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ATLAS VOL 2

OF ANTERIOR

SEGMENT

OCT



CONTRIBUTORS

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C.S.O. COSTRUZIONE STRUMENTI OFTALMICI

ATLAS OF ANTERIOR SEGMENT OCT

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FABIANO EDITORE

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AS-OCT

ATLAS

- INTRODUCTION
- CLINICAL CASES

INTRODUCTION

I feel honored to present to my ophthalmology colleagues this second edition – just a year after the initial appearance – of the *Atlas of Anterior Segment OCT*, which was strongly promoted by the CSO management board.

The volume collects, in the form of clinical cases, a series of contributions by prominent, experienced international colleagues, who had the opportunity to use this new instrument in their clinical practice.

The ample iconographic documentation and the uniqueness of some of the described cases give evidence of the fundamental role played by this instrument – the result of Italian technology and research – in helping international colleagues solve their clinical challenges.

I am certain that readers of this rich and comprehensive *Atlas* will find great pleasure in browsing through its pages, possibly finding correlations between the cases described and their daily clinical practice.

Many thanks also to our colleagues for their contributions, as well as to the editorial team, and most of all to the CSO management for sponsoring and strongly promoting the realization of this educational enterprise which started a year ago with the first volume of the *Atlas*, and is now successfully completed with the addition of this second volume.

Rome, September 2019

Vittorio Picardo

The evaluation of corneal and anterior segment morphology and structure has been recently improved thanks to several diagnostic instruments, which allow us to obtain even more detailed and precise information.

In my thirty year-long career, I have had the pleasure of being part of the birth, the growth and the global diffusion of several diagnostic technologies that, today, are part of our routine armamentarium for the anterior segment analysis.

Since my graduation as a medical doctor in 1988, I have witnessed the entire process starting from idealization to commercialization of videokeratography for the measurement of the anterior corneal curvature.

I experienced the advent of the first Scheimpflug cameras for the visualization of the anterior chamber and the evaluation of the posterior corneal curvature.

I saw great ideas arise and then fall (corneal holography, raster-stereography), other ones taking off but never becoming widely spread (high-frequency ultrasonography) either due to the high associated costs, or from difficult to understand strategical and commercial decisions. I have also observed techniques for the anterior segment developed and applied to the posterior segment, such as optical coherence tomography (OCT).

This Atlas celebrates the introduction of a combined diagnostic technology that allows to obtain very high-resolution images, and consequently extremely accurate and precise anatomy-topographical data, related to several structures of the anterior segment: tear film, corneal epithelium, Bowman membrane, corneal stroma, corneal endothelium, anterior and posterior corneal curvature, anterior chamber, iris-sclera-corneal angle, iris, pupil size and dynamics, crystalline lens.

All of this is possible due to the combination of the highest technology for the analysis of the anterior corneal curvature (videokeratography Placido-disc based), with quality spectral domain OCT, found in a single instrument that has yet many other innovative technical features. In the time of a "click", this instrument provides a complete, yet detailed panorama of the anterior segment.

In other words, this is the coupling of the best corneal topographer and the best anterior segment OCT, with a commercial name, MS-39, that recalls the founder of the company, the father of this technology. This system is perfectly integrated with the CSO diagnostic platform (aberrometer, Scheimpflug camera, corneal topographer, etc.) which connects in an interactive way to provide even more diagnostic information.

I had the opportunity to use one of the first MS-39 prototypes in my clinical practice. After almost one year of daily use, I can honestly say that I could no longer practice without it. If I had to choose one single diagnostic tool to work with, no doubt, this one would be my choice. As a corneal, refractive and cataract surgeon I have to admit I learned so much from the information, previously unknown, provided by this technology.

There are countless clinical examples, most of them illustrated in this Atlas, that helped me find an easier diagnostic/surgical direction only through the use of this instrument. And it has been so wonderfully exciting, over my thirty years of ophthalmology practice, to witness the path CSO has made side by side with the ophthalmologists. Indeed, for ophthalmology, CSO was already there thirty years ago when, beside slit lamps and keratometers, its innovation was demonstrated by the launch of one of the very first videokeratographers.

Today CSO is present with this one-of-a-kind technology and it is destined to force all the competitors to strive to keep up with this shining example of the Italian excellence. For all these reasons, I strongly wish that CSO achieves all the popularity that it deserves for the innovation and development of this diagnostic technology. Empowered by this technology, future achievements of the scientific community will arise by enabling research thanks to an instrument capable to evaluate, measure and visualize information that was not accessible before. These advances will make our profession easier and more efficient, allowing us to provide our patients, the final consumers, with continuously better and more efficient services.

Milan, September 2018

Francesco Carones

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Described by Francesco Carones

1

POST REFRACTIVE SURGERY ECTASIA

DIAGNOSIS AND IDENTIFICATION OF THE INITIAL SURGERY PROCEDURE

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A 30-year-old woman presented to my office complaining of a progressive decrease in vision in both eyes over the past year. She stated that around 10 years ago she underwent bilateral PRK in order to correct about 6 D of myopia, and afterwards she claimed to have had good vision until a year ago. She also stated that she delivered her first baby a year ago. Her corrected distance visual acuity was 20/60 with +2.50/-6.00 x 075, and 20/30 with +1.50/-3.00 x 90, for the right and left eye, respectively. No LASIK flaps were seen on slit lamp evaluation. Her bilateral MS-39 tomography can be seen in Figure 1. I typically prefer to display what I call the "Hexamap", instead of the conventional "Quadmap". My customized Hexamap consists of the captured image that assures that the measurement is unobstructed and centered, and further assesses the position of the measurement center position in comparison with the center of the cornea, the epithelial map, the anterior and posterior instantaneous curvature, posterior BFS, and the pachymetry map. In addition to the ectatic cone seen in the curvature and elevation maps, one can appreciate the epithelial thinning over the cone in both eyes, and the thickening area diametrically opposite to it.

However, looking at the corneal OCT, one can notice the bilaminar structure of Bowman's layer, which suggests that the latter has not been ablated (Figure 2). A closer look at the periphery (Figure 3) shows the meniscal edge of the flap (microkeratome cut). Obviously, the patient was misinformed concerning what treatment she had underwent 10 years ago. Further, on slit lamp exam, a microkeratome-cut flap can sometimes be difficult to identify 10 years later. The ultra-high-resolution OCT technology of the MS-39 has proven to be of primary importance in elucidating the history and disease course of this patient.



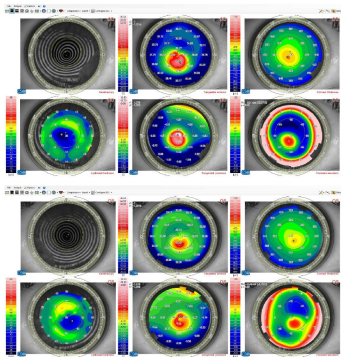


Figure 1. Tomography Hexamaps of the right eye (A) and left eye (B), showing bilateral ectasia, with epithelial thinning over the cone, and diametrical opposed thickening.

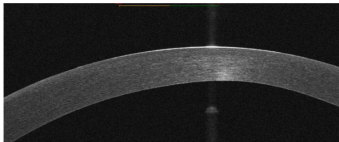


Figure 2. OCT cut of the cornea showing the bilaminar structure of Bowman's layer. Its presence indicates that no surface ablation has been performed on the cornea.

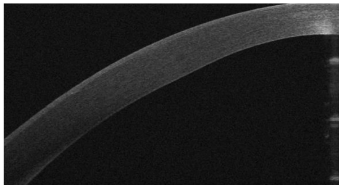


Figure 3. OCT cut of the cornea showing the edge of what appears to be a meniscal corneal flap, as opposed to a planar flap, thus indicating that laser in situ keratomileusis (LASIK) has been performed using a microkeratome.

TAKE HOME MESSAGE

Examining the bilaminar pattern of Bowman's layer can aid in differentiating a history of LASIK from PRK, in the situation in which the flap is not identifiable on exam and OCT.

2

THE EPITHELIUM DESERVES ATTENTION

NO REFRACTIVE SURGERY EVALUATION IS COMPLETE WITHOUT A LOOK AT THE EPITHELIAL MAP

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A 44-year-old woman presented to our clinic seeking an evaluation for refractive surgery. Her manifest refraction was 20/20 with +1.50/-0.25 x 050, in the right eye, and 20/20 with +1.50/-0.75 x 90 in the left eye. Her MS-39 tomography Hexamap display for the right and left eye is featured below in Figure 1. One can note an inferior steepening, similar to keratoconus, on the absolute 1.5 D instantaneous curvature maps in both eyes. Nonetheless, the posterior BFS appears normal, and the instantaneous posterior curvature map shows in both eyes a very symmetrical bowtie with the rule astigmatism and no focal steepening. On the other hand, the epithelial map readily displays bilateral focal thickening of the epithelium centrally, with more thickening inferocentrally, accounting for the focal steepening on the anterior curvature map. This could be due to contact lens warpage, although the patient denies any contact lens wear. In my experience, these unusual epithelial distributions are not that uncommon, and the clinician should always consider the aforementioned possibility in eyes with a mismatch between the anterior curvature and the posterior curvature and float. The MS-39 in this scenario does a great job in measuring all variables and aligning all the maps for an easy diagnosis.



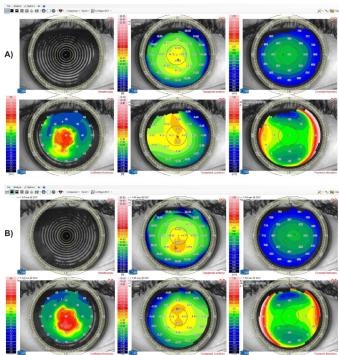


Figure 1. Tomography Hexamaps of the right eye (A) and left eye (B), showing inferior steepening on the instantaneous curvature map with normal posterior curvature and posterior BFS elevation maps. The epithelial map shows bilateral inferocentral thickening.

TAKE HOME MESSAGE

Asymmetric bowties and focal inferior steepening on the anterior curvature map can sometimes be secondary to epithelial warpage. Evaluation of the epithelial map and comparison between anterior and posterior curvature maps can aid to differentiate this condition from early corneal ectatic alterations.

3

IOL POWER CALCULATION FOLLOWING RADIAL KERATOTOMY

THE RAY TRACING APPROACH

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Many methods and formulas have been developed in order to calculate the intraocular lens (IOL) power in eyes that have undergone LASIK or PRK. On the other hand, only a few methods are currently available for eyes that have undergone radial keratotomy (RK).

Radial keratotomy was carried out to correct myopia by flattening the corneal curvature. The calculation of the IOL power in eyes with RK is problematic for the following three reasons: 1) the relationship between the anterior and the posterior corneal curvature is altered,¹ so that the standard 1.3375 keratometric index is no longer valid; 2) the optic zone may be smaller than the diameter along which the corneal curvature readings are taken; 3) the formula that utilizes the corneal power as a predictor for the IOL position (such as the Hoffer Q, Holladay 1 and 2, and SRK/T) makes an erroneous estimation due to the artificial flattening induced by surgery.

Ray tracing, which has been successfully used to calculate the IOL power in eyes with myopic LASIK and PRK,² is an elegant solution also suitable in eyes with previous RK. It offers several advantages with respect to traditional thin-lens vergence formulas:

- it does not rely on a fixed ratio between the anterior and posterior corneal curvature, but instead is based on the curvature measurements of both surfaces;
- it does not need any historical information (e.g., the amount of myopia corrected by refractive surgery);
- it does not estimate the IOL position from corneal power (which is artificially modified by refractive surgery). Rather, the IOL position is predicted using a proprietary algorithm based on varied anterior segment parameters, such as the position of the scleral spur;
- it can be calculated over different diameters, depending on the pupil size or the optic zone diameter;
- it does not perform paraxial calculations, but instead takes into consideration higher order aberrations, which can be relevant in eyes with RK;
- it directly performs calculations for the cylinder of the IOL in case of corneal astigmatism;
- once it is installed on a device such as the MS-39, it is an easy solution that does not require complicated Excel files.

The following case highlights its usefulness. A 52-year-old man was referred to us due to visual disturbances that had been worsening over the last two years. He had undergone RK in 1989 to correct myopia, with 12 incisions in the right eye and 8 incisions in the left eye. He reported that the preoperative refraction was -4.00 D in both eyes. Since he is an airline pilot, he was suffering from haloes and glare especially at night and needed the best possible uncorrected visual acuity. Therefore, I decided to implant a pinhole IOL (IC-8, Acufocus) in both eyes. Figures 1 and 2 show the corneal maps generated by the MS-39, displaying a central flattening and a small asymmetric optic zone.



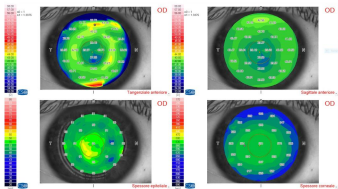


Figure 1. Corneal maps of the right eye. Secondary to RK, a small optic zone can be observed on the anterior surface. The optic zone is slightly asymmetrical, with flatter corneal curvature in its lower half.

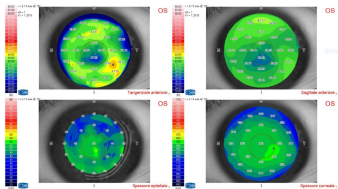


Figure 2. Corneal maps of the left eye show the same features as found in the right eye, with a small optic zone and asymmetric curvature within the pupil diameter.

Optical biometry revealed an axial length of 27.27 mm and 26.84 mm, in the right and left eye, respectively. When calculating the IOL power by ray tracing, we selected the A-constant of 120.5 suggested by the IOL manufacturer. The power calculated by ray tracing for emmetropia was 18.5 D in the RE (Figure 3) and 18.0 in the LE (Figure 4). Following the recommendation of the IOL manufacturer, we targeted for a low myopia (-0.50 D) and we implanted a 19.0 D IOL in the RE and an 18.5 D in the LE. One-month after surgery, the uncorrected distance visual acuity was 20/25 in the RE and 20/20 in the LE. The refractions were plano in the RE with a cylinder of -1.25 D axis 20° in the LE. The pinhole IOL permitted the patient to read newspaper fonts at near without glasses and assisted him in the elimination of visual disturbances at night.

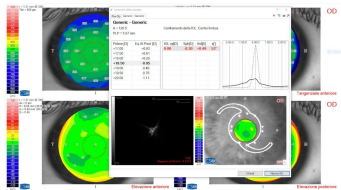


Figure 3. Ray tracing in the right eye indicates an 18.5 D IOL power for emmetropia.

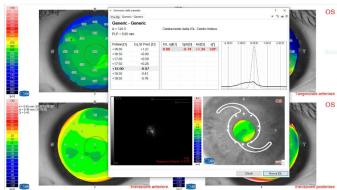


Figure 4. Ray tracing in the left eye indicates an 18 D IOL power for emmetropia.

Following this patient, we operated on three other eyes with previous RK, choosing standard IOLs and having axial lengths of 28.91 mm, 32.84 mm and 33.06 mm. In these cases, we achieved good results by modifying the axial length values according to the formula proposed by Wang et al.³ The modified values entered into the ray tracing software were thus decreased to 28.23 mm, 31.49 mm and 31.67 mm. This approach, which has been demonstrated to improve the results in unoperated eyes, is also likely to function in post-refractive surgery eyes, especially when the axial length is greater than 28 mm.

TAKE HOME MESSAGE

Ray tracing, as calculated by the M5-39, is a promising solution for eyes with prior RK that need cataract surgery. In this patient an excellent outcome was achieved in both eyes, but two factors played a role and must be accounted for. First, the axial length was long, but not as elongated as can be found in eyes with high myopia, where it can be greater than 30 mm. Second, small refractive errors may be masked by the pinhole IOL. Further studies are needed to assess the outcomes with standard IOLs and eyes with higher axial length, where adjustments such as those suggested by Wang and Koch may be useful.

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4

HIGH RESOLUTION OCT IMAGING OF THE EPITHELIUM

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In 2009, Reinstein et al. introduced the importance of mapping the corneal epithelial thickness for keratoconus screening. This arises from the well proven compensatory effect of the corneal epithelium to mask underlying stromal surface irregularities by thinning itself over hills and becoming thicker over valleys.

Presently, corneal epithelium evaluation is becoming critical as well as mandatory for any preoperative refractive surgery assessment. Furthermore, recent published evidence is helping to establish epithelial thickness thresholds in order to increase the accuracy in early keratoconus detection. For example, in the following case we can observe an unremarkable topography with normal curvature, corneal thickness and posterior elevation maps. However, the epithelial thickness map shows a suspicious distribution with an inferior asymmetry.

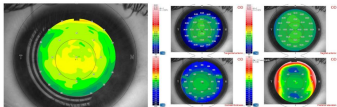


Figure 1. Right eye: seemingly apparent normal topographic maps apart from epithelial thickness which displays a vertically asymmetric pattern with paracentral inferior thinning.

If we analyse the contralateral eye, we can observe that it shows a clear keratoconic disease, with abnormal distribution patterns in all maps. Thus, epithelial thickness mapping was the most sensitive map and the only measurement able to predict a potential keratoconus in the apparently normal right eye.

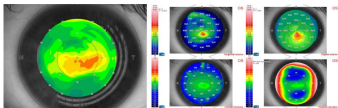


Figure 2. Contralateral eye of the previous case: curvature maps show a clear asymmetric steepening in the central zone. The epithelial thickness map shows an infero-temporal thinning.

