.

Focus assistant slider in neutral position

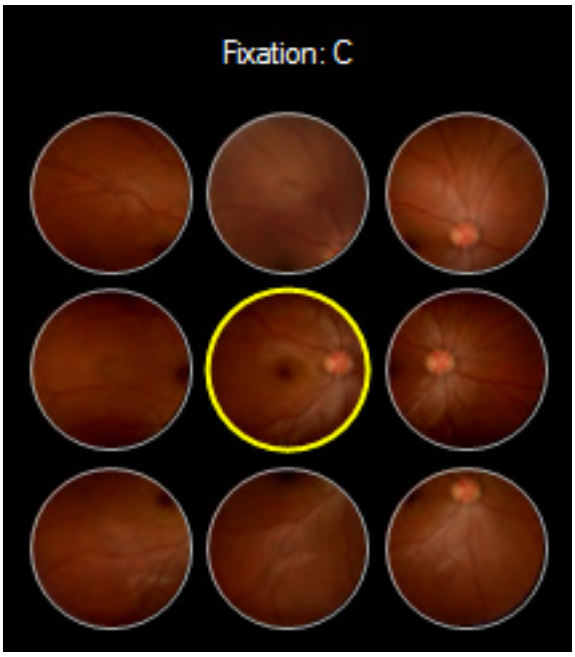
MULTIFIX

MultiFix Fundus Camera is provided with 9 fixations leds which can be switched during the examination in order to capture a complete mosaic of the fundus.

The MultiFix interface allows for rapid switching between central (C), superior (S), inferior (I), temporal superior (TS), temporal inferior (TI), nasal superior (NS), nasal inferior (NI), nasal (N), temporal (T) fixation.

Click the desired fixation to change the active led.
Alternatively, use the numeric keypad or arrows on keyboard to move the fixation cursor on the checkerboard.

Every fixation position displays a "preview" of what the acquired area of retina should look like. The preview changes according to the current laterality.
When a picture is taken, the preview is replaced with the real image and, if the picture fits the actual mosaic, it is merged into a mosaic preview.



Fixation selection interface

ANALYSIS | AVR

ARTERIOLAR-TO-VENULAR RATIO (AVR)

Retinal vascular analysis assists in evaluating the diameter of the veins and arteries present in the image, with the aim of calculating the mean value of the ratios of the diameters between individual pairs of adjacent blood vessels.

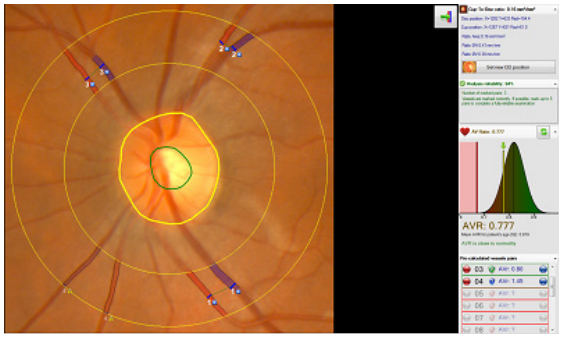
The vascularisation status of the retina and, in particular, the AVR (Arteriolar to Venular Ratio), are highly indicative of potential cardiovascular problems and are fundamental to screening examinations, since they can highlight arterial restrictions which may require more detailed follow-up examinations to reduce the risk of cerebral and cardiac infarction.

Clinical studies and statistical results are available in the following article, currently considered the state of the art in this subject:

Wong TY, Klein R, Couper DJ, Cooper LS, Shahar E, Hubbard LD, Wofford MR, Sharrett AR. Retinal microvascular abnormalities and incident strokes: the Atherosclerosis Risk in the Communities study.
Lancet.2001;358:1134-1140

The new retinal analysis environment provided by the software is capable of automatically identifying the principal retinal blood vessels, discriminate between arteries and veins, and select the most reliable pairs for use in calculating the AVR.

The result of the AVR calculation is presented in an intuitive way by using a representation of the normal statistical distribution of the value for the patient's age population. The numerical value is accompanied by graphic and textual aids to help with comprehension of the results, while the examination is assigned a reliability index which indicates the need for more detailed manual measurements, following on-screen prompts.
The following section describes the entire examination procedure, starting from image capturing, through marking of the optic disk and of artery-vein pairs, to the final evaluation of the result.



AVR Main window

CLINICAL AVR MEASUREMENT PROCEDURE

Two examination protocols have been formally established in recent years: the Japanese method and the US
method.

The US method means marking from 3 to 5 pairs of adjacent veins and arteries, exiting from the optic nerve and tracing approximately parallel paths at a close distance to each other. The marking area is a ring covering an area between 2 to 3 radii of the optic disk, starting from the center of the disk itself.

For each pair, the AVR ratio (arteriolar diameter over venular diameter) is calculated, after which the mean of these values is taken to obtain the final AVR value.

Start from the Cup-To-Disk measurement as a first step in the AVR examination process.
When the optical disk has been marked correctly on the fundus image (cup is not necessary for AVR detection) click on the Analysis menu to start AVR processing

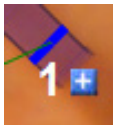
ANALYSIS | AVR: PROCESSING

When AVR analysis is started, the system attempts to identify pairs of adjacent veins and arteries in the area of interest, calculated in relation to the position and size of the optic disk as the American method states.

N.B.: the analysis run by the system is sufficiently precise so long as the image quality is very good. However, even when the image is a good one, it is still recommended that you carefully review each pair of vessels, and manually edit the pairs as necessary, adding new ones or deleting incorrectly detected ones, so as to optimize the quality of the examination.

The system automatically distinguishes between veins and arteries, and the diameter is calculated in the most reliable section of the vessels.

The system can also run self-diagnostics and assess the accuracy of its analysis: each pair of vessels can be confirmed if not sufficiently reliable, or modified manually, or eliminated from the overall calculation, as follows:



The light blue symbol "+" indicates an automatically detected pair which is judged to be sufficiently reliable, and hence included in the overall AVR calculation.

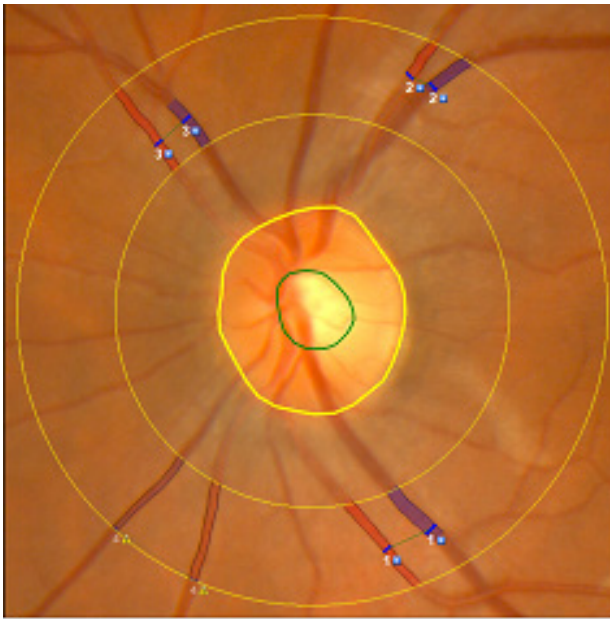
The yellow exclamation mark indicates an automatically detected pair which the system judges to be doubtful, and is not included in the overall AVR calculation. Click on the pair and select whether to accept it or eliminate it from the screen.

A green check mark indicates that the pair has been reviewed and accepted manually

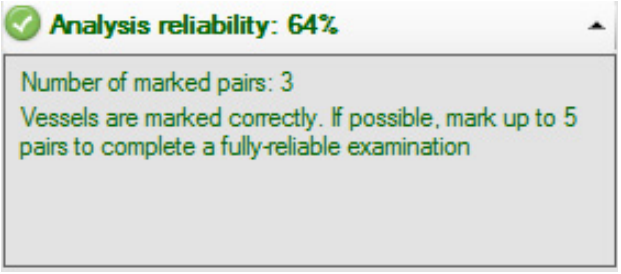
The reliability of each pair, together with the number of pairs marked on the screen, contribute to the overall reliability score (expressed as a percentage).

Manual confirmation of the pairs greatly increases the final reliability score: scores above 60% can be considered reliable. Along with the numerical value, a short tutorial is also available which indicates any problems and suggests how to improve the marking.

The next section provides instructions on how to manually edit coupled vessels in order to increase the analysis accuracy.



Main AVR processing interface



AVR reliability summary

ANALYSIS | AVR: COUPLING

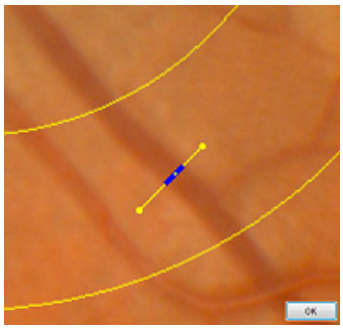
Click on a vein/artery pair to display a context menu:

This menu allows you to confirm the pair, if it has been judged doubtful by the system, or eliminate it completely, or change the classification from vein to artery or vice-versa if the automatic classification is incorrect.
If several pairs are overlapping or it is difficult to select pairs on the image, a list of all pairs detected by the system is displayed on the right, both those highlighted on the image as reliable and those which are not included but available for review and manual inclusion if necessary (see the picture on the right column).
Touching a pair in the list with the cursor highlights it in the image. The number of the pair in the list matches that of the pair on the image. The shield symbol indicates the status of the pair: reliable and included in the calculation (green shield), not reliable and excluded from the calculation, but available for review and confirmation (light blue shield), not reliable and excluded from the calculation (red shield).
Clicking on a pair in the list displays the context menu shown above, with the difference that in this case the system also displays pairs not shown on the image itself.

List of all available vessel pairs

MODIFYING EXISTING PAIRS

In the event that the automatically calculated diameter is incorrect, move the mouse over the vessel you wish to edit, at the point in which their cross-section is marked graphically: click when the pencil tool is shown, which brings up the advanced editing dialogue:

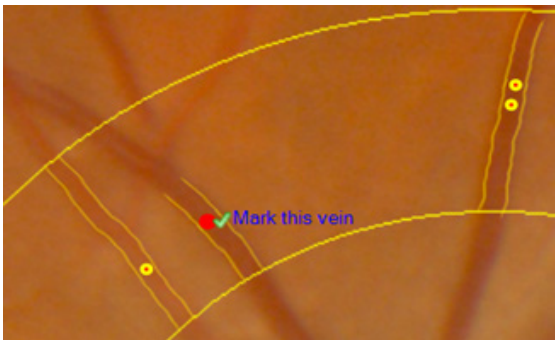


To modify the selection of the vessel's diameter, you can move, rotate and change the size of the blue marker:
Use the yellow side indicators to rotate and widen/narrow the section, or use the yellow central indicator to move the entire section.
Click on OK to confirm the selection. Vessels which have been modified manually display with a green check mark and will increase the examination's reliability score.

CREATING NEW AV PAIRS

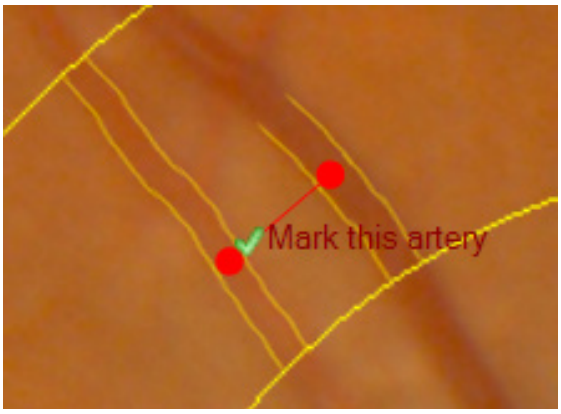
Click on the  icon on the top right of the screen in order to create a new vein-artery pair which was not correctly identified by the system.

All the hot-spots are then displayed on the image: they are a list of points of interest which have been detected by the system as potential vessels for creating new pairs.
Click on a hot-spot to select a vessel. Click on the second vessel of the pair to complete and confirm the pair automatically:

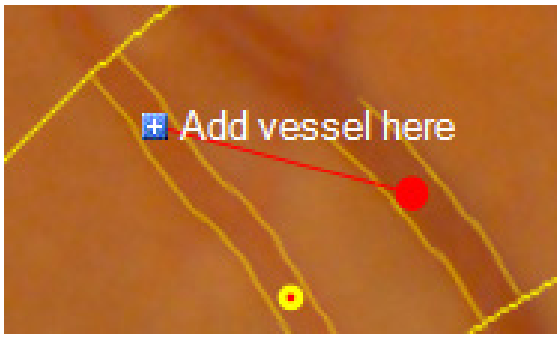


The AV pair is created automatically using information detected previously by the system, such as the vein/ artery classification and diameter of the vessel (each hot-spot already contains this information).
However, you may wish to mark vessels which have not been detected by the system and, therefore, for which no hot-spot exists.

To select such vessels, simply move the cursor onto any point of the zone of interest to add a new vessel: this opens the advanced manual editing dialogue (as shown in Modifying existing pairs) which is used to adjust manually the diameter indicator:



When all vessels pairs have been detected and adjusted, proceed to the results section to finalize the analysis.



ANALYSIS | AVR: RESULTS

When the reliability score of the examination is greater than 60%, the resulting Arteriolar to Venular Ratio is considered reliable.

The AVR value is the mean of the individual AVR's of the reliable pairs of veins and arteries. The result is given in the side panel which is displayed automatically on the right of the screen when the examination reaches a high enough score.

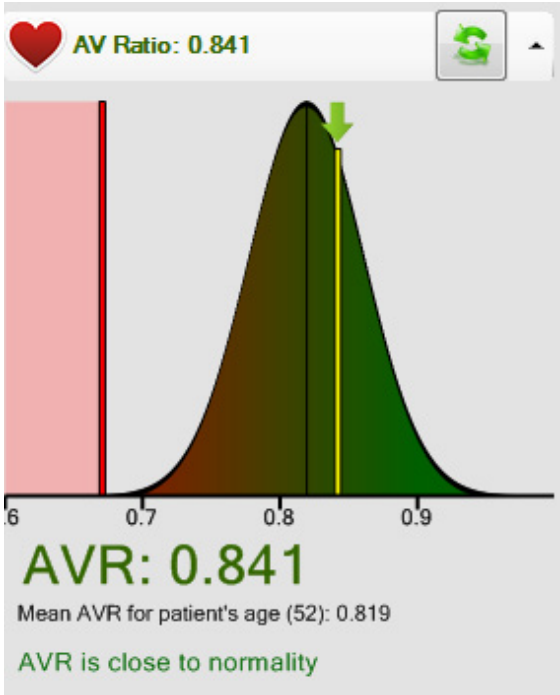
The Gaussian curve gives the statistical distribution of AVR values over the population, generated in relation to the patient's age.

The mean value of the distribution (0.819 in the example in the right column) is the optimal value. The red line is the threshold below which one can consider it possible that the patient is affected by a significant arterial restriction. This threshold depends largely on the patients age. For AVR's less than 0.60 it is recommended that further examinations be conducted regardless of the patients age.

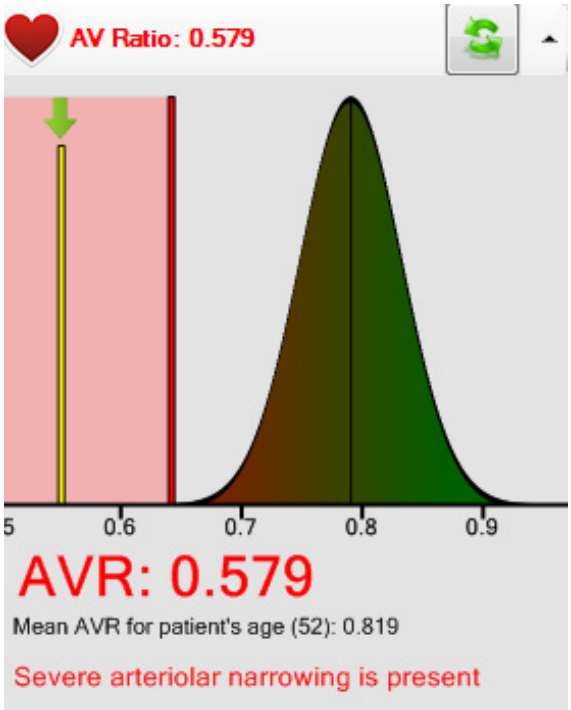
The yellow line indicates the calculated AVR, and is positioned in relation to the normal distribution. The second picture shows an examination whose result is significantly below the norm.

Once a satisfactory result is obtained, the examination procedure is complete. The current status is saved and will be displayed when the AVR form is opened once again, unless the current cup / disk
measurement is deleted.

In this case, the old examination no longer applies to the new position and size of the disk, and a new examination procedure must be initiated.



Results panel: Healthy patient's AVR



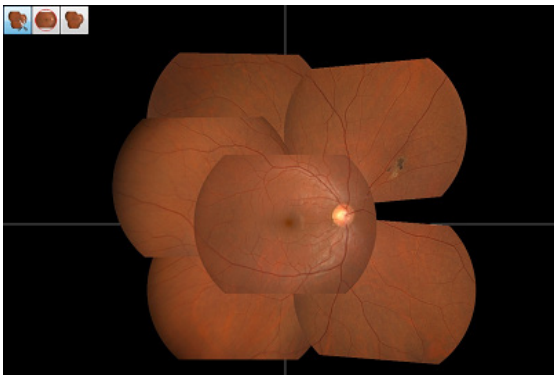
Results panel: Patient with severe AVR restriction

ANALYSIS | MOSAIC

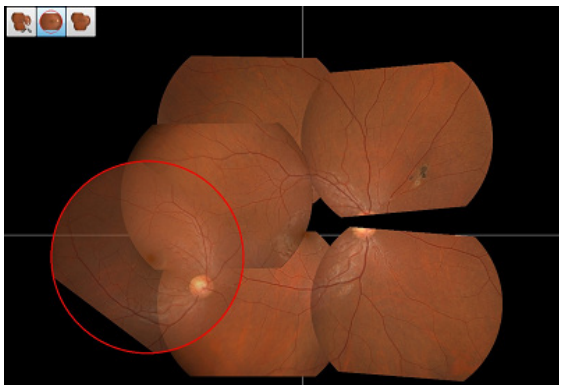
The mosaic or panoramic mode, can be used to extend the field of view for the fundus camera. The software matches single images and provides the User with an overview of the central and peripheral areas of the retina.

Please note that Mosaic preview mode can be activated during image acquisition in order to provide live support in acquiring well-matching mosaic images.

From the Analysis menu , click the  icon to access the Mosaic mode. This mode can be accessed from any acquisition in the study, then all other acquisitions will be automatically added to the mosaic, up to a total of 7 acquisitions. If the study contains more than 7 acquisitions, the Image Selection window is presented to select the desired acquisitions until the maximum allowed number is reached.



Fundus camera mosaic (*Global view mode*)



Fundus camera mosaic (*Manual edit mode*)

Fundus camera mosaic (*Mosaic mode*)

	**Global view mode**	This is the default mode immediately after the mosaic has been built. The mosaic is shown as a set of fixed overlapping images and the global image can be moved and zoomed in or out using the mouse and mouse wheel. Single mosaic images cannot be moved or rotated here.
	**Manual edit Mode**	Every single mosaic image is now selectable (circled in red) and can be dragged using the left mouse button or rotated using the mouse wheel. While being dragged the mosaic image becomes transparent to make manual linking easier. This way any issue due to the automatic reconstruction can be fixed manually. Right-clicking on a single image brings up a pop up menu that enables you to remove that image from the mosaic. Removed images are placed in a gallery on the bottom of the screen. All images that were not selected for the automatic reconstruction process are also placed in this gallery. They can be re-inserted manually in the mosaic by double-clicking them from the gallery.
	**MOSAIC**	This button finalizes mosaic creation as it merges all overlapping images together in a single image, excluding all the pictures that have been placed in the discarded gallery. All image edges are smoothed and image transitions combined in a more uniform image.
	**Infrared mosaic**	Same as the previous Mosaic mode, the final mosaic is composed using Infrared (IR) versions of the fundus images.
	**Save mosaic**	The composed mosaic is saved as a stand-alone acquisition and becomes available in the examination gallery.

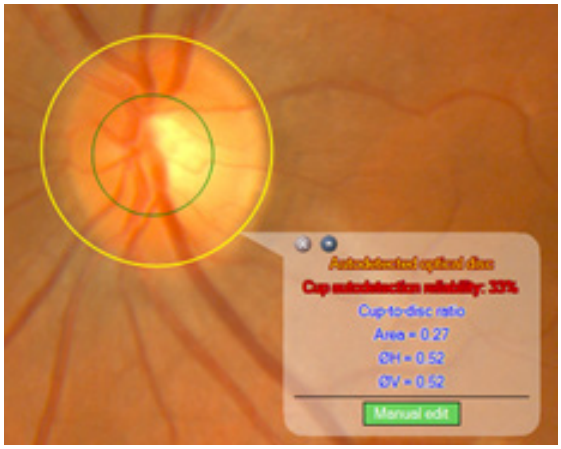
ANALYSIS | CUP-TO-DISC RATIO

The Cup-to-Disc measurement is calculated automatically by the system every time a new fundus image is opened.
An auto-detection reliability score is displayed on the balloon tip associated to the measurement.
When automatic detection is not precise enough, or the disc is not circular, manual editing is available for increased accuracy.
Quick cup and disc measurement requests 6 points to create circular cup and disc.
Advanced cup and disc measurement provides a drawing interface for accurate marking.

Fundus image with correctly centered optical disc

QUICK CUP AND DISC MEASUREMENT

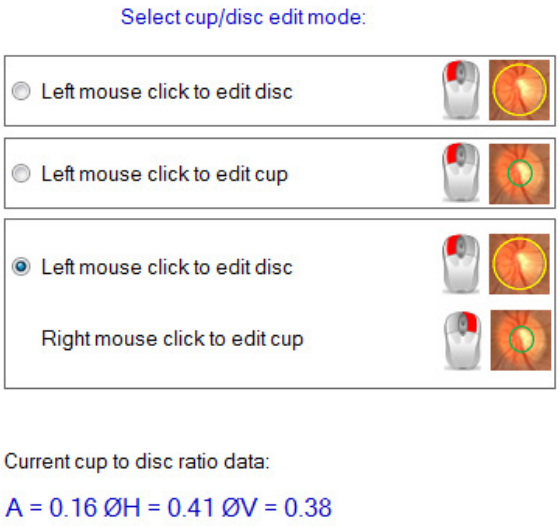
Click the  icon from the Tools Menu in the main image interface to start this measurement.
First mark three points on the image to set the external optical disk circle, then mark another three internal points to set the cup. Cup/Disk Area ratio and diameter ratio is displayed inside the measurement for immediate evaluation once the operation is complete.
Cup and disk areas marked this way are two perfect circles set by the three points.
Choose the Advanced cup and disc measurement function to trace a custom path for both cup and disc for a more accurate analysis.

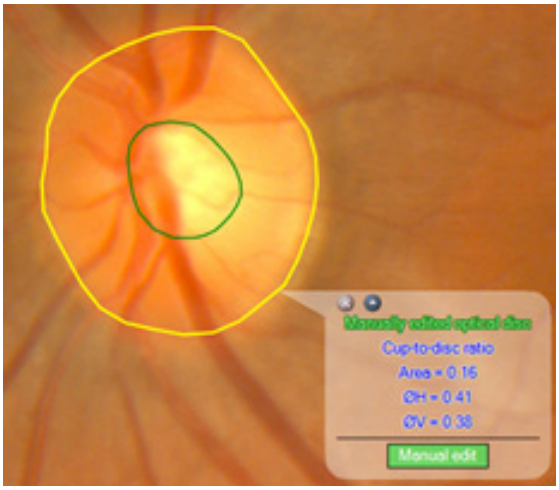


Auto-detected optical disc with unreliable cup (low auto-detection score)

ADVANCED CUP AND DISC MEASUREMENT

In order to access the advanced editing interface click Manual Edit on the balloon tip associated with an existing Cup-to-Disc measurement on the image (see the picture on the right column).
The advanced interface may also be accessed immediately after the Quick cup and disc measurement by replying Yes to the message box.





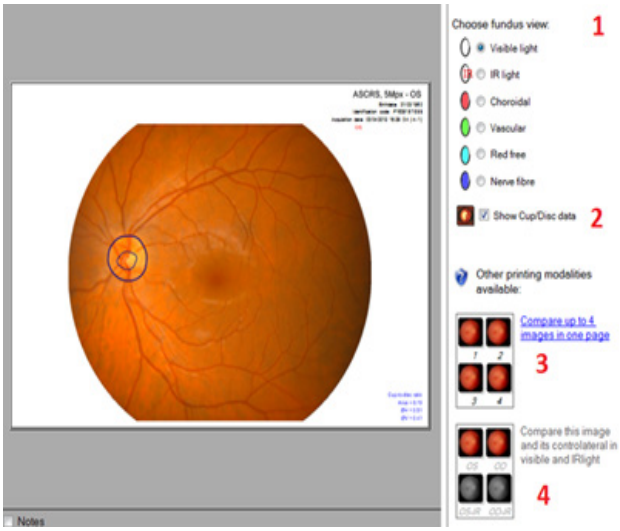
Manually edited optical disc with reliable cup

First choose the desired editing mode on the right side of the interface (for example the third option implements left click to define the outline of the disk and right click to define the outline of the cup), then trace the outlines of the cup and disk on the image, respectively. When both cup and disc are marked correctly click  icon to start the AVR analysis.

PRINTING

The fundus camera's printing interface provides some advanced functionalities in addition to the standard printing tools provided by the software printing preview interface.

1	Choose a different layer for the printed image. The available layers are explained in the Wavelength division section.
2	Show/hide Cup-to-Disc measurement data on the printing, if available. Cup and disc are marked with blue brush on the image, while numeric data is shown on the bottom-right corner.
3	Click this hyperlink to select more pictures (up to 4 in a page) from the same patient to be added to the current printing preview.
4	When the current picture has a valid image of the other patient eye this option creates a printing preview containing both pictures in visible light and IR light (4 pictures in a page).



Fundus camera printing preview

OPENING AND EDITING IMAGES

This section describes the advanced functions and tools which are available only for Fundus camera images.
All other generic functions and tools are available for this instrument as well.

Fundus camera image viewing and editing window

MENU ANALYSIS

	**Single image**	Loads the single image from different menus like comparison, a
	**Comparison**	Compares two or more images (depending on examination typ
	**Mosaic**	Brings up the Mosaic composition and editing window.
	**Wave-length division**	Brings up the wave-length division window.

	AVR	Brings up the Arteriolar-to-Venular ratio window (if included in the software license).

MENU TOOLS

	Cup to disk ratio	This tool provides manual setting of the Cup-to-Disc ratio measurement on the image.

BARRIER FILTERS

	This set of image filters provides different levels of interpretation for a single fundus image. See the wavelength division window for more details.

FUNDUS WIDGETS

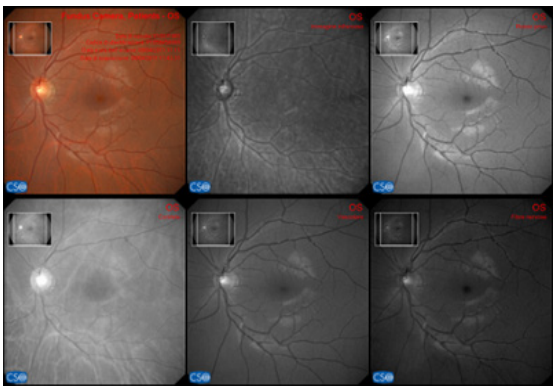
	Place cup-disc widget	The cup-disc widget is an automatic cup and disc mark-up measurement which is placed on the image automatically when detection is possible. The measurement could be inaccurate, or the cup could be missing due to insufficient image quality. Click Cup to disk ratio icon to start a manual measurement.
Place widgets automatically on first open		When this option is checked the system always tries to place the automatic cup-disc widget on the image. When this option is not checked the widget is never placed on new images from now on.

WAVE-LENGTH DIVISION

This analysis windows splits-up the original fundus image into different levels.

Please note that the Infrared image is a stand-alone acquisition taken with IR illumination, while other images are obtained by processing the original visible light image.

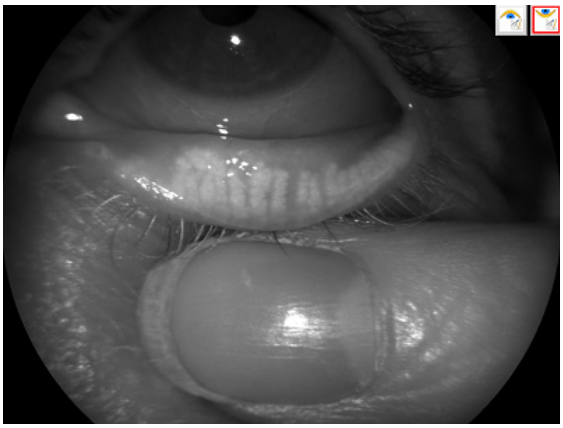
- Original image (top-left image. from the single image window).
- Infrared image (second image, first row. from the single image window).
- Red-free image (third image, first row. from the single image window). Displays the original image without the red component, in order to enhance all detailed elements like veins/vessels, optical nerve etc.
- Choroidal image (bottom-left image. from the single image window). Displays the red component only, enhancing the choroidal level of the fundus while excluding all detailed elements like veins/vessels, optical nerve etc.
- Vascular image (second image, second row. from the single image window). Displays the green component only, enhancing all blood vessels and veins in the fundus image.
- Nerve fiber image (third image, second row. from the single image window). Displays the blue component only, enhancing the nerve fiber layer at choroidal level in the fundus image.



Fundus camera wave-length division

MEIBOGRAPHY

MEIBOGRAPHY



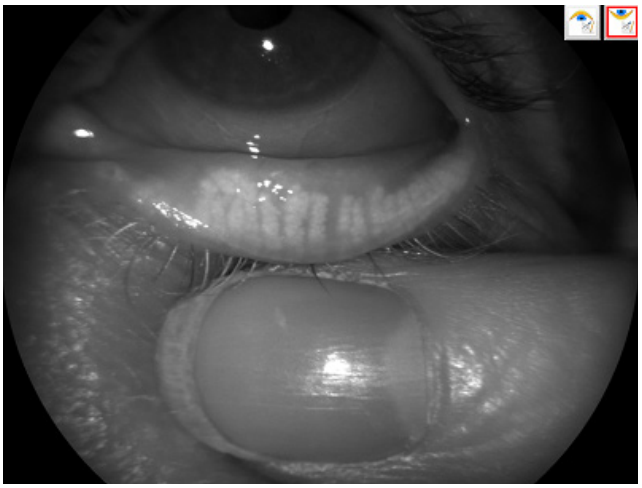
The purpose of Meibography is to evaluate the health of meibomian glands. Such examination can be performed by scheimpflug camera, keratoscope or fundus camera using the instruments' IR (infra-red) illumination source, since meibomian glands cannot be spotted using standard visible light illumination.

After the IR images of meibomian glands have been acquired using the Live acquisition environment of the selected instrument, they have to be manually processed by the operator in order to calculate the gland health score and save it for further patient evaluation.

As a principle, the glands' health tends to decrease as its area becomes smaller inside the eye-lid: while a healthy eye presents the inside of upper and lower eye-lids completely filled with meibomian glands, a suffering (dry) eye presents a surface of "eroded" meibomian glands. So the main idea is to calculate the ratio between the area covered with glands and the total eye-lid area. A low ratio determines a high probability of suffering dry eye.

Meibomian glands examination involves acquisition and further analysis.

MEIBOGRAPHY | ACQUISITION



Meibography images can be acquired by scheimpflug camera, keratoscope and fundus camera.

Please note that there could be some major differences in images acquired with the different instruments due to the individual optical engineering adopted in each of them. Meibography examination should indeed be considered as a secondary examination type which takes advantage of the infra-red illumnation capalibilies of the mentioned instruments, whilst they have been developed for completely different primary tasks.

N.B.: When acquiring with scheimpflug camera it is highly advisable to place a 4x Lens in front of the instrument, otherwise the image cannot cover the whole glands area due to a reduced field of view.

The acquisition procedure explained below is very simple and is replicable using every supported instrument. Consult the manual for more detalis about the live acquisition environment for each instrument.

» Start the acquisition and prepare the patient by exposing the upper-lid and lower-lid meibomian glands, in any order.

» Center the glands on-screen and focus the image moving the instrument forwards or backwards (or using the focus handle in case of fundus camera).

» Take the picture using joystick button. Acquired picture will be shown on screen as a thumbnail. Acquire at least one image for the upper-lid and one for the lower-lid.

» After a satisfactory amount of images has been acquired, exit Live acquisition.

After the acquisition is complete, exit the live environment and open the examination to start the analysis.

MEIBOGRAPHY ANALYSIS

Enter the meibography examination gallery in the main screen and double-click on the desired image to start meibomian glands evaluation. The procedure is computer-assisted but requires manual tracing of glands points.

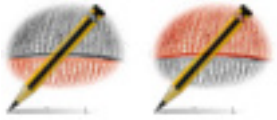


Fig 1. Upper / lower eye lid selector

SELECT THE EYE-LID

First of all, use the buttons on the top-right of the screen (fig. 1) to select the evaluation for upper-lid and lower-lid, respectively: the example described above shows a case where the lower lid evaluation is selected.
The same buttons can be used to delete the evaluation measure and restart the process at any time. Deletion is preceded by a confirmation message.
Deleting the measurement means that all control points currently displayed will be lost.

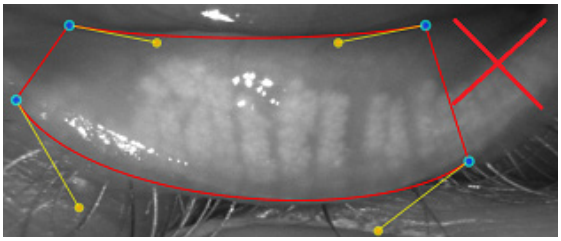


Fig 2. Correctly selected eye-lid area. The red cross indicates the area that should not be selected since the eye-lid is not completely reverted there.

TRACE EYE-LID BOUNDARIES

Four (4) control points must be set in order to define a very raw bound of the eye-lid's area of interest.
Place the blue points in order to build a trapezoidal shape. Exclude lid areas that are not completely reverted, since they are not useful for the computation.
One point (in the example case the left-most one) should be placed near the tear punctum, while the opposite side points (the right-most ones) should be placed on the end-fold of the eye-lid or, as stated before, where the eye-lid is not completely reverted anymore (as show in fig. 2). All the control points that have already been set can still be canceled until the last point is set by hovering the mouse on them and left-clicking when the white cross appears.
The bounds (red lines) do not need to be very precise in this phase, since they will be adjusted automatically in the next phase.

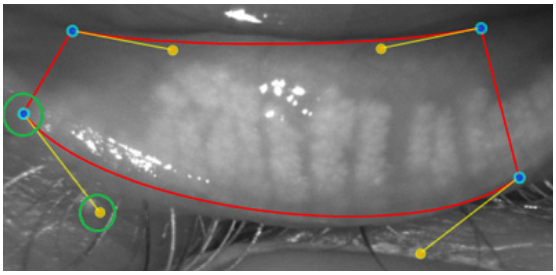


Fig 3. Adjust the boundaries by moving the yellow control points

ADJUST THE BOUNDARIES

Use the all yellow points to adjust the red shape. Try to move the points (including the 4 manually set points) and see how their movement affects the global shape (see fig. 3).
The yellow points at the end of the yellow lines can be stretched, such as to modify the curvature of the red shape.
The mechanism is very intuitive anyway: try to approximate the eye-lid shape, but remember that there is no need to be too strict in this approximation.

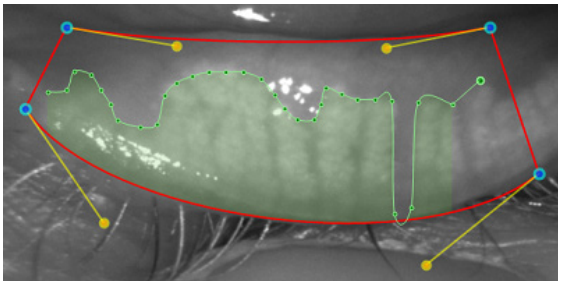


Fig 4. Marked green gland-points

TRACE THE GLANDS POINTS

Highlight the glands area by left-clicking on the upper glands bounds (or lower bounds, in case of upper eye-lid meibography), as shown in fig. 4.

Every click adds a green gland-point: the more points are set, the more accurate the gland area is. It is also possible to keep the mouse button clicked, then moving the mouse to draw the glands bound: green points will be automatically set.
Avoid crossing lines or creating loops or complex paths.
It is not possible to create gland points outside of the red bounds: a mouse-click outside the red borders will result in the adding of a gland point on the nearest red bound.

EDIT THE GLANDS POINTS

Defined points can be removed by left-clicking the mouse; a white cross appears on the point when the mouse passes over the point. Right-click on a single point pops up a context menu which allows removing the single point or all the gland points defined so far.

New points can also be set between existing ones in order to refine the green line shape. Just move the mouse between points to obtain a preview of the new point's influence, then left-click to add it to the points set definitively (see fig. 5).

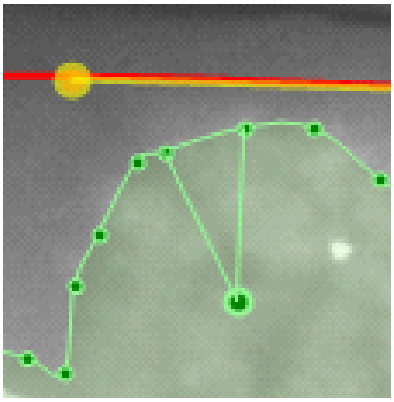


Fig 5. Edit existing glands points

SWITCH BETWEEN ZOOM MODE AND TRACE MODE

Sometimes it is necessary to zoom in the image to obtain more precision in tracing gland points.
While tracing points on a zoomed meibography image, it is no longer possible to move the zoomed image as usual, since a left-click on the image would produce a new gland point, not a "moving grip" as it would in normal image viewing.

To by-pass this behavior, click and keep clicked the right mouse button (an alert appears as shown in the screenshot) to switch between points-tracing mode and standard zoom mode (which allows moving the image), as shown in fig 6.

The same switching function can be obtained by clicking the  icon which appears only when image is zoomed in.

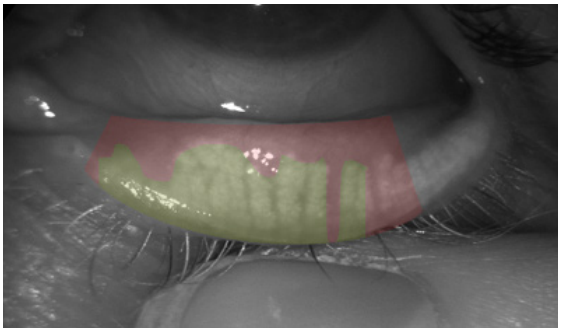


Fig. 7 Complete examination

FINALIZE MEIBOGRAPHY EXAMINATION

Once all gland points have been placed, click the  icon to end the editing phase.
Healthy gland area will be drawn in green, while loss area will be red.
Area of loss score is calculated together with a pre-established degree in the meibomian scale.
Score and degree are printed and visible directly on the image, while a detailed review of the attributed score is available in a separate window which appears on the top left corner of the main form.
Meibography score is automatically calculated even if the flag-button is not pressed and edit mode is closed by clicking the quit button.

The updated image can now be printed (alone or compared with other processed or unprocessed meibographies), saved in pdf format etc.

It is possible to return to the editing mode by clicking the  icon which becomes visible after the meibography has been validated with the flag-button.
This way the examination is always editable after re-entering it in the future.

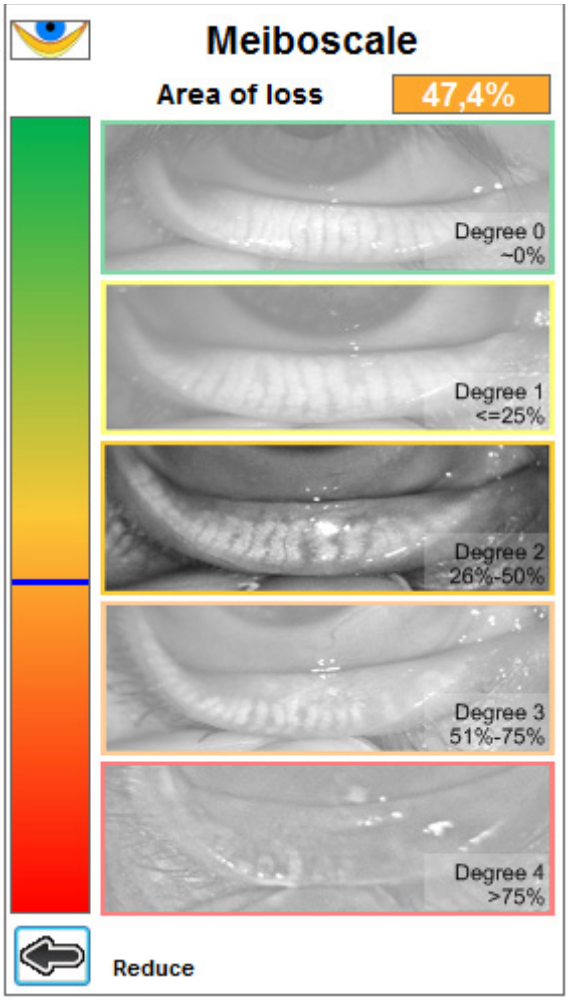
MEIBOGRAPHY | MEIBOMIAN SCALE

The meibo-scale window in the top left corner of the screen can be expanded (and then collapsed again) for further reviewing of the attributed score.
The scale (1) is available only after the meibomian glands analysis is complete.

The meibomian scale classifies 5 distinct degrees of loss of glands functionality.

The scale also provides 5 image samples (one for each degree of loss) for consulting and visual comparison with the current examination image.

Those samples may help to understand if the whole process has been completed correctly, so that the sample image reflects the health state of the processed image with a coherent area of loss score.



1. *Pult H1, Riede-Pult B.. "Comparison of subjective grading and objective assessment in meibography" Cont Lens Anterior Eye. 2013 Feb;36*

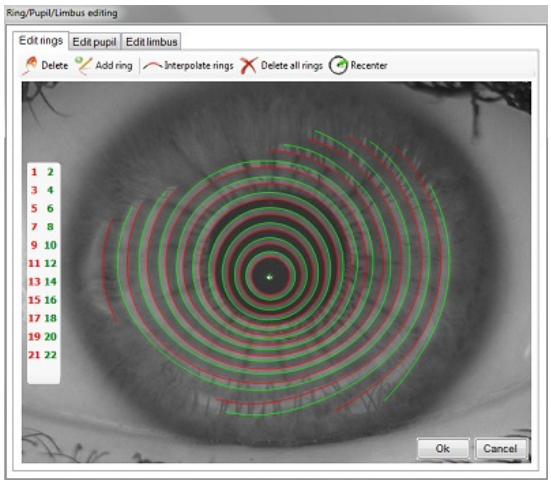
ASOCT BASED CORNEAL TOPOGRAPHY

To access the Rings/Pupil/Limbus editing functions select

Rings/Pupil/Limbus editing from the **Edit** menu.

RINGS EDITING

The software automatically recognizes the keratoscopic rings positions reflected off the cornea, detecting dark-to-bright or bright-to-dark transitions. The rings detection is emphasized on the screen as alternating green and red circles. Irregularities, corneal opacity or shadows from eyelashes or the nose may cause mistakes on proper ring identification: it is important to check the correct detection of the rings before starting the analysis of topographic maps. The software offers the possibility to fix the detected rings by manually editing them. The window contains a set of buttons identifying rings on keratoscopy, and five buttons that allow editing of the rings.



Rings editing

SELECTING A RING

To select a ring move the mouse cursor onto the ring to be selected and right-click or press the button with the corresponding number on the screen.
When selecting a ring, points situated on the ring are joined by an orange line, the addition or removal will only happen to this ring. When selecting a ring, it is possible to select the previous or next ring by using the arrow keys on the keyboard.

DELETING A RING

To delete points, press the button **Delete** icon. Moving the mouse cursor over the keratoscopic image and holding the left mouse button, a circular cursor appears: points below the cursor will be removed. When you select a ring, you can remove only points belonging to that particular ring. To delete an entire ring press the Del or Backspace key on the keyboard.

Pupil editing

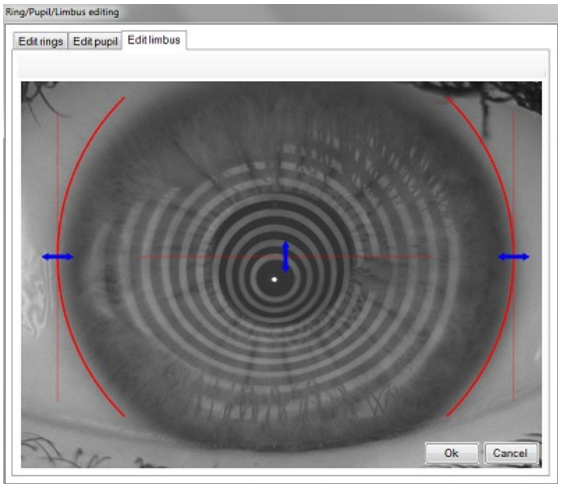
DELETE ALL RINGS AND RE-CENTER

Pressing the **Delete all rings** icon will erase all the detected points. After confirming the alert message "Are you sure you want to erase all the rings?"

press **Recenter** and the program will let you choose a new keratoscopic center. Use arrow keys to find the correct position of the center and confirm by pressing the Enter key.

ADDING A RING

To add points press the **Add ring** icon and select the ring you want to complete. Then press the left mouse button on a point that is part of the ring image. Interpolating rings. To complete a missing part of a ring, just press the Interpolate rings icon.



Limbus editing

PUPIL EDITING

After pressing the **Edit pupil** icon, the pupil is highlighted as a red circle with a red center,bordered by three yellow crosses.
To change position and size of the pupil:

» Drag and drop the red circle representing the pupil in the right position.

or

» Drag and drop the yellow crosses that define the red circle.

Pressing the **Delete** pupil the pupil will be deleted.
Right-clicking on the image the corneal vertex will be assigned.

LIMBUS EDITING

When you open this editing window, the limbus is marked with two red semicircles.
To change the size of the limbus:

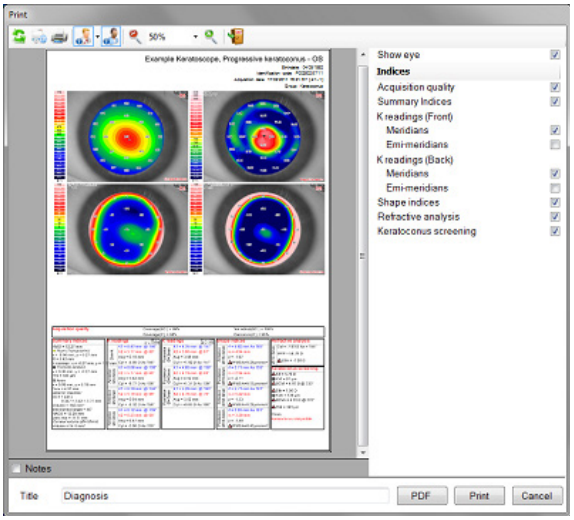
» Drag and drop the blue horizontal arrows and drag to resize the limbus.
» Drag and drop the blue vertical blue arrow to move the limbus vertically.

AS-OCT CORNEAL TOPOGRAPHY | PRINTING

You can access the print functionality through **Print** and **Print screen** under the menu **File.**
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

On the right side of the screen a list of options is shown which allows you to display or hide indices on the final printout.

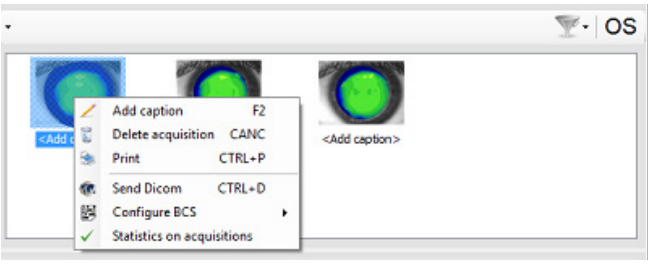
Print (Quick) and **Print screen** (quick) functionality, also under the File menu, allows you to print without preview.



Print preview

AS-OCT | STATISTICS ON ACQUISITION

Statistics on acquisition window can be accessed by right-clicking on one of the thumbnails in the acquisition gallery and then left-clicking the **Statistics on acquisition** menu item of the contextual menu.



This window is useful for evaluating the quality and the repeatability of the acquisitions belonging to the same examination.

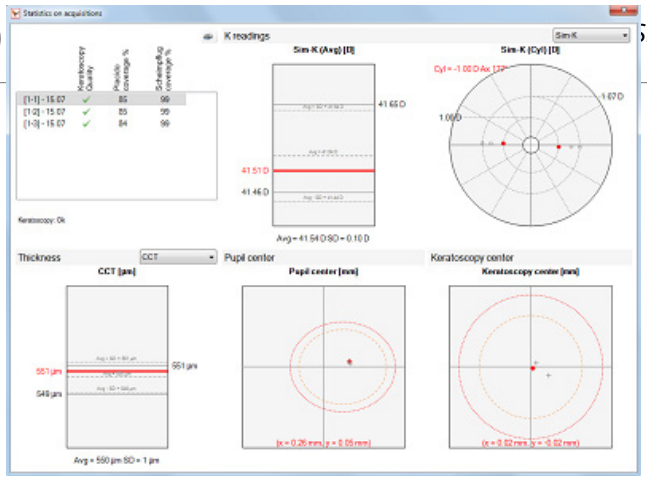
At the top-left corner a table is shown with the list of the selected acquisitions. Each row of the table refers to a single acquisition and contains its ID, date and time of the acquisition, a symbol for the quality of the keratoscopy (green for good quality, red for bad quality), the percentage coverage for the Placido disc, the percentage coverage for the OCT sectional images (Section coverage).
By selecting a row in the table (i.e a certain acquisition), the corresponding data are highlighted in the plots described below.

At the top of the window for K readings (Sim-K or Meridians at 3 mm) a scatter-box plot for the average value and a polar scatter plot for cylinder are shown. Average and standard deviation are reported for the Sim-K (Avg) and

for the Meridians at 3 mm (Avg).

At the bottom-left corner of the window a cartesian scatter plot is dedicated to pupil decentration with respect to corneal vertex.

At the bottom-right corner of the window a cartesian scatter plot is dedicated to keratoscopy decentration with respect to the optical instrument axis. Low decentration values are within the yellow dashed circle, high decentration values are outside the red dotted circle. When the keratoscopy center is outside the red circle it is strongly advised to discard the acquisition.



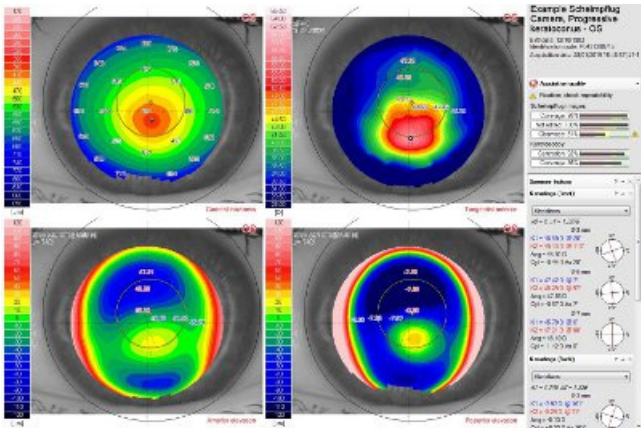
Statistics on acquisition window

SUMMARY

» by double-clicking on an AS-OCT Topography acquisition on the main screen.

» by choosing **Summary** from the **Analysis** menu by clicking the icon  on the toolbar

This screen is the shown first: it displays a clinical summary of the maps and data derived from processing each single image capture. The Summary consists of four maps (tangential, sagittal, elevation, and refractive power) and a right-hand panel with customizable indices. The software will save the state of the panel and will restore it when a new window is opened.



Summary

SECTION IMAGES

Section images screen is displayed:
» by choosing **Section images** from the **Analysis menu**

» by clicking the  icon on the toolbar
» by double-clicking on the acquisition icon in the right and left eye gallery (only for AS-OCT Section exams)

This windows is used
» to review the sectional images captured by the AS-OCT instrument
» to adjust grey levels
» to make measurements of interesting structures

Section image

AS-OCT CORNEAL TOPOGRAPHY | SINGLE MAP

Single map screen is displayed:

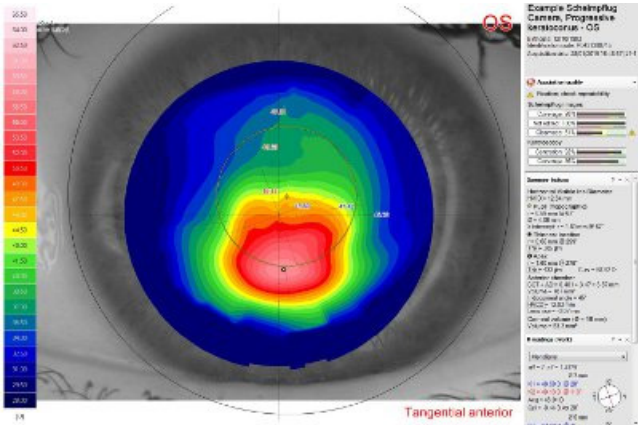
» by choosing **Single map** from the **Analysis** menu

» by clicking the icon on the toolbar
» double-clicking the map of choice from the Summary.

This screen displays a single map in full-screen mode. The type of map can be selected from the toolbar between:

» Corneal thickness
» Epithelial thickness
» Tangential anterior
» Tangential posterior
» Sagittal anterior
» Sagittal posterior
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber
» Background

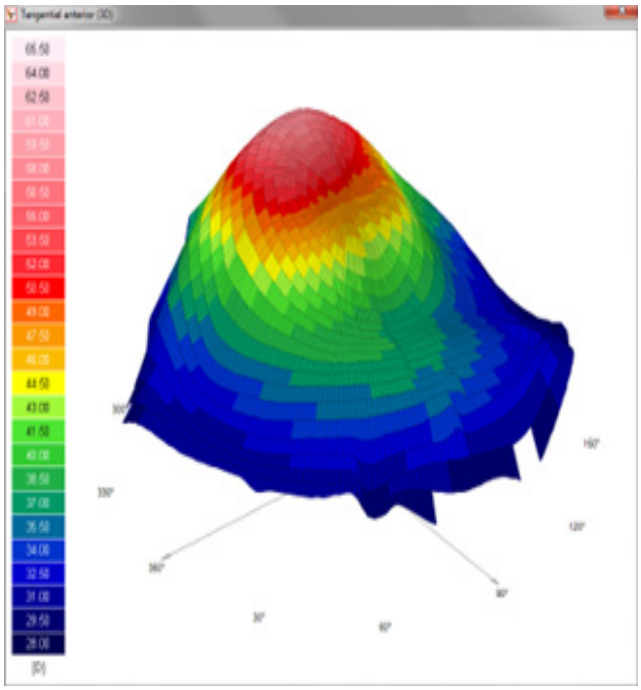
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Single map

3-D MAP

The icon becomes active only in this screen. When pressed a three-dimensional view of the current corneal map is shown.
Hold down the left mouse and drag the end points of the Cartesian diagram enclosing the map to view it from different perspectives.
Right-clicking a context menu to print the screen, save the screen as an image, or change the view type is shown.



Three-dimensional view of the tangential anterior map

AS-OCT CORNEAL TOPOGRAPHY | MULTIMAP

Multimap screen is displayed:

» by choosing **Multimap** from the **Analysis** menu

» by clicking the  icon on the toolbar

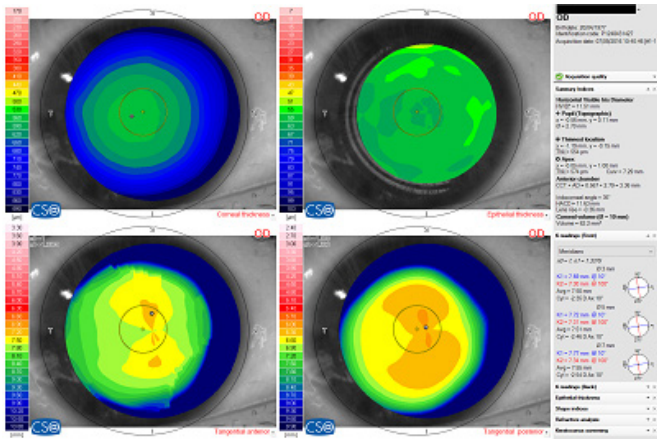
This customizable screen displays maps according to the user preferences. Three types of customizable layouts are available:

» Multi-map+Indices, to select 4 maps and their respective indices
» Multi-map+Images, to select 4 maps and Section images
» Multi-map 6X, to select 6 maps

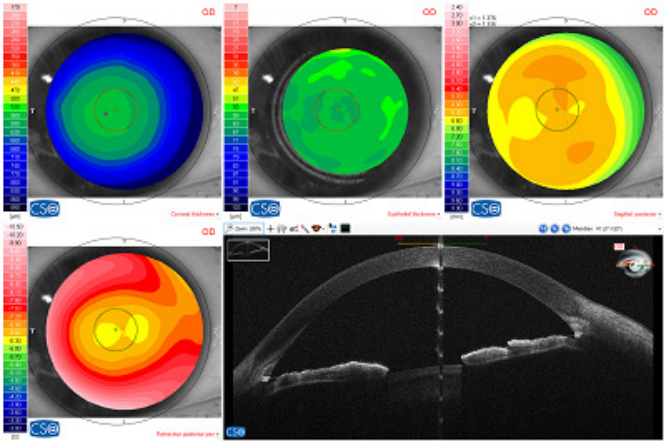
At the bottom right corner of each map the following types of map can be selected in the following list:

» Corneal thickness
» Epithelial thickness
» Tangential anterior
» Tangential posterior
» Sagittal anterior
» Sagittal posterior
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber
» Background

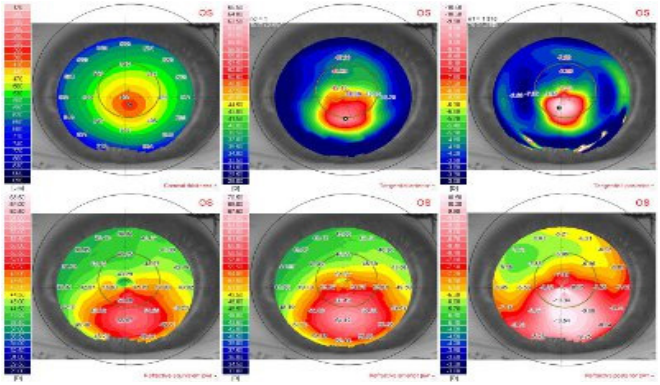
Only in Multi-map+Indices a panel with customizable panel indices is shown at the right of the window: the software will save the state of the panel and will restore it when a new window is opened.



Multimap+Indices



Multimap+Images



Multimap 6X

KERATOCONUS SUMMARY

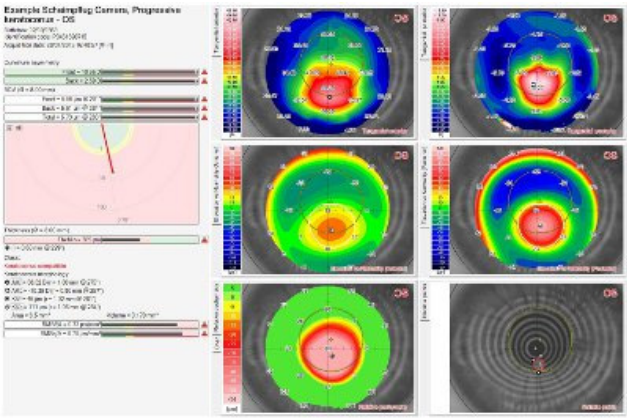
Keratoconus Summary is displayed by:

» by choosing **Keratoconus Summary** from the **Analysis** menu

» by clicking the icon on the toolbar

Analysis is performed by means of the following maps:

» Tangential anterior map on an area of 8 mm
» Tangential posterior map on an area of 8 mm
» Elevation anterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. This type of representation, that hides information on astigmatism and medium corneal power, is particularly useful since it highlights the higher orders only and therefore, in cases of keratoconus, the ectasic area and its entity.
» Elevation posterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. The considerations made for the information on anterior elevation are even more important for the posterior surface, since the ectatic effect is shown anticipatively and more pronounced respective to the anterior surface
» Difference between the patients corneal thickness and the 2.5th percentile of pachymetry for a healthy population.
» **PTI** (Thickness Increase %) and **CTSP** (Corneal thickness spatial profile) charts[2].
» The position of some interesting markers Steepest point of the anterior corneal surface (**AKf** – Apical Keratoscopy FRONT); Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK); Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT); Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK); Thinnest point of cornea (**ThkMin** – Minimum Thickness).



Keratoconus summary

In order to help the practitioner in the identification of keratoconus cases or to evaluate, during follow-up, the entity and the progression of keratoconus, a series of indices is shown based on curvature, pachymetry and elevation data of anterior and posterior corneal surfaces. These indices describe the most relevant features of keratoconus:

CURVATURE ASYMMETRY

» The Symmetry Index of the curvature (**SIf** – SymmetryIndex) SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normality values are shown (95° percentile and 99° percentile of a normal population);
» The Symmetry Index of the posterior curvature (SIb – SymmetryIndexBACK) is defined as the difference of the mean posterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump

has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

ELEVATION BASED INDICIES

» The BCVf e BCVb allow the evaluation of the presence and of the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of elevations $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$,in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) + \gamma C_4^{0}$$

» The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components. The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normal values are shown (95° percentile e 99° percentile of a normal population);

» The index BCV or vectorial BCV is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normal values are shown (95° percentile and 99° percentile of a normal population).

The previous data are processed by a neural network in order to classify the case in one of the following groups:

» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

In case of classification as Keratoconus compatible some further morphologic indices are shown:

Steepest point of the anterior corneal surface (**AKf** – Apical KeratoscopyFRONT);
Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK); Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK);
Thinnest point of cornea (**ThkMin** – Minimum Thickness).

» Area and volume of the ectasic zone;
» RMS/A and RMSb/A, root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 8 mm zone for both the anterior and posterior surfaces of cornea.

The keratoconus screening indices provide indications which are not sufficient for assessing either instrument calibration status or the patient's clinical situation. These indices should thus be considered as diagnostic tools for the user but not as indicators of certain diagnosis of keratoconus.
We therefore caution the user to take maximum care when evaluating these values and to correlate the screening indices with other tests and with the patient's clinical history.

The **Keratoconus Summary** *was developed and validated by CSO srl in cooperation with the following eye clinics:*

» Arbelaez, Maria Clara MD, Muscat Eye Laser Center, Muscat, Oman
» Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy
» Piero Barboni MD, Studio Oculistico d'Azeglio. Bologna, Italy

1. Arbelaez, Maria Clara, et al. "Use of a support vector machine for keratoconus and subclinical keratoconus detection by topographic and tomographic data."Ophthalmology 119.11 (2012): 2231-2238.

2. Ambrósio R Jr, Simonato Alonso R, Luz A, Coca Velarde LG. Corneal-thickness spatial profile and corneal-volume distribution: tomographic indices to detect keratoconus. J Cataract Refract Surg 2006;32:1851-1859.

CATARACT SUMMARY

Cataract summary is displayed:

» by choosing **Cataract summary** from the **Analysis** menu

» by clicking the icon on the toolbar

This module is dedicated to the calculation of intra-ocular lenses (IOL). This calculation is not based on synthetic parameters like SimK, but uses measurements of the anterior segment obtained from the instrument. In particular, the calculation uses the elevation measurements of the anterior and posterior corneal surface, and the entry pupil. This information is used to create a three-dimensional model of the eye, that considers also potential asymmetries and irregularities of the examined eye. The ray-tracing method is used to trace the way light rays pass through the various surfaces of the eye, following Snell's Law. In this way we simulate the way the light ray passes from cornea to retina, passing intra-ocular lenses of different powers.

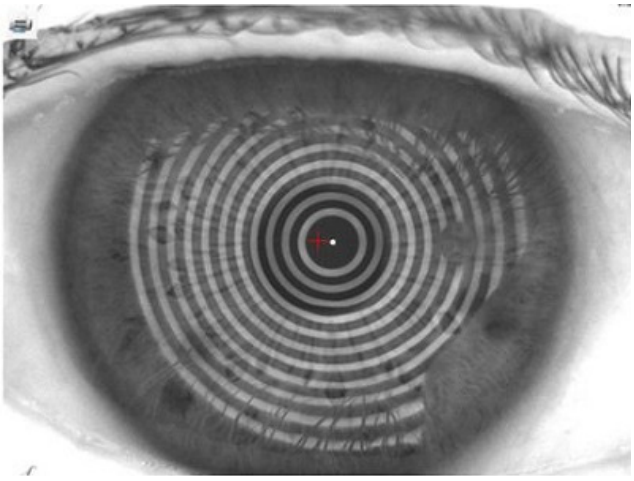


Figure 1: Example of a badly centered keratoscopy

CORRECT USE OF THE INSTRUMENT

Golden rules for an optimal result
The acquired eye must be wide open and well centered - The tear film must be regularly distributed - The pupil must not be dilated - Make at least three similar acquisitions - Check the auto-detected pupil's position; edit when necessary

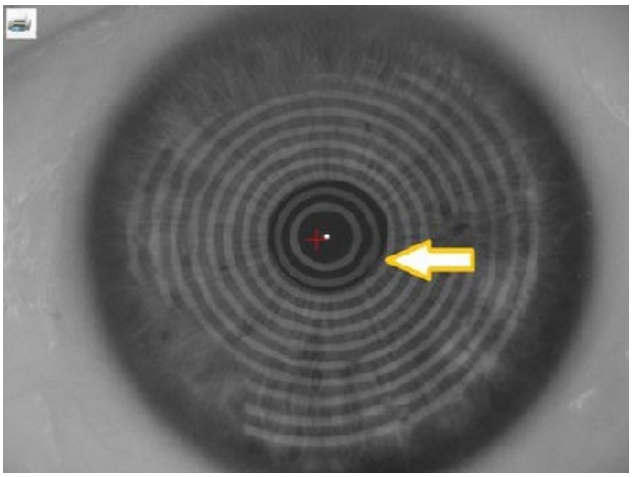


Figure 2: Decentered keratoscopy with artifacts: the rings in the indicated zone are distorted

To correctly use the Sirius for calculation of intra-ocular lenses, we strongly advise that you acquire at least 3 images of the eye, in which the lens is to be implanted. The patient's pupil must not be dilated when using the instrument. The acquisitions all need to be well-centered (see Figure 1) and taken while the eye is wide open. The operator should verify that there are no residual anomalies or artifacts on the acquisition, due to an irregular distribution of the tear film. If a distortion is verified, e.g. shades and/or interruptions over the rings (see Figure 2 and Figure 3), it is advised to ask the patient to blink in order to restore the tear film.

If any of the three acquired images shows a deviation of SimK greater than 0.3 D, we recommend that you take another acquisition. When the pupil position is different in the various acquisitions, it is recommended that you repeat the acquisition process: it is an indication that the patient is not fixating correctly. A quick evaluation of repeatability, for the presence of artifacts and tear film coverage can be performed from the main management window, by reviewing the various acquisitions from the current exam (see Figure 4).

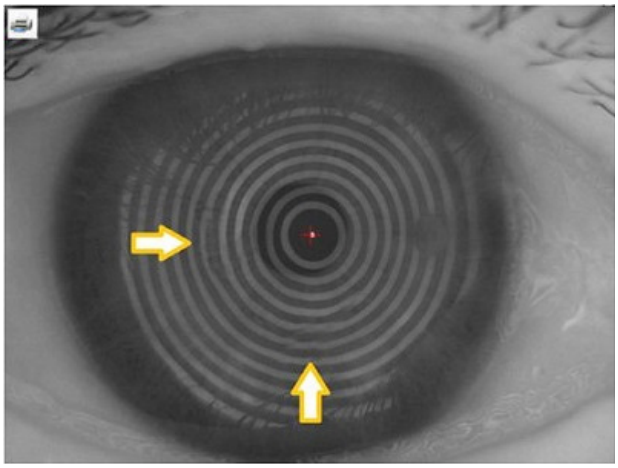


Figure 3: Well-centered keratoscopy with artifacts: The rings in the indicated zone are distorted

The incorrect detection of the scleral spurs might influence negatively the prediction of the IOL position. In the case where irido-corneal angles are not visible in the 7 meridians where the measurement of this angle is available (0°, 7°, 14°, 21, 158°, 166°, 173°) we recommend that you repeat the acquisition, making sure that the patient's eye is wide open during the entire acquisition sequence. If the patient is not able to keep their eye wide open for the entire duration of the acquisition, the software will show a pop-up asking for the manual editing of the missing scleral spurs. The operator should, in this case manually, add the scleral spur point in the position that is likely to be the correct position (see Figure 6).

DATA TO BE INSERTED

Before starting the intra-ocular lens calculation, the user should insert and/or verify the following information:

» The eye's axial length in mm has been obtained using a biometer
» The device used for the measurement of the axial length: PCI (Partial Coherence Interferometry), Ultrasound (US) by immersion, Ultrasound (US) by contact.
» The target refraction, i.e. the desired spherical equivalent after the implantation of the lens
» The pupil diameter for which we want to optimize the calculation for the lens power, in order to obtain the target refraction.
» The A Constant (or ACD or SF) of the implanted lens

All of the data, except for the last one parameter, needs to be (re)inserted in the Pre-Op page.

For the sake of convenience, the keratometries and the indices of Refractive Analysis are shown in the left part of the page. Besides those, optional warnings are shown that might guide the user in verifying the correctness of the input data. Those warnings are, e.g., an inserted axial length outside the normal range or excessive pupil decentering that might be caused by the patient's incorrect fixation during acquisition or by the software not having (correctly) auto-detected the pupil.
On the right-hand side of the Pre-Op page these options are available:

» the iris image with indication of the principal meridians and SimK. A goniometer is shown in overlay, in order to help the operator search for a reference to aid with the implantation of a toric lens.
» according to the operator's preference, the sagittal map of the anterior surface or the equivalent refractive power.

The software for calculating the IOL allows for the specification of a pupil diameter between 2 and 3 mm. This is the entry pupil taken into consideration for the calculation of the best lens, for the currently examined eye.
We suggest the use of a pupil diameter of 3 mm for normal eyes. For eyes examined after refractive surgery, it might be useful to choose a diameter of 2 mm, when the optical zone is very small and/or decentered.
When the axial length is set and optionally other input data is corrected, the calculation for the new intraocular lens can be started by pressing the button New IOL. A small window is shown where you can set the following parameters:

» IOL manufacturer
» IOL model
» The lens constant in one of its forms (A or ACD or SF). Based on this constant and the measured morphological parameters, the software calculates the Predicted Lens Position (PLP).
» The position of IOL center. The IOL center can be chosen equal to the corneal vertex, pupil center or limbus center.
» The axis of the least powerful meridian of the lens
» The values of the cylinders for the toric lenses which will be considered in the calculation

By clicking **OK**, the lens calculation is started.
When the pupil center or limbus center are chosen as the position of the IOL center, it is very important to check whether the software was able to

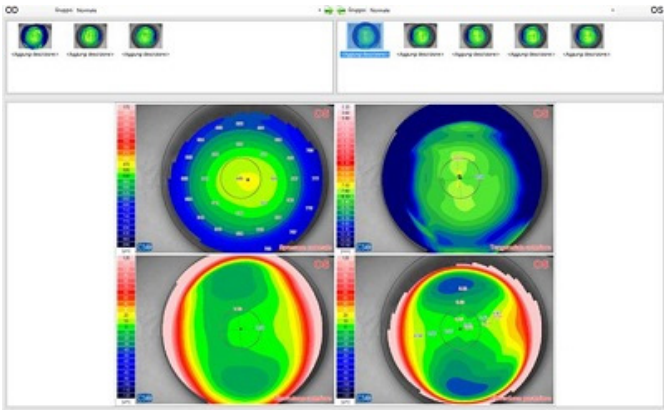


Figure 4: Patient management window: evaluation of repeatability, presence of artifacts, and correct coverage

detect them automatically or use the manual editing when necessary.
The axis of the least powerful meridian is set by default as the axis of the corneal cylinder calculated from OPD (or WFE).