The MS-39 offers the highest resolution image among all commercially available AS-OCTs; vertical resolution = $3.5\mu\text{m}$; horizontal resolution = $12.5\mu\text{m}$, which are key resolution values for any refractive and corneal surgeon. Following version 3.7, the MS-39 is also able to provide an anamorphic image of the corneal layers. This new method of representing the cornea arose from the need to evaluate details of a few microns in elevation within an overall corneal thickness of around $500\mu\text{m}$. This new display mode consists in straightening the image along its corneal anterior surface.

1. KERATOCONUS

The following topography and corneal epithelial thickness maps show a more advanced case of keratoconus.

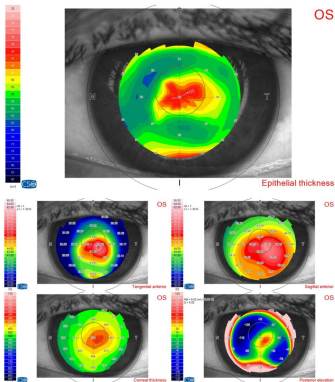


Figure 3. Advanced keratoconus: epithelial thinning around the cone apex (left image); curvature steepening in the anterior curvature maps, corneal thinning and bulging zone in the posterior elevation map (images on the right).

By using the new MS-39 software for high-resolution epithelial imaging we can observe precisely how the epithelium thins exactly in correspondence with the apex of the cone.

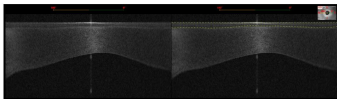


Figure 4. The “straightened” version of a corneal section highlights an epithelial thinning in the position of the cone apex.

2. EPITHELIAL INGROWTH

Epithelial ingrowth can be a disturbing complication after any kind of laser refractive surgery. The following image presents a case of an isolated mild nest of epithelial ingrowth adjacent to the incision of a primary SMILE procedure treated with YAG laser in early post-op in order to prevent its spread (A). Standard corneal OCT image (B) clearly shows the SMILE surgical plane as well as the area of ingrowth. However, the new epithelial display mode allows a much better visualization with higher resolution and magnification of all corneal layers (C-D).

This epithelial nest unfortunately induced a secondary topographic cylinder that left a residual refractive astigmatism of 1.25D (see below). As a consequence, mechanical removal of the deposit

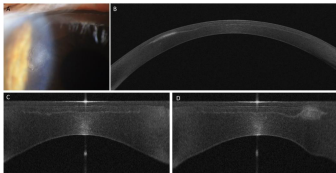


Figure 5. A) Isolated mild nest of epithelial ingrowth adjacent to the incision of a primary SMILE procedure treated with YAG laser in early post-op. B) Standard OCT section: SMILE surgical plane and area of ingrowth. C) and D) Straightened versions of OCT corneal sections.

was considered. However, careful examination of the epithelial nest in image D (see above) displays a melt of the overlying stroma of the SMILE cap, indicating a high risk of anterior cap perforation if such maneuver were attempted.

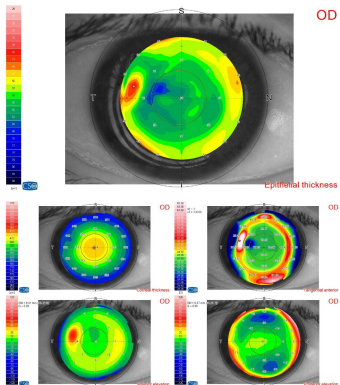


Figure 6. Topographic maps: epithelial thickness (left image) and corneal thickness, tangential anterior curvature, anterior and posterior elevation (smaller images on the right).

3. POSTERIOR KERATOCONUS

Posterior keratoconus is a rare form of corneal ectatic disease. Here we present a case of advanced posterior keratoconus associated with a progressive stromal scar.

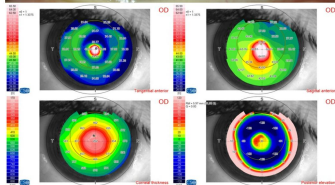
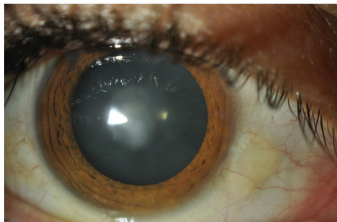


Figure 7. Topographic maps and slit lamp frontal images of an advanced posterior keratoconus case.



Because this patient had a decimal visual acuity of 0.05 decimal with a visual potential of 0.5, the potential advantages of corneal grafting were discussed. For surgical evaluation, the appraisal of the scar depth is essential. By using the standard high resolution corneal OCT image, it is difficult to assess the actual involvement of the deep stroma and Descemet's membrane, but with the new display mode we can precisely analyse all corneal layers and, in this case, see how the deep stroma and DM are affected and opacified by a full thickness scar. We can observe with a resolution never seen before the posterior ectasia as well as the overlying compensatory effect of the epithelium.

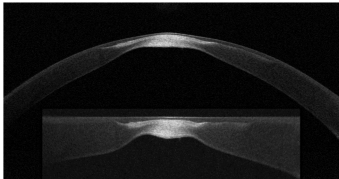


Figure 8. High-resolution corneal OCT section (top) and "straightened" version of a smaller portion of this corneal section (bottom). Both stroma and DM are opacified.

TAKE HOME MESSAGE

Corneal epithelium thickness mapping is becoming essential for early keratoconus detection as well as for the identification of those cases at risk for developing ectasia following laser refractive surgery. Thus, this map is critical during the preoperative assessment of any patient candidate for refractive surgery. High definition corneal OCT images allow an accurate diagnosis, surgical planning and postoperative follow-up of any corneal disorder.

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5

LATE CORNEAL EDEMA FOLLOWING PENETRATING KERATOPLASTY

DIFFERENTIATION BETWEEN CAUSES OF EDEMA PRESENTING AFTER KERATOPLASTY

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A 65-year-old patient presented to our clinic reporting visual loss. The patient had received 30 years prior a penetrating keratoplasty in the right eye for keratoconus. On slit lamp examination, corneal edema was visible, and the main diagnostic hypotheses were chronic endothelial decompensation or acute endothelial rejection (Figure 1).

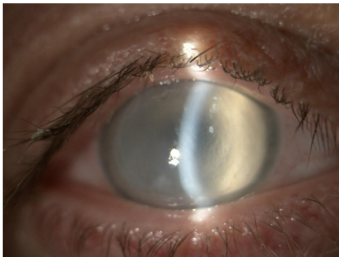


Figure 1. Slit lamp exam displays corneal edema.

OCT examination with the MS-39 showed the presence of detachment of Descemet's Membrane (Figure 2), most likely due to progressive thinning of the posterior section of the graft-host junction.

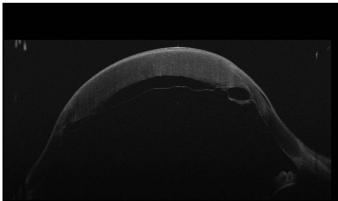


Figure 2. AS-OCT section demonstrates the presence of Descemet Membrane detachment.

Two weeks later, the patient received an air injection into the anterior chamber with resolution of the corneal edema after one month (Figure 3). Vision improved and a scleral contact lens was re-fitted with an optimal visual outcome.

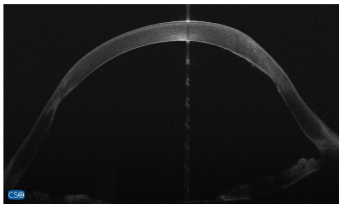


Figure 3. One month after air injection into the anterior chamber: corneal edema was resolved.

TAKE HOME MESSAGE

A high resolution AS-OCT such as the MS-39 is essential to evaluate potential causes of edema after corneal surgery and serves as a guide for pre and post-operative management.

6

CORNEAL PENETRATING INJURIES

EVALUATION OF THE DEPTH OF INVOLVEMENT

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A 12-year-old child presented to our department with a corneal opacity following accidental injury three months prior by a tree branch (Figure 1).



Figure 1. Corneal opacity following accidental injury with a tree branch.

Previous physicians hypothesized the presence of retained organic material and suspected possible fungal or bacterial infection. Corneal edema was reported with a partial response to topical steroids. AS-OCT scans obtained with the MS-39 clearly highlighted a small Descemet rupture, which explained the previous presence of corneal edema (Figure 2).

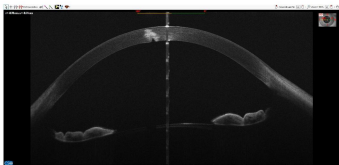


Figure 2. AS-OCT scan obtained with MS-39 clearly highlights a small Descemet rupture.

A few months after discontinuing all medications, the corneal scar remained stable. In this specific clinical scenario, if corneal edema had been present, then injection of air in the anterior chamber could have been utilized to favour Descemet Membrane reattachment.

TAKE HOME MESSAGE

A high-resolution AS-OCT such as the MS-39 is extremely useful to evaluate penetrating corneal injuries since it adds important additional information for clinical observation and surgical planning.



7

INFECTIOUS KERATITIS SEQUELAE

SURGICAL PLANNING BASED ON HIGH DEFINITION IMAGING

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A 52-year-old male presented to our department with acanthamoeba keratitis associated with contact lens wear. The patient had been treated for over one year with topical antiamebic drugs (PHMB, Chlorhexidine, and Hexamidine) without success. Central corneal melting was present (Figure 1) and the patient complained of chronic pain and reported use of analgesics for over 10 months.

A Gundersen conjunctival flap was performed, thus allowing the ocular surface to heal (Figure 2).

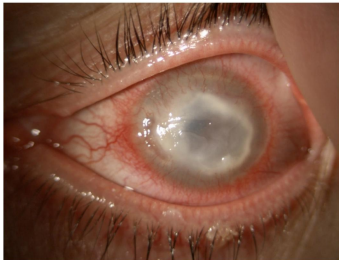


Figure 1. Central corneal melting.

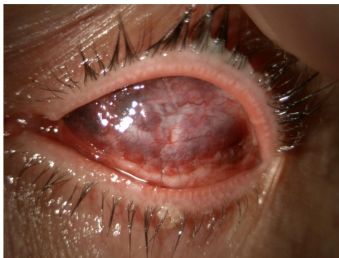


Figure 2. Gundersen conjunctival flap.

The patient responded well with complete reduction of pain and resolution of the infection. Six months after surgery, the eye was not inflamed, and the patient was evaluated for potential surgery (Figure 3).



Figure 3. Six months after Gundersen conjunctival flap.

The two therapeutic options in these cases consist of a large diameter penetrating keratoplasty (9.5-10 mm) or a tectonic lamellar keratoplasty, followed by a standard size penetrating keratoplasty graft (8-8.5 mm). AS-OCT performed with the MS-39 (Figure 4) demonstrated corneal thinning in the periphery.

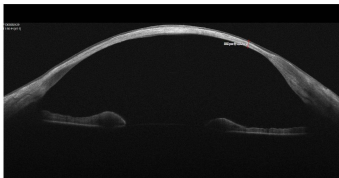


Figure 4. AS-OCT section clearly shows corneal thinning in the periphery.

In this clinical scenario, a full-thickness graft would require a large diameter, exposing the patient to a higher risk of endothelial rejection, while the altered thickness in the recipient bed would make suturing more difficult. A lamellar tectonic graft was successfully performed (Figure 5) with the objective of restoring appropriate thickness in the corneal periphery as observed on AS-OCT (Figure 6).

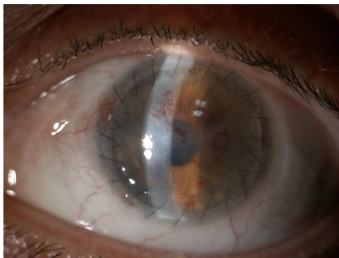


Figure 5. Frontal view of the lamellar tectonic graft.

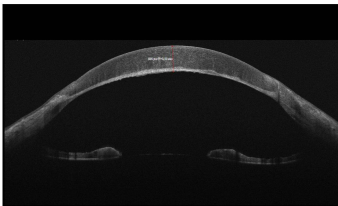


Figure 6. AS-OCT section clearly shows that the appropriate thickness in the corneal periphery was restored by the lamellar tectonic graft.

The patient is scheduled to receive a standard diameter penetrating keratoplasty inside the lamellar graft diameter.

TAKE HOME MESSAGE

An AS-OCT such as the MS-39 is essential in order to evaluate alterations in corneal thickness in preparation for lamellar or penetrating corneal graft surgery. High quality imaging aids in the appropriate surgical planning and post-operative management.

8

ALLOGENIC CORNEAL LENTICULE IMPLANTATION FOR HYPEROPIA

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Additive corneal procedures such as implantation of a corneal lenticule are promising approaches for correction of moderate to high hyperopia. Corneal lenticules extracted through SMILE (Small Incision Lenticule Extraction) represent a good potential source of donor tissue.

So far, several implantation surgical techniques have been developed:

- *In the pocket*: in this procedure the lenticule is implanted into a pocket similar to the one obtained with SMILE. Undercorrection may occur due to posterior surface changes.
- *Epikeratophakia*: in this procedure the lenticule is placed on top of the cornea after the epithelium removal without any stromal cut. Epithelial ingrowth is commonly reported.
- *Under the flap*: as in LIKE (Lenticular Implantation Keratoplasty), the lenticule is implanted under a corneal flap. Enhancement for residual refractive errors is relatively easier.

We present two cases of allogenic corneal lenticule implantation from SMILE. Serological tests were negative and informed consents were obtained from both the donor and the recipient.

Case 1

A 22-year-old female with a preoperative refraction of $+8.75 / +1.00 \times 80^\circ$ (OD) and $+9.75 / +1.00 \times 95^\circ$ (OS) presented to our clinic for hyperopic correction. BCVA (Best Corrected Visual Acuity) was 0.5 in both eyes. We performed an epikeratophakia using a corneal lenticule from a SMILE patient having a -7.00 D correction. The lenticule was 6.5 mm in diameter. A trans-PTK (6.6 mm ablation zone and 60 μ m ablation depth) centered on the corneal vertex was performed in order to remove the epithelium and was also utilized as a centration guide for the corneal lenticule. After an adequate dehydration in air of the corneal lenticule, a bandage contact lens was applied. Thirteen months after surgery, the patient's UCVA (Uncorrected Visual Acuity) was 0.5 on the right eye and 0.4+ on the left eye, and the BCVA were 0.6- and 0.5, respectively. The refraction was $+1.75 / +0.50 \times 70^\circ$ for the right eye and $+2.00 / +1.00 \times 110^\circ$ for the left eye.



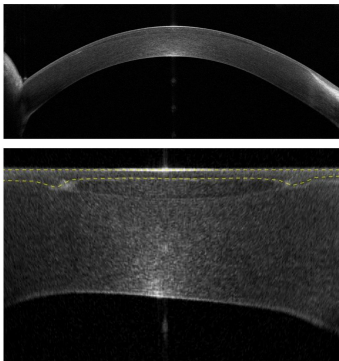


Figure 1. Case 1: right eye. A) Thirteen months post epikeratophakia using a +7.00 D corneal lenticule from a myopic SMILE patient. A trace amount of epithelial ingrowth is seen at the edge of the lenticule. B) Anamorphic display of the corneal section reveals the lenticule just under the epithelium.

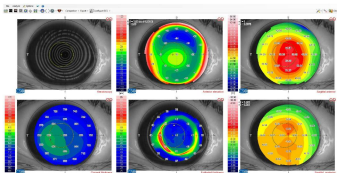


Figure 2. Case 1: post thirteen-month results. The central steep zone is regular and centered on the corneal vertex. The epithelium thickness map shows central thinning corresponding to the curvature changes.

Case 2

A 30-year-old male patient (+5.00D in the right eye and +5.25D in the left) presented to our clinic for hyperopic correction. A 9 mm corneal flap was created using the Alcon FS-200 femtosecond laser. The flap was 120 μ m thick. The donor lenticles were obtained from a SMILE correction of -5.00D. The corneal lenticle was 6.5 mm in diameter and was placed on the stromal bed centered on the first Purkinje image under the excimer laser microscope. Subsequently, the flap was re-positioned in a similar manner to a LASIK procedure. Ten months post-surgery, UCVA was 1.0 in the right eye and 0.8+ in the left. The refraction was +0.25 / -0.50 $\times$ 40° (OD) and +0.25 / 1.00 $\times$ 5° (OS). No change in the BCVA was detected in either eye, thus indicating the complete surgical success.

The differential follow-up with the Scheimpflug camera demonstrated over time a very stable posterior surface using “epikeratophakia” or the “under a flap” technique.

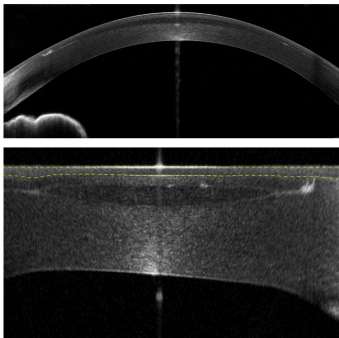


Figure 3. Case 2: right eye, 10 months post surgery. A) The lenticule is under the corneal flap. B) Anamorphic display of the corneal section shows the lenticule inside a stromal flap.

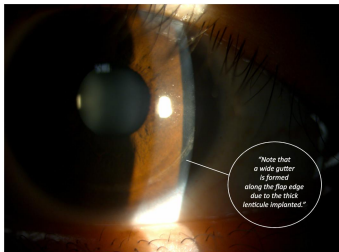


Figure 4. The wide gutter along the flap edge is formed due to the thick lenticule implanted.

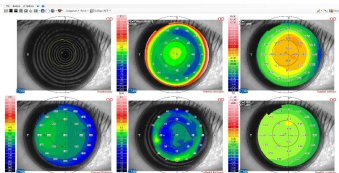


Figure 5. Case 2: right eye, 10 months after surgery.

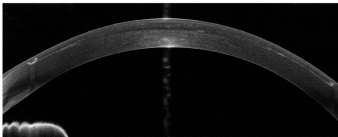


Figure 6. Case 2: left eye, 10 months after corneal lenticule implantation. The corneal stroma looks more homogeneous and the lenticule is less visible.

TAKE HOME MESSAGE

Corneal lenticule implantation for correction of high hyperopia is a promising technique. The MS-39 provides detailed information of the implanted corneal lenticule, which is essential in order to evaluate this procedure.

9

CORNEAL RESHAPING ASSISTANCE AND PREMIUM IOL IMPLANTATION

FROM DIAGNOSIS TO MULTI-STAGE MINI-INVASIVE VISUAL REHABILITATION

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University of Parma and National Research Council - Parma, Italy

In a case of long-standing penetrating keratoplasty, a severe bullous keratopathy was successfully reversed by means of ultrathin-DSAEK surgery. Unfortunately, the recovery of corneal transparency was largely incomplete. Despite optimal resolution of deep stromal and epithelial edema, the high-resolution OCT section image (Figure 1) clearly showed opacification as well as irregularity of the superficial stromal layer.

While a haze-like loss of transparency of the subepithelial stroma is very often present after long-standing corneal endothelial decompensation, the presence of irregular subepithelial material highly suggests on the other hand that previous surface laser ablations had been performed. When asked about this possibility, the patient recalled that a PRK treatment was indeed performed sometime after the penetrating keratoplasty.

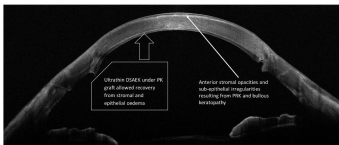


Figure 1. Display of subepithelial stromal opacities following resolution of bullous keratopathy after ultrathin-DSAEK.

Subsequent customized transepithelial PRK allowed us to obtain both regularization of curvature and full recovery of corneal transparency, as shown in the anterior segment OCT high-resolution section image (Figure 2).

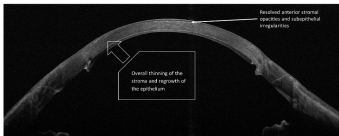


Figure 2. Regularization after surface transepithelial customized laser ablation.

The combined Placido disc and OCT corneal topography analysis performed by the M5-39 provided an accurate evaluation of the total corneal power and astigmatism, resulting in a precise IOL calculation. Due to the presence of previous PK, an add-on toric IOL in the sulcus (Figure 3) was preferred instead of a totally in-the-bag IOL for the correction of the high astigmatism (7 D), in order to ensure the possibility of less invasive surgical options in the case of future possible corneal curvature modifications.

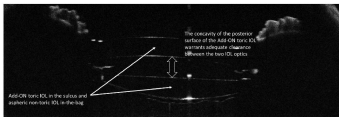


Figure 3. Subsequent phaco and in-the-bag IOL implantation combined with a sulcus add-on toric IOL.

TAKE HOME MESSAGE

The high-resolution anterior segment OCT scans provided by the M5-39 have been fundamental throughout all stages of the treatment decisions and follow up.

The precise characterization of subepithelial stromal opacities allowed correct diagnosis and treatment, as well as an evaluation of laser ablation depth and assessment of the correct placement of both in-the-bag and add-on IOLs. Utilizing the most accurate combined Placido plus OCT-based topographic measurements effectively assist in IOL calculation.



10

MYORING IN KERATOCONUS

FROM DIAGNOSIS TO IMPLANTATION INCLUDING EPITHELIAL MAPS

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A patient affected by bilateral keratoconus, more severe in the left eye, had difficulties wearing a spectacle correction, was intolerant to contact lenses, with a low expected compliance in the case of keratoplasty surgery. Uncorrected visual acuities were 20/80 and 20/200 in the right and left eye, respectively. The right eye achieved 20/25 vision with glasses, while the BCVA in the left eye was 20/63 and not tolerated in binocular vision.

Preferring a mini-invasive, additive and reversible solution, bilateral non-simultaneous MyoRing implantation was considered. Dr. Dexter's team at DiopTex (Linz, Austria) recommended a 6/240 and a 5/280 ring for the right and left eye, respectively, that were implanted in a 9mm diameter, 300µm deep femtolaser stromal pocket.

Besides assisting preoperatively in providing a precise map of the stromal depth for implantation, the postoperative MS-39 high-resolution AS-OCT section images (Figure 1) allowed a detailed characterization of corneal anatomy modifications induced by surgery.



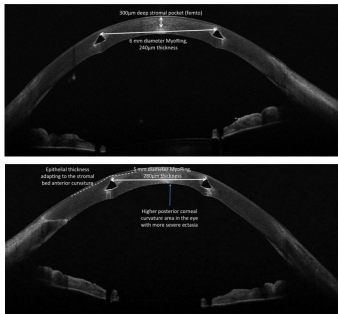


Figure 1. MyoRing implants in eyes affected by keratoconus.

The regularization of the central corneal curvature within the perimeter created by MyoRing implants inside the stroma resulted in good visual recovery even without spectacle correction, subsequently achieving visual acuities of 20/25 and 20/32 in the right and left eye, respectively. Topography maps originating from the combination of Placido disc and high-resolution OCT (Figures 2 and 3) allowed the precise definition of both anterior and posterior corneal curvature as well as of thickness modifications induced by the MyoRings implantation. Moreover, the relative contribution of epithelial and stromal thicknesses to curvature changes could be identified.

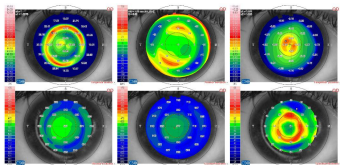


Figure 2. MyoRing implant in the right mild keratoconic eye.

While in the right eye (Figure 2) affected by a less severe keratoconus the pattern of epithelial thickness in the central cornea is quite regular, on the other hand in the left eye (Figure 3) it must adapt to the underlying stroma, compensating for its irregularities, with more than a $30\mu\text{m}$ difference between the most and the least ectatic areas. The slightly protruding stromal annular margin created by the MyoRing is fundamental in inducing this adaptation of the adjacent epithelium and the subsequent improvement in curvature regularization.

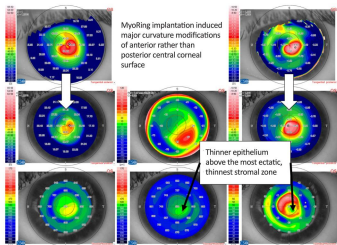


Figure 3. MyoRing implant in the left eye, affected by a more severe keratoconus. The top row shows the preoperative anterior and posterior tangential curvature maps.

TAKE HOME MESSAGE

The exceptional resolution scans provided by the MS-39 provide the means to see and measure all corneal layers in greater detail, thus granting total confidence in planning and performing corneal surgeries.

Not the least, the ability to characterize both epithelial and stromal corneal layers can finally transform "precise guesswork" into a deeper understanding of the anatomical and optical consequences of our interventions.

11

DESCEMETORHEXIS WITHOUT ENDOTHELIAL KERATOPLASTY

FROM DIAGNOSIS TO MULTI-STAGE MINI-INVASIVE VISUAL REHABILITATION

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A patient affected by Fuchs endothelial corneal dystrophy presented to our clinic with a cataract and central corneal edema but with a transparent peripheral cornea having a densely populated peripheral endothelium.

Because the vision in the fellow eye was good, the patient agreed to confront a slower-than-normal recovery of vision after surgery, with the potential advantage of completely avoiding any risk of graft rejection. Phacoemulsification with IOL implantation associated with a primary 4 mm central descemetorhexis without endothelial keratoplasty was then performed, without intra- or post-operative complications.

The MS-39 high-resolution AS-OCT section images (Figure 1) allowed detailed characterization of the corneal anatomy modifications induced first by surgery and then by the progressive recovery of transparency over a 5-month follow-up due to corneal endothelial cells migration into the central descemetorhexis area. At baseline, the cornea was slightly thickened centrally with a prominent hyperreflective Descemet layer. Just after surgery, the lack of endothelial cells in the central cornea induced a major central edema of both epithelium and stroma, with folds on the endothelial side. Over the following months the edema progressively resolved. Interestingly, the process was not symmetric, with the superior central cornea recovering always faster at all time points. At 90 days post-op, the central cornea transparency was already acceptable, without signs of epithelial edema, and with a further improvement at the 5-month examination, in conjunction to functional recovery (20/32 BCVA). High-resolution OCT-based maps (Figure 2) accurately displayed the parallel modifications in corneal thickness and posterior corneal curvature. Two days after surgery, the central cornea was highly thickened (911µm vs 599µm preop), but it progressively recovered, reaching a thickness less than preop at 5 months (586µm). One month after surgery, both posterior corneal curvature and thickness showed clear signs of recovery in the central-superior cornea, while more inferiorly, the thickness was still greater and the curvature was flatter. At the successive follow-up examinations, the central thinner healing zone progressively expanded, with the inferior paracentral area at about 210° still failing to recover completely at the 5-month time point.



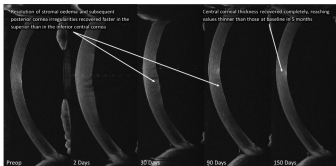


Figure 1. Effect of central descemetorhexis surgery and progressive recovery of normal corneal thickness during follow-up.

Further examination with anterior segment high-resolution OCT scans (Figure 3) showed an area of altered posterior stroma along the inferior edge of the descemetorhexis, corresponding to the area of delayed recovery. Most likely, some lesion of the inner stroma was induced at the position where the descemetorhexis was initiated during surgery. Such irregularities may represent an obstacle that delays the endothelial cells migration over the margin of the capsulorhexis towards the denuded central stroma, thereby providing a justification for the delayed recovery of thickness and transparency in the same area.

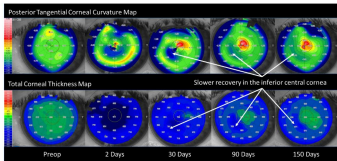


Figure 2. Progressive recovery during follow-up of corneal posterior curvature and thickness after central descemetorhexis.

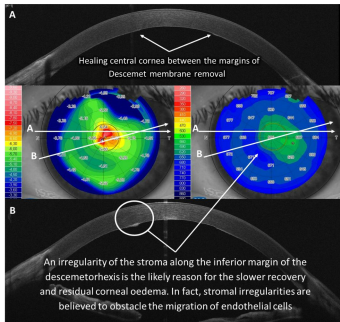


Figure 3. High-res OCT scans and maps of the corneal posterior curvature and corneal thickness 5 months after central descemetorhexis.

TAKE HOME MESSAGE

The superior imaging provided by the MS-39 grants total control, as well as a perfect display of all corneal layers details coupled by reliable measurements even in corneas with reduced transparency. It thus grants the confidence necessary to program the surgery and to follow-up the case with a wealth of information that aids in a thorough understanding at all timepoints.

Moreover, during the first postoperative months the high-resolution images and measurements were very useful to clearly show the patient his improvement even at times when visual function was still lagging behind.

12

CORNEAL WOUND

LATE FINDINGS

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Early age acquired corneal wounds may later in life lead to almost unnoticeable anterior topography changes. However, when comprehensive information is gathered with the MS-39, it is possible to obtain detailed findings and understand some of the corneal mechanisms of compensation.

1. A FIRST GLANCE

When examining a corneal topography, the first image that we usually look at is the anterior sagittal map. Although in this case a slight asymmetry is present, there is nonetheless no clear reason to suspect an abnormality.

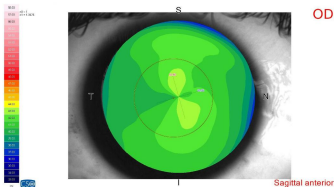


Figure 1. Right eye: Sagittal Anterior Map showing almost unnoticeable superficial asymmetry.

2. A SECOND GLANCE

The second aspect of analysis consist in the observation of the Multi-Map, where the presence of localized thinning and abnormal posterior corneal elevation is clearly depicted.

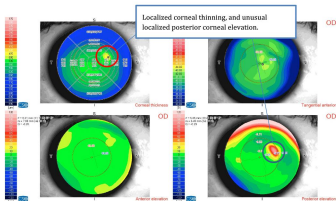


Figure 2. Multimap: One can easily note an eccentric paracentral thinning and a sudden elevation on the posterior elevation map (with asphero-toric reference surface). Both anomalies are related and localized in the same corneal location.

3. ANTERIOR SEGMENT OCT

Corneal scarring with oblique contraction of tissue leaving an irregular posterior indentation in the area of injury is evident. There is also a disparity between the density of the tissue peripheral to the wound when compared to the uninjured opposite meridian.

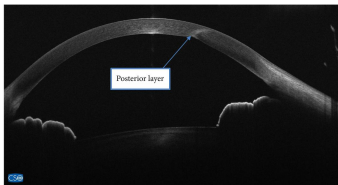


Figure 3. This is a 16 mm AS-OCT scan crossing the lesion. It is fully compatible with the 4 Multimap images. The notch and corresponding thinning are evident along with scarring in the wound path.

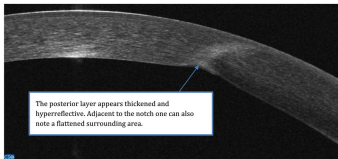


Figure 4. Zoomed in area from a 16 mm AS-OCT scan revealing a thickened posterior layer, the wound path and hyporeflectivity of the distal portion of the deep stroma.

3. COMPENSATION MECHANISM

Quite possibly, in order to maintain the least surface irregularity, an epithelial compensation could smooth out the irregularity caused by the corneal injury by increasing the peripheral corneal thickness.

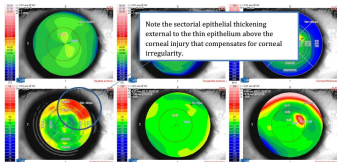


Figure 5. In the 6-Map image, that includes epithelium thickness, it is striking to notice that there is a zone of peripheral thickening (circled area).

Using the chart tool in the epithelial thickness map, the user can note that the "small hill at the center" is followed by a valley and finally ends up into the "rising foothills" around the 50 degree hemimeridian.

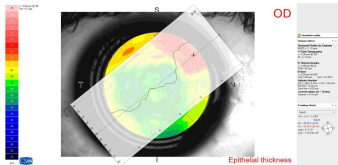


Figure 6. Right eye: Using the Chart feature, it is possible to quite easily recognize the height profile and compare these two hemimeridians. The zone distal to the wound has undergone epithelial hyperplasia to compensate for surface irregularities.

TAKE HOME MESSAGE

This particular case is useful to demonstrate how an almost normal anterior axial map can mislead a clinician when only the anterior information is analyzed. If corneal thickness and posterior information is available, anomalies are evident. On the other hand, if epithelial maps are also available, a dynamic appreciation of corneal compensation mechanisms provide clear evidence of the living cornea.

13

LACTEOCRUMENASIA

CASE REPORT

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A 55-year-old patient who underwent cataract surgery 5 years before presented to our clinic for consultation. Uncorrected visual acuity in this eye was 20/50 and could be corrected to a hazy 20/20 vision with a -1.00 sphere. At the slit lamp we noted a light green milky substance located between the IOL and posterior capsule (Figure 1). Retroilluminated photos (Figure 2) show PCO and Elschnig pearls with a predominance at 6 o'clock. When the anterior pearls were focused upon, the posterior pearls were significantly out of focus, suggesting that they were more posterior than customary.

1. LACTEOCRUMENASIA AS SEEN ON THE SLIT LAMP

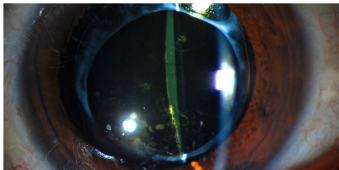


Figure 1. Right eye: Slit Lamp photograph showing the clear IOL and the greenish color of the posterior liquid trapped in the posterior capsule.

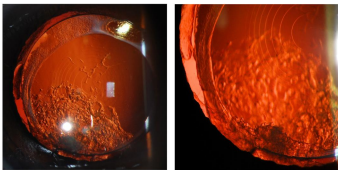


Figure 2. (Left image) Slit Lamp photograph focused on the posterior capsule opacification. In this picture the presence of liquid in the capsular bag is not obvious. (Right image) Anterior Elschnig pearls are in focus, thus rendering a beautiful Bokeh effect suggesting that the posterior capsule is farther away than customary.

2. LACTEOCRUMENASIA AS SEEN WITH THE MS-39

Using the Lens Biometry exam, it is possible to highlight this form of late capsular bag distension syndrome (lactecocrumenasia) (Figure 3).

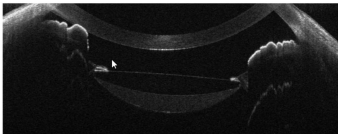


Figure 3. Lens Biometry exam: the IOL-distended bag complex is shown with excellent contrast and resolution. Details on the lens, the retained liquid (lactecocrumenasia) and the increased curvature and/or anterior displacement of this complex may explain the 1 D of myopic shift.