PREDICTED LENS POSITION (PLP)

The PLP (Predicted Lens Position) is the software's predicted distance from anterior surface of the implanted lens to the posterior surface of the cornea. This prediction is based on a collection of measured factors, obtained from the anterior segment, and on the provided A (ACD or SF) constant. It is noted that a prediction error is normally one of the principal sources of error for all formulas and systems for calculation of intra-ocular lens power.

FIRST TIME USE OF AN IOL MODEL

When starting out with this software, and using a IOL model for the first time, it is advised to use the nominal A constant value, provided by the IOL constructor, and to optimize the value based upon post-operative information, obtained at least one month after the operation. In particular, when collecting post-operative cases, the operator should check the actual position of the anterior surface of the IOL after the operation (see Figure 7), and verify with the position predicted by the software before the surgery. Adjust the Gamma level, if necessary, using the mouse wheel or the +/- buttons in order to make the implanted IOL more visible in the tomographic images (see Figure 7). If the actual distance of the lens is greater than the predicted one, the constant value should be adjusted upwards, if it is smaller than the predicted distance, the value should be adjusted downwards.

RESULTS

For any new calculated lens, a new page of the module is created containing results of processing.
At the top of the page the following data are shown: IOL manufacturer and model, lens constant, position of the center of the lens and predicted position of the lens (PLP).
In the central part of the page the following information is available:

» a table containing summarized results of the calculus, i.e. for a list of powers the respective predicted spherical equivalents
» a table containing the predicted refraction in for to a certain IOL cylinder (at the IOL plane) for the mean power selected in the previous table
» a chart for Focusing

The Focusing chart contains the curve of the merit figure for visual acuity, obtained with various corrections, for the lens selected from the calculated lens power table. From a different point of view, the Focusing chart shows how the visual acuity varies for several vergences of the observed object. This chart is therefore useful to evaluate the depth of field for the pseudo-phakic eye.
At the bottom of the page the following information is available

» the Point Spread Function (PSF) for the selected lens
» according to the operator's preference, the simulated wavefront map (OPD or WFE) or the Refractive Error map

The 2 previous maps reference the lens selected in the two upper tables, characterized by the mean power selected in the left table and by the cylinder selected in the central table. The map for refractive error shows the refractive error for any ray passing through the pupil. It is useful to evaluate the presence of possible defocus, astigmatism and asymmetries in the optical ocular system

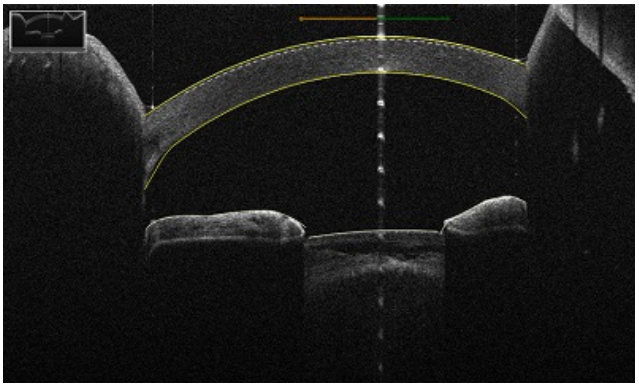


Figure 5: Half-closed eye

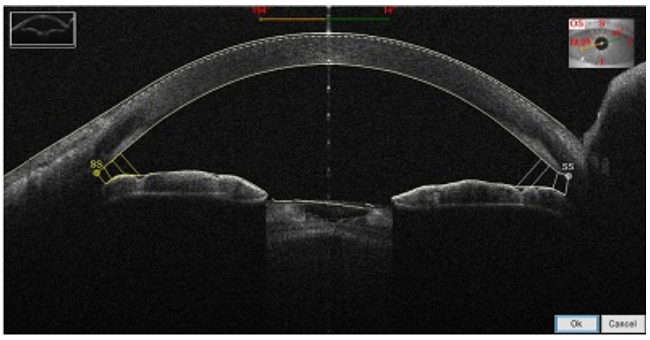


Figure 6: Editing of the scleral spur

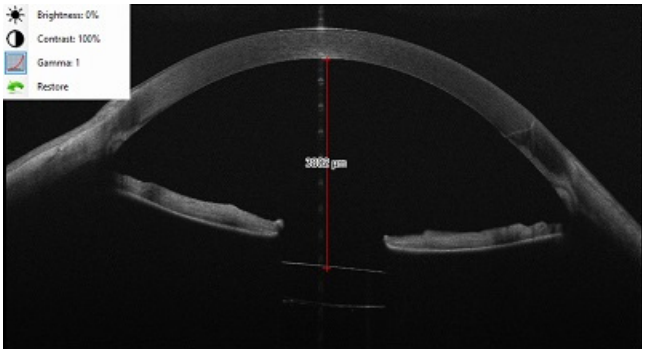


Figure7: How to verify the position of the IOL at 1 month after surgery

The results of the calculation can be printed by pressing the **Print** icon in the upper right corner.

The **Toric IOL Marker** icon launches the tool dedicated to the marking of toric intraocular lenses.

A page dedicated to the lens calculation can be removed by pressing the **Remove IOL** icon in the upper right corner.

The manufacturer bears no liability for consequential damages resulting from any application of the results contained in Cataract Summary, particularly for damages coming from an erroneous IOL calculation. The user of the program has to make sure that the proposed values do not contain any mistakes.

The **Cataract Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:

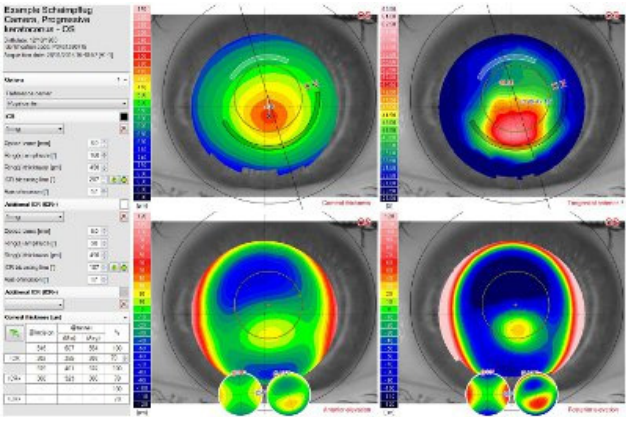
» Aramberri Jaime MD, BEGITEK Clínica Oftalmológica. San Sebastián, Spain OKULAR Clínica Oftalmológica. Vitoria-Gasteiz, Spain
» Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy
» Camellin Massimo MD, Sekal Microchirurgia Rovigo S.r.L. Rovigo, Italy
» Bedei Andrea MD, Pietrelli Alessia MD, Casa di Cura "San Camillo". Forte dei Marmi, Lucca, Italy
» Bellucci Roberto MD, Cargnoni Miriam Ort., Nguyen Deborah Ort., Hospital of Verona. Verona, Italy
» Ligabue Edoardo MD, Giordano Cristina OD, LA MIA
» VISTA. Milano, Italy
» Fantozzi Marco MD, Fortunato Francesco Ort., Studio Oculistico Fantozzi. Pescia, Pistoia, Italy

INTRASTROMAL RINGS SUMMARY

Intrastromal rings summary is displayed:

» by choosing **Intrastromal rings** from the **Analysis** menu

» by clicking the icon on the toolbar



Intrastromal rings summary

Intra Corneal Rings Segments (ICRS) are devices made of PMMA that are successfully used in the treatment of myopia, severe post-keratoplasty astigmatism, post-refractive surgery ectasia of the cornea, keratoconus and pellucid marginal degeneration. Correction of myopia (from -1D to -3D) was the first field in which these rings were used[1], however, today they are widely used in eyes with keratoconus or pellucid marginal degeneration[2–7].

ICRs are semi-circular rings (or ring segments) the length, thickness and section of which varies. Their action is based on the fact that, by inserting these stiff elements inside the corneal stroma, they separate the corneal lamellae and thus shorten the anterior corneal arc. Introducing the ring segments in the peripheral media reduces the length of the fibre arc, thus flattening the central cornea. To get a better understanding of the modifications in corneal structure achieved with the "additive" surgical technique, we can look at the Barraquer "thickness law"[8–9]. According to this law, when you add material to the periphery of the cornea, therefore increasing the thickness of the peripheral cornea, you flatten the central cornea; instead, if you add material at the center of the cornea, you increase the central curvature. The extent of this effect is directly proportional to the thickness of the implant and inversely proportional to its diameter. Moreover, some scholars[10] who have used mathematical models that take into account the asphericity and/or spherical distortion of the eye to examine the effect of ICRs in correcting myopia, have shown that, to better flatten the anterior corneal surface, and thus improve the refractive effect, one needs to either insert thicker ring segments or implant them in a more central position.

When ICRs are used to treat corneas with keratoconus, the goal is not so much to eliminate the refractive defect as to improve both the patient's visual acuity and visual quality. In fact, in these cases, such rings lead to re-centring of the conus, thus normalizing the anterior corneal surfaces through a reduction in chromatic aberration, and reducing the ectasia by flattening the central cornea; all this reduces the irregular component of the astigmatism and reduces refractive correction (myopic and astigmatic). ICR implants for keratoconus must take into account the fact that, while the surgical technique is not particularly invasive and carries low risk of complications, there is the drawback that the pathological tissue is maintained. And thus it ensues that there are limitations for the choice of patients; in particular, patients with altered corneal transparency — Vogt's striae or stromal opacities -, advanced keratoconus and degenerated apex must be ruled out.

Different types of ICRs are available according to arc, thickness and implantation site. INTACSs are hexagonal-section segments in PMMA with arc circumference of 150 degrees. The external diameter of each segment is 8.10 mm, the internal diameter 6.77 mm and the thickness varies (ranging from 0.25 to 0.45 mm). Instead, INTACS SKs have an internal diameter of 6 mm, an oval section, and come in two thicknesses: 0.40 mm and 0.45 mm. The other two types of ICR are the Ferrara and Kerarings rings. Both have triangular section and come in various thicknesses and arc lengths.

For each ICR model, nomograms are available. Considering the patient's refraction and corneal morphology — obtained via corneal topography - these nomograms make it possible to precisely calculate the number, thickness and arc length for the rings to be implanted. It can also be decided whether to correct the patient's astigmatism or give priority to correction of chromatic aberration, as in the case of keratoconus patients whose visual capacity is limited by high corneal surface asymmetry. There is no fixed rule for this; one should take into account the best visual acuity correction and subjective refraction for each patient, above all for the axis of the subjective cylinder, and check these against the topographic and coma axes (in most cases one or the other coincides). It is possible to implant a ring or two segments that match or having different dimensions and thicknesses, or one can even insert several segments. Except for the site of the incision, the surgical technique for ICR implant treatment of keratoconus is similar to that used for the corrections of minor myopia. In fact, the incision site depends on where the segments are to be inserted and is calculated on a case-by-case basis. If the two segments to be implanted are asymmetrical, the thicker of the two is inserted in the lower position — as this recentres the conus —, while the thinner is inserted in the upper position — thus flattening the cornea and reducing the irregular astigmatism.

The ICR implant calls for making a peripheral incision, its distance from the centre varies according to the ring diameter; then a circular canal is created to accommodate the ICRs which are inserted by rotating them until they reach the desired position. The incision and canal can be created manually, with the aid of special instrumentation, or with a femtosecond laser. For myopia correction the incision is generally made at 12 o'clock, with the introduction of two segments set symmetrically on opposite sides, in the nasal and temporal sectors. To achieve the desired effect it is also important to insert the ICR in the back 2/3 of the cornea (70-78%) and, to that purpose, the pachymetric map must be carefully studied in order to calculate the proper implant depth. Remember, often the estimated incision depth does not correspond to the actual depth achieved; therefore the ICRs may actually be closer to the surface than envisaged; this is more evident when the incision is performed manually while use of a femtosecond laser appears to ensure greater precision.

The Summary of Intrastromal Corneal Rings is used to monitor corneal thickness in the area of the implant and, at the same time, provide a printable summary depicting the main topographic maps which are useful for this type of surgery.
The left side of the summary shows:

» The center of reference: choice between Center of the pupil and Center of the Limbus, specifying the site where the implant is to be centered;
» for each Ring/Pair of rings (up to 3), the tables provide the data for:
  - o Optical zone: indicating the diameter of the ring to be inserted, in millimetres;
  - o Size of the ring/s: indicating the amplitude of the arc for the ring to be insert, in degrees;
  - o Thickness of the ring/s: indicating the thickness of the ring selected for the implant, in microns;
  - o ICR bisector: indicating the degrees of the segment bisector and, in conjunction with the data for the Optical Zone and the center selected, determining the position for the corneal ring;
  - o Incision axis: indicating the position selected for the incision, in degrees. This position is suggested whenever the parameters, such as ring Bisector or Optical Zone, are changed.
» On the basis of the above parameters and the corneal morphology, the following are calculated, in microns:
  - o Corneal thickness in the incision zone.
  - o Average corneal thickness in the tunnel zone.
  - o Minimum corneal thickness in the tunnel zone.

These values are also provided, in percentages, when planning to use a femtosecond laser.
The central part of the screen shows:

» A Corneal thickness map: this map shows the ring (or rings) described in the previous section on the background of the patient's pachymetric map. Also, the thinner points, the center of the pupil and the distance between them, are also indicated.
» A curvature map among tangential anterior, tangential posterior and sagittal anterior: the keratometry data (SimK) are presented on the map.
» An anterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.
» A posterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.

The manufacturer bears no liability for consequential damages ensuing rom application of the results contained in the ICR Summary. The user of the program is responsible for checking the results and ensuring that the proposed values do not contain mistakes.

The ICRS Summary was developed and validated by CSO srl in cooperation with the following eye clinics:

» Prof. Giovanni Alessio, Ophthalmology Department, Policlinico di Bari, Bari, Italy
» Prof. Jose F. Alfonso, Cornea and Lens Department, Instituto Oftalmológico Fernández-Vega, Oviedo, Spain
» Prof. Luca Buzzonetti, Ophthalmology Department, Ospedale IRCCS "Bambino Gesù", Rome, Italy

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5. *Ferrara G, Torquetti L, Ferrara P, et al. Intrastromal corneal ring segments: visual outcomes from a large case series. Clin and ExpOphthalm 2012; 40: 433–439*
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ASPHERO-TORIC FITTING (ANTERIOR/POSTERIOR)

Asphero-toric fitting screen is displayed:

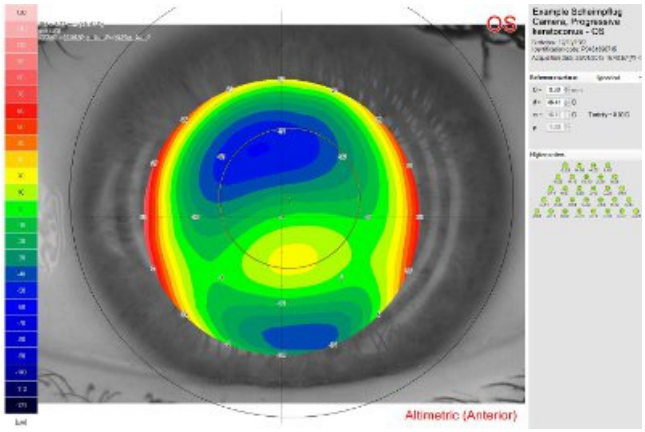
» by choosing **Asphero-toric fitting (Anterior)** or **Asphero-toric fitting (Posterior)** from the Analysis ▶ Advanced menu

» by clicking the ▶ icon on the toolbar

The asphero-toric fitting represents the corneal map as offset by a surface reference, that can be chosen by the operator using the menu options on the right hand side of the screen.
Using the pull-down list it is possible to select the surface against which we want to offset the examined eye:

» Spherical the reference surface is a sphere
» Aspheric the reference surface is aspheric or more precisely a conicoid. The asphericity value, (in p, e, e2 or Q) can be chosen from options
» Asphero-toric the reference surface is asphero-toric. The toricity is calculated by the software as the difference between rf and rs.

Depending on the selected surface reference type, some of the parameters (like rf, rs or the asphericity) are editable. Any modification of the diameter will result in an adjustment of the parameters for the reference surface to the surface that best represents the examined eye on the diameter (Ø mm) chosen.
The difference between the selected surface and the surface reference is decomposed in Zernike polynomials up to the 7th order, allowing the selection (by double-clicking) of each single fitting component on the map.



Asphero-toric fitting anterior

Asphero-toric fitting posterior

Gaussian curvature screen is displayed:

» by choosing **Gaussian curvature** from the **Analysis ▶ Advanced** menu

» by clicking the ▶ icon on the toolbar

This screen displays a **Gaussian curvature** map in full-screen mode.
Both, Sagittal and Tangential maps, show the curvature values of a surface along meridians: in other words, they do not consider the surface curvature in sections different from the meridional one.
The Gaussian curvature of a point on a surface is the “real” curvature being the geometric mean of the principal curvatures, i.e. the square of the product of the curvatures along the directions where they are maximum and minimum.
Is measured in millimeters or diopters according to the preferred user setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

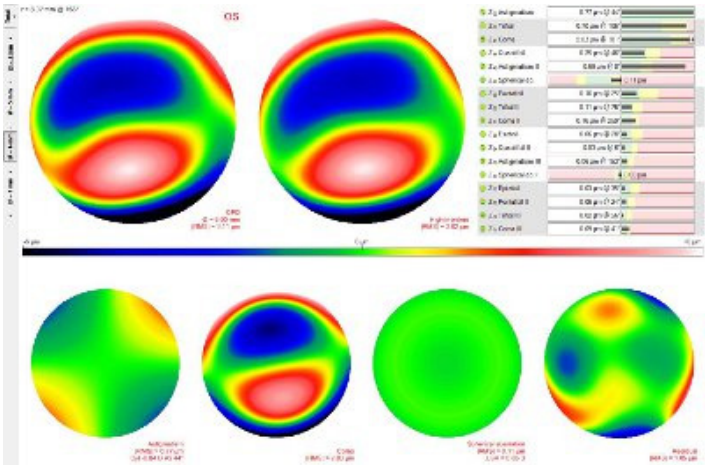
At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The gaussian curvature at the point taken into consideration.

ZERNIKE SUMMARY

Summary is displayed:
» by choosing **Zernike Summary** from the **Analysis** menu
» by clicking the icon on the toolbar

The program permits conducting analysis of the wavefront generated by the cornea, obtained by topographic data through Zernike analysis. The aberrometric map expresses the differences in height between the wavefront generated by the cornea being examined and a spherical perfect wavefront. The aberrations are displayed as total aberrations and divided into their various components. A set of 36 Zernike polynomials is used for the analysis of the various components of total aberration; the analysis results are reported in the summary as numerical indices and as graphic representations. The pupil diameter may be selected on the left side of the screen in a range from 2 mm to 8 mm with 0.5 mm steps. Total wavefront (obtained by ray-tracing using both anterior and posterior surface), anterior surface wavefront (i.e. considering only the anterior surface) or the posterior surface wavefront (defined as the difference between the total and anterior only) analysis is allowed.
This screen is highly influenced by the parameters chosen on the Wavefront configuration window.



Zernike Summary

Several Wavefront error maps are shown in the screen:
» Total OPD/WFE (i.e. the total amount of the Wavefront error within the analysis diameter)
» Higher orders (i.e. the amount of the Wavefront corresponding to the order polynomials from 3 to 7)
» Astigmatism (i.e. the amount of polynomials Z2-2 and Z2+2). Bottom-right of the map the value of the Cylinder and its RMS are shown.
» Coma (i.e. the amount of polynomials Z3-1 and Z3+1). Bottom-right of the map the value of coma RMS is shown.
» Spherical aberration (i.e. the amount of polynomial Z40). Bottom-right of the map the value of the LSA and the Spherical Aberration RMS are shown.
» Residual (i.e. the total amount of the Wavefront removing the amount of Astigmatism, Coma and Spherical Aberration)

ZERNIKE POLYNOMIALS

On the upper right there is a table which summarizes the decomposition of Zernike for the current wavefront into its aberrations:
» The first column carries the names of the polynomials. Generally speaking, each aberration is represented by a pair of polynomials. Axis-symmetric aberrations are represented by single polynomials.
» The second column gives a RMS value and the relative meridian for each aberration.
» The last column displays the histogram of the coefficients of expansion of the Zernike polynomials: the bars represent the weighted value for each aberration. The normality data, represented by the green, yellow and red bars, are derived from a statistical study on 1000 normal eyes.

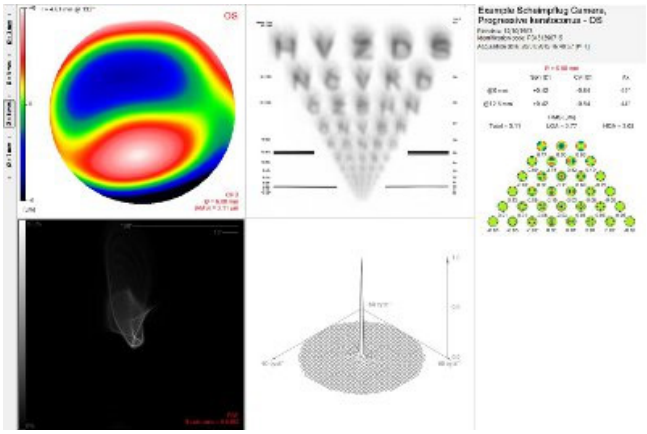
OPTICAL QUALITY SUMMARY

Optical Quality Summary is displayed:
» by choosing Optical Quality Summary from the Analysis menu
» by clicking the icon on the toolbar

This form permits an overall analysis of visual quality.
From top-left to the bottom-right are shown:
» OPD/WFE map;
» Vision Simulation;
» PSF;
» MTF.

In the right panel the Zernike pyramid, displaying the coefficients of the corneal wavefront decomposition, is shown.

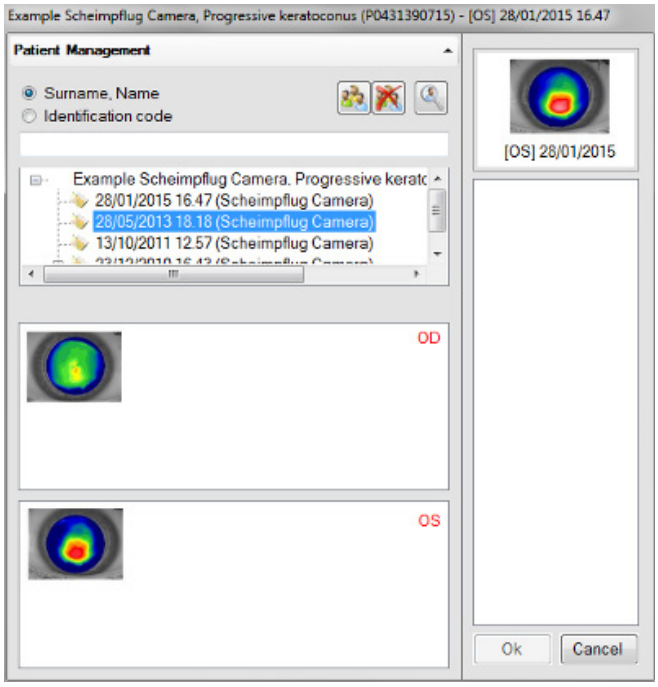
The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Total, Anterior or Posterior).



Optical Analysis Summary

COMPARISON/FOLLOW-UP IMAGE SELECTION

The first operation to start a comparison/follow-up analysis is to select the images to be compared. The first image is chosen by default, the one from where we open the selection window, other images have to be manually chosen by the user. The window that shows up provides on opening the current patient/examination.
If the images to be compared do not belong to the current patient/examination standard tools for the examination search are provided: the button shows the complete patient database, whereas the button allows for an advanced search. Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel. The number of selected images may vary depending on the context of the follow-up operation. Click **OK** to continue, **Cancel** to stop the comparison.



Manual selection of the acquisitions to be compared.

COMPARISON

Comparison is displayed by:

» Choosing **Comparison** from the **Analysis** menu

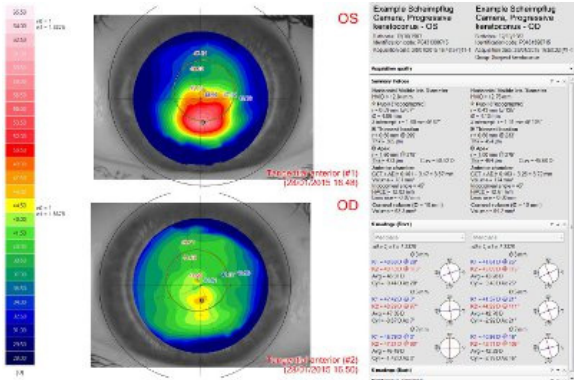
» clicking the icon from the toolbar.

After the manual selection of the images to be compared, a window with the selected images is shown. It's possible to select 2, 3 or 4 maps.

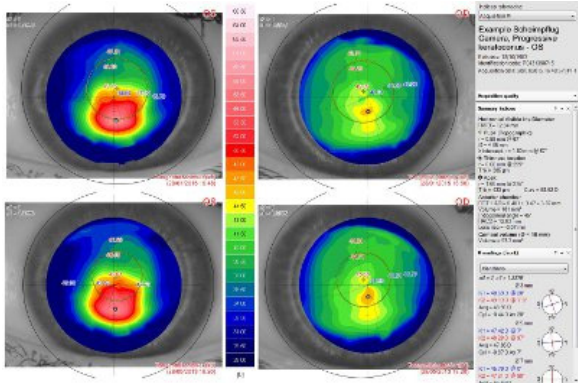
The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label Current map.

The comparison of two maps allows for the contemporary display of both sets of indices. The selection of more than 2 maps, means you have to choose the indices to be displayed. In this case the drop down box at the top of the right panel is for selecting the images the indices refer to.

Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Comparison X2



Comparison X4

COMPARE OD/OS

It is possible to compare the right and left eye avoiding the manual selection by:

» Choosing Compare OD-OS from the Analysis ▶ Comparison menu

» Clicking the icon on the toolbar.

A comparison screen between the current eye and the fellow eye will be shown.

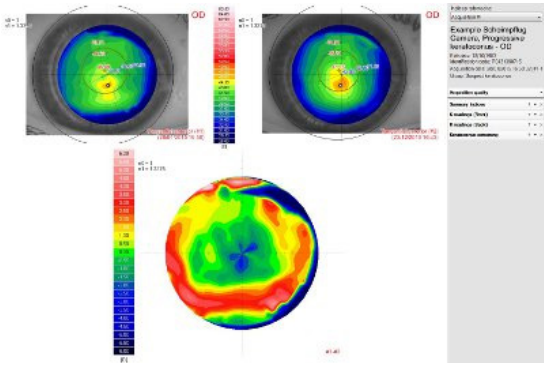
DIFFERENTIAL

Differential is displayed by:

» Choosing **Differential** from the **Analysis** menu

» clicking the icon from the toolbar.

After the manual selection of the images to be compared two or three maps (current map plus one or current map plus two) and their relative difference are shown: maps in the lower part of the window show the differences between the maps in the upper part. In the case of a differential on 2 maps, the difference between 1st and 2nd is shown. In the case of a differential on 3 maps, the difference between 1st and 2nd, between 1st and 3rd and between 2nd and 3rd are shown.



Differential

The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label Current map.
The drop down box at the top of the right panel is for selecting the image the indices refer to.

Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.

WAVEFRONT COMPARISON

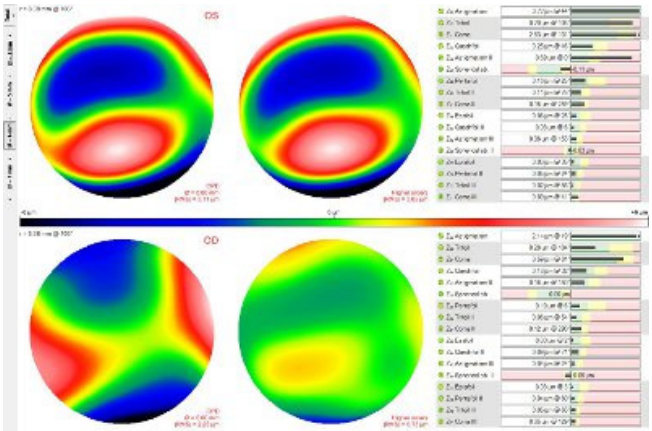
Comparison is displayed by:

» Choosing **Wavefront Comparison** from the **Analysis** menu

» clicking the  icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:
» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



wavefront Comparison

WAVEFRONT DIFFERENTIAL

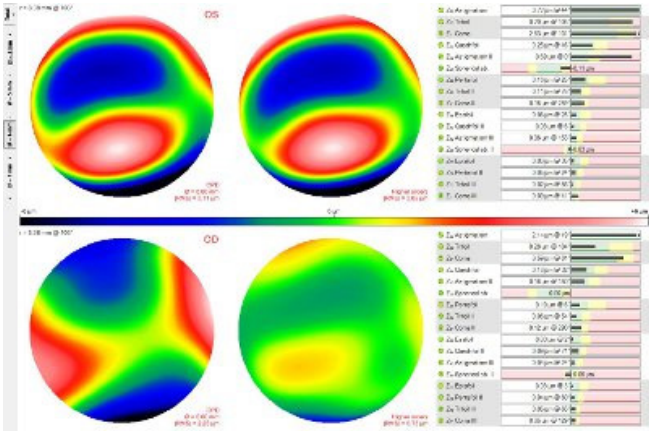
Comparison is displayed by:

» Choosing **Wavefront Comparison** from the **Analysis** menu

» clicking the  icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:
» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



wavefront Comparison

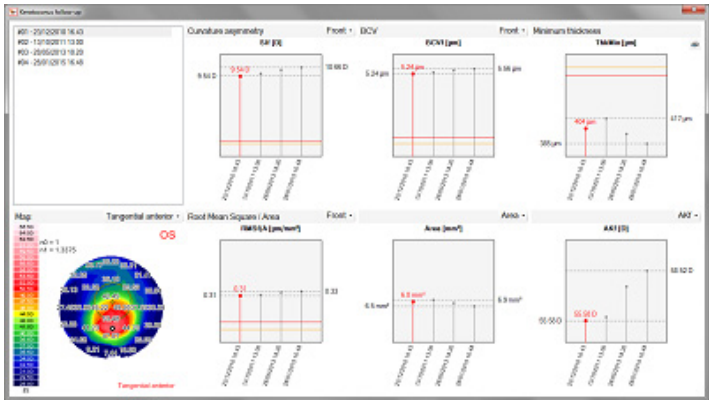
KERATOCONUS FOLLOW-UP

Comparison is displayed by:
» Choosing **Keratoconus follow-up** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

The screen is made up as follows:
» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.
» One of following maps can be selected for displaying.
  - o Corneal thickness
  - o Tangential anterior
  - o Tangential posterior
  - o Elevation anterior
  - o Elevation posterior

  The map refers to the selected image.
» 6 histograms referring to the main keratoconus indices are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. If available the border-line threshold (5th or 95th percentile) is shown in orange and the abnormality threshold (1th or 99th percentile) is shown in red.



Keratoconus follow-up

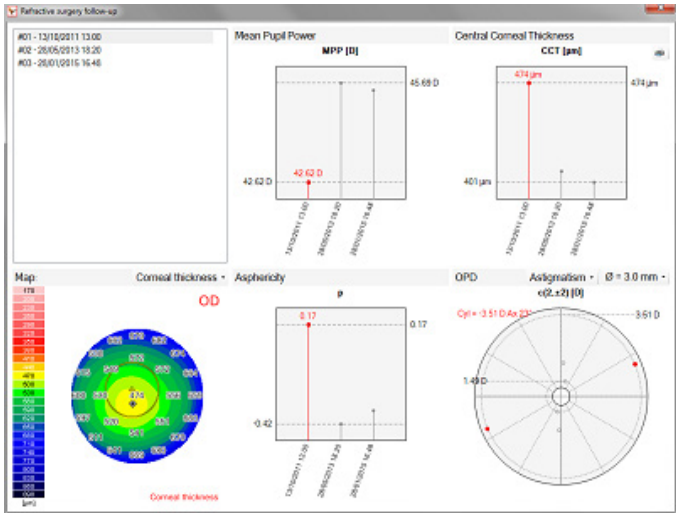
REFRACTIVE SURGERY FOLLOW-UP

Comparison is displayed by:
» Choosing **Refractive surgery follow-up** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

The screen is made up as follows:
» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.
» One of following map can be selected:
  - o Corneal thickness
  - o Tangential anterior
  - o Tangential posterior
  - o Sagittal anterior
  - o Sagittal posterior
  - o Elevation anterior
  - o Elevation posterior
  - o Refractive anterior power
  - o Refractive posterior power
  - o Refractive equivalent power

  The map refers to the selected acquisition.
» 3 histograms (MPP from Refractive analysis, CCT from Summary Indices and corneal asphericity at 8mm from Shape Indices) are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. A polar chart displaying magnitude and axis of the cylinder at a selectable diameter (from Refractive analysis) is also shown.



Refractive surgery follow-up

AS-OCT IMAGES

The control shows a single sectional image acquired by the AS-OCT instrument.

Above the image a toolbar with the following tools can be found:

Display of the AS-OCT sectional image

	Zoom	When selected, it is possible to change the magnification of the image shown on the screen, using the mouse wheel or the +/- keys
	Distance	Allows for measurement of a distance between two points on the image. Click to mark the starting point and click again to mark the end point. To delete the latest measurement, press **Del** or **Backspace** key.
	Cartesian coordinates	When selected, clicking on a point of the anterior chamber its (x,y) location from the corneal vertex is shown. To delete the latest measurement, press **Del** or **Backspace** key.
	Magic wand	When selected, clicking on a point of the anterior chamber, a line passing through that point going from the corneal posterior surface to the iris or to the lens will be drawn and measured. If the point is higher than the anterior surface it will measure corneal sagitta, when lower than the posterior surface, the anterior chamber depth is measured. The function will not work outside of mapped zones. To delete the latest measurement, press **Del** or **Backspace** key.
	Angle	Allows to draw and measure an angle. To draw the angle, click to mark once the vertex and two times to indicate both sides of the angle. To delete the latest measurement, press **Del** or **Backspace** key.
	Histogram	An indication of the opacity of the cornea and lens is provided: the numeric value assigned indicates a value from 0 to 100 reflecting the relative opacity. To move the origin of the graph, click on the point of interest
	Brightness	When this item is selected, it is possible to change the brightness of the image, using the mouse wheel
	Contrast	When this item is selected, it is possible to change the contrast of the image, using the mouse wheel
	Gamma	When this item is selected, it is possible to change the gamma of the image, using the mouse wheel

	Restore	Restores the original values for the image, undoing any kind of modification to brightness, contrast and gamma
	Toggle smoothing	Sets the interpolation mode of the image
	Invert background color	Inverts the image's greyscale
	Play/Pause	Starts/stops the automatic scrolling of the frames.
	Forward	Shows the next image.
	Rewind	Shows the previous image

MAPS

Several maps are available taking into consideration different corneal attributes:

» Sagittal anterior
» Sagittal posterior
» Tangential anterior
» Tangential posterior
» Corneal thickness
» Epithelial thickness map
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber

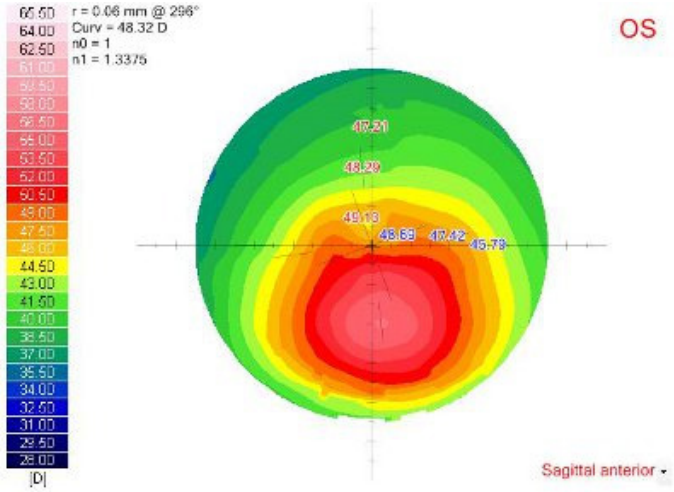
SAGITTAL ANTERIOR MAP

This map represents, point by point, the distribution of the ante-rior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flat-ter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar accoding to the preferred setting;
» The curvature at the point taken into consideration.

The refraction index used for the conversion formula be-tween millimeters and diopters.

Right-clicking opens the Tools and display options menu.



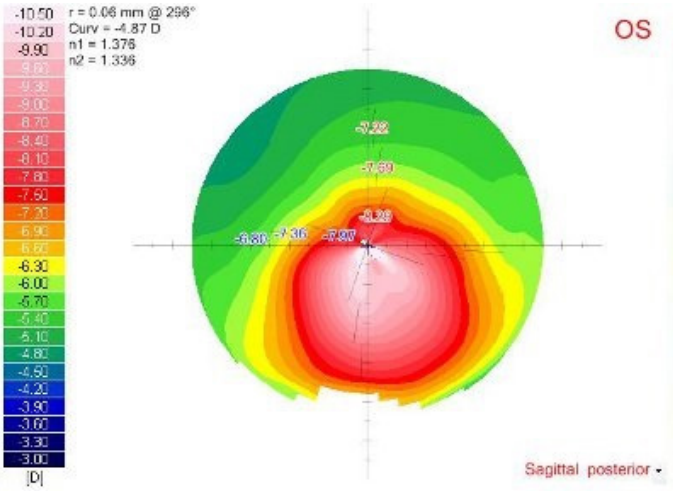
Anterior sagittal curvature map

SAGITTAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



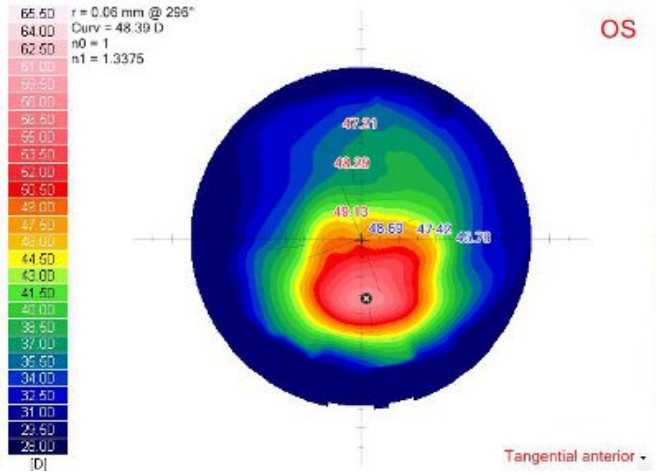
Posterior sagittal curvature map

TANGENTIAL ANTERIOR MAP

This map represents, point by point, the distribution of the anterior tangential curvature in millimeters or diopters according to the preferred setting. With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊗ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



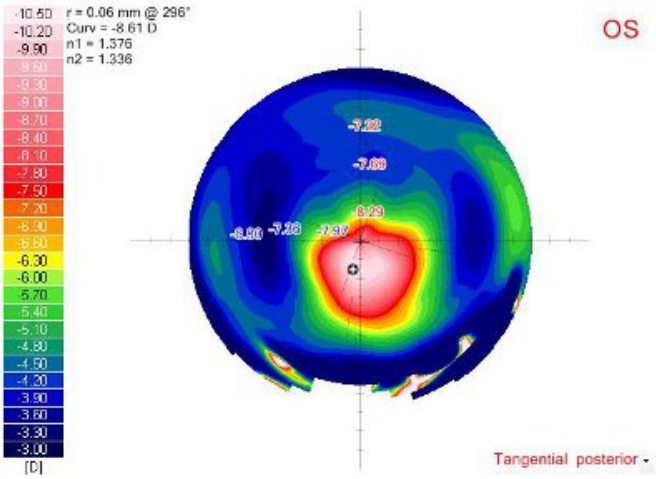
Anterior tangential curvature map

TANGENTIAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior tangential curvature in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊕ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



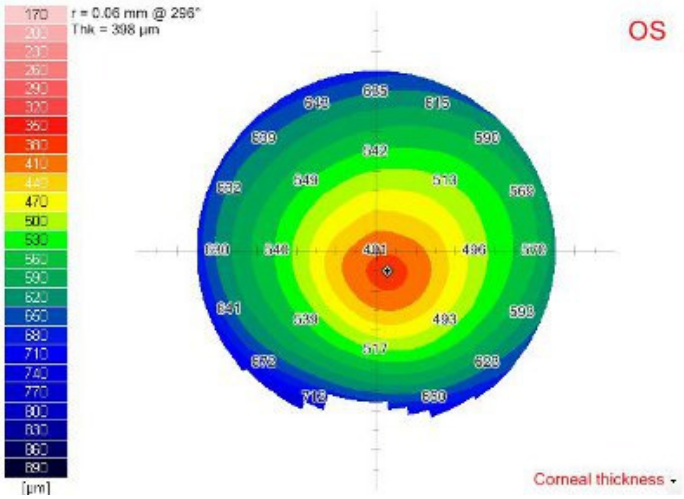
Posterior tangential curvature map

CORNEAL THICKNESS MAP

This map represents, point by point, the distribution of the thickness of the cornea in microns (µm).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with thinner zones and the cool colors (green, blue) are associated with thicker zones.
The thinnest point is marked by the ⊕ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The corneal thickness at the point taken into consideration.

Right-clicking opens the Tools and display options menu.



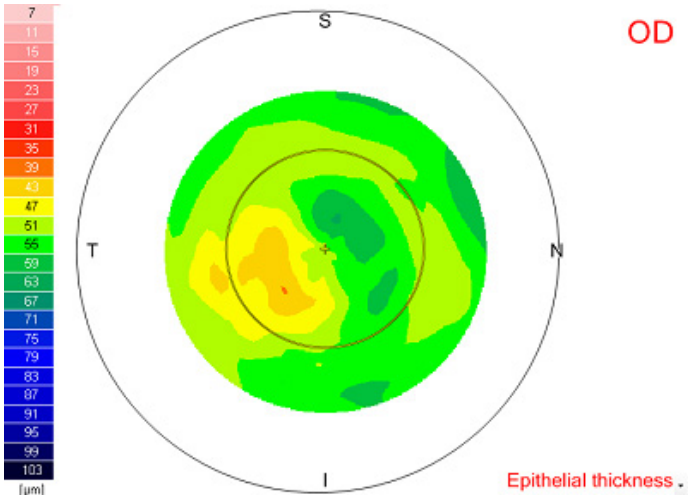
Corneal thickness map

EPITHELIAL THICKNESS MAP

This map locally represents the corneal epithelial thickness, i.e. the distance between the tear film layer and Bowman's layer.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The epithelial thickness at the position of the cursor. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu



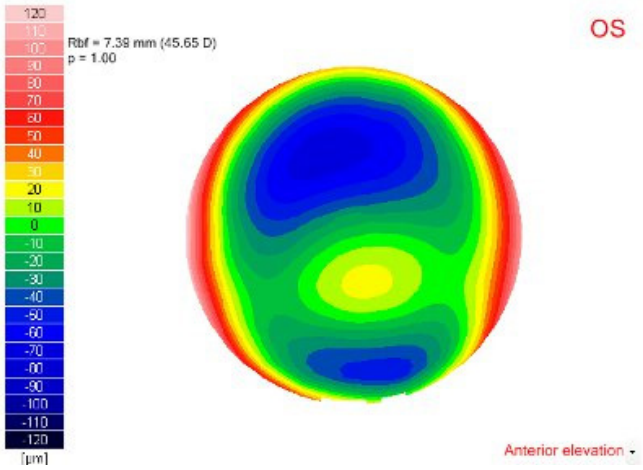
Epithelial thickness map

ELEVATION ANTERIOR MAP

This map represents in microns (µm), the elevations of the anterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



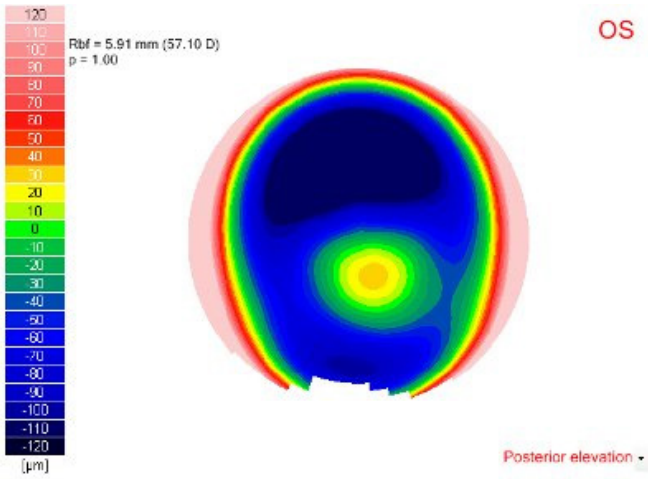
Elevations anterior map

ELEVATION POSTERIOR MAP

This map represents in microns (µm), the elevations of the posterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



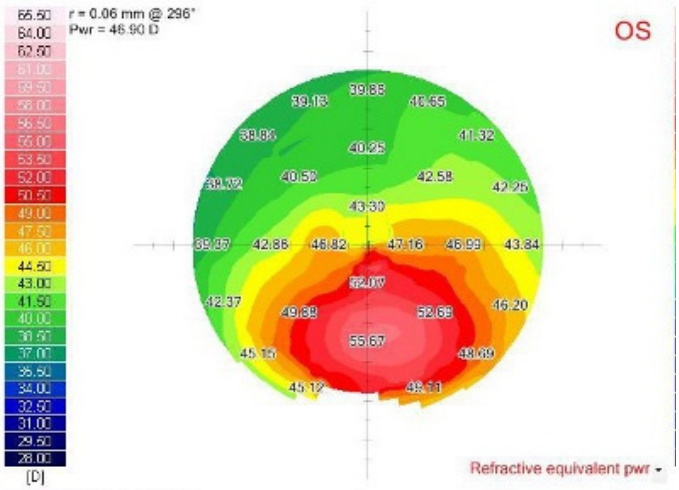
Elevations posterior map

REFRACTIVE EQUIVALENT POWER MAP

This map represents, point by point, the distribution of the total corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior and posterior corneal surface for each point. The reference indices for the two interfaces are the air index (N0=1), stroma index (N1=1.376) and the index for the aqueous humor (N2=1.336).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration . This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



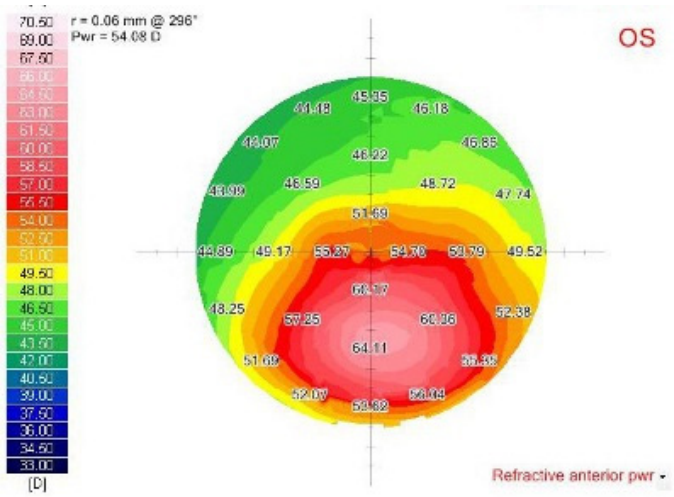
Refractive equivalent power map

REFRACTIVE ANTERIOR POWER MAP

This map represents, point by point, the distribution of the anterior corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior corneal surface for each point. The refractive indices for the interface Air-Cornea are those of the air (N0=1) and of stroma (N1=1,376).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



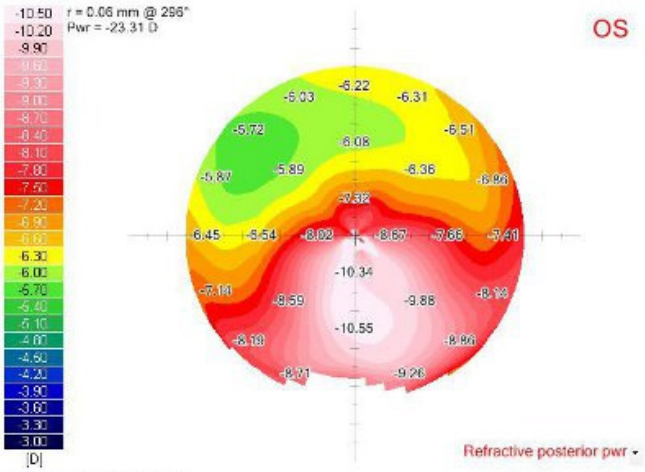
Refractive anterior power map

REFRACTIVE POSTERIOR POWER MAP

This map represents, point by point, the distribution in diopters of the power of the posterior corneal surface and is calculated as the difference between the total refractive power and the anterior refractive power.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



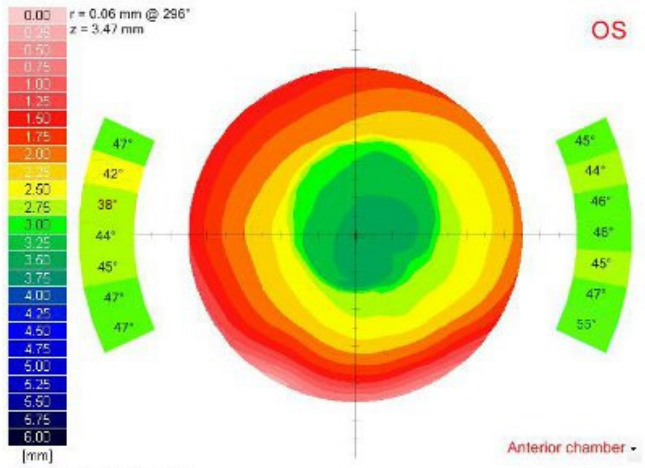
Refractive posterior power map

ANTERIOR CHAMBER MAP

This map represents, locally the anterior chamber depth, i.e. the distance between the posterior surface of the cornea and the iris or the crystalline lens. On the left and right sides of the map, the values of the irido-corneal angles are reported.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Chamber depth at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Anterior chamber map

MAP CONTEXT MENU

	Cursor	When this item is selected, the coordinates and the numeric values of the map under the mouse pointer are displayed as it is moved. Left-click drops the cross, making it independent of the mouse pointer. A second click realigns the reference cross with the mouse pointer.
	Distance	Select this item to trace a segment on the map for measuring the distance between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The length of the chosen segment will be displayed on the map, in millimeters.
	Graph	With this item selected the graphs representing the map profile along the meridian passing center of the map and the mouse pointer is displayed. The graph rotates during selection of the meridian: clicking on the desired orientation that particular meridian will be chosen and its chart will be shown horizontally.
	Gradient	Select this item to trace a segment on the map for measuring the distance and the gradient between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The difference and the gradient between the two selected points will be shown and the length of the chosen segment will be displayed on the map.
	Show/Hide value on cursor	Shows or hides the numeric value over the map at the cursor position when a mouse movement occurs.
	Show/Hide pupil	Shows or hides the contour of the pupil.
	Show/Hide eye	Shows or hides the image of the eye under the map.
	Show/Hide eye	Shows or hides the image of the eye under the map.
	Background	▶ **Keratoscopy:** The keratoscopy is shown as background on the map. This setting is enabled when Show Eye is activated. ▶ **Iris:** The iris image is shown as background for the map. This setting is enabled when Show Eye is activated.
	Show/Hide ruler	Shows or hides the two perpendicular millimeter rulers (the shorter division corresponds to 0.5 mm; the longer division corresponds to 1 mm).
	Show/Hide meridians	Shows or hides a polar grid.
	Show/Hide goniometer	Shows or hides a goniometer.
	Show/Hide zones	Shows or hides a series of concentric rings (with 3, 5, 7, 9 mm diameters)
	Show on map	Show or hide numeric values over the map: ▶ **Nothing:** No numeric value is displayed over the map. ▶ **Numeric values:** The numeric values are shown on each map on a point grid. ▶ **Map-dependent:** K-readings (Front) are shown on the anterior curvature maps and anterior elevation map. K-readings (Back) are shown on the posterior curvature maps and the posterior elevation map. Numeric values are shown on all other maps.

INDICES

On the right side of several analysis windows a selection of panels is available, containing information and indices referencing the current image:

» Patient data
» Acquisition Quality
» Summary Indices
» K-Readings (Anterior)
» K-Readings (Posterior)
» Shape Indices
» Refractive analysis
» Keratoconus Screening

The ▼/▲ arrow on the title bar expands/collapses the related panel.
The ? button opens its help window.

Click the button × on the title bar to remove a panel from the lateral section of the window. To restore the removed panels, elect ►**Restore** on the right side of the main Toolbar.

ACQUISITION QUALITY

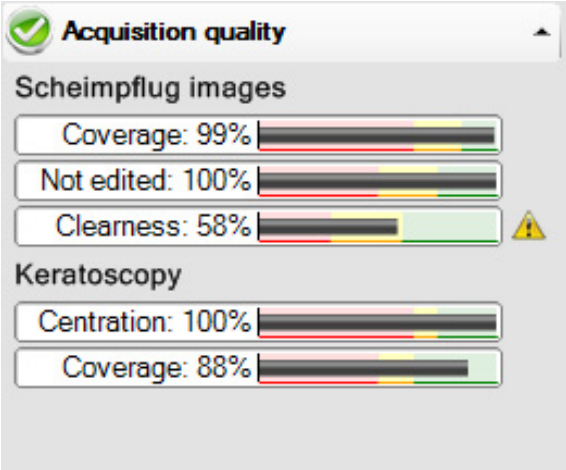
It shows some indices which indicate the quality of both the Scheimpflug and keratoscopic acquisitions.
In more detail, the coverage of the Scheimpflug tomographies is considered, the percentage of images that were manually edited, as well as the clearness of the stromal tissue is taken into consideration as an index of corneal hyper-scattering.
Rings coverage for the Keratoscopy and the well-centeredness of the cornea respective to the instruments axis is reported under the group Keratoscopy.

The indices are preceded by when the acquisition quality seems to be satisfactory; by a warning when we recommend you take more acquisitions.

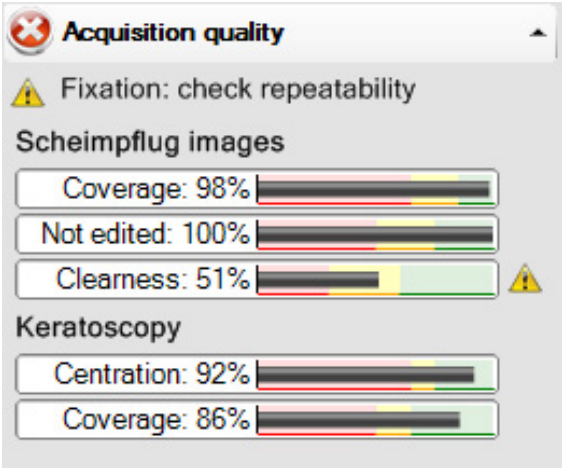
The warning "Fixation: check repeatability" is a help for selecting good acquisitions. It appears when the pupil position of the current acquisition is outside a "normal zone", i.e. the zone where the pupil position is located in normal fixating eyes. If this warning is present, there can be two cases:

» The patient is not fixating, so it is necessary to acquire again after asking the patient to fixate on the fixation point.

The patient is fixating, but the eye is anomalous (for example if the eye is a keratoconus). In this case the pupil position is always decentered in every acquisition. So, the warning has to be interpreted as an anomalous fixation of the patient.



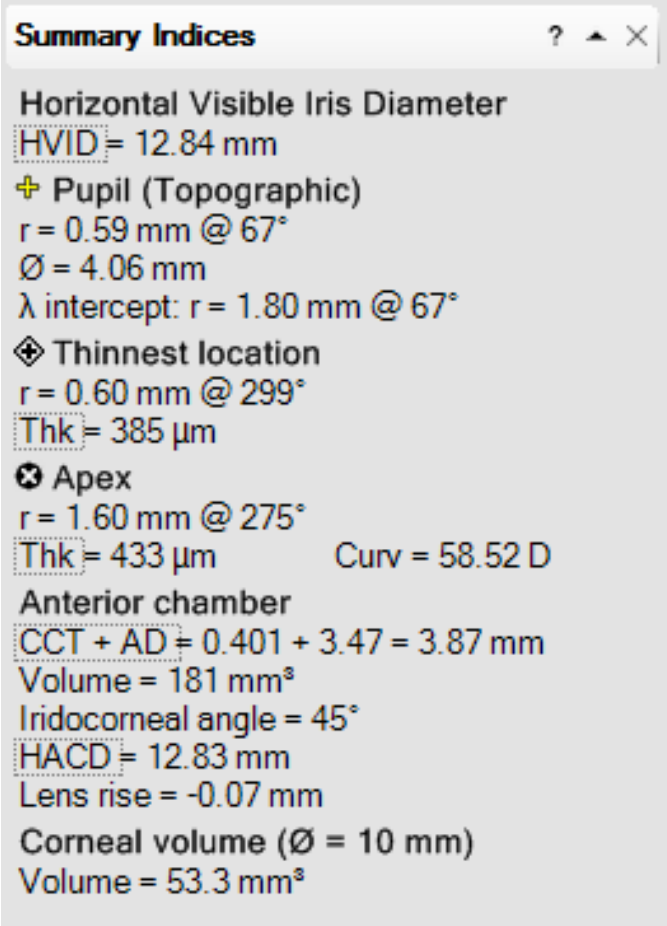
Acquisition quality for a satisfactory acquisition



Acquisition quality for an unsatisfactory acquisition

SUMMARY INDICES

- **HVID (Horizontal Visible Iris Diameter):** it is the limbus size (in mm) in the horizontal direction. It is derived from the keratoscopic image.
- **Pupil** (Topographic): the symbol shows the pupil center position in the maps. x,y and r,@ are, respectively, the cartesian and polar coordinates of the pupil centre, shown in the Summary indices panel according to the preferred setting. Ø is the diameter of the topographic pupil.
  λ intercept is the intercept between the pupillary axis and the anterior corneal surface. The pupillary axis is the line passing through the center of the entrance pupil, and which is normal to the cornea.
- **Thinnest location:** the symbol indicates the position of the corneal thinnest point in the maps. Its coordinates are shown in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry in this point.
- **Apex:** the symbol indicates the steepest point position in the maps. Its coordinates are shown in in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry and Curv is the curvature in this point.
- **Anterior Chamber**
  - **CCT + AD** : **CCT** is the central corneal thickness. AD is the aqueous depth, (i.e. the distance between the corneal posterior surface and the anterior surface of crystalline lens in correspondence to corneal vertex).
  - **Volume:** the volume of the portion of the anterior chamber limited by the back surface of cornea, the iris and the crystalline lens, in a 12mm diameter zone.
  - **Iridocorneal angle:** the average of the measured angles for the meridians whose angular position is included in the range +/- 25° from the horizontal meridian.
  - **HACD (Horizontal Anterior Chamber Diameter):** it is measured as the distance between the vertices of the iridocorneal angles.
  - **Lens rise:** it is the difference between the position of the crystalline lens and the iridocorneal plane, i.e. the best-fit plane "passing" through the vertices of the iridocorneal angles. A negative value means that the crystalline lens is above the iridocorneal plane.
- **Corneal Volume:** the corneal volume within a diameter equal to 10 mm.



Summary indices

K-READINGS (FRONT)

From the sagittal data of the anterior cornea it is possible to derive kerato-metric data related to the principal meridians: these data can be expressed as

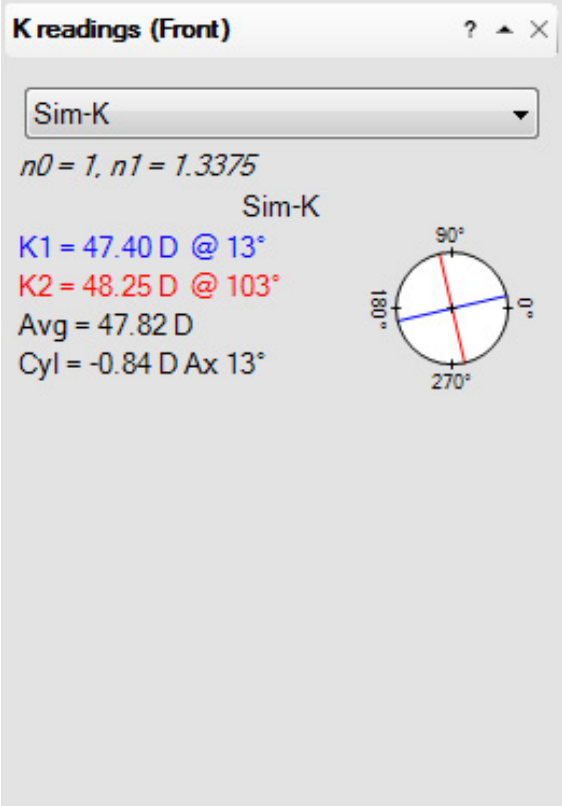
» Sim-K
» Meridians
» Emi-meridians
» Peripheral degrees

SIM-K

Sim-K represents the simulation of the readings that would be ob-tained with a keratometer, (i.e. the mean sagittal curvature from the 4th to the 8th Placido ring). The considered zone has a variable amplitude depending on the curvature of the measured cornea.
The following values are available for Sim-K:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



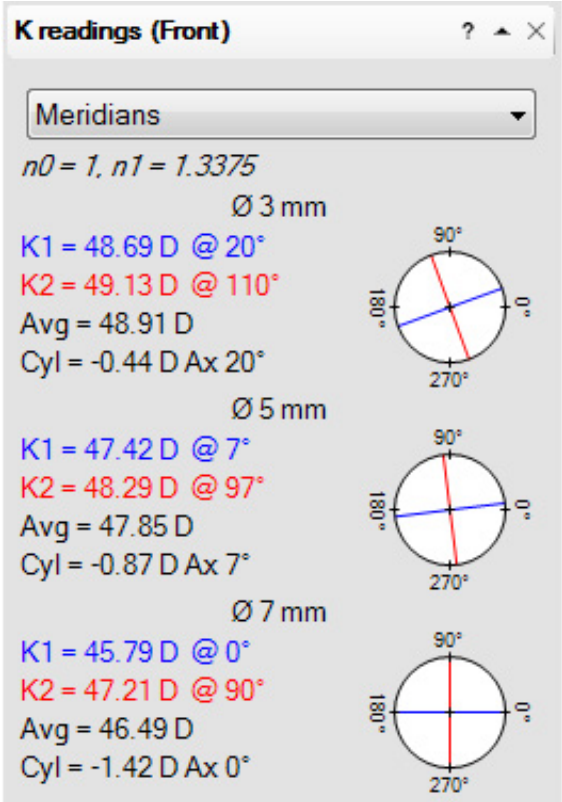
K-readings (front): Sim-K

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the anterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



K-readings (front): Meridians

HEMI-MERIDIANS

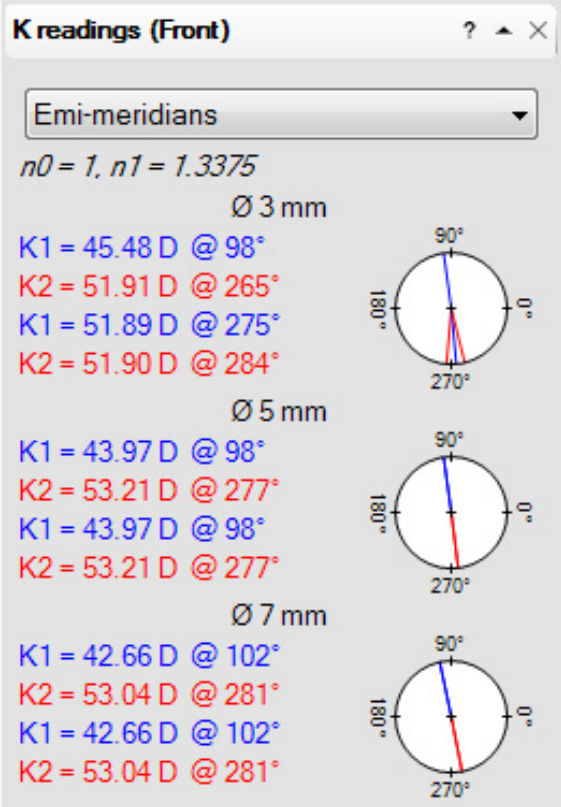
If this option is selected, the two pairs of flattest and steepest hemi-meri-dians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-me-ridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians K1 and K2.

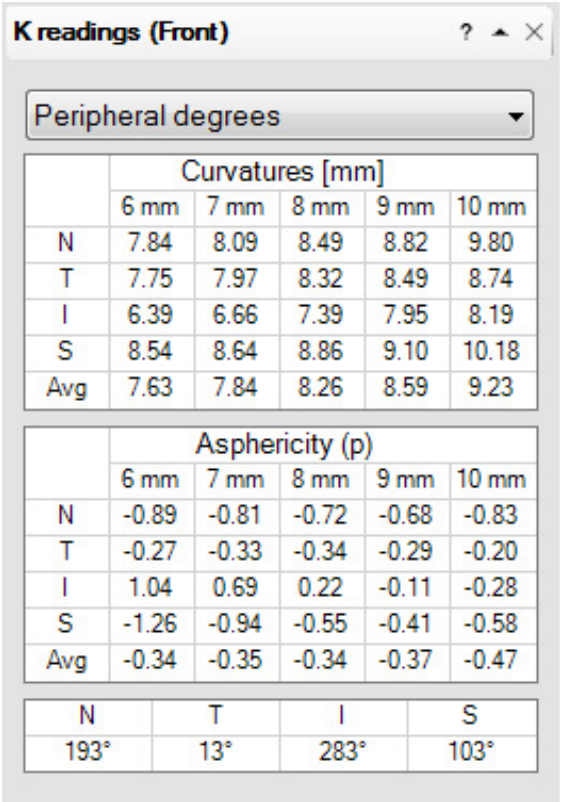
N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.

PERIPHERAL DEGREES

If this option is selected, two tables of curvatures and asphericities (expressed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the considered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity con-tains the average values for each zone of the values of the 4 consid-ered he-mi-meridians.
The angular positions of the 4 Hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S) are available in a third table.



K-readings (front): Hemi-meridians



K readings (Front)

Peripheral degrees

	Curvatures [mm]				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	7.84	8.09	8.49	8.82	9.80
T	7.75	7.97	8.32	8.49	8.74
I	6.39	6.66	7.39	7.95	8.19
S	8.54	8.64	8.86	9.10	10.18
Avg	7.63	7.84	8.26	8.59	9.23

	Asphericity (p)				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	-0.89	-0.81	-0.72	-0.68	-0.83
T	-0.27	-0.33	-0.34	-0.29	-0.20
I	1.04	0.69	0.22	-0.11	-0.28
S	-1.26	-0.94	-0.55	-0.41	-0.58
Avg	-0.34	-0.35	-0.34	-0.37	-0.47

N	T	I	S
193°	13°	283°	103°

K-readings (front): Peripheral degrees

K-READINGS (BACK)

From the sagittal data of the posterior cornea it is possible to derive kerato-metric data related to the principal meridians: these data can be expressed as

» Meridians
» Hemi-meridians
» Peripheral degrees

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the posterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians **K1** and **K2**.
» **Avg:** mean curvature of the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N1 and N2 are the refractive indices used for converting the values of curva-ture from mm to D: N1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

HEMI-MERIDIANS

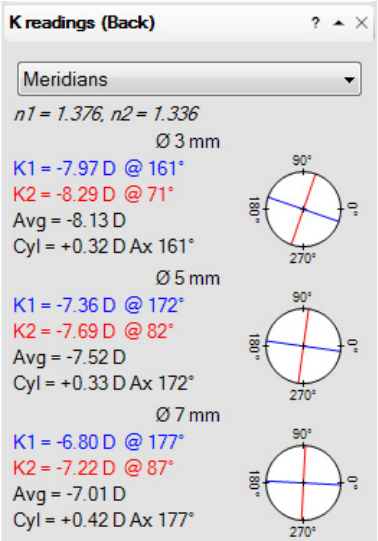
If this option is selected, the two pairs of flattest and the steepest hemi-me-ridians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-me-ridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians **K1** and **K2**.

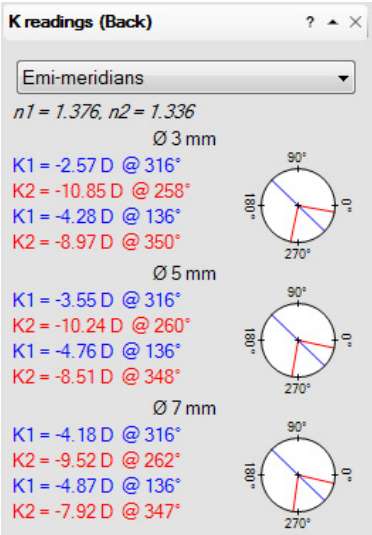
N_1 and N_2 are the refractive indices used for converting the values of curva-ture from mm to D: N_1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

PERIPHERAL DEGREES

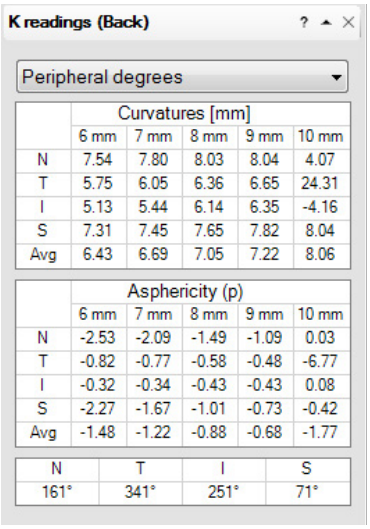
If this option is selected, two tables of curvatures and asphericities (expres-sed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the con-sidered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity con-tains the average values for each zone of the values of the 4 consid-ered hemi-me-ridians.
The angular positions of the 4 Hemi-meridians Nasal (N), Temporal (T), Infe-rior (I) and Superior (S) are available in a third table.



K-readings (back): Meridians



K-readings (back): Hemi-meridians



	Curvatures [mm]				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	7.54	7.80	8.03	8.04	4.07
T	5.75	6.05	6.36	6.65	24.31
I	5.13	5.44	6.14	6.35	-4.16
S	7.31	7.45	7.65	7.82	8.04
Avg	6.43	6.69	7.05	7.22	8.06

	Asphericity (p)				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	-2.53	-2.09	-1.49	-1.09	0.03
T	-0.82	-0.77	-0.58	-0.48	-6.77
I	-0.32	-0.34	-0.43	-0.43	0.08
S	-2.27	-1.67	-1.01	-0.73	-0.42
Avg	-1.48	-1.22	-0.88	-0.68	-1.77

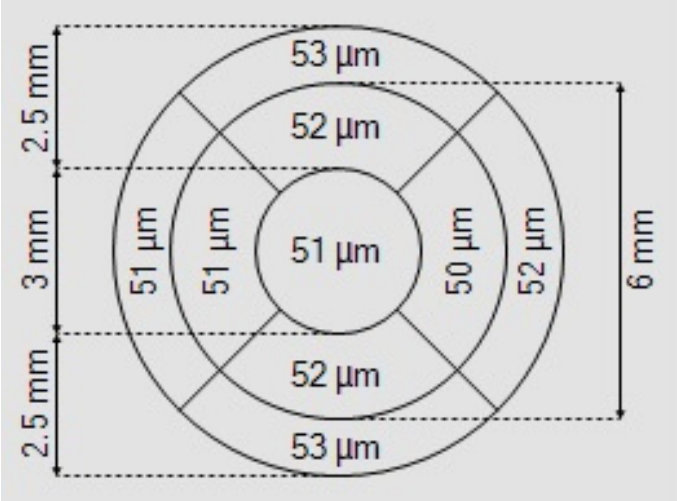
N	T	I	S
161°	341°	251°	71°

K-readings (back): Peripheral degrees

EPITHELIAL THICKNESS

This panel contains a schematic representation of zonal averaged values of the epithelial thickness map. Each averaged value is the average of the local values of the epithelial thickness map in a certain zone.