After Nd:YAG laser capsulotomy (Figure 4), the fluid disappeared immediately, the patient's symptomatology improved with recovery of emmetropia and the refraction changed from $-1.00D$ to plano. Uncorrected visual acuity was restored to 20/20.

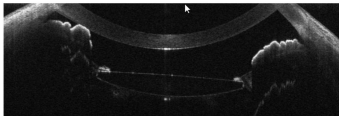


Figure 4. Image taken immediately after Nd:YAG capsulotomy.

TAKE HOME MESSAGE

Lactecrurmenasia is a late complication of cataract surgery occurring mostly due to accumulation of turbid fluid behind the IOL with or without a refractive change. In such cases, it is difficult to distinguish between lactecrurmenasia and IOL opacification. The AS-OCT is a powerful diagnostic tool that is essential in distinguishing between these two differential diagnoses.

14

CORNEAL ALLOGRAFT INLAYS

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The Allotex Corneal Transform Allograft (TCA) clinical trial started just after mid-year 2018 with the first case of the clinical trial being performed in Dublin, Ireland. At that point, all known anterior segment OCT devices had been used in order to try and image the inlays in the eyes that underwent the surgery during the pilot trial in Istanbul, Turkey.

This allograft, shaped by an excimer laser, is obtained from an eye-bank from a donor that has explicitly given permission for the cornea to be used for presbyopia lenticules if it is found to be unsuitable for penetrating keratoplasty or DALK. These inlays are 2.65mm in diameter, are around 22 μm in thickness centrally and taper out to the edge of the inlay. A LASIK flap is created and subsequently the inlay is placed under the flap, directly over the light-constricted pupil. As mentioned before, no other clinically available anterior segment OCT could visualize the TCA in the cornea. The situation changed when we used the MS-39 directly after surgery on our first TCA patient. Not only could we now visualize the TCA, but we could also measure its thickness. In this case, it was 29 μm directly after surgery due to swelling and overhydration and, the very next morning, it became 22 μm thick. At the same time, the tangential topography map could display the alignment of the TCA with the line of sight.

The series of images in Figure 1 show the very first Allotex inlay that was performed. Figure 1a is the immediately postoperative MS-39 image. Figure 1b is the image taken the morning after surgery and Figure 1c the following morning, when the calipers measured the TCA thickness centrally at 22 μm . The expected thickness of the TCA in the laboratory had been found to be 22 or 23 μm .



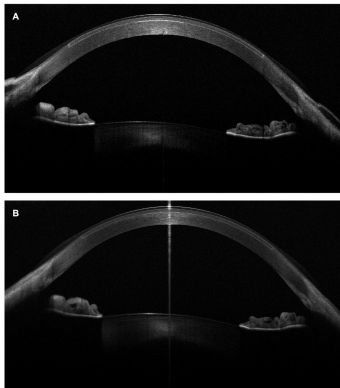


Figure 1 A, B. MS-39 image directly after surgery (A) and TCA the next day (B).

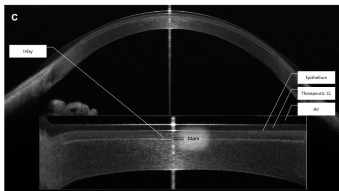


Figure 1 C. MS-39 image of the TCA the following day with the TCA measuring 22 µm in thickness.

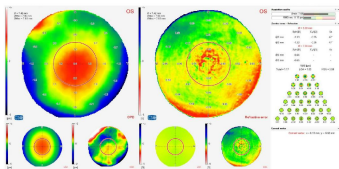


Figure 2. Left eye: The Osiris wavefront map shows the placement of the optical effect of the TCA inlay (top right).

The MS-39 has been invaluable in helping determine the position of the inlay. Figure 3 below shows the tangential anterior map (top right) illustrating the position of the inlay relative to the pupil. During the surgery, the inlay is visually placed over the light-constricted pupil.

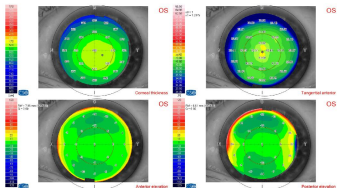


Figure 3. Left eye: The Osiris wavefront map shows the placement of the optical effect of the TCA inlay (top right).

On the odd occasion, the tangential map shows a slight decentration of an inlay that otherwise looked perfectly centered (Figure 4, top right) – the flap can then be lifted, and the inlay repositioned to improve the centration, (Figure 5, top right).

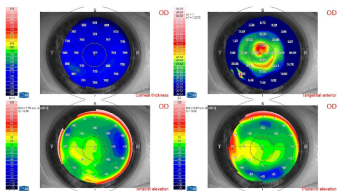


Figure 4. Right eye: The slightly decentered inlay as seen on the anterior tangential map top right.



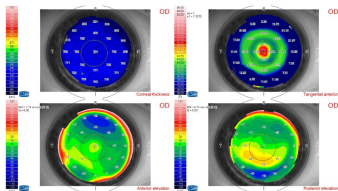


Figure 5. Right eye: The improved centration (top right) after repositioning the inlay in Figure 4.

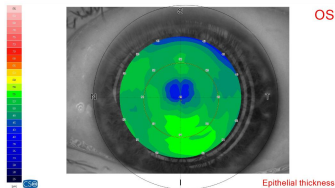


Figure 6. Left eye: Epithelial map showing the thinning of the epithelium over the inlay at 6-months postoperative. Careful follow-up suggests that this is stable at 3 months postoperative and that no further remodeling occurs after the 3-month postoperative visit.

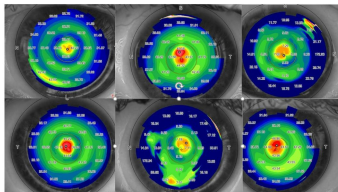


Figure 7. Left eye: Tangential maps with variations demonstrating how the inlay can appear on OCT topography on day 1 postoperative.

TAKE HOME MESSAGE

No other clinically available OCT could image the TCA inlay. With the Pentacam, the TCA inlay, due to scatter, is seen at the 1week mark. However, at the 1-month, 3-month and 6-month visits, it no longer appears on Pentacam images. On the hand, the M5-39 not only can image the curvature changes on the anterior tangential maps and the epithelial changes over the TCA, but can also measure to the micron the dimensions of the TCA under the lamellar LASIK flap. This device has transformed the way in which we perform and manage the Allotex TCA procedure.



15

CORNEAL DECOMPENSATION WITH ANTERIOR GRANULOMATOUS UVEITIS

A COMPLICATED CATARACT SURGERY CASE

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The present case discusses a patient with corneal decompensation with bullous keratopathy and anterior granulomatous uveitis following a complicated cataract surgery. The patient underwent cataract surgery and had a posterior capsular rupture with vitreous hemorrhage. One week after cataract surgery, a pars plana posterior vitrectomy was performed. The corneal epithelium was removed during vitrectomy and a bandage contact lens was applied in order to reduce pain. One week after the vitrectomy, the cornea appeared edematous with Descemet's folds and with an initial corneal decompensation. Despite proper treatment, the patient returned to our hospital with a bullous keratopathy and granulomatous uveitis.

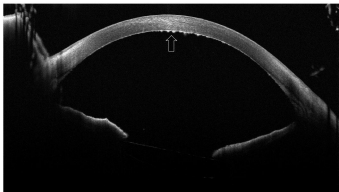


Figure 1. Corneal decompensation with stromal edema and mutton-fat keratic precipitates (KPs) following a complicated cataract surgery.

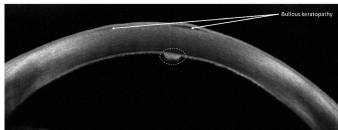


Figure 2. Left eye: Detail of bullous keratopathy with mutton-fat keratic precipitates (KPs) following a complicated cataract surgery.

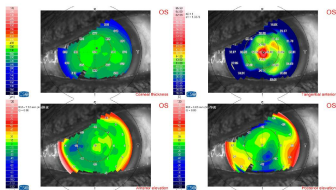


Figure 3. Left eye: Corneal topography confirming the bullous keratopathy.

TAKE HOME MESSAGE

The high-resolution anterior segment OCT scans provided by the MS-39 are a useful tool also in patients with anterior uveitis. The precise details of the mutton-fat keratic precipitates (KPs) and of the corneal epithelium lesions allow a correct diagnosis and proper treatment of these patients. Moreover, OCT imaging is a non-invasive technique that can be very appropriate in case of inflammation with patients with corneal lesions and keratopathy.



16

A CASE OF SUBCONJUNCTIVAL DIROFILARIASIS

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Dirofilariasis is a rare parasitic disease caused by helminths of the genus *Dirofilaria* which are parasites hosted in dogs, cats, foxes and wolves. *Dirofilariasis* can be transmitted to humans by mosquito bites (the mosquito is the intermediate host of the parasites) and can involve subcutaneous tissue, eye, lung, and most rarely brain, testes and mammary glands.

We present a case of a 59-year-old man with a subconjunctival nodule and hyperemia in his left eye, who complained of a foreign body sensation with "movements", redness and conjunctival swelling. He reported a painful insect bite that had occurred 15 days prior on the superior lid. At slit lamp biomicroscopy, a white cyst was visible on the bulbar conjunctiva (Figure 1).

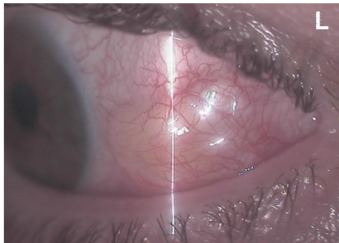


Figure 1. Left eye: Subconjunctival nodule on slit lamp examination.

The MS-39 OCT sections clearly display the nematode rolled up under the conjunctiva (Figures 2 and 3).

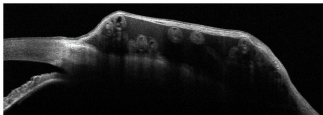


Figure 2. MS-39 OCT image of nematode section in the subconjunctival space.

Intestinal and genital tubules, cuticle with myoid fibers, lateral cords and the outer edge of cuticle were identified in the high-resolution OCT section of the nematode (Figure 3).

The parasite was surgically removed and histologically examined. The nematode was identified as a *Dirofilaria Repens*.

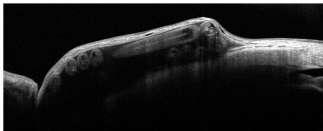


Figure 3. MS-39 OCT image identifying the inner structures of the nematode.

TAKE HOME MESSAGE

The MS-39 OCT is capable of detecting parasites in the subconjunctival space and allows identification of the intestine as well as other details of the nematode itself.

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17

A FROG JUMPING INTO THE PUPIL

A CASE OF PERSISTENT PUPILLARY MEMBRANE

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Sometimes, anomalies of ocular structures resemble curious shapes. A 40-year-old white female presented to our clinic with a structure in her right pupil that looked like a small frog jumping into a pond (Figures 1 and 2). This condition is known as persistent pupillary membrane (PPM). In the reported subject at the age of 7 years this condition was diagnosed at an ophthalmological consultation.

PPM is a common congenital anomaly which may be unilateral or bilateral. It is seen in 95% of normal newborn babies and in about 20% of adults. PPM represents an incomplete regression of the anterior tunica vasculosa lentis, which usually has resolved by six months of gestation. Further regression of PPMs occurs in the first year of life^{1,2}. A variety of clinical appearances can be associated with a failure of an adequate involution of the anterior tunica vasculosa lentis. Epicapsular stars or stellate pigment dust, fine star-shaped spots of pigment on the anterior capsule (Figures 1 and 2), are a very common finding. There may be one or two or seemingly hundreds in number. They very rarely interfere with vision, although vision loss has been reported^{3,4}. In other cases, fine strands may cross the pupil aperture, arising from the collarette or Fuchs' cleft. The strands can be quite thick and occlude the pupil aperture. Alternatively, the membrane may attach to the anterior lens capsule or rarely to the posterior corneal surface.

The present case reports the form of PPM in which strands are adherent to the anterior lens capsule (see Figures 1, 2, 3 and 4), and epicapsular stars are also present (Figures 1 and 2).

Since PPM rarely affects vision, treatment other than conservative management with frequent review is usually unnecessary. As long as there is a viable pupil aperture of 1.5mm or more, deprivation amblyopia should not be an issue. Mydriatics and amblyopia therapy may otherwise be required. More extensive membranes may be treated with the Nd:YAG laser or surgery^{5,6}.

In this case, vision should be unaffected. With the best refraction (RE sph -0.25 cyl -0.25 ax 180° and LE sph -1.75 cyl -1.25 ax 180°) her high contrast visual acuity was 0.00 logMAR (1.00 decimal) and -0.04 logMAR (about 1.1 decimal) in the right eye and left eye, respectively. On the other hand, low contrast (12.5%) visual acuity dropped physiologically to 0.26 logMAR (about 0.55 decimal) and 0.16 logMAR (about 0.69 decimal) in the two eyes, respectively⁷.

Modern investigative technologies such as the digital slit lamp (Figures 1 and 2), the anterior segment optical coherent tomography (AS-OCT) (Figures 3 and 4) and the pupillographer (Figure 5) offer the possibility of reviewing the condition longitudinally, evaluating with high precision the shape, the position and the presence of possible adhesions. For example, an adherence of the strands to the anterior lens capsule is detectable with AS-OCT (Figure 3) and pupillography (Figure 5), in which the PPM remains adherent to the same point under physiological dilation in scotopic conditions. Moreover, if needed, these technologies can guide the surgeon in treating the condition.





Figure 1. Slit lamp image of the persistent pupillary membrane (PPM). The shape looks like a small frog. Stellate pigment dust is visible under the PPM head.



Figure 2. Slit Lamp side view of the persistent pupillary membrane (PPM). The adherence (whitish area) is visible under the head, along with stellate pigment dust.

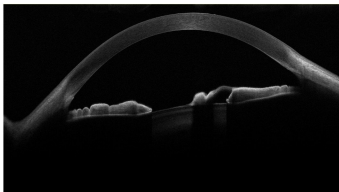


Figure 3. AS-OCT horizontal scan (180 degree) of the PPM. The strand stretches as the pupil physiologically dilates.

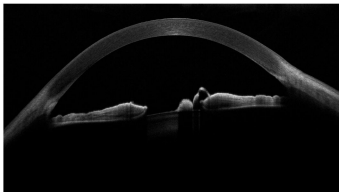


Figure 4. AS-OCT horizontal scan (180 degree) of the PPM. The strand relaxes as the pupil physiologically closes.

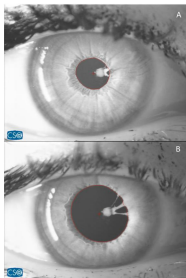


Figure 5. A) Photopic pupillography shows relaxation of the strand. B) Scotopic pupillography shows stretching of the PPM which remains adherent to lens surface.

TAKE HOME MESSAGE

Modern investigative technologies such as the AS-OCT offer the possibility to evaluate with high precision the shape, the position and the presence of possible adhesions.

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18

OCT FOR THE FOLLOW-UP OF ECTATIC DISEASE AND CROSS-LINKING

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Ectatic corneal diseases (ECD) or corneal ectasia are a group of progressive eye disorders characterized by thinning and bulging of the cornea, that can result in moderate to severe impairment of vision. ECD can on one hand occur as a non-inflammatory, progressive and degenerative process including keratoconus or pellucid marginal degeneration. Iatrogenic ectasia on the other hand can develop after surgical treatments such as LASIK. Both pathologic entities are characterized by progressive thinning and increased corneal curvature. Accordingly, follow-up is mandatory in order to rule out progression that might be treated by corneal cross-linking (CXL).

The standard measurements to describe the progression of corneal ectasia consist of maximum keratometry curvature readings, corneal thickness and the posterior float. Whereas isolated information about the anterior corneal curvature can be derived from Placido topography, corneal thickness and the posterior float require corneal tomography. Nowadays, most common corneal tomographers are based upon video keratography, such as the Oculus Pentacam (Optikgeräte GmbH, Wetzlar, Germany) that denotes both anterior and posterior curvature. Although this method is reliable in detecting early stage keratoconus and pellucid marginal degeneration with clear corneas, on the other hand in more advanced stage keratoconus including scarring or haze after cross-linking, its diagnostic value is limited due to various factors. Corneal opacities lead to light scatter which results in reduced accuracy of the tomographer and its digital evaluation.

Corneal thickness after cross-linking, for example, is significantly underestimated using the Scheimpflug camera, while OCT and ultrasound pachymetry yield identical values.

To illustrate these findings, we present a case of keratectasia following LASIK with microkeratome and its course after cross-linking. As we can observe in Figure 1, the LASIK flap is nearly 280 µm thick, resulting in a thin residual stromal pachymetry of about 240 µm. The extended inferior gutter appears filled with Salzmannoid tissue and epithelium.



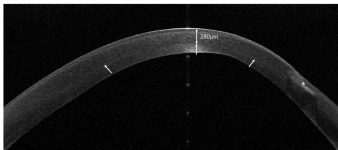


Figure 1. Right eye: Corneal OCT image of a patient with keratectasia after LASIK with microkeratome. The LASIK flap is nearly 280 μm thick resulting in a thin residual stromal thickness of about 240 μm . The inferior gutter is filled with Salzmannoid tissue and epithelium (*).