The central circle contains the average thickness value within a 3 mm diameter.
Outside the central circle, the averaged values for 4 annuli sectors (nasal N, temporal T, inferior I, superior S) are shown. The internal and external diameters of these annuli are respectively 3 and 6 mm. Their limiting angles are 45°, 135°, 225° and 315°.
The most external annuli sectors have a diameter within 6 and 8 mm.

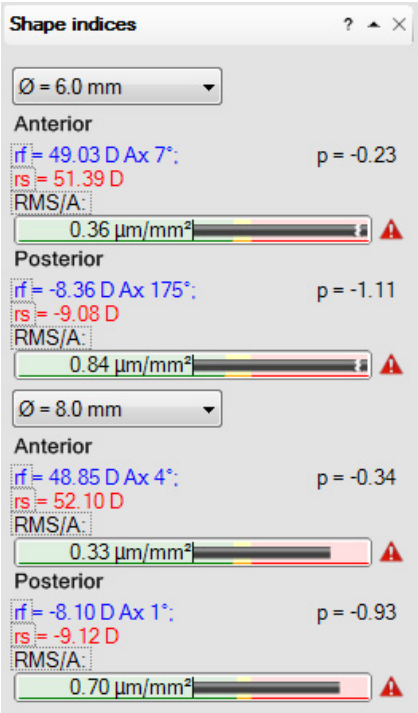


Epithelial thickness: zonal averaged values

SHAPE INDICES

Shape indices are available for the two corneal surfaces (anterior and posterior) for two different diameters selectable by the user. These indices are the parameters which define the asphero-toric surface best approximating the samples of the measured corneal surface within the zone delimited by the chosen diameter.

- **rf (Flat Radius):** the apical radius (in mm or in D according to the preferred setting) of the flattest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **rs:** Steep Radius: the apical radius (in mm or in D according to the preferred setting) of the steepest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **p, e, E, Q:** different forms of the asphericity according to the preferred setting for the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **RMS (Root Mean Square):** represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax. If the RMS is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS, the more irregular the corneal surface.
- **RMS/A:** Root Mean Square per unit of area.



Shape Indicies

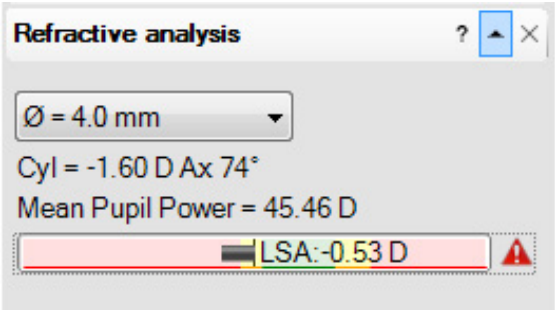
REFRACTIVE ANALYSIS

All the indices in this group are calculated from the corneal wavefront related to an entrance pupil located in the position of the patient's pupil, for diameters ranging from 2.5 to 7 mm.
Both the measured anterior and posterior corneal surfaces are taken into account and ray tracing is performed as described below.

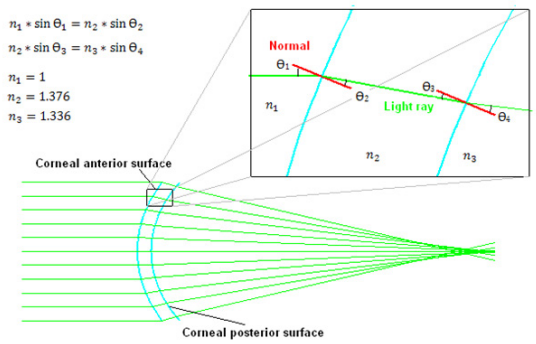
A bundle of rays parallel to the instrument axis and passing within the entrance pupil of the eye are traced through the anterior and posterior corneal surfaces using Snell's law. For each incoming ray its intersection with the anterior corneal surface and its angle of incidence relative to the anterior surface normal are calculated. The ray refracted by the anterior surface is obtained using Snell's law with n_{air} = 1.0 and $_{stroma}$= 1.376. This ray is then considered as an incoming ray for the posterior corneal surface and the same procedure as above is applied to calculate the ray refracted by this surface using Snell's law with n $_{stroma}$ = 1.376 and n $_{aqueous}$ = 1.336.

» **Cyl:** the corneal cylinder (in D) and its axis.
» **Mean Pupil Power**: is the equivalent corneal power (in D) .
» **LSA** is the corneal Longitudinal Spherical Aberration (in D).

Right-clicking opens the a contextual menu for the selection of the display mode of the Pupil Power (**PWR1/PWR2** or **Mean Pupil Power/Cyl)** and the Spherical Aberaation (**c(4,0)** or **LSA**).



Refractive analysis

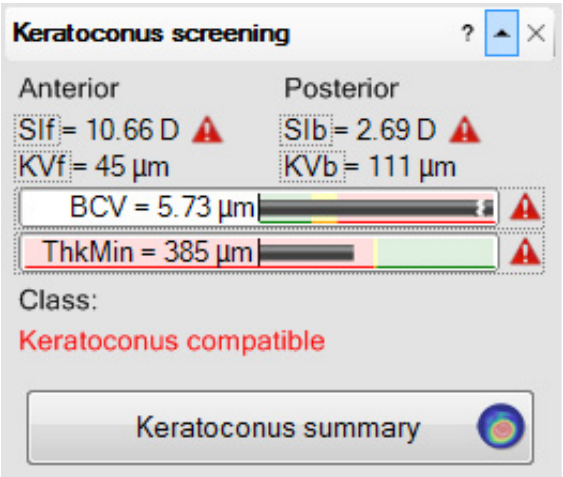


KERATOCONUS SCREENING

The software displays a series of indices describing the morphology of the cornea, which are useful in the diagnosis of keratoconus and in follow-ups. It is also possible to open the Keratoconus summary (see Keratoconus summary) pressing the namesake button.

CURVATURE ASYMMETRY

» The Symmetry Index of the anterior curvature (**SIf** – SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normal values are shown (95° percentile and 99° percentile of a normal population);
» The Symmetry Index of the posterior curvature (**SIb** – SymmetryIndexBACK) is defined as the difference of the mean poste



Keratoconus screening

» rior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

VERTICES

» Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT) and on the on the posterior corneal surface (**KVb** – Keratoconus VertexBACK) are shown.

ELEVATION BASED INDICIES

» The indices **BCVf** e **BCVb** allow the evaluation of the presence of, and the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetries $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) + \gamma C_4^{0}$$

The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normality values are shown (95° percentile e 99° percentile of a normal population);
The index BCV or vectorial **BCV** is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normality values are shown (95° percentile and 99° percentile of a normal population).

THINNEST POINT

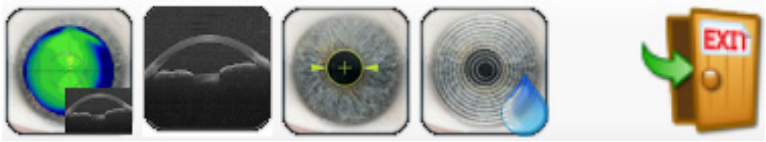
» Thinnest point of cornea ThkMin is shown.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:
» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

AS-OCT SINGLE SECTION ANALYSIS

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the icon opens the window for selecting the instrument with which to capture an image.



To capture a topographic-tomographic image, select the icon. The instrument automatically sets to the capture position and a live capture window opens.

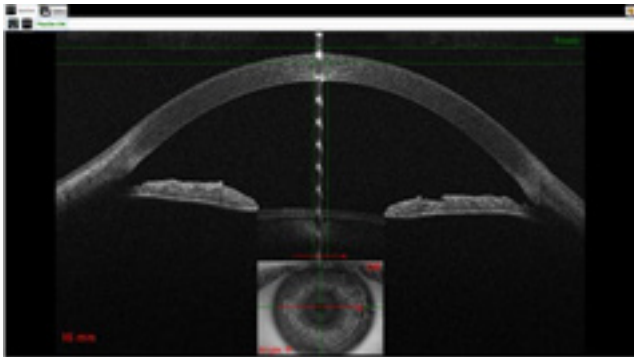
FOCUSING AND ANGLE SELECTION

With this exam you can acquire specific corneal section simply selecting the desired position and angle. In order to conduct the examination at the correct distance from the corneal vertex, move the joystick forward and back until the corneal vertex is within the two green lines (ASOCT Camera) When the joystick is moved forward, the profile of the cornea displayed on the monitor moves upward; when the joystick is moved back, the profile of the cornea moves downward. To move the central camera cross to the left and right, move the joystick to the left and right. To move the cross up and down, rotate the joystick clockwise and counterclockwise. The section angle can be changed simply rotating the wheel placed on top to the joystick; angle selection status is highlighted by the presence of yellow reference lines. During angle selection status the acquisition is disabled.

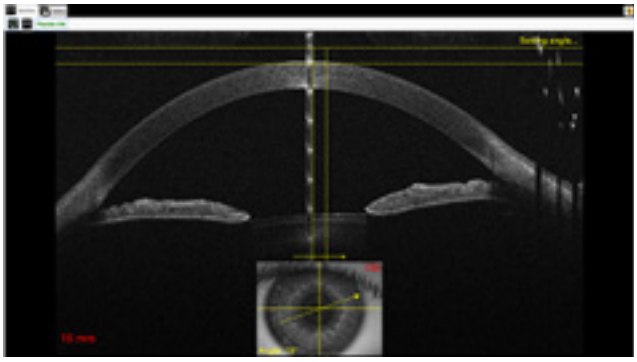
CAPTURE

When the desired section is displayed at the correct distance press the button on the joystick to capture the image. This action starts the capture procedure (all the reference elements become red), at the end of which all data are saved. After each acquisition the OD/OS gallery are populated; Once all the data needed have been captured, the capture environment may be closed; the program returns to the main screen. Select one of the captured images to process it.

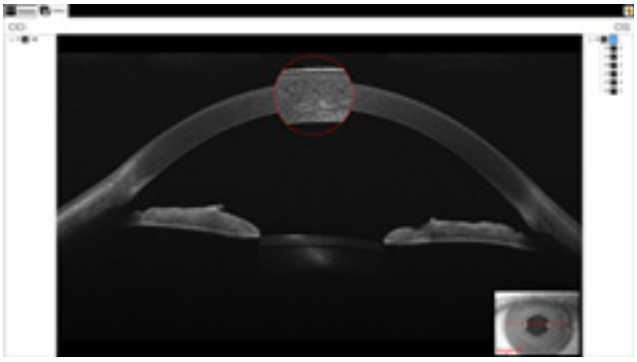
CAPTURE MODALITIES



Section aligning



Setting section angle



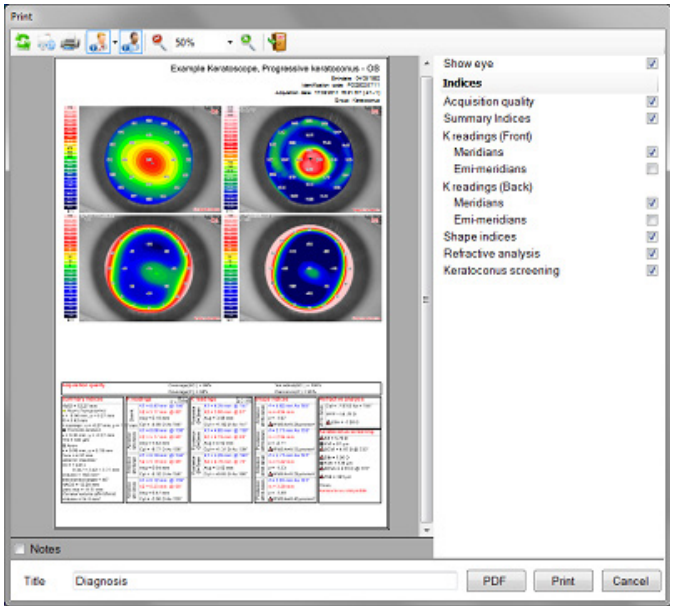
Gallery

ACQUISITIONS PREVIEW | PRINTING

You can access the print functionality through **Print** and **Print screen** under the **File** menu.
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

On the right side of the screen a list of options is shown which allows you to display or hide indices on the final printout.

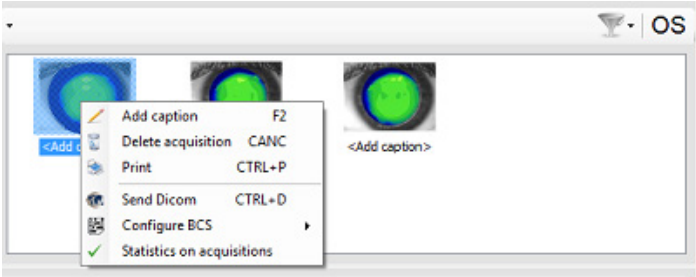
Print (Quick) and **Print screen (quick)** functionality, also under the **File menu**, allows you to print without preview.



Print preview

STATISTICS ON ACQUISITION

Statistics on acquisition window can be accessed by right-clicking on one of the thumbnails in the acquisition gallery and then left-clicking the Statistics on acquisition menu item of the contextual menu.



This window is useful for evaluating the quality and the repeatability of the acquisitions belonging to the same examination.

At the top-left corner a table is shown with the list of the selected acquisitions. Each row of the table refers to a single acquisition and contains its ID, date and time of the acquisition, a symbol for the quality of the keratoscopy (green for good quality, red for bad quality), the percentage coverage for the Placido disc, the percentage coverage for the OCT sectional images (Section coverage).
By selecting a row in the table (i.e a certain acquisition), the corresponding data are highlighted in the plots described below.

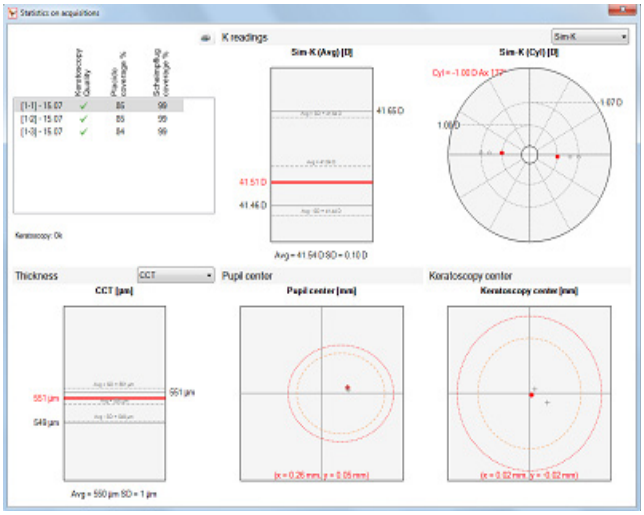
At the top of the window for K readings (Sim-K or Meridians at 3 mm) a scatter-box plot for the average value and a polar scatter plot for cylinder are shown. Average and standard deviation are reported for the Sim-K (Avg) and for the Meridians at 3 mm (Avg).

At the bottom-left corner of the window a scatter-box plot is shown for corneal thickness indices (Central Corneal Thickness or Minimum Thickness). Average and standard deviation are reported for these indices too.

At the bottom of the window in its central part a Cartesian scatter plot is dedicated to pupil decentration respect to corneal vertex. The normality zones are also shown in the graph. Normal values for pupil decentration are within the yellow dashed ellipse. Border line values are in the zones

between the yellow dashed ellipse and the red dotted one.

At the bottom-right corner of the window a Cartesian scatter plot is dedicated to keratoscopy decentration respect to the optical instrument axis. Low decentration values are within the yellow dashed circle, high decentration values are outside the red dotted circle. When the keratoscopy center is outside the red circle it is strongly advised to discard the acquisition



Statistics on acquisition window

SUMMARY

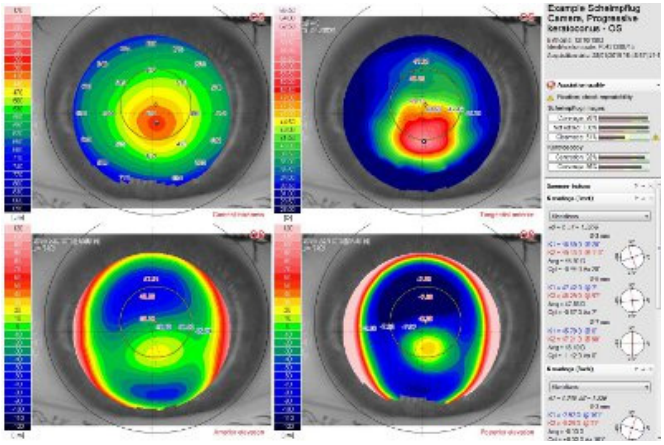
Summary is displayed:

» by double-clicking on an AS-OCT Topography acquisition on the main screen.

» by choosing **Summary** from the Analysis menu

» by clicking the  icon on the toolbar

This screen is the shown first: it displays a clinical **summary** of the maps and data derived from processing each single image. The **Summary** consists of four maps: corneal thickness, tangential anterior, anterior elevation, and posterior elevation. Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Summary

SECTION IMAGES

Section images screen is displayed:
» by choosing **Section images** from the **Analysis** menu
» by clicking the icon on the toolbar
» by double-clicking on the acquisition icon in the right and left eye gallery (only for AS-OCT Section exams)

This windows is used
» to review the sectional images captured by the AS-OCT instrument
» to adjust grey levels
» to make measurements of interesting structures

Section image

SINGLE MAP

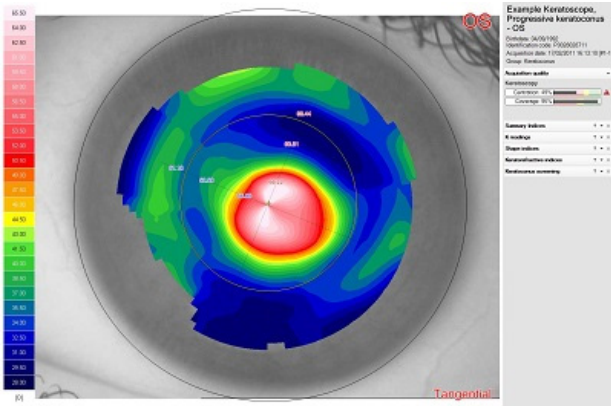
Single map screen is displayed:

» by choosing **Single map** from the **Analysis** menu
» by clicking the icon on the toolbar
» double-clicking the map of choice from the Summary.

This screen displays a single map in full-screen mode. The type of map can be selected from the toolbar between:

» Tangential
» Sagittal
» Elevation
» Refractive power
» Gaussian curvature

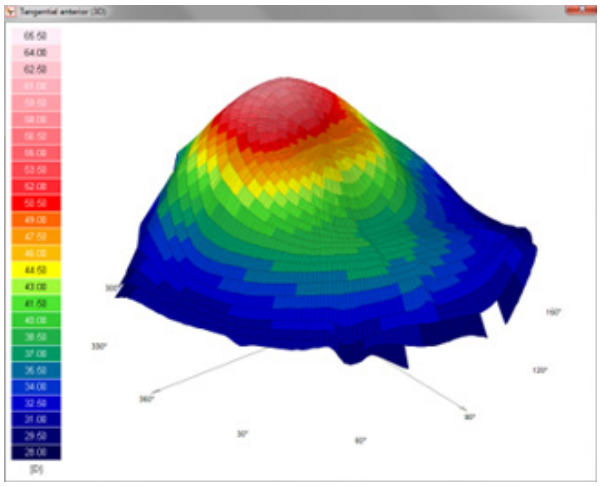
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Single map

3-D MAP

The icon becomes active only in this screen. When pressed a three-dimensional view of the current corneal map is shown.
Hold down the left mouse and drag the end points of the Cartesian diagram enclosing the map to view it from different perspectives.
Right-clicking a context menu to print the screen, save the screen as an image, or change the view type is shown.



Three-dimensional view of the tangential anterior map

MULTIMAP

Multimap screen is displayed:

» by choosing **Multimap** from the **Analysis** menu

» by clicking the icon on the toolbar

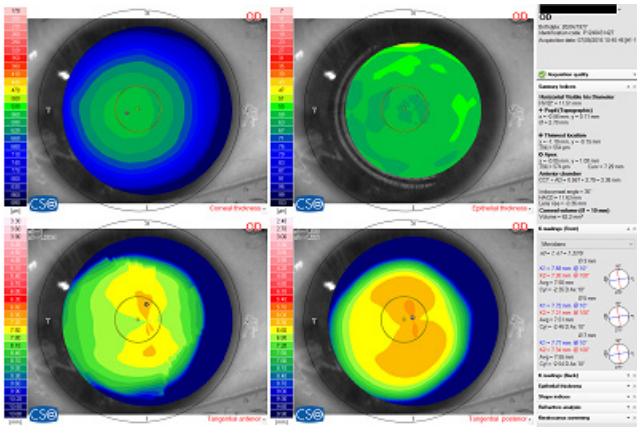
This customizable screen displays maps according to the user preferences: three types of customizable menus are available:

» Multi-map+Indices, to select 4 maps and their respective indices.
» Multi-map+Images, to select 4 maps and Scheimpflug images.
» Multi-map 6X, to select 6 maps.

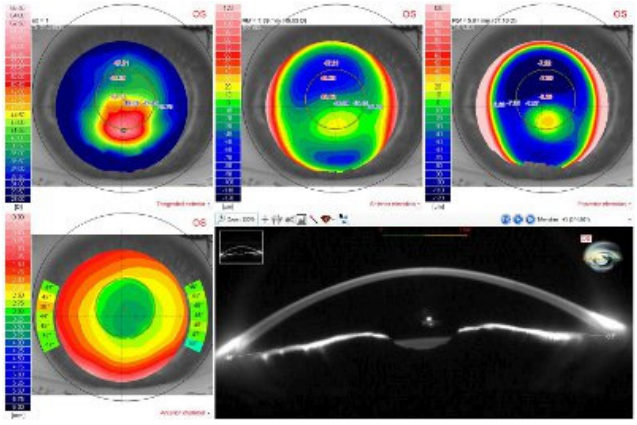
The types of map can be selected from the toolbar:

» Corneal thickness
» Tangential anterior
» Tangential posterior
» Sagittal anterior
» Sagittal posterior
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber
» Background

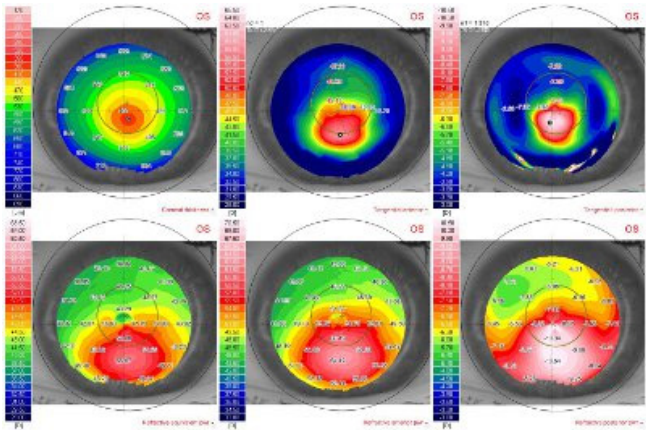
Just in Multi-map+Indices, right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Multi-map+Indices



Multi-map+Images



Multimap 6X

KERATOCONUS SUMMARY

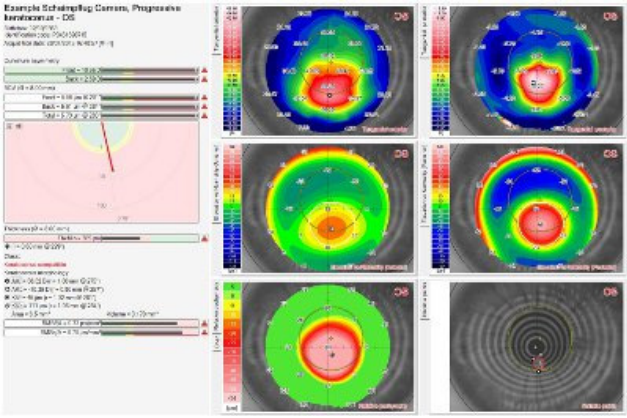
Keratoconus summary[1] is displayed:

» by choosing **Keratoconus Summary** from the **Analysis** menu

» by clicking the  icon on the toolbar
» by pressing the button Keratoconus summary in the index panel for Keratoconus screening.

Analysis is performed by means of following maps:

» Tangential anterior map on an area of 8 mm
» Tangential posterior map on an area of 8 mm
» Elevation anterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. This type of representation, that hides infor



Keratoconus summary

» mation on astigmatism and medium corneal power, is particularly useful since it highlights the higher orders only and therefore, in cases of keratoconus, the ectasic area and its entity.
» Elevation posterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. The considerations made for the information on anterior elevation are even more important for the posterior surface, since the ectasic effect is shown anticipatively and more pronounced respective to the anterior surface.
» Difference between the patients corneal thickness and the 2.5th percentile of pachymetry for a healthy population.
» **PTI** (Thickness Increase %) and **CTSP** (Corneal thickness spatial profile) charts[2].
» The position of some interesting markers
Steepest point of the anterior corneal surface (**AKf** – Apical KeratoscopyFRONT);
Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK);
Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK);
Thinnest point of cornea (**ThkMin** – Minimum Thickness).

In order to help the practitioner in the identification of keratoconus cases or to evaluate, during follow-up, the entity and the progression of keratoconus, a series of indices is shown based on curvature, pachymetry and elevation data of anterior and posterior corneal surfaces. These indices describe the most relevant features of keratoconus:

CURVATURE ASYMMETRY

» The Symmetry Index of the anterior curvature (SIf – SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normality values are shown (95° percentile and 99° percentile of a normal population);
» The Symmetry Index of the posterior curvature (SIb – SymmetryIndexBACK) is defined as the difference of the mean posterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

ELEVATION BASED INDICIES

» The indices BCVf e BCVb allow the evaluation of the presence and of the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of elevations $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) \; + \gamma C_4^{0}$$

» The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal)

» and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
» The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normal values are shown (95° percentile e 99° percentile of a normal population);
» The index BCV or vectorial BCV is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normal values are shown (95° percentile and 99° percentile of a normal population).

The previous data are processed by a neural network in order to classify the case in one of the following groups:

» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

In case of classification as Keratoconus compatible some further morphologic indices are shown:

Steepest point of the anterior corneal surface (**AKf** – Apical KeratoscopyFRONT);
Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK); Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK);
Thinnest point of cornea (**ThkMin** – Minimum Thickness).
» Area and volume of the ectasic zone;
» RMS/A and RMSb/A, root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 8 mm zone for both the anterior and posterior surfaces of cornea.

The keratoconus screening indices provide indications which however are not sufficient for assessing either instrument calibration status or the patient's clinical situation. These indices should thus be considered as diagnostic tools for the user but not as indicators of certain diagnosis of keratoconus.
We therefore caution the user to take maximum care when evaluating these values and to correlate the screening indices with other tests and with the patient's clinical history.

*The **Keratoconus Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:*

» *Arbelaez, Maria Clara MD, Muscat Eye Laser Center, Muscat, Oman*
» *Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy*
» *Piero Barboni MD, Studio Oculistico d'Azeglio. Bologna, Italy*

1. *Arbelaez, Maria Clara, et al. "Use of a support vector machine for keratoconus and subclinical keratoconus detection by topographic and tomographic data."Ophthalmology 119.11 (2012): 2231-2238.*
2. *Ambrósio R Jr, Simonato Alonso R, Luz A, Coca Velarde LG. Corneal-thickness spatial profile and corneal-volume distribution: tomographic indices to detect keratoconus. J Cataract Refract Surg 2006;32:1851-1859.*

CATARACT SUMMARY

Cataract summary is displayed:

» by choosing **Cataract summary** from the A**nalysis** menu

» by clicking the  icon on the toolbar

This module is dedicated to the calculation of intra-ocular lenses (IOL). This calculation is not based on synthetic parameters like SimK, but uses measurements of the anterior segment obtained from the instrument. In particular, the calculation uses the elevation measurements of the anterior and posterior corneal surface, and the entry pupil. This information is used to create a three-dimensional model of the eye, that considers also potential asymmetries and irregularities of the examined eye. The ray-tracing method is used to trace the way light rays pass through the various surfaces of the eye, following Snell's Law. In this way we simulate the way the light ray passes from cornea to retina, passing intra-ocular lenses of different powers.

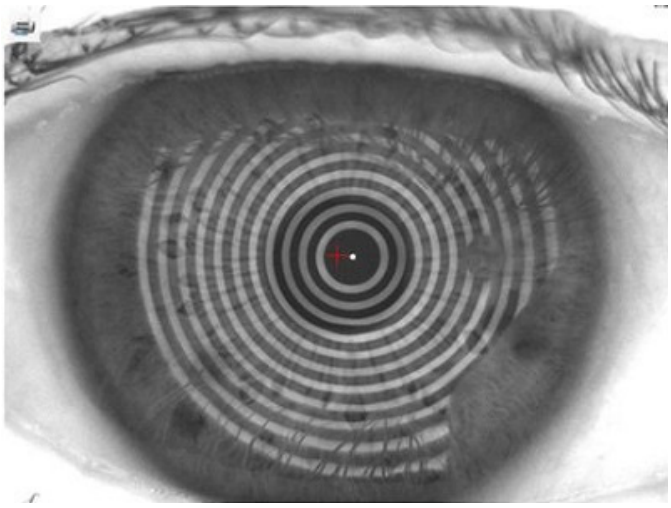


Figure 1: Example of a badly centered keratoscopy

CORRECT USE OF THE INSTRUMENT

Golden rules for an optimal result
• The acquired eye must be wide open and well centered • The tear film must be regularly distributed • The pupil must not be dilated • Make at least three similar acquisitions • Check the auto-detected pupil's position; edit when necessary

To correctly use the Sirius for calculation of intra-ocular lenses, we strongly advise that you acquire at least 3 images of the eye, in which the lens is to be implanted. The patient's pupil must not be dilated when using the instrument. The acquisitions all need to be well-centered (see Figure 1) and taken while the eye is wide open. The operator should verify that there are no residual anomalies or artifacts on the acquisition, due to an irregular distribution of the tear film. If a distortion is verified, e.g. shades and/or interruptions over the rings (see Figure 2 and Figure 3), it is advised to ask the patient to blink in order to restore the tear film.

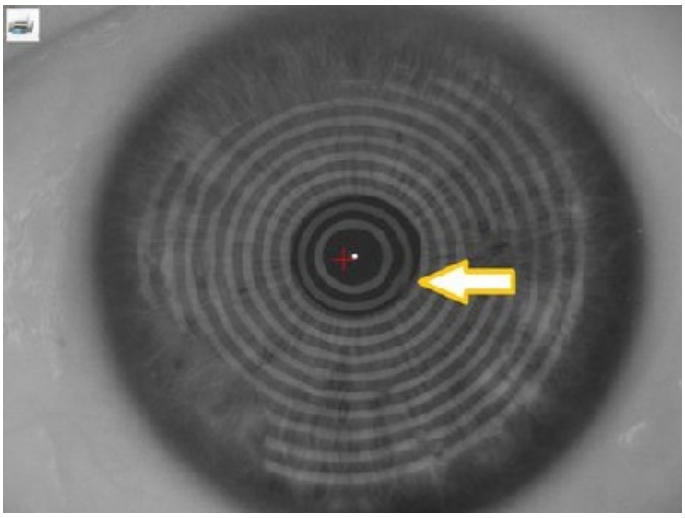


Figure 2: Decentered keratoscopy with artifacts: the rings in the indicated zone are distorted

If any of the three acquired images shows a deviation of SimK greater than 0.3 D, we recommend that you take another acquisition. When the pupil position is different in the various acquisitions, it is recommended that you repeat the acquisition process: it is an indication that the patient is not fixating correctly. A quick evaluation of repeatability, for the presence of artifacts and tear film coverage can be performed from the main management window, by reviewing the various acquisitions from the current exam (see Figure 4).

The incorrect detection of the vertices of irido-corneal angles might influence negatively the prediction of the IOL position. In the case where irido-corneal angles are not visible in the 7 meridians where the measurement of this angle is available (0°, 7°, 14°, 21, 158°, 166°, 173°) we recommend that you repeat the acquisition, making sure that the patient's eye is wide open during the entire acquisition sequence. If the patient is not able to keep their eye wide open for the entire duration of the acquisition, the software will show a pop-up asking for the manual editing of the missing angles. The operator should, in this case manually add the angle in the position that is likely to be the correct position, i.e. such that

it is the ideal intersection between the extension of the posterior corneal surface profile and that of the iris. It is sufficient to indicate the angle's vertex (see Figure 6).

DATA TO BE INSERTED

Before starting the intra-ocular lens calculation, the user should insert and/or verify the following information:

» The eye's axial length in mm has been obtained using a biometer
» The device used for the measurement of the axial length: PCI (Partial Coherence Interferometry), Ultrasound (US) by immersion, Ultrasound (US) by contact.
» The target refraction, i.e. the desired spherical equivalent after the implantation of the lens
» The pupil diameter for which we want to optimize the calculation for the lens power, in order to obtain the target refraction.
» The A Constant (or ACD or SF) of the implanted lens

All of the data, except for the last one parameter, needs to be (re)inserted in the Pre-Op page.

For the sake of convenience, the keratometries and the indices of Refractive Analysis are shown in the left part of the page. Besides those, optional warnings are shown that might guide the user in verifying the correctness of the input data. Those warnings are, e.g., an inserted axial length outside the normal range or excessive pupil decentering that might be caused by the patient's incorrect fixation during acquisition or by the software not having (correctly) auto-detected the pupil.

On the right-hand side of the Pre-Op page these options are available:

» the iris image with indication of the principal meridians and SimK. A goniometer is shown in overlay, in order to help the operator search for a reference to aid with the implantation of a toric lens.
» according to the operator's preference, the sagittal map of the anterior surface or the equivalent refractive power.

The software for calculating the IOL allows for the specification of a pupil diameter between 2 and 3 mm. This is the entry pupil taken into consideration for the calculation of the best lens, for the currently examined eye.
We suggest the use of a pupil diameter of 3 mm for normal eyes. For eyes examined after refractive surgery, it might be useful to choose a diameter of 2 mm, when the optical zone is very small and/or decentered.
When the axial length is set and optionally other input data is corrected, the calculation for the new intraocular lens can be started by pressing the button **New IOL**. A small window is shown where you can set the following parameters:

» IOL manufacturer
» IOL model
» The lens constant in one of its forms (A or ACD or SF). Based on this constant and the measured morphological parameters, the software calculates the Predicted Lens Position (PLP).
» The position of IOL center. The IOL center can be chosen equal to the corneal vertex, pupil center or limbus center.
» The axis of the least powerful meridian of the lens

The values of the cylinders for the toric lenses which will be considered in the calculation
By clicking **OK**, the lens calculation is started.
When the pupil center or limbus center are chosen as the position of the IOL center, it is very important to check whether the software was able to detect

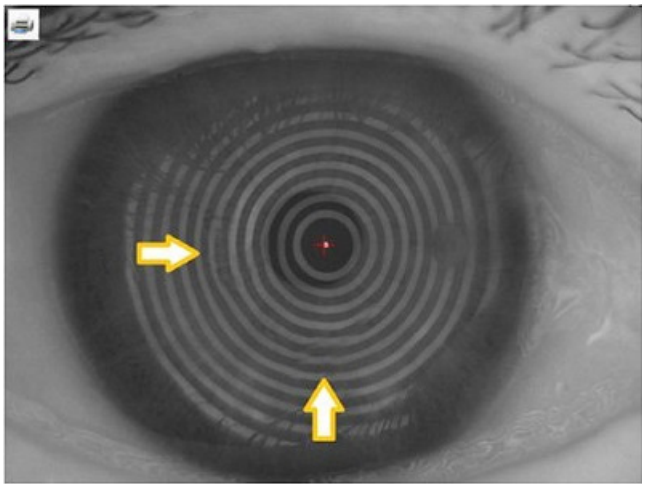


Figure 3: Well-centered keratoscopy with artifacts: The rings in the indicated zone are distorted

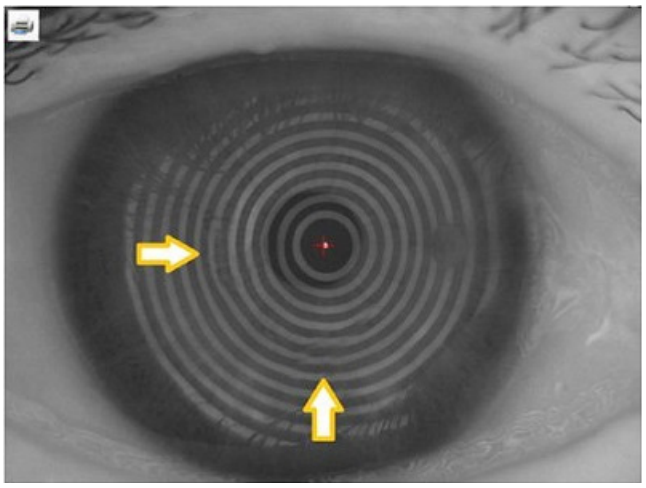


Figure 3: Well-centered keratoscopy with artifacts: The rings in the indicated zone are distorted

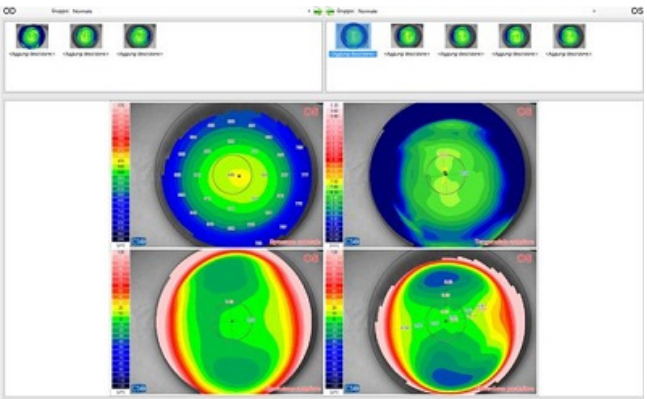


Figure 4: Patient management window: evaluation of repeatability, presence of artifacts, and correct coverage

them automatically or use the manual editing when necessary.
The axis of the least powerful meridian is set by default as the axis of the corneal cylinder calculated from OPD (or WFE).

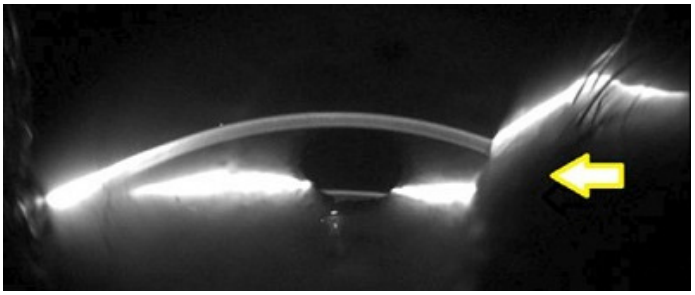


Figure 5: Half-closed eye, not allowing for the auto-detection of the irido-corneal angles

PREDICTED LENS POSITION (PLP)

The PLP (Predicted Lens Position) is the software's predicted distance from anterior surface of the implanted lens to the posterior surface of the cornea. This prediction is based on a collection of measured factors, obtained from the anterior segment, and on the provided A (ACD or SF) constant. It is noted that a prediction error is normally one of the principal sources of error for all formulas and systems for calculation of intra-ocular lens power.

FIRST TIME USE OF A IOL MODEL

When starting out with this software, and using a IOL model for the first time, it is advised to use the nominal A constant value, provided by the IOL constructor, and to optimize the value based upon post-operative information, obtained at least one month after the operation. In particular, when collecting post-operative cases, the operator should check the actual position of the anterior surface of the IOL after the operation (see Figure 7), and verify with the position predicted by the software before the surgery. Adjust the Gamma level using the mouse wheel or the +/- buttons in order to make the implanted IOL visible in the Scheimpflug images (see Figure 7). If the actual distance of the lens is greater than the predicted one, the constant value should be adjusted upwards, if it is smaller than the predicted distance, the value should be adjusted downwards.

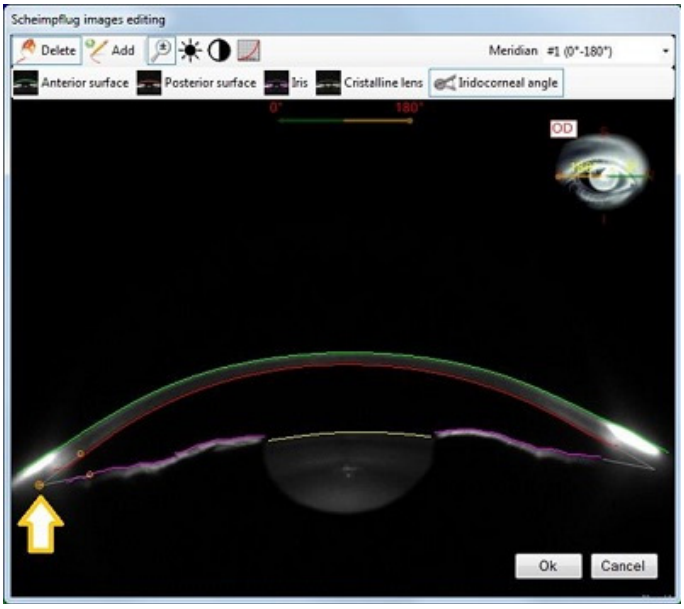


Figure 6: The arrow indicates the angle's vertex

RESULTS

For any new calculated lens, a new page of the module is created containing results of processing.
At the top of the page the following data are shown: IOL manufacturer and model, lens constant, position of the center of the lens and predicted position of the lens (PLP).

In the central part of the page the following information is available:

» a table containing summarized results of the calculus, i.e. for a list of powers the respective predicted spherical equivalents
» a table containing the predicted refraction in for to a certain IOL cylinder (at the IOL plane) for the mean power selected in the previous table
» a chart for Focusing

The Focusing chart contains the curve for the merit figure for visual acuity, obtained with various corrections, for the lens selected from the calculated lens power table. From a different point of view, the Focusing chart shows how the visual acuity varies for several vergences of the observed object. This chart is therefore useful to evaluate the depth of field for the pseudo-phakic eye.
At the bottom of the page the following information is available:

» the Point Spread Function (PSF) for the selected lens
» according to the operator's preference, the simulated wavefront map (OPD or WFE) or the Refractive Error map

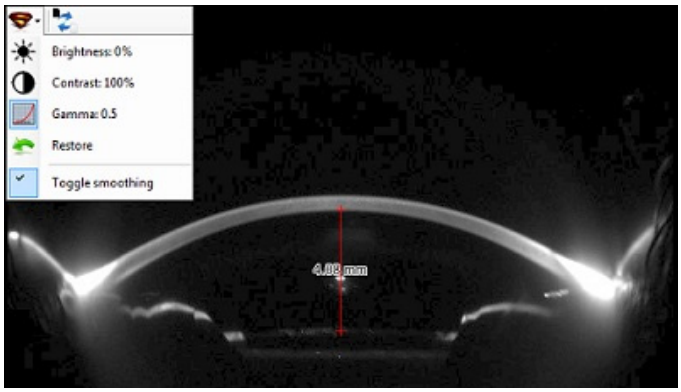


Figure7: How to verify the position of the IOL at 1 month after surgery

The 2 previous maps reference the lens selected in the two upper tables, characterized by the mean power selected in the left table and by the cylinder selected in the central table. The map for refractive error shows the refractive error for any ray passing through the pupil. It is useful to

evaluate the presence of possible defocus, astigmatism and asymmetries in the optical ocular system.

The results of the calculation can be printed by pressing the **Print** icon in the upper right corner.

The Toric **IOL Marker** icon launches the tool dedicated to the marking of toric intraocular lenses.

A page dedicated to the lens calculation can be removed by pressing the **Remove IOL** icon in the upper right corner.

The manufacturer bears no liability for consequential damages resulting from any application of the results contained in Cataract Summary, particularly for damages coming from an erroneous IOL calculation. The user of the program has to make sure that the proposed values do not contain any mistakes.

The Cataract **Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:

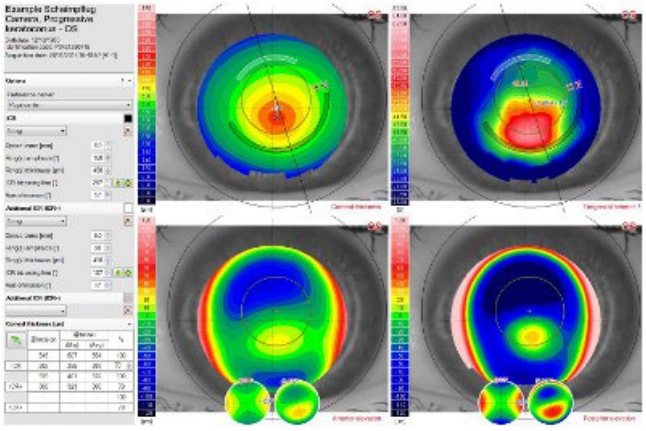
- Aramberri Jaime MD, BEGITEK Clínica Oftalmológica. San Sebastián, Spain OKULAR Clínica Oftalmológica. Vitoria-Gasteiz, Spain
- Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy
- Camellin Massimo MD, Sekal Microchirurgia Rovigo S.r.L. Rovigo, Italy
- Bedei Andrea MD, Pietrelli Alessia MD, Casa di Cura "San Camillo". Forte dei Marmi, Lucca, Italy
- Bellucci Roberto MD, Cargnoni Miriam Ort., Nguyen Deborah Ort., Hospital of Verona. Verona, Italy
- Ligabue Edoardo MD, Giordano Cristina OD, LA MIA VISTA. Milano, Italy
- Fantozzi Marco MD, Fortunato Francesco Ort., Studio Oculistico Fantozzi. Pescia, Pistoia, Italy

INTRASTROMAL RINGS SUMMARY

Intrastromal rings summary is displayed:

» by choosing **Intrastromal rings** from the **Analysis** menu

» by clicking the icon on the toolbar



Intrastromal rings summary

Intra Corneal Rings Segments (ICRS) are devices made of PMMA that are successfully used in the treatment of myopia, severe post-keratoplasty astigmatism, post-refractive surgery ectasia of the cornea, keratoconus and pellucid marginal degeneration. Correction of myopia (from -1D to -3D) was the first field in which these rings were used[1], however, today they are widely used in eyes with keratoconus or pellucid marginal degeneration[2–7].

ICRs are semi-circular rings (or ring segments) the length, thickness and section of which varies. Their action is based on the fact that, by inserting these stiff elements inside the corneal stroma, they separate the corneal lamellae and thus shorten the anterior corneal arc. Introducing the ring segments in the peripheral media reduces the length of the fibre arc, thus flattening the central cornea. To get a better understanding of the modifications in corneal structure achieved with the "additive" surgical technique, we can look at the Barraquer "thickness law"[8–9]. According to this law, when you add material to the periphery of the cornea, therefore increasing the thickness of the peripheral cornea, you flatten the central cornea; instead, if you add material at the center of the cornea, you increase the central curvature. The extent of this effect is directly proportional to the thickness of the implant and inversely proportional to its diameter. Moreover, some scholars[10] who have used mathematical models that take into account the asphericity and/or spherical distortion of the eye to examine the effect of ICRs in correcting myopia, have shown that, to better flatten the anterior corneal surface, and thus improve the refractive effect, one needs to either insert thicker ring segments or implant them in a more central position.

When ICRs are used to treat corneas with keratoconus, the goal is not so much to eliminate the refractive defect as to improve both the patient's visual acuity and visual quality. In fact, in these cases, such rings lead to re-centring of the conus, thus normalizing the anterior corneal surfaces through a reduction in chromatic aberration, and reducing the ectasia by flattening the central cornea; all this reduces the irregular component of the astigmatism and reduces refractive correction (myopic and astigmatic). ICR implants for keratoconus must take into account the fact that, while the surgical technique is not particularly invasive and carries low risk of complications, there is the drawback that the pathological tissue is maintained. And thus it ensues that there are limitations for the choice of patients; in particular, patients with altered corneal transparency — Vogt's striae or stromal opacities -, advanced keratoconus and degenerated apex must be ruled out.

Different types of ICRs are available according to arc, thickness and implantation site. INTACSs are hexagonal-section segments in PMMA with arc circumference of 150 degrees. The external diameter of each segment is 8.10 mm, the internal diameter 6.77 mm and the thickness varies (ranging from 0.25 to 0.45 mm). Instead, INTACS SKs have an internal diameter of 6 mm, an oval section, and come in two thicknesses: 0.40 mm and 0.45 mm. The other two types of ICR are the Ferrara and Kerarings rings. Both have triangular section and come in various thicknesses and arc lengths.

For each ICR model, nomograms are available. Considering the patient's refraction and corneal morphology — obtained via corneal topography - these nomograms make it possible to precisely calculate the number, thickness and arc length for the rings to be implanted. It can also be decided whether to correct the patient's astigmatism or give priority to correction of chromatic aberration, as in the case of keratoconus patients whose visual capacity is limited by high corneal surface asymmetry. There is no fixed rule for this; one should take into account the best visual acuity correction and subjective refraction for each patient, above all for the axis of the subjective cylinder, and check these against the topographic and coma axes (in most cases one or the other coincides). It is possible to implant a ring or two segments that match or having different dimensions and thicknesses, or one can even insert several segments. Except for the site of the incision, the surgical technique for ICR implant treatment of keratoconus is similar to that used for the corrections of minor myopia. In fact, the incision site depends on where the segments are to be inserted and is calculated on a case-by-case basis. If the two segments to be implanted are asymmetrical, the thicker of the two is inserted in the lower position — as this recentres the conus —, while the thinner is inserted in the upper position — thus flattening the cornea and reducing the irregular astigmatism.

The ICR implant calls for making a peripheral incision, its distance from the centre varies according to the ring diameter; then a circular canal is created to accommodate the ICRs which are inserted by rotating them until they reach the desired position. The incision and canal can be created manually, with the aid of special instrumentation, or with a femtosecond laser. For myopia correction the incision is generally made at 12 o'clock, with the introduction of two segments set symmetrically on opposite sides, in the nasal and temporal sectors. To achieve the desired effect it is also important to insert the ICR in the back 2/3 of the cornea (70-78%) and, to that purpose, the pachymetric map must be carefully studied in order to calculate the proper implant depth. Remember, often the estimated incision depth does not correspond to the actual depth achieved; therefore the ICRs may actually be closer to the surface than envisaged; this is more evident when the incision is performed manually while use of a femtosecond laser appears to ensure greater precision.

The Summary of Intrastromal Corneal Rings is used to monitor corneal thickness in the area of the implant and, at the same time, provide a printable summary depicting the main topographic maps which are useful for this type of surgery.
The left side of the summary shows:

» The center of reference: choice between Center of the pupil and Center of the Limbus, specifying the site where the implant is to be centered;
» for each Ring/Pair of rings (up to 3), the tables provide the data for:
  - o Optical zone: indicating the diameter of the ring to be inserted, in millimetres;
  - o Size of the ring/s: indicating the amplitude of the arc for the ring to be insert, in degrees;
  - o Thickness of the ring/s: indicating the thickness of the ring selected for the implant, in microns;
  - o ICR bisector: indicating the degrees of the segment bisector and, in conjunction with the data for the Optical Zone and the center selected, determining the position for the corneal ring;
  - o Incision axis: indicating the position selected for the incision, in degrees. This position is suggested whenever the parameters, such as ring Bisector or Optical Zone, are changed.
» On the basis of the above parameters and the corneal morphology, the following are calculated, in microns:
  - o Corneal thickness in the incision zone.
  - o Average corneal thickness in the tunnel zone.
  - o Minimum corneal thickness in the tunnel zone.

These values are also provided, in percentages, when planning to use a femtosecond laser.
The central part of the screen shows:

» A Corneal thickness map: this map shows the ring (or rings) described in the previous section on the background of the patient's pachymetric map. Also, the thinner points, the center of the pupil and the distance between them, are also indicated.
» A curvature map among tangential anterior, tangential posterior and sagittal anterior: the keratometry data (SimK) are presented on the map.
» An anterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.
» A posterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.

The manufacturer bears no liability for consequential damages ensuing rom application of the results contained in the ICR Summary. The user of the program is responsible for checking the results and ensuring that the proposed values do not contain mistakes.

The ICRS Summary was developed and validated by CSO srl in cooperation with the following eye clinics:

» Prof. Giovanni Alessio, Ophthalmology Department, Policlinico di Bari, Bari, Italy
» Prof. Jose F. Alfonso, Cornea and Lens Department, Instituto Oftalmológico Fernández-Vega, Oviedo, Spain
» Prof. Luca Buzzonetti, Ophthalmology Department, Ospedale IRCCS "Bambino Gesù", Rome, Italy

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1. *Schanzlin DJ: Studies of intrastromal ring segments for the correction of low to moderate myopic errors. Trans Am OphthalmolSoc 1999; 97:815-819Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol (Copenh). 1975;53:34-43.*
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3. *Shetty R, Kurian M, Anand D, et al. Intacs in advanced keratoconus. Cornea 2008;27:1022–9.*
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8. *Barraquer JI: Queratoplastiarefractiva, estudios e informaciones. Oftalmologicas (Barcelona) 1949; 2:10–30*
9. *Barraquer JI: Modification of refraction by means of intracorneal inclusion. IntOphthalmolClin 1966; 6:53–78*
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ASPHERO-TORIC FITTING (ANTERIOR/POSTERIOR)

Asphero-toric fitting screen is displayed:

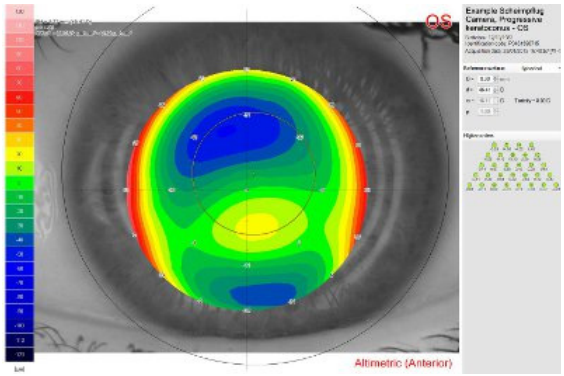
» by choosing **Asphero-toric fitting (Anterior)** or **Asphero-toric fitting (Posterior)** from the Analysis ▶ Advanced menu

» by clicking the ▶ icon on the toolbar

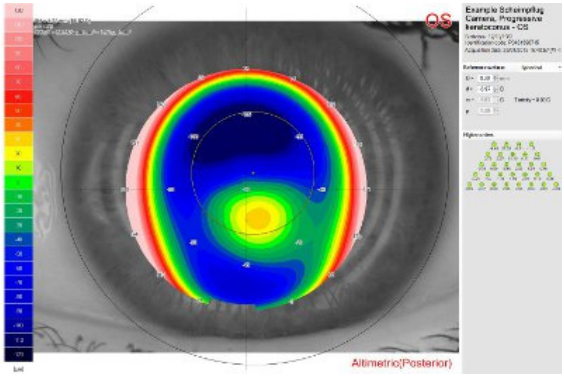
The asphero-toric fitting represents the corneal map as offset by a surface reference, that can be chosen by the operator using the menu options on the right hand side of the screen.
Using the pull-down list it is possible to select the surface against which we want to offset the examined eye:

» Spherical the reference surface is a sphere
» Aspheric the reference surface is aspheric or more precisely a conicoid. The asphericity value, (in p, e, e2 or Q) can be chosen from options
» Asphero-toric the reference surface is asphero-toric. The toricity is calculated by the software as the difference between rf and rs.

Depending on the selected surface reference type, some of the parameters (like rf, rs or the asphericity) are editable. Any modification of the diameter will result in an adjustment of the parameters for the reference surface to the surface that best represents the examined eye on the diameter (Ø mm) chosen.
The difference between the selected surface and the surface reference is decomposed in Zernike polynomials up to the 7th order, allowing the selection (by double-clicking) of each single fitting component on the map.



Asphero-toric fitting anterior



Asphero-toric fitting posterior

ZERNIKE SUMMARY

Summary is displayed:

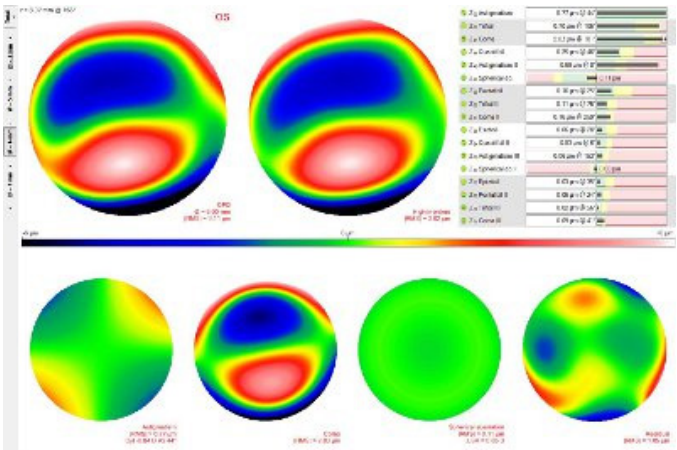
» by choosing **Zernike Summary** from the **Analysis** menu

» by clicking the icon on the toolbar

The program permits conducting analysis of the wavefront generated by the cornea, obtained by topographic data through Zernike analysis. The aberrometric map expresses the differences in height between the wavefront generated by the cornea being examined and a spherical perfect wavefront. The aberrations are displayed as total aberrations and divided into their various components. A set of 36 Zernike polynomials is used for the analysis of the various components of total aberration; the analysis results are reported in the summary as numerical indices and as graphic representations. The pupil diameter may be selected on the left side of the screen in a range from 2 mm to 8 mm with 0.5 mm steps. Total wavefront (obtained by ray-tracing using both anterior and posterior surface), anterior surface wavefront (i.e. considering only the anterior surface) or the posterior surface wavefront (defined as the difference between the total and anterior only) analysis is allowed.
This screen is highly influenced by the parameters chosen on the Wavefront configuration window.

Several Wavefront error maps are shown in the screen:

» **Total OPD/WFE** (i.e. the total amount of the wavefront error within the analysis diameter)



Zernike Summary

» **Higher orders** (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» **Astigmatism** (i.e. the amount of polynomials Z2-2 and Z2+2). Bottom-right of the map the value of the Cylinder and its RMS are shown.
» **Coma** (i.e. the amount of polynomials Z3-1 and Z3+1). Bottom-right of the map the value of coma RMS is shown.
» **Spherical aberration** (i.e. the amount of polynomial Z40). Bottom-right of the map the value of the LSA and the Spherical

Aberration RMS are shown.

» **Residual** (i.e. the total amount of the wavefront removing the amount of Astigmatism, Coma and Spherical Aberration)

ZERNIKE POLYNOMIALS

On the upper right there is a table which summarizes the decomposition of Zernike for the current wavefront into its aberrations:

» The first column carries the names of the polynomials. Generally speaking, each aberration is represented by a pair of polynomials. Axis-symmetric aberrations are represented by single polynomials.
» The second column gives a RMS value and the relative meridian for each aberration.
» The last column displays the histogram of the coefficients of expansion of the Zernike polynomials: the bars represent the weighted value for each aberration. The normality data, represented by the green, yellow and red bars, are derived from a statistical study on 1000 normal eyes.

OPTICAL QUALITY SUMMARY

Optical Quality Summary is displayed:

» by choosing **Optical Quality Summary** from the Analysis menu

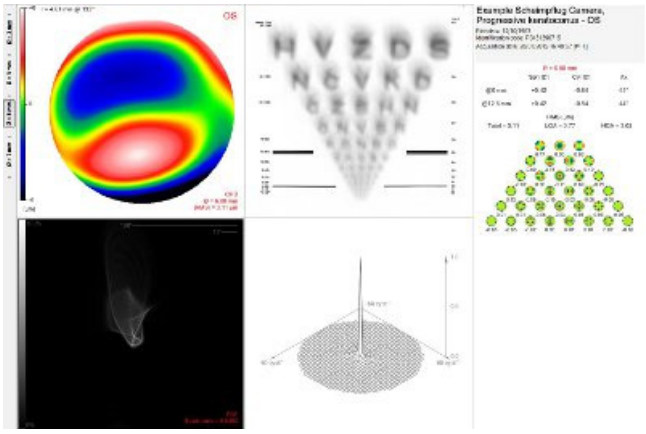
» by clicking the  icon on the toolbar

This form permits an overall analysis of visual quality.
From top-left to the bottom-right are shown:

» OPD/WFE map;
» Vision Simulation;
» PSF;
» MTF.

In the right panel the Zernike pyramid, displaying the coefficients of the Corneal wavefront decomposition, is shown.

The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Total, Anterior or Posterior).



Optical Analysis Summary

COMPARISON/FOLLOW-UP IMAGE SELECTION

The first operation to start a comparison/follow-up analysis is to select the images to be compared.

The first image is chosen by default, the one from where we open the selection window, other images have to be manually chosen by the user.

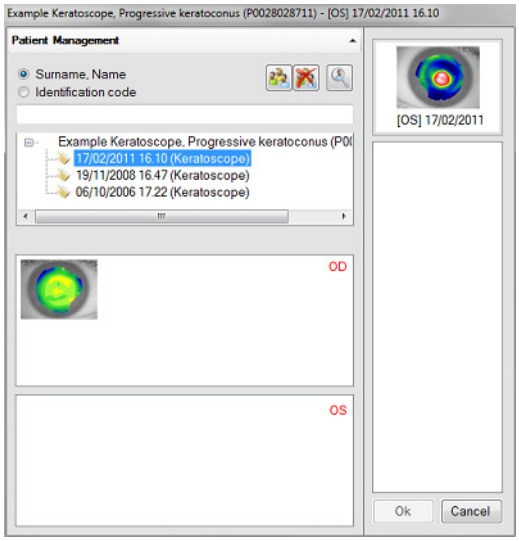
The window that shows up provides on opening the current patient/examination.

If the images to be compared do not belong to the current patient/examination standard tools for the examination search are provided: the button  shows the complete patient database, whereas the button  allows for an advanced search.

Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel.

The number of selected images may vary depending on the context of the follow-up operation.

Click **OK** to continue, **Cancel** to stop the comparison.



Manual selection of the acquisitions to be compared.

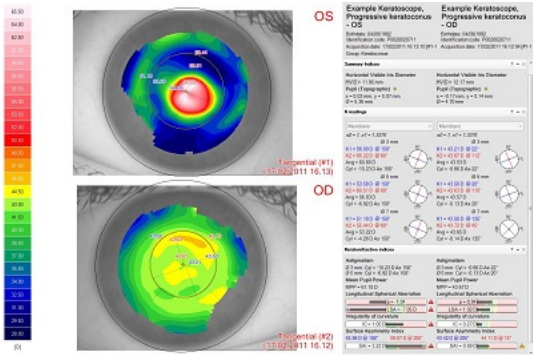
COMPARISON

Comparison is displayed by:

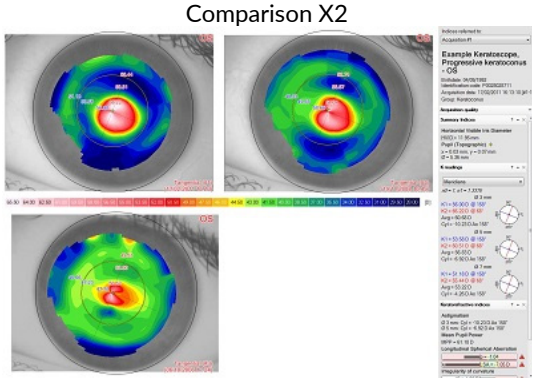
» Choosing **Comparison** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the images to be compared, a window with the selected acquisitions is shown. It's possible to select 2, 3 or 4 maps. The topographic information to be compared is selected from the drop-down menu in the upper-right corner, next to the label **Current map.**

The comparison of two maps allows for the contemporary display of both sets of indices. The selection of more than 2 maps, means you have to choose the indices to be displayed. In this case the drop down box at the top of the right panel is for selecting the images the **indices refer too**. Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Comparison X2



Comparison X3

COMPARE OD/OS

It is possible to compare the right and left eye avoiding the manual selection by:

» Choosing **Compare OD-OS** from the Analysis ► Comparison menu

» Clicking the icon on the toolbar.
A comparison screen between the current eye and the fellow eye will be shown.

DIFFERENTIAL

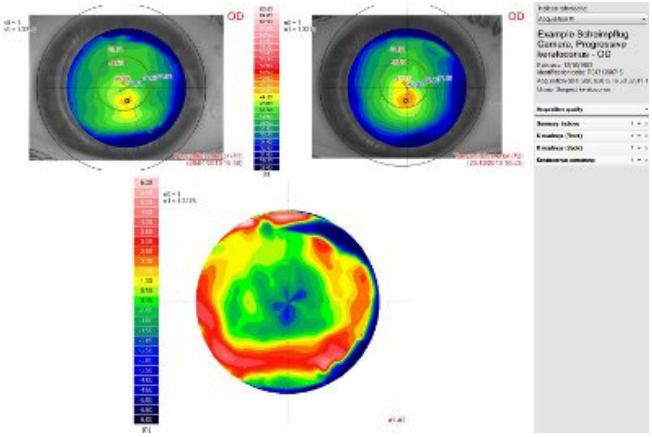
Differential is displayed by:

» Choosing **Differential** from the **Analysis** menu

» clicking the icon from the toolbar.

After the manual selection of the images to be compared two or three maps (current map plus one or current map plus two) and their relative difference are shown: maps in the lower part of the window show the differences between the maps in the upper part. In the case of a differential on 2 maps, the difference between 1st and 2nd is shown. In the case of a differential on 3 maps, the difference between 1st and 2nd, between 1st and 3rd and between 2nd and 3rd are shown.

The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label **Current map.** The drop down box at the top of the right panel is for selecting the image the **indices refer too.**
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Differential

WAVEFRONT COMPARISON

Comparison is displayed by:

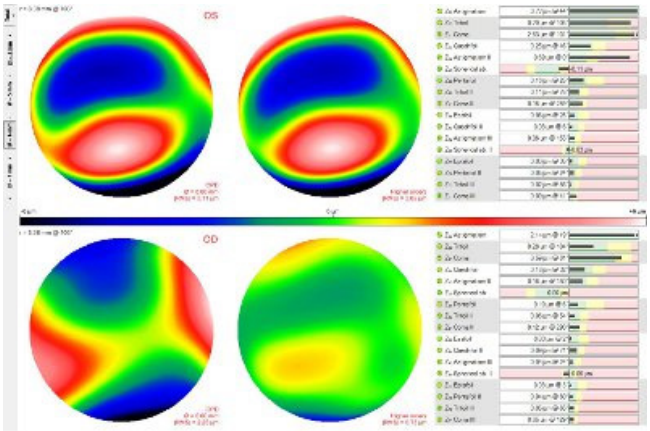
» Choosing **Wavefront Comparison** from the A**nalysis** menu

» clicking the icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:

» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



Wavefront Comparis

WAVEFRONT DIFFERENTIAL

Comparison is displayed by:

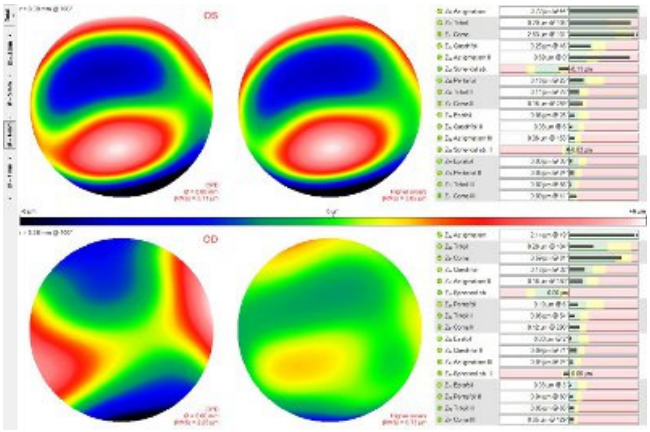
» Choosing **Wavefront Comparison** from the A**nalysis** menu

» clicking the icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:

» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



Wavefront Comparis

KERATOCONUS FOLLOW-UP

Comparison is displayed by:

» Choosing **Keratoconus follow-up** from the **Analysis** menu

» clicking the icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

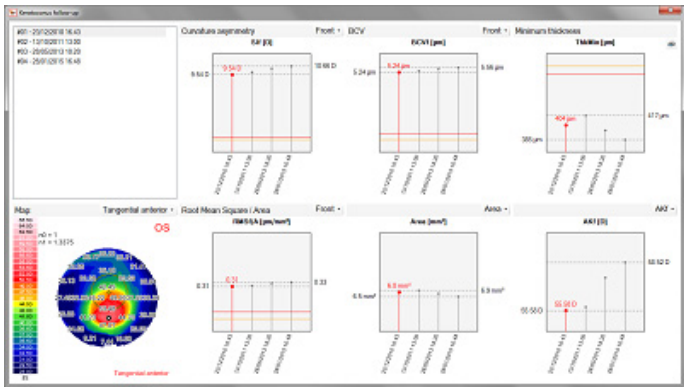
The screen is made up as follows:

» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.

» One of following maps can be selected for displaying.
  - o Corneal thickness
  - o Tangential anterior
  - o Tangential posterior
  - o Elevation anterior
  - o Elevation posterior

  The map refers to the selected image.

» 6 histograms referring to the main keratoconus indices are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. If available the border-line threshold (5th or 95th percentile) is shown in orange and the abnormality threshold (1th or 99th percentile) is shown in red.



Keratoconus follow-up

REFRACTIVE SURGERY FOLLOW-UP

Comparison is displayed by:

» Choosing **Refractive surgery follow-up** from the **Analysis** menu

» clicking the icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

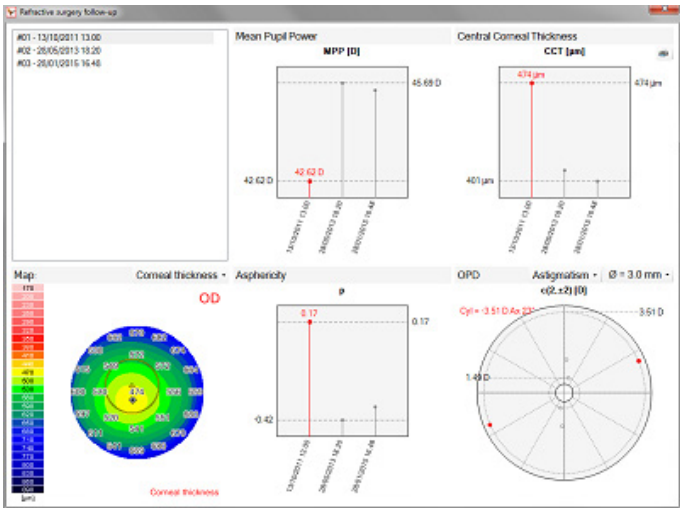
The screen is made up as follows:

» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.

» One of following map can be selected:
  - o Corneal thickness
  - o Tangential anterior
  - o Tangential posterior
  - o Sagittal anterior
  - o Sagittal posterior
  - o Elevation anterior
  - o Elevation posterior
  - o Refractive anterior power
  - o Refractive posterior power
  - o Refractive equivalent power

  The map refers to the selected acquisition.

» 3 histograms (MPP from Refractive analysis, CCT from Summary Indices and corneal asphericity at 8mm from Shape Indices) are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. A polar chart displaying magnitude and axis of the cylinder at a selectable diameter (from Refractive analysis) is also shown.



Refractive surgery follow-up

AS-OCT IMAGES

The control shows a single sectional image acquired by the AS-OCT instrument.
Above the image a toolbar with the following tools can be found:

	Zoom	When selected, it is possible to change the magnification of the image shown on the screen, using the mouse wheel or the +/- keys
	Distance	Allows for measurement of a distance between two points on the image. Click to mark the starting point and click again to mark the end point. To delete the latest measurement, press **Del** or **Backspace** key.
	Cartesian coordinates	When selected, clicking on a point of the anterior chamber its (x,y) location from the corneal vertex is shown. To delete the latest measurement, press **Del** or **Backspace** key.
	Magic wand	When selected, clicking on a point of the anterior chamber, a line passing through that point going from the corneal posterior surface to the iris or to the lens will be drawn and measured. If the point is higher than the anterior surface it will measure corneal sagitta, when lower than the posterior surface, the anterior chamber depth is measured. The function will not work outside of mapped zones. To delete the latest measurement, press **Del** or **Backspace** key.
	Angle	Allows to draw and measure an angle. To draw the angle, click to mark once the vertex and two times to indicate both sides of the angle. To delete the latest measurement, press **Del** or **Backspace** key.
	Histogram	An indication of the opacity of the cornea and lens is provided: the numeric value assigned indicates a value from 0 to 100 reflecting the relative opacity. To move the origin of the graph, click on the point of interest
	Brightness	When this item is selected, it is possible to change the brightness of the image, using the mouse wheel
	Contrast	When this item is selected, it is possible to change the contrast of the image, using the mouse wheel
	Gamma	When this item is selected, it is possible to change the gamma of the image, using the mouse wheel

Display of the AS-OCT sectional image

	Restore	Restores the original values for the image, undoing any kind of modification to brightness, contrast and gamma
	Toggle smoothing	Sets the interpolation mode of the image
	Invert background color	Inverts the image's greyscale
	Play/Pause	Starts/stops the automatic scrolling of the frames.
	Forward	Shows the next image.
	Rewind	Shows the previous image
	Show detected surfaces	Shows the edges of the corneal surfaces, of the iris and of the crystalline lens on the image

MAPS

Several maps are available taking into consideration different corneal attributes:

» Sagittal anterior
» Sagittal posterior
» Tangential anterior
» Tangential posterior
» Corneal thickness
» Epithelial thickness map
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber

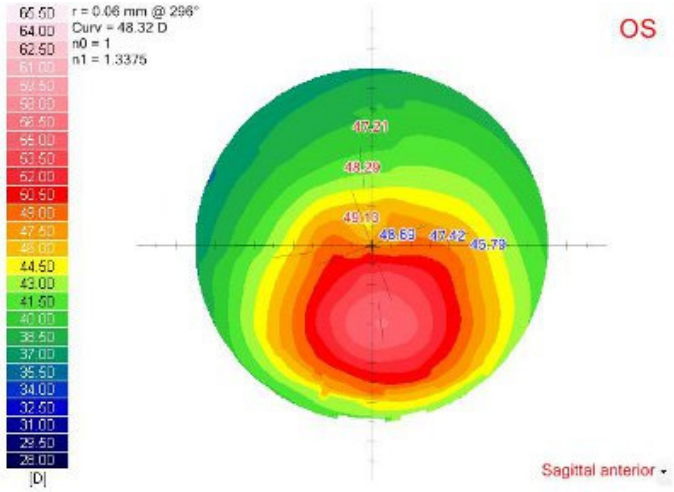
SAGITTAL ANTERIOR MAP

This map represents, point by point, the distribution of the ante-rior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flat-ter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar accoding to the preferred setting;
» The curvature at the point taken into consideration.

The refraction index used for the conversion formula be-tween millimeters and diopters.

Right-clicking opens the Tools and display options menu.



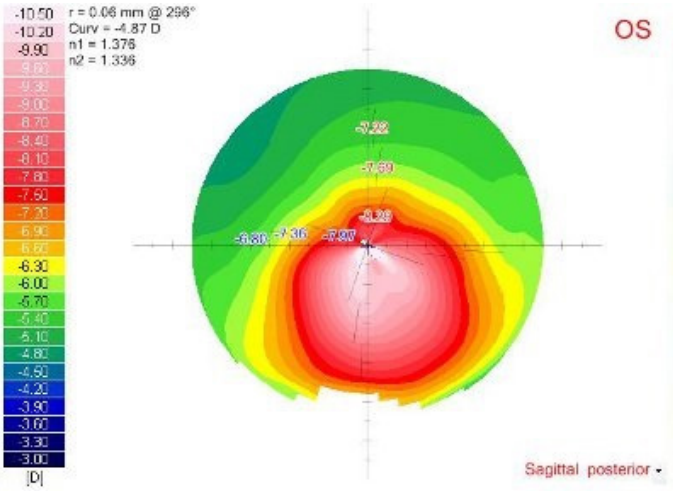
Anterior sagittal curvature map

SAGITTAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



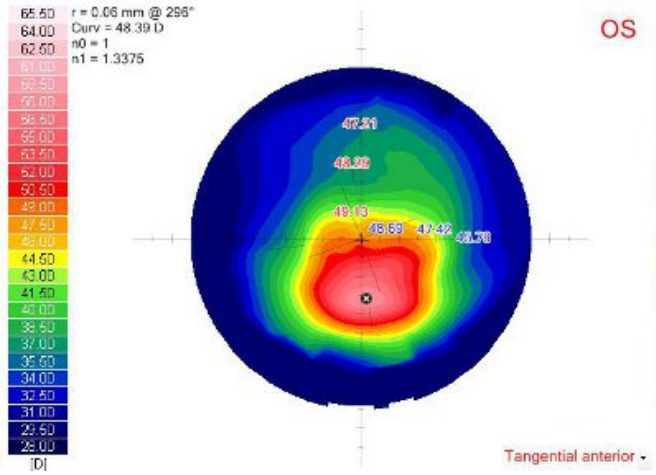
Posterior sagittal curvature map

TANGENTIAL ANTERIOR MAP

This map represents, point by point, the distribution of the anterior tangential curvature in millimeters or diopters according to the preferred setting. With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊗ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



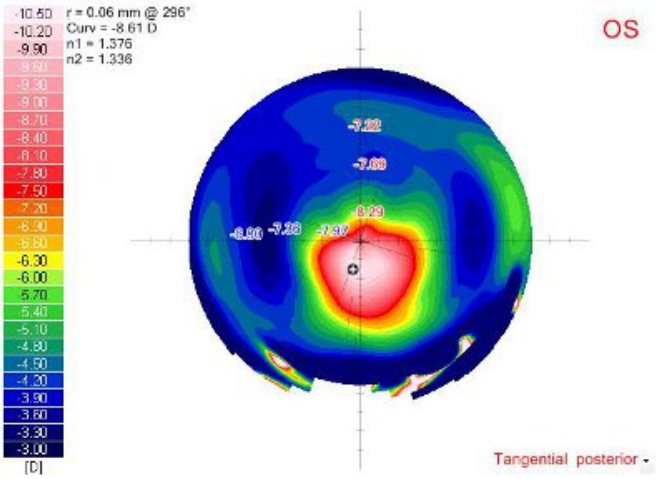
Anterior tangential curvature map

TANGENTIAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior tangential curvature in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊕ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



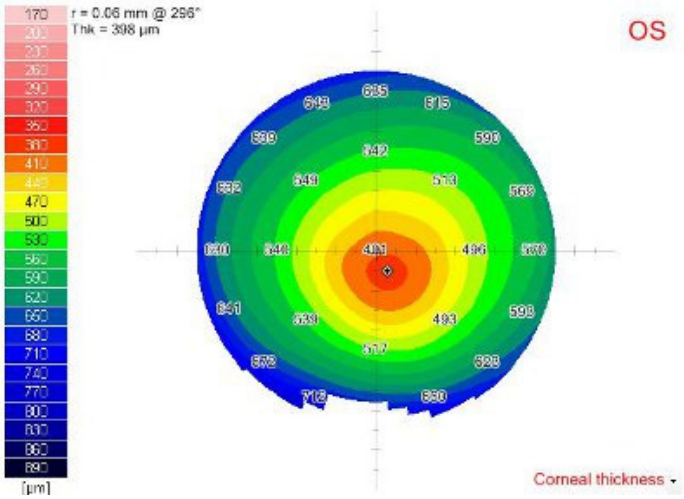
Posterior tangential curvature map

CORNEAL THICKNESS MAP

This map represents, point by point, the distribution of the thickness of the cornea in microns (µm).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with thinner zones and the cool colors (green, blue) are associated with thicker zones.
The thinnest point is marked by the ⊕ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The corneal thickness at the point taken into consideration.

Right-clicking opens the Tools and display options menu.



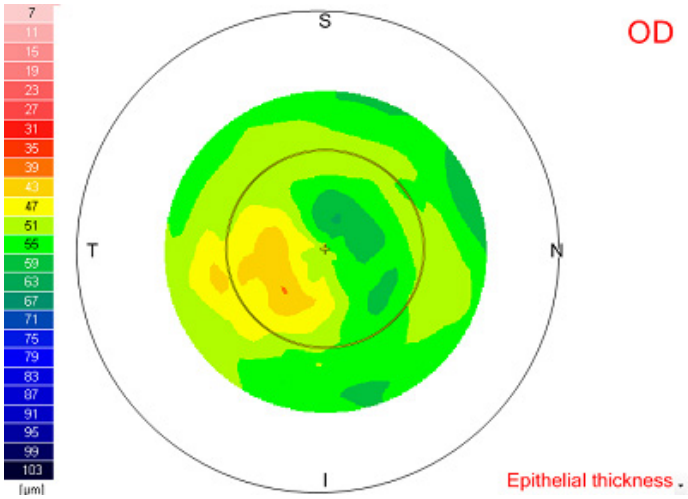
Corneal thickness map

EPITHELIAL THICKNESS MAP

This map locally represents the corneal epithelial thickness, i.e. the distance between the tear film layer and Bowman's layer.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The epithelial thickness at the position of the cursor. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu



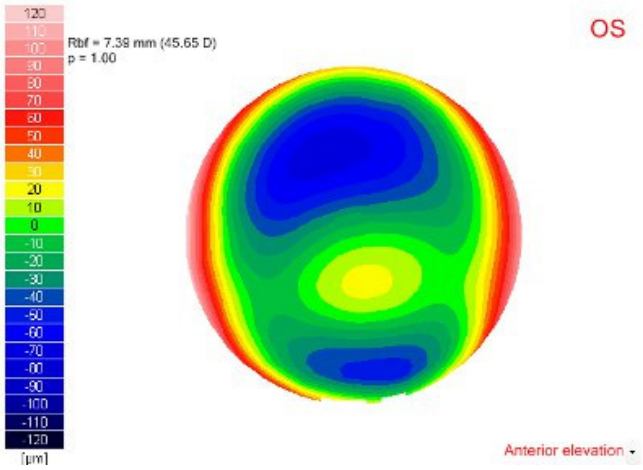
Epithelial thickness map

ELEVATION ANTERIOR MAP

This map represents in microns (µm), the elevations of the anterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



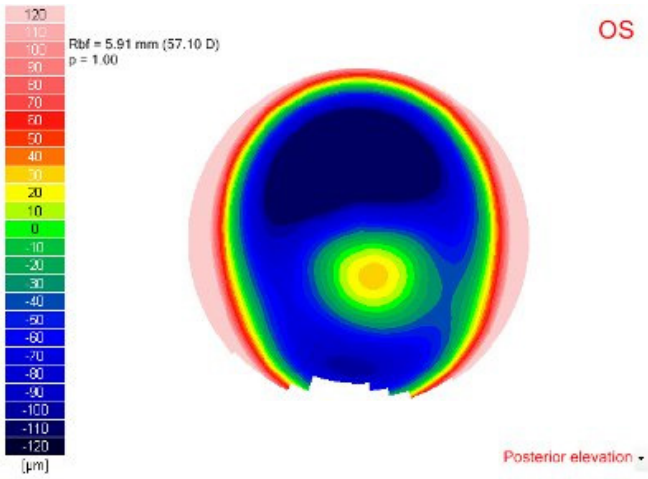
Elevations anterior map

ELEVATION POSTERIOR MAP

This map represents in microns (µm), the elevations of the posterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



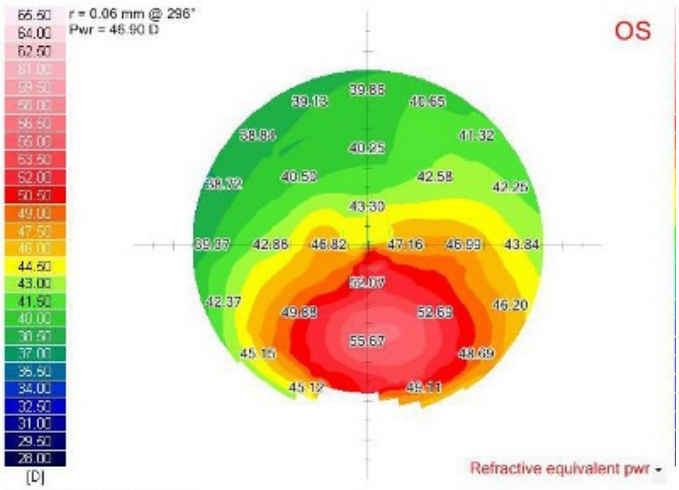
Elevations posterior map

REFRACTIVE EQUIVALENT POWER MAP

This map represents, point by point, the distribution of the total corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior and posterior corneal surface for each point. The reference indices for the two interfaces are the air index (N0=1), stroma index (N1=1.376) and the index for the aqueous humor (N2=1.336).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration . This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



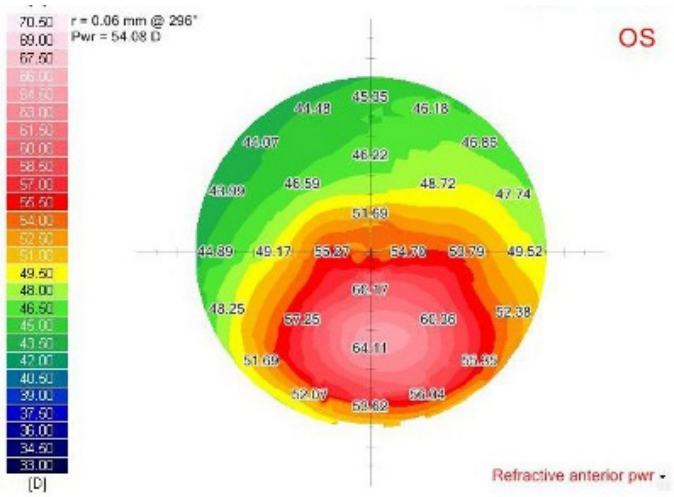
Refractive equivalent power map

REFRACTIVE ANTERIOR POWER MAP

This map represents, point by point, the distribution of the anterior corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior corneal surface for each point. The refractive indices for the interface Air-Cornea are those of the air (N0=1) and of stroma (N1=1,376).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



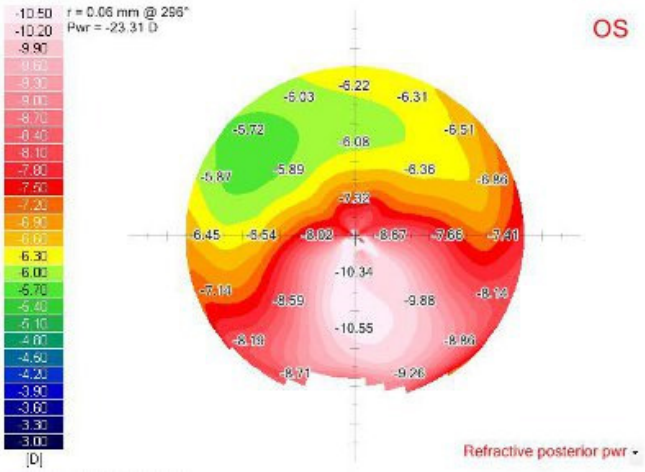
Refractive anterior power map

REFRACTIVE POSTERIOR POWER MAP

This map represents, point by point, the distribution in diopters of the power of the posterior corneal surface and is calculated as the difference between the total refractive power and the anterior refractive power.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



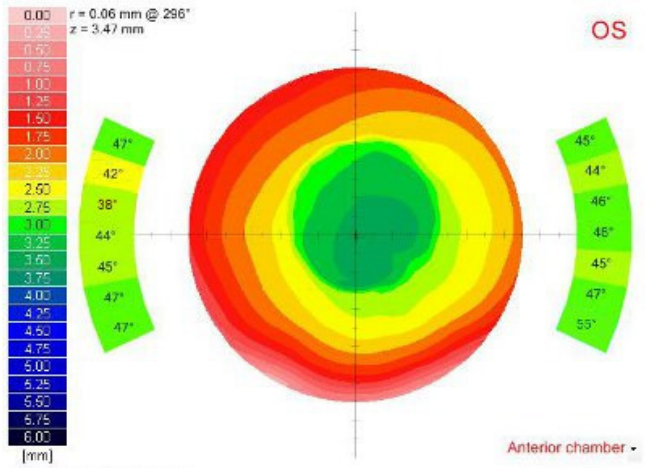
Refractive posterior power map

ANTERIOR CHAMBER MAP

This map represents, locally the anterior chamber depth, i.e. the distance between the posterior surface of the cornea and the iris or the crystalline lens. On the left and right sides of the map, the values of the irido-corneal angles are reported.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Chamber depth at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Anterior chamber map

INDICES

On the right side of several analysis windows a selection of panels is available, containing information and indices referencing the current image:

» Patient data
» Acquisition Quality
» Summary Indices
» K-Readings (Anterior)
» K-Readings (Posterior)
» Shape Indices
» Refractive analysis
» Keratoconus Screening

The ▼/▲ arrow on the title bar expands/collapses the related panel.
The ? button opens its help window.

Click the button × on the title bar to remove a panel from the lateral section of the window. To restore the removed panels, elect ►**Restore** on the right side of the main Toolbar.

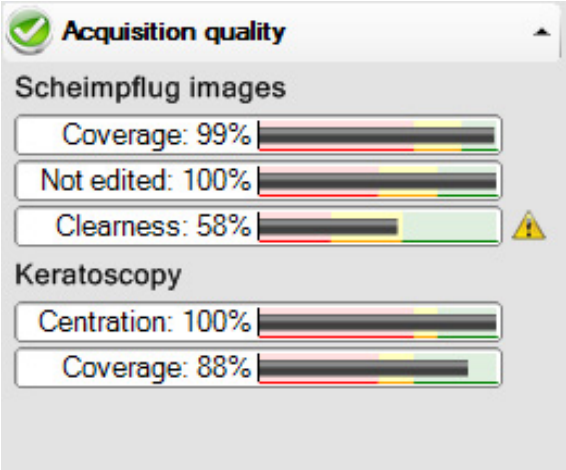
ACQUISITION QUALITY

It shows some indices which indicate the quality of both the Scheimpflug and keratoscopic acquisitions.
In more detail, the coverage of the Scheimpflug tomographies is considered, the percentage of images that were manually edited, as well as the clearness of the stromal tissue is taken into consideration as an index of corneal hyper-scattering.
Rings coverage for the Keratoscopy and the well-centeredness of the cornea respective to the instruments axis is reported under the group Keratoscopy.
The indices are preceded by when the acquisition quality seems to be satisfactory; by a warning when we recommend you take more acquisitions.

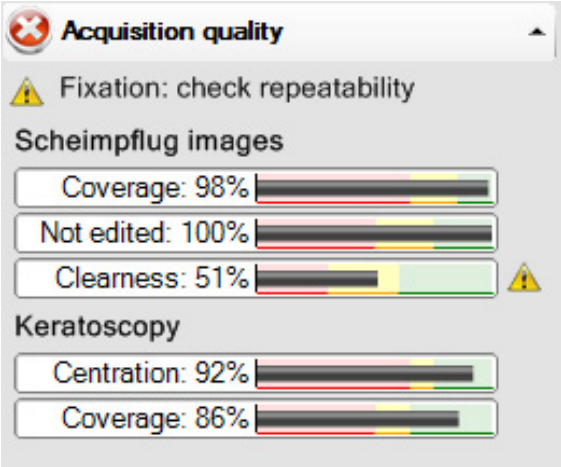
The warning "Fixation: check repeatability" is a help for selecting good acquisitions. It appears when the pupil position of the current acquisition is outside a "normal zone", i.e. the zone where the pupil position is located in normal fixating eyes. If this warning is present, there can be two cases:

» The patient is not fixating, so it is necessary to acquire again after asking the patient to fixate on the fixation point.

The patient is fixating, but the eye is anomalous (for example if the eye is a keratoconus). In this case the pupil position is always decentered in every acquisition. So, the warning has to be interpreted as an anomalous fixation of the patient.



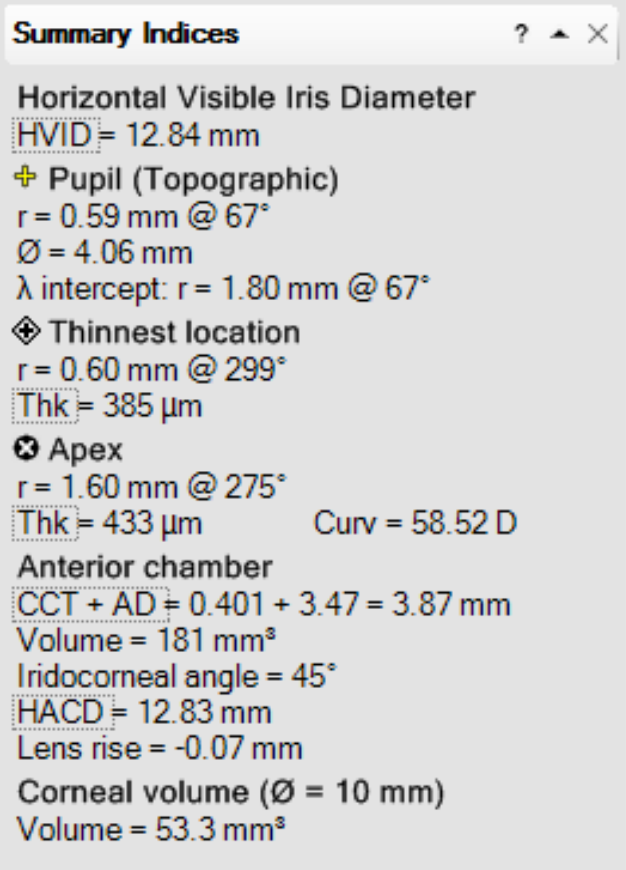
Acquisition quality for a satisfactory acquisition



Acquisition quality for an unsatisfactory acquisition

SUMMARY INDICES

- **HVID (Horizontal Visible Iris Diameter):** it is the limbus size (in mm) in the horizontal direction. It is derived from the keratoscopic image.
- **Pupil** (Topographic): the symbol shows the pupil center position in the maps. x,y and r,@ are, respectively, the cartesian and polar coordinates of the pupil centre, shown in the Summary indices panel according to the preferred setting. Ø is the diameter of the topographic pupil.
  λ intercept is the intercept between the pupillary axis and the anterior corneal surface. The pupillary axis is the line passing through the center of the entrance pupil, and which is normal to the cornea.
- **Thinnest location:** the symbol indicates the position of the corneal thinnest point in the maps. Its coordinates are shown in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry in this point.
- **Apex:** the symbol indicates the steepest point position in the maps. Its coordinates are shown in in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry and Curv is the curvature in this point.
- **Anterior Chamber**
  - **CCT + AD** : **CCT** is the central corneal thickness. AD is the aqueous depth, (i.e. the distance between the corneal posterior surface and the anterior surface of crystalline lens in correspondence to corneal vertex).
  - **Volume:** the volume of the portion of the anterior chamber limited by the back surface of cornea, the iris and the crystalline lens, in a 12mm diameter zone.
  - **Iridocorneal angle:** the average of the measured angles for the meridians whose angular position is included in the range +/- 25° from the horizontal meridian.
  - **HACD (Horizontal Anterior Chamber Diameter):** it is measured as the distance between the vertices of the iridocorneal angles.
  - **Lens rise:** it is the difference between the position of the crystalline lens and the iridocorneal plane, i.e. the best-fit plane "passing" through the vertices of the iridocorneal angles. A negative value means that the crystalline lens is above the iridocorneal plane.
- **Corneal Volume:** the corneal volume within a diameter equal to 10 mm.



Summary indices

K-READINGS (FRONT)

From the sagittal data of the anterior cornea it is possible to derive kera-tometric data related to the principal meridians: these data can be expressed as

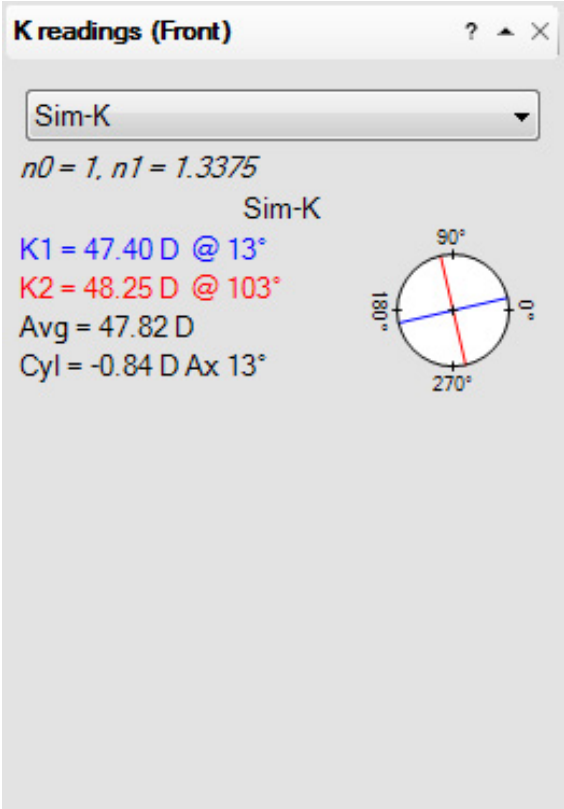
» Sim-K
» Meridians
» Emi-meridians
» Peripheral degrees

SIM-K

Sim-K represents the simulation of the readings that would be ob-tained with a keratometer, (i.e. the mean sagittal curvature from the 4th to the 8th Placido ring). The considered zone has a variable amplitude depending on the curvature of the measured cornea.
The following values are available for Sim-K:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



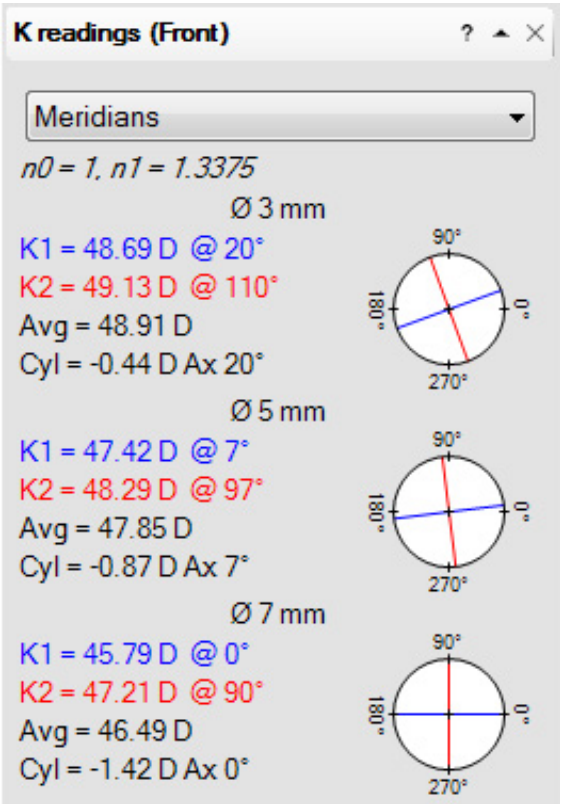
K-readings (front): Sim-K

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the anterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



K-readings (front): Meridians

HEMI-MERIDIANS

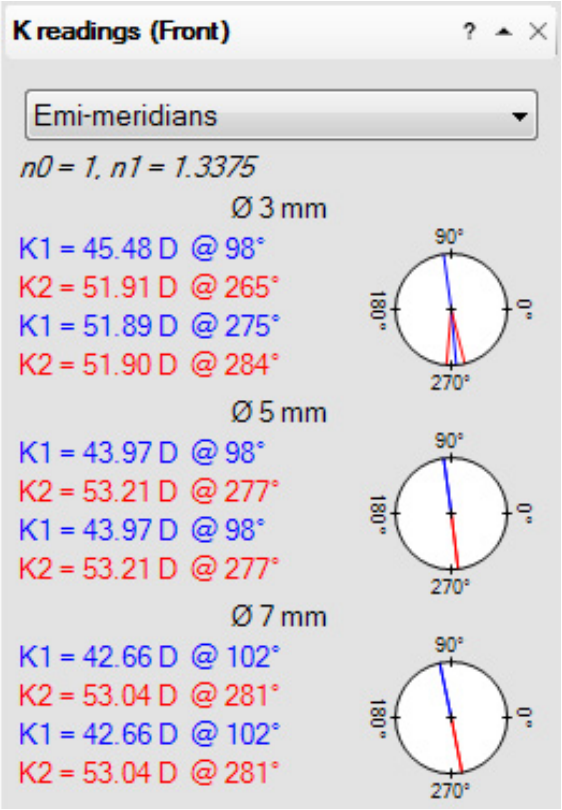
If this option is selected, the two pairs of flattest and steepest hemi-meridians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-meridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians K1 and K2.

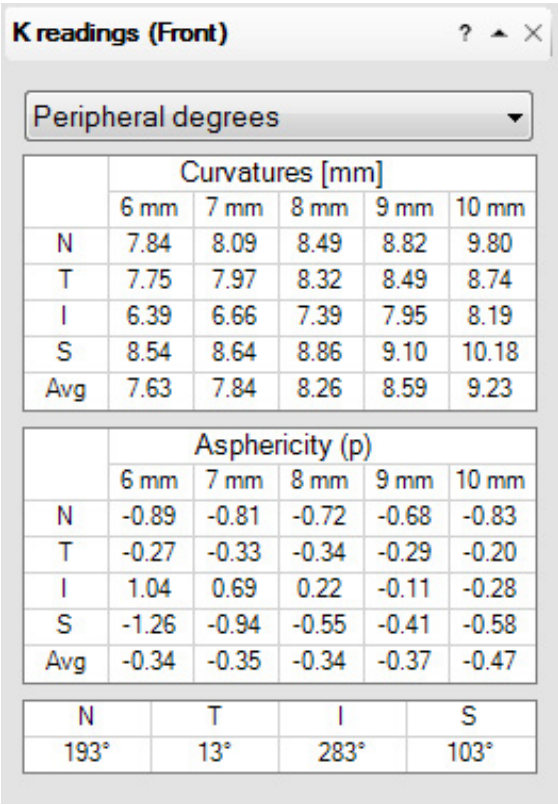
N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.

PERIPHERAL DEGREES

If this option is selected, two tables of curvatures and asphericities (expressed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the considered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity con-tains the average values for each zone of the values of the 4 consid-ered hemi-meridians.
The angular positions of the 4 Hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S) are available in a third table.



K-readings (front): Hemi-meridians



K readings (Front)

Peripheral degrees

	Curvatures [mm]				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	7.84	8.09	8.49	8.82	9.80
T	7.75	7.97	8.32	8.49	8.74
I	6.39	6.66	7.39	7.95	8.19
S	8.54	8.64	8.86	9.10	10.18
Avg	7.63	7.84	8.26	8.59	9.23

	Asphericity (p)				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	-0.89	-0.81	-0.72	-0.68	-0.83
T	-0.27	-0.33	-0.34	-0.29	-0.20
I	1.04	0.69	0.22	-0.11	-0.28
S	-1.26	-0.94	-0.55	-0.41	-0.58
Avg	-0.34	-0.35	-0.34	-0.37	-0.47

N	T	I	S
193°	13°	283°	103°

K-readings (front): Peripheral degrees

K-READINGS (BACK)

From the sagittal data of the posterior cornea it is possible to derive kerato-metric data related to the principal meridians: these data can be expressed as

» Meridians
» Hemi-meridians
» Peripheral degrees

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the posterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians **K1** and **K2**.
» **Avg:** mean curvature of the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N1 and N2 are the refractive indices used for converting the values of curva-ture from mm to D: N1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

HEMI-MERIDIANS

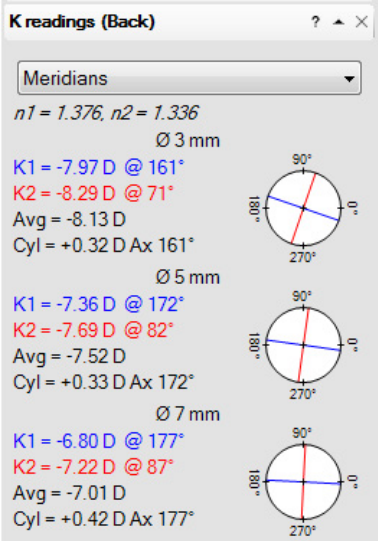
If this option is selected, the two pairs of flattest and the steepest hemi-me-ridians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-me-ridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians **K1** and **K2**.

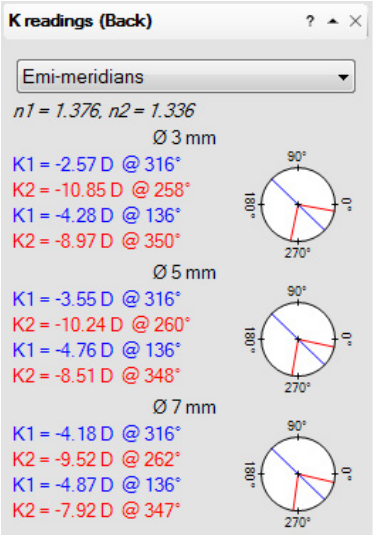
N_1 and N_2 are the refractive indices used for converting the values of curva-ture from mm to D: N_1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

PERIPHERAL DEGREES

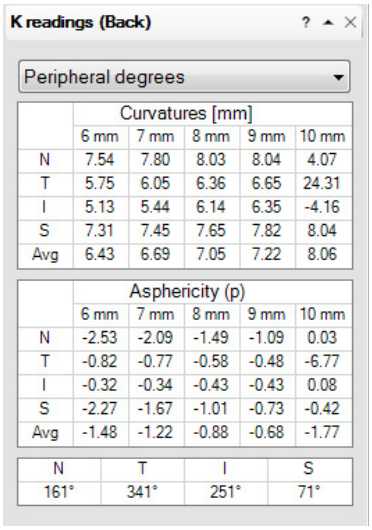
If this option is selected, two tables of curvatures and asphericities (expres-sed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the con-sidered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity con-tains the average values for each zone of the values of the 4 consid-ered hemi-me-ridians.
The angular positions of the 4 Hemi-meridians Nasal (N), Temporal (T), Infe-rior (I) and Superior (S) are available in a third table.



K-readings (back): Meridians



K-readings (back): Hemi-meridians



K readings (Back)

Peripheral degrees

	Curvatures [mm]				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	7.54	7.80	8.03	8.04	4.07
T	5.75	6.05	6.36	6.65	24.31
I	5.13	5.44	6.14	6.35	-4.16
S	7.31	7.45	7.65	7.82	8.04
Avg	6.43	6.69	7.05	7.22	8.06

	Asphericity (p)				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	-2.53	-2.09	-1.49	-1.09	0.03
T	-0.82	-0.77	-0.58	-0.48	-6.77
I	-0.32	-0.34	-0.43	-0.43	0.08
S	-2.27	-1.67	-1.01	-0.73	-0.42
Avg	-1.48	-1.22	-0.88	-0.68	-1.77

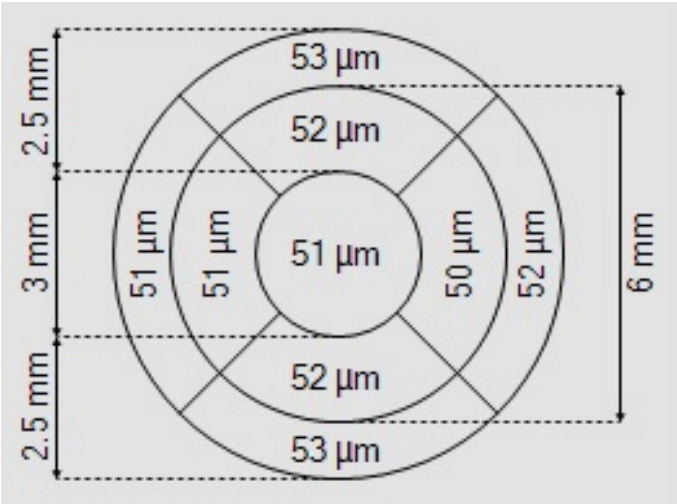
N	T	I	S
161°	341°	251°	71°

K-readings (back): Peripheral degrees

EPITHELIAL THICKNESS

This panel contains a schematic representation of zonal averaged values of the epithelial thickness map. Each averaged value is the average of the local values of the epithelial thickness map in a certain zone.

The central circle contains the average thickness value within a 3 mm diameter.
Outside the central circle, the averaged values for 4 annuli sectors (nasal N, temporal T, inferior I, superior S) are shown. The internal and external diameters of these annuli are respectively 3 and 6 mm. Their limiting angles are 45°, 135°, 225° and 315°.
The most external annuli sectors have a diameter within 6 and 8 mm.

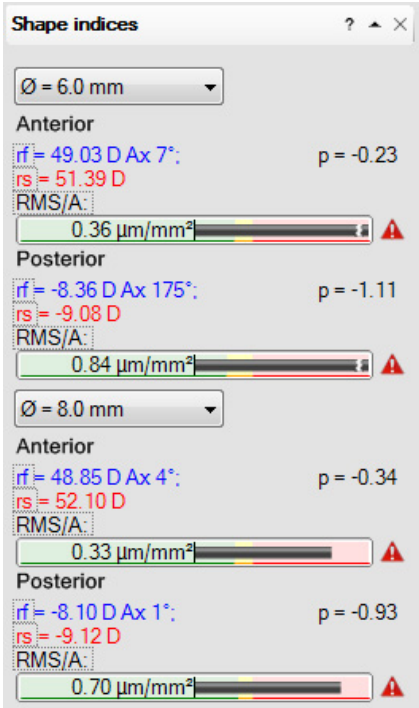


Epithelial thickness: zonal averaged values

SHAPE INDICES

Shape indices are available for the two corneal surfaces (anterior and posterior) for two different diameters selectable by the user. These indices are the parameters which define the asphero-toric surface best approximating the samples of the measured corneal surface within the zone delimited by the chosen diameter.

- **rf (Flat Radius):** the apical radius (in mm or in D according to the preferred setting) of the flattest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **rs Steep Radius:** the apical radius (in mm or in D according to the preferred setting) of the steepest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **p, e, E, Q:** different forms of the asphericity according to the preferred setting for the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **RMS (Root Mean Square):** represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax. If the RMS is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS, the more irregular the corneal surface.
- **RMS/A:** Root Mean Square per unit of area.



Shape Indicies

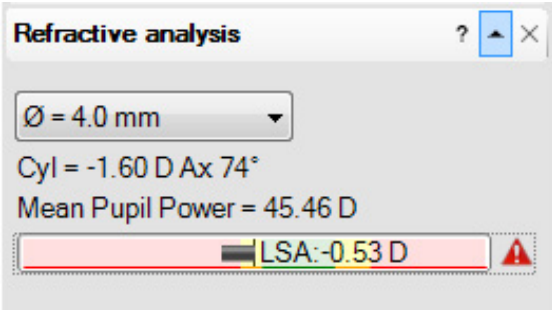
REFRACTIVE ANALYSIS

All the indices in this group are calculated from the corneal wavefront related to an entrance pupil located in the position of the patient's pupil, for diameters ranging from 2.5 to 7 mm.
Both the measured anterior and posterior corneal surfaces are taken into account and ray tracing is performed as described below.

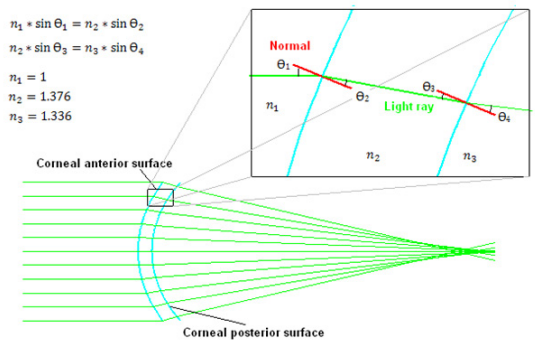
A bundle of rays parallel to the instrument axis and passing within the entrance pupil of the eye are traced through the anterior and posterior corneal surfaces using Snell's law. For each incoming ray its intersection with the anterior corneal surface and its angle of incidence relative to the anterior surface normal are calculated. The ray refracted by the anterior surface is obtained using Snell's law with n_{air} = 1.0 and $_{stroma}$= 1.376. This ray is then considered as an incoming ray for the posterior corneal surface and the same procedure as above is applied to calculate the ray refracted by this surface using Snell's law with n $_{stroma}$ = 1.376 and n $_{aqueous}$ = 1.336.

» **Cyl:** the corneal cylinder (in D) and its axis.
» **Mean Pupil Power**: is the equivalent corneal power (in D) .
» **LSA** is the corneal Longitudinal Spherical Aberration (in D).

Right-clicking opens the a contextual menu for the selection of the display mode of the Pupil Power (**PWR1/PWR2** or **Mean Pupil Power/Cyl)** and the Spherical Aberaation (**c(4,0)** or **LSA**).



Refractive analysis

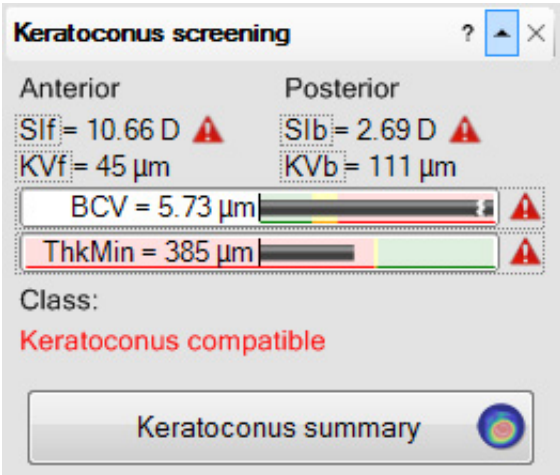


KERATOCONUS SCREENING

The software displays a series of indices describing the morphology of the cornea, which are useful in the diagnosis of keratoconus and in follow-ups. It is also possible to open the Keratoconus summary (see Keratoconus summary) pressing the namesake button.

CURVATURE ASYMMETRY

» The Symmetry Index of the anterior curvature (**SIf** – SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normal values are shown (95° percentile and 99° percentile of a normal population);
» The Symmetry Index of the posterior curvature (**SIb** – SymmetryIndexBACK) is defined as the difference of the mean poste



Keratoconus screening

» rior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

VERTICES

» Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT) and on the on the posterior corneal surface (**KVb** – Keratoconus VertexBACK) are shown.

ELEVATION BASED INDICIES

» The indices **BCVf** e **BCVb** allow the evaluation of the presence of, and the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetries $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) \; + \gamma C_4^{0}$$

The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normality values are shown (95° percentile e 99° percentile of a normal population);
The index BCV or vectorial **BCV** is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normality values are shown (95° percentile and 99° percentile of a normal population).

THINNEST POINT

» Thinnest point of cornea ThkMin is shown.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:
» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

PLACIDO BASED CORNEAL TOPOGRAPHY

CALIBRATION

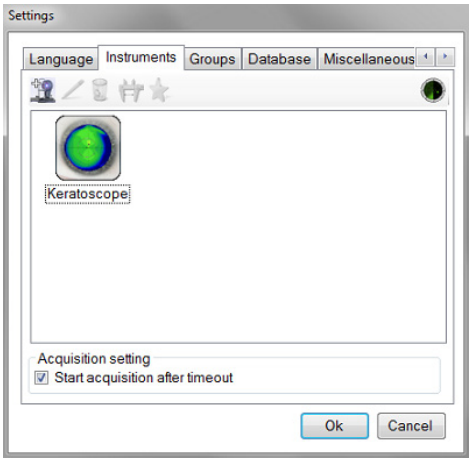
Calibration is essential for obtaining accurate measurements: to calibrate correctly, follow the instructions given step-by-step on the screen and carry out all the captures needed, with the calibration standards requested in a dark environment.

Follow the steps below to complete the calibration process:

» Place the supplied calibration tools in front of the device.
» Open the settings menu and select the Instruments panel.
» Select the instrument **Keratoscope** and click the calibration button  ;

- o if requested carry out linear calibration as described be low.
- o carry out the curvature calibration as described below.

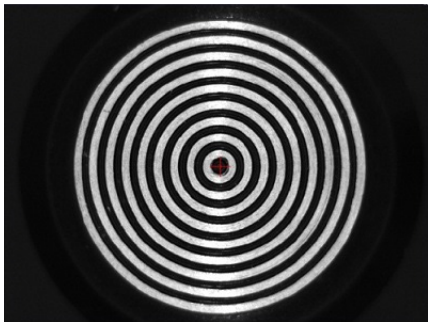
The entire procedure must be carried out carefully.



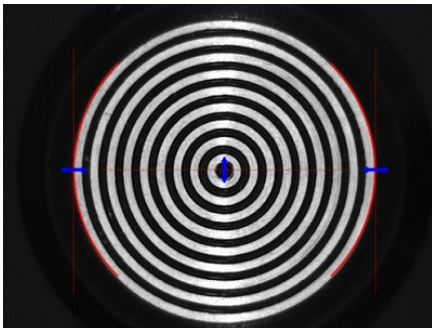
Keratoscope under Instruments panel

LINEAR CALIBRATION

Linear calibration is necessary to permit the program to correctly measure the distances on the image. Linear calibration is carried out by capturing the flat calibration disk image when focused. To capture, press the joystick button or the space bar.
After capturing the disk, move the horizontal and vertical blue arrows to establish the boundaries of the disk. Position the two red circumference arcs so that they coincide with the external side of the last white ring.
When done, click Next to continue.



Calibration disk

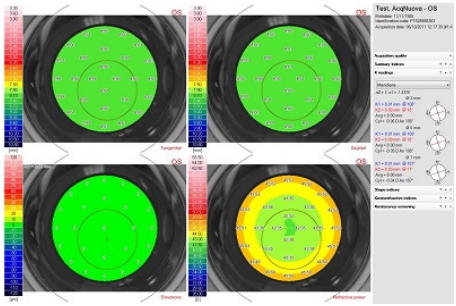


Linear calibration

CURVATURE CALIBRATION

Curvature calibration is necessary to permit the program to correctly measure the curvatures.
Carefully acquire an image of the calibration sphere. If the acquisition is not satisfactory a message will ask to repeat the procedure.

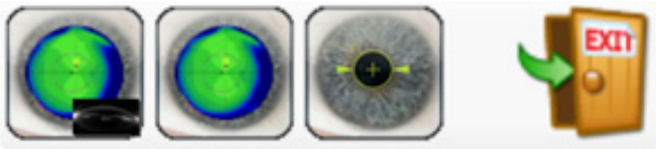
After having successfully calibrated you should capture some images of the calibration sphere, creating a patient and a test exam to verify correct instrument calibration. If the processed measurements are not found to be reliable, repeat the entire calibration procedure.
Last image represents the acquisition summary for a sphere after a correct calibration procedure.



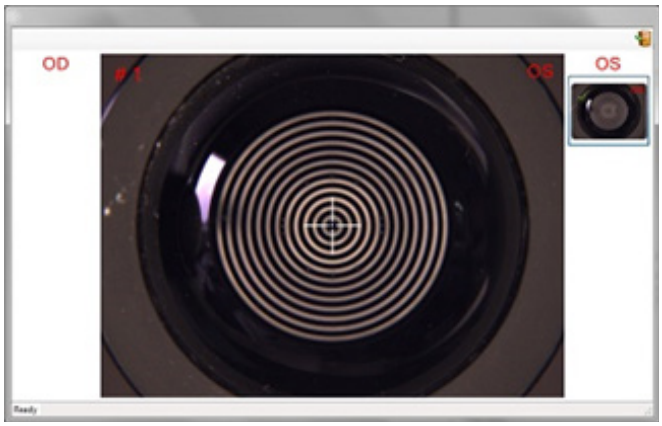
Linear calibration

ACQUISITION

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the icon opens the window for selecting the instrument with which to capture an image.



To capture a keratoscopy image, select the icon. The instrument automatically sets to the capture position and a live capture window opens.



Acquisition screen

FOCUS-BASED DEVICES ACQUISITION

Position the patient's head on the chin rest and move the topographer in front of the patient's eye you want to acquire. Adjust the height of the topographer until the cross is in the center of the rings. Move the topographer forward or backward to find the best focus and then move the joystick backwards to defocus the image.

To acquire an image press the joystick button and move the topographer slowly forward until the image defocuses again. During this movement make sure that the cross remains near the center of the rings. Passing through the focus the software captures the best image and you will see it in the gallery. The procedure will be finished when you hear a sound.

To force the acquisition press again the joystick button: the image with the best focus until than, will be saved.

Acquire several images per eye to choose the best of these, deleting the unclear images.

To check the keratoscopy quality right-click on the thumbnail: the image will be shown on the live area.

To select/unselect a keratoscopy left-click on its thumbnail: a check/cross icon will appear on the side.

To process the images, exit the image capture process by pressing the button and select the keratoscopy to be processed from the gallery images in the main screen.

When the device is too far or too close to the cornea the slits appear disjoint or overlapping in the corneal periphery

TRIANGULATION-BASED DEVICES ACQUISITION

Position the patient's head on the chin rest and move the topographer in front of the patient's eye you want to acquire. Adjust the height of the topographer until the cross is in the center of the rings.
Move the topographer forward or backward: when the device is too far or too close to the corneal vertex the slits appear disjoint or overlapping in the corneal periphery. On the contrary, when the slits

MENU

A menu is displayed at the top of the screen: a short description of the functionalities and options that are available follows:

FILE

Save screen-capture as image	Opens a window from which the current screen-capture can be saved in various image formats.
Close	Closes the current analysis environment and returns to main page.
Print screen-capture	Opens a window to set-up printing parameters and to print the current screen-capture.
Print screen-capture (quick)	Directly prints the screen-capture.
Print	Opens a window to set-up printing parameters. The final printout is screen dependent.
Print (quick)	Directly prints.
Export	Exports for external program.
Quit	Exits the application after confirmation of the warning message.

EDIT

Ring/Pupil/ imbus editing	Opens the environment for the editing of reflected Placido rings, of the pupil and of the limbus edge.
Reprocess	Reprocess all Scheimpflug images and the keratoscopy.

ANALYSIS

Summary	Opens up the default overview summary, containing information on curvature, elevation and refractive power.
Keratoscopy	Displays the keratoscopy image.
Single map	Displays a single map to permit detailed analysis.
3D	Displays a 3D chart of the current displayed map.
Keratoconus summary	Displays a detailed summary of keratoconus.
Aspherotoric fitting	Displays a screen for the elevation analysis of the corneal surface.
Autofit	Accesses the contact lens simulation environment
Corneal aberrometry	Displays an overview dedicated to the corneal wave-front analysis.

Optical Quality Summary	Opens up a summary focused on the patient quality of vision.
Comparison	Allows comparison of up to 4 different maps.
OD/OS	Allows comparison the current and the fellow eye.
Differential	Show the difference-map between acquisitions (up to 3).
Wavefront comparison	Allows comparison of 2 different corneal Wavefront maps.
Internal components	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.
OPTIONS	
Options	Set-up the user preferences for the display of topography or aberrometry.
INFORMATION	
About...	Shows information on the software release.

TOOLBAR

A toolbar is displayed at the top of the screen: a short description of the functionalities and options that are available follows.

Summary	Opens up the default overview summary, containing information on curvature, elevation and refractive power.
Keratoscopy	Displays the keratoscopy image.
Single map	Displays a single map to permit detailed analysis.
3D	Displays a 3D chart of the current displayed map.
Keratoconus summary	Displays a detailed summary of keratoconus.
Aspherotoric fitting	Displays a screen for the elevation analysis of the corneal surface.
Autofit	Accesses the contact lens simulation environment

	Corneal aberrometry	Displays an overview dedicated to the corneal wave-front analysis.
	Optical Quality Summary	Opens up a summary focused on the patient quality of vision.
	Comparison	Allows comparison of up to 4 different maps.
	OD/OS	Allows comparison the current and the fellow eye.
	Differential	Show the difference-map between acquisitions (up to 3).
	Wavefront comparison	Allows comparison of 2 different corneal Wavefront maps.
	Internal components	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.
EXPORT		
	Close	Closes the current analysis environment and returns to main page.

OPTIONS

Options screen is displayed by:

» Choosing **Options** from the menu

Preferences on the representation of the measured information can be changed here.

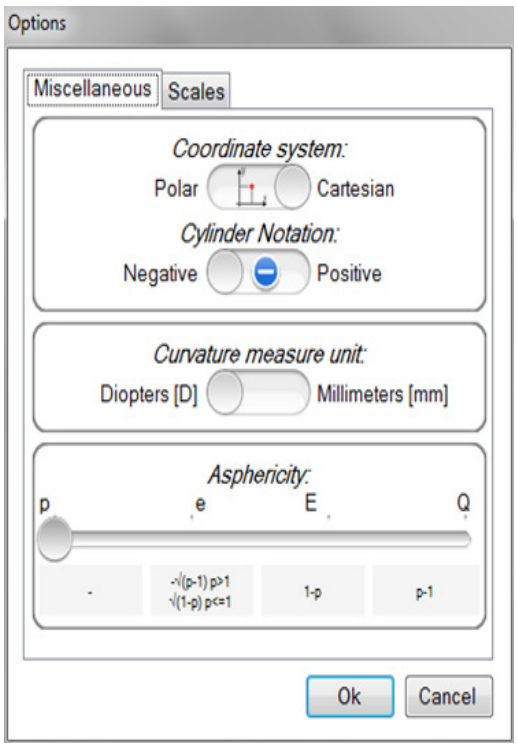
MISCELLANEOUS

» **Coordinate system:** Polar/Cartesian. Each point position will be expressed in ρ (distance from center) and @ (position in degrees) or in x (horizontal distance from center) and y (vertical distance from center).

» **Cylinder notation:** Negative/Positive. Negative or Positive will be used as the cylinder notation.

» **Curvature measure unit** can be expressed in **Millimeters [mm]** or in **Diopters [D].**

» **Asphericity:** the asphericity of a conic measurement can be set as **e, p, SF(E),** or **Q.**



Options: Miscellanea

SCALES

Three different color scales are available:

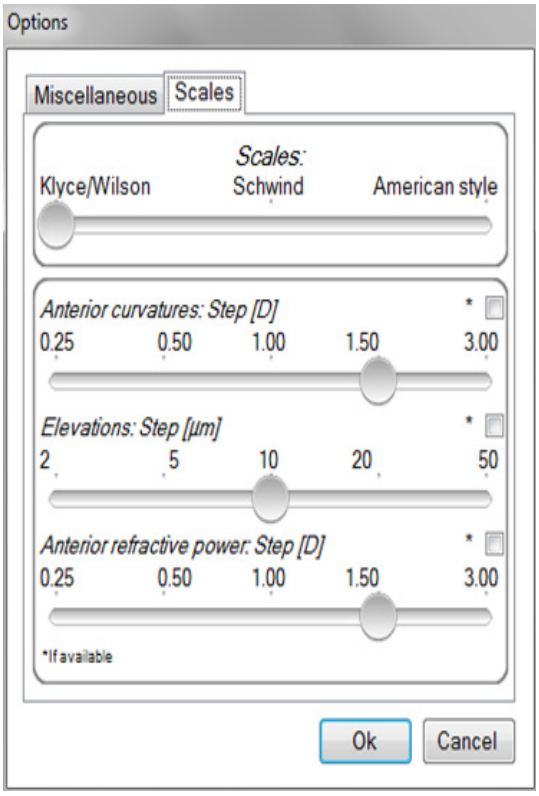
» Klyce/Willson

» Schwind

» American style

It is also possible to set the step value for the following scales:

» Anterior curvatures;
» Elevations
» Anterior refractive power



Options: Scale

RINGS/PUPIL/LIMBUS EDITING

To access the Rings/Pupil/Limbus editing functions select

Rings/Pupil/Limbus editing from the **Edit** menu.

RINGS EDITING

The software automatically recognizes the keratoscopic rings positions reflected off the cornea, detecting dark-to-bright or bright-to-dark transitions. The rings detection is emphasized on the screen as alternating green and red circles. Irregularities, corneal opacity or shadows from eyelashes or the nose may cause mistakes on proper ring identification: it is important to check the correct detection of the rings before starting the analysis of topographic maps. The software offers the possibility to fix the detected rings by manually editing them. The window contains a set of buttons identifying rings on keratoscopy, and five buttons that allow editing of the rings.

SELECTING A RING

To select a ring move the mouse cursor onto the ring to be selected and right-click or press the button with the corresponding number on the screen.
When selecting a ring, points situated on the ring are joined by an orange line, the addition or removal will only happen to this ring. When selecting a ring, it is possible to select the previous or next ring by using the arrow keys on the keyboard.

DELETING A RING

To delete points, press the button **Delete** icon. Moving the mouse cursor over the keratoscopic image and holding the left mouse button, a circular cursor appears: points below the cursor will be removed. When you select a ring, you can remove only points belonging to that particular ring. To delete an entire ring press the Del or Backspace key on the keyboard.

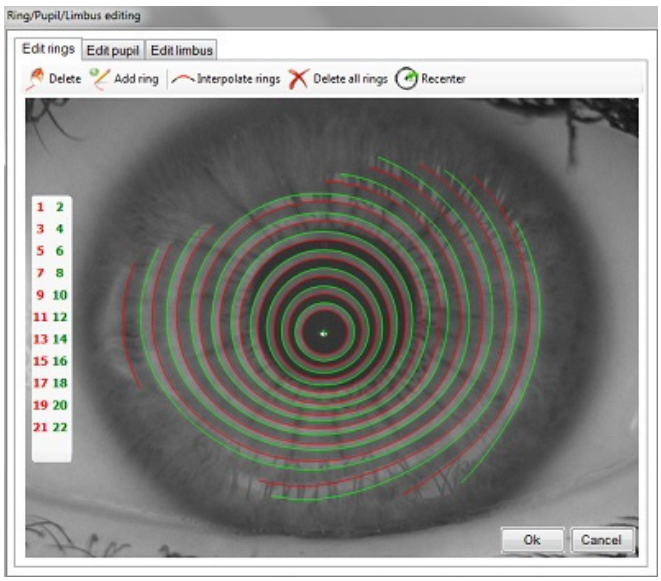
DELETE ALL RINGS AND RE-CENTER

Pressing the **Delete all rings** icon will erase all the detected points. After confirming the alert message "Are you sure you want to erase all the rings?"

press **Recenter** and the program will let you choose a new keratoscopic center. Use arrow keys to find the correct position of the center and confirm by pressing the Enter key.

ADDING A RING

To add points press the **Add ring** icon and select the ring you want to complete. Then press the left mouse button on a point that is part of the ring image. Interpolating rings. To complete a missing part of a ring, just press the Interpolate rings icon.



Rings editing

Pupil editing

PUPIL EDITING

After pressing the **Edit pupil** icon, the pupil is highlighted as a red circle with a red center,bordered by three yellow crosses.
To change position and size of the pupil:

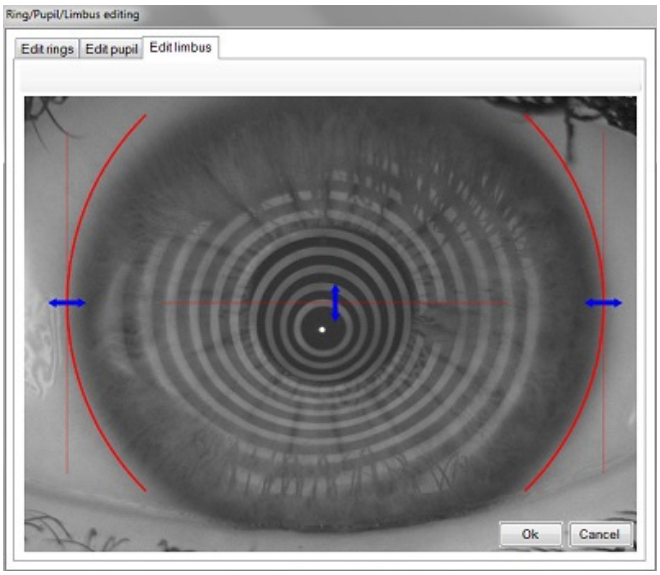
» Drag and drop the red circle representing the pupil in the right position.
or
» Drag and drop the yellow crosses that define the red circle.

Pressing the **Delete** pupil the pupil will be deleted.
Right-clicking on the image the corneal vertex will be assigned.

LIMBUS EDITING

When you open this editing window, the limbus is marked with two red semicircles.
To change the size of the limbus:

» Drag and drop the blue horizontal arrows and drag to resize the limbus.
» Drag and drop the blue vertical blue arrow to move the limbus vertically.



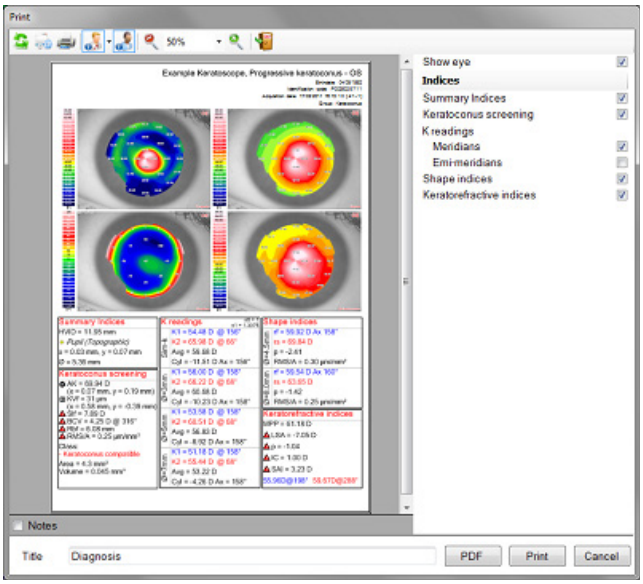
Limbus editing

PRINTING

You can access the print functionality through **Print** and **Print screen** under the menu **File.**
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

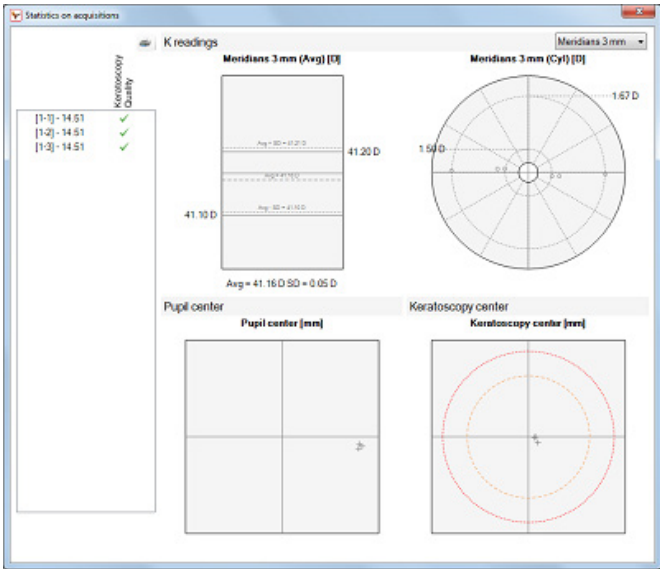
On the right side of the screen a list of options is shown which allows you to display or hide indices on the final printout.

Print (Quick) and **Print screen** (quick) functionality, also under the File menu, allows you to print without preview.



Print preview

STATISTICS ON ACQUISITION



Statistics on acquisition window can be accessed by right-clicking on one of the thumbnails in the acquisition gallery and then left-clicking the **Statistics on acquisition** menu item of the contextual menu.

This window is useful for evaluating the quality and the repeatability of the acquisitions belonging to the same examination.

At the top-left corner a table is shown with the list of the selected acquisitions. Each row of the table refers to a single acquisition and contains its ID, date and time of the acquisition, a symbol for the quality of the keratoscopy (green for good quality, red for bad quality).
By selecting a row in the table (i.e a certain acquisition), the corresponding data are highlighted in the plots described below.

At the top of the window for K readings (Sim-K or Meridians at 3 mm) a scatter-box plot for the average value and a polar scatter plot for cylinder are shown. Average and standard deviation are reported for the Sim-K (Avg) and for the Meridians at 3 mm (Avg).

At the bottom-left corner of the window a cartesian scatter plot is dedicated to pupil decentration with respect to corneal vertex.

At the bottom-right corner of the window a cartesian scatter plot is dedicated to keratoscopy decentration with respect to the optical instrument axis. Low decentration values are within the yellow dashed circle, high decentration values are outside the red dotted circle. When the keratoscopy center is outside the red circle it is strongly advised to discard the acquisition.

Summary is displayed:

» double-clicking on a Keratoscope acquisition on the main screen.
» by choosing **Summary** from the **Analysis** menu
» by clicking the icon on the toolbar

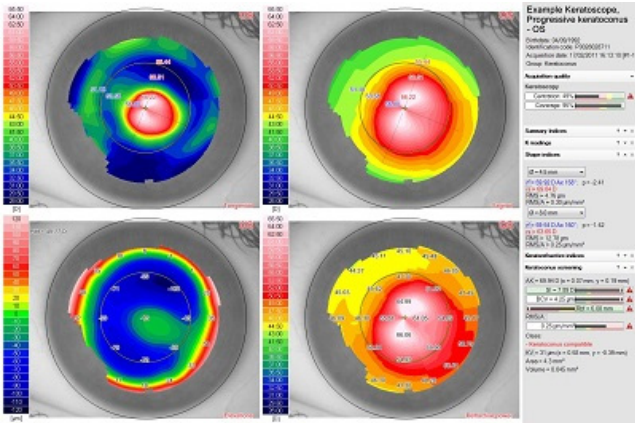
This screen is the shown first: it displays a clinical summary of the maps and data derived from processing each single image capture. The Summary consists of four maps (tangential, sagittal, elevation, and refractive power) and a right-hand panel with customizable indices. The software will save the state of the panel and will restore it when a new window is opened.

SUMMARY

Summary is displayed:

» double-clicking on a Keratoscope acquisition on the main screen.
» by choosing **Summary** from the **Analysis** menu
» by clicking the icon on the toolbar

This screen is the shown first: it displays a clinical summary of the maps and data derived from processing each single image capture. The Summary consists of four maps (tangential, sagittal, elevation, and refractive power) and a right-hand panel with customizable indices. The software will save the state of the panel and will restore it when a new window is opened.



Summary

SINGLE MAP

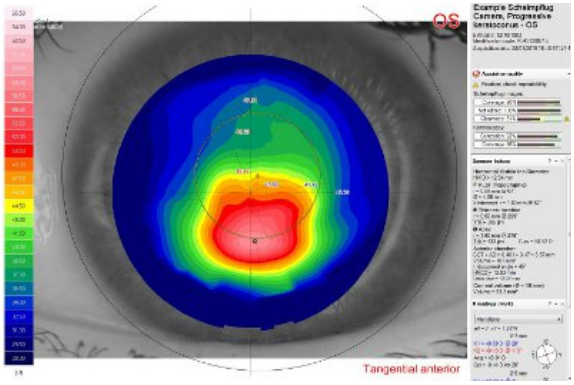
Single map screen is displayed:

» by choosing **Single map** from the **Analysis** menu
» by clicking the icon on the toolbar
» double-clicking the map of choice from the Summary.

This screen displays a single map in full-screen mode. The type of map can be selected from the toolbar between:

» Tangential
» Sagittal
» Elevation
» Refractive power
» Gaussian curvature

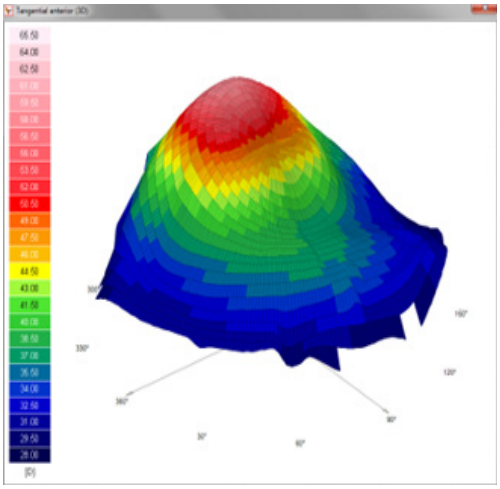
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Single map

3-D MAP

The icon becomes active only in this screen. When pressed a three-dimensional view of the current corneal map is shown.
Hold down the left mouse and drag the end points of the Cartesian diagram enclosing the map to view it from different perspectives.
Right-clicking a context menu **to print the screen, save the screen as an image**, or change the view type is shown.



Three-dimensional view of the tangential anterior map

KERATOCONUS SUMMARY

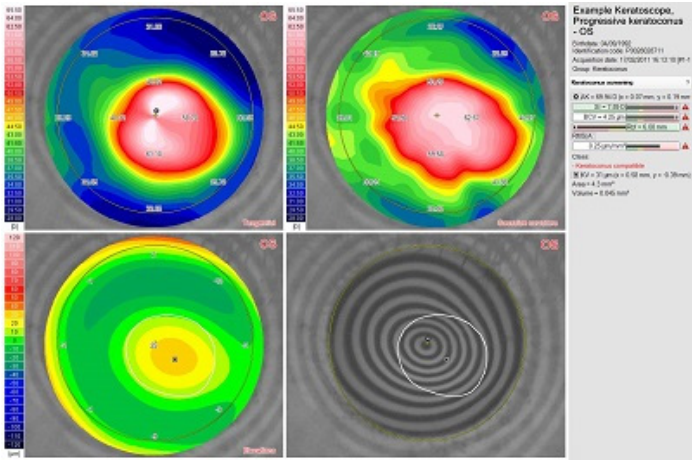
Keratoconus Summary is displayed by:

» by choosing **Keratoconus Summary** from the **Analysis** menu

» by clicking the  icon on the toolbar

Analysis is performed by means of the following maps:

» Tangential map over an area of 6mm
» Corneal elevation with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'nor mal' eye over an area of 6mm. This type of representation, that hides information on astigmatism and medium corneal power, is particularly useful since it highlights the higher orders only and therefore, in cases of keratoconus, the ectasic area and its entity.
» The position of some interesting markers ⊗ Steepest point of the corneal surface (**AK** – Apical Keratoscopy);
⊞ Highest point of ectasia on the corneal surface (**KV** – Keratoconus Vertex);



Keratoconus summary

In order to help the practitioner in the identification of keratoconus cases or to evaluate, during follow-up, the entity and the progression of keratoconus, a series of indices is shown based on curvature, pachymetry and elevation data of anterior and posterior corneal surfaces. These indices describe the most relevant features of keratoconus:

CURVATURE ASYMMETRY

» The Symmetry Index of the curvature (**SI** – SymmetryIndex) is defined as the difference of the mean tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SI is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normal values are shown (95° percentile e 99° percentile of a normal population);

ELEVATION BASED INDICIES

» The BCV index allows for the evaluation of the presence and of the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetry's $\left(C_3^{+1}, C_3^{+3}, C_4^0\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) + \gamma C_4^0$$

The basic idea behind this index is that the ectasia statisticall develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C(3,±1)αx) which attenuates the value when the direction is not the statistically expected.
The parameters A, B and D are obtained on a statistical base for weighing

the importance of the various components.

The value C(3,±1)AX is defined as the axis of ectasia (direction of ectasia respect to the reference system). For this index too normal values are shown (95° percentile e 99° percentile of a normal population).

» **Rbf:** The radius (in mm) of spheric surface which best approximates the measured surface within a 6mm diameter.

» **RMS/A** (Root Mean Square/Area): represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax per unit of area. If the RMS/A is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS/A, the more irregular the corneal surface.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:

» Normal
» Suspect keratoconus
» Keratoconus
» Abnormal or treated

In case of classification as Keratoconus some further morphologic indices are shown:

Steepest point of the anterior corneal surface (**AKf** – Apical Keratoscopy$_{FRONT}$);
Steepest point of the posterior corneal surface e (**AKb** – Apical Keratoscopy$_{BACK}$);
Highest point of ectasia on the anterior corneal surface (KVf – Keratoconus Vertex$_{FRONT}$);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus Vertex$_{BACK}$);
Thinnest point of cornea

The keratoconus screening indices provide indications which are not sufficient for assessing either instrument calibration status or the patient's clinical situation. These indices should thus be considered as diagnostic tools for the user but not as indicators of certain diagnosis of keratoconus.
We therefore caution the user to take maximum care when evaluating these values and to correlate the screening indices with other tests and with the patient's clinical history.