The MS-39 yields a minimum pachymetry of 427 μm located inferiorly at 1 mm distance from the corneal vertex (Figure 2), in accordance with ultrasound and Scheimpflug camera (Figure 3B) pachymetry. The Scheimpflug image is transparent and does not show any signs of hyperscattering (Figure 3A).

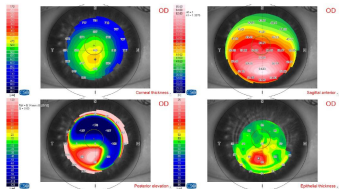


Figure 2. Topographic maps measured by the MS-39 before cross-linking.

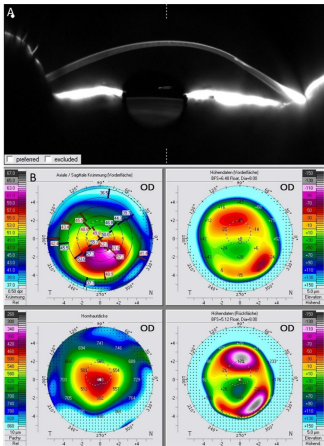


Figure 3. Scheimpflug image (A) and Scheimpflug-based corneal topographic maps (B) before cross-linking.

One month after the eye underwent a cross-linking treatment, the exams were repeated with both the AS-OCT and Scheimpflug camera. The OCT section taken by the MS-39 (Figure 4) shows the effects of the procedure (e.g. the demarcation line at 90% of the total stromal thickness and diffuse scattering of the tissue above). The corneal topographic maps show a morphological pattern similar to the pre-operative maps (Figure 5), that are in agreement with clinical findings, with a minimum pachymetry of 431 μm similar to the ultrasound measurement.

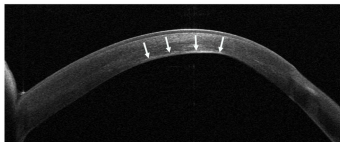


Figure 4. Corneal OCT image one month after cross-linking. The demarcation line can be evaluated at a depth of about 90% of the stromal thickness.

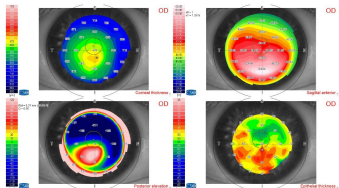
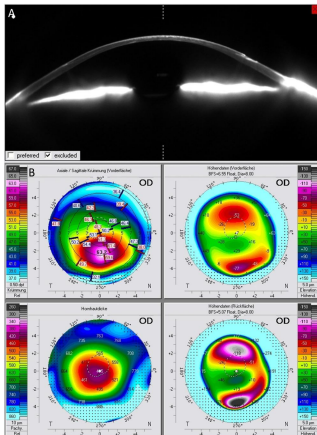


Figure 5. Topographic maps measured by the MS-39 one month after cross-linking.





On the other hand, the demarcation line is not clearly detectable on the Scheimpflug images (Fig. 6A), but rather show a high amount of scatter due to stromal haze, which is probably the reason why the corneal thickness is underestimated at 415 μm (Figure 6B).

Three months after the procedure, the demarcation line can still be noted in the OCT sections but not in the Scheimpflug images. In contrast, in the Scheimpflug images scatter has disappeared completely and the corneal minimum thickness measurement is again comparable with the one displayed by the anterior segment OCT device produced.

TAKE HOME MESSAGE

Corneal OCT yields more reliable measurements of the posterior curvature and corneal thickness with less dependency on corneal transparency or surface regularity, compared to Scheimpflug imaging. Moreover, high-resolution anterior segment cross-sectional images allow for higher definition of corneal details useful for evaluating the progression of advanced ectasia or the depth of the demarcation line after cross-linking.

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19

HIGH RESOLUTION OCT FOR THE FOLLOW-UP OF NOVEL REFRACTIVE TECHNIQUES- LIKE

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In young highly hyperopic patients, refractive surgery displays its limits. On the one hand, for refractive laser treatments such as PRK or LASIK, refractive results and long-term stability are unacceptable. On the other hand, hyperopia often presents with a shallow anterior chamber making unfavorable the implantation of anterior chamber lenses. In these cases, Lenticule Intrastromal Keratoplasty (LIKE) seems to be a valuable alternative in case of contact lens intolerance.

In the first step of this procedure, a LASIK flap is created on the patient's eye and a customized pre-prepared LIKE lenticule with Bowman membrane from human donor tissue is centered on the optical axis. The flap is then repositioned back to its original position. The eye requires then approximately eight weeks to stabilize. In the second step, if necessary, the flap is re-lifted and a final touch-up laser correction on the LIKE lenticule is performed.

We would like to present some images taken by the MS-39 in Hi-Res section modality (Figure 1 and Figure 2) of a LIKE procedure, demonstrating in a clear manner the lenticule details so that it is possible to identify a double Bowman layer (one from the donor and one from the recipient).

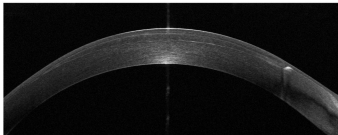


Figure 1. OCT section post-LIKE surgery one month after corneal lenticule implantation.

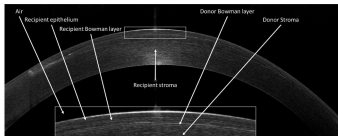


Figure 2. OCT section after a LIKE procedure; labelled corneal details.

TAKE HOME MESSAGE

LIKE is a very promising additive surgical technique. AS-OCT Hi-Res section modality also permits to detect the Bowman layer in the host cornea. The MS-39 turns out to be an essential tool for the follow-up of patients undergoing LIKE surgery.

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20

EPITHELIAL INGROWTH IN LASIK FOLLOWING OCULAR TRAUMA

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We present the case of a 60-year-old male who underwent a LASIK procedure 20 years ago for bilateral high myopia.

The patient presented at our institution following ocular trauma in the right eye caused by a tree branch, being the only eye with residual useful vision. The visual acuity with correction was 0.2. Immediately after trauma, the patient underwent flap reposition in the ER at another hospital. Following the trauma and flap repositioning, the patient reported a progressive decrease in vision quality.

On slit lamp examination, epithelial ingrowth under the LASIK flap was present, extending vertically from the periphery to the corneal center along with a central area of corneal thinning (white arrow in Figures 1A and 1B). No cells or flare were noted in the anterior chamber, nor signs of infection or inflammation.

Figures 1A and 1B highlight the LASIK flap and epithelial ingrowth.



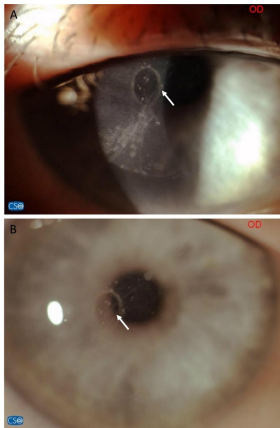


Figure 1. Slit lamp examination reveals epithelial ingrowth extending vertically from the periphery to the corneal center under the LASIK flap. The arrows indicate a central area of corneal thinning.

ANATOMICAL APPEARANCE

Anterior segment OCT sections (Figure 2A and 2B) showed the flap profile and a hyperreflective band (blue arrow) coinciding with the area of epithelial ingrowth. At the thinnest corneal point, the corneal thickness was 493 μm and the residual stroma was 302 μm thick. The lesion thus involved the anterior third of the cornea.

High-definition anterior segment OCT highlights features of the corneal tissue, detailing each corneal layer and its changes (epithelium, stroma, endothelium, flap and epithelial ingrowth).³

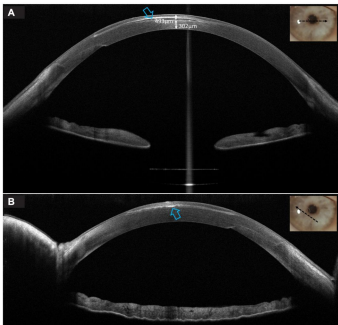


Figure 2. Anterior segment OCT displays all corneal layers (epithelium, stroma, endothelium as well as the flap and epithelial ingrowth). Blue arrow indicates the epithelial ingrowth under the corneal flap, appearing as a hyperreflective band. High-definition OCT provides accurate depth measurement of epithelial ingrowth, residual stroma, and entire corneal thickness.

TOPOGRAPHIC AND TOMOGRAPHIC ANALYSIS

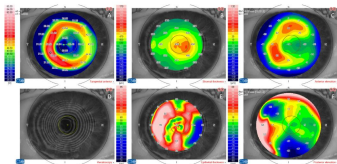


Figure 3. A) Anterior tangential map showing curvature irregularity with corneal hyper-curvature from 6 to 10 o'clock, as well as a central flattening area. The red ring indicates the presence of spherical aberration on aberrometric analysis, while the blue central clover pattern generates trefoil aberration. B) The stromal thickness map shows the thickness reduction and pachymetric gradient with eccentric thinning area. C-F) The anterior elevation map shows a scar, while the posterior elevation indicates evident trefoil pattern. D) Keratometry analyzing corneal curvature. Placido rings in the optical zone are irregular and undefined in the infero-temporal area. This pattern represents extremely high order aberrations which are by definition unmeasurable. E) Epithelial thickness analysis highlights the central thinning with surrounding compensatory epithelial hypertrophy.

Topographic and tomographic analysis highlights the lack of correspondence between the steepest and the thinnest points (pseudo-ectasia).

The cornea shows an irregular curvature with a central flattening area featuring a trefoil pattern, surrounded from 4 to 1 o'clock by a hyper-curved area. Aberrometric analysis will show spherical aberration and trefoil.

Stromal thickness is reduced, with an eccentric thinning peak.

Epithelial thickness appears lower in the corneal center rather than in the surrounding, mid-central and peripheral cornea.



CORNEAL ABERROMETRIC ANALYSIS

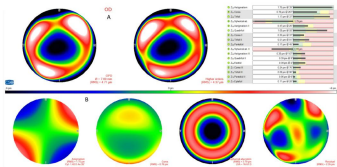


Figure 4. A) Aberrometry indicates high order spherical aberration (Zernike analysis).

B) Wavefront components of coma and astigmatism do not share the same axis.

Corneal aberrometry confirms the presence of elevated order spherical aberration, and a trefoil pattern (2nd order aberration).^{2,3} Wavefront maps show that astigmatism and coma do not share the same axis and confirm the presence of high order aberrations.

Topographic, tomographic and aberrometric analysis clearly explain this patient's visual impairment and his post-traumatic progressive decrease in vision quality.

Anatomical analysis indicates in detail which corneal layer is involved. High-definition anterior segment OCT measures the thickness of all corneal layers and their changes (flap, epithelium, stroma, epithelial ingrowth in the middle and endothelium).

The residual corneal thickness is worrisome (only 302 µm). This indicates DALK (Deep Anterior Lamellar Keratoplasty) as the only possible procedure. The insufficient corneal thickness excludes the possibility of excimer laser phototherapeutic treatment with Sequential Customized Therapeutic Keratectomy (SCTK).

TAKE HOME MESSAGE

High-definition anterior segment OCT provided by the MS-39 is a useful tool for measuring the thickness of corneal layers and their changes, as well as it aids in deciding upon the best possible treatment. Aberrometry provides information for understanding patient visual impairment due to any significant corneal aberrations.

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21

COMPLEX INTRAOCULAR LENS CASES

CATARACT SURGERY POST RK, CORNEAL SCARRING, CUSTOM PRK AND PSEUDOEXFOLIATION

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The AS-OCT MS-39 becomes a multipurpose tool for the planning of complex cataract cases. The accurate anterior and posterior corneal measurements permits thick lens ray tracing intraocular lens (IOL) calculations. The careful analysis of the anterior segment with the measurements of anatomical parameters are essential in planning the appropriate strategy for correcting any residual refraction and, for example in the present case, to calculate the size of a piggyback sulcus IOL.

CASE PRESENTATION

A 59-year-old woman presented to our clinic. She underwent radial keratotomy in the right eye for mild myopia 30 years ago. She noted a complicated postoperative outcome with subsequent poor visual quality. There had been a significant hyperopic shift throughout the years and one year ago a custom PRK had been performed to reduce coma and spherical aberration. At the patient's appointment, the refraction of the eye was +8.00 sph / -4.00 cyl x 116° with BCVA of 0.50. The patient was contact lens intolerant and a similar situation was noted in the left eye. Slit lamp exploration displays 8 radial incisions, 2 transverse incisions, corneal scarring with some focal thinning, mild lens nuclear cataract and pseudoexfoliation syndrome.

CASE 21

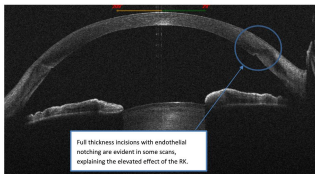


Figure 1. OCT section image from the corneal topography analysis.

Refractive lensectomy with toric monofocal IOL implantation was planned. The AS-OCT tomography is an essential tool as it allows accurate and precise anterior and posterior corneal surface curvature measurements, thus avoiding keratometric assumptions. A thick lens pseudophakic eye model was inputted with the appropriate numbers for a calculation of the best IOL through exact ray tracing.

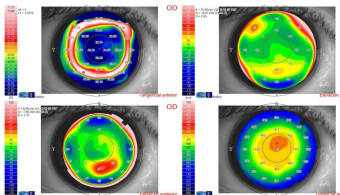


Figure 2. Right eye: Quad map. Aberrated anterior and posterior surfaces with very oblate anterior corneal shape.



Figure 3. AS-OCT anterior and posterior keratometry. Biometry is performed with an OLCR optical biometer.

The Phoenix software within the MS-39 allows these types of IOL calculations. The IOL position estimation is based upon a proprietary algorithm in which the predicting variables are the anterior segment measurements. The cornea is not utilized and therefore the so-called formula error is avoided. The light rays are mathematically traced through the anterior and posterior cornea and the IOL, thus leading to calculation at the image plane. The spectacle refraction can be later paraxially calculated.

Pre-op Alcon - SIBOWY Alcon - SABGAT Alcon - SNEAT Generic - Test

Generic - Toric

ACD = 5,20

PLP = 3,90 mm

Centrado IOL: Centro de limbo

IOL ax° = 26°

* Meridiano menos potente de la IOL

Potencia [D]	Pred.Sph.Eq [D]
+31,00	+0,88
+31,50	+0,53
+32,00	+0,13
+32,50	-0,28
+33,00	-0,71
+33,50	-1,09
+34,00	-1,13

CI IOL [D]	Sph [D]	Cyl [D]	Avg [°]
4,50	+0,02	-1,48	115°

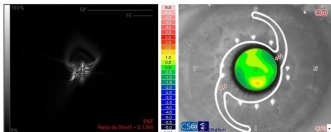
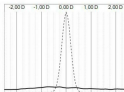


Figure 4. MS-39 IOL calculation display. The spherical equivalent refraction prediction for a +33.00 IOL is -0.71 D. For a well aligned toric IOL, the residual astigmatism will be 1.48 D. The left inferior image of the point spread function, with the Strehl ratio index, and the right inferior image of the wavefront OPD map, display varied optical metrics of the eye beyond paraxial diopters. This can aid to select the most appropriate IOL when the cornea exhibits an elevated level of higher order aberrations.

The surgery was successfully performed implanting a ZCT525 toric monofocal IOL. Five months later, the refraction in this eye was +0.75 sph / -2.00 cyl (Sph. Equiv. is -0.25 sph) with some IOL rotation. This IOL model is equivalent to a +33 D in the calculation shown in Figure 4. The refraction prediction error of the model is therefore 0.46 D.

This refractive error was corrected seven months later with an implantation of a toric piggyback ICL lens. The sizing was calculated using the following AS-OCT measurements (Figure 5): angle-to-angle distance (ATA), angle magnitude and distance from ATA plane to IOL anterior surface. Finally, a 13.2 mm toric ICL model VTICM5 was implanted into the sulcus achieving an UCVA of 0.60 and BCVA of 0.70 with a -0.50 sphere refraction. The final OCT analysis displayed a good ICL size with no distortion of the anterior segment elements, i.e. angle, iris, pupil and IOL.

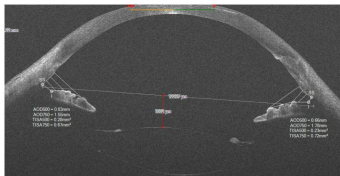


Figure 5. Anterior segment measurements of the pseudophakic eye.



Figure 6. After ICL implant. The sizing of the lens is correct: open angles, no iris distortion and no IOL touch risk.

COMMENT

IOL calculations with corneal deformations are a big challenge. The optical calculations are driven beyond paraxial assumptions, and regular thin lens vergence formulas perform less accurately due to higher order aberrations. Corneal surface irregularities decrease the precision of topo-tomographers. To exacerbate this situation, the abnormal anterior-to-posterior corneal ratio does not obey the conditions upon which the keratometric index of refraction is based, thus the Sim-K becomes inaccurate. On the other hand, any formula that predicts IOL position by using corneal curvature as the predicting variable will introduce error if this figure is outside normal values, since it will not correspond to the anatomical dimensions of the anterior segment. The present case is a compendium of such factors. The best choice in this scenario is a thick lens ray tracing formula based on reliable corneal anterior and posterior measurements and by not using corneal curvature as an IOL position predictor. The MS-39 adopts a proprietary formula that predicts the position of the IOL from several anterior segment parameters and calculates the IOL power by means of exact ray tracing. The optical performance of any IOL is expressed as the predicted spectacle refraction and Strehl ratio, as well as by PSF and OPD maps.