ADVANCED ALTIMETRY

Advanced Altimetry screen is displayed:

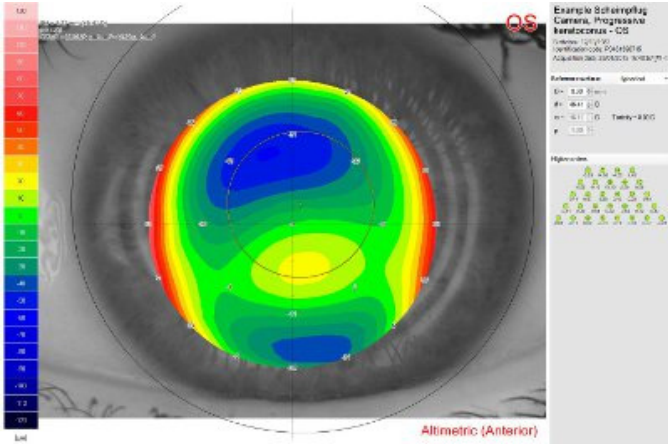
» by choosing **Advanced altimetry** from the **Analysis** menu

» by clicking the  icon on the toolbar

The Advanced altimery represents the corneal map as offset by a surface reference, that can be chosen by the operator using the menu options on the right hand side of the screen.
Using the pull-down list it is possible to select the surface against which we want to offset the examined eye:

» **Spherical** the reference surface is a sphere
» **Aspheric** the reference surface is aspheric or more precisely a conicoid. The asphericity value, (in p, e, e2 or Q) can be chosen from options
» **Asphero-toric** the reference surface is asphero-toric. The toricity is calculated by the software as the difference between rf and rs.

Depending on the selected surface reference type, some of the parameters (like rf, rs or the asphericity) are editable. Any modification of the diameter will result in an adjustment of the parameters for the reference surface to the surface that best represents the examined eye on the diameter (Ø mm) chosen.
The difference between the selected surface and the surface reference is decomposed in Zernike polynomials up to the 7th order, allowing this way the selection (by double-clicking) of each single fitting component on the map.

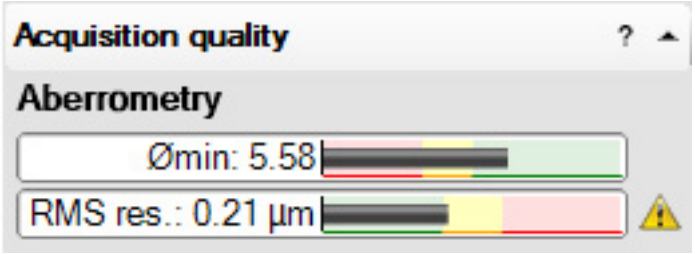


Advanced altimery

ACQUISITION QUALITY

It shows some indices which indicate the quality of the current aberrometric measurement.
In more detail, the minimum pupil diameter and the RMS residual are shown.

» The minimum pupil diameter takes into consideration the possibility to analyze wide OPD areas over a big pupil.
» The RMS residual takes into consideration how the Zernike fitting result to be appropriate by highlighting the difference between row data and fitted data over the maximum available pupil. High values of this index may be attributed to highly aberated eyes or can be due to tear film breakages.



Acquisition quality panel

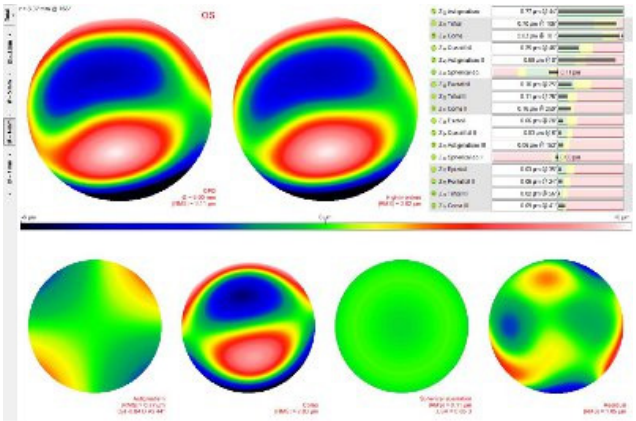
ZERNIKE SUMMARY

Summary is displayed:

» by choosing **Zernike Summary** from the **Analysis** menu

» by clicking the icon on the toolbar

The program permits conducting analysis of the wavefront generated by the cornea, obtained by topographic data through Zernike analysis. The aberrometric map expresses the differences in height between the wavefront generated by the cornea being examined and a spherical perfect wavefront. The aberrations are displayed as total aberrations and divided into their various components. A set of 36 Zernike polynomials is used for the analysis of the various components of total aberration; the analysis results are reported in the summary as numerical indices and as graphic representations. The pupil diameter may be selected on the left side of the screen in a range from 2 mm to 8 mm with 0.5 mm steps. Total wavefront (obtained by ray-tracing using both anterior and posterior surface), anterior surface wavefront (i.e. considering only the anterior surface) or the posterior surface wavefront (defined as the difference between the total and anterior only) analysis is allowed. This screen is highly influenced by the parameters chosen on the Wavefront configuration window.



Zernike Summary

Several Wavefront error maps are shown in the screen:

» **Total OPD/WFE** (i.e. the total amount of the wavefront error within the analysis diameter)
» **Higher orders** (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» **Astigmatism** (i.e. the amount of polynomials Z2-2 and Z2+2). Bottom-right of the map the value of the Cylinder and its RMS are shown.
» **Coma** (i.e. the amount of polynomials Z3-1 and Z3+1). Bottom-right of the map the value of coma RMS is shown.
» **Spherical aberration** (i.e. the amount of polynomial Z40). Bottom-right of the map the value of the LSA and the Spherical Aberration RMS are shown.
» **Residual** (i.e. the total amount of the wavefront removing the amount of Astigmatism, Coma and Spherical Aberration)

ZERNIKE POLYNOMIALS

On the upper right there is a table which summarizes the decomposition of Zernike for the current wavefront into its aberrations:

» The first column carries the names of the polynomials. Generally speaking, each aberration is represented by a pair of polynomials. Axis-symmetric aberrations are represented by single polynomials.
» The second column gives a RMS value and the relative meridian for each aberration.
» The last column displays the histogram of the coefficients of expansion of the Zernike polynomials: the bars represent the weighted value for each aberration. The normality data, represented by the green, yellow and red bars, are derived from a statistical study on 1000 normal eyes.

OPTICAL QUALITY SUMMARY

Optical Quality Summary is displayed:

» by choosing Optical Quality Summary from the Analysis menu

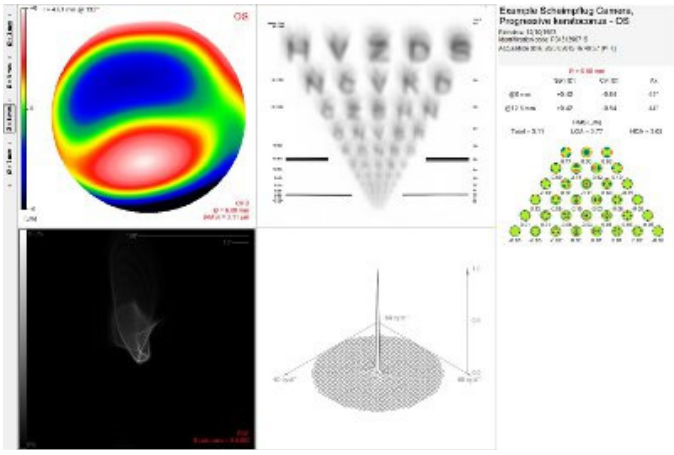
» by clicking the icon on the toolbar

This form permits an overall analysis of visual quality.
From top-left to the bottom-right are shown:

» OPD/WFE map;
» Vision Simulation;
» PSF;
» MTF.

In the right panel the Zernike pyramid, displaying the coefficients of the Corneal wavefront decomposition, is shown.

The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Total, Anterior or Posterior).



Optical Analysis Summary

COMPARISON/FOLLOW-UP IMAGE SELECTION

The first operation to start a comparison/follow-up analysis is to select the images to be compared.

The first image is chosen by default, the one from where we open the selection window, other images have to be manually chosen by the user.

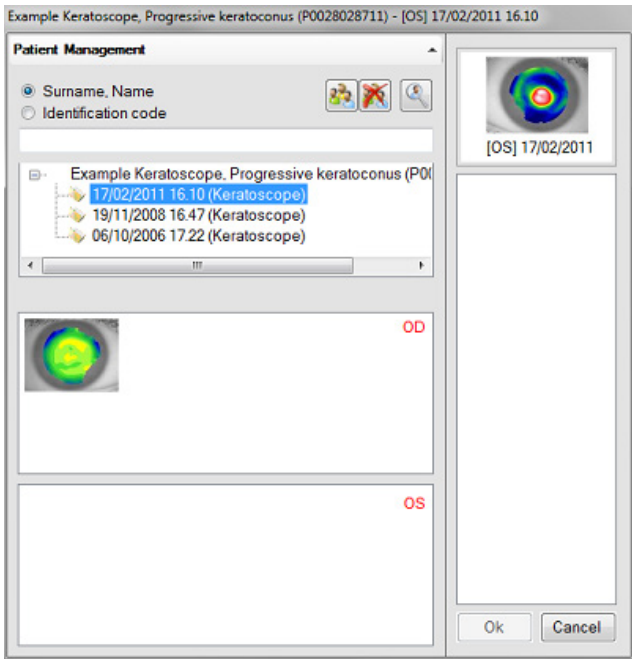
The window that shows up provides on opening the current patient/examination.

If the images to be compared do not belong to the current patient/examination standard tools for the examination search are provided: the button shows the complete patient database, whereas the button allows for an advanced search.

Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel.

The number of selected images may vary depending on the context of the follow-up operation.

Click **OK** to continue, **Cancel** to stop the comparison.



Manual selection of the acquisitions to be compared.

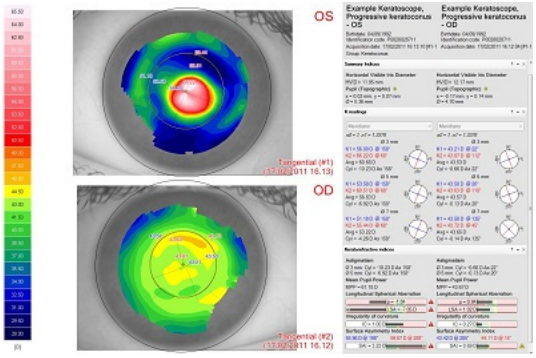
COMPARISON

Comparison is displayed by:

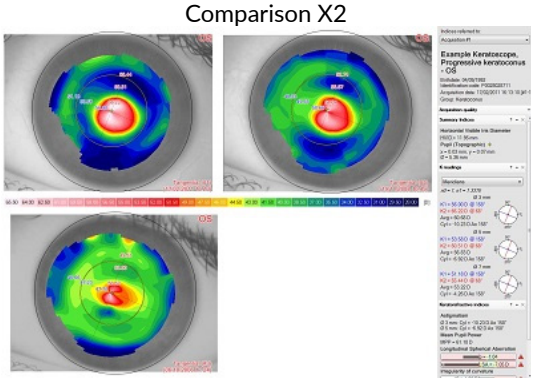
» Choosing **Comparison** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the images to be compared, a window with the selected acquisitions is shown. It's possible to select 2, 3 or 4 maps.
The topographic information to be compared is selected from the drop-down menu in the upper-right corner, next to the label **Current map.**

The comparison of two maps allows for the contemporary display of both sets of indices. The selection of more than 2 maps, means you have to choose the indices to be displayed. In this case the drop down box at the top of the right panel is for selecting the images the **indices refer too**.
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Comparison X2



Comparison X3

COMPARE OD/OS

It is possible to compare the right and left eye avoiding the manual selection by:

» Choosing **Compare OD-OS** from the Analysis ► Comparison menu

» Clicking the icon on the toolbar.
A comparison screen between the current eye and the fellow eye will be shown.

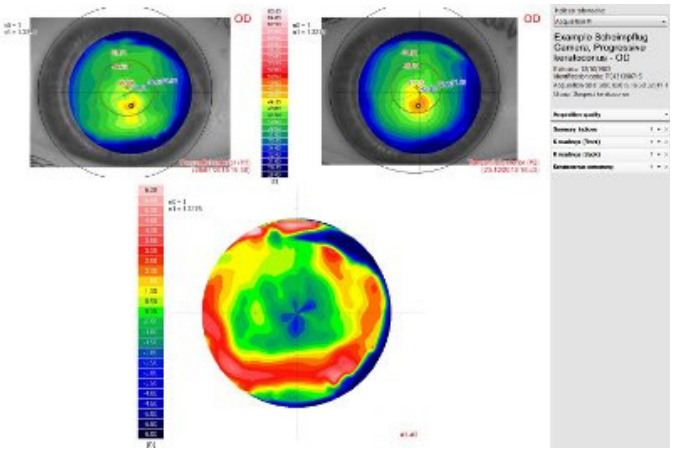
DIFFERENTIAL

Differential is displayed by:

» Choosing **Differential** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the images to be compared two or three maps (current map plus one or current map plus two) and their relative difference are shown: maps in the lower part of the window show the differences between the maps in the upper part. In the case of a differential on 2 maps, the difference between 1st and 2nd is shown. In the case of a differential on 3 maps, the difference between 1st and 2nd, between 1st and 3rd and between 2nd and 3rd are shown.

The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label **Current map.**
The drop down box at the top of the right panel is for selecting the image the **indices refer too.**
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Differential

WAVEFRONT COMPARISON

Comparison is displayed by:

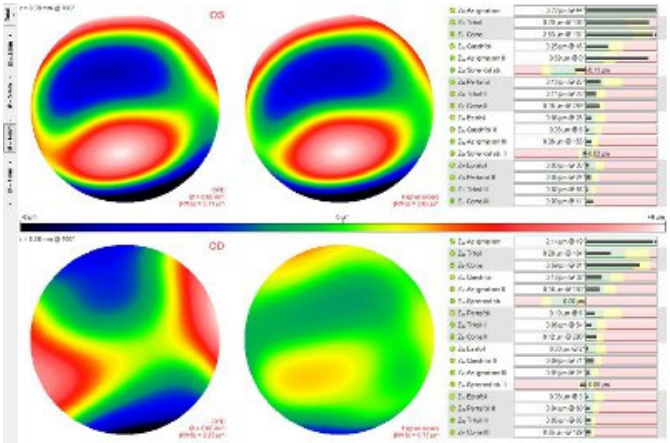
» Choosing **Wavefront Comparison** from the A**nalysis** menu

» clicking the  icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:

» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



Wavefront Comparis

WAVEFRONT DIFFERENTIAL

Comparison is displayed by:

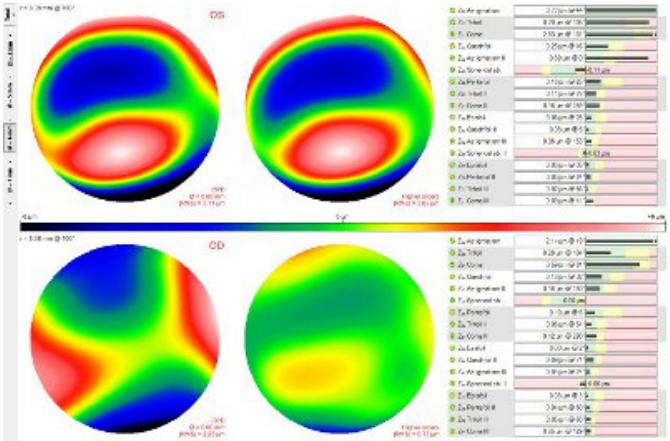
» Choosing **Wavefront Comparison** from the A**nalysis** menu

» clicking the  icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:

» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



Wavefront Comparis

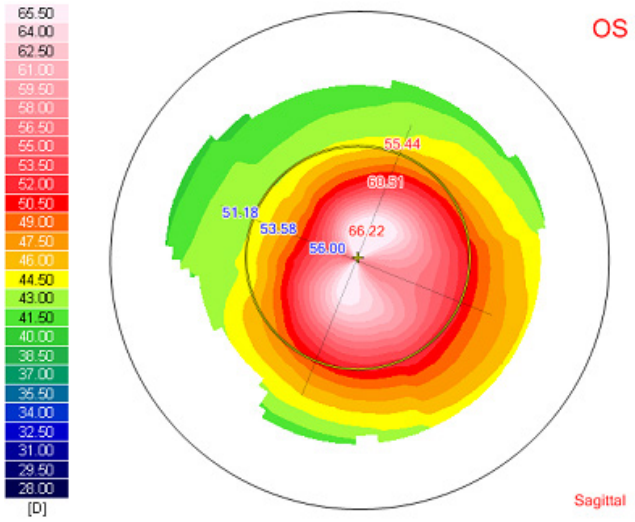
SAGITTAL MAP

This map represents, point by point, the distribution of the sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvatures zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.

Right-clicking opens the Tools and display options menu



Sagittal curvature map

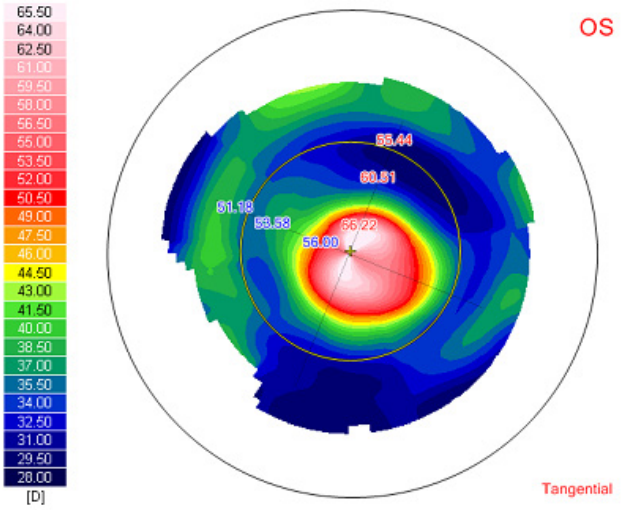
TANGENTIAL MAP

This map represents, point by point, the distribution of the tangential curvature in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊠ sign.

At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.

Right-clicking opens the Tools and display options menu.



Tangential curvature map

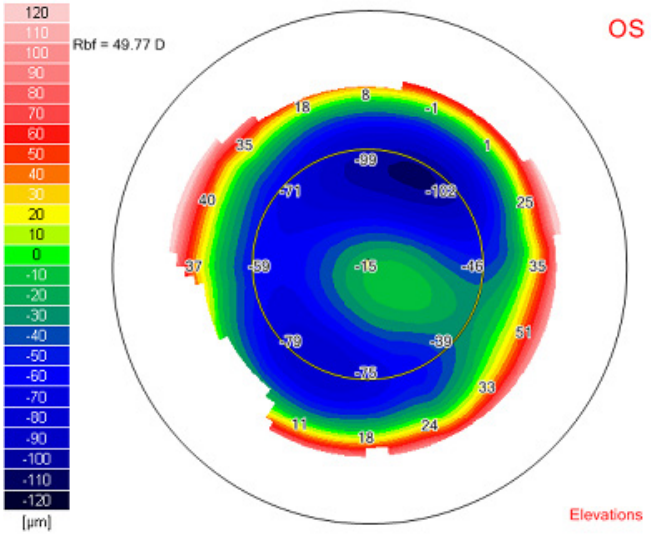
ELEVATION MAP

This map represents in microns (µm), the elevations of the anterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» The apical radius of the best-fit reference sphere.

Right-clicking opens the Tools and display options menu



Elevation map

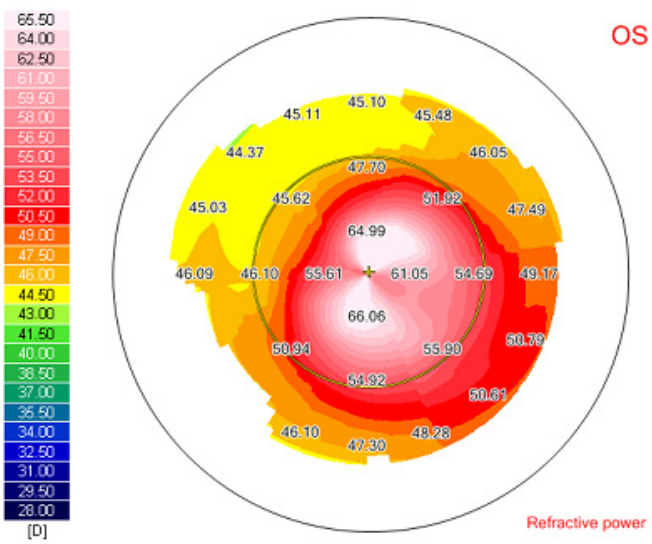
REFRACTIVE POWER MAP

This map represents, point by point, the distribution of the corneal power, expressed in diopters and is calculated by ray-tracing through the anterior corneal surface for each point. The refractive indices for the interface Air-Cornea are those of the air (N0=1) and the keratorefractive (N1=1,3375).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration . This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Refractive power map

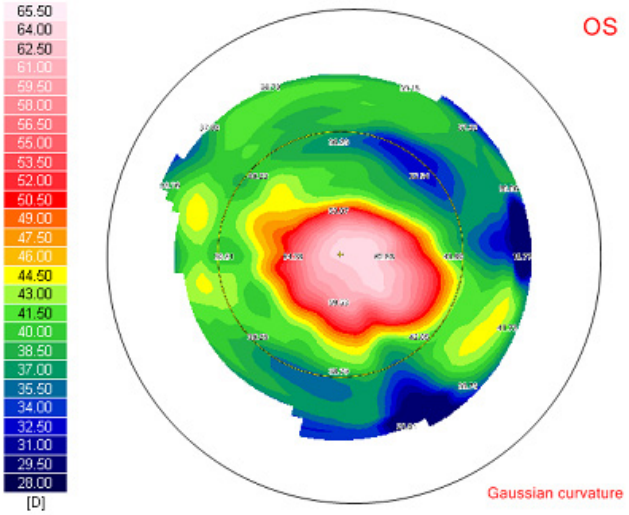
GAUSSIAN CURVATURE MAP

Both, Sagittal and Tangential maps, show the curvature values of a surface along meridians: in other words, they do not consider the surface curvature in sections different from the meridional one.
The **Gaussian curvature** of a point on a surface is the "real" curvature being the geometric mean of the principal curvatures, i.e. the square of the product of the curvatures along the directions where they are maximum and minimum.
Is measured in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:

» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The gaussian curvature at the point taken into consideration. This value is only visible when the mouse cursor moves on a map.

Right-clicking opens the Tools and display options menu.



Gaussian curvature map

KERATOSCOPE MAP CONTEXTUAL MENU

	**Cursor**	When this item is selected, the coordinates and the numeric values of the map under the mouse pointer are displayed as it is moved. Left-click drops the cross, making it independent of the mouse pointer. A second click realigns the reference cross with the mouse pointer.
	**Distance**	Select this item to trace a segment on the map for measuring the distance between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The length of the chosen segment will be displayed on the map, in millimeters.
	**Graph**	With this item selected the graphs representing the map profile along the meridian passing center of the map and the mouse pointer is displayed. The graph rotates during selection of the meridian: clicking on the desired orientation that particular meridian will be chosen and its chart will be shown horizontally.
	**Gradient**	Select this item to trace a segment on the map for measuring the distance and the gradient between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The difference and the gradient between the two selected points will be shown and the length of the chosen segment will be displayed on the map.
	**Show/Hide value on cursor**	Shows or hides the numeric value over the map at the cursor position when a mouse movement occurs.
	**Show/Hide pupil**	Shows or hides the contour of the pupil.

	Show/Hide limbus	Shows or hides the contour of the limbus.
	Show/Hide eye	Shows or hides the image of the eye under the map.
	Show/Hide map	Shows or hides the map.
	Show/Hide ruler	Shows or hides the two perpendicular millimeter rulers (the shorter division corresponds to 0.5 mm; the longer division corresponds to 1 mm).
	Show/Hide meridians	Shows or hides a polar grid.
	Show/Hide goniometer	Shows or hides a goniometer.
	Show/Hide zones	Shows or hides a series of concentric rings (with 3, 5, 7, 9 mm diameters)
	Show on map	Show or hide numeric values on the map: ► **Nothing:** No numeric value is displayed over the map. ► **Numeric values:** The numeric values are shown on each map on a point grid. ► **Map-dependent:** K-readings are shown on the curvature maps. Numeric values are shown on all other maps.

KERATOSCOPY INDICIES

On the right side of several analysis windows a section of panels is available, containing information and indices referring to the current acquisition:

» Patient data
» Acquisition Quality
» Summary Indices
» K-Readings
» Shape Indices
» Keratorefractive Indices
» Keratoconus Screening

The ▼/▲ arrow on the title bar expands/collapses the related panel.
The **?** button opens its help window.
Click the button **×** on the title bar to remove a panel from the lateral section of the window.

To restore the removed panels, select  ► **Restore** on the right side of the main Toolbar.

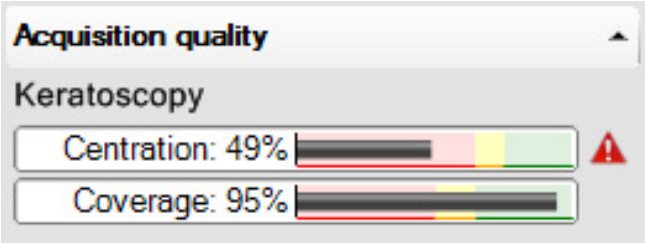
ACQUISITION QUALITY

It shows some indices which indicate the quality of the current keratoscopic image.

In more detail, rings coverage for the Keratoscopy and the well-centeredness of the cornea respective to the instruments axis is reported under the group Keratoscopy.

The warning **"Fixation: check repeatability"** is a help for selecting good images. It appears when the pupil position of the current image is outside of the expected "normal zone", i.e. the zone where the pupil position is located in normal fixating eyes. If this warning is present, there can be two cases:

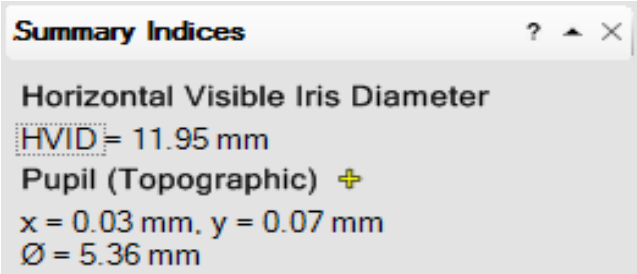
» The patient is not fixating, so it is necessary to acquire again after asking the patient to fixate on the fixation point.
» The patient is fixating, but the eye is anomalous (for example if the eye is a keratoconus). In this case the pupil position is always decentered in every acquisition. So in this case, the warning has to be interpreted as an anomalous fixation of the patient.



Acquisition quality panel

SUMMARY INDICES

» **HVID (Horizontal Visible Iris Diameter):** it is the limbus size (in mm) in the horizontal direction. It is derived from the keratoscopic image.
» **Pupil:** the symbol shows the pupil center position in the maps. x,y and r,@ are, respectively, the cartesian and polar coordinates of the pupil centre, shown in the Summary indices panel according to the preferred setting. Ø is the diameter of the topographic pupil.



Summary indices

K-READINGS

From the sagittal data of the cornea it is possible to derive keratometric data related to the principal meridians: these data can be expressed as

» **Sim-K**
» **Meridians**
» **Emi-meridians**
» **Peripheral degrees**

SIM-K

Sim-K represents the simulation of the readings that would be obtained with a keratometer, (i.e. the mean sagittal curvature from the 4th to the 8th Placido ring). The considered zone therefore has a variable amplitude depending on the curvature of the measured cornea.
The following values are available for Sim-K:

» Curvature (expressed in mm or D according to the preferred setting) and axis for the principal meridians **K1** and **K2.**
» **Avg:** mean curvature of the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curvatures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375).

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the anterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred setting) and axis for the principal meridians **K1** and **K2**.
» **Avg:** mean curvature of the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curvatures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375).

HEMI-MERIDIANS

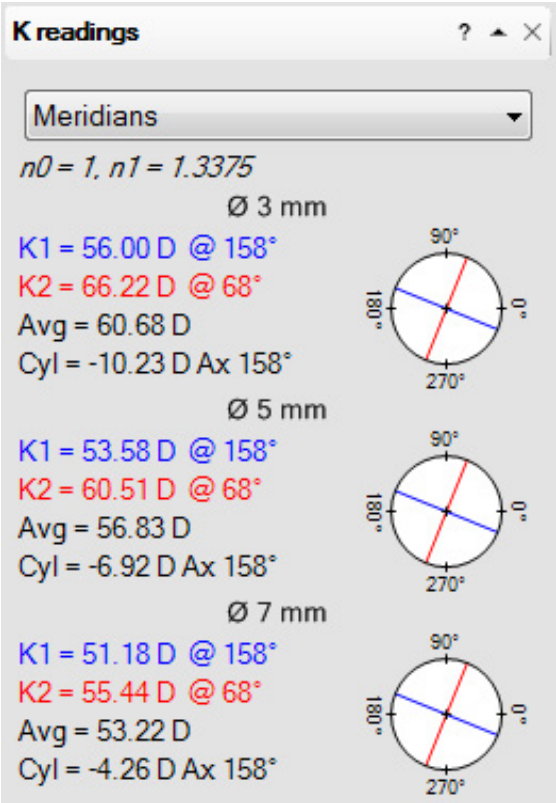
If this option is selected, the two pairs of flattest and the steepest hemi-meridians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-meridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred setting) and axis for the two pairs of flattest and steepest meridians **K1** and **K2.**

N0 and N1 are the refractive indices used for converting the values of curvature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375).

PERIPHERAL DEGREES

If this option is selected, two tables of curvatures and asphericities (expressed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the considered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity contains the average values for each zone of the values of the 4 considered hemi-meridians.
The angular positions of the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S) are available in a third table.

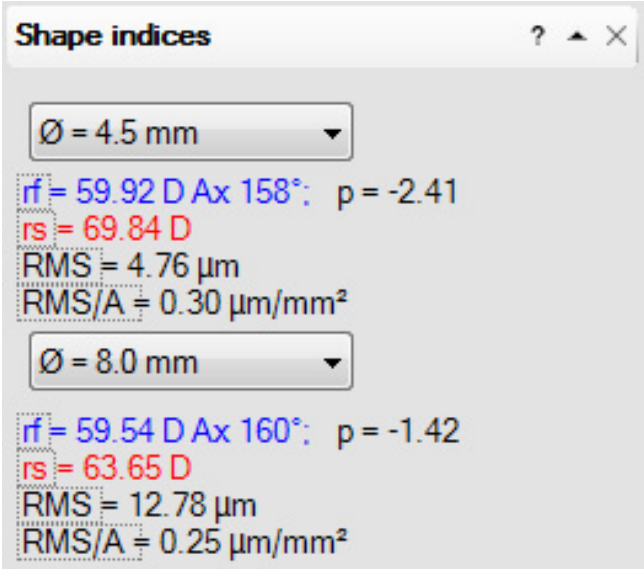


K-readings (front): Meridians

SHAPE INDICES

Shape indices are available for two different diameters selectable by the user. These indices are the parameters which define the asphero-toric surface which best approximates the samples of the measured corneal surface within the zone delimited by the chosen diameter.

- rf (Flat Radius): the apical radius (in mm or in D according to the preferred setting) of the flattest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- rs: Steep Radius: the apical radius (in mm or in D according to the preferred setting) of the steepest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **p, e, E, Q:** different forms of the asphericity according to the preferred setting for the asphero-toric surface which best approximates the measured surface within the chosen diameter.
- **RMS (Root Mean Square):** represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax. If the RMS is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS, the more irregular the corneal surface.
- **RMS/A:** Root Mean Square per unit of area.



Shape Indicies

KERATOREFRACTIVE INDICES

This section contains some indices that are related to the refractive features of the cornea.
Astigmatism:

- 3 mm: corneal toricity expressed in D on a 3mm diameter area of the cornea, centered on the corneal vertex.
- 5 mm: corneal toricity expressed in D on a 5mm diameter area of the cornea, centered on the corneal vertex.

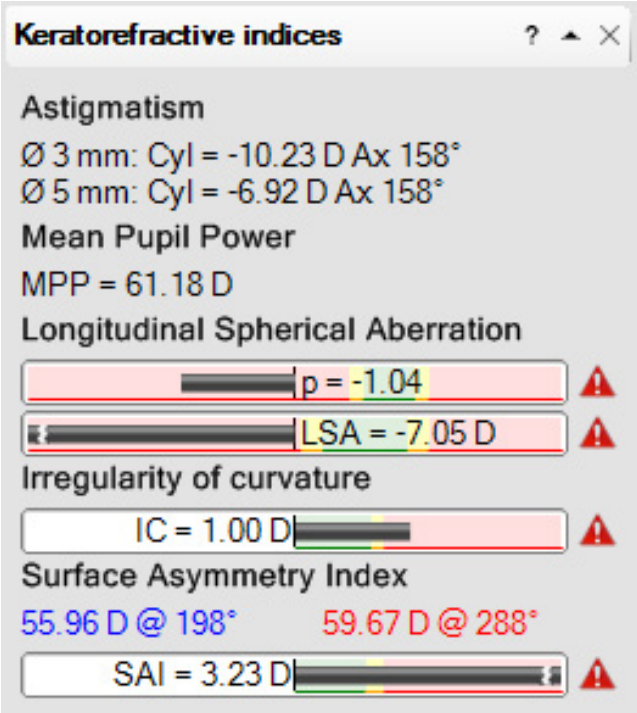
These data refer to an area of 4.5 mm of diameter, centered in the center of the pupil:

Mean pupillary power: This is the mean axial curvature, expressed in D, for the entire portion of the cornea of a 3mm diameter centered on the entrance pupil. These parameters represents the spherical equivalent of the cornea within a pupillary zone of a 3mm diameter.

Asphericity (e, p, SF or Q): This is the mean asphericity for an area on the cornea with a diameter of 4.5 mm, centered on the center of the pupil.

Longitudinal Spherical Aberration (LSA): It expresses the difference between the marginal and the paraxial power for an area on the cornea with a diameter of 4.5 mm centered in the center of the pupil. It is calculated by applying ray-tracing to the best-fit conic of the pupillary zone of 4.5 mm.

Irregolarity of curvature (SD: standard deviation): This is the standard deviation of the tangential curvature respect to a best fit aspherical surface, calculated for an area of cornea with a diameter of 4.5 mm centered on the pupil center and expressed in diopters. A zero index of irregularity indicates a perfectly smooth surface which can be modeled with an aspherical-toric surface.



Keratorefractive indices

Surface Asymmetry Index (SAI): It is the index of surface asimmetry of the area of cornea with a diameter of 4.5 mm, centered in the center of pupil. It is calculated as the mean of the differences between the mean tangential curvature of all couples of opposite hemi-meridians. If the cornea is perfectly symmetrical, SAI is zero. The mean tangential curvature of the steepest and flattest hemispheres of the optical zone are shown respectively in red and blue.
In order to facilitate the clinical interpretation of these indices the values of asphericity, longitudinal spherical aberration (LSA), irregularity of curvature (SD) and corneal asymmetry (SAI) are compared with the values measured in a sample of normal eyes:
Values that lie between two standard deviations around the mean values of normal eyes are considered normal and evidenced by a green point.
Values that lie between two and three standard deviations the mean values of normal eyes are considered suspicious and are evidenced by a yellow point.
Values that lie beyond three standard deviations from the mean values of normal eyes are considered anomalous and are evidenced by a red point.

KERATOREFRACTIVE SCREENING

The software displays a series of indices describing the morphology of the cornea, which are useful in diagnosis of keratoconus and in follow-ups.

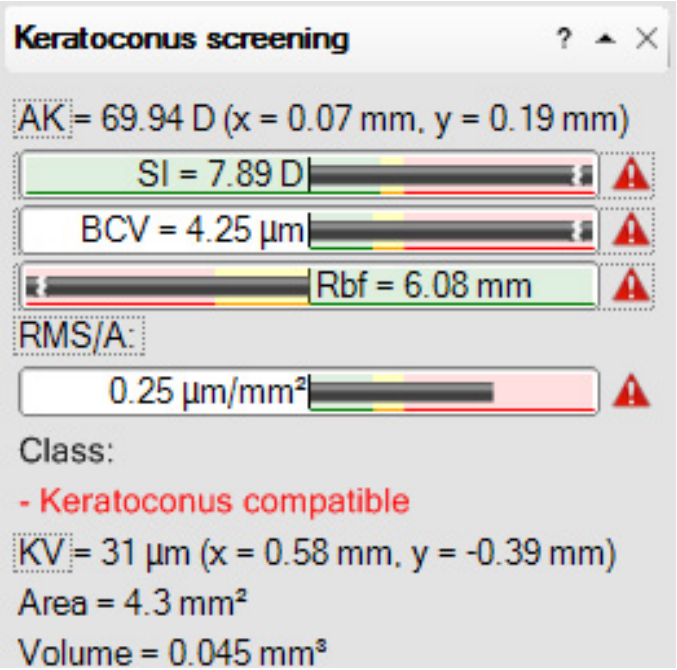
APEX

Steepest point of the anterior corneal surface (**AK** – Apical Keratoscopy) Curvature Asymmetry The Symmetry Index of curvature (**SI** – SymmetryIndex) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SI is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normal values are shown (95° percentile and 99° percentile of a normal population);

ELEVATION BASED INDICIES

» The index BCV allows the evaluation of the presence and of the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetries , in the zone where keratoconus statistically arises.

The basic idea behind this index is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). For BCV index normality values are shown (95° percentile e 99° percentile of a normal population).



Keratoconus screening

» Rbf: The radius (in mm) of a spheric surface which best approximates the measured surface within a 6mm diameter.

» RMS/A (Root Mean Square/Area): represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax per unit of area. If the RMS/A is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS/A, the more irregular the corneal surface.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:

» Normal
» Suspect keratoconus
» Keratoconus
» Abnormal or treated

In case of classification as Keratoconus some further morphologic indices are shown:

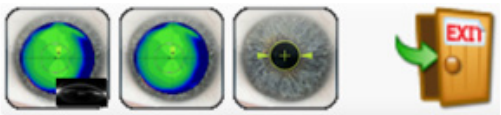
⊞ Highest point of ectasia on the anterior corneal surface (**KV** – Keratoconus Vertex);
» Area and volume of the ectasic zone;
» RMS/A and RMSb/A, root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 8 mm zone for both the anterior and posterior surfaces of cornea.

PUPILLOGRAPHY | ACQUISITION

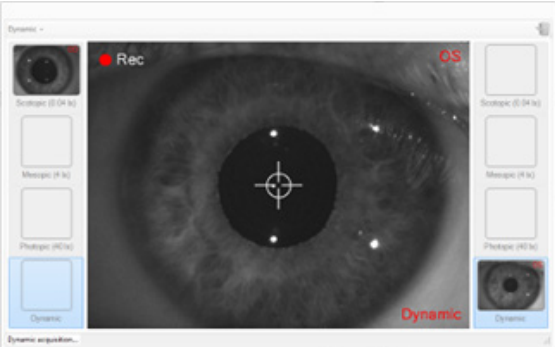
In the Pupillography environment, the user may make automatic measurements of the pupil diameter and its offset from the corneal vertex in various controlled light conditions.
If we assume the light contribution from the environment to be null (for this reason, during the Pupillography examination, the examination room must be completely dark, with the Pupillograph as the only light source), three lighting conditions are available to the user:

- **Scotopic**, the only visible light source is the LED source (0.4 lux).
- **Mesopic**, the disk is illuminated in such a manner as to bring ambient light intensity to about 4 lux (not available for exams with topographer)
- **Photopic**, the disk is illuminated in such a manner as to bring ambient light intensity to about 40 lux.
- **Dynamic**, the capture is begun with the disk rings fully illuminated (500 lux ca.); it is switched off at the moment capture begins. In this manner, it is possible to monitor pupil dilation in conditions from photopic to scotopic conditions and analyze pupil size and pupil offset instant by instant.

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the icon opens the window for selecting the instrument with which to capture.



Acquisition



Dynamic acquisition

To capture Pupillography images, select the  icon.
The instrument automatically sets to the capture position and a live capture window opens.

SELECTING LIGHT CONDITION, CENTERING AND FOCUSING

Correctly position the patient's head on the chin rest and move the instrument to visualize the selected eye in the live capture window. Before proceeding with the acquisition select the desired light condition using mouse or Up/Down arrow keys (depending the installed instrument four light condition are available: Scotopic, Mesopic, Photopic and Dynamic). To correctly center the instrument set the crosshair target over the fixation point. To obtain the correct position move the joystick right and left to perform horizontal movements, or turn the joystick clockwise-counterclockwise to perform vertical movements; once the instrument is centered focus the image of the iris.

ACQUIRE

When the instrument is correctly centered, press the button on the joystick or keyboard space bar to capture the image. For Dynamic acquisition a recording message is displayed, click a second time in order to stop the acquisition. During the dynamic acquisition phase all functionalities are disabled except for joystick and spacebar.

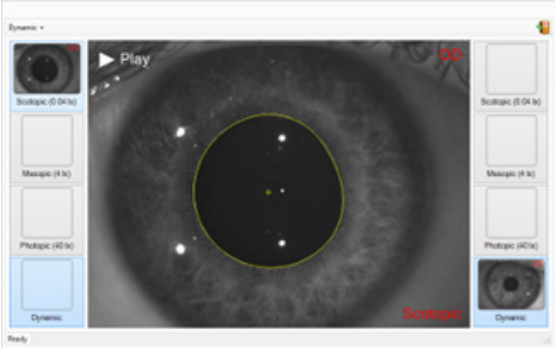
Note: *for acquisitions in static light conditions (scotopic, mesopic, or photopic), 3-5 seconds delay between captures are generally sufficient, since the observable phenomenon should already be established. In the case of dynamic acquisition we recommend continuing capture until the pupil has assumed a dilation that may be reasonably considered to be the maximum for the lighting condition.*

PREVIEW

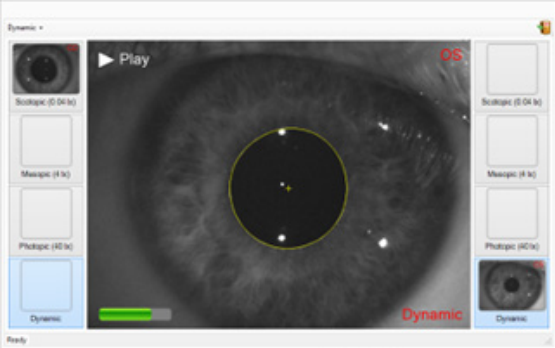
Preview image (with perimeter and pupil center superimposed) can be displayed by keeping the mouse left button pressed over the corresponding button as shown in Preview figure. For dynamic acquisition the entire image sequence is displayed.

EXIT

Once the images have been acquired you can complete the process using the button; in this case the program return to the main screen from which you can proceed with the subsequent analysis procedures of examinations stored.



Preview



Dynamic Preview

PUPILLOGRAPHY | MENU

A menu is displayed at the top of the screen: a short description of the functionalities and options that are available follows:

FILE		
	Save screen-capture as image	Opens a window from which the current screen-capture can be saved in various image formats.
	Close	Closes the current analysis environment and returns to main page.
	Print screen-capture	Opens a window to set-up printing parameters and to print the current screen-capture.
	Print	Print report of the pupillography examination session, in graphics form.
	Quit	Exits the application after confirmation of the warning message.
EDIT		
	Edit Pupil	Opens the environment for pupil and corneal vertex editing.
	Reprocess	The pupillography images are reprocessed from the top; any changes made during pupil editing are lost.
TOOLS		
	Zoom	Select this item to change the size of the image shown on the screen, using the mouse scroll wheel
	Distance	With this button selected, the user may draw a line segment on the image and measure its length in order to evaluate distances.
	Brightness	This item allows the user to use the mouse scroll wheel to change the brightness of the image. This button is also available on the main screen's toolbar under Advanced options .
	Contrast	This item allows the user to use the mouse scroll wheel to change the image contrast. This button is also available on the main screen's toolbar under Advanced options .

	Gamma	This item allows the user to use the mouse scroll wheel to change the image correction range. This button is also available on the main screen's toolbar under Advanced options .
	Restore	Recover original image settings.
ANALYSIS		
	Single eye	Sets the single eye analysis screen. This button is also available in the toolbar of the main screen.
	Comparison	Set the screen for comparison with the fellow eye. This button is also available in the toolbar of the main screen.
	Pupillography	Allows you to select the image under dynamic, scotopic (0.04 lux), mesopic (4 lux) and photopic (40 lux) conditions. A drop down menu with these buttons is available in the toolbar of the main screen.
INFO		
	Info	Information about the acquisition device.
	Manual	Provides access to the software manual.

PUPILLOGRAPHY TOOLBAR

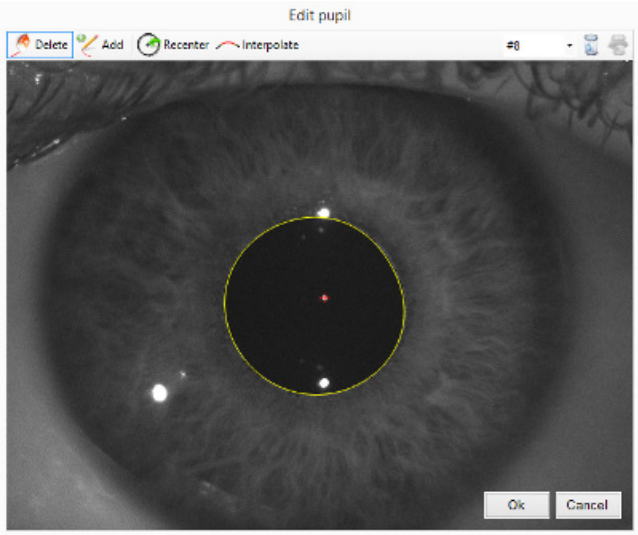
A toolbar is displayed at the top of the screen: a short description of the functionalities and options that are available follows:

	Single Eye	Sets the single eye analysis screen.
	Comparison	Set the screen for comparison with the fellow eye.
	Pupillography	Allows you to select the image under dynamic, scotopic (0.04 lux), mesopic (4 lux) and photopic (40 lux) conditions.
	Zoom	Select this item to change the size of the image shown on the screen using the mouse scroll wheel.
	Distance	With this button selected, the user may draw a line segment on the image and measure its length in order to evaluate distances.
	Advanced	Select this item to access Brightness, Contrast and Gamma change buttons.
	Vertex	Select this item to display a cross at the corneal vertex.
	Graphs	Shows or hides the image Pupillography graphs. The graph type displayed depends on the currently selected Pupillographic image

Time [ms] 0	**Time selection**	Allows selecting and comparing different time acquisition on dynamic Pupillography. To make a comparison between different time frames select and change the second timespan
	Background color	Allows selection of the background color Black or White.
	Close	Closes the current analysis environment and returns to main page.

PUPILLOGRAPHY TOOLBAR

The program automatically identifies the pupil border. The commands for correcting automatic editing of the pupil are displayed at the top of the window. By selecting the number of the image from the drop down menu in the upper right corner of the screen you can choose which image to edit. The buttons and allow for ignoring the current frame from the sequence of Pupillography, or to restore it to the sequence. The buttons on the left hand side allow for the actual editing, as described in further paragraphs. Pressing the **Ok** button allows for confirming the changes, and returning to the principal Pupillography screen. The **Cancel** button closes the screen without saving the modifications.



Pupil Editing

Delete	Once chosen, the **Delete** command allows you to remove the existing Pupillary border by moving the mouse cursor over the border.
Add	Once having deleted part of the pupil's border it is possible to redraw the border using the **Add command.**
Interpolate rings	You can interpolate the pupil's border by clicking the button **Interpolate rings.**
Recent	To recenter the pupil, move the cursor with the arrow keys towards the vertex and press **Enter.**

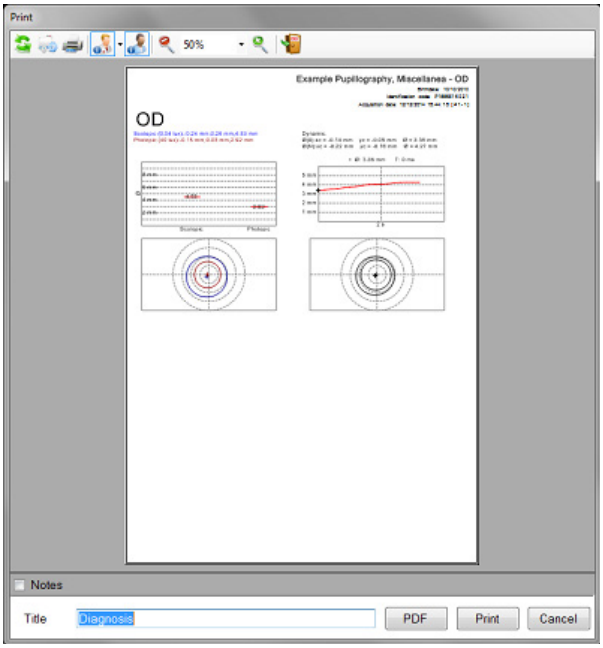
You can access the print functionality through **Print** and **Print screen** under the **File menu**.
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

Print (Quick) and **Print screen (quick)** functionality, also under the File menu, allows you to print without preview.

PUPILLOGRAPHY | EDIT

You can access the print functionality through **Print** and **Print screen** under the **File menu**.
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

Print (Quick) and **Print screen (quick)** functionality, also under the File menu, allows you to print without preview.



Print preview

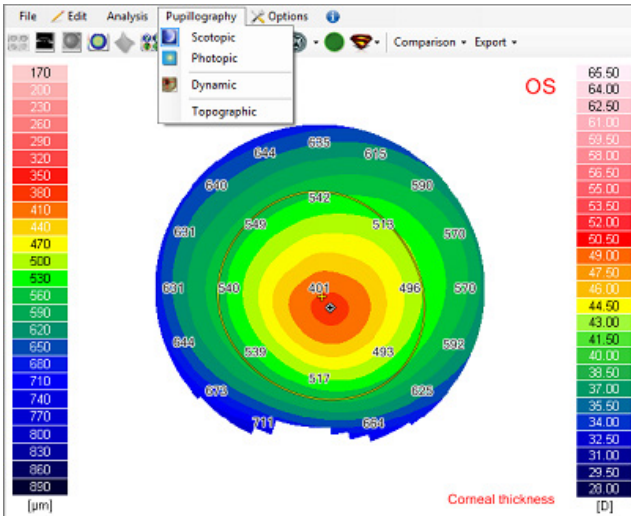
ASSOCIATE EXAM

CREATE LINK

A Pupillography can be associated to a corneal topography (Keratoscopy or Scheimpflug exam) in order to superimpose Pupillography information over a topographic map. To create this link close the Pupillography examination and return to the main screen, open the list of examinations associated with the patient and then drag the selected Pupillography examination over the corneal topography to be associate with. The new association is confirmed by the following icon over the selected exam.
If a **Pupillography** has been linked to a topography a new menu item will be added on the main menu bar. By this the user may select the view on the map of the Scotopic, Mesopic, or Photopic pupil or, alternatively, the topographic pupil (derived from the keratoscopy image).

REMOVE AND FOLLOW LINK

To remove the link, open the list of examinations associated to the patient on the main screen and right click on the exam. It will be possible to remove the link by selecting the Remove link command on the contextual menu or to check its reference by the **Follow link** command.

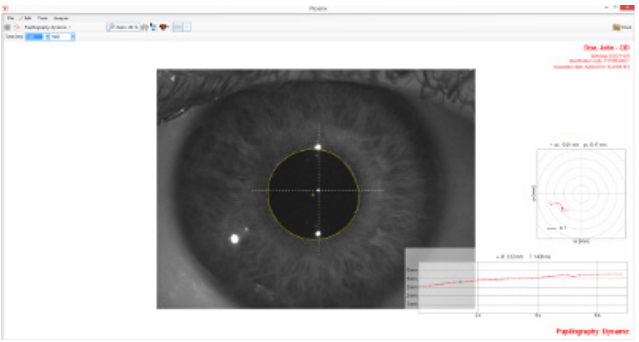


Access to Pupillography information after link creation

SINGLE ACQUISITION

SINGLE ACQUISITION ANALYSIS

Once the required captures have been completed (or, alternatively, once an earlier Pupillography examination has been opened), the program calls up the Pupillography environment in which to view the information obtained or from which to print the information in a predefined report form.



Single acquisition screen

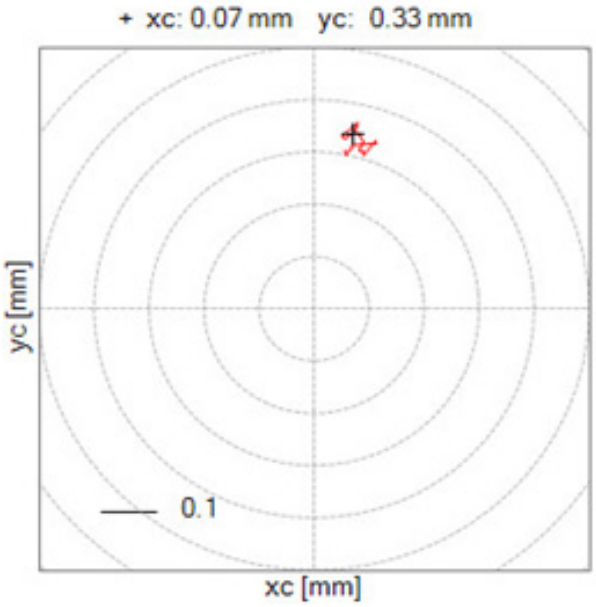
ASSOCIATE EXAM

Graphs Types

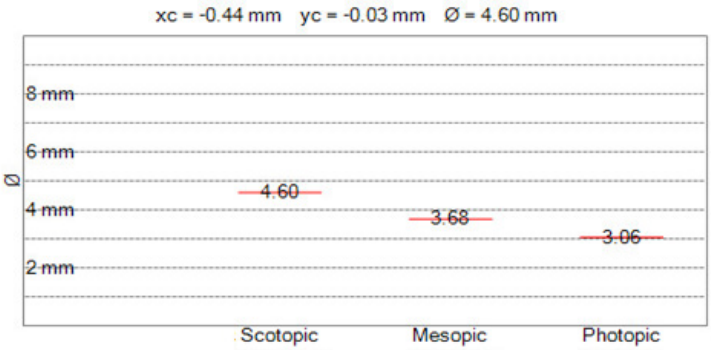
According to the selected Pupillography the following charts are visualized:

Light Condition	Graphs
Scotopic, Mesopic, Photopic	Static pupil diameters.
Dynamic	Temporal pupil diameter variations and pupil center position (relative to corneal vertex).

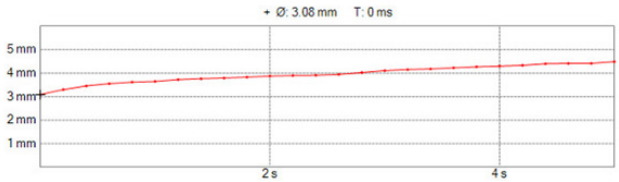
Within each graph the center coordinates and Pupillary diameter are indicated respectively by the letters xc, yc, Ø; in the context of dynamic Pupillography a cursor + is also reported for the currently displayed time instant.



Dynamic pupil center coordinates



Static pupil offset and diameters



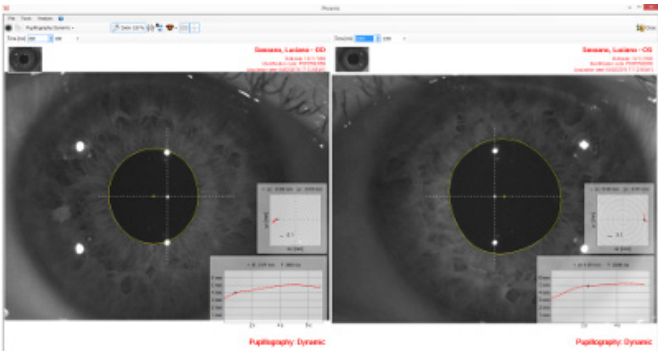
Dynamic pupil diameter chart

COMPARISON

SWITCH TO COMPARISON WINDOW

When the Pupillography examination also contains a fellow eye, it is possible to perform a comparison using the icon on the toolbar. In this window the same functions as for single Pupillography are available.

Press to return to the single image window.



Pupillography comparison

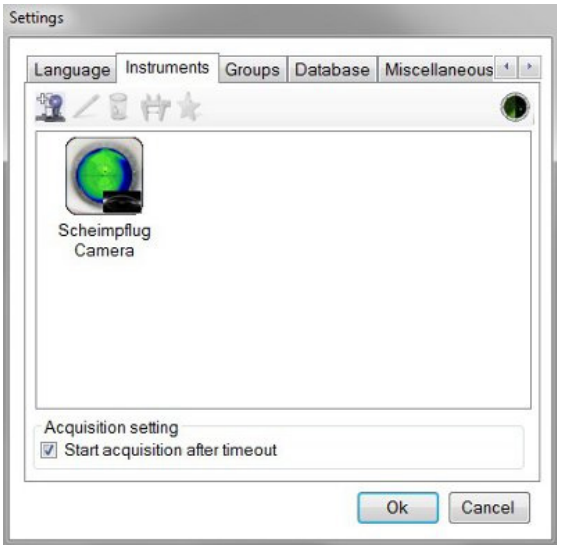
SCHEIMPFLUG BASED CORNEAL TOPOGRAPHY | CALIBRATION

Calibration is essential for obtaining accurate measurements: to calibrate correctly, follow the instructions given step-by-step on the screen and carry out all the captures needed, with the calibration standards requested in a dark environment, similar to the one used for normal acquisition.

The steps in instrument calibration are the following:

» Place the supplied calibration tools in front of the device
» Open the settings menu and select the Instruments panel.
» Select the instrument Scheimpflug Camera and click the calibration button;
  o if requested carry out linear calibration as described below.
  o carry out the curvature calibration as described below.

The entire procedure must be carried out carefully.



Scheimpflug camera under Instruments

LINEAR CALIBRATION

Linear calibration is necessary to permit the program to correctly measure the distances on the image. Linear calibration is carried out by capturing the flat calibration disk image when focused. To capture, press the joystick button or the space bar.
After capturing the disk, move the horizontal and vertical blue arrows to delimit the disk. Position the two red circumference arcs so that they coincide with the external side of the last white ring.

When done, click **Next** to continue.

Calibration disk

CURVATURE CALIBRATION

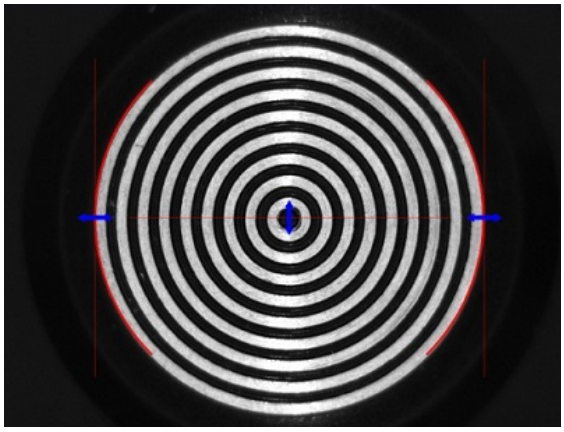
Curvature calibration is necessary to permit the program to correctly measure the curvatures. Position the instrument as illustrated. Make sure to perform as follows:

» Center the red cross for the frontal camera (the one on the lower part of the screen) in the middle of the rings reflected by the 8 mm sphere.
» Place the instrument at the correct distance from the sphere. The correct distance is such that the white arc, which is the reflection of

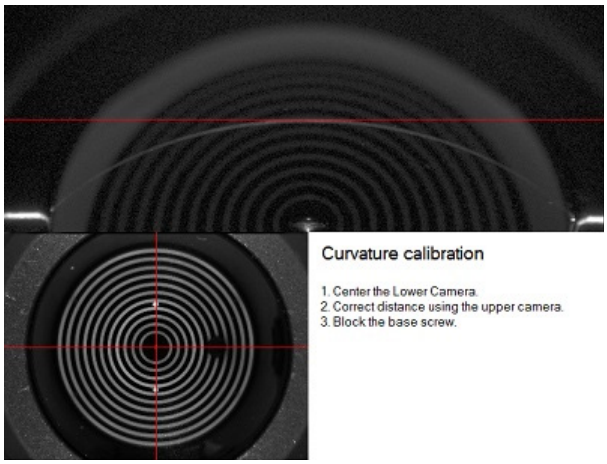
the blue slit on the surface of the sphere, touches the red horizontal line displayed on the lateral camera (the one in the upper side of the screen).

» Block the instrument, using the base screw.

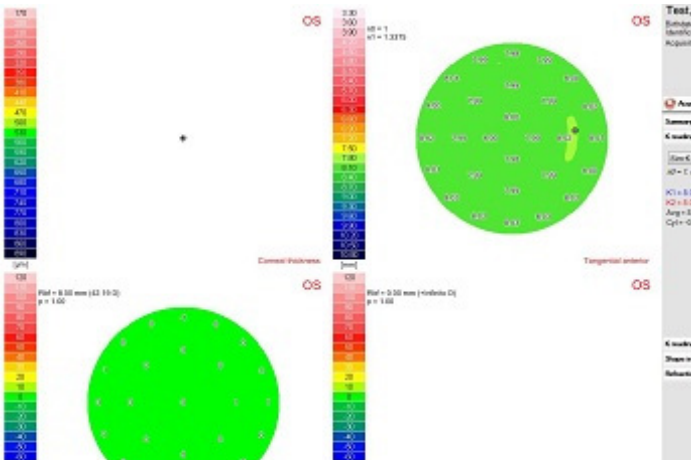
If the calibration procedure is performed correctly, a confirmation message will appear on screen. After having successfully calibrated you should capture some images of the 8-mm sphere, creating a patient and a test exam to verify correct instrument calibration. If the processed measurements are not found to be reliable, repeat the entire calibration procedure.
Last image represents the acquisition summary for a sphere after a correct calibration procedure, and after having edited manually the anterior surface's edges, using the tool for Scheimpflug image editing.



Linear calibration



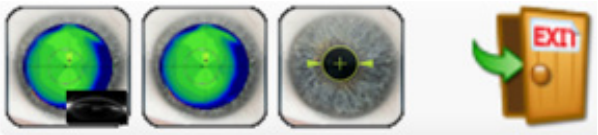
Curvature calibration



Acquisition of a 8mm calibration sphere

ACQUISITION

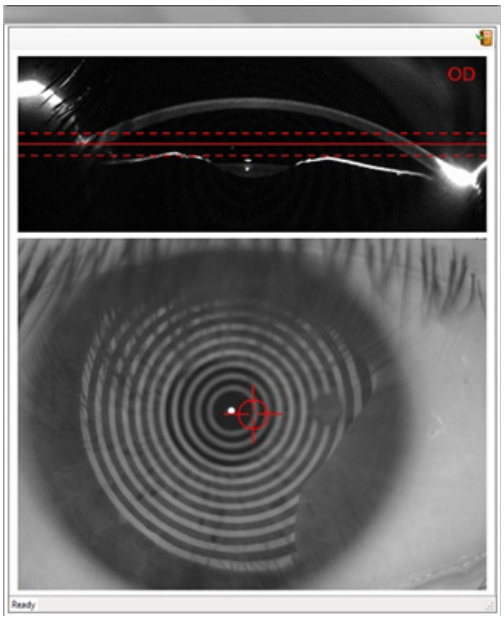
The  icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the icon opens the window for selecting the instrument with which to capture an image.



To capture a topographic-tomographic image, select the  icon.
The instrument automatically sets to the capture position and a live capture window opens.

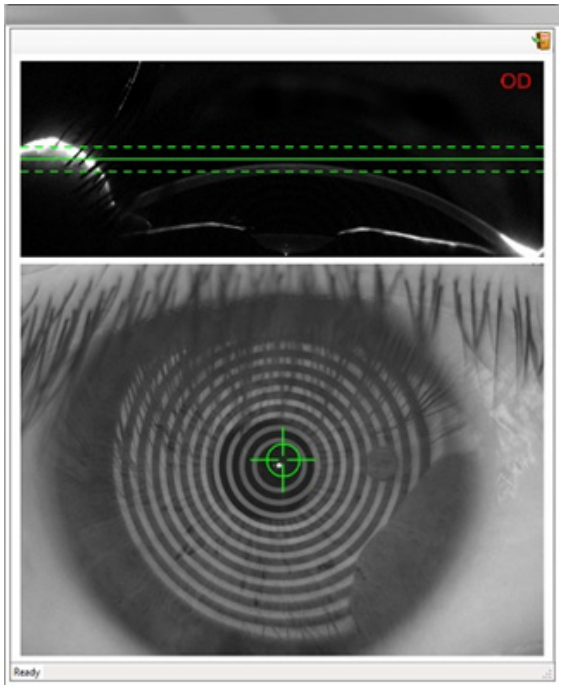
CENTERING AND FOCUSING

The window displaying the live images of the capture process shows images



Both distance and centering are incorrect

from two cameras: one coming from the lateral camera (positioned in the upper part of the screen) this shows the cornea in profile and permits setting the instrument to the correct distance, the other coming from the central camera (lower part of the screen), which permits correct centering of the instrument and monitoring of the tear film.
In order to conduct the examination at the correct distance from the corneal vertex, move the joystick forward and back until the corneal vertex is within the two green lines. As long as the corneal vertex is not at the correct distance, the horizontal lines will be red; when the apex is between the two dashed lines, they will turn green. When the joystick is moved forward, the profile of the cornea displayed on the monitor moves upward; when the joystick is moved back, the profile of the cornea moves downward.
To increase or decrease the camera brightness use the **+** and **–** keyboard keys The instrument is centered when the reflected white fixation point, in the middle of the reflected rings, is inside the aiming cross-hair target.
To move the cross to the left and right, move the joystick to the left and right.
To move the cross up and down, rotate the joystick clockwise and counterclockwise.
The cross-hair turns green when the instrument is centered.



Distance and centering are correct

CAPTURE

When the instrument is centered and at the correct distance, press the button on the joystick to capture the image.
This action starts the capture procedure, at the end of which the image is saved.
Once all the images needed have been captured, the capture environment may be closed; the program returns to the main screen.
Select one of the captured images to process it and access the Summary.

MENU

A menu is displayed at the top of the screen: a short description of the available functionalities and options follows.

FILE

	Save screen-capture as image	Opens a window from which the current screen-capture can be saved in various image formats.
	Close	Closes the current analysis environment and returns to main page.
	Print screen-capture (quick)	Directly prints the screen-capture.
	Print	Opens a window to set-up printing parameters. The final printout is screen dependent.
	Print (quick)	Directly prints.
	Export	Exports for external program.
	Exit	Exits the application after confirmation of the warning message.

EDIT

	Ring/Pupil/ Limbus editing	Opens the environment for the editing of reflected Placido rings, of the pupil and of the limbus edge.

	Scheimpflug images editing	Opens the environment for the editing of front and back corneal surfaces, of the iris and of the crystalline lens.
	Reprocess	Reprocess all Scheimpflug images and the keratoscopy.

ANALYSIS

	Summary	Opens up the default overview summary, containing information on pachymetry, curvature and elevation.
	Scheimpflug mages	Displays the Scheimpflug images.
	Keratoscopy	Displays the keratoscopy image.
	Single map	Displays a single map to permit detailed analysis.
	3D	Displays a 3D chart of the current displayed map.
	Multimap	The screen can be displayed as follows: o Display 6 maps chosen by the user; o Display 4 maps chosen by the user with the possibility to view the single Scheimpflug images; o Display 4 maps chosen by the user with the possibility to view the indices.
	Cataract summary	Displays an overview dedicated to IOL calculation.
	Keratoconus summary	Displays a detailed summary of keratoconus.
	Glaucoma summary	Displays an overview dedicated to the analysis of the anterior chamber, for the glaucoma screening.
	Intrastromal rings	Displays an overview dedicated to the intra-stromal rings surgery planning.
	Advanced ►Gaussian anterior	Displays a single Gaussian curvature map for the anterior surface.
	Advanced ► Aspherotoric fitting posterior	Displays a screen for the elevation analysis of posterior corneal surface.
	Advanced ►Gaussian anterior	Displays a single Gaussian curvature map for the anterior surface.
	Advanced ►Advanced pachymetry	Displays an overview dedicated to the analysis of the corneal thickness.
	Corneal aberro-metry	Displays an overview dedicated to the corneal wavefront analysis.

Optical Quality Summary	Opens up a summary focused on the patient quality of vision.
Autofit	Accesses the contact lens simulation environment.
Comparison	Allows comparison of up to 4 different maps.
OD/OS	Allows comparison of the current eye and the fellow eye.
Differential	Show the difference-map between acquisitions (up to 3).
Image comparison	Allows comparison of 2 different sets of Scheimpflug images.
Wavefront comparison	Allows comparison of 2 different corneal wavefront maps.
Keratoconus follow-up	Allows comparison of acquisitions of keratoconus or suspect keratoconus, to evaluate the temporal evolution of the pathology.
Refractive surgery follow-up	Allows comparison of acquisitions of eyes with the aim of evaluating the changes over time.
Internal components	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.

OPTIONS

Options	Set-up the user preferences for the display of topography or aberrometry.

INFORMATION

About...	Shows information on the software release.

TOOLBAR

A toolbar is displayed at the top of the screen: a short description of the functionalities and options associated to its items follows.

The toolbar configuration can be customized by the **Customize toolbar** button under the **Configure indices panel** button.

Summary	Opens up the default overview summary, containing information on pachymetry, curvature and elevation.
Reprocess	Displays the Scheimpflug images.
Analysis	Displays the keratoscopy image.
Single map	Displays a single map to permit detailed analysis.
3D	Displays a 3D chart of the current displayed map.
Multimap	The screen can be displayed as follows: • Display 6 maps chosen by the user; • Display 4 maps chosen by the user with the possibility to view the single Scheimpflug images; • Display 4 maps chosen by the user with the possibility to view the indices.
Cataract summary	Displays an overview dedicated to IOL calculation.
Keratoconus summary	Displays a detailed summary of keratoconus.
Glaucoma summary	Displays an overview dedicated to the analysis of the anterior chamber, for the glaucoma screening.
Intrastromal rings	Displays an overview dedicated to the intra-stromal rings surgery planning.
Corneal aberrometry	Displays an overview dedicated to the corneal wavefront analysis.
Optical Quality Summary	Opens up a summary focused on the patient quality of vision.
Autofit	Accesses the contact lens simulation environment.
Aspherotoric fitting anterior	Displays a screen for the elevation analysis of anterior corneal surface.
Aspherotoric fitting posterior	Displays a screen for the elevation analysis of posterior corneal surface.

Gaussian anterior	Displays a single Gaussian curvature map for the anterior surface.
Advanced pachymetry	Displays an overview dedicated to the analysis of the corneal thickness.
Comparison ►Comparison	Allows comparison of up to 4 different maps.
Comparison ►OD/OS	Allows comparison of the current eye and the fellow eye.
Comparison ►OD/OS	Show the difference-map between acquisitions (up to 3).
Comparison ►Image comparison	Allows comparison of 2 different sets of Scheimpflug images.
Comparison ►Wavefront comparison	Allows comparison of 2 different corneal wavefront maps.
Comparison ►Keratoconus follow-up	Allows comparison of acquisitions of keratoconus or suspect keratoconus, to evaluate the temporal evolution of the pathology.
Comparison ►Refractive surgery follow-up	Allows comparison of acquisitions of eyes with the aim of evaluating the changes over time.
Comparison ►Internal components	Calculates the map for internal aberrations, from the ocular and the corneal wavefront map.
Export	Exports for external program.
Configure indices panel	Allows for restoring index panels previously been closed, or to customize the visibility of buttons on the toolbar.
Close	Closes the current analysis environment and returns to main page.

OPTIONS

Options screen is displayed by:

» Choosing  **Options** from the menu

Preferences on the representation of the measured information can be changed here.

NOTATIONS

» **Curvature measure unit** can be expressed in **Millimeters [mm]** or in **Diopters [D]** according to this setting.

» **Refractive index:** The refraction index used is displayed on the tangential anterior map, on the sagittal anterior map and in keratometric indices. Note that expressing the curvature of the cornea in diopters is merely a convention and that whatever refraction index is used for converting from millimeters to diopters, the real curvature of the cornea does not change.

- o **Keratometric index:** if this option is selected the keratometric refraction index (1.3375) will be used for the conversion from millimeters to diopters of the curvature of the anterior surface. This function permits comparing the curvature values with the values given by a keratometer or ophthalmometer.
- o **Use stromal index:** if this option is selected the stromal refraction index (1.376) will be used for the conversion from millimeters to diopters of the curvature of the anterior surface.