The AS-OCT scans and topo-tomography aid in the management of any residual refraction in such complex cases. First off, in the selection of the best options of corneal excimer treatment or secondary IOL implantation. Second, in deciding which type of piggyback lens might be best suited for the eye and finally, when different IOL sizes are available, in assisting the sizing process since the anterior segment measurements are very accurate.

TAKE HOME MESSAGE

Complex IOL cases can be managed with the MS-39 AS-OCT by taking advantage of its full-range performance of anterior and posterior corneal measurements, IOL calculations based on thick lens ray tracing, selection of toric IOL, astigmatism axis determination, anterior segment diagnostic analysis and measurements and sulcus piggyback lens sizing.



22

DEEP ANTERIOR LAMELLAR KERATOPLASTY

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Deep Anterior Lamellar Keratoplasty (DALK) has become the gold standard for surgical correction of keratoconus when a corneal graft is indicated.¹ It presents many advantages over penetrating keratoplasty (PKP) including the preservation of the patient's endothelium and consequent reduced graft rejection, faster rehabilitation and a better option to perform a secondary refractive surgery to improve refractive and visual outcome. Big bubble dissection is accepted as the appropriate procedure of choice to reach the pre-descemet layer during DALK, and to achieve the best possible visual outcome.² Modern AS-OCT can be of tremendous assistance for patient selection, surgical planning and in postoperative management.

PATIENT SELECTION

A corneal stromal scar reaching the Descemet's membrane is an important risk factor during big bubble injection as it may lead to escape of the injected air into the anterior chamber which could cause the completion of the procedure to become extremely difficult and in many cases would force the surgeon to convert to a PKP. In such cases, other DALK techniques such as manual layer by layer dissection or hydro-delamination are safer. The MS-39 can help the surgeon to differentiate between deep corneal scars that are confined to the stroma in which big bubble DALK can be successful from those reaching the Descemet's membrane.



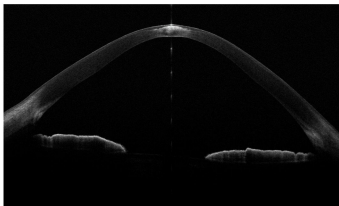


Figure 1. AS-OCT section image where the central corneal scar is deep but does not reach Descemet's membrane. In this case a big bubble can be easily achieved without risk.

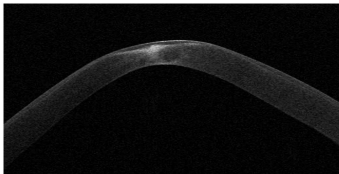


Figure 2. A deep corneal scar reaching Descemet's membrane. In this case, the air injected into the deep stroma may break through the scar and find its way into the anterior chamber thus increasing the risk of converting to a penetrating graft.

SURGICAL PLANNING

The trephination depth is a crucial step during DALK and it is recommended to reach a goal depth of 50-100 µm above the Descemet's layer, as this increases up to 90% the chance of creating a type I bubble.³ Deeper trephination carries the risk of penetrating the anterior chamber, and shallower trephination may lead to superficial air injection with a subsequent lower chance of achieving the contemplated separation at the pre-descemetotic layer level. An accurate OCT pachymetry of the peripheral cornea is mandatory to calculate the proper depth of trephination and to decide the appropriate diameter of the graft.

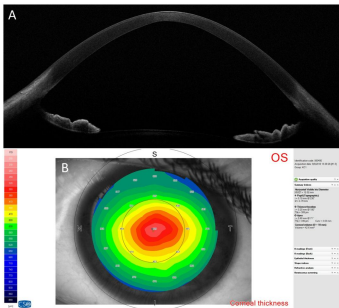


Figure 3. Left eye: Corneal section (A) and corneal thickness map (B) of an eye before DALK. In this case, it is recommended to use an 8.5 mm diameter graft and to safely set the guided trephine at depth of 450 μ m in order to allow deep trephination without risk of perforation and air injection near to Descemet's membrane.

POSTOPERATIVE MANAGEMENT: DESCMET'S MEMBRANE DETACHMENT

Descemet's membrane detachment is not uncommon after DALK, leading to the formation of pseudo-anterior chamber. A Descemet detachment is frequently associated with microperforation; management includes observation and intracameral gas injection. Slit lamp biomicroscopy may not be useful to detect small detachments especially with edematous grafts. AS-OCT plays an important role in detecting the presence/absence of Descemet's detachment as well as its extent and exact location thus giving the surgeon tools to complete a proper management.

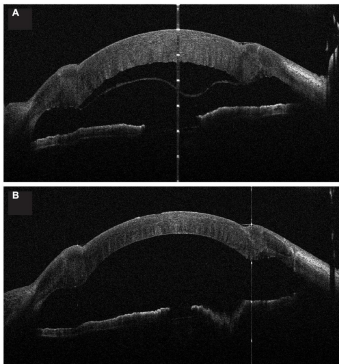


Figure 4. An extensive Descemet's membrane detachment three days after DALK (A). Air injection was performed, and a total Descemet reattachment was immediately observed (B).



POSTOPERATIVE MANAGEMENT: THE GRAFT-HOST JUNCTION

Postoperative astigmatism is a common cause of slow visual rehabilitation after corneal grafts, including DALK. The alignment pattern of the graft-host junction correlates significantly with the magnitude of astigmatism⁶. The AS-OCT is a valuable tool to evaluate the graft-host junction profile and assists the surgeon to decide between suture removal, replacement, compression sutures or other interventions that may help to decrease postoperative astigmatism.

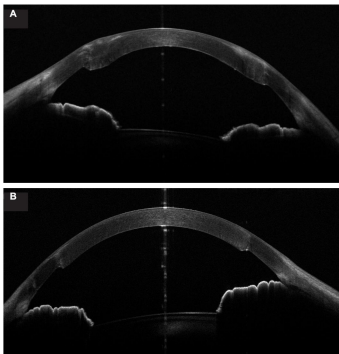


Figure 5 A, B. Alignment pattern of the graft-host junction after DALK. Protrusion of the donor is not uncommon in eyes that underwent DALK for keratoconus mainly due to the discrepancy between the thickness of the donor and host.

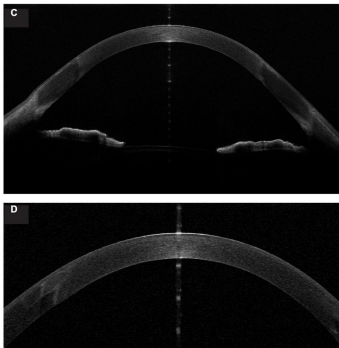


Figure 5 C, D. Alignment pattern of the graft-host junction after DALK. Appropriately apposed profile (C) may help reduce postoperative astigmatism. (D) Displays a mushroom trephination pattern, eleven years after Femtosecond assisted DALK.

TAKE HOME MESSAGE

Modern AS-OCT can be of tremendous assistance in patient selection, surgical planning and postoperative management in corneal graft surgery.

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23

PROGRESSIVE THICKNESS INTRASTROMAL CORNEAL RING SEGMENTS

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Intrastromal Corneal Ring Segments (ICRS) are an excellent surgical alternative treatment for keratoconus, that can regularize the corneal curvature and improve the vision of these patient, and prevent or delay the need of a corneal transplant. A new type of ring segment from Mediphacos, the Keraring-AS, comes with a progressive thickness ranging from 150 to 250 μm or from 200 to 300 μm , following Barraquer's corneal thickness law^{1,2} to produce a progressive flattening effect (i.e. more central flattening effect with more thickness added in the periphery) in corneas with duck-like phenotype, as previously described by the classification of Fernandez-Vega Alfonso.³ This progressive flattening effect allows for a better corneal remodeling that is customized to the specific need of different corneas.



Figure 1. 3D model of the progressive thickness ICRS.



Figure 2. Duck-like phenotype with a progressive thickness ICRS. The yellow area represents the thinnest part of the segment progressively changing to orange, in correspondence with its thickest zone.

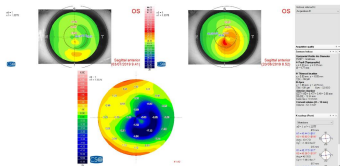


Figure 3. Differential sagittal anterior maps demonstrate in an 18-year-old male the progressive clockwise flattening effect achieved with 160° arc ICRS with a progressive thickness ranging from 150 to 200 μm , and the regularization of the anterior corneal curvature.

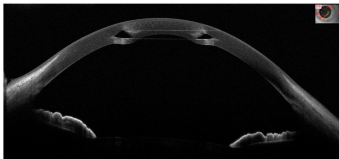


Figure 4. OCT images displaying the thickest portion of the segment, on the left, and the thinnest one, on the right.

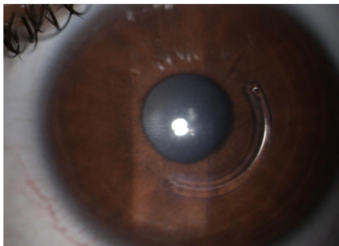


Figure 5. Slit lamp image of the implanted ring.

TAKE HOME MESSAGE

Implantation of asymmetrical intracorneal rings is a promising technique that allows the regularization of the anterior corneal curvature in case of keratoconus. The MS-39 section images are very useful in evaluating the position of the rings. Differential maps in corneal topography also aid in analyzing the corrective effects of this surgical procedure.

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24

HERBERT'S PITS

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Trachoma is an infectious disease caused by bacteria called chlamydia trachomatis. This disease is the leading infectious cause of blindness in the world with a high prevalence in developing countries¹. It is a bilateral, chronic follicular conjunctivitis that leads to conjunctival and corneal scarring². During the acute infection phase, these patients develop a severe follicular reaction, prominently affecting the superior tarsal conjunctiva and the superior limbus. The involution and necrosis of follicles on the superior limbus result in limbal depressions, leaving scars with an overlying intact epithelium known as Herbert's pits³ (Figure 1, 2). In the anterior curvature maps of patients with Herbert's pits one commonly notes a superior steepening caused by the adjacent flattened area produced by the pits in the superior limbus (Figure 3).

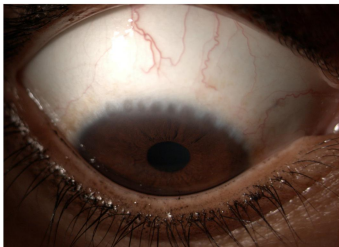


Figure 1. Slit lamp photo of a 39-year-old female with history of trachoma demonstrates multiple pits on the superior limbus.

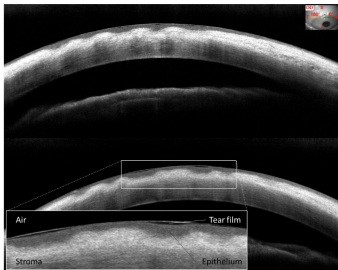


Figure 2. OCT section images of the pits. Below high magnification picture

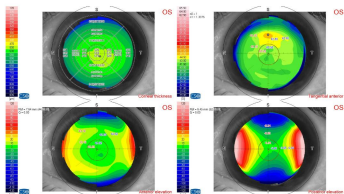


Figure 3. Left eye: Superior steepening in the tangential anterior map induced by the peripheral adjacent corneal flattening along the pits.

TAKE HOME MESSAGE

Anterior segment OCT in conjunction with corneal topography is an excellent tool to understand the changes produced by the pits on the anterior curvature maps, as a superior steepening of the anterior curvature is commonly seen in these patients.

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DELLEN

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The irregular tear film coverage and drying of a specific area of the cornea results in an area of tissue thinning that leads to the appearance of Dellen, and is associated to an adjacent elevation such as pterygium, pinguecula, dermoids, filtering blebs and other elevated bulbar structures¹. Clinically, it is observed as an oval depression with overlying intact epithelium and is found most commonly in the temporal peripheral cornea.

In this case, a 34-year-old male presented to our clinic with blepharitis OU. He referred to severe eye rubbing on the temporal side of his right eye during the last three days, causing a temporal conjunctival chemosis. The OCT image shows a peripheral temporal corneal thinning with overlying intact epithelium.

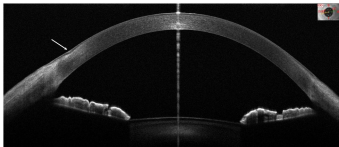


Figure 1. OCT section shows a peripheral temporal corneal thinning with overlying intact epithelium.

TAKE HOME MESSAGE

In conjunction with slit lamp imaging, modern anterior segment OCT offers the possibility to evaluate stromal degenerations like Dellen, for both diagnosis and follow-up.

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AS-OCT IMAGING IN A CASE OF POST-PENETRATING KERATOPLASTY SCLERAL LENS FITTING

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In the last 15 years, there has been an increase in scleral contact lens (ScCL) fittings not only limited to severe ocular conditions such as corneal ectasia, post-keratoplasty or exposure conditions but expanded now to “non-pathological” cases¹. This renaissance was due to the contemporary availability of highly oxygen permeable materials for ScCL manufacture, a wide range of ScCL designs, an increased practitioner’s knowledge and modern instrumentation that assist practitioners in the clinical routine of this particular kind of fitting. More recently, the introduction of anterior segment optical coherence tomography (AS-OCT) imaging granted a new opportunity to further improve ScCL fitting in addition to the more traditional devices such as the slit lamp and the corneal topographer. Specifically, AS-OCT allows practitioners to assess the corneoscleral limbal junction and scleral curvature, to monitor corneal ectasia and ScCL-induced corneal edema, to measure the epithelial thickness and the tear clearance and finally to evaluate the alignment of the landing zone^{2,6}. Many of these potential advantages are discussed in the following clinical case of post-penetrating keratoplasty ScCL fitting.

A 55-year-old male patient was initially diagnosed with bilateral keratoconus at the age of 16. After a successful RGP contact lens (CL) fit that lasted about 16 years and a following subsequent loss of tolerance and corneal scarring, he underwent penetrating keratoplasty (PK) at the age of 31 and at 33 years in the right and left eye, respectively (Figures 1 and 2). Twenty years after his PKs, his spectacle correction was completely unsatisfactory. He used two pairs of spectacles, one for distance and one for reading and he complained with respect to the previous years of a severe decrease in vision-related quality of life. The spectacle refraction was OD -5.00 / -9.00 x 0.75 and OS -7.00 / -3.75 x 170 with a reading addition of +1.75 DS. His high contrast best corrected visual acuity (BCVA) was 0.22 logMAR (about 0.6 decimal) and -0.04 logMAR (about 1.1 decimal) in the right eye and left eye, respectively. Whereas, at low contrast (12.5%), BCVA decreased significantly to 0.86 logMAR (about 0.14 decimal) and 0.26 logMAR (0.55 decimal) in the two eyes, respectively. Although he had a certain resistance towards CL wear due to the memories of poor comfort before the PKs, he sought a new CL fitting in order to attempt to improve the low quality of his vision.



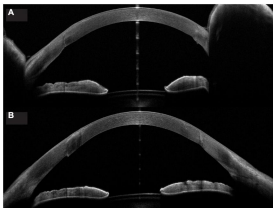


Figure 1. AS-OCT image of the right eye. a) 90° scan b) 180° scan. Both scans were obtained immediately after the ScCL removal after 4 hours of wear time.

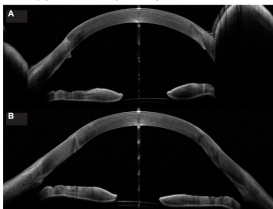


Figure 2. AS-OCT image of the left eye. a) 90° scan b) 180° scan. Both scans were obtained immediately after the ScCL removal, after 4 hours of wear time.

Initially, he had a trial with corneal RGP CLs but with a poor outcome due to the difficulty to stabilize the lenses on this particularly challenging corneal topography (Figures 3 and 4). The elevation map of the anterior corneal surface (Figure 3a) shows more than 250 μm of difference between the highest and lowest portions under and above the reference best fit sphere, which had a radius of 6.94 mm in the right eye. The highest difference in elevation was in the inferior temporal area. The patient was fitted in both eyes with the ICDTM design ScCLs (Figure 5). They had a total diameter of 16.5 mm and 4300 and 4600 μm of sagittal depth in OD and OS, respectively. With the ScCLs, high-contrast BCVA became 0.02 logMAR (about 0.96 decimal) and -0.10 logMAR (1.25 decimal) in the right eye and left eye, respectively. Whereas, at low contrast (12.5%), BCVA decreased as expected to 0.26 logMAR (about 0.69 decimal) and 0.16 logMAR (0.55 decimal) in the two eyes, respectively. To avoid reading glasses for near work, he was fitted with monovision CLs, with the right eye for near vision (under correction of -2.00 D) and with the left eye (dominant eye) for distance. The patient obtained 10 hours of successful wearing time with only a limited increase in bulbar redness. No "mid-day fogging" was reported and he did not complain of any difficulty with lens removal, and no lens "seal-off" was experienced. At the aftercare visit, a slight evidence of epithelial bogging was noted. A problem immediately evident at the slit lamp assessment was the asymmetry in the vertical corneal clearance in both eyes (Figure 6). The tear layer thickness under the ScCL in the upper zone of the cornea was approximately one-fifth of the lens thickness, whereas at the lowest zone it was roughly 1.5 times the lens thickness. As it was possible to assess in slit lamp, a good haptic alignment was present due to the scarce presence of blanching² underneath the landing zone (Figure 7).

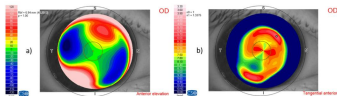


Figure 3. Topographical maps of the right eye: a) elevation map of anterior corneal surface; b) tangential map of anterior corneal surface.

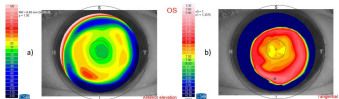


Figure 4. Topographical maps of the left eye: a) elevation map of anterior corneal surface; b) tangential map of anterior corneal surface.

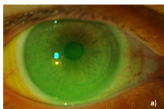


Figure 5. ScCL immediately after insertion in a) the right and b) the left eye.

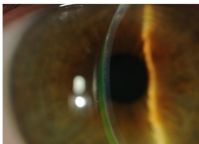


Figure 6. Optical section of the ScCL fitted in the right eye. Tear film layer is coloured with fluorescein.

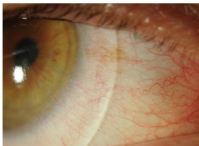


Figure 7. Landing zone assessment with the slit lamp. A moderate blanching was present, but possibly it may be an artifact due to light diffusion by the thicker edge of the ScCL.

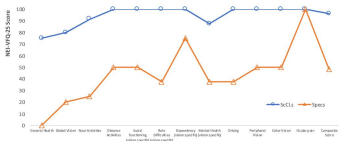


Figure 8. Case report NEI-VFQ-25 score in the two conditions: with spectacles and ScCLs. (orange triangle markers and continuous line, blue round markers and dotted line).

The patient was asked to answer the Italian version of the 25-item National Eye Institute Visual Function Questionnaire (NEI-VFQ 25)³ both in the case of spectacles and ScCL wear. Note in Figure 8 that the scores in 11 out of 12 subscales were definitely better (100 indicates the best functioning quality, while 0 indicates the worst functioning) in the case of ScCL scenario. Clearly, this was also reflected in the overall composite score (average of 12 sub-scales). Even the general health scale improved through the use of scleral lenses in comparison with spectacles. The positive impact of ScCLs fitting on patients has been reported previously⁴.

The results reported in this case were extremely favorable and one could indeed think that the corneal and limbal clearance asymmetry appear negligible when considering the overall results. However, if we analyze the AS-OCT assessment we can confirm certain aspects and gain new insights.

In Figure 9 and 10, the vertical and horizontal scans of right and left ScCLs after 4 hours of wear can be noted for right and left eye, respectively. The images confirm the asymmetry in corneal and limbal clearance already assessed at slit lamp. Clearly, AS-OCT offers the possibility to accurately measure the tear layer thickness at every point. The measurement of distance by OCT must take into account the index of refraction of the different mediums revealed from the OCT interferometric principle of operation, and the practitioner has to be aware of this feature and should not generally consider OCT imaging to be similar to a photographic camera. This signifies that the measurement taken under the internal surface of the lens to the corneal surface can be affected by micrometric errors of accuracy with respect to no interferometric imaging. These errors increase from the center of the image to the periphery⁵. Another advantage of the OCT in assessing the corneal and limbal clearance is the possibility to evaluate the horizontal meridian, which is less possible with slit lamp.

Aside from the imaging of the horizontal meridian and increased precision in tear layer measurement, it could be argued that the AS-OCT does not offer any additional value. However, Figure 11 displays a possible conjunctival prolapse that would have been otherwise undetected. Conjunctival prolapse could be linked to the area of relative corneal depression. Although the potential consequences of corneal prolapse are not well understood⁶, it would be nonetheless more prudent to avoid this condition. This can be managed by decreasing tear film clearance in the prolapsed area. Therefore,



despite the favorable fitting result, the AS-OCT can anticipate a problem that is more difficult to detect with the slit lamp, and help to better identify the difference in clearance related to the CL design. Furthermore, the AS-OCT offers the possibility to measure epithelial thickness. In fact, no other non-invasive technology can measure epithelial thickness with such high resolution. Information regarding the corneal epithelium can be crucial in monitoring ScCL fitting. Epithelial changes can be determined by the mechanical relationship between the lens design (clearance, touch and moulding etc.) and hypoxic stress^{5,8}. In the present case, a medium epithelial thickness of 58 μm , (ranging from 44 to 71 μm) can be seen in Figure 12. This wide range of 27 μm is equivalent to almost half of the average value. No action on the ScCL fitting was taken in regard to these epithelium characteristics which were present before the fitting and were likely due to PK. Nonetheless, these characteristics should be monitored during follow-up visits to observe any potential changes.

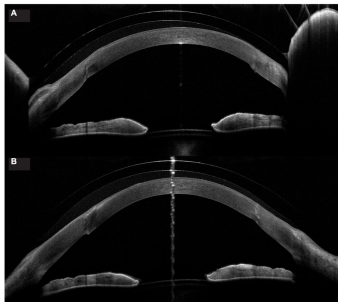


Figure 9. Right eye: AS-OCT with the ScCL in place: a) 90° scan image; b) 180° scan image. Both scans were obtained with the ScCL worn for 4 hours. The corneal and the limbal clearance are clearly detectable.

It is known that the limbal area has a different morphology for each meridian of the eye. Using the AS-OCT it is possible to investigate the pressure on the conjunctiva and sclera of the landing area of the ScCL (Figure 13), while with the slit lamp it is only possible to infer the pressure by examining indirectly the conjunctival blanching or impingement, as well as the vessels constrictions underneath the edge (Figure 7). Therefore, with respect to the slit lamp assessment, the AS-OCT can help to visualize more precisely how the ScCL periphery lands on the scleral area and how it bridges the limbal area for each meridian.

Although the slit lamp remains the gold standard to assess CL fitting, the AS-OCT can offer a better understanding of the complexity of the relationship between the sophisticated design of specialty lenses and the anterior segment corneal, limbal and scleral profile surfaces.

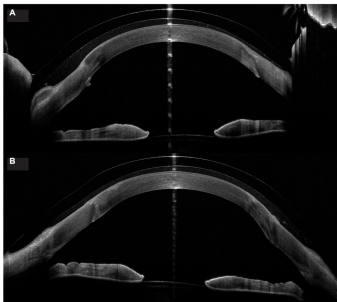


Figure 10. Left eye: AS-OCT with ScCL in place: a) 0° scan image; b) 90° scan image. Both scans were obtained with the ScCL worn for 4 hours. The corneal and the limbal clearance are easily detectable.

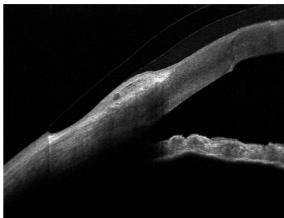


Figure 11. AS-OCT image of a conjunctival prolapse in the right eye visible at the 270° meridian.

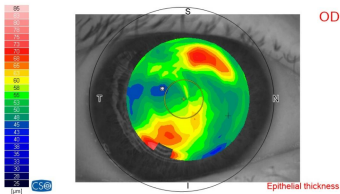


Figure 12. Epithelial map of the right eye displaying the large differences in 3 mm area and in 3-6 mm area.



Figure 13. Assessment of the landing zone of the ScCL in the right eye at the 0° meridian obtained through the AS-OCT.

TAKE HOME MESSAGE

In addition to slit lamp biomicroscopy, modern AS-OCTs offer the possibility to evaluate a scleral lens fitting, thus assisting the practitioner both in the fitting process and in clinical follow-up.

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CORNEAL INFECTIONS

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Corneal infections are potential sight-threatening conditions that can affect patients of all ages. After the etiological diagnosis has been made, the key to successful management is a careful follow-up during the treatment phase. Modern technology, including the MS-39 anterior segment OCT, can be very helpful for this purpose because it is able to highlight the anatomical changes caused by infective and inflammatory processes.

1. BACTERIAL KERATITIS

We present a case of a contact lens wearer who was referred to our attention due to a corneal infiltrate in her left eye. The corneal scraping culture analysis revealed the presence of *Pseudomonas aeruginosa* colonies. The patient had been using for four days fortified tobramycin and ciprofloxacin eyedrops, to which the bacteria is sensitive according to the antibiogram. Figures 1 and 2 are slit lamp photos before and after fluorescein staining. The infiltrate was paracentral and still mildly fluo-positive, with an attached mucous filament.

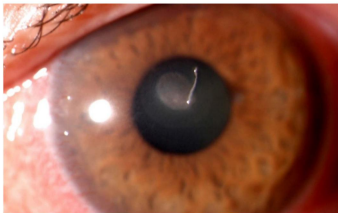


Figure 1. Slit lamp photo before fluorescein staining.

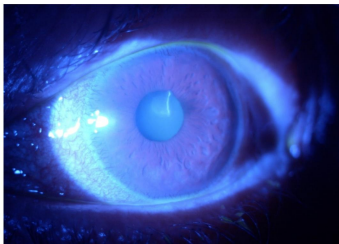


Figure 2. Slit lamp photo after fluorescein staining.

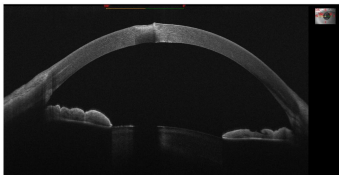


Figure 3. 16-mm AS-OCT section shows a stromal reflectivity that involves one third of the stromal thickness.

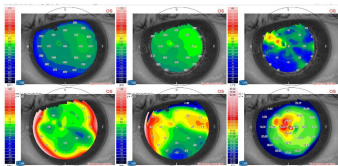


Figure 4. AS-OCT Topography (25X1, 16 mm). The epithelial thickness map (upper-right image) shows an irregular pattern especially in the upper-left quadrant. The anterior tangential map displays irregular astigmatism. Both corneal and stromal thickness maps reveal a thickening in the central and left quadrants compared to the right quadrants.

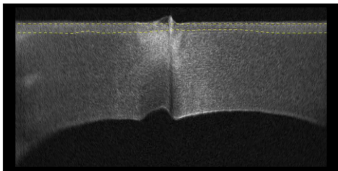


Figure 5. AS-OCT topography (12X5, 10 mm -detail). The image shows the presence of a still irregular epithelium with the attached mucous filament. This detail highlights the deformation of the corneal posterior profile, that is also visible in the AS-OCT section (Figure 3), probably caused by the localized corneal edema.

The topical antibiotic dose was reduced and a steroid drop per day was added.

2. ACANTHAMOEBA KERATITIS

Acanthamoeba is one of the most harmful causes of infectious keratitis, that can very often lead to a corneal transplant. This is a case of a 25-year-old contact lens wearer referred to us after 15 days of ineffective topical antibiotic treatment. The PCR for Acanthamoeba performed on the corneal scraping was positive and confocal microscopy revealed intrastromal cysts. Cultures for bacteria and fungi were negative. Topical anti-amoebic therapy was immediately started.



Figure 6. Slit lamp photo.

Even though the AS-OCT topography could not be easily performed due to the patient's intense photophobia and pain, it did reveal a diffuse stromal and total corneal thickening, with an irregular epithelium (Figure 7).

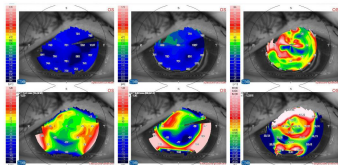


Figure 7. AS-OCT topography

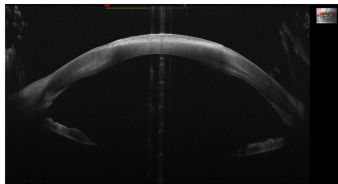


Figure 8. 16 mm AS-OCT section shows hyperreflectivity of the anterior stroma in the central cornea and a posterior stroma hyperreflective band, indicating deep corneal involvement by the pathological process.

3. HERPETIC STROMAL KERATITIS

An 80-year-old man presented to the emergency room complaining of pain, redness and loss of vision in his left eye. He reported an episode of herpetic anterior uveitis one year before and had been treated for one month with topical mild steroids and anti-glaucoma drugs for a recent diagnosis of ocular hypertension. At the slit lamp examination, a dendritic epithelial ulcer was detected, associated with diffuse stromal haze, intense ocular hyperemia and ocular hypertension. After one week of systemic antiviral, oral acetazolamide and topical antibiotics and lubricants, the ulcer was healed but the stromal involvement was still evident (Figure 9).

A drop of topical steroid per day was then added to the current treatment.



Figure 9. The slit lamp photo of the AS-OCT section revealed an endothelial hyperreflectivity caused by inflammation (endothelitis), stromal diffuse and band-shape hyperreflectivity (Figure 10).

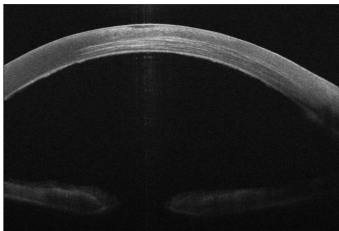


Figure 10. Same patient of fig. 9, AS-OCT section (10 mm).

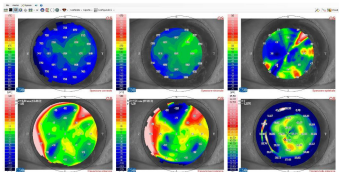


Figure 11. AS-OCT topography (25x1, 16 mm): corneal thickness was greater than normal, with irregular stromal and epithelial maps.

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The high-resolution scans provided by the MS-39 allow the detection of the anatomical changes induced by corneal infections of various etiologies and the identification of the corneal layers affected by the pathological process. Moreover, it allows the practitioner to monitor the wound-healing process, that may not be easily assessable at the slit lamp examination, especially in severe cases.



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AS-OCT AND IMPLANTABLE COLLAMER LENSES

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Implantable collamer lenses (ICL) such as the STAAR ICL (STAAR Surgical AG) Visian EVO are common surgical implantable devices used to correct refractive errors, and have been reported to have a good long-term safety, effectiveness, and predictability. ICLs have been demonstrated to improve visual function more effectively¹ than laser in situ keratomileusis in eyes with moderate to high myopia and hyperopia, inducing a smaller amount of high-order aberrations and leading to better contrast sensitivity. ICL surgery may also be combined with other corneal surgeries such as intrastromal rings (Figure 1).

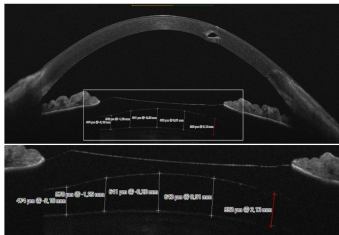


Figure 1. Myopic ICL implanted in a patient previously treated with intrastromal rings (Keraring®). Below high magnification image.

ICL sizing is usually done utilizing the corneal white-to-white (WTW) and anterior chamber depth (ACD) measurements, which are included in the online calculator provided by the manufacturer. A formula for the calculation of ICL size using sulcus-to-sulcus (STS) measurements has also been proposed². The drawbacks of the calculation methods, which use WTW measurements, include errors in the measuring device itself and errors that occur when the WTW distance is poorly defined. Calculation methods using the STS distance require the use of ultrasound biomicroscopy, which is invasive for patients. Moreover, the resolution of ultrasound technology is rather low compared to that provided by AS-OCT devices, and this results in a less reliable measurement. With the development of anterior segment optical coherence tomography (AS-OCT), calculating the ICL size using angle-to-angle (ATA) measurement and iris pigment end-to-pigment end diameter (PTP) has yielded favorable results³.

Complications of ICLs due to the increase of intraocular pressure are rare¹⁻⁴, especially with Visian EVO, due to the patented central hole (AquaPort[®]) (Figure 1) created to improve aqueous flow in myopic ICLs, because the central hole eliminates the need of laser or surgical iridotomy before the ICL implant.

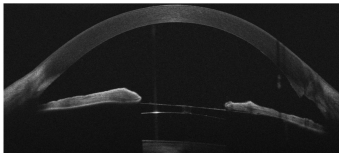


Figure 2. AS-OCT section displays the central AquaPort hole in the latest Evo Visian ICL.

The main postoperative complications are mainly related to insufficient or excessive distance, i.e. vaulting, between the ICL and the anterior surface of the crystalline lens. Vault variations are due to many factors. However, preoperative evaluation of WTW, ATA and PTP must be properly performed to avoid uncorrected vault⁴.

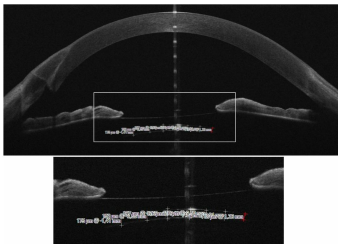


Figure 3. Multiple vault measurements. Below high magnification image.

The evaluation of intraocular lenses (ICL) vault is an important parameter in postoperative follow-up both in hyperopic (Figure 4) and in myopic ICLs⁶.

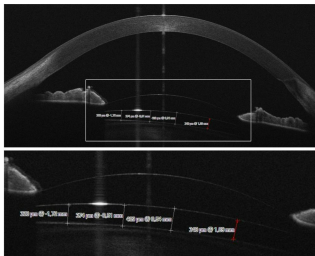


Figure 4. Hyperopic ICL. Below high magnification image.

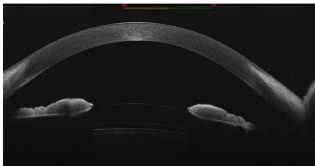


Figure 5. Hyperopic +6D ICL implant with peripheral Yag laser iridotomy.