» **Asphericity:** the asphericity measurement can be set as **e**, **p**, **SF(E)**, or **Q**.

SCALES

Three different color scales are available to choose from:

» Klyce/Willson

» Schwind

» American style

It is also possible to set the step value for following scales:

» Anterior curvatures;
» Posterior curvatures;
» Elevations
» Anterior/Total refractive power
» Posterior refractive power

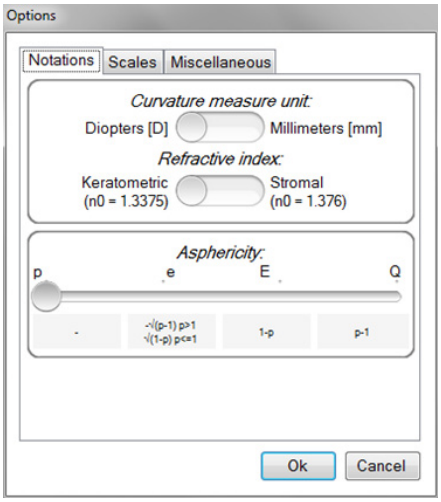
MISCELLANEOUS

» **Coordinate system:** Polar/Cartesian. Each point position will be expressed in ρ (distance from center) and @ (position in degrees) or in x (horizontal distance from center) and y (vertical distance from center).

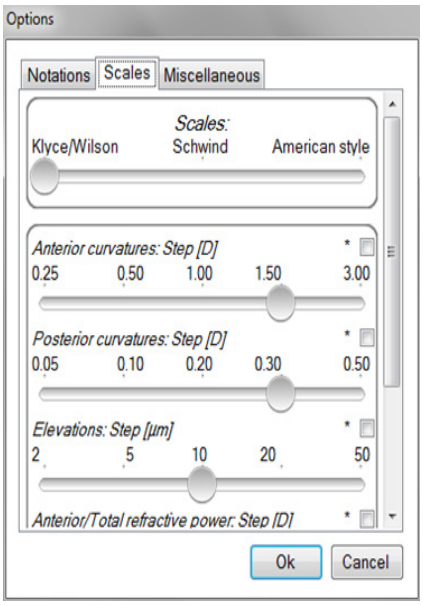
» **Cylinder notation:** Negative/Positive. Negative or Positive notation will be used as cylinder notation.

» **Representation diameter:** 9mm/12mm: Each sample exceeding a distance of 4.5 or 6 mm from the corneal vertex will not be displayed.

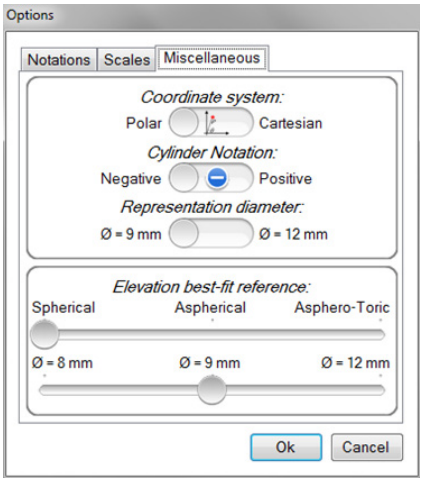
Elevation best-fit reference: The reference surface can be spherical, aspherical or asphero-toric according to the preference and the samples used for the best-fit calculation will not exceed the diameter of 8 mm, 9 mm or 12 mm.



Options: Notations



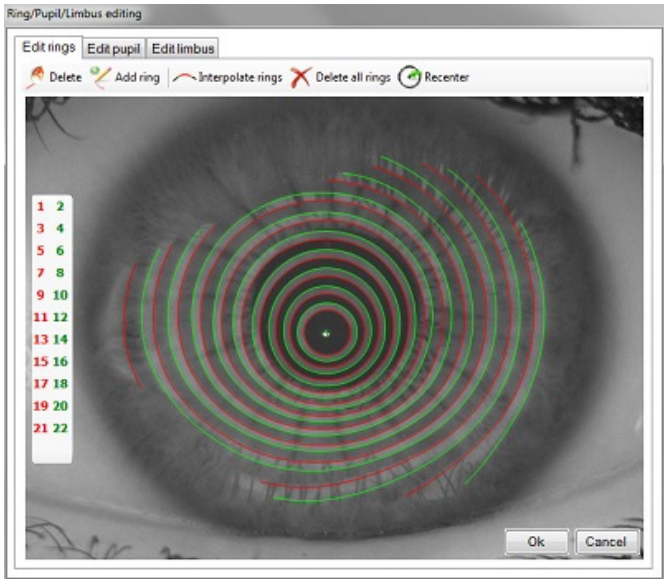
Options: Scales



Options: Miscellanea

RINGS | PUPIL | LIMBUS EDITING

To access the Rings/Pupil/Limbus editing functions select **Rings/Pupil/Limbus editing** from the **Edit menu**.



Rings editing

RINGS EDITING

The software automatically recognizes the keratoscopic rings positions reflected off the cornea, detecting dark-to-bright or bright-to-dark transitions. The rings detection is emphasized on the screen as alternating green and red circles.
Irregularities, corneal opacity or shadows from eyelashes or the nose may cause mistakes on the identification of the rings correct position: it is important to check the correct detection of the rings before starting the analysis of the topographic maps. The software offers the possibility to fix the detected rings by manually editing them.
The window contains a set of buttons identifying rings on keratoscopy, and five buttons that allow editing of the rings.

SELECTING A RING

To select a ring move the mouse cursor onto the ring to be selected and right-click or press the button with the corresponding number on the screen.
When selecting a ring, points situated on the ring are joined by an orange line, the addition or removal will only happen to this ring.

When selecting a ring, it is possible to select the previous or next ring by using the arrow keys on the keyboard.

Pupil editing

DELETING A RING

To delete points, press the **Delete** icon. Moving the mouse cursor over the keratoscopic image and holding the left mouse button, a circular cursor appears: points below the cursor will be removed. When you select a ring, you can remove only points belonging to that particular ring. To delete an entire ring press the Del or Backspace key on the keyboard.
Delete all rings and Recenter

Pressing the **Delete all rings** icon will erase all the detected points. After confirming the alert message "Are you sure you want to erase all the rings?" press **Recenter** and the program will let you choose a new keratoscopic center. Use arrow keys to find the correct position of the center and confirm by pressing the **Enter** key.

ADDING A RING

To add points press the **Add ring** icon and select the ring you want to complete. Then press the left mouse button on a point that is part of the ring image.

INTERPOLATING RINGS

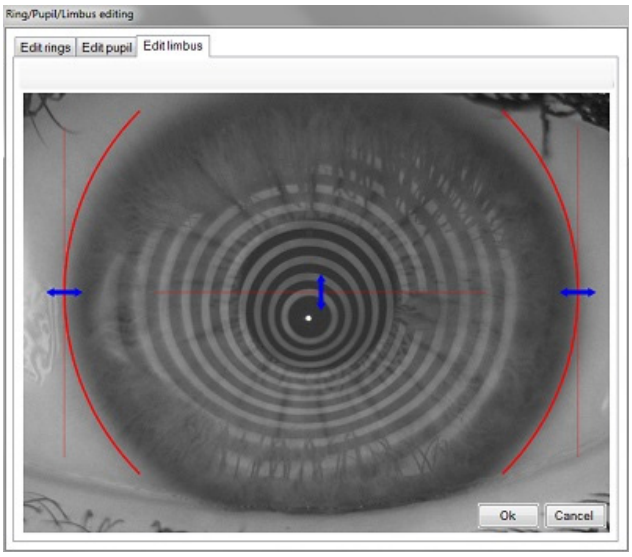
To complete a missing part of a ring, just press the **Interpolate rings** icon.

PUPIL EDITING

After pressing the **Edit pupil** icon, the pupil is highlighted as a red circle with a red center, bordered by three yellow crosses.
To change position and size of the pupil:
» Drag and drop the red circle representing the pupil in the right position.
or
» Drag and drop the yellow crosses that define the red circle.
Pressing the Delete pupil icon will delete the pupil.
Right-clicking on the image the corneal vertex will be assigned.

LIMBUS EDITING

When you open this editing window, the limbus is marked with two red semicircles.
To change the size of the limbus:
» Drag and drop the blue horizontal arrows and drag to resize the limbus.
» Drag and drop the blue vertical blue arrow to move the limbus vertically.



Limbus editing

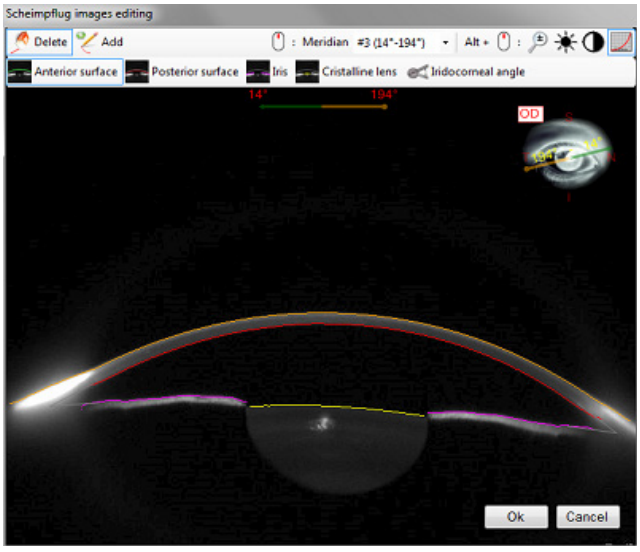
SCHEIMPFLUG IMAGES EDITING

To access these functions select **Scheimpflug images editing** from the **Edit** menu.

The software automatically recognizes the front and rear surface of the cornea as well as the iris and the lens.
Irregularities, corneal opacity or shadows from eyelashes or the nose may cause mistakes on the edge identification: it is important to check the correct detection of the edges before starting the analysis of maps. The software offers the possibility to fix the detected edges by manually editing them.

As a first step the meridian to be edited has to be selected by using the mouse wheel: the screen opens on the horizontal meridian.

Some buttons on the toolbar allows for editing of the surfaces.



By clicking one of the surface buttons (Front, back, Iris and Crystalline lens), the corresponding surface will change color to orange and will be ready for editing.

By selecting the **Irido-corneal angle** button the editing of the right and left angle between rear cornea and sclera is allowed.
The angle is delimited by three points, which can be individually moved by keeping the left mouse button pressed.
To add an angle when the angle is missing, left-click in the vertex position.

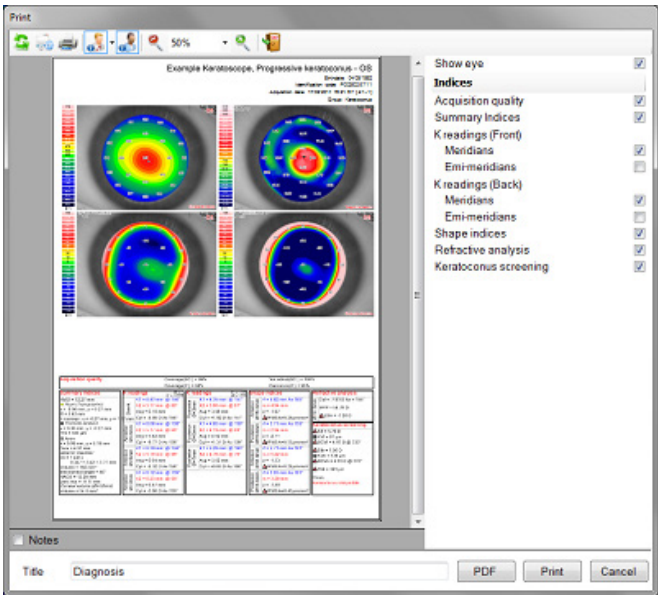
	Allows for deletion of a part of the selected surface: by left-clicking, the samples close to the clicked point will be removed from the surface. By pressing **Del** or **Backspace** key the whole surface will be deleted.
	Allows addition of a part of the selected surface: by left-clicking on a point of the image the closest edge will be selected, tracked and added to the current surface.
	By pressing the **Alt** key and using simultaneously the mouse wheel the magnification factor of the image will be changed.
	By pressing the **Alt** key and using simultaneously the mouse wheel the brightness of the image will be changed.
	By pressing the **Alt** key and using simultaneously the mouse wheel the contrast of the image will be changed.
	By pressing the **Alt** key and using simultaneously the mouse wheel the gamma of the image will be changed.

PRINTING

You can access the print functionality through **Print** and **Print screen** under the **File** menu.
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

On the right side of the screen a list of options is shown which allows you to display or hide indices on the final printout.

Print (Quick) and **Print screen (quick)** functionality, also under the **File menu**, allows you to print without preview.

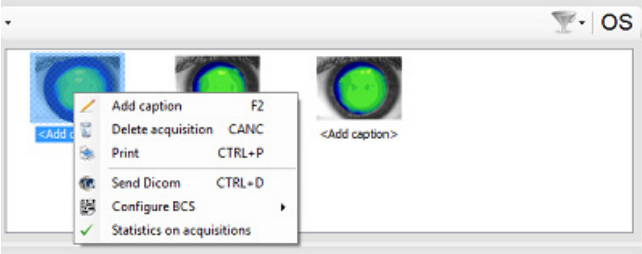


Print preview

STATISTICS ON ACQUISITION

Statistics on acquisition window can be accessed by right-clicking on one of the thumbnails in the acquisition gallery and then

left-clicking the **Statistics on acquisition** menu item of the contextual menu.



This window is useful for evaluating the quality and the repeatability of the acquisitions belonging to the same examination.

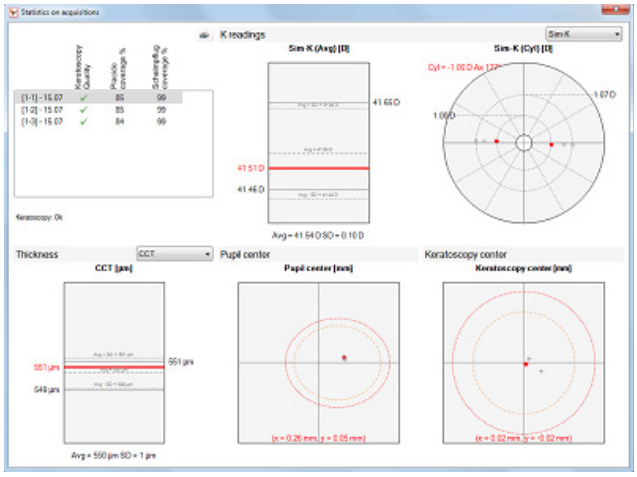
At the top-left corner a table is shown with the list of the selected acquisitions. Each row of the table refers to a single acquisition and contains its ID, date and time of the acquisition, a symbol for the quality of the keratoscopy (green for good quality, red for bad quality), the percentage coverage for the Placido disc, the percentage coverage for the Scheimpflug images.
By selecting a row in the table (i.e a certain acquisition), the corresponding data are highlighted in the plots described below.

At the top of the window for K readings (Sim-K or Meridians at 3 mm) a scatter-box plot for the average value and a polar scatter plot for cylinder are shown. Average and standard deviation are reported for the Sim-K (Avg) and for the Meridians at 3 mm (Avg).

At the bottom-left corner of the window a scatter-box plot is shown for corneal thickness indices (Central Corneal Thickness or Minimum Thickness). Average and standard deviation are reported for these indices too.

At the bottom of the window in its central part a cartesian scatter plot is dedicated to pupil decentration respect to corneal vertex. The normality zones are also shown in the graph. Normal values for pupil decentration are within the yellow dashed ellipse. Border line values are in the zones between the yellow dashed ellipse and the red dotted one.

At the bottom-right corner of the window a cartesian scatter plot is dedicated to keratoscopy decentration respect to the optical instrument axis. Low decentration values are within the yellow dashed circle, high decentration values are outside the red dotted circle. When the keratoscopy center is outside the red circle it is strongly advised to discard the acquisition.



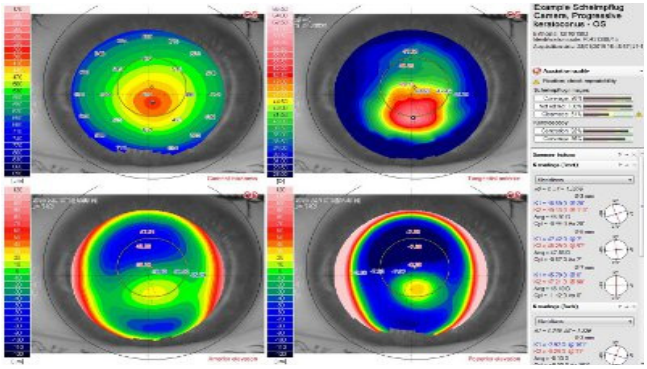
Statistics on acquisition window

SUMMARY

Summary is displayed:

» double-clicking on a Scheimpflug acquisition on the main screen.
» by choosing **Summary** from the **Analysis** menu
» by clicking the icon on the toolbar

This screen is the shown first: it displays a clinical summary of the maps and data derived from processing each single image.
The **Summary** consists of four maps: corneal thickness, tangential anterior, anterior elevation, and posterior elevation. Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Summary

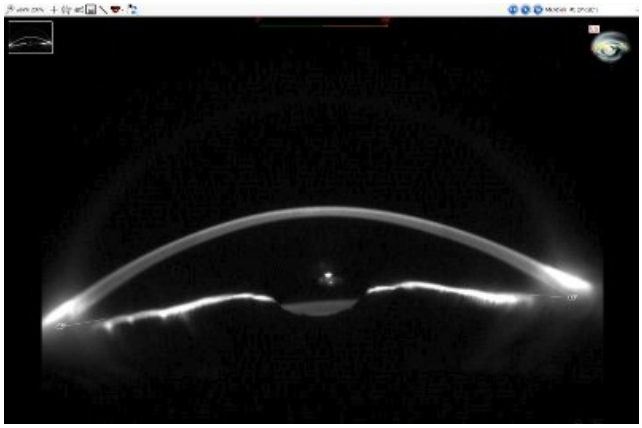
SCHEIMPFLUG IMAGES

Sheimpflug images screen is displayed:

» by choosing **Sheimpflug images** from the Analysis menu

» by clicking the icon on the toolbar

This screen displays the single images captured by the Scheimpflug camera on all 25 meridians.



Scheimpflug images

SINGLE MAP

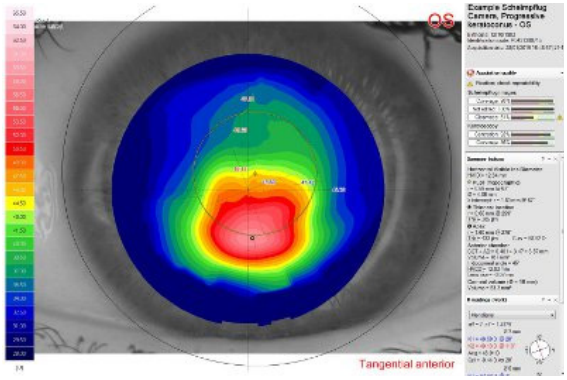
Single map screen is displayed:

» by choosing Single map from the Analysis menu
» by clicking the icon on the toolbar
» double-clicking the map of choice from the Summary.

This screen displays a single map in full-screen mode. The type fo map can be selected from the toolbar:

» Corneal thickness
» Tangential anterior
» Tangential posterior
» Sagittal anterior
» Sagittal posterior
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber
» Background

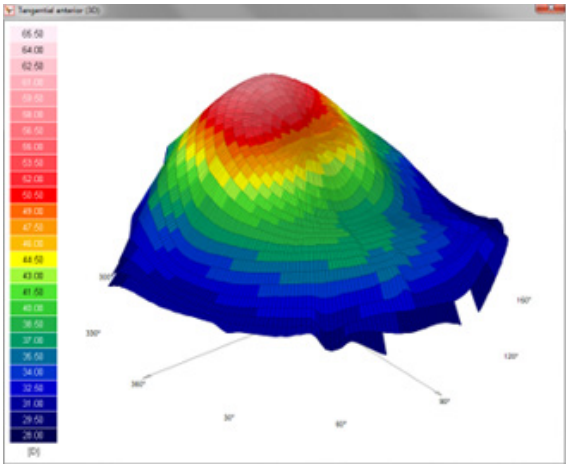
Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Single map

3-D MAP

The icon becomes active only in this screen. When pressed a three-dimensional view of the current corneal map is shown.
Hold down the left mouse and drag the end points of the Cartesian diagram enclosing the map to view it from different perspectives.
Right-clicking a context menu to **print the screen, save the screen as an image**, or change the view type is shown.



Three-dimensional view of the tangential anterior map

MULTIMAP

Multimap screen is displayed:

» by choosing **Multimap** from the **Analysis** menu

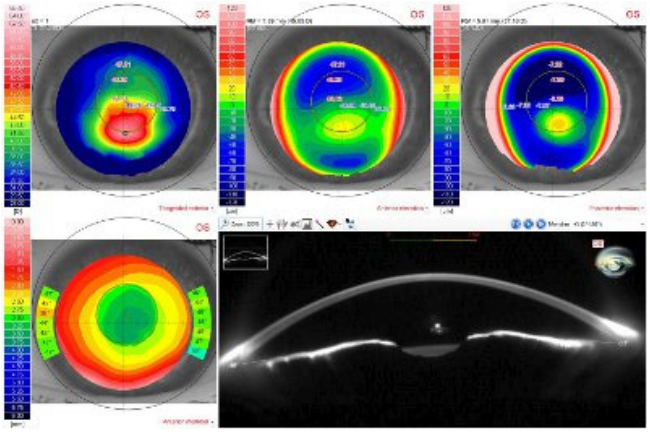
» by clicking the  icon on the toolbar

This customizable screen displays maps according to the user preferences: three types of customizable menus are available:

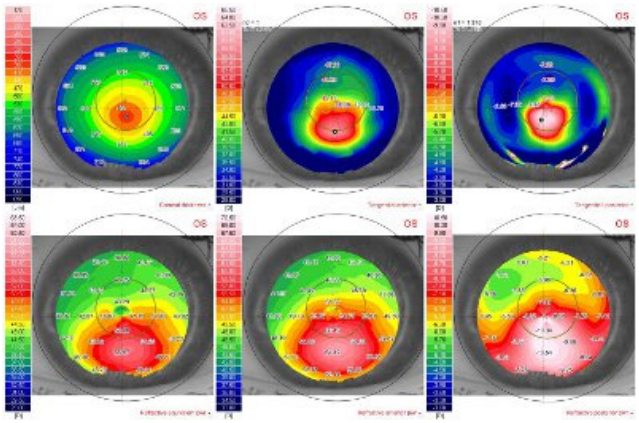
» Multi-map+Indices, to select 4 maps and their respective indices.
» Multi-map+Images, to select 4 maps and Scheimpflug images.
» Multi-map 6X, to select 6 maps.

The types of map can be selected from the toolbar:

» Corneal thickness
» Tangential anterior
» Tangential posterior
» Sagittal anterior
» Sagittal posterior
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber
» Background

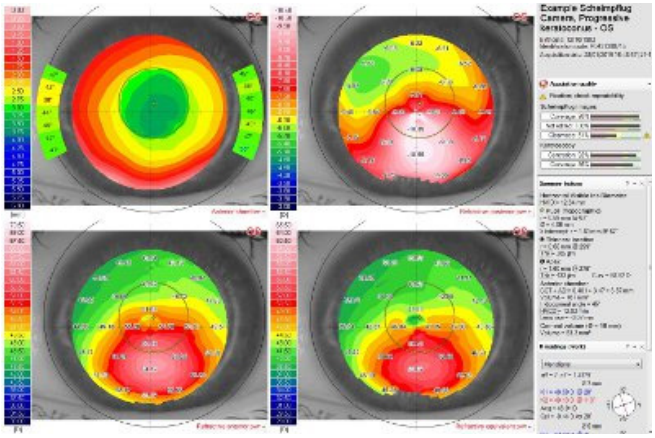


Multi-map+Images



Multi-map 6X

Just in Multi-map+Indices, right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Multi-map+Indices

CATARACT SUMMARY

Cataract summary is displayed:

» by choosing **Cataract summary** from the A**nalysis** menu

» by clicking the icon on the toolbar

This module is dedicated to the calculation of intra-ocular lenses (IOL). This calculation is not based on synthetic parameters like SimK, but uses measurements of the anterior segment obtained from the instrument. In particular, the calculation uses the elevation measurements of the anterior and posterior corneal surface, and the entry pupil. This information is used to create a three-dimensional model of the eye, that considers also potential asymmetries and irregularities of the examined eye. The ray-tracing method is used to trace the way light rays pass through the various surfaces of the eye, following Snell's Law. In this way we simulate the way the light ray passes from cornea to retina, passing intra-ocular lenses of different powers.

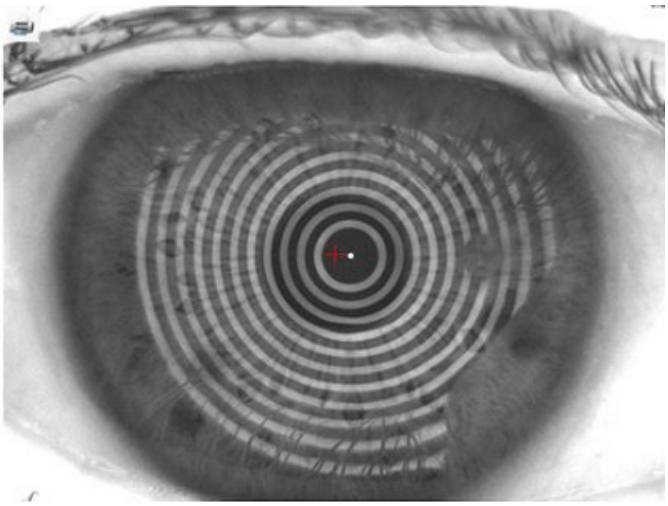


Figure 1: Example of a badly centered keratoscopy

CORRECT USE OF THE INSTRUMENT

Golden rules for an optimal result
• The acquired eye must be wide open and well centered • The tear film must be regularly distributed • The pupil must not be dilated • Make at least three similar acquisitions • Check the auto-detected pupil's position; edit when necessary

To correctly use the Sirius for calculation of intra-ocular lenses, we strongly advise that you acquire at least 3 images of the eye, in which the lens is to be implanted. The patient's pupil must not be dilated when using the instrument. The acquisitions all need to be well-centered (see Figure 1) and taken while the eye is wide open. The operator should verify that there are no residual anomalies or artifacts on the acquisition, due to an irregular distribution of the tear film. If a distortion is verified, e.g. shades and/or interruptions over the rings (see Figure 2 and Figure 3), it is advised to ask the patient to blink in order to restore the tear film.

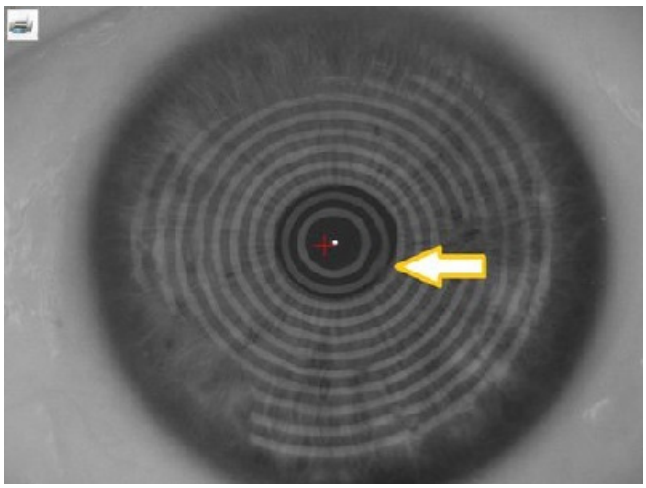


Figure 2: Decentered keratoscopy with artifacts: the rings in the indicated zone are distorted

If any of the three acquired images shows a deviation of SimK greater than 0.3 D, we recommend that you take another acquisition. When the pupil position is different in the various acquisitions, it is recommended that you repeat the acquisition process: it is an indication that the patient is not fixating correctly. A quick evaluation of repeatability, for the presence of artifacts and tear film coverage can be performed from the main management window, by reviewing the various acquisitions from the current exam (see Figure 4).

The incorrect detection of the vertices of irido-corneal angles might influence negatively the prediction of the IOL position. In the case where irido-corneal angles are not visible in the 7 meridians where the measurement of this angle is available (0°, 7°, 14°, 21, 158°, 166°, 173°) we recommend that you repeat the acquisition, making sure that the patient's eye is wide open during the entire acquisition sequence. If the patient is not able to keep their eye wide open for the entire duration of the acquisition, the software will show a pop-up asking for the manual editing of the missing angles. The operator should, in this case manually add the angle in the position that is likely to be the correct position, i.e. such that it is

the ideal intersection between the extension of the posterior corneal surface profile and that of the iris. It is sufficient to indicate the angle's vertex (see Figure 6).

DATA TO BE INSERTED

Before starting the intra-ocular lens calculation, the user should insert and/or verify the following information:

» The eye's axial length in mm has been obtained using a biometer
» The device used for the measurement of the axial length: PCI (Partial Coherence Interferometry), Ultrasound (US) by immersion, Ultrasound (US) by contact.
» The target refraction, i.e. the desired spherical equivalent after the implantation of the lens
» The pupil diameter for which we want to optimize the calculation for the lens power, in order to obtain the target refraction.
» The A Constant (or ACD or SF) of the implanted lens

All of the data, except for the last one parameter, needs to be (re)inserted in the Pre-Op page.

For the sake of convenience, the keratometries and the indices of Refractive Analysis are shown in the left part of the page. Besides those, optional warnings are shown that might guide the user in verifying the correctness of the input data. Those warnings are, e.g., an inserted axial length outside the normal range or excessive pupil decentering that might be caused by the patient's incorrect fixation during acquisition or by the software not having (correctly) auto-detected the pupil.

On the right-hand side of the Pre-Op page these options are available:

» the iris image with indication of the principal meridians and SimK. A goniometer is shown in overlay, in order to help the operator search for a reference to aid with the implantation of a toric lens.
» according to the operator's preference, the sagittal map of the anterior surface or the equivalent refractive power.

The software for calculating the IOL allows for the specification of a pupil diameter between 2 and 3 mm. This is the entry pupil taken into consideration for the calculation of the best lens, for the currently examined eye.
We suggest the use of a pupil diameter of 3 mm for normal eyes. For eyes examined after refractive surgery, it might be useful to choose a diameter of 2 mm, when the optical zone is very small and/or decentered.
When the axial length is set and optionally other input data is corrected, the calculation for the new intraocular lens can be started by pressing the button **New IOL**. A small window is shown where you can set the following parameters:

» IOL manufacturer
» IOL model
» The lens constant in one of its forms (A or ACD or SF). Based on this constant and the measured morphological parameters, the software calculates the Predicted Lens Position (PLP).
» The position of IOL center. The IOL center can be chosen equal to the corneal vertex, pupil center or limbus center.
» The axis of the least powerful meridian of the lens

The values of the cylinders for the toric lenses which will be considered in the calculation
By clicking **OK**, the lens calculation is started.

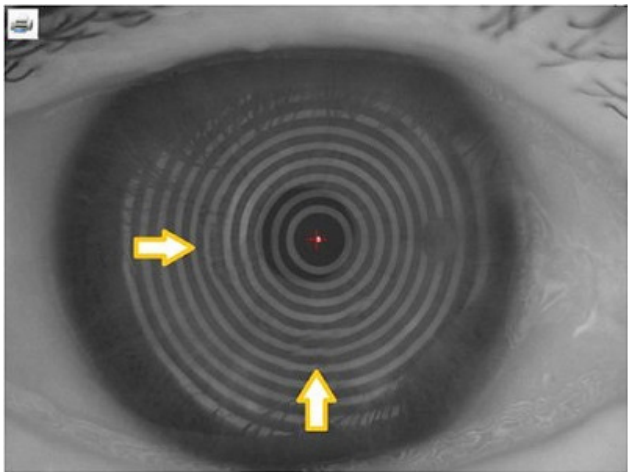


Figure 3: Well-centered keratoscopy with artifacts: The rings in the indicated zone are distorted

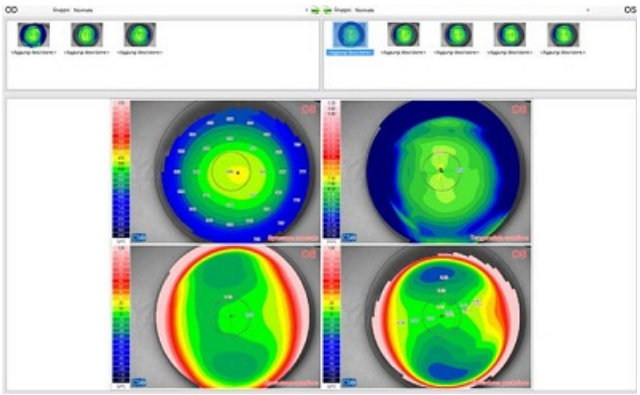


Figure 4: Patient management window: evaluation of repeatability, presence of artifacts, and correct coverage

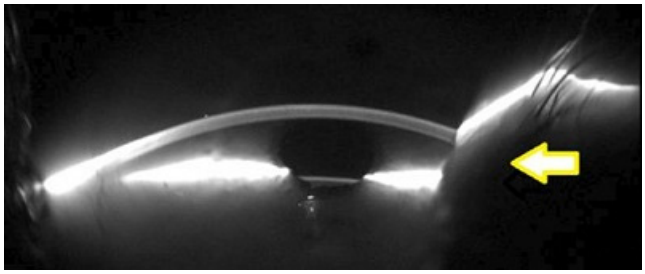


Figure 5: Half-closed eye, not allowing for the auto-detection of the irido-corneal angles

When the pupil center or limbus center are chosen as the position of the IOL center, it is very important to check whether the software was able to detect them automatically or use the manual editing when necessary. The axis of the least powerful meridian is set by default as the axis of the corneal cylinder calculated from OPD (or WFE).

PREDICTED LENS POSITION (PLP)

The PLP (Predicted Lens Position) is the software's predicted distance from anterior surface of the implanted lens to the posterior surface of the cornea. This prediction is based on a collection of measured factors, obtained from the anterior segment, and on the provided A (ACD or SF) constant. It is noted that a prediction error is normally one of the principal sources of error for all formulas and systems for calculation of intra-ocular lens power.

FIRST TIME USE OF A IOL MODEL

When starting out with this software, and using a IOL model for the first time, it is advised to use the nominal A constant value, provided by the IOL constructor, and to optimize the value based upon post-operative information, obtained at least one month after the operation. In particular, when collecting post-operative cases, the operator should check the actual position of the anterior surface of the IOL after the operation (see Figure 7), and verify with the position predicted by the software before the surgery. Adjust the Gamma level using the mouse wheel or the +/- buttons in order to make the implanted IOL visible in the Scheimpflug images (see Figure 7). If the actual distance of the lens is greater than the predicted one, the constant value should be adjusted upwards, if it is smaller than the predicted distance, the value should be adjusted downwards.

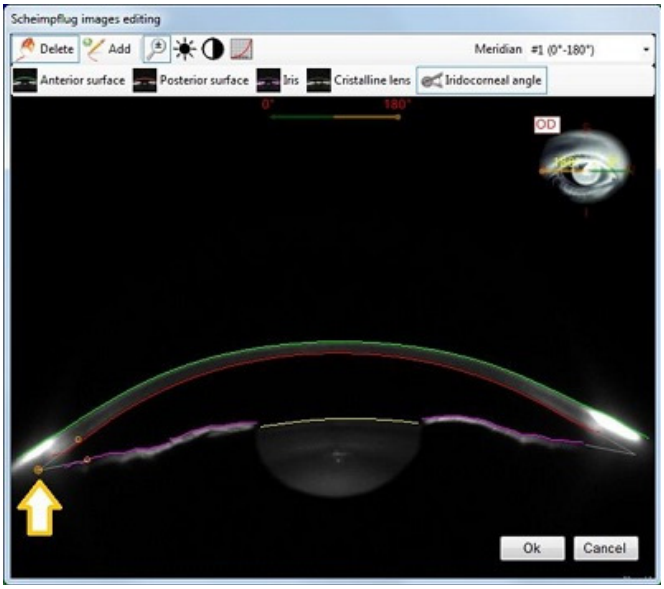


Figure 6: The arrow indicates the angle's vertex

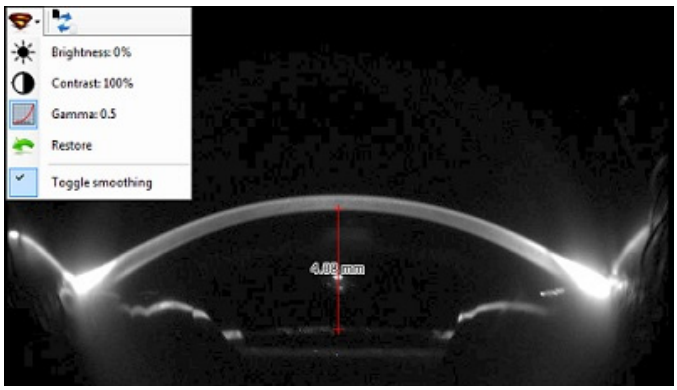


Figure7: How to verify the position of the IOL at 1 month after surgery

RESULTS

For any new calculated lens, a new page of the module is created containing results of processing.
At the top of the page the following data are shown: IOL manufacturer and model, lens constant, position of the center of the lens and predicted position of the lens (PLP).

In the central part of the page the following information is available:

» a table containing summarized results of the calculus, i.e. for a list of powers the respective predicted spherical equivalents
» a table containing the predicted refraction in for to a certain IOL cylinder (at the IOL plane) for the mean power selected in the previous table
» a chart for Focusing

The Focusing chart contains the curve for the merit figure for visual acuity, obtained with various corrections, for the lens selected from the calculated lens power table. From a different point of view, the Focusing chart shows how the visual acuity varies for several vergences of the observed object. This chart is therefore useful to evaluate the depth of field for the pseudo-phakic eye.
At the bottom of the page the following information is available:

» the Point Spread Function (PSF) for the selected lens
» according to the operator's preference, the simulated wavefront map (OPD or WFE) or the Refractive Error map

The 2 previous maps reference the lens selected in the two upper tables, characterized by the mean power selected in the left table and by the cylinder selected in the central table. The map for refractive error shows the refractive error for any ray passing through the pupil. It is useful to evaluate the presence of possible defocus, astigmatism and asymmetries in the optical ocular system.

The results of the calculation can be printed by pressing the **Print** icon in the upper right corner.

The Toric **IOL Marker** icon launches the tool dedicated to the marking of toric intraocular lenses.

A page dedicated to the lens calculation can be removed by pressing the **Remove IOL** icon in the upper right corner.

The manufacturer bears no liability for consequential damages resulting from any application of the results contained in Cataract Summary, particularly for damages coming from an erroneous IOL calculation. The user of the program has to make sure that the proposed values do not contain any mistakes.

The Cataract **Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:

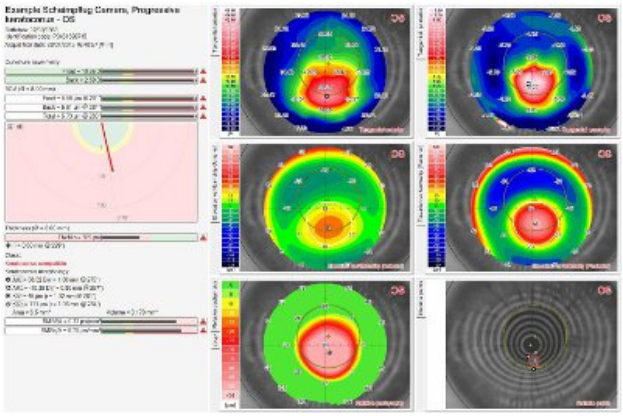
- Aramberri Jaime MD, BEGITEK Clínica Oftalmológica. San Sebastián, Spain OKULAR Clínica Oftalmológica. Vitoria-Gasteiz, Spain
- Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy
- Camellin Massimo MD, Sekal Microchirurgia Rovigo S.r.L. Rovigo, Italy
- Bedei Andrea MD, Pietrelli Alessia MD, Casa di Cura "San Camillo". Forte dei Marmi, Lucca, Italy
- Bellucci Roberto MD, Cargnoni Miriam Ort., Nguyen Deborah Ort., Hospital of Verona. Verona, Italy
- Ligabue Edoardo MD, Giordano Cristina OD, LA MIA VISTA. Milano, Italy
- Fantozzi Marco MD, Fortunato Francesco Ort., Studio Oculistico Fantozzi. Pescia, Pistoia, Italy

KERATOCONUS SUMMARY

Keratoconus summary[1] is displayed:

» by choosing **Keratoconus Summary** from the **Analysis** menu

» by clicking the  icon on the toolbar
» by pressing the button Keratoconus summary in the index panel for Keratoconus screening.



Keratoconus summary

Analysis is performed by means of following maps:

» Tangential anterior map on an area of 8 mm
» Tangential posterior map on an area of 8 mm
» Elevation anterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. This type of representation, that hides information on astigmatism and medium corneal power, is particularly useful since it highlights the higher orders only and therefore, in cases of keratoconus, the ectasic area and its entity.
» Elevation posterior with respect to an asphero-toric reference surface with a toricity of best-fit and asphericity equal to a 'normal' eye on 8 mm. The considerations made for the information on anterior elevation are even more important for the posterior surface, since the ectasic effect is shown anticipatively and more pronounced respective to the anterior surface.
» Difference between the patients corneal thickness and the 2.5th percentile of pachymetry for a healthy population.
» **PTI** (Thickness Increase %) and **CTSP** (Corneal thickness spatial profile) charts[2].
» The position of some interesting markers
Steepest point of the anterior corneal surface (**AKf** – Apical KeratoscopyFRONT);
Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK);
Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK);
Thinnest point of cornea (**ThkMin** – Minimum Thickness).

In order to help the practitioner in the identification of keratoconus cases or to evaluate, during follow-up, the entity and the progression of keratoconus, a series of indices is shown based on curvature, pachymetry and elevation data of anterior and posterior corneal surfaces. These indices describe the most relevant features of keratoconus:

CURVATURE ASYMMETRY

» The Symmetry Index of the anterior curvature (SIf – SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normality values are shown (95° percentile and 99° percentile of a normal population);
» The Symmetry Index of the posterior curvature (SIb – SymmetryIndexBACK) is defined as the difference of the mean posterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

ELEVATION BASED INDICIES

» The indices BCVf e BCVb allow the evaluation of the presence and of the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of elevations $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) \; + \gamma C_4^{0}$$

» The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal)

» and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
» The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normal values are shown (95° percentile e 99° percentile of a normal population);
» The index BCV or vectorial BCV is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normal values are shown (95° percentile and 99° percentile of a normal population).

The previous data are processed by a neural network in order to classify the case in one of the following groups:

» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

In case of classification as Keratoconus compatible some further morphologic indices are shown:

Steepest point of the anterior corneal surface (**AKf** – Apical KeratoscopyFRONT);
Steepest point of the posterior corneal surface e (**AKb** – Apical KeratoscopyBACK); Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT);
Highest point of ectasia on the posterior corneal surface (**KVb** – Keratoconus VertexBACK);
Thinnest point of cornea (**ThkMin** – Minimum Thickness).
» Area and volume of the ectasic zone;
» RMS/A and RMSb/A, root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 8 mm zone for both the anterior and posterior surfaces of cornea.

The keratoconus screening indices provide indications which however are not sufficient for assessing either instrument calibration status or the patient's clinical situation. These indices should thus be considered as diagnostic tools for the user but not as indicators of certain diagnosis of keratoconus.
We therefore caution the user to take maximum care when evaluating these values and to correlate the screening indices with other tests and with the patient's clinical history.

*The **Keratoconus Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:*

» *Arbelaez, Maria Clara MD, Muscat Eye Laser Center, Muscat, Oman*
» *Savini Giacomo MD, Studio Oculistico d'Azeglio. Bologna, Italy*
» *Piero Barboni MD, Studio Oculistico d'Azeglio. Bologna, Italy*

1. *Arbelaez, Maria Clara, et al. "Use of a support vector machine for keratoconus and subclinical keratoconus detection by topographic and tomographic data."Ophthalmology 119.11 (2012): 2231-2238.*
2. *Ambrósio R Jr, Simonato Alonso R, Luz A, Coca Velarde LG. Corneal-thickness spatial profile and corneal-volume distribution: tomographic indices to detect keratoconus. J Cataract Refract Surg 2006;32:1851-1859.*

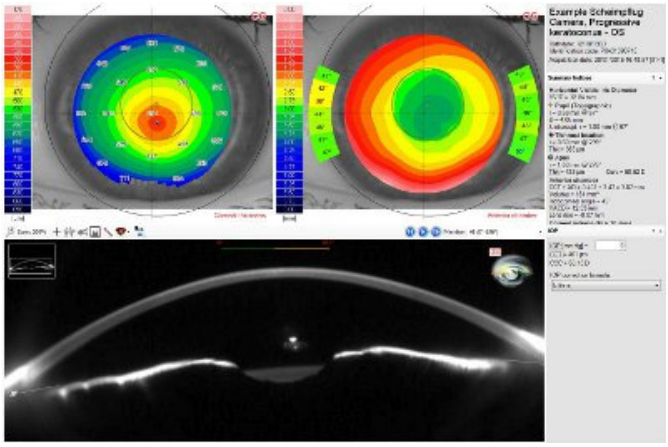
GLAUCOMA SUMMARY

Glaucoma summary is displayed by:
» by choosing **Glaucoma Summary** from the **Analysis** menu
» by clicking the icon on the toolbar

The summary consists of:
» Corneal thickness
» Anterior chamber
» A control for analyzing Scheimpflug images

The right hand panel shows:

» A panel with summary indices
» A control for the correction of intraocular pressure IOP from tomographic information.



Glaucoma summary

IOP

Insert the IOP number [mm Hg], the value of IOP measured with Goldmann applanation tonometer.
Independent studies show that the intraocular pressure (IOP) measured by Goldmann applanation tonometers maybe influenced by the thickness and corneal curvature..The software can adjust the IOP measurement on the basis of curvature and thickness, using various formulas for correction:

» Ehlers[1]
» Shah[2]
» Desdner[3]
» Orssengo/Pye[4]
» Kolhaas[5]

To assess the applicability of each formula please consult the related publications.

The acronyms for the IOP control have the following meaning:

» CCT: Central corneal thickness.
» CCC: Central corneal curvature.
» ΔIOP: Correction value for intraocular pressure measured with the Goldmann tonometer.
» IOP correct: Correct value by ΔIOP from IOP measured with Goldmann tonometer.

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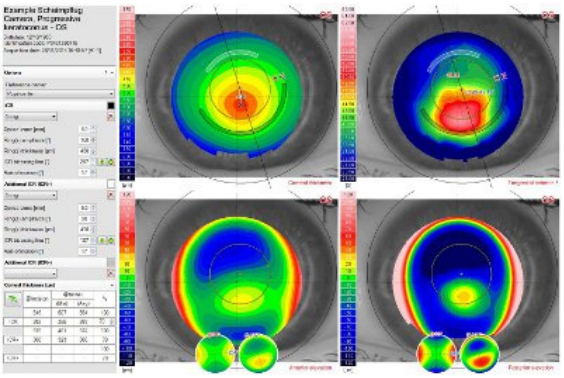
1. *Ehlers N, Hansen FK. Central corneal thickness in low-tension glaucoma. Acta Ophthalmol (Copenh). 1974;52:740-746.*
2. *Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol (Copenh). 1975;53:34-43.*
3. *Shah S, Chatterjee A, Mathai M, et al. Relationship between corneal thickness and measured intraocular pressure in a general ophthalmology clinic. Ophthalmology. 1999;106:2154-2160.*
4. *Shah S. Accurate intraocular pressure measurement—the myth of modern ophthalmology Ophthalmology. 2000;107:1805-1807.*
5. *Orssengo GJ, Pye DC. Determination of the true intraocular pressure and modulus of elasticity of the human cornea in vivo. Bull Math Biol. 1999;61: 551-572.*

INTRASTROMAL RINGS SUMMARY

Intrastromal rings summary is displayed:

» by choosing **Intrastromal rings** from the **Analysis** menu

» by clicking the icon on the toolbar



Intrastromal rings summary

Intra Corneal Rings Segments (ICRS) are devices made of PMMA that are successfully used in the treatment of myopia, severe post-keratoplasty astigmatism, post-refractive surgery ectasia of the cornea, keratoconus and pellucid marginal degeneration. Correction of myopia (from -1D to -3D) was the first field in which these rings were used[1], however, today they are widely used in eyes with keratoconus or pellucid marginal degeneration[2–7].
ICRs are semi-circular rings (or ring segments) the length, thickness and section of which varies. Their action is based on the fact that, by inserting these stiff elements inside the corneal stroma, they separate the corneal lamellae and thus shorten the anterior corneal arc. Introducing the ring segments in the peripheral media reduces the length of the fibre arc, thus flattening the central cornea. To get a better understanding of the modifications in corneal structure achieved with the "additive" surgical technique, we can look at the Barraquer "thickness law"[8–9]. According to this law, when you add material to the periphery of the cornea, therefore increasing the thickness of the peripheral cornea, you flatten the central cornea; instead, if you add material at the center of the cornea, you increase the central curvature. The extent of this effect is directly proportional to the thickness of the implant and inversely proportional to its diameter. Moreover, some scholars[10] who have used mathematical models that take into account the asphericity and/or spherical distortion of the eye to examine the effect of ICRs in correcting myopia, have shown that, to better flatten the anterior corneal surface, and thus improve the refractive effect, one needs to either insert thicker ring segments or implant them in a more central position.
When ICRs are used to treat corneas with keratoconus, the goal is not so much to eliminate the refractive defect as to improve both the patient's visual acuity and visual quality. In fact, in these cases, such rings lead to re-centring of the conus, thus normalizing the anterior corneal surfaces through a reduction in chromatic aberration, and reducing the ectasia by flattening the central cornea; all this reduces the irregular component of the astigmatism and reduces refractive correction (myopic and astigmatic). ICR implants for keratoconus must take into account the fact that, while the surgical technique is not particularly invasive and carries low risk of complications, there is the drawback that the pathological tissue is maintained. And thus it ensues that there are limitations for the choice of patients; in particular, patients with altered corneal transparency — Vogt's striae or stromal opacities -, advanced keratoconus and degenerated apex must be ruled out.
Different types of ICRs are available according to arc, thickness and implantation site. INTACSs are hexagonal-section segments in PMMA with arc circumference of 150 degrees. The external diameter of each segment is 8.10 mm, the internal diameter 6.77 mm and the thickness varies (ranging from 0.25 to 0.45 mm). Instead, INTACS SKs have an internal diameter of 6 mm, an oval section, and come in two thicknesses: 0.40 mm and 0.45 mm. The other two types of ICR are the Ferrara and Kerarings rings. Both have triangular section and come in various thicknesses and arc lengths.
For each ICR model, nomograms are available. Considering the patient's refraction and corneal morphology — obtained via corneal topography - these nomograms make it possible to precisely calculate the number, thickness and arc length for the rings to be implanted. It can also be decided whether to correct the patient's astigmatism or give priority to correction of chromatic aberration, as in the case of keratoconus patients whose visual capacity is limited by high corneal surface asymmetry. There is no fixed rule for this; one should take into account the best visual acuity correction and subjective refraction for each patient, above all for the axis of the subjective cylinder, and check these against the topographic and coma axes (in most cases one or the other coincides). It is possible to implant a ring or two segments that match or having different dimensions and thicknesses, or one can even insert several segments. Except for the site of the incision, the surgical technique for ICR implant treatment of keratoconus is similar to that used for the corrections of minor myopia. In fact, the incision site depends on where the segments are to be inserted and is calculated on a case-by-case basis. If the two segments to be implanted are asymmetrical, the thicker of the two is inserted in the lower position — as this recentres the conus —, while the thinner is inserted in the upper position — thus flattening the cornea and reducing the irregular astigmatism.
The ICR implant calls for making a peripheral incision, its distance from the centre varies according to the ring diameter; then a circular canal is created to accommodate the ICRs which are inserted by rotating them until they reach the desired position. The incision and canal can be created manually, with the aid of special instrumentation, or with a femtosecond laser. For myopia correction the incision is generally made at 12 o'clock, with the introduction of two segments set symmetrically on opposite sides, in the nasal and temporal sectors. To achieve the desired effect it is also important to insert the ICR in the back 2/3 of the cornea (70-78%) and, to that purpose, the pachymetric map must be carefully studied in order to calculate the proper implant depth. Remember, often the estimated incision depth does not correspond to the actual depth achieved; therefore the ICRs may actually be closer to the surface than envisaged; this is more evident when the incision is performed manually while use of a femtosecond laser appears to ensure greater precision.

The Summary of Intrastromal Corneal Rings is used to monitor corneal thickness in the area of the implant and, at the same time, provide a printable summary depicting the main topographic maps which are useful for this type of surgery.
The left side of the summary shows:

» The center of reference: choice between Center of the pupil and Center of the Limbus, specifying the site where the implant is to be centered;
» for each Ring/Pair of rings (up to 3), the tables provide the data for:
  - o Optical zone: indicating the diameter of the ring to be inserted, in millimetres;
  - o Size of the ring/s: indicating the amplitude of the arc for the ring to be insert, in degrees;
  - o Thickness of the ring/s: indicating the thickness of the ring selected for the implant, in microns;
  - o ICR bisector: indicating the degrees of the segment bisector and, in conjunction with the data for the Optical Zone and the center selected, determining the position for the corneal ring;
  - o Incision axis: indicating the position selected for the incision, in degrees. This position is suggested whenever the parameters, such as ring Bisector or Optical Zone, are changed.
» On the basis of the above parameters and the corneal morphology, the following are calculated, in microns:
  - o Corneal thickness in the incision zone.
  - o Average corneal thickness in the tunnel zone.
  - o Minimum corneal thickness in the tunnel zone.

These values are also provided, in percentages, when planning to use a femtosecond laser.
The central part of the screen shows:

» A Corneal thickness map: this map shows the ring (or rings) described in the previous section on the background of the patient's pachymetric map. Also, the thinner points, the center of the pupil and the distance between them, are also indicated.
» A curvature map among tangential anterior, tangential posterior and sagittal anterior: the keratometry data (SimK) are presented on the map.
» An anterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.
» A posterior elevation map: this map shows the astigmatism and coma data, in terms of the axis, derived from a calculation of the minimum squared error for a diameter of 8 mm.

The manufacturer bears no liability for consequential damages ensuing rom application of the results contained in the ICR Summary. The user of the program is responsible for checking the results and ensuring that the proposed values do not contain mistakes.

The **ICRS Summary** was developed and validated by CSO srl in cooperation with the following eye clinics:

» Prof. Giovanni Alessio, Ophthalmology Department, Policlinico di Bari, Bari, Italy
» Prof. Jose F. Alfonso, Cornea and Lens Department, Instituto Oftalmológico Fernández-Vega, Oviedo, Spain
» Prof. Luca Buzzonetti, Ophthalmology Department, Ospedale IRCCS "Bambino Gesù", Rome, Italy

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1. *Schanzlin DJ: Studies of intrastromal ring segments for the correction of low to moderate myopic errors. Trans Am OphthalmolSoc 1999; 97:815-819Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol (Copenh). 1975;53:34-43.*
2. *Coskunseven E, Kymionis GD, Tsiklis NS, et al. One-year results of intrastromal corneal ring segment implantation (KeraRing) using femtosecond laser in patients with keratoconus. Am J Ophthalmol 2008;145:775–9.Shah S. Accurate intraocular pressure measurement—the myth of modern ophthalmology Ophthalmology. 2000;107:1805-1807.*
3. *Shetty R, Kurian M, Anand D, et al. Intacs in advanced keratoconus. Cornea 2008;27:1022–9.*
4. *Colin J. European clinical evaluation: use of Intacs for the treatment of keratoconus. J Cataract Refract Surg 2006;32:747–55.*
5. *Ferrara G, Torquetti L, Ferrara P, et al. Intrastromal corneal ring segments: visual outcomes from a large case series. Clin and ExpOphthalm 2012; 40: 433–439*
6. *Rodrigues-Prats J, Galal A, Garcia-Lledo M et al. Intracorneal rings for the correction of pellucid marginal degeneration. J Cataract Refract Surg 2003; **29**: 1421–4.*
7. *Ertan A, Colin: Intracorneal rings for keratoconus and keratectasia. J Cataract Refract Surg 2007; 33:1303–1314*
8. *Barraquer JI: Queratoplastiarefractiva, estudios e informaciones. Oftalmologicas (Barcelona) 1949; 2:10–30*
9. *Barraquer JI: Modification of refraction by means of intracorneal inclusion. IntOphthalmolClin 1966; 6:53–78*
10. *Patel S, Marshall J, Fitzke FW III: Model for deriving the optical performance of the myopic eye corrected with an intracorneal ring. J Refract Surg 1995; 11:248–52*

ASPHERO-TORIC FITTING | ANTERIOR/POSTERIOR

Asphero-toric fitting screen is displayed:

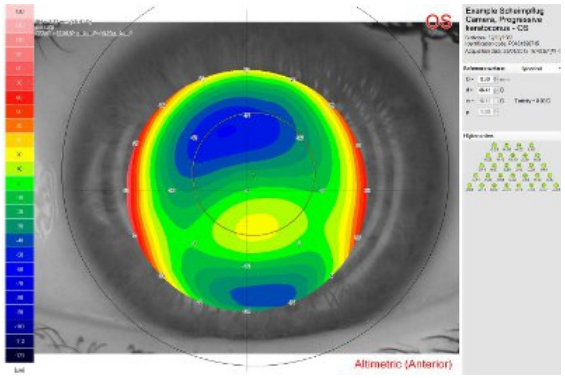
» by choosing **Asphero-toric fitting (Anterior)** or **Asphero-toric fitting (Posterior)** from the Analysis ▶ Advanced menu

» by clicking the ▶ icon on the toolbar

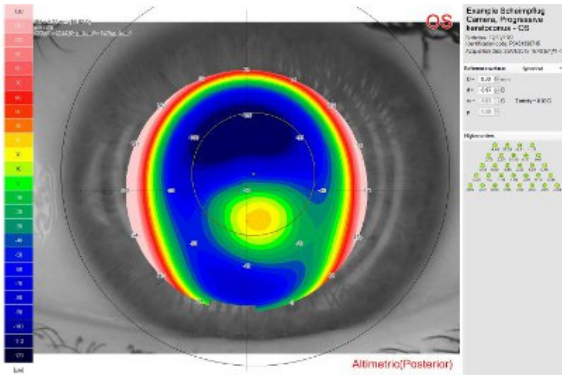
The asphero-toric fitting represents the corneal map as offset by a surface reference, that can be chosen by the operator using the menu options on the right hand side of the screen.
Using the pull-down list it is possible to select the surface against which we want to offset the examined eye:

» Spherical the reference surface is a sphere
» Aspheric the reference surface is aspheric or more precisely a conicoid. The asphericity value, (in p, e, e2 or Q) can be chosen from options
» Asphero-toric the reference surface is asphero-toric. The toricity is calculated by the software as the difference between rf and rs.

Depending on the selected surface reference type, some of the parameters (like rf, rs or the asphericity) are editable. Any modification of the diameter will result in an adjustment of the parameters for the reference surface to the surface that best represents the examined eye on the diameter (Ø mm) chosen.
The difference between the selected surface and the surface reference is decomposed in Zernike polynomials up to the 7th order, allowing the selection (by double-clicking) of each single fitting component on the map.



Asphero-toric fitting anterior



Asphero-toric fitting posterior

GAUSSIAN CURVATURE ANTERIOR

Gaussian curvature screen is displayed:

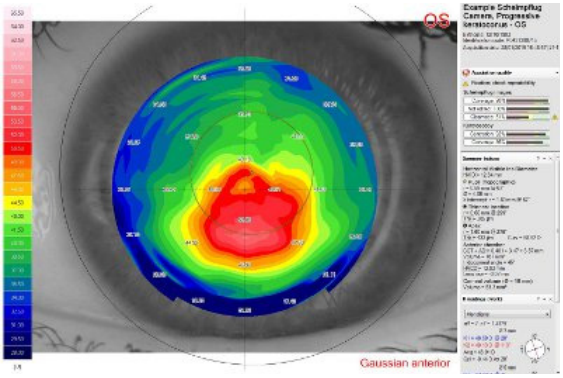
» by choosing **Gaussian curvature** from the **Analysis** ▶ **Advanced** menu

» by clicking the ▶ icon on the toolbar

This screen displays a **Gaussian curvature** map in full-screen mode.
Both, Sagittal and Tangential maps, show the curvature values of a surface along meridians: in other words, they do not consider the surface curvature in sections different from the meridional one.
The Gaussian curvature of a point on a surface is the "real" curvature being the geometric mean of the principal curvatures, i.e. the square of the product of the curvatures along the directions where they are maximum and minimum.
Is measured in millimeters or diopters according to the preferred user setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:

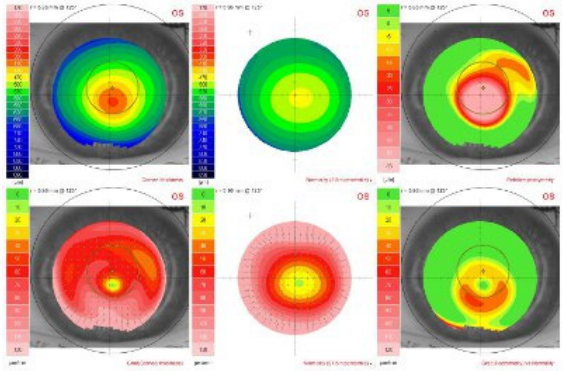
» The coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The gaussian curvature at the point taken into consideration.



Gaussian curvature anterior

ADVANCED PACHYMETRY

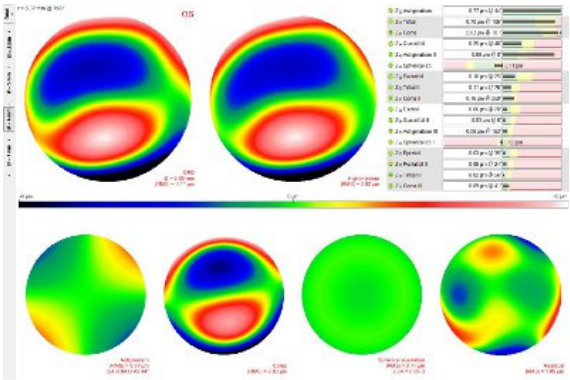
Advanced pachymetry screen is displayed:
» by choosing **Advanced pachymetry** from the **Analysis** ▶ **Advanced** menu
» by clicking the ▶ icon on the toolbar


Glaucoma summary

This screen displays a clinical summary of the advanced analysis of thickness data.
The summary is made up of six maps:
» corneal thickness map is shown in top left position;
» the reference threshold map for normality is shown in the top center position: the user can choose between the 1st, the 2.5th, the 5th and the 50th percentile of the thickness map of the normal population;
» the difference between the corneal thickness map and the chosen reference threshold is shown in top right position: the non-green areas show a value inferior to the reference;
» the gradient of corneal thickness map is shown in bottom left position;
» the reference threshold map for normality referred to the gradient of corneal thickness is shown in the bottom center position: the user can choose between the 50th, the 97.5th, the 95th and the 99th percentile of the gradient of corneal thickness map of the normal population;
» the difference between the gradient of corneal thickness map and the chosen reference threshold is shown in bottom right position: the non-green areas show a value superior to the reference.

ZERNIKE SUMMARY

Summary is displayed:
» by choosing **Zernike Summary** from the **Analysis** menu
» by clicking the icon on the toolbar


Zernike Summary

The program permits conducting analysis of the wavefront generated by the cornea, obtained by topographic data through Zernike analysis. The aberrometric map expresses the differences in height between the wavefront generated by the cornea being examined and a spherical perfect wavefront. The aberrations are displayed as total aberrations and divided into their various components. A set of 36 Zernike polynomials is used for the analysis of the various components of total aberration; the analysis results are reported in the summary as numerical indices and as graphic representations. The pupil diameter may be selected on the left side of the screen in a range from 2 mm to 8 mm with 0.5 mm steps. Total wavefront (obtained by ray-tracing using both anterior and posterior surface), anterior surface wavefront (i.e. considering only the anterior surface) or the posterior surface wavefront (defined as the difference between the total and anterior only) analysis is allowed.
This screen is highly influenced by the parameters chosen on the Wavefront configuration window.

Several Wavefront error maps are shown in the screen:
» Total OPD/WFE (i.e. the total amount of the Wavefront error within the analysis diameter)
» Higher orders (i.e. the amount of the Wavefront corresponding to the order polynomials from 3 to 7)
» Astigmatism (i.e. the amount of polynomials Z2-2 and Z2+2). Bottom-right of the map the value of the Cylinder and its RMS are shown.
» Coma (i.e. the amount of polynomials Z3-1 and Z3+1). Bottom-right of the map the value of coma RMS is shown.
» Spherical aberration (i.e. the amount of polynomial Z40). Bottom-right of the map the value of the LSA and the Spherical Aberration RMS are shown.
» Residual (i.e. the total amount of the Wavefront removing the amount of Astigmatism, Coma and Spherical Aberration).

ZERNIKE POLYNOMIALS

On the upper right there is a table which summarizes the decomposition of Zernike for the current wavefront into its aberrations:

» The first column carries the names of the polynomials. Generally speaking, each aberration is represented by a pair of polynomials. Axis-symmetric aberrations are represented by single polynomials.
» The second column gives a RMS value and the relative meridian for each aberration.
» The last column displays the histogram of the coefficients of expansion of the Zernike polynomials: the bars represent the weighted value for each aberration. The normality data, represented by the green, yellow and red bars, are derived from a statistical study on 1000 normal eyes.

OPTICAL QUALITY SUMMARY

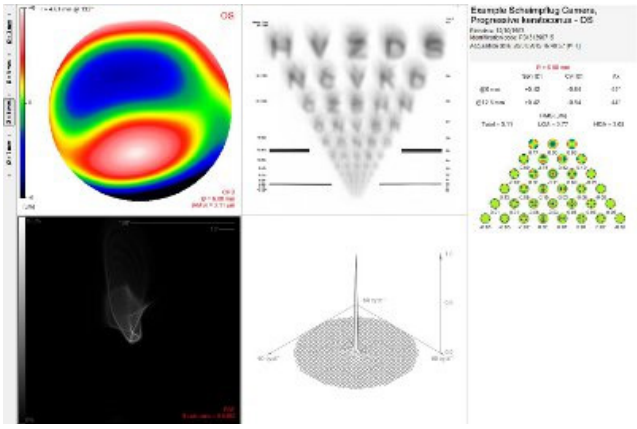
Optical Quality Summary is displayed:
» by choosing Optical Quality Summary from the Analysis menu
» by clicking the icon on the toolbar

This form permits an overall analysis of visual quality.
From top-left to the bottom-right are shown:

» OPD/WFE map;
» Vision Simulation;
» PSF;
» MTF.

In the right panel the Zernike pyramid, displaying the coefficients of the corneal wavefront decomposition, is shown.

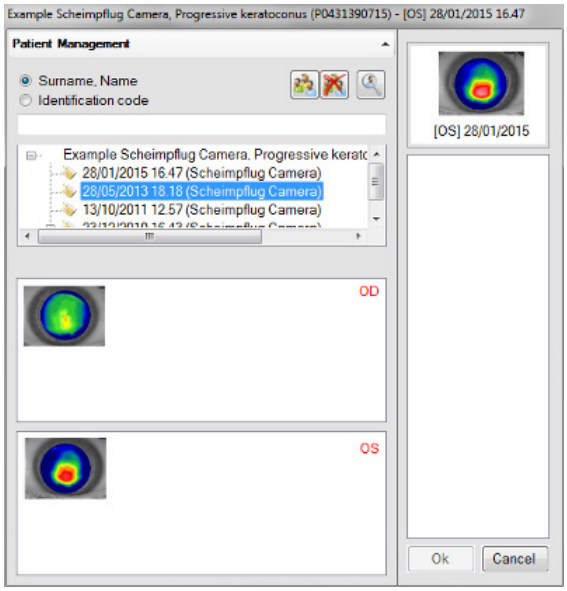
The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Total, Anterior or Posterior)



Optical Analysis Summary

COMPARISON/FOLLOW-UP IMAGE SELECTION

The first operation to start a comparison/follow-up analysis is to select the images to be compared. The first image is chosen by default, the one from where we open the selection window, other images have to be manually chosen by the user. The window that shows up provides on opening the current patient/examination.
If the images to be compared do not belong to the current patient/examination standard tools for the examination search are provided: the button shows the complete patient database, whereas the button allows for an advanced search. Upon selecting a patient and the accompanying examination you can add images to the selection by double-clicking them or dragging them to the selection panel. The number of selected images may vary depending on the context of the follow-up operation. Click **OK** to continue, **Cancel** to stop the comparison.



Manual selection of the acquisitions to be compared.

COMPARISON

Comparison is displayed by:

» Choosing **Comparison** from the **Analysis** menu

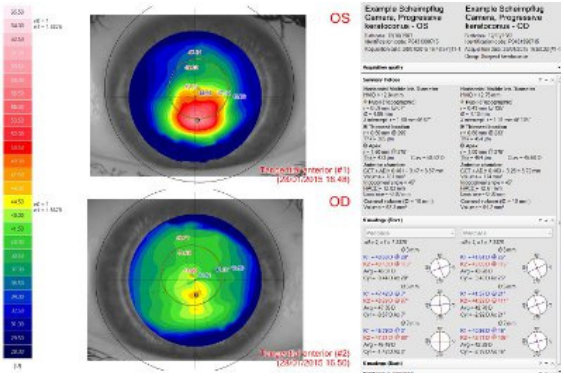
» clicking the icon from the toolbar.

After the manual selection of the images to be compared, a window with the selected images is shown. It's possible to select 2, 3 or 4 maps.

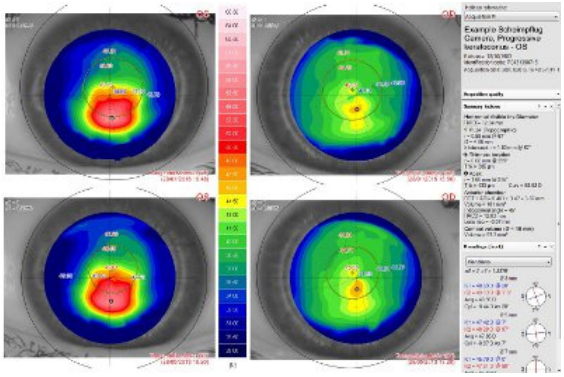
The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label Current map.

The comparison of two maps allows for the contemporary display of both sets of indices. The selection of more than 2 maps, means you have to choose the indices to be displayed. In this case the drop down box at the top of the right panel is for selecting the images the indices refer to.

Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Comparison X2



Comparison X4

COMPARE OD/OS

It is possible to compare the right and left eye avoiding the manual selection by:

» Choosing Compare OD-OS from the Analysis ▶ Comparison menu

» Clicking the icon on the toolbar.

A comparison screen between the current eye and the fellow eye will be shown.

DIFFERENTIAL

Differential is displayed by:

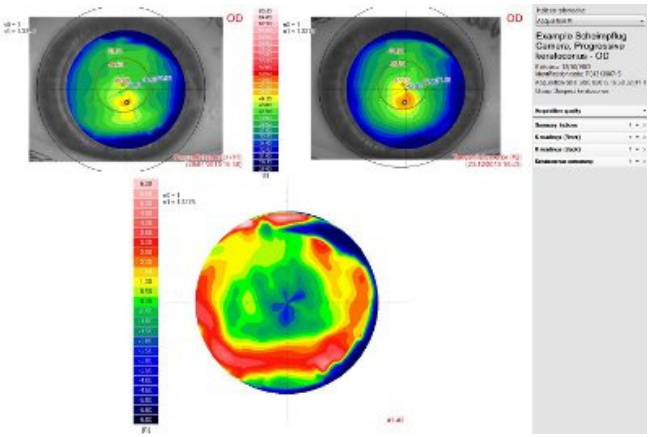
· Choosing **Differential** from the **Analysis** menu

clicking the icon from the toolbar.

After the manual selection of the images to be compared two or three maps (current map plus one or current map plus two) and their relative difference are shown: maps in the lower part of the window show the differences between the maps in the upper part. In the case of a differential on 2 maps, the difference between 1st and 2nd is shown. In the case of a differential on 3 maps, the difference between 1st and 2nd, between 1st and 3rd and between 2nd and 3rd are shown.

The topographic information to be compared is to be selected from the drop-down menu in the upper-right corner, next to the label Current map. The drop down box at the top of the right panel is for selecting the image the indices refer to.

Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Differential

IMAGE COMPARISON

Comparison is displayed by:
» Choosing **Image comparison** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection, the Scheimpflug images are shown.

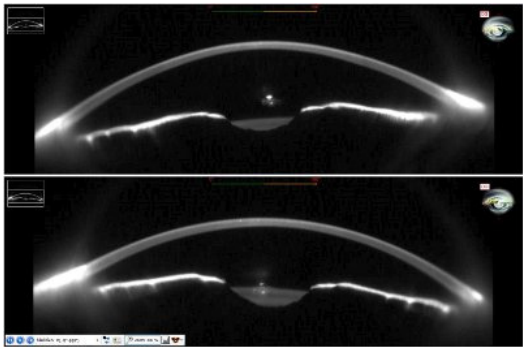


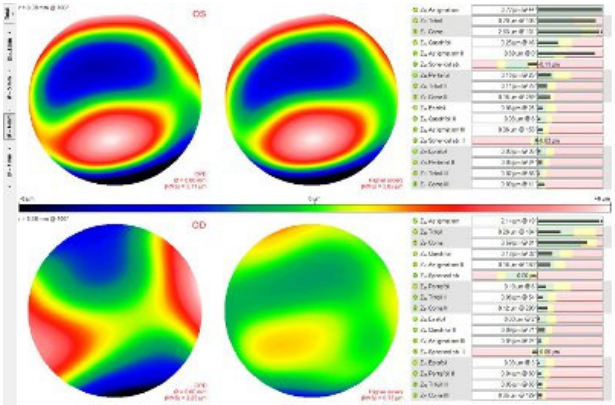
Image Comparison

WAVEFRONT COMPARISON

Comparison is displayed by:
» Choosing **Wavefront Comparison** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:
» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



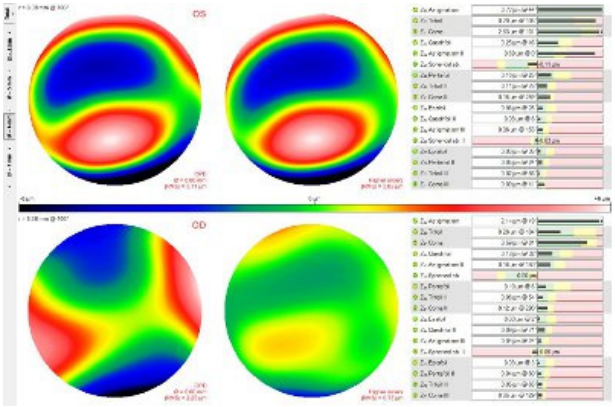
wavefront Comparison

WAVEFRONT DIFFERENTIAL

Comparison is displayed by:
» Choosing **Wavefront Comparison** from the **Analysis** menu
» clicking the icon from the toolbar.

After the manual selection of the image to be compared, the Zernike wavefront analysis of the two selected images is shown.

The analysis consists of:
» Total OPD/WFE map (i.e. the total amount of the wavefront error within the analysis diameter)
» Higher orders map (i.e. the amount of the wavefront corresponding to the order polynomials from 3 to 7)
» The list of the Zernike coefficient summarizing the decomposition of Zernike for the current wavefront into its aberrations.



wavefront Comparison

KERATOCONUS FOLLOW-UP

Comparison is displayed by:

» Choosing **Keratoconus follow-up** from the **Analysis** menu

» clicking the  icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

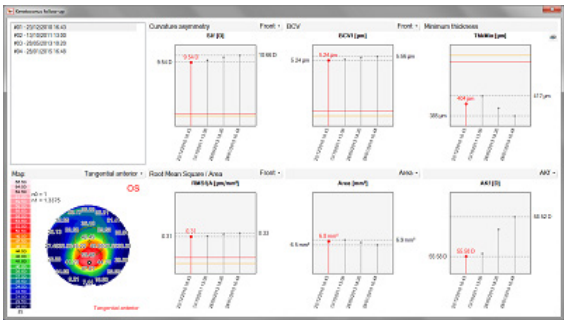
The screen is made up as follows:

» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.

» One of following maps can be selected for displaying.
- o Corneal thickness
- o Tangential anterior
- o Tangential posterior
- o Elevation anterior
- o Elevation posterior

The map refers to the selected image.

» 6 histograms referring to the main keratoconus indices are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. If available the border-line threshold (5th or 95th percentile) is shown in orange and the abnormality threshold (1th or 99th percentile) is shown in red



Keratoconus follow-up

REFRACTIVE SURGERY FOLLOW-UP

Comparison is displayed by:

» Choosing **Refractive surgery follow-up** from the **Analysis** menu

» clicking the icon from the toolbar.

After the manual selection of the images to be inserted on the follow-up, a window with the selected images is shown.

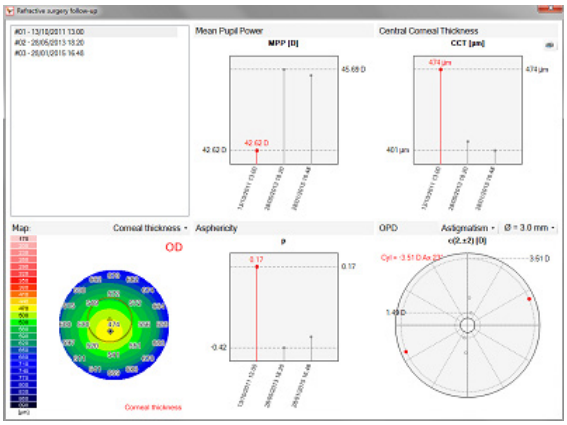
The screen is made up as follows:

» List of selected images ordered by date: by selecting an item the corresponding map is shown and the corresponding index will be highlighted.

» One of following map can be selected:
- o Corneal thickness
- o Tangential anterior
- o Tangential posterior
- o Sagittal anterior
- o Sagittal posterior
- o Elevation anterior
- o Elevation posterior
- o Refractive anterior power
- o Refractive posterior power
- o Refractive equivalent power

The map refers to the selected acquisition.

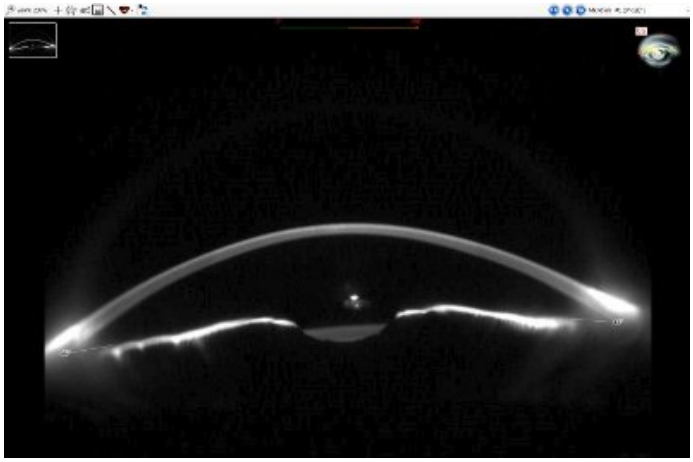
» 3 histograms (MPP from Refractive analysis, CCT from Summary Indices and corneal asphericity at 8mm from Shape Indices) are shown. In abscissa the date and time of the acquisition is shown; in ordinate the value of the index is associated to the height of a vertical bar. A polar chart displaying magnitude and axis of the cylinder at a selectable diameter (from Refractive analysis) is also shown.



Refractive surgery follow-up

SCHEIMPFLUG IMAGES

The control shows a single Scheimpflug image.
Above the image a toolbar with the following tools can be found:



Display of the Scheimpflug image

	Zoom	When selected, it is possible to change the magnification of the image shown on the screen, using the mouse wheel or the +/- keys
	Distance	Allows for measurement of a distance between two points on the image. Click to mark the starting point and click again to mark the end point. To delete the latest measurement, press **Del** or **Backspace** key.
	Cartesian coordinates	When selected, clicking on a point of the anterior chamber its (x,y) location from the corneal vertex is shown. To delete the latest measurement, press **Del** or **Backspace** key.
	Magic wand	When selected, clicking on a point of the anterior chamber, a line passing through that point going from the corneal posterior surface to the iris or to the lens will be drawn and measured. If the point is higher than the anterior surface it will measure corneal sagitta, when lower than the posterior surface, the anterior chamber depth is measured. The function will not work outside of mapped zones. To delete the latest measurement, press **Del** or **Backspace** key.
	Angle	Allows to draw and measure an angle. To draw the angle, click to mark once the vertex and two times to indicate both sides of the angle. To delete the latest measurement, press **Del** or **Backspace** key.
	Histogram	An indication of the opacity of the cornea and lens is provided: the numeric value assigned indicates a value from 0 to 100 reflecting the relative opacity. To move the origin of the graph, click on the point of interest
	Brightness	When this item is selected, it is possible to change the brightness of the image, using the mouse wheel
	Contrast	When this item is selected, it is possible to change the contrast of the image, using the mouse wheel
	Gamma	When this item is selected, it is possible to change the gamma of the image, using the mouse wheel
	Restore	Restores the original values for the image, undoing any kind of modification to brightness, contrast and gamma
	Toggle smoothing	Sets the interpolation mode of the image
	Invert background color	Inverts the image's greyscale

MAPS

Several maps are available taking into consideration different corneal attributes:

» Sagittal anterior
» Sagittal posterior
» Tangential anterior
» Tangential posterior
» Corneal thickness
» Epithelial thickness map
» Elevation anterior
» Elevation posterior
» Refractive anterior power
» Refractive posterior power
» Refractive equivalent power
» Anterior chamber

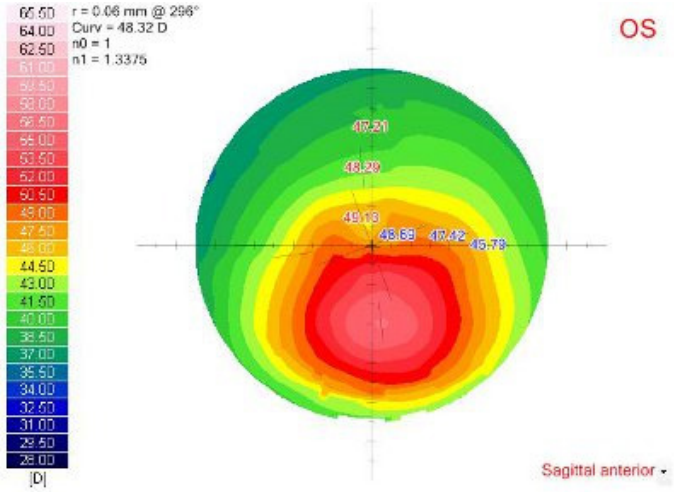
SAGITTAL ANTERIOR MAP

This map represents, point by point, the distribution of the ante-rior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flat-ter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar accoding to the preferred setting;
» The curvature at the point taken into consideration.

The refraction index used for the conversion formula be-tween millimeters and diopters.

Right-clicking opens the Tools and display options menu.



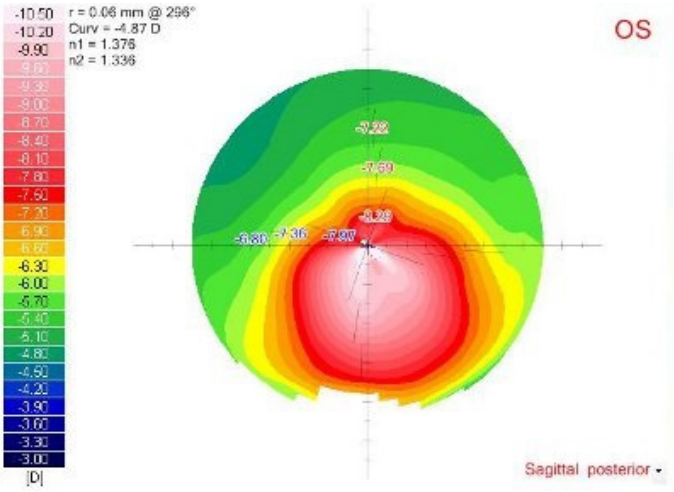
Anterior sagittal curvature map

SAGITTAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior sagittal curvature (also called axial curvature) in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



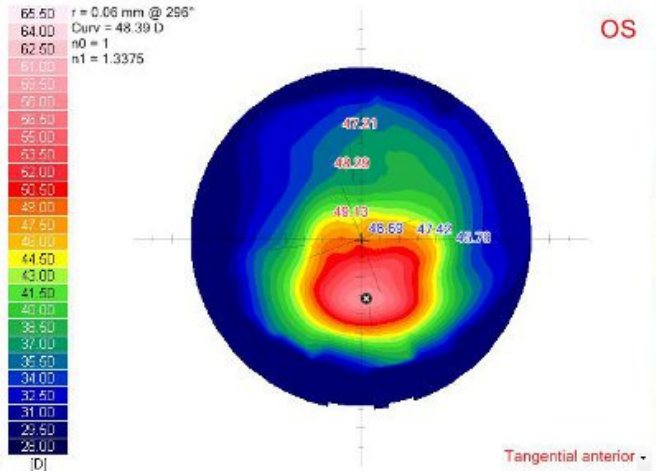
Posterior sagittal curvature map

TANGENTIAL ANTERIOR MAP

This map represents, point by point, the distribution of the anterior tangential curvature in millimeters or diopters according to the preferred setting. With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊗ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



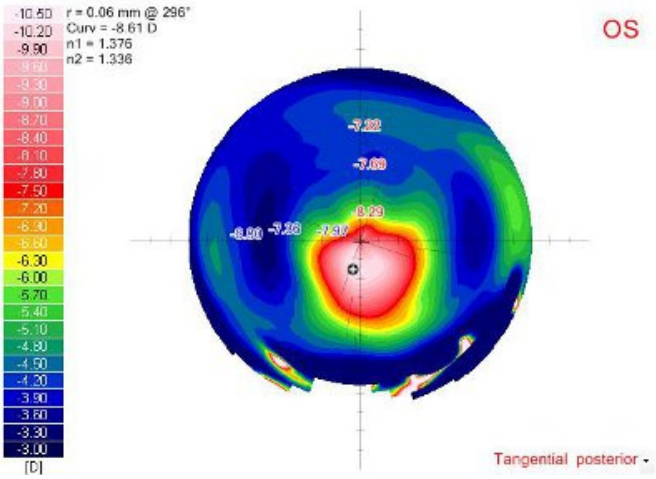
Anterior tangential curvature map

TANGENTIAL POSTERIOR MAP

This map represents, point by point, the distribution of the posterior tangential curvature in millimeters or diopters according to the preferred setting. When the values are expressed in diopters, conversion is carried out taking into consideration the refraction indices of the stroma (1.376) and the aqueous humor (1.336) and the curvatures are indicated with negative numbers.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with steeper curvature zones and the cool colors (green, blue) are associated with flatter curvature zones.
The steepest point is marked by the ⊗ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The curvature at the point taken into consideration.
» The refraction index used for the conversion formula between millimeters and diopters.

Right-clicking opens the Tools and display options menu.



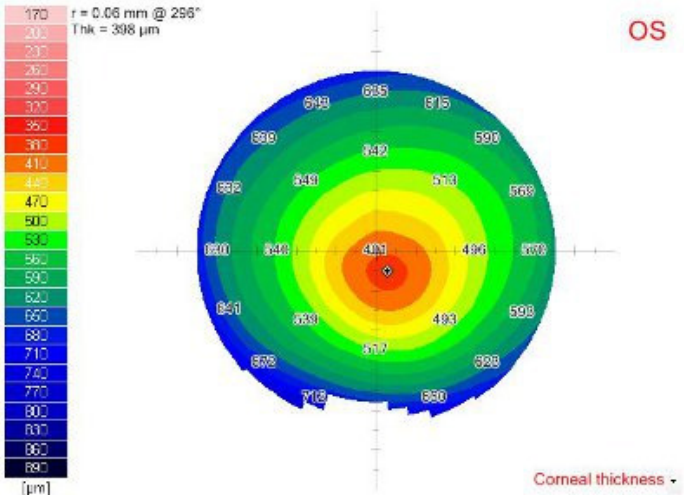
Posterior tangential curvature map

CORNEAL THICKNESS MAP

This map represents, point by point, the distribution of the thickness of the cornea in microns (µm).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with thinner zones and the cool colors (green, blue) are associated with thicker zones.
The thinnest point is marked by the ⊕ sign.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The corneal thickness at the point taken into consideration.

Right-clicking opens the Tools and display options menu.



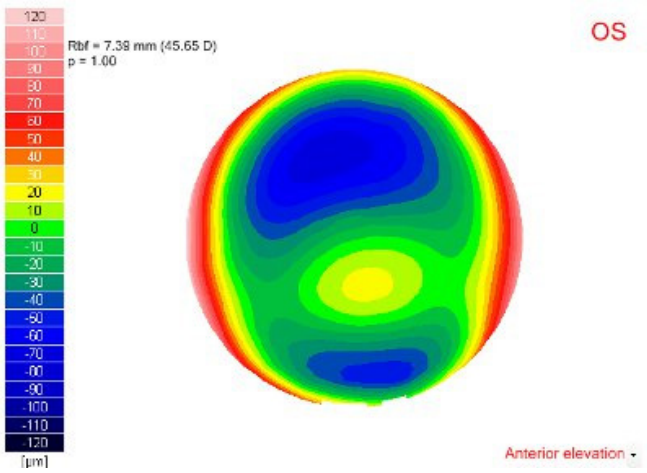
Corneal thickness map

ELEVATION ANTERIOR MAP

This map represents in microns (µm), the elevations of the anterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



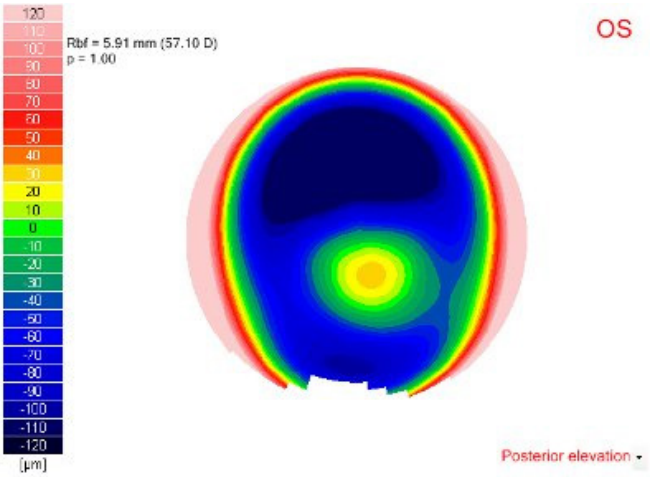
Elevations anterior map

ELEVATION POSTERIOR MAP

This map represents in microns (µm), the elevations of the posterior surface of the cornea as a difference with respect to a reference surface. The reference surface is selected in such a manner as to minimize the mean square error of the corneal elevations.
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with areas lying above the reference surface and the cool colors (green, blue) are associated with areas lying below the reference surface.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Δz: point-by-point difference along the z axis, in µm.
» Shape parameters (apical radius, asphericity and toricity axis of the best-fit reference surface).

Right-clicking opens the Tools and display options menu.



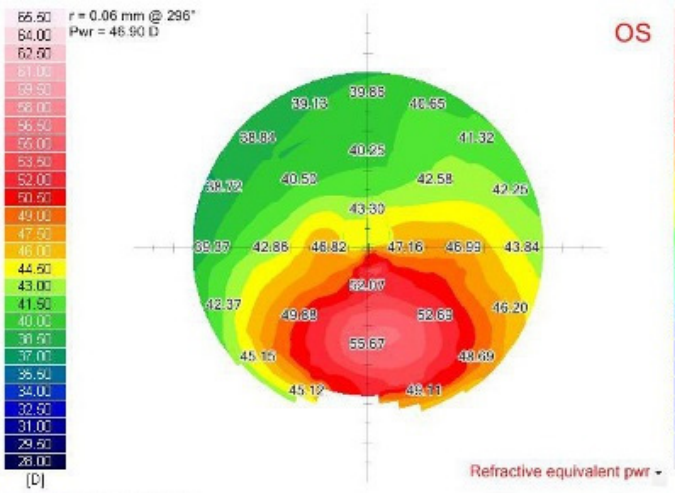
Elevations posterior map

REFRACTIVE EQUIVALENT POWER MAP

This map represents, point by point, the distribution of the total corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior and posterior corneal surface for each point. The reference indices for the two interfaces are the air index (N0=1), stroma index (N1=1.376) and the index for the aqueous humor (N2=1.336).
With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:
» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration . This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Refractive equivalent power map

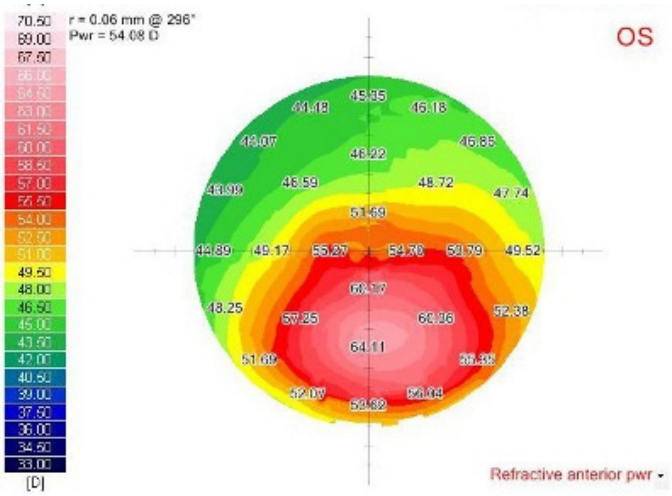
REFRACTIVE ANTERIOR POWER MAP

This map represents, point by point, the distribution of the anterior corneal power.
It's expressed in diopters and is calculated by ray-tracing through the anterior corneal surface for each point. The refractive indices for the interface Air-Cornea are those of the air (N0=1) and of stroma (N1=1,376). With reference to the Klyce/Wilson scale the warm colors on the map (red, orange, yellow) are associated with higher power zones and the cool colors (green, blue) are associated with lower power zones.

At the top left of the map are indicated:

» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» The refractive error at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Refractive anterior power map

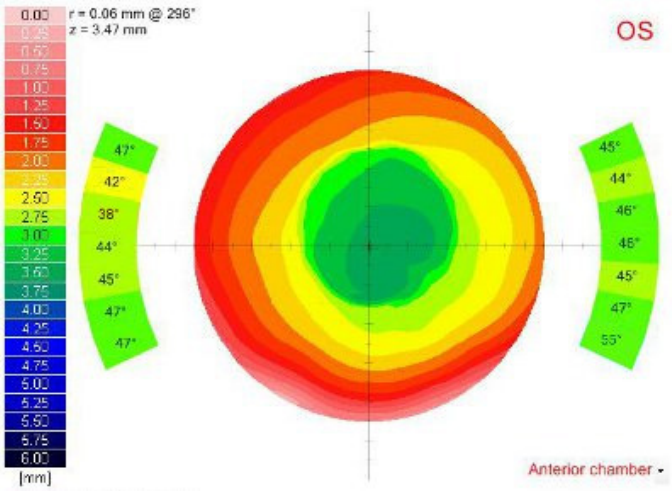
ANTERIOR CHAMBER MAP

This map represents, locally the anterior chamber depth, i.e. the distance between the posterior surface of the cornea and the iris or the crystalline lens. On the left and right sides of the map, the values of the irido-corneal angles are reported.

At the top left of the map are indicated:

» the coordinates of the cursor (visible only when the mouse cursor moves on a map) expressed in Cartesian or Polar according to the preferred setting;
» Chamber depth at the point taken into consideration. This value is only visible when the mouse cursor moves on the map.

Right-clicking opens the Tools and display options menu.



Anterior chamber map

MAP CONTEXT MENU

	Cursor	When this item is selected, the coordinates and the numeric values of the map under the mouse pointer are displayed as it is moved. Left-click drops the cross, making it independent of the mouse pointer. A second click realigns the reference cross with the mouse pointer.
	Distance	Select this item to trace a segment on the map for measuring the distance between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The length of the chosen segment will be displayed on the map, in millimeters.
	Graph	With this item selected the graphs representing the map profile along the meridian passing center of the map and the mouse pointer is displayed. The graph rotates during selection of the meridian: clicking on the desired orientation that particular meridian will be chosen and its chart will be shown horizontally.
	Gradient	Select this item to trace a segment on the map for measuring the distance and the gradient between two points. To trace the segment, left-click any point on the map, then move the mouse to the desired end-point and left-click again. The difference and the gradient between the two selected points will be shown and the length of the chosen segment will be displayed on the map.
	Show/Hide value on cursor	Shows or hides the numeric value over the map at the cursor position when a mouse movement occurs.
	Show/Hide pupil	Shows or hides the contour of the pupil.
	Show/Hide eye	Shows or hides the image of the eye under the map.
	Show/Hide eye	Shows or hides the image of the eye under the map.
	Background	▶ **Keratoscopy:** The keratoscopy is shown as background on the map. This setting is enabled when Show Eye is activated. ▶ **Iris:** The iris image is shown as background for the map. This setting is enabled when Show Eye is activated.
	Show/Hide ruler	Shows or hides the two perpendicular millimeter rulers (the shorter division corresponds to 0.5 mm; the longer division corresponds to 1 mm).
	Show/Hide meridians	Shows or hides a polar grid.
	Show/Hide goniometer	Shows or hides a goniometer.
	Show/Hide zones	Shows or hides a series of concentric rings (with 3, 5, 7, 9 mm diameters)
	Show on map	Show or hide numeric values over the map: ▶ **Nothing:** No numeric value is displayed over the map. ▶ **Numeric values:** The numeric values are shown on each map on a point grid. ▶ **Map-dependent:** K-readings (Front) are shown on the anterior curvature maps and anterior elevation map. K-readings (Back) are shown on the posterior curvature maps and the posterior elevation map. Numeric values are shown on all other maps.

INDICES

On the right side of several analysis windows a selection of panels is available, containing information and indices referencing the current image:

» Patient data
» Acquisition Quality
» Summary Indices
» K-Readings (Anterior)
» K-Readings (Posterior)
» Shape Indices
» Refractive analysis
» Keratoconus Screening

The ▼/▲ arrow on the title bar expands/collapses the related panel.
The ? button opens its help window.

Click the button × on the title bar to remove a panel from the lateral section of the window. To restore the removed panels, elect ►**Restore** on the right side of the main Toolbar.

ACQUISITION QUALITY

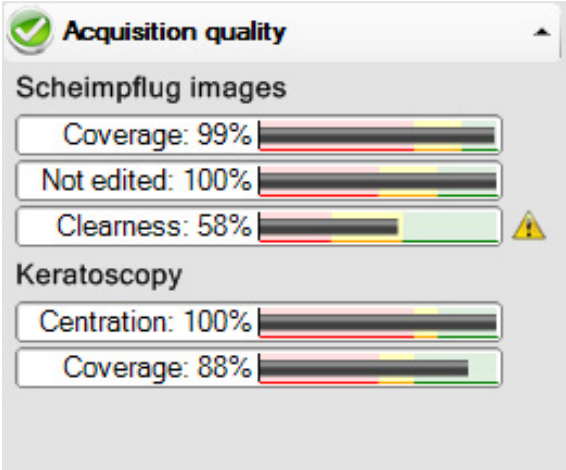
It shows some indices which indicate the quality of both the Scheimpflug and keratoscopic acquisitions.
In more detail, the coverage of the Scheimpflug tomographies is considered, the percentage of images that were manually edited, as well as the clearness of the stromal tissue is taken into consideration as an index of corneal hyper-scattering.
Rings coverage for the Keratoscopy and the well-centeredness of the cornea respective to the instruments axis is reported under the group Keratoscopy.

The indices are preceded by when the acquisition quality seems to be satisfactory; by a warning when we recommend you take more acquisitions.

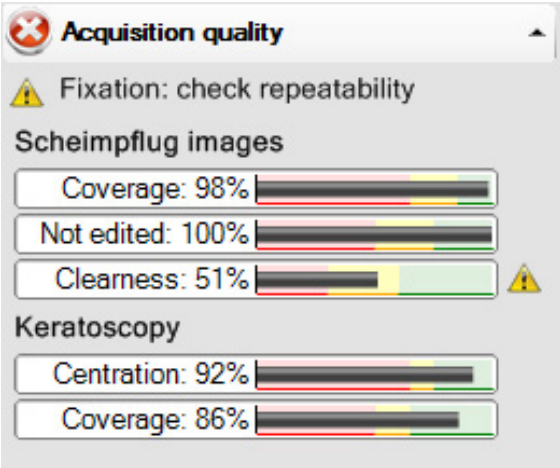
The warning "Fixation: check repeatability" is a help for selecting good acquisitions. It appears when the pupil position of the current acquisition is outside a "normal zone", i.e. the zone where the pupil position is located in normal fixating eyes. If this warning is present, there can be two cases:

» The patient is not fixating, so it is necessary to acquire again after asking the patient to fixate on the fixation point.

The patient is fixating, but the eye is anomalous (for example if the eye is a keratoconus). In this case the pupil position is always decentered in every acquisition. So, the warning has to be interpreted as an anomalous fixation of the patient.



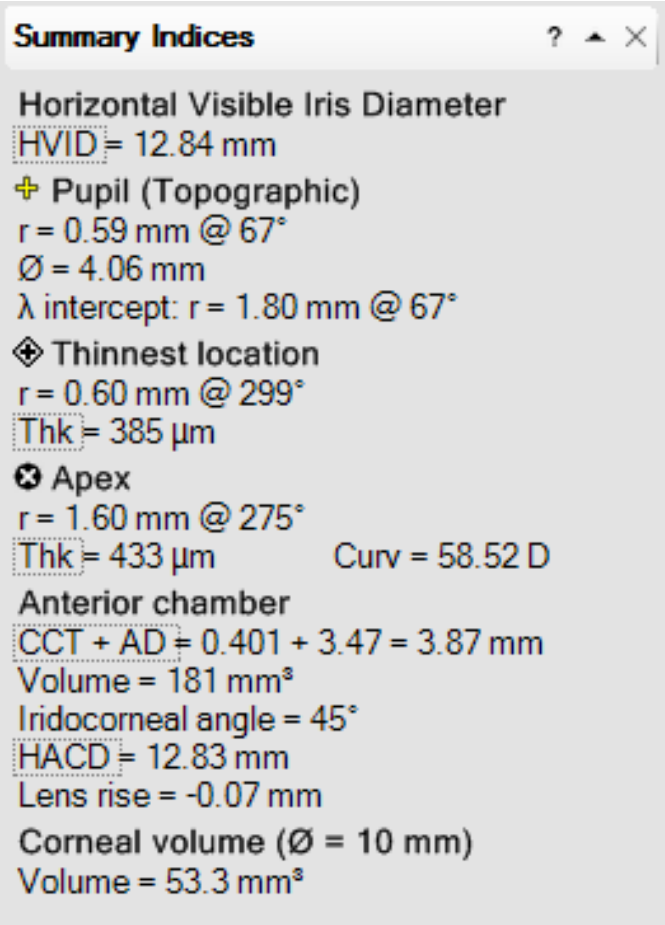
Acquisition quality for a satisfactory acquisition



Acquisition quality for an unsatisfactory acquisition

SUMMARY INDICES

- **HVID (Horizontal Visible Iris Diameter):** it is the limbus size (in mm) in the horizontal direction. It is derived from the keratoscopic image.
- **Pupil** (Topographic): the symbol shows the pupil center position in the maps. x,y and r,@ are, respectively, the cartesian and polar coordinates of the pupil centre, shown in the Summary indices panel according to the preferred setting. Ø is the diameter of the topographic pupil.
  λ intercept is the intercept between the pupillary axis and the anterior corneal surface. The pupillary axis is the line passing through the center of the entrance pupil, and which is normal to the cornea.
- **Thinnest location:** the symbol indicates the position of the corneal thinnest point in the maps. Its coordinates are shown in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry in this point.
- **Apex:** the symbol indicates the steepest point position in the maps. Its coordinates are shown in in the Summary indices panel in cartesian or polar coordinates according to the preferred setting. Thk is the pachymetry and Curv is the curvature in this point.
- **Anterior Chamber**
  - **CCT + AD** : **CCT** is the central corneal thickness. AD is the aqueous depth, (i.e. the distance between the corneal posterior surface and the anterior surface of crystalline lens in correspondence to corneal vertex).
  - **Volume:** the volume of the portion of the anterior chamber limited by the back surface of cornea, the iris and the crystalline lens, in a 12mm diameter zone.
  - **Iridocorneal angle:** the average of the measured angles for the meridians whose angular position is included in the range +/- 25° from the horizontal meridian.
  - **HACD (Horizontal Anterior Chamber Diameter):** it is measured as the distance between the vertices of the iridocorneal angles.
  - **Lens rise:** it is the difference between the position of the crystalline lens and the iridocorneal plane, i.e. the best-fit plane "passing" through the vertices of the iridocorneal angles. A negative value means that the crystalline lens is above the iridocorneal plane.
- **Corneal Volume:** the corneal volume within a diameter equal to 10 mm.



Summary indices

K-READINGS (FRONT)

From the sagittal data of the anterior cornea it is possible to derive kerato-metric data related to the principal meridians: these data can be expressed as

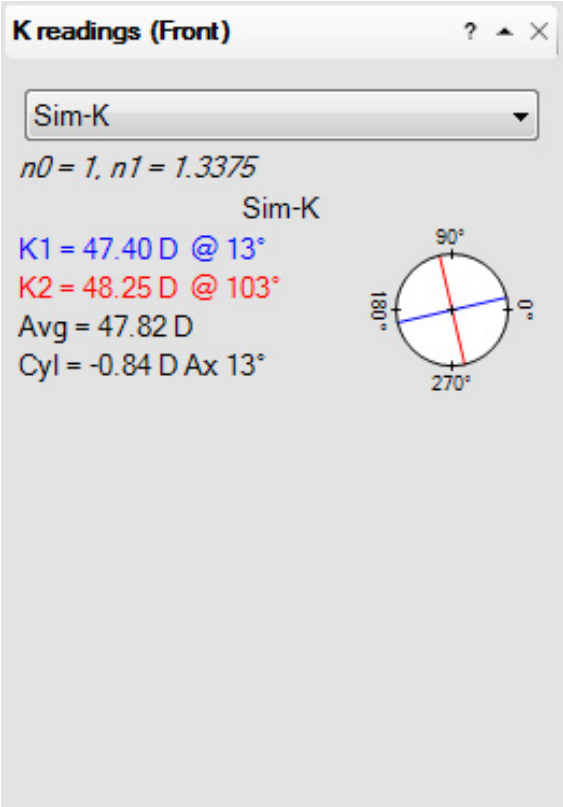
» Sim-K
» Meridians
» Emi-meridians
» Peripheral degrees

SIM-K

Sim-K represents the simulation of the readings that would be ob-tained with a keratometer, (i.e. the mean sagittal curvature from the 4th to the 8th Placido ring). The considered zone has a variable amplitude depending on the curvature of the measured cornea.
The following values are available for Sim-K:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



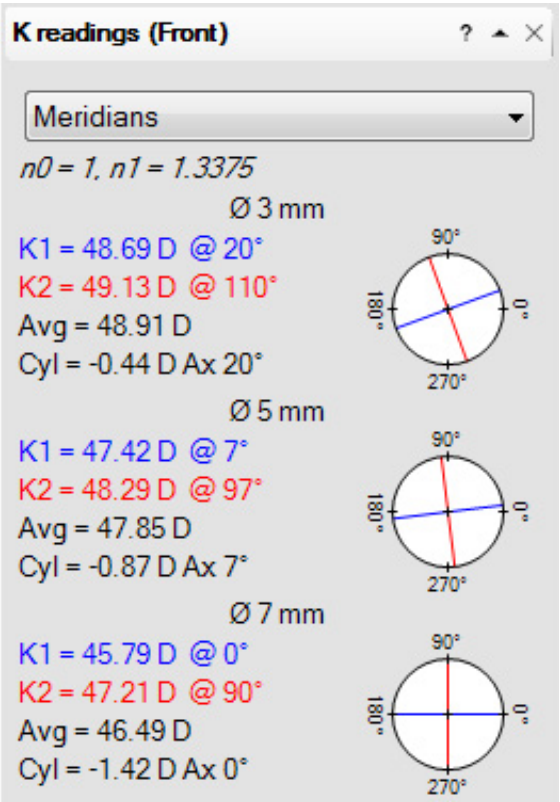
K-readings (front): Sim-K

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the anterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians K1 and K2.
» **Avg:** mean curvature for the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.



K-readings (front): Meridians

HEMI-MERIDIANS

If this option is selected, the two pairs of flattest and steepest hemi-meri-dians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-me-ridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians K1 and K2.

N0 and N1 are the refractive indices used for converting the values of cur-vature from mm to D. N_0 is the index of refraction of the air (=1). N1 is the keratometric index (=1.3375) or the index of refraction of cornea (=1.376) according to the preferred setting.

» rior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

VERTICES

» Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT) and on the on the posterior corneal surface (**KVb** – Keratoconus VertexBACK) are shown.

ELEVATION BASED INDICIES

» The indices **BCVf** e **BCVb** allow the evaluation of the presence of, and the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetries $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) \; + \gamma C_4^{0}$$

The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normality values are shown (95° percentile e 99° percentile of a normal population);
The index BCV or vectorial **BCV** is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normality values are shown (95° percentile and 99° percentile of a normal population).

THINNEST POINT

» Thinnest point of cornea ThkMin is shown.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:
» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

K-READINGS (BACK)

From the sagittal data of the posterior cornea it is possible to derive kerato-metric data related to the principal meridians: these data can be expressed as

» Meridians
» Hemi-meridians
» Peripheral degrees

MERIDIANS

If this option is selected, the steepest and the flattest meridians in the 3, 5, 7 mm zones of the posterior cornea are shown. Meridians are bound to be perpendicular between them.
The following values are available for Meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the principal meridians **K1** and **K2**.
» **Avg:** mean curvature of the principal meridians.
» **Cyl:** corneal toricity, (i.e. difference in diopters between curva-tures of the principal meridians and axis of the cylinder).

N1 and N2 are the refractive indices used for converting the values of curva-ture from mm to D: N1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

HEMI-MERIDIANS

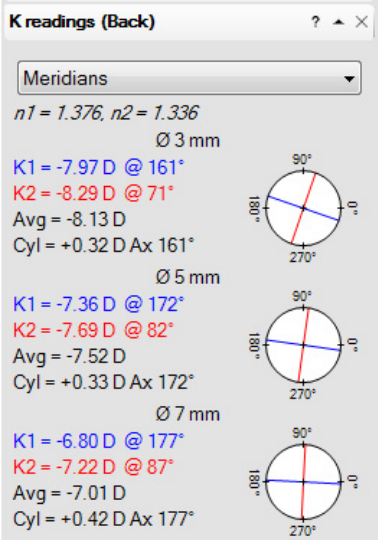
If this option is selected, the two pairs of flattest and the steepest hemi-me-ridians for the 3, 5 and 7 millimeter zone of the cornea are shown. Hemi-me-ridians are not bound to be perpendicular among them.
The following values are available for Hemi-meridians:

» Curvature (expressed in mm or D according to the preferred set-ting) and axis for the two pairs of flattest and steepest meridians **K1** and **K2**.

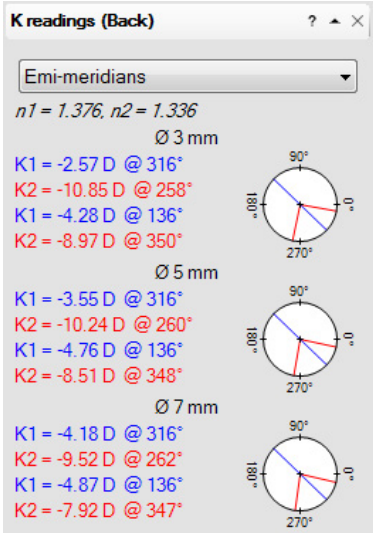
N_1 and N_2 are the refractive indices used for converting the values of curva-ture from mm to D: N_1 (=1.376) is the index of refraction of the cornea and N2 (= 1.336) is the index of refraction of the aqueous hu-mor.

PERIPHERAL DEGREES

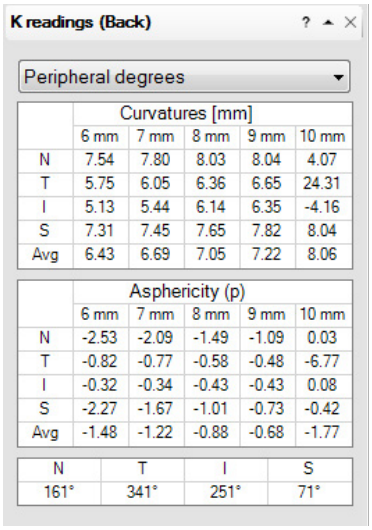
If this option is selected, two tables of curvatures and asphericities (expres-sed as p, e, E, Q) are shown.
These values are obtained in the 20°, 25°, 30°, 35°, 40° zones or in the 6, 7, 8, 9, 10 mm zones for the 4 hemi-meridians Nasal (N), Temporal (T), Inferior (I) and Superior (S).
The values of curvatures are the sagittal curvatures at the limit of the con-sidered zone.
The values of asphericity are the asphericities of the best-fit conic curves in the various zones for the various emi-meridians.
The last line Avg of the two tables Curvatures and Asphericity con-tains the average values for each zone of the values of the 4 consid-ered hemi-me-ridians.
The angular positions of the 4 Hemi-meridians Nasal (N), Temporal (T), Infe-rior (I) and Superior (S) are available in a third table.



K-readings (back): Meridians



K-readings (back): Hemi-meridians



K readings (Back)

Peripheral degrees

	Curvatures [mm]				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	7.54	7.80	8.03	8.04	4.07
T	5.75	6.05	6.36	6.65	24.31
I	5.13	5.44	6.14	6.35	-4.16
S	7.31	7.45	7.65	7.82	8.04
Avg	6.43	6.69	7.05	7.22	8.06

	Asphericity (p)				
	6 mm	7 mm	8 mm	9 mm	10 mm
N	-2.53	-2.09	-1.49	-1.09	0.03
T	-0.82	-0.77	-0.58	-0.48	-6.77
I	-0.32	-0.34	-0.43	-0.43	0.08
S	-2.27	-1.67	-1.01	-0.73	-0.42
Avg	-1.48	-1.22	-0.88	-0.68	-1.77

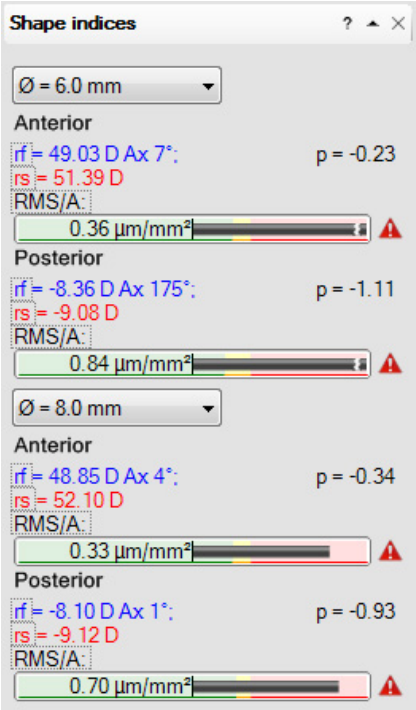
N	T	I	S
161°	341°	251°	71°

K-readings (back): Peripheral degrees

SHAPE INDICES

Shape indices are available for the two corneal surfaces (anterior and posterior) for two different diameters selectable by the user. These indices are the parameters which define the asphero-toric surface best approximating the samples of the measured corneal surface within the zone delimited by the chosen diameter.

» **rf (Flat Radius):** the apical radius (in mm or in D according to the preferred setting) of the flattest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
» **rs:** Steep Radius: the apical radius (in mm or in D according to the preferred setting) of the steepest meridian of the asphero-toric surface which best approximates the measured surface within the chosen diameter.
» **p, e, E, Q:** different forms of the asphericity according to the preferred setting for the asphero-toric surface which best approximates the measured surface within the chosen diameter.
» **RMS (Root Mean Square):** represents the deviation of the surface being examined from the asphero-toric best-fit surface characterized by rf, rs, asphericity and Ax. If the RMS is low, the surface of the cornea, in the area delimited by the given diameter, is very regular. The higher the RMS, the more irregular the corneal surface.
» **RMS/A:** Root Mean Square per unit of area.



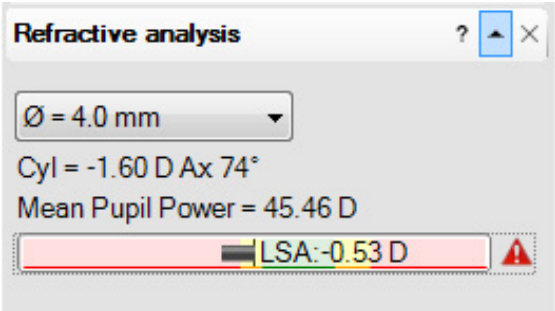
Shape Indicies

REFRACTIVE ANALYSIS

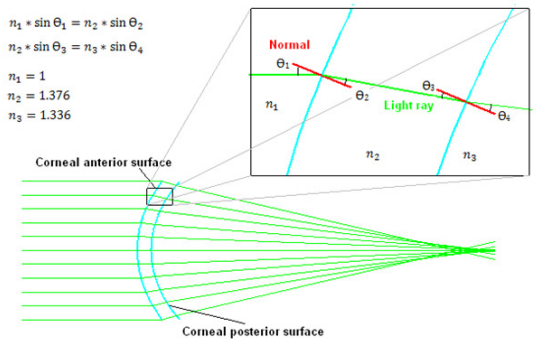
All the indices in this group are calculated from the corneal wavefront related to an entrance pupil located in the position of the patient's pupil, for diameters ranging from 2.5 to 7 mm.
Both the measured anterior and posterior corneal surfaces are taken into account and ray tracing is performed as described below.

A bundle of rays parallel to the instrument axis and passing within the entrance pupil of the eye are traced through the anterior and posterior corneal surfaces using Snell's law. For each incoming ray its intersection with the anterior corneal surface and its angle of incidence relative to the anterior surface normal are calculated. The ray refracted by the anterior surface is obtained using Snell's law with n_{air} = 1.0 and $_{stroma}$= 1.376. This ray is then considered as an incoming ray for the posterior corneal surface and the same procedure as above is applied to calculate the ray refracted by this surface using Snell's law with n $_{stroma}$ = 1.376 and n $_{aqueous}$ = 1.336.
» **Cyl:** the corneal cylinder (in D) and its axis.
» **Mean Pupil Power**: is the equivalent corneal power (in D) .
» **LSA** is the corneal Longitudinal Spherical Aberration (in D).

Right-clicking opens the a contextual menu for the selection of the display mode of the Pupil Power (**PWR1/PWR2** or **Mean Pupil Power/Cyl)** and the Spherical Aberaation (**c(4,0)** or **LSA**).

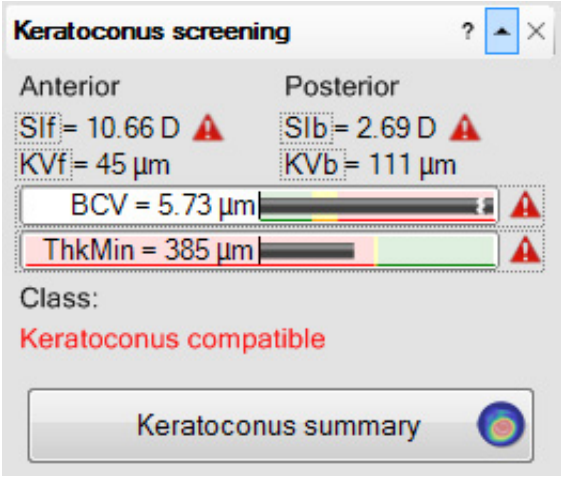


Refractive analysis



KERATOCONUS SCREENING

The software displays a series of indices describing the morphology of the cornea, which are useful in the diagnosis of keratoconus and in follow-ups. It is also possible to open the Keratoconus summary (see Keratoconus summary) pressing the namesake button.



Keratoconus screening

CURVATURE ASYMMETRY

» The Symmetry Index of the anterior curvature (**SIf** – SymmetryIndexFRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. For this index normal values are shown (95° percentile and 99° percentile of a normal population);

» The Symmetry Index of the posterior curvature (**SIb** – SymmetryIndexBACK) is defined as the difference of the mean poste

» rior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in (x = 0 mm, y = ±1.5 mm) and their radius is 1.5 mm. Note that, as the index is expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf. For this index too normal values are shown (95° percentile and 99° percentile of a normal population).

VERTICES

» Highest point of ectasia on the anterior corneal surface (**KVf** – Keratoconus VertexFRONT) and on the on the posterior corneal surface (**KVb** – Keratoconus VertexBACK) are shown.

ELEVATION BASED INDICIES

» The indices **BCVf** e **BCVb** allow the evaluation of the presence of, and the state of an ectasia, through the analysis of the coma, trefoil and spherical aberration components of Zernike's decomposition of altimetries $\left(C_3^{+1}, C_3^{+3}, C_4^{0}\right)$, in the zone where keratoconus statistically arises.

$$BCV \quad \left(\alpha C_3^{+1}{}_{RMS} + \beta C_3^{+3}{}_{RMS}\right) f\left(C3 \pm 1\alpha x\right) \; + \gamma C_4^{0}$$

The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike's decomposition of altimetry: the evaluation is thus obtained by the combination of the RMS values of coma, trefoil and spherical aberration weighed by a function F(C3±1αx) which attenuates the value when the direction is not the statistically expected. The parameters α, β and γ are obtained on a statistical base for weighing the importance of the various components.
The value C3±1αx is defined as the axis of ectasia (direction of ectasia respect to the reference system). The index BCV is calculated for both the anterior (BCVf) and the posterior (BCVb) corneal surfaces. For these indices too normality values are shown (95° percentile e 99° percentile of a normal population);
The index BCV or vectorial **BCV** is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated. The coincidence of the axes of BCVf e BCVb produces an increase of the modulus of BCV respect to BCVf and BCVb; conversely, the diversity of the axes of BCVf e BCVb (in abnormal non keratoconic eyes) produces a decrease of the modulus of BCV respect to BCVf and BCVb. For BCV too normality values are shown (95° percentile and 99° percentile of a normal population).

THINNEST POINT

» Thinnest point of cornea ThkMin is shown.

CLASSIFICATION

The previous data are processed by a neural network in order to classify the case in one of the following groups:
» Normal
» Suspect keratoconus (a normal eye with changes typical of an initial ectasia in the posterior corneal surface)
» Keratoconus
» Abnormal or treated
» Myopic Post-OP

SLITLAMP IMAGING ACQUISITION

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Slit Lamp icon opens the acquisition environment.

QUICK ACQUISITION

When the instrument is centered and at the correct distance, press the button on the joystick to capture the image. Both pictures and videos can be acquired, depending on the selected acquisition mode.

Acquisition mode can be switched from the toolbar, where the icon enables photo acquisition mode (default), while the icon switches to video acquisition mode.

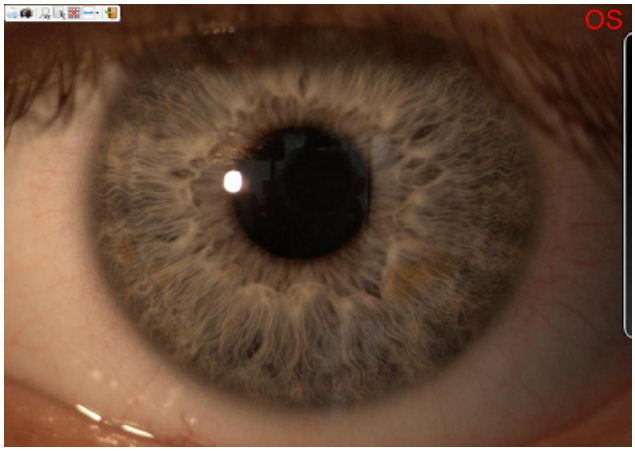
All the acquired images become available in the gallery located at the bottom of the screen. Click on the thumbnail to preview the acquisition.

When a video is recorded, it can be played using the main program's video player from the examination gallery.

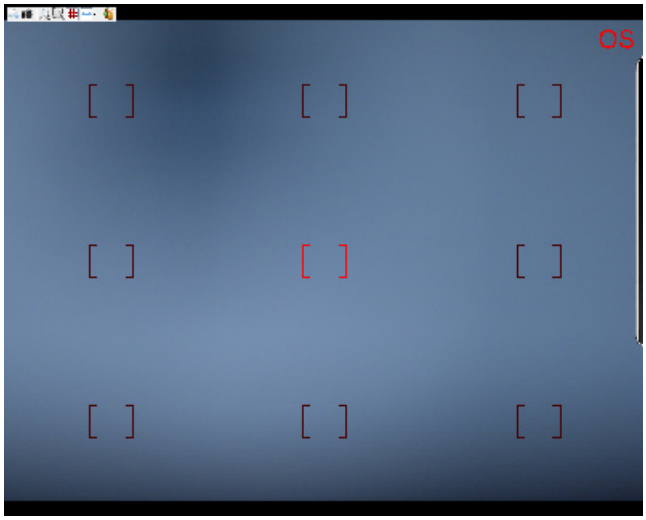
Advanced camera settings are available in the Control Panel. Available acquisition tools and modalities are described in the Toolbar section.

ZONES OF INTEREST

Moving the mouse on the screen displays clickable zones of interest on the live image. Selecting a zone adjusts the camera exposure on the underlying area. This feature is critical when observing an image with different illuminated areas (for example iris and sclera) , so that exposure control can be adjusted dynamically while taking several shots.



Acquire



Zones of interest selection grid

CONTROL PANEL

The control panel is loaded by hovering the mouse on the label on the right side of the screen.
Modifying any options have immediate effect on the live image.

CAMERA CONTROL

Slide the trackbars to adjust different camera parameters.

Gain: controls camera light sensitivity without affecting exposure time.

Shutter: controls camera exposure time. When Auto checkbox is selected exposure is calculated at runtime automatically.

Autoexposure: when *Auto* checkbox is selected this parameter sets the illumination value which should be reached by the dynamic shutter adjustment algorithm.

Brightness: adjusts image brightness.

Sharpness: adjusts camera sensitivity to edges and corners.

Saturation: adjusts color saturation, from grayscale image to over-saturated image.

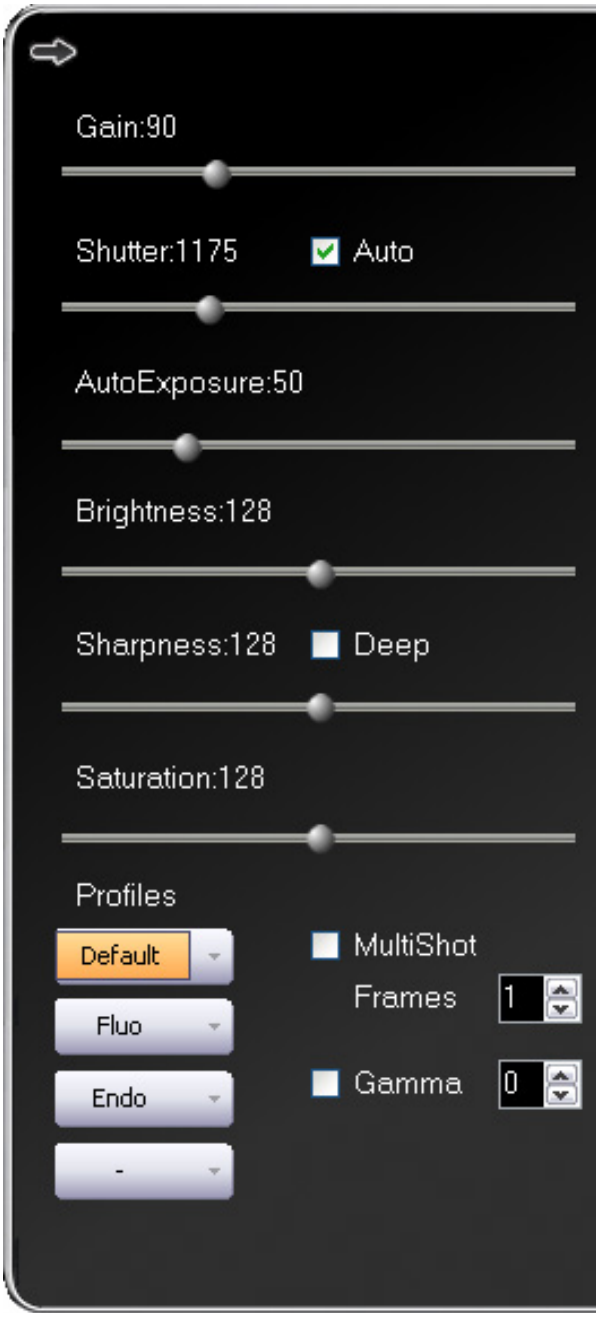
Gamma: different gamma profiles can be loaded by switching the numeric indicator from 0 to 7. Every gamma profile affects the image in an unique way by changing the color distribution sensitivity of the camera. Experiment different gamma values and observe how they modify the camera response.

USER PROFILES

Four different profiles are available on the control panel.
The *Default* profile provides standard camera settings and cannot be changed. The other 3 profiles are pre-optimized for Fluoresceina and endothelial image acquisition respectively, while the last one is empty.
Such profiles can be customized by the user: adjust the camera parameters, then click the chosen profile then select Save to store the parameters permanently, or Rename to change the profile name.
In order to reload a previously customized profile just click it while in the live environment.

MULTISHOT MODE

When multishot mode is selected one joystick shot produces more than one acquisitions in a row. Such acquisitions are very close in the timeline, which can be very useful when performing special acquisitions i.e. endothelial image capturing which requires perfect timing.
Shooting more images lets you choose the best one in a very short timeline.
Select the number of desired frames for each acquisition by switching the *Frames* numeric indicator.



Control panel

Profile customization menu

TOOLBAR

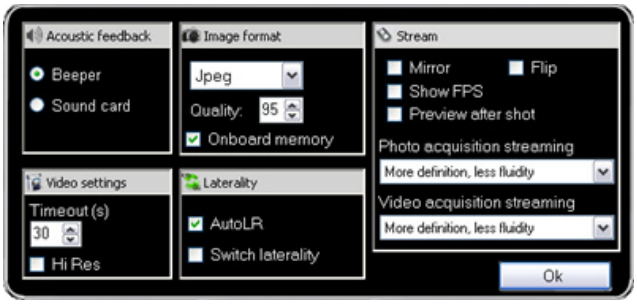
The toolbar provides useful functions to customize the acquisition environment or switch between different acquisition functions.

TOOLBAR ITEMS

	Magnification	Zooms in the camera image by 2X to enhance central details reviewing
	Screen adjustment	Adjusts the camera output image to screen height, screen width, or just keeps its original size (1624x1232) unmodified. Please note that portions of the image might be cut off the screen depending on the effective screen size and the chosen adjustment option. Try different options to best-fit the screen size.
	Photo mode	Photo mode is enabled when this icon is shown in the toolbar. Click the icon to switch to video acquisition mode.
	Video mode	Video mode is enabled when this icon is shown in the toolbar. Click the icon to switch to photo acquisition mode.
	Reset zone of interest	Resets the selected zone of interest to the default central one.
	Quit	Exits the application and saves all acquired pictures and videos.

SETTINGS

The icon on the Toolbar brings up the settings window.



Settings window

PROGRAM SETTINGS

Acoustic feedback: switches between internal beeper and sound card as audio device.

Image format: any available image format can be selected here. Choose between Jpeg and other lossless formats like PNG or TIFF.
The *Quality* setting adjusts the Jpeg compression level.

Video settings: sets the *Timeout* (in seconds) for video acquisition.
A recorded video can't be longer than the selected numeric value. The *Hi Res* check box enables hi resolution videos. Such hi res videos require a fast enough CPU and much more free space on the hard drive than standard resolution videos.

Laterality: the *AutoLR* switch is selected by default and enables Laterality auto-detection using the sensor installed on the slit lamp device. *Switch laterality* option should be checked only when there is need to switch OD with OS or should be left unchecked otherwise.

STREAM SECTION

Mirror: inverts the image on the X-axis.

Flip: inverts the image on the Y-axis.

Show FPS: displays the number of frames-per-second on screen during live stream.

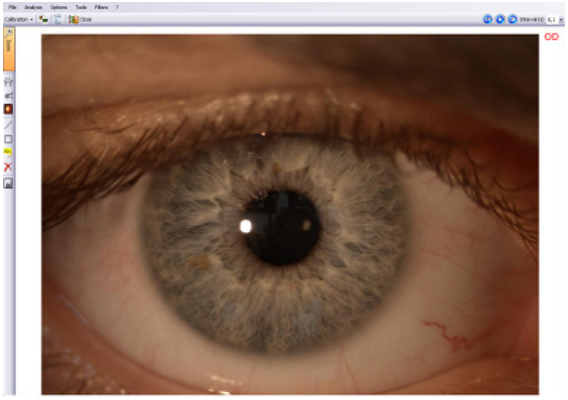
Preview after shot: every acquired pictured is displayed on screen after being taken when this option is selected.

Photo acquisition streaming: when in photo mode, this combo box lets you choose if definition or fluidity should be privileged, respectively. More definition means that a higher resolution streaming is displayed with a lower FPS (frames per second), while the second choice displays a lower res streaming at higher FPS. It is very important to notice that this option does not affect the resolution of the acquired images which remains fixed and is not dependent to the live streaming resolution.

Video acquisition streaming: when in video mode, this combo box lets you choose if definition or fluidity should be privileged, respectively. More definition means that a higher resolution streaming is displayed with a lower FPS (frames per second), while the second choice displays a lower res streaming at higher FPS. It is very important to notice that this option does not affect the resolution of the acquired videos which can be adjusted in the Video settings section and is not dependent to the live streaming resolution.

OPENING AND EDITING IMAGES

This section describes the advanced functions and tools that are available only for Slit Lamp acquisitions.
All other generic functions and tools are available for this instrument too.



Slit lamp image viewing and editing window

Menu Options	
Measure unit	Changes measurement unit between microns and *millimeters*. This action is possible only if the picture was acquired with a calibrated instrument, otherwise only *pixel* unit measurement is available.
Menu Analysis	
Single image	Loads back the single image from different menus like comparison, analysis etc.
Comparison	Compares two or more images (depending on examination type) into a single screen
Menu Tools	
Cup to disk ratio	This tool provides cup to disk ratio calculation when Fundus pictures are acquired using a Slit lamp. First mark three points on the image to set the external optical disk circle, then mark another three internal points to set the cup. Cup/Disk Area ratio and diameter ratio is displayed inside the measurement for immediate evaluation once the operation is complete.
Menu Filters	
Barrier filters	Enables or disable a cyan or blue software filtering process for the acquired image.
Calibration	
Magnification ?X	Use the magnification menu in order to set the correct magnification that was used at the time of image acquisition with the Slit lamp. Setting the magnification parameter adjusts all on-screen measurements with the correct value (*microns* or *millimeters*). The instrument needs to be calibrated cor-rectly before this menu is made available.
Calibrate with this image (just 15x/16x)	Opens up the calibration procedure for the instrument. After the process is complete, the calibration is available for all future ac-quisitions.
Set cur-rent cali-bration to image	When a picture was acquired with an uncali-brated instrument, *microns* or *millimeters* measurements are still not available since there is no guarantee that the instrument was correctly calibrated at the time of the acqui-sition. Use this function to associate the ex-isting calibration to the current image, only if you are confident enough that such calibra-tion is compatible with the acquired image.

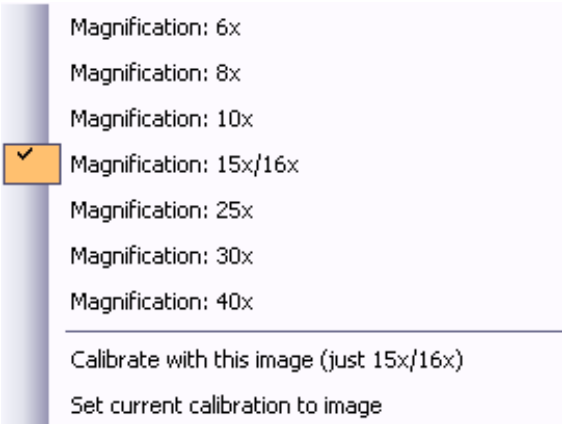
CALIBRATING THE SLIT LAMP

The Slit lamp calibration procedure is required to enable calibrated measurements with *microns* or *millimeters* instead of standard *pixels*.

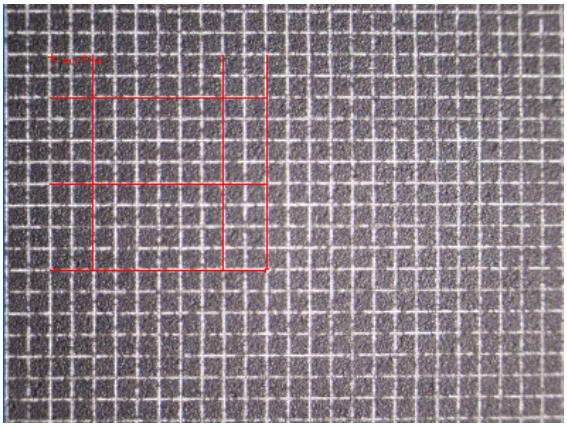
Start the calibration procedure by clicking Calibrate with this image *(just 15x/16x)* in the Calibration menu.
Use a paper grid as a slit lamp target (i.e. graph paper with 1-mm blocks), and acquire using 15X/16X magnification.

Once the image has been acquired, use the calibration form and manually drag the red grid with the mouse **until the red squares match 1 mm x 1 mm real paper squares.**

When finished, click *Ok* on the calibration form then Yes to finally save the calibration.
All the measurements placed on the images from now on will be available in *microns* or *millimeters*.



Slit lamp calibration me



Slit lamp calibration grid with 0.5 x 0.5 mm squares: the red grid must be adjusted until each red square contains 4 white-bordered squares (1mm x 1mm).

TEAR ANALYSIS

TEAR ANALYSIS

The purpose of the tear film break-up analysis is to assess the integrity of the tear film spread on the patient's anterior corneal surface over time. The layer is restored after every eyelid blink and tends to get thinner and break-up in a few seconds, until the next blink. A very short time interval between the eyelid blink and the first break-up may indicate an eye condition like, for instance, contact lens-related eye disorder symptoms.

This test is performed through videokeratoscopy, the video recording of the Placido's disk ring projection on the patient's cornea. The perfect reflection of the disk's rings is actually ensured by the even distribution of the tear film on the anterior corneal surface: any distortion or interruption of this surface causes one or more of the disk's reflected rings to deform or often break, showing exactly when and where the break-up has occurred.

The system processes the video in real time and autonomously, also performing the measurement without any need for the user to intervene, thus avoiding the elaborate manual frame-by-frame checking of the film.
Tear Analysis examination involves acquisition and further analysis, whilst the following paragraph describes the measurement units employed.

NIF-BUT AND NIAVG-BUT

NIF-BuT (Non Invasive First Break-up Time) is the time, expressed in seconds and tenths of a second, that elapses between the moment the eyelid opens again after one or more blinks and a) the very first tear film break-up, or b) the moment in which the following blink takes place.

It is the most relevant clinical measure since patients with tear film in optimum conditions should not present any break-up for a time that varies between 10 to 17 seconds. Such measurement, however, does not take into account any break-ups that may occur following the first one, thus limiting the overall evaluation of the tear film health condition.

NIAvg-BuT (Non Invasive Average Breakup Time) introduces an auxiliary and complementary measurement, i.e. the tear film break-up average time which is measured by averaging the times of all the reflected disk's sections that actually broke-up throughout the examination. Such value may be used arbitrarily to obtain a more accurate diagnosis, together with the NIF-BuT.

For example: a NIF-BuT value of 3 seconds would indicate a tear film poor health condition, since at least one sector of the film broke up within 3 seconds after the blink; however, if the associated NIAvg-BuT value measured 10 seconds, this would indicate that -on average- the other sectors degraded considerably later, therefore tempering the negativity of the examination's results.

Concerning the above, it is important to associate to the numerical values described also the overall Break-up map evaluation (paragraph 3.4 of the manual), that visually gives information regarding the amount of sectors that have been damaged throughout the measurements.

To exemplify further, the NIF-BuT value of 3 seconds mentioned above would be irrelevant from a clinical point of view if only one sector of the tear film map was damaged.

It is useful, moreover, to measure the same eye more than once, in order to obtain information regarding the patient's break-up condition stability and repeatability.

As per the definitive evaluation of the patient's health conditions in relation to the lachrymal film, it must be said that it depends on the subjective opinion of the specialist performing the test: you must also take into consideration all the related variables and other factors connected to the specific context.

ACQUISITION

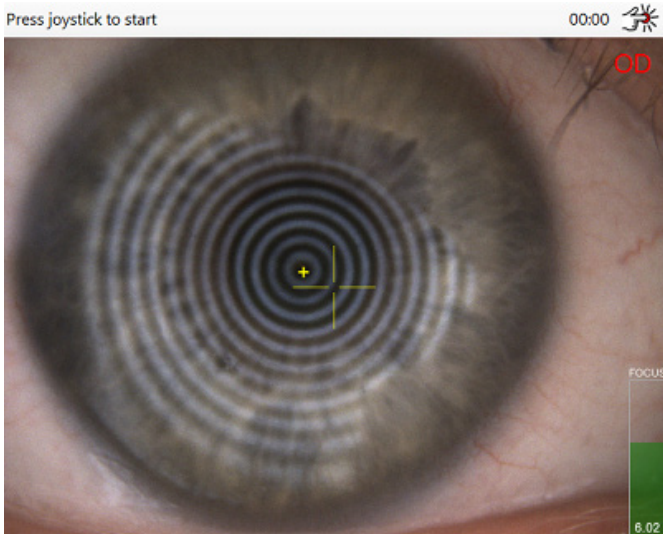
The  icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Tear analysis icon opens the acquisition environment.

CENTERING THE RINGS

Start the tear film break-up analysis and position the patient on the chinrest. Focus the rings (centering phase). The centering phase is extremely important as the final reliability of the examination can be compromised by poor focusing. The figures on the right side show two samples of out of focus and well-focused images, respectively.
The indicator on the right bottom of the screen gives a feedback in real time on the focusing operation.
When the image is clear and focused, press the joystick button to start the measuring phase.

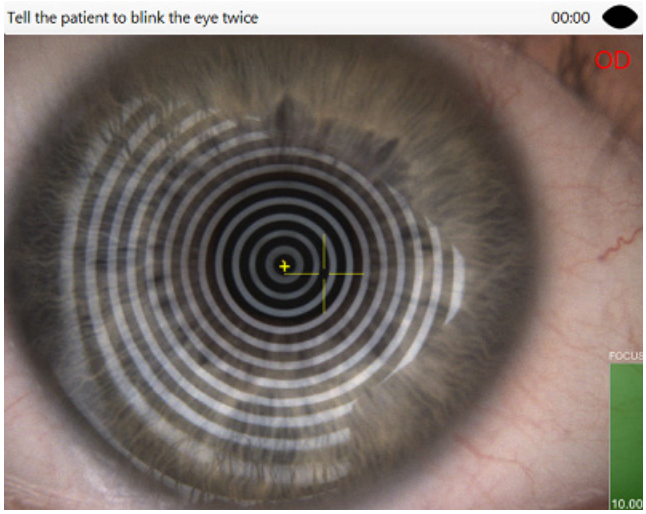
MEASURING

Tell the patient to blink twice, then the system automatically starts taking measurements.



Out of focus rings

During the measurement, the central target becomes red and the recording symbol appears on the top right corner. It is important that the eye be very well centered and focused throughout the acquisition.
The measuring and the filming automatically stop when the patient closes the eyelids again, or when the joystick button is pushed again.