Optimal ICL vaulting² ranges from 250 to 750 μm and must not exceed the range between a minimum of 90 μm and a maximum of 1000 μm . Static vaulting evaluation previously performed with Scheimpflug-based instruments has several limits due to light reflection and scattering phenomena.

During the postoperative course, thanks to the new generation AS-OCT MS-39, it is possible to acquire dynamic images of the anterior chamber for evaluating the vault and the position during accommodation^{4,5} and the scotopic, mesopic and photopic vaulting changes. This leads to improved reliability of vaulting evaluation. The photos below are useful to display these features (Fig. 6, 7, 8, 9).

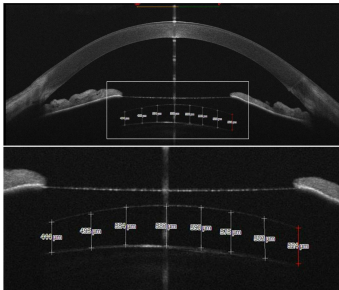


Figure 6. Scotopic vault measurements in a myopic ICL correcting -9D implanted in a 28-year-old male. Below high magnification image.

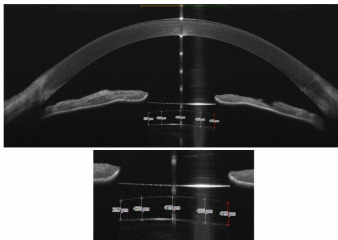


Figure 7. Photopic vault measurements in the same eye of Figure 6; a mild reduction of vault is noticeable. Below high magnification image.

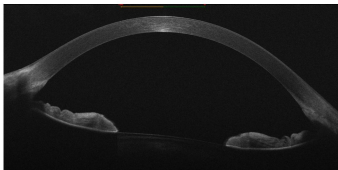


Figure 8. Preoperative acquisition for a myopic ICL on a myopic keratoconic patient (sph -15D / cyl -3D ax 180°).

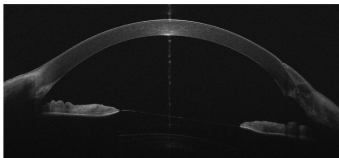


Figure 9. AS-OCT section – same eye of Figure 7: two hours after the ICL implantation visual acuity 20/20 Snellen.

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AS-OCT acquisitions outclass Scheimpflug acquisitions. AS-OCT images are very useful in our daily clinical practice to evaluate ICLs both in the pre- and postoperative stages. In the preoperative stage, AS-OCT is helpful in measuring the WTW, ATA, PTP parameters necessary for ICL sizing. In the postoperative stage, AS-OCT is useful also in dynamic acquisitions for checking the ICL position and vaulting.

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THE QUESTION FOR EARLY KERATOCONUS DETECTION: THE ROLE OF EPITHELIAL MAPPING

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Nowadays, an early diagnosis of keratoconus gives us important benefits. The advent of UV-riboflavin corneal cross-linking helped to decrease the progression of the disease. In cases of early detected keratoconus, cross-linking is of particular interest since this treatment can prevent significant corneal irregularity and consequent best corrected visual acuity loss. Keratoconus detection in its earliest stages is extremely important in order to avoid treating potentially pathologic corneas with laser refractive surgery.

Several different diagnostic tools may aid in the detection of early keratoconus. Anterior surface corneal topography has historically been considered the gold-standard instrument to assess early changes in the corneal curvature. More recently, anterior segment tomographers equipped with Scheimpflug cameras, and subsequently combined with Placido disk-based corneal topography, increased the interest concerning the associated relationship between both anterior and posterior corneal topography, and corneal thickness. This relationship increased both sensitivity and specificity useful in detecting early changes. The measurement of corneal hysteresis also can help in the diagnosis of incipient keratoconus.

On the other hand, the development first of Very High Ultrasound technology, and later of Optical Coherence Tomography, allows an accurate and precise measurement of the epithelial layer, currently providing wide diameter corneal epithelial mapping. The relationship between epithelial thickness changes and keratoconus has already been extensively discussed. This chapter describes the initial changes that can be detected at the earliest stages of keratoconus development and their importance in the context of a very early diagnosis. Focus is also given on those cases where the differential diagnosis of corneal curvature anomalies can be resolved by the analysis of the corneal epithelial layer. All the following images, except the first one, are presented in the same way as reported in the structure here below.

Usually in normal, healthy eyes, the corneal epithelium has a variable thickness ranging from 40 to 60 μm with no significant differences between the center and the periphery.



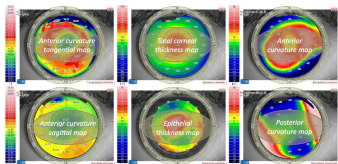


Figure 1. Layout of a 6-map topographic summary showing anterior tangential and sagittal maps (top-left and bottom-left), total and epithelial thickness maps (top-center and bottom-center) and anterior and posterior elevation maps (top-right and bottom-right).

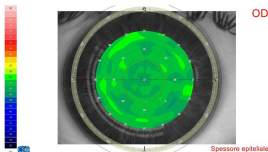


Figure 2. Epithelial thickness map of a normal eye.

In eyes with keratoconus, the following features can be typically observed: thinning of the epithelium over the ectatic area and corresponding thickening of the epithelium in the surrounding areas where the curvature is flatter. A topographical correlation is always found between the anterior curvature steepening, the posterior elevation bulging, the epithelial thinning, and stromal thinning. The epithelial changes (both thinning and thickening) become more significant as the disease progresses

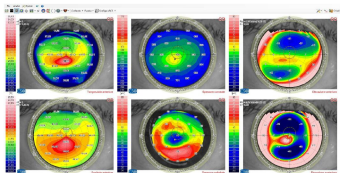


Figure 3. Typical 6-map topographic display of a patient with keratoconus. The “notable points”: steepest points (anterior and posterior), most elevated points (anterior and posterior) and the thinnest point (corneal and epithelial) correspond.

and certainly they represent a “smoothing” response of the epithelium in its attempt to regularize the curvature. These changes are minimized in the early development stages of keratoconus, as can be seen in the following example, in which the typical topographical correlation (anterior curvature steepening and bulging, the posterior curvature bulging, the epithelial thinning, and stromal thinning) can still be detected.

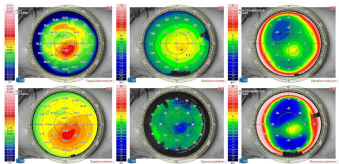


Figure 4. Early cases of keratoconus: typical signs of bulging are visible on every map.

The topographical correlation of the epithelial thinning with the other features is not different in relation to the position of the ectatic area. The following two images show both eyes in a relatively uncommon case of bilateral temporal keratoconus, in which the common findings can easily be detected.

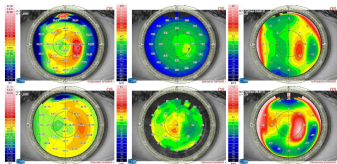


Figure 5. Bilateral temporal keratoconus: left eye.

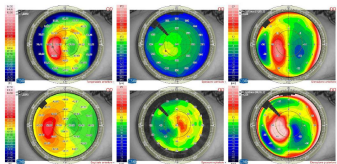


Figure 6. Bilateral temporal keratoconus: right eye.

Please note the last image located above. The topographical maps measuring the anterior corneal surface (top left: tangential curvature; bottom left: sagittal curvature; top right: anterior elevation) display the ectatic area more temporally located (i.e., at 9 o'clock) compared to the corneal thickness map (top center) and in the posterior elevation map (bottom right), in which the ectasia seems to be positioned instead at 7-8 o'clock. Surprisingly, the epithelial thickness map (bottom center) correlates better with these two latter maps. This case is useful in considering some unanswered questions regarding the earlier stages of keratoconus development and progression, particularly what occurs first. Are the first alterations related to the anterior curvature, or to the posterior curvature, or to the corneal thickness? In other words, what is the most sensitive and specific parameter to detect the earliest deviations of an eye from "normal" to "suspect"? At present, there is no answer, or it can be considered that there is a combination of these changes (anterior and posterior curvature, and corneal thickness). In reality, also epithelial changes occur at the earlier stages of keratoconus development, and they can help significantly in the detection of the first signs of ectasia.

The following case presents an eye with an already diagnosed clinical keratoconus. All the features of keratoconus can be noted: anterior curvature steepening and bulging (top, bottom left and top right), posterior elevation bulging (bottom right) and both corneal and epithelial thinning (top center and bottom center) topographically correlated with the changes of both anterior and posterior curvatures.

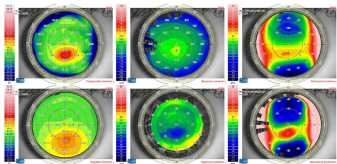


Figure 7. Eye with keratoconus: typical signs of bulging are visible on every map.

The next case presents another keratoconic eye, in which the steepening of the anterior curvature is less prominent (top and bottom left, top right), and the posterior elevation displays a well-defined bulging (bottom right), that is well topographically correlated with the thinnest corneal (top center) and the thinnest epithelial area (bottom center).

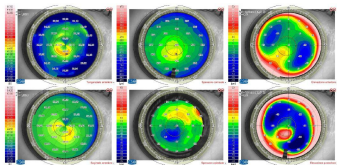


Figure 8. Bilateral keratoconus: anterior bulging is hidden partially by the epithelial masking layer in both eyes.

The other eye of the same patient above demonstrates findings that are even more interesting. The anterior corneal curvature is only mildly compromised (top and bottom left) and shows almost no bulging (top right), whereas the posterior elevation is significantly altered (bottom right), yet the epithelium (top center) displays thinning topographically corresponding with the thinning of the cornea. In this specific eye, the most altered parameter is the posterior elevation bulging.

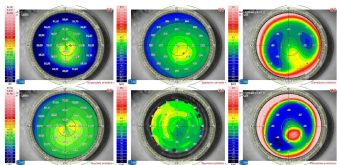


Figure 9. Bilateral keratoconus: anterior bulging is hidden partially by the epithelial masking layer in both eyes.

This next case is even more interesting. As can be noted, the anterior curvature does not demonstrate either signs of steepening or corneal irregularity (top and bottom left), and no bulging is displayed (top right). There would be no reason to suspect any abnormality if solely the anterior corneal surface was analyzed. The corneal thickness map (top center) shows a normal thickness, but an infero-nasal position of the thinned area. This finding is suspicious. The posterior corneal elevation reveals some degree of bulging, that is also suspicious (bottom right). The epithelial thickness map (bottom center) shows some degree of thinning, topographically corresponding with the posterior elevation bulging and the decentered area of corneal thinning. For this eye, only the diagnosis as a keratoconus suspect was made and the patient was discouraged from having laser refractive surgery. The epithelial thickness values aided in reaching this decision, yielding one more criterium in addition to the posterior elevation bulging and the location of the decentered thinnest corneal area.

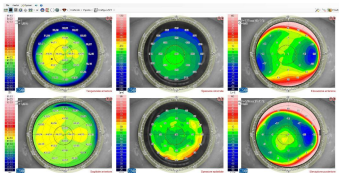


Figure 10. Sub-clinical keratoconus: neither anterior elevation nor anterior curvature show signs of irregularity or steepening but the ectasia is well demonstrated on the back surface and on the epithelial thickness map.

The next case follows similarly to the previous example. No anomalies related to the anterior curvature or elevation are detectable. The cornea values are thinner than normal with a decentered thinnest area (top center), making this finding suspicious. The posterior corneal elevation shows no bulging. Yet, the epithelial map (bottom center) exhibits a suspicious thinning in the same area in which the thinnest corneal area is located.

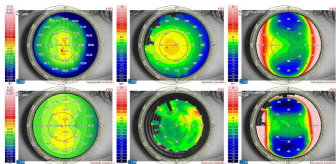


Figure 11. No signs of keratoconus are visible in this topographic display apart from the signs on the epithelial thickness map, that show the typical asymmetrical doughnut pattern.

By analyzing in the next image the other eye of the same patient, the previous case may be better understood. In this case, keratoconus is quite evident with all surfaces and thicknesses values altered. Hence, in the previous image of the right eye of this patient, the change in epithelial thickness and its topographical correlation with the decentered thinnest corneal area is indicative at least of a diagnosis of suspect keratoconus, if not of early keratoconus. Both eyes of this patient were treated by UV-riboflavin corneal cross-linking.

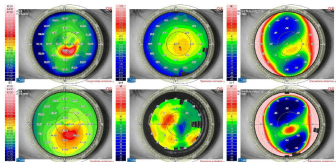


Figure 12. Fellow eye of the previous image: this topographic pattern confirms the presence of the keratoconus disease and the validity of the suspect classification for the right eye.

Note the right and left eye of the same patient in the following two images. Both eyes present no anomalies at the anterior curvature, no irregularity, and no bulging. The corneal thickness is normal along with almost no decentration of the thinnest area. The posterior corneal elevation demonstrates some mild degree of bulging (bottom right), and the epithelial thickness map displays some significant thinning corresponding with the posterior elevation bulging area and with the thinnest area of epithelial thickness, that are both central in this case. Is this keratoconus? Presently, there is no answer. Based on other clinical and patient history data (patient age, family history of keratoconus, atopy or eye-rubbing history, DNA testing) a diagnosis can potentially be made. Without any additional non-corneal criteria, the indication in a case like this one is routine follow-up exams to detect possible future topographic changes.

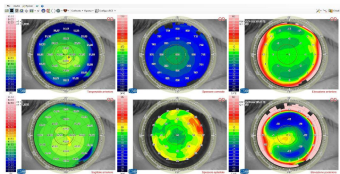


Figure 13. Case of suspect keratoconus: in both eyes no signs of keratoconus are visible on the anterior surface, but the posterior surface demonstrates signs of ectasia and the epithelial thickness demonstrates a doughnut pattern.

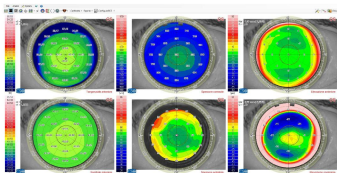


Figure 14. Case of suspect keratoconus: in both eyes no signs of keratoconus are visible on the anterior surface, but the posterior surface demonstrates signs of ectasia and the epithelial thickness demonstrates a doughnut pattern.

All the previous cases demonstrate how epithelial mapping may be useful in detecting early keratoconus or alerting the clinician of a possible suspect case of keratoconus. The next examples aid in understanding how epithelial mapping may be useful to avoid a misdiagnosis of keratoconus. As previously discussed, in case of keratoconus the epithelial layer becomes thinner on the area corresponding with the steepening and bulging of the anterior corneal curvature, posterior corneal elevation bulging, and corneal thinning.

The following example demonstrate some anterior curvature steepening (top left), but normal posterior corneal curvature and normal corneal thickness map. The epithelium is actually thicker where the cornea is steeper. In this eye, the anterior curvature steepening is caused by the thickening of the epithelium. All these features rule out a diagnosis of keratoconus.

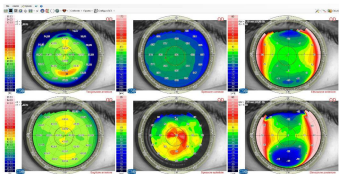


Figure 15. The anterior steepening shown in this topographical display can be explained by the local epithelium thickening. The posterior corneal surface appears normal.

The following case displays some anterior curvature inferior steepening (top and bottom left) and an asymmetry of the anterior curvature elevation located inferiorly (top right), which usually causes an inferior anterior curvature steepening. The posterior elevation is normal (bottom right). All these features are not in agreement with a diagnosis of keratoconus. However, the cornea is thinner than normal (top center). The epithelial thickness map helps clarify the matter. The thickest zone is located in the same area of the anterior curvature steepening, thus confirming this is a non-keratoconic eye.

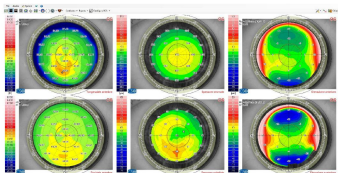


Figure 16. The anterior steepening shown in this topographical display can be explained by the local epithelium thickening. The posterior corneal surface appears normal.

The following case is similar to the previous one. The steepening of the anterior curvature corresponds with a thicker epithelial area, and all the other parameters are normal. The confounding keratoconus-like pattern of the anterior curvature is due to epithelial thickening and not to ectasia. In this case, epithelial thickening was related to an epithelial basement membrane dystrophy (EBMD).

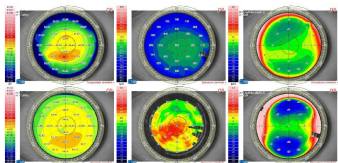


Figure 17. Epithelial Basement Membrane Dystrophy (EBMD) caused an epithelial thickening that indicates an anterior corneal steepening.

TAKE HOME MESSAGE

The assessment of the epithelial thickness over a large area and its representation in a corneal map format significantly aids in the detection of keratoconus, especially in those very early stages of the disease in which the diagnosis may lead to decisions that can have a significant impact on vision. An early diagnosis permits early cross-linking treatment, which can avoid the generation of all the aberrations induced by a clinically evident keratoconus. A diagnosis of suspect keratoconus may help to avoid corneal refractive surgery on an eye that could develop ectasia not because of the surgery itself, but due to an ocular predisposing factor. The assessment of the epithelial layer thickness may also help to avoid a misdiagnosis of keratoconus in healthy eyes.

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