Focused rings

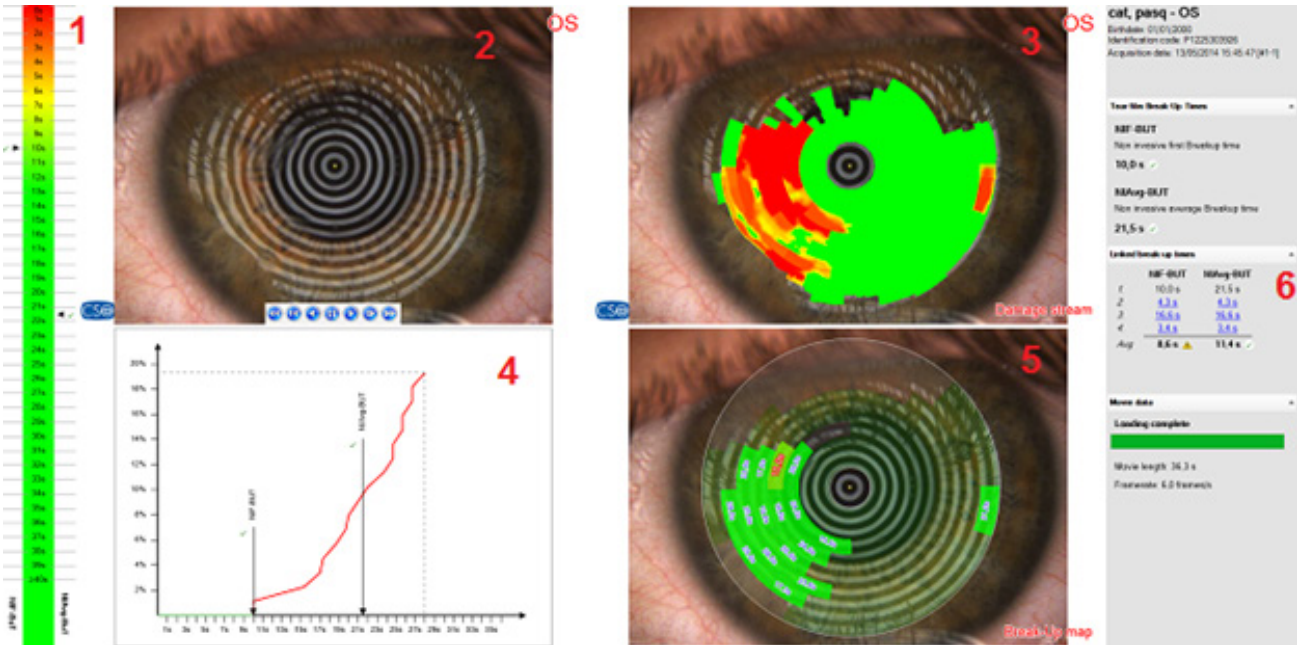
REVIEWING

Each successful measurement completed will be inserted in the gallery. Results can be checked by clicking on the thumbnail in the gallery directly from within the acquisition environment, without necessarily returning to the main patient management.

The meaning of the maps and of the numerical data is well explained in the Analysis section.

Notably, the maps shown in the live preview are the map of the final Break-Up status (paragraph 3.3) to the left and the Break- Up map (paragraph 3.4) to the right.

ANALYSIS



Zooming-in the break-up details in the movie quadrant

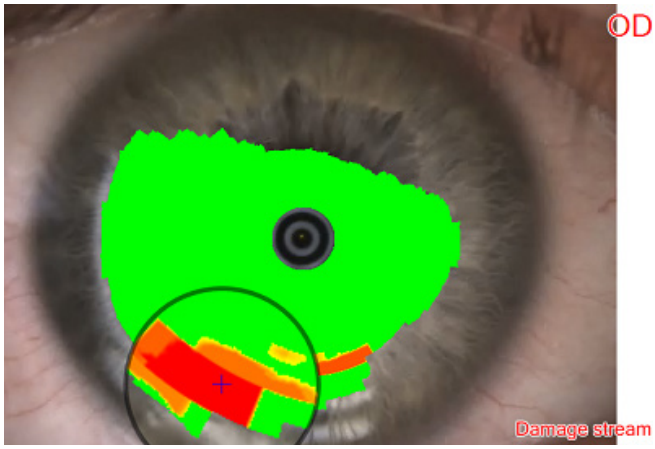
The Tear analysis summary displays several maps and graphs in the same screen.

BREAK-UP SCALE (1)

The Break-up chromatic scale provides an intuitive feedback to support the NIF-BuT and NIAvg-But numerical values. It can be found both in the preview window of the acquisition environment (which can be accessed by clicking on a thumbnail in the gallery) and in the main software environment. In addition, the sectors' colors of the Break-Up maps described in this paragraph refer to this scale.

Generally speaking, a tear film break up time that falls within a range of 0 and 4 seconds is to be considered health condition for the patient. A time falling within a range of 4 and 10 seconds can be considered below standard and therefore it must be assessed individually, taking into account the other parameters for the patient. A time over 10 seconds generally indicates good tear film conditions and may be attributed to a healthy patient. The maximum time allowed by the software is 17 seconds, since tear film integrity time exceeding that amount of time are not relevant from a clinical point of view and do not support the analysis in any way.

To the sides of the scale there are two indicators, the NIF-BuT one on the left and the NIAvg-But to the right. The indicators are represented by red, yellow or green icons, according to the category they belong to as described above



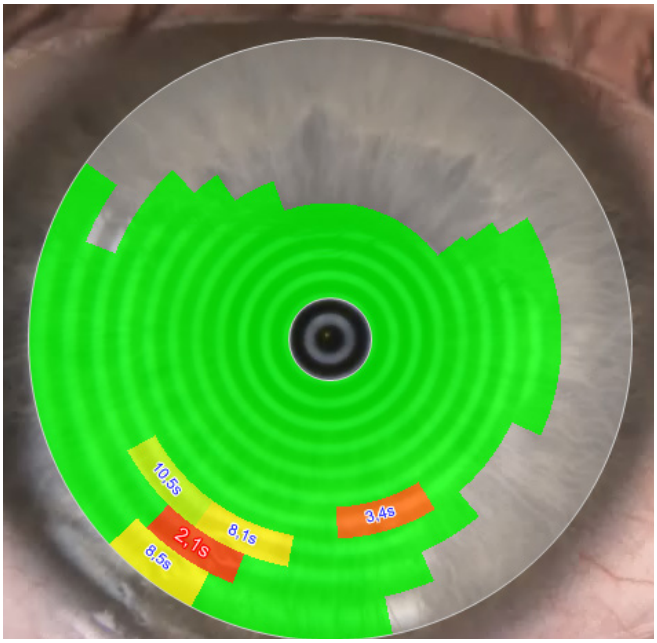
Zooming in the break-up details in the break-up flow quadrant

MEDIA PLAYER (2)

The first quadrant displays an unaltered video of the videokeratoscopy as well as a set of controls similar to MediaPlayer that move forward or rewind the video, that play it frame by frame, and that display the first or the last frame of the video.
The recording starts the moment the patient blinks up to the action that determines the end of the measurement (the successive blinking, a joystick button pressure, the end of the maximum time allowed), and it therefore shows the actual degrading over time of the tear film conditions.

MAP OF THE BREAK-UP FLOW (3)

The second quadrant map is dynamic and changes in real time according to the video that is being played on its left. The purpose
of this map is to highlight, frame after frame, in which areas of the disk break-ups are occurring and the approximate extent of their severity.
The yellow color indicates a slight break-up, which is probably hardly visible to the naked eye; the bright red color indicates a more sever break-up, probably an abrupt interruption of one or more of the rings.
By clicking with the mouse on a point of the video or of the break-up flow map, it is possible to enlarge in real time that area in order to observe the break-up in detail even while the video is being played.



MAP OF THE BREAK-UP FLOW (4)

The third quadrant displays a graph summarizing the examination timeline (X-axis is time in seconds, Y-axis is break-up percentage). The graph line stays green until the first break-up occurs, then turns to red and indicates the percentage of examined eye area that is actually broken at the corresponding time. The black vertical lines indicate NIF-BuT and NIAvg-But, respectively.

BREAK-UP MAP (5)

The map located in the bottom right area is the most important of all, it being a summary of the analysis outcome.
The map is divided in radial sectors and it shows the evolution over time of each sector in terms of tear film integrity, according the following interpretation:

» the opaque and transparent sections show areas of the map that have not been considered in the final measurement of the Break-up time, probably due to the fact that they included areas of the eyelids, eyelashes or simply because they were not considered sufficiently reliable.

» the green sections without numerical values, indicate those areas of the map in which the tear film has remained intact throughout the examination.
» sectors containing numerical values indicate those areas of the map in which a tear film has degraded or broken up: the numerical value shows the exact moment in time in which the first deterioration of the sector occurred, and such value is marked red in case it represents the sector that broke-up first in the map (First Break-up sector). To the numerical value is, furthermore, associated a color that indicates the "severity" of the break-up: a color shifting to green means that the break-up occurred in normal conditions, i.e. after about 10 seconds from the beginning of the test. A color shifting to red indicates that the break-up is more severe, i.e. that it occurred within few seconds.

The figure below is an example for a Break-up map: the sector measuring 2.1s was the first to show a tear film break-up. The fact that it is red indicates that it is a severe break-up since it occurred after such a short delay of time. The other sections "broke-up" respectively after 3.4s, 8.1s, 8.5s, 10.5s. The NIF-BuT time is obviously 2.1s, whereas the NIAvg-But time is 6.5s, i.e. (2.1s + 3.4s + 8.1s + 8.5s + 10.5s) / 5 = 6.5s

LINKED EXAMINATIONS (6)

It is advisable to take more than just one test per patient, since Tear film break-up analysis may vary slightly from acquisition to acquisition. 3 consecutive acquisitions are the best option in order to obtain the most reliable results.
When more acquisitions are taken for the same patients, the averaged data are shown here and the other acquisitions are lined up as clickable hyperlinks. Clicking the link loads the corresponding examination and closes the current one.

TOPOABERROMETRY CALIBRATION

Calibration is essential for obtaining accurate measurements: to calibrate correctly, follow the instructions given step-by-step on the screen and carry out all the captures needed, with the calibration standards requested in a dark environment.

Follow the steps below to complete the calibration process:

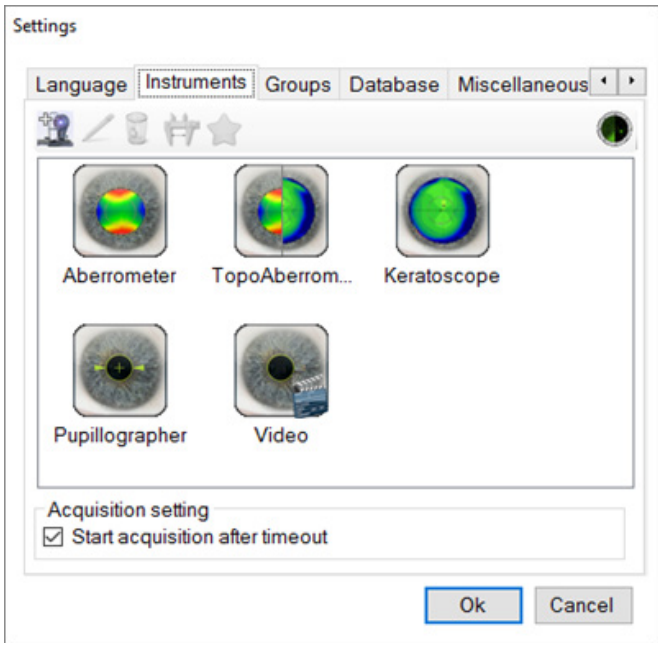
» Place the supplied calibration tools in front of the device.
» Open the settings menu and select the Instruments panel Select the instrument TopoAberrometer and click the calibration button .
» Carry out the curvature calibration as described below.

The entire procedure must be carried out carefully

CURVATURE CALIBRATION

Curvature calibration is necessary to permit the program to correctly measure the curvatures.
Carefully acquire an image of the calibration sphere. If the acquisition is not satisfactory a message will ask to repeat the procedure.

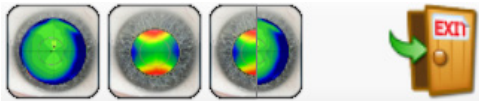
After having successfully calibrated you should capture some images of the calibration sphere, creating a patient and a test exam to verify correct instrument calibration. If the processed measurements are not found to be reliable, repeat the entire calibration procedure.



TopoAberrometer under Instruments panel

ACQUISITION

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Tear analysis icon opens the acquisition environment.



To capture a TopoAberrometry, select the icon. The instrument automatically sets to the capture position and a live capture window opens.

CENTERING AND FOCUSING

To correctly center the instrument, position the cross-hair target between the reflected white spots. To obtain the correct position move the joystick right or left to perform horizontal movements, or turn the joystick clockwise-counterclockwise to perform vertical movements. Once the instrument is centered focus the image of the iris by moving the joystick back and forth.

ABERROMETRY ACQUISITION

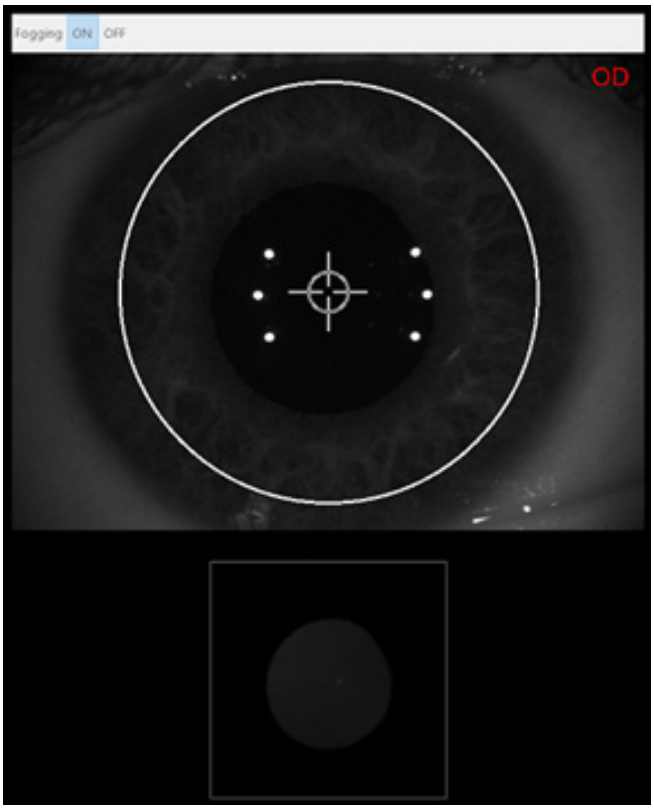
When the instrument is centered and focused at the correct distance, press the button on the joystick and wait the device to perform the full aberrometry capture.
If the Fogging buttons was set as active the last step of the acquisition will be a fogging procedure else the fogging will be skipped.

KERATOSCOPY ACQUISITION

When the keratoscopy image grab starts the Placido disk and the blue slits light up. Move the topographer forward or backward: when the device is too far or too close to the corneal vertex the slits appear disjoint or overlapping in the corneal periphery. On the contrary, when the slits are aligned and overlapping in the center the device at the right distance: make sure that the cross remains near the center of the rings and that the rings are not corrupted by tears or eyelashes and press the joystick button to grab the image. Once the images is captured a thumbnail is shown on the left or right side of the screen according to the acquisition laterality.

CYCLOTORSION IMAGE CAPTURE

If the option SCC is activated, a cyclotorsion image capture will follow the aberrations measurement. Visible LEDs will light up in order to minimize the pupil diameter. Ensure the image remains focused while the time-lapse image capture process takes place: this will allow for the correct processing of the iris structure.
If the cyclotorsion acquisition succeeds, and the image turns out to be useful, no further images are required for the eye under examination. If the image does not correspond to minimal requirements for the acquisition of an image with cyclotorsion, the image capture process has to be repeated.



Acquisition

When the device is too far or too close to the cornea the slits appear disjoint or overlapping in the corneal periphery

IMAGE STORAGE AND PREVIEW

It is possible to manage the images in the gallery, by selecting whether an acquisition have to be saved or deleted. By right-clicking on the small thumbnail of the acquisition on the gallery a preview is shown instead of the live panel. A double left click on the thumbnail will set the relative acquisition as "to be deleted", the thumbnail will be marked with a litter bin, and will be not saved once the live session is over.

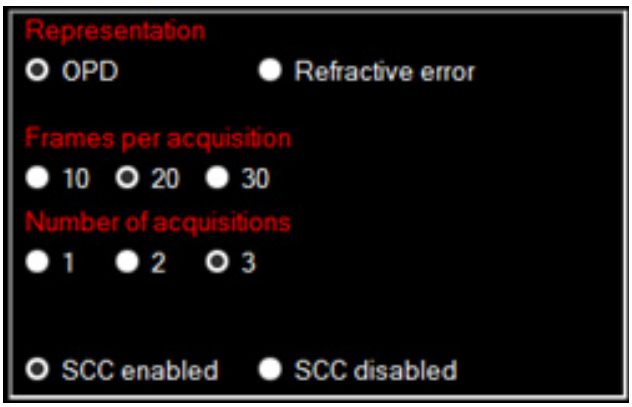
OPTIONS

To access to the acquisition settings click on the icon.
It will be possible to select between OPD and refractive error representation, or to chose the number of acquisitions per session and the number of frames per acquisitions. From this panel is also possible to activate/deactivate the cyclotorsion image capture.
To toggle in live press the settings icon back.

Once all the images needed have been captured, the capture environment may be closed pressing the button; the program returns to the main screen.

Select one of the captured images to process it and access the TopoAberrometry Summary.

When the device is at the right distance the slits appear overlapping in the center



Aberrometry settings

MENU

A menu is displayed at the top of the screen: a short description of the functionalities and options that are available follows:

FILE		
	Save screen-capture as image	Opens a window from which the current screen-capture can be saved in various image formats.
	Close	Closes the current analysis environment and returns to main page.
	Print screen-capture (quick)	Directly prints the screen-capture
	Print	Opens a window to set-up printing parameters. The final printout is screen dependent.
	Print (quick)	Directly prints.
	Export	Exports for external program.
	Quit	Exits the application after confirmation of the warning message.
EDIT		
	Ring/Pupil/Limbus editing	Opens the environment for the editing of reflected Placido rings, of the pupil and of the limbus edge.
	Reprocess	Reprocess all Scheimpflug images and the keratoscopy.
	Edit Pupil/Corneal Vertex	Opens the environment for the editing of the pupil and the corneal vertex
ANALYSIS Displays an overview dedicated to the corneal wave-front analysis		
	Summary	Opens up the default overview summary, containing information on curvature, elevation and Wave Front
	Images	Displays the keratoscopy, the the image of the iris and pupil at acquisition time
	Single map	Displays a single map to permit detailed analysis
	Optical quality summary	Opens up a summary report showing patient's quality of vision
	Toric IOL assistant	Opens up a summary report for the management of toric IOL post implant.
	Comparison	Allows comparison of up to 4 different maps.
	Wavefront comparison	Allows comparison of 2 different corneal Wavefront maps.
	OD/OS	Allows comparison the current and the fellow eye.

	Differential	Show the difference-map between topographies.
	Wavefront Differential	Show the difference-map between Wavefront
OPTIONS		
	Options	Set-up the user preferences for the display of topography or aberrometry.
INFORMATION		
	About...	Shows information on the software release.

TOOLBAR

A toolbar is displayed at the top of the screen: a short description of the functionalities and options that are available follows.

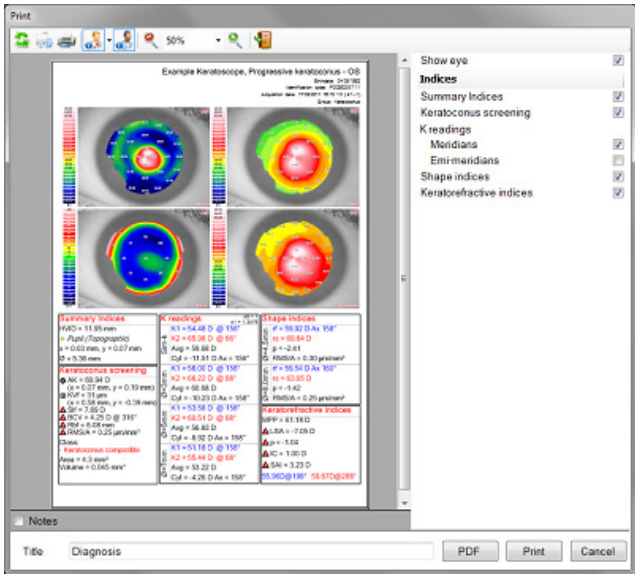
	Summary	Opens up the default overview summary, containing information on curvature, elevation and Wave Front
	Images	Displays the keratoscopy, the the image of the iris and pupil at acquisition time
	Single map	Displays a single map to permit detailed analysis.
	Optical quality summary	Opens up a summary report showing patient's quality of vision.
	Toric IOL assistant	Opens up a summary report for the management of toric IOL post implant.
	Comparison	Allows comparison of up to 4 different maps.
	Wavefront comparison	Allows comparison of 2 different corneal Wavefront maps.
	OD/OS	Allows comparison the current and the fellow eye.
	Differential	Show the difference-map between topographies.
	Wavefront Differential	Show the difference-map between Wavefront
	Export	Exports for external program

PRINTING

You can access the print functionality through Print and Print screen under the menu File.
With reference to the print preview, it is possible to check the report preview, adjust print settings and add an optional header.

On the right side of the screen a list of options is shown which allows you to display or hide indices on the final printout.

Print (Quick) and Print screen (quick) functionality, also under the File menu, allows you to print without preview



Print preview

ANALYSIS | STATISTICS ON ACQUISITION

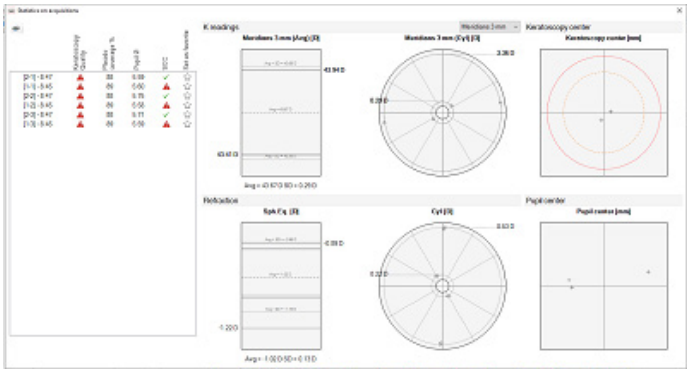
Statistics on acquisition window can be accessed by right-clicking on one of the thumbnails in the acquisition gallery and then left-clicking the Statistics on acquisition menu item of the contextual menu.

This window is useful for evaluating the quality and the repeatability of the acquisitions belonging to the same examination.

At the top-left corner a table is shown with the list of the selected acquisitions. Each row of the table refers to a single acquisition and contains its ID, date and time of the acquisition, a symbol for the quality of the keratoscopy (green for good quality, red for bad quality).
By selecting a row in the table (i.e a certain acquisition), the corresponding data are highlighted in the plots described below.

At the top of the window for K readings (Sim-K or Meridians at 3 mm) a scatter-box plot for the average value and a polar scatter plot for cylinder are shown. Average and standard deviation are reported for the Sim-K (Avg) and for the Meridians at 3 mm (Avg).
At the top-right corner of the window a cartesian scatter plot is dedicated to pupil decentration with respect to corneal vertex.

At the bottom-right corner of the window a scatter-box plot containing information on the Spherical Equivalent of the acquisitions and a radial scatter-chart containing information on the Cylinder and Axis of the acquisitions.



Print preview

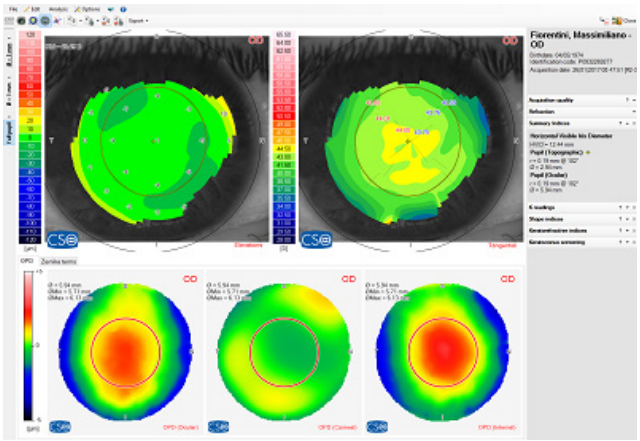
SUMMARY

Summary is displayed:

» double-clicking on a TopoAberrometry acquisition on the main screen.
» by choosing Summary from the Analysis menu
» by clicking the icon on the toolbar

This screen is the shown first: it displays a clinical summary of the maps and data derived from processing each single image capture. The Summary consists of two topographic maps (elevation and tangential), three aberrometric maps (ocular, corneal and internal OPD/WFE maps)and a right-hand panel with customizable indices. The software will save the state of the panel and will restore it when a new window is opened.

The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Ocular, Corneal or Internal)



Summary

SINGLE MAP

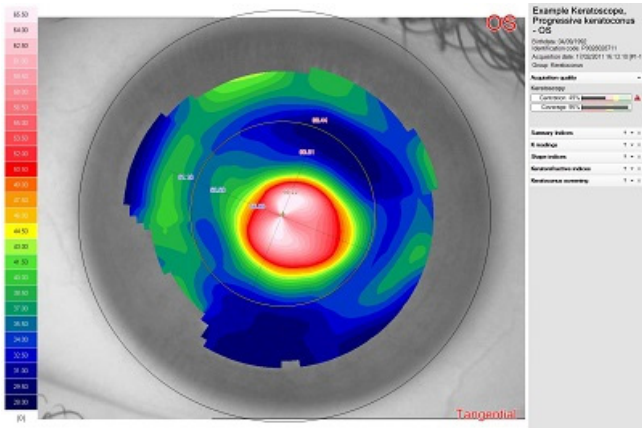
Single map screen is displayed:

» by choosing Single map from the Analysis menu.
» by clicking the icon on the toolbar

This screen displays a single map in full-screen mode. The type of map can be selected from the toolbar between:

» Tangential
» Sagittal
» Elevation
» Refractive power

Right-hand a panel with customizable indices is shown: the software will save the state of the panel and will restore it when a new window is opened.



Single map

OPTICAL QUALITY SUMMARY

Optical Quality Summary is displayed:

» by choosing Optical Quality Summary from the Analysis menu.

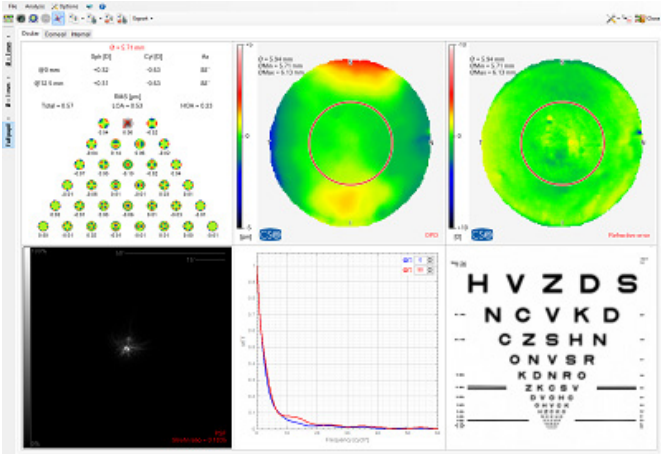
» by clicking the  icon on the toolbar

This form permits an overall analysis of visual quality.
From top-left to the bottom-right are shown:

» Zernike pyramid;
» OPD/WFE map;
» Refractive error map;
» PSF;
» Vision Simulation;
» MTF.

The analysis is available for Ocular, Corneal or Internal WaveFront according to the selected tab page.

The pupil diameter may be selected on the left side of the screen in a range from 2 mm to the full pupil size with 0.5 mm steps as well as the type of displayed wavefront (Ocular, Corneal or Internal)



Optical Analysis Summary

INDICIES

On the right side of several analysis windows a section of panels is available, containing information and indices referring to the current acquisition:

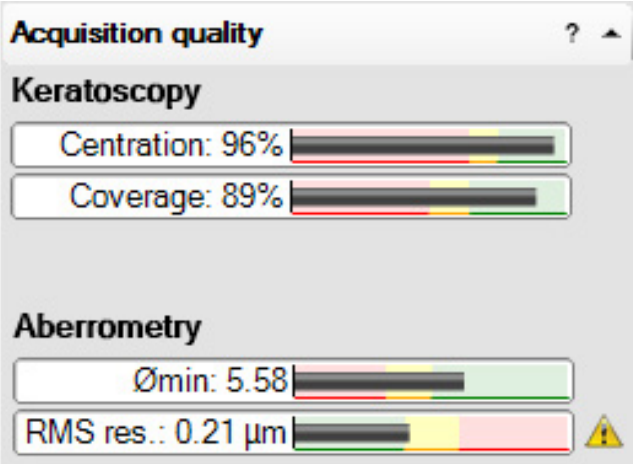
» Patient data
» Acquisition Quality
» Summary Indices
» K-Readings
» Shape Indices
» Keratorefractive Indices
» Keratoconus Screening

The ▲/▼ arrow on the title bar expands/collapses the related panel.
The **?** button opens its help window.

Click the button × on the title bar to remove a panel from the lateral section of the window. To restore the removed panels, select  ► Restore on the right side of the main Toolbar

ACQUISITION QUALITY

It shows some indices which indicate the quality of the current keratoscopic image and aberrometric acquisition



Acquisition quality panel

KERATOSCOPY

Rings coverage for the Keratoscopy and the well-centeredness of the cornea respective to the instruments axis is reported under the group Keratoscopy.

The warning “Fixation: check repeatability” is a help for selecting good images. It appears when the pupil position of the current image is outside of the expected “normal zone”, i.e. the zone where the pupil position is located in normal fixating eyes. If this warning is present, there can be two cases:

» The patient is not fixating, so it is necessary to acquire again after asking the patient to fixate on the fixation point.
» The patient is fixating, but the eye is anomalous (for example if the eye is a keratoconus). In this case the pupil position is always decentered in every acquisition. So in this case, the warning has to be interpreted as an anomalous fixation of the patient.

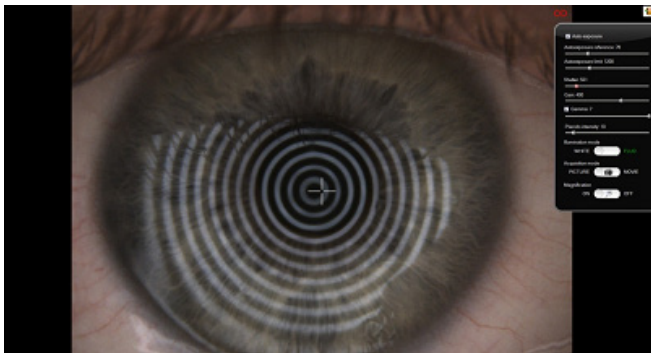
ABERROMETRY

The minimum pupil diameter and the RMS residual are shown.

» The minimum pupil diameter takes into consideration the possibility to analyze wide OPD areas over a big pupil.
» The RMS residual takes into consideration how the Zernike fitting result to be appropriate by highlighting the difference between row data and fitted data over the maximum available pupil. High values of this index may be attributed to highly aberated eyes or can be due to tear film breakages.

VIDEOKERATOSCOPY ACQUISITION

The icon on the main screen becomes active when a new examination is created or when an empty exam is selected. Clicking the Video icon opens the acquisition environment.



Acquire

QUICK ACQUISITION

When the instrument is centered and at the correct distance, press the button on the joystick to capture the image.
When video acquisition mode is enabled press the button to start recording a video, press it again to stop recording and save.
Both pictures and videos can be acquired, depending on the selected acquisition mode.
Acquisition mode can be switched from the Control Panel, where the icon enables photo acquisition mode (default), while the icon switches to video acquisition mode.

All the acquired items become available in the gallery located at the bottom of the screen.
Click on the thumbnail to preview the acquisition.

When a video is recorded, it can be played using the main program's video player from the examination gallery.

Advanced camera settings are available in the Control Panel.

CONTROL PANEL

The control panel is loaded by hovering the mouse on the label on the right side of the screen.
Modifying any options have immediate effect on the live image.

CAMERA CONTROL

Slide the trackbars to adjust different camera parameters.

Autoexposure reference: when Auto-exposure checkbox is selected this parameter sets the illumination value which should be reached by the dynamic shutter adjustment algorithm.

Autoexposure limit: when Auto-exposure checkbox is selected this parameter sets the maximum illumination value that can be reached by the dynamic shutter adjustment algorithm.

Shutter: controls camera exposure time. When Auto-exposure checkbox is selected shutter is calculated at runtime automatically.

Gain: controls camera light sensitivity without affecting exposure time.

Gamma: different gamma profiles can be loaded by switching the numeric indicator from 0 to 7. Every gamma profile affects the image in an unique way by changing the color distribution sensitivity of the camera. Experiment different gamma values and observe how they modify the camera response.

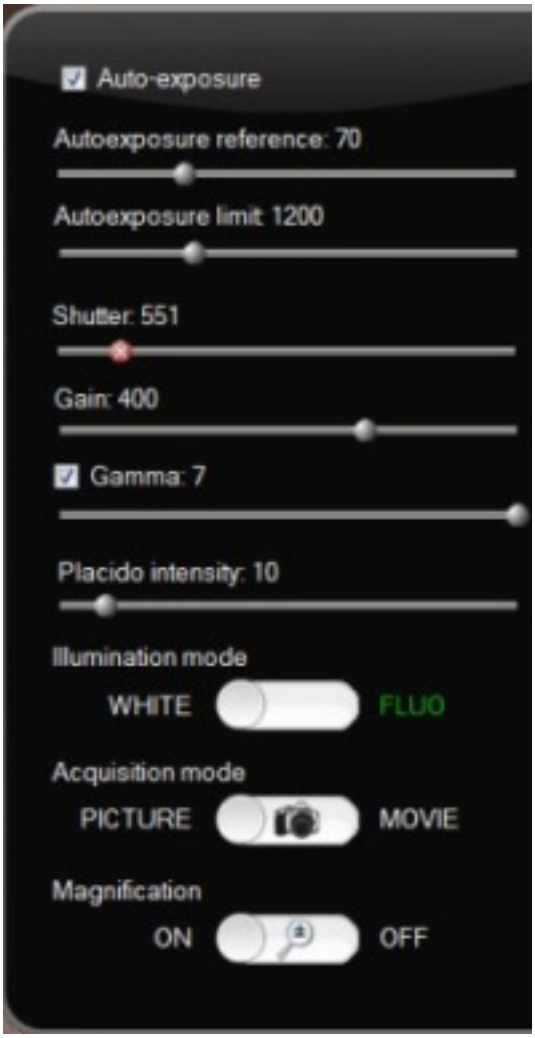
Placido intensity: adjusts placid disk light intensity. Very high values might be annoying for the patient when used for a long time.

Illumination mode: enables / disables fluoresceina acquisition mode.

Acquisition mode: switches between photo and video acquisition mode.

Magnification: toggles a special lens which optically zooms in / out the image.

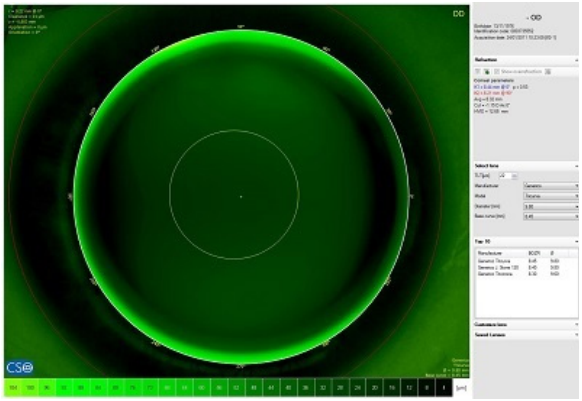
Tear meniscus mode : select check-box to optimize camera parameters for acquisition of the tear meniscus. Acquired images can be analyzed in the Tear meniscus analysis window in the main program.



Control panel

CONTACT LENS FITTING

The working environment for contact lens fitting is accessed from the Analysis/Contact Lenses/Autofit menu or by clicking the toolbar icon in one of the corneal map analysis environments, e.g. Summary and Single map.



Contact Lens Fitting environment

MENUS

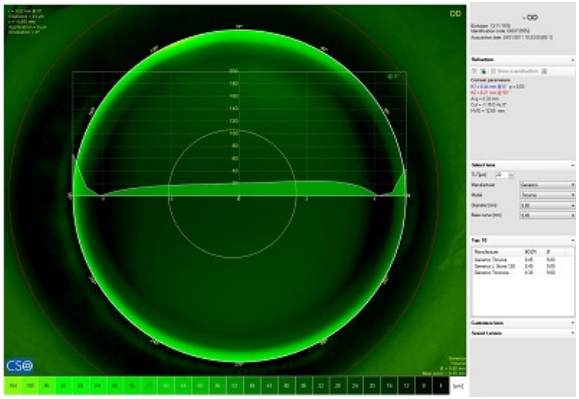
The main bar at the top of the screen shows the main menus for accessing the various corneal analysis environments.

TOOLBAR

When this button is pressed the local values are enabled and shown on the top left of the screen. The A series of data are thus associated to the position of the mouse pointer:

- r, @: distance in mm and angle in ° of the mouse pointer from the selected center (corneal center or lens center). They are visible only if polar coordinates are chosen in window Options/Miscellaneous/Coordinates.
- x,y: cartesian coordinates of the mouse pointer respect to the selected center (corneal center or lens center). They are visible only if Cartesian coordinates are chosen in window Options/Miscellaneous/Coordinates.
- Clearance: lifting of the lens with respect to the cornea at that point chosen with the mouse cursor.
- z: corneal sagitta in mm
- Applanation: value of applanation forced by the user in µm (see below).
- Orientation: orientation axis chosen for the flattest meridian of lens backsurface (in °).

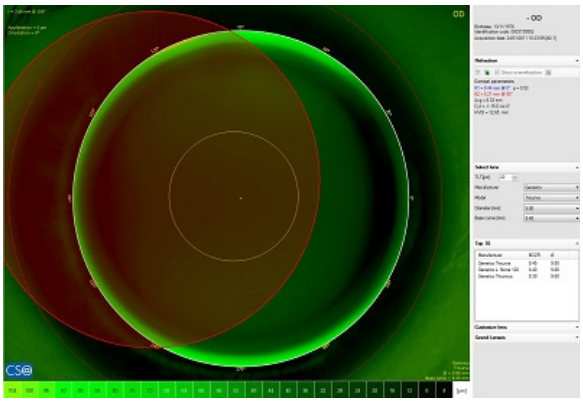
Shows a graph of the fluorescein profile for the selected meridian. In order to select a new meridian, move the mouse pointer over the lens and left-click on the point belonging to the desired meridian. The graph will be shown on the lens as shown in the image on the right.



Fluoresceinic profile along a lens

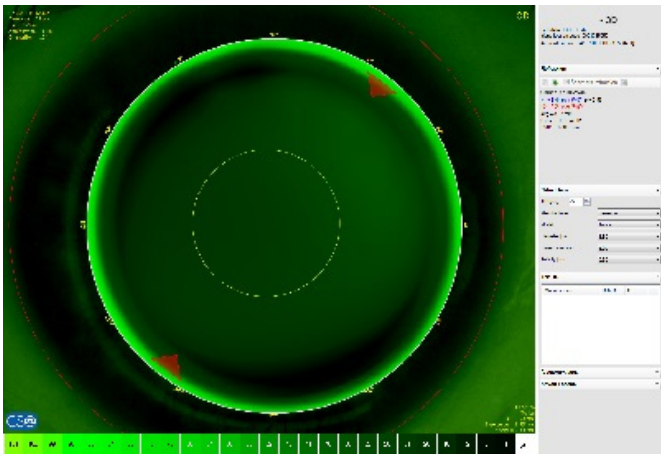
Measures the distance between two points on the lens. Left-click to select the first point; select a second point with another click. The distance in mm between the two selected points will be shown alongside the second point.

Moves the lens. Hold down the left mouse key to drag the lens to the desired position. When the key is released, the software redraws the lens in the new position. For the shift in position to be valid, the edge of the lens must not extend beyond the contour of the limbus. If the shift takes place within this limit, the edge of the lens will be drawn in white and the software will proceed with the new simulation; if the contour of the limbus is crossed, the edge of the lens will be drawn in red and the operation will be canceled. To restore the default position of the lens, click the black arrow under the  button and click  **Undo lens movement.**



Invalid lens shift

	Used for tilting the lens. When this button is pressed, a tilting tool will be displayed on the lens. Click any point on this tool to exert pressure on the lens in that direction and, consequently, lift the opposite hemimeridian. The effect of tilting can be observed on the simulation and on the graph of the tear layer profile.
	Shows the red arrows indicating the flattest meridian of the posterior face of the toric lens and orient it. Move the cursor inside the lens and click when the arrows are aligned with the desired axis. Examples can be seen in Figure 17-3. To ignore changes, click the black arrow under the button and click **Undo axis orientation.**
	Shows the red arrows indicating the flattest meridian of the posterior face of the toric lens and orient it. Move the cursor inside the lens and click when the arrows are aligned with the desired axis. Examples can be seen in Figure 17-3. To ignore changes, click the black arrow under the button and click **Undo axis orientation.**
	Shows or hides the image of the eye in the background
	Shows or hides the pupil edge in the foreground of the lens
	Shows or hides the limbus edge in the image
	Shows two rulers, in millimeters, along the vertical and horizontal axes.
	Shows or hides the meridians on the lens.
	Shows or hides the goniometer with divisions at 30° intervals.
	Shows or hides the concentric rings, the first with a 1.5 mm radius, drawn on the lens at 1mm the one from the next.
	These buttons are mutually exclusive. They are for choosing the reference center which can be the lens center or the corneal vertex.



Axis orientation of a toric lens

SCALE

The color scale for the fluorescein simulation is shown alongside the icons on the left side of the lens or below it: the lightest green represents the thickest accumulation of fluorescein; darker greens represent increasingly thinner accumulations, shading to black, which represents contact between the cornea and the lens. Right-clicking the scale opens a menu for selecting one of three degrees of resolution for the representation:

» High resolution: most suitable when the deposits are very thin.
» Medium resolution: the most widely used; best simulates the real image of a fluorescein lens fit.
» Low resolution: for highlighting the contour lines.

REFRACTION

In the pull-down window on the right-hand side of the screen the user may enter the eye refraction data or the over-refraction on a trial contact lens.

When eyeglass refraction data is entered, the program automatically calculates the refraction at corneal vertex.
When over-refraction is selected, the user must enter the radius of the optical zone (BOZR) and the power of the trial contact lens. In the case of toric lenses, both the radii (**BOZRf** and **BOZRs**) and the powers (**PWRf** and **PWRs**) of the principal lens meridians have to be inserted for a valid over-refraction.
Refraction or over-refraction data are used by the program to calculate the lens power. This is shown at the bottom right corner of the fluoresceinic simulation image only if the refraction or over-refraction data have been entered.
The restore icon lets you remove of the over-refraction details.

SELECT LENS

The pull-down **Select Lens** panel allows the user to set the parameters for lens search.

TLT (TEAR LAYER THICKNESS)

Permits setting the target value for the tear layer thickness at the center of the lens.
When the TLT is changed, a new lens search must be done to apply this change. The program “remembers” the change in TLT setting and uses this criterion the next time the Contact Lenses environment is accessed.

MANUFACTURER

Opens the list of contact lens manufacturers from which to search best lenses for the the lens to be simulated.
When conducting a manufacturer search, only models belonging to the Autofit group are considered by the software. In general, reverse geometry models are managed in a different manner (see below) and are not included in the Autofit group.
In the cases of some manufacturers, the lens parameters are not protected and may be viewed and edited in the Customize Lens panel (see below). Many commercial manufacturers data are protected and therefore cannot be either viewed or edited.

MODEL

Contains the list of models available from the selected manufacturer.
If the selected model is not a reverse geometry model, the program will search for the best lens among that model lenses.
If the model selected is a reverse geometry model, the program opens a window from which to select the desired inversion.

DIAMETER

Contains the list of diameters available for the selected model.

BASE CURVE

Contains the list of base curve radii available for the selected diameter.

TORICITY

Contains the list of toricities available for the selected base curve. This parameter is visible only for toric models.

TOP 10

The Top 10 section contains the data for up to ten different lenses from the selected manufacturer that best adapt to the current cornea. Select one of the lenses in the list to draw its fluoresceinic simulation. The data for the selected lens are also automatically entered in the corresponding boxes of the Select Lens panel (see above).

CUSTOMIZE LENS

This section allows the user to display the construction parameters for a lens, if the lens model is not protected, or to enter the data relative to a customized lens.
If this section is opened but the simulated lens is protected, a warning message will be shown: “Crypted lens model not customizable. Please select a geometry and set parameters manually.”
To simulate a user-created lens, first select the number of curves (from 2 to 6) and choose whether the lens is toric or not. Then, the numeric

boxes containing the parameters of the lens are to be filled in. Lenses are made up of a series of curves, which are conical arcs, characterized by the following parameters:

» *r* is the radius of apical curvature in mm. In the case of toric lenses, r stands for the flattest and steepest radii of lens.
» *w* is the semi-diameter of the curve (in mm).
» ∅ is the diameter (in mm) of the curve.
» *e* is the asphericity of the curve, expressed as "e"
» *off* is the offset of the curve (in mm), i.e. the displacement of its axis from the axis of the base curve.

For toric lenses, radii, asphericities and offsets have to be set for both the flattest and the steepest principal meridians.

To draw the fluoresceinic simulation, click the icon.

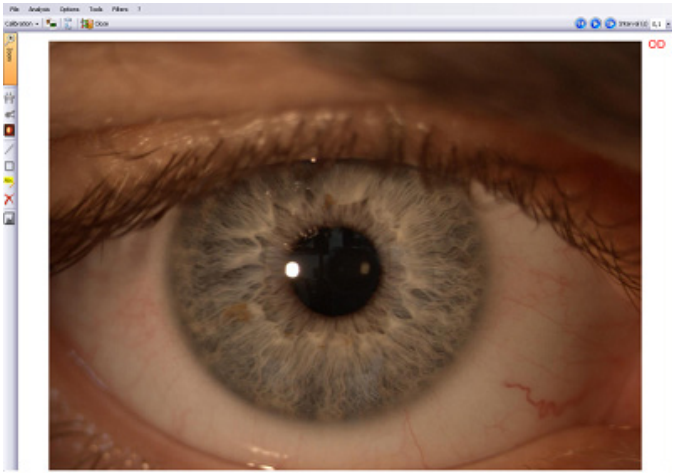
SAVED LENSES

It is possible to save the simulation by pressing .
The saved lenses will be shown in the gallery. To delete a saved lens, choose it from the gallery and press the Del button on your keyboard, or right-click your mouse and choose **Delete acquisition.** To add a description to the saved lens, select the lens icon and press **F2** or right-click. The saved lenses will also be shown in the main patient management gallery.

OPENING AND EDITING IMAGES

Different examinations i.e. SlitLamp, Fundus Camera, Densitometer, Meibographer share a common interface that is used to open, review and edit the acquired images even if they are taken with different instruments each with a specific resolution.

Every specific examination type has its own set of custom functions which add directly to the ones described in this section. Please refer to the specific examination section in order to learn more information about those functions.



Generic image viewing and editing window

BROWSE COMMANDS

Next image	Moves to the next image in the acquisition gallery, if available.
Previous image	Moves to the previous image in the acquisition gallery, if available.

MENU FILE

Save screen-capture as image	Captures the current screen and saves it to an output file allowing the selection of various image formats.
Save image	Saves the current image to an output file allowing the selection of various image formats.
Close	Closes the current analysis environment and returns to main page.
Print	Opens the advanced print management form.
Quit	Exits the application after confirming of the warning message.

MENU ANALYSIS

Single image	Loads the single image from different menus like comparison, analysis etc.

Comparison	Compares two or more images (depending on examination type) into a single screen
Full screen	Displays the current image at full-screen. Use the arrow keys to switch between images belonging to the same gallery.

MENU OPTIONS

Show info on image	Shows or hides patient data informations on the screen.
Toggle smoothing	Enables or disables a smoothing effect on the image, which may induce the sharpest edges in the image to appear softer and less defined.
Overlay	Opens up a sub-menu that allows you to customize some of the available drawing function tools, i.e. font size for text, brush color and brush size. Some of these settings may not be available depending on the examination type.

MENU TOOLS

Please note that some of the following tools may not be available depending on the specific examination type.

All measurements and custom drawings can be removed from the image by hovering the mouse on them and then selecting "Delete" from the balloon tip as soon as it appears on screen.

Zoom	Scroll the mouse wheel to zoom in and out the image.
Distance	Marks a line on the image by clicking two different points. The measured distance may be expressed in pixels or specific units (i.e. millimeters) depending on the examination type.
Angle	Marks an angular measurement on the image by clicking three different points on the image, where the first point represents the angle vertex. The measured angle is expressed in degrees (0-180).
Area	Deploys a custom polygon on the image and calculates its area. Every left click on the image creates a new polygon vertex. When finished, click the right mouse button to close the area and complete the measurement. The measured area may be expressed in pixels^2 or specific units (i.e. mm^2) depending on the examination type.
Draw arrow	Draws an arrow on the image. Mark two points on the image to define the arrow. Brush color and size can be customized in the Overlay menu.
Draw rectangle	Draws a rectangle on the image. Mark two points on the image to define the rectangle top-left and bottom-right corners. Brush color and size can be customized in the Overlay menu.
Write text	Creates a balloon-tip with text on the image. Click the point where the balloon should be deployed, then input the text and press Ok to complete.

MENU FILTERS

Please note that some of the following tools may not be available depending on the specific examination type.

Brightness	Scroll the mouse wheel to adjust image brightness.
Contrast	Scroll the mouse wheel to adjust image contrast.
Gamma	Scroll the mouse wheel to adjust image gamma. Every gamma value produces a different color mapping starting from the original image. Experiment with different gammas to find the one that fits the image best.
Restore	Turns off any applied filters and restores the original image on screen.

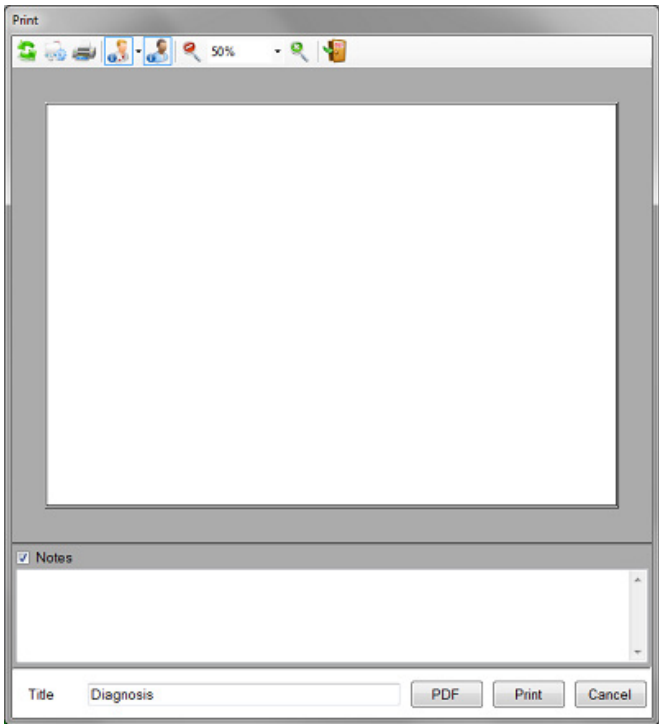
PRINT PREVIEW

This form lets you configure and preview the layout of a print.
A menu is displayed at the top of the screen: a short description of the functionalities and options available follows.

Refresh	Refreshes the print preview to the current status
Page setup	Allows for setup of the page by setting page size and margins
Print	Starts the print job opening the Print window will be shown to obtain the final conformation. The **Print** acts in the same way.
Practice header	Shows/hides the practice header on the printout. This header contains information on the practice.
Edit practice header	Allows editing of the practice header.
Patient header	Shows/hides the patient header on the printout. This header contains demographic information of the patient.
Zoom In/Out	Allows you to zoom in/out the print preview.
Cancel print	Returns to the previous screen. The Cancel acts in the same way.

By selecting or unselecting the check-button Notes the content of the text box below will be shown/hidden on the final printout.

The PDF button makes a print PDF file. It is necessary to choose whether to save the file on desktop or keep it in the examination gallery.



Generic printing form

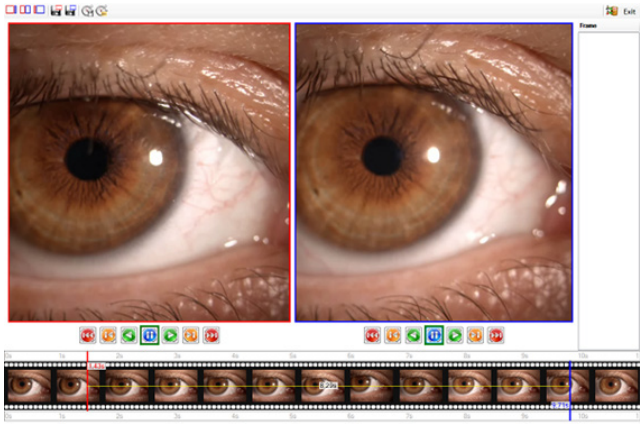
VIDEO PLAYER

Slit lamp imaging , videokeratoscopy and aberrometry provide the functionality to record and play generic videos.

Click the video thumbnail in the examination gallery to start the video player.

The main player screen shows two different frames of the same video together, loading the first and the last frame in the red and blue square, respectively.

The timeline at the bottom of the screen provides a visual preview of the whole movie.



Movie frames with player controls and streaming preview timeline

The movie player toolbar under each frame provides basic control functions like play, pause, move one frame forward / backwards, go to first / last frame.

Here is a list of advanced functions provided by the top toolbar:

» Displays left frame image only

» Displays the right frame image only

» Displays both left and right frame

» Saves the left frame currently displayed as a stand-alone image, so that it becomes available in the examination gallery. Saved frames are also shown as thumbnails in the right column of the video player.

» Saves the right frame currently displayed as a stand-alone image, so that it becomes available in the examination gallery. Saved frames are also shown as thumbnails in the right column of the video player.

» Saves the time range between the left frame and the right frame. This function is useful in many cases, for example when marking the time elapsed between an eye-blink and the first tear film breakup. The saved time range is automatically loaded the next time the movie is opened.

» Loads back the previously saved time range, if present.

CONIC EQUATION

The equation of a conic curve can be expressed as below:

$$z = \frac{-R + \sqrt{R^2 - p * r^2}}{p}$$

where r is the distance from center, R is the **apical radius**, p is the **asphericity** in one of its forms.

The **apical radius** is the local radius of curvature in r = 0, i.e. at the apex of the curve.
Asphericity can also be expressed as e, E and q.
Here below are the formulas for converting p to e, E and q.

$$e = \begin{cases} -\sqrt{p-1}\, if\, p > 1 \\ \sqrt{1-p}\, if\, p \leq 1 \end{cases}$$

$$E = 1 - p$$

$$Q = p - 1$$

For a circle, we have p = 1, e = 0, E = 0, Q = 0.

TEAR MENISCUS

Images acquired by **SlitLamp** and **Videokeratoscopy** can be subjected to advanced tear meniscus analysis.

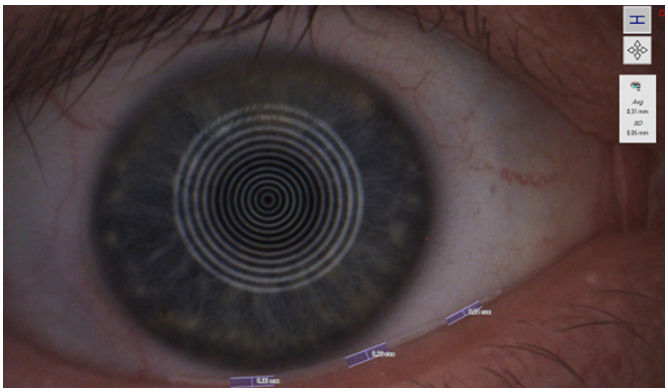
Click  in the **Opening and editing images** window to start the tear meniscus analysis.

The purpose is to mark three or more points of interest in the tear meniscus in order to obtain reliable statistic data about the average height and standard deviation.

Click on one edge of the tear meniscus, then move the mouse over the other edge to adjust the marker's height and orientation, then click again to set the marker.
The panel on the right displays the average (Avg) and standard deviation (SD) for the existing markers.

Hovering the mouse on an existing marker brings up the "delete measurement" menu.

All measurements are saved automatically when the tear meniscus analysis window is closed.



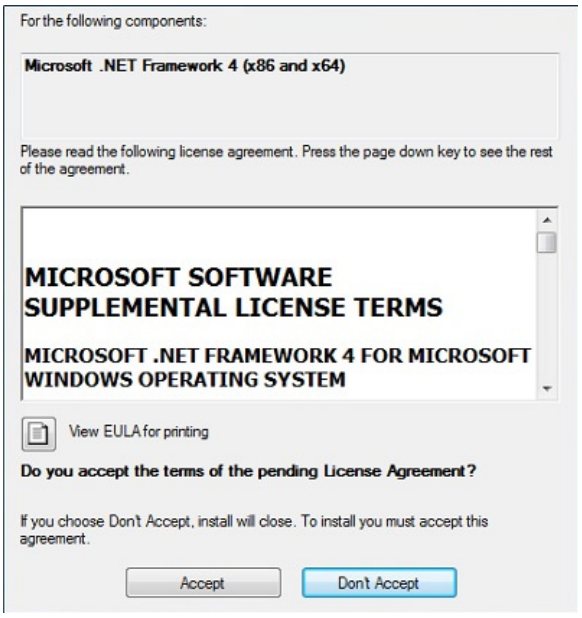
Tear meniscus analysis window

FIRST INSTALLATION AND STARTUP

In order to install the software please follow all the instruction reported below.

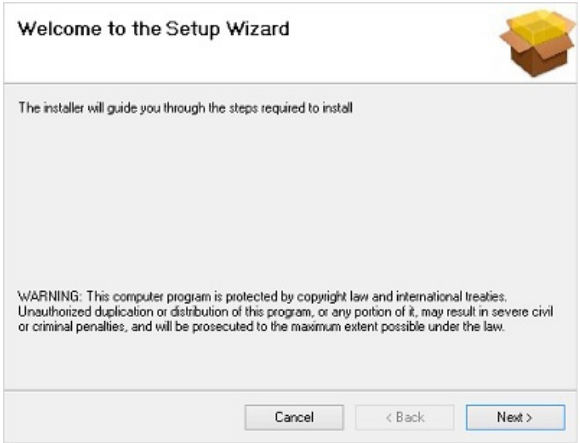
Insert the CD and wait for the installation procedure to start. In case autorun operating system feature is disabled launch manually "Setup.exe" executable file.

If Microsoft .NET 4.0 Framework is not installed on the PC, the "Microsoft license agreement" screen will be displayed. Accept the licensing conditions and wait for the installation complete.



Microsoft license agreement

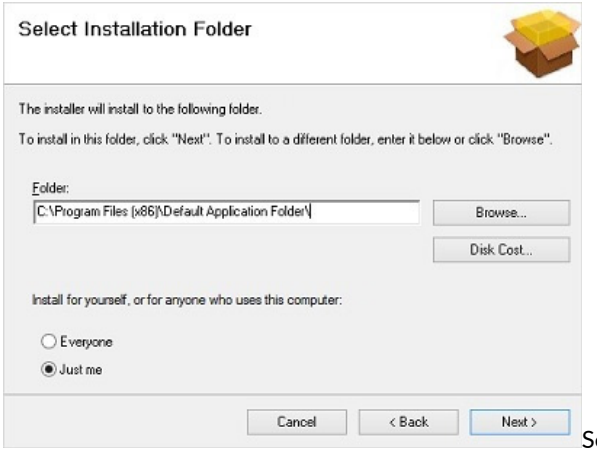
Upon completion of the procedure outlined below or if Framework is already installed click Next on the "Setup Wizard" screen to begin the software installation.



Start Setup Wizard

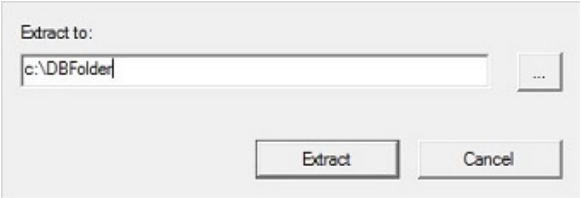
Select the destination file path for software installation and click Next. We recommend not changing the default displayed path.

Click Next over the "Confirm Installation" screen to start the installation.



Select installation folder

Upon completion of the installation click OK to confirm and proceed with the installation of a demo database, press Cancel otherwise. Select the desired destination folder using the "Extract to" field.



Demo database installation folder

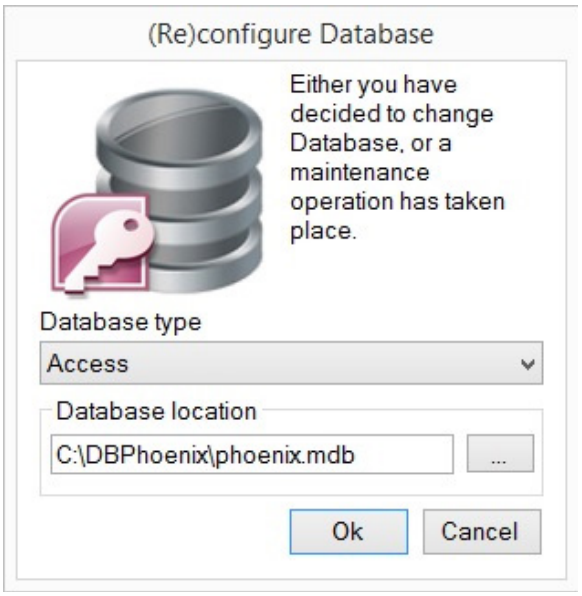
After demo database installation click Close to complete the entire procedure.

The application can be now executed using the shortcut  displayed on the desktop.
In order to be executed, the application requires operating system user with local machine administrative privileges: if this requirement is in conflict with user internal security policy, please contact support to evaluate possible solutions.

In case of first execution please refer to Software activation and registration procedure.

After registration procedure you need to connect with the working database by the "Database Configuration Dialog". Press OK if the database has been created during the installation.
If the database is just present press browse button and select the desired phoenix.mdb file

The application is now ready to be used, please refer to Managing patients and examinations for more detail.



Database configuration dialog

ACTIVATION AND REGISTRATION

LICENSING

Every software installation requires a license.

There are 3 license modules available.

» **LITE:** includes all basic features for all instruments.
» **PUPIL:** includes advanced topography features and pupillography.
» **PUPIL_IOL:** includes advanced topography features, pupillography and IOL calculation.

The extra module **CARDIO** can be added to the previous license types and enables advanced AVR (Arteriolar-to-Venular Ratio) for fundus camera.

Check the instrument's Serial Number: all instruments released from 2016 contain their own license on-board, so that the software will auto-activate as soon as the instrument is plugged to the USB/Firewire port.
If this is your case, the software will launch without asking for activation and a pop-up appears at the bottom of the screen showing license type, P-number and Serial Number found on the instrument(s).
Do not consider the following section as it is not going to be necessary at all.

FIND AND ENTER THE "P-NUMBER"

Please note that the software becomes unactivated again when the instrument is unplugged from the PC port.

If the instrument was released before 2016 or there are no instruments plugged in, the Activation form appears every time the software is launched. Click Use free trial to start the software in DEMO mode, which includes the same features as PUPIL license, but can be run 60 times before preventing the software to launch again.

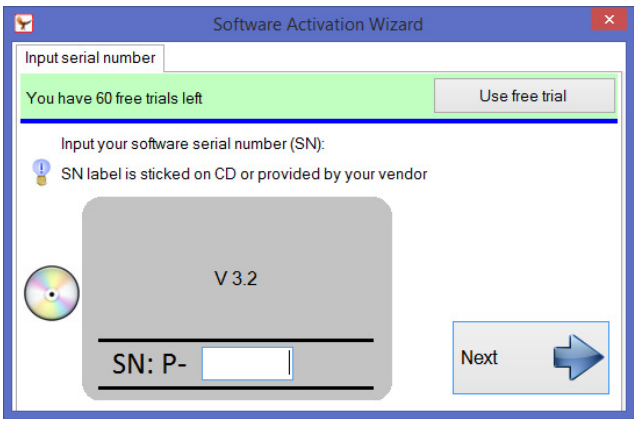
The activation form requires to input **P-number**, which is a software license identifier usually printed on a gray label sticked on the instrument, or transmitted by your vendor.

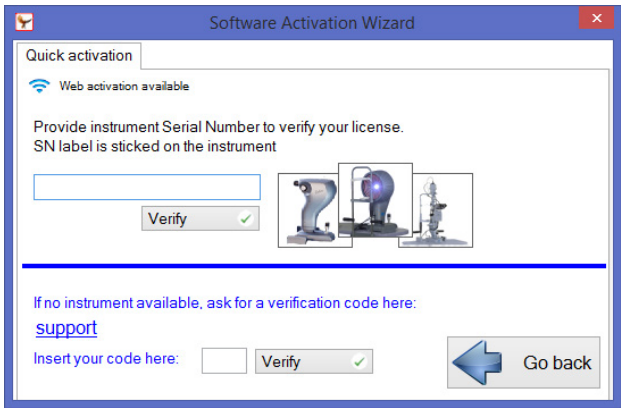
Input the **P-number** then click Next.

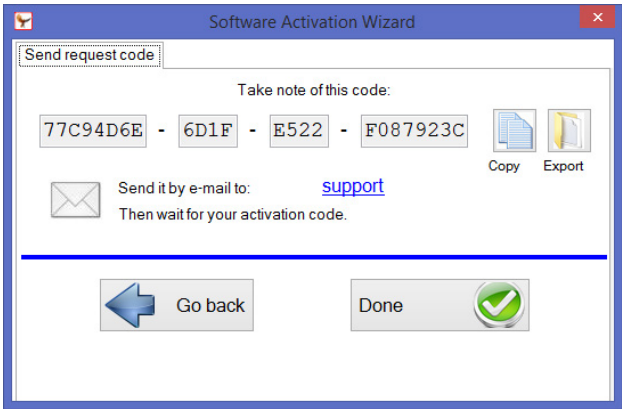
If the computer is connected to Internet the web verification form is shown: enter the 8-digit **instrument Serial Number**, which is also sticked on the device (it is different from the 4-digit P-number that was entered at the previous step), or, if such number is missing, contact the support or vendor for a 2-digit verification code which must be entered in the text box at the bottom of the web activation form.
Choose a verification mode entering one of the two numbers, then click Verify to complete the process.

If the computer is NOT connected to Internet then a 24-digit request code is produced. Take note of this code and send it to your support contact, then click *Done*.

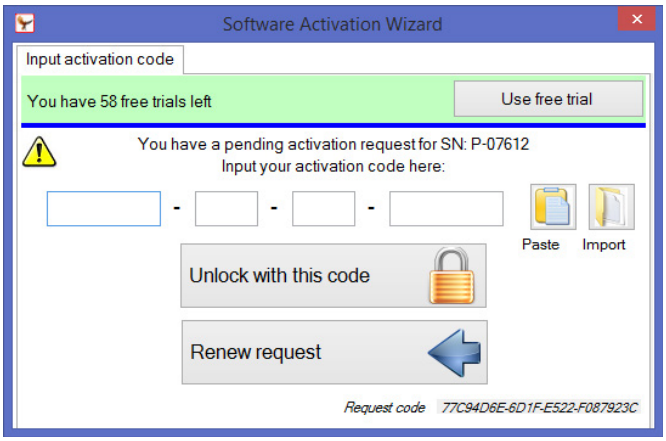
Select installation folder







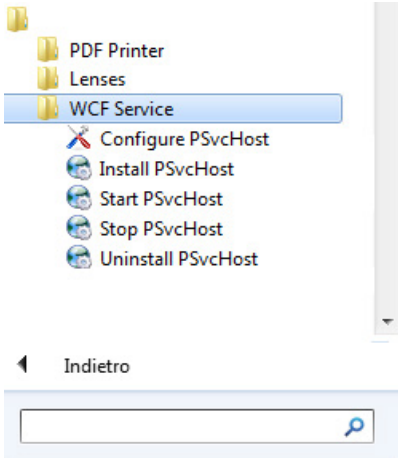
Upon receiving an activation code, enter it in the activation form that loads up every time the software is launched again.
The request code is shown also in this form, in case it hadn't been noted at the previous step.
Insert the 24-digit activation code then click Unlock with this code to complete the activation process.
If something went wrong in the activation process, click Renew request to get back to the P-number form a start a new activation request.



UPGRADE

In case of software upgrade (i.e. replacing previous version), the screen reported on "Figure 1" might appear.

This means that the WCF service menu has been used to install the Application Web Service interface. Before proceed please make sure to uninstall the service, following the menu application path reported below:



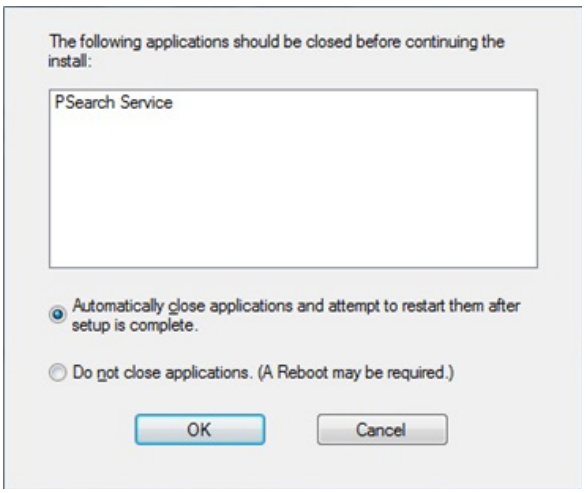


Figure 1

After this action, the uninstall procedure will correctly complete.

IMPORT/EXPORT EXAMINATIONS

To export an examination or a patient right-click on the corresponding line of the Patients/Examinations list and select the icon. After editing demographics data (not mandatory and for privacy reason) and confirming the export a file is created with extension **zcs**.

To import an existing **zcs** file, drag and drop the file into the Patients/Examinations list panel (Windows XP and Windows Seven) or select File ▶ **Import** in the main screen

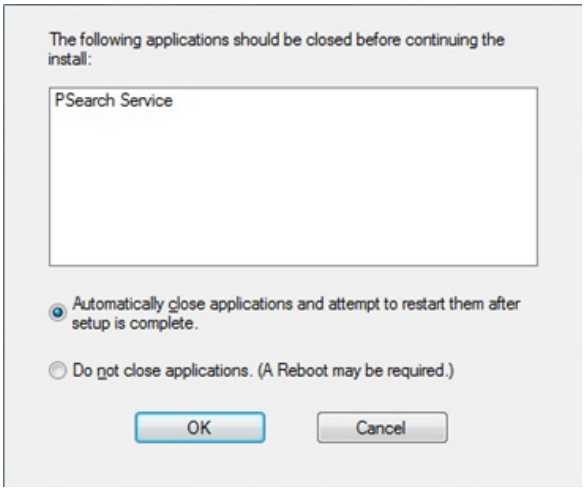


Figure 1

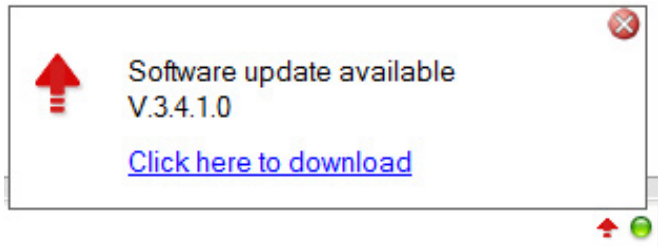
SOFTWARE UPDATE

The software checks for available updates when it is connected to the internet.
The green circle on the right system tray indicates that the system is online.

When an update is available an alert is displayed on screen.

Select Click to download to start downloading the update.

When download is complete, select Click to install on the update window.
The software is closed and the update process begins.



Software update alert

COSTRUZIONE STRUMENTI OFTALMICI

Via degli Stagnacci 12/E | 50018 Badia a Settimo | Scandicci (FI) | ITALY
phone: +39 055 722191 | fax: +39 055 721557

cso@csoitalia.it | www.csoitalia.it