Cataract & Refractive Surgery TODAY

GALILEI

ALL-IN-ONE
The most complete solution for refractive and cataract surgery.
## CONTENTS

### TECHNOLOGICAL ADVANCES OF THE GALILEI
All you need for daily clinical practice, in one device.
By Harald Studer, PhD

### THE ADVANTAGES OF AN ALL-IN-ONE SYSTEM
An interview with Han Bor Fam, MD.

### AUTOMATED DETECTION PROGRAM FOR SUBCLINICAL KERATOCONUS
With the GALILEI Analyzer’s artificial intelligence system, clinicians can improve their detection of mild ectatic corneas without expertise in interpreting corneal imaging.
By David Smadja, MD

### KERATOCONUS SCREENING WITH THE GALILEI
This device produces highly accurate posterior curvature measurements for precise keratoconus screening.
By Ronald R. Krueger, MD

### AVOIDING VISUAL COMPLAINTS WITH PREMIUM IOLs
Total corneal power must be evaluated to achieve success with multifocal and toric IOLs.
By Carlos G. Arce, MD

### TOTAL CORNEAL ASTIGMATISM FOR TORIC IOLs
An interview with Douglas D. Koch, MD.

### PLANNING A PROCEDURE WITH LRIS
Preoperative measurements with the GALILEI and incision creation with the FEMTO LDV is a winning combination.
By Bojan Pajic, MD, PhD, FEBO
Technological Advances of the GALILEI

All you need for daily clinical practice, in one device.

BY HARALD STUDER, PhD

There are two groups of technologies for diagnostics in ophthalmology, Placido-disc (ie, topography; Figure 1) and Scheimpflug (Figure 2). Each group has a unique set of advantages and disadvantages. For instance, elevation can be directly measured with Scheimpflug technology, but it must be calculated with Placido-disc technology. On the other hand, corneal curvature must be calculated from Scheimpflug data, but it can be measured with Placido-disc.

Because both types of information are relevant in daily clinical practice and because measured values are always favored over calculated ones, the only way to provide accurate curvature and elevation information is to combine both technologies into one device. Today, this combination of diagnostic technologies is featured in the GALILEI (Ziemer Ophthalmic Systems AG).

A DUAL-SCHEIMPFLUG SYSTEM

In addition to the availability of Placido-disc and Scheimpflug technologies in the same device, the latest GALILEI, the GALILEI G6 Lens Professional,* now also offers biometry based on optical coherence technology. Such a combination has many advantages for cataract surgeons worldwide. First, it means that we can buy and maintain a single device to perform all the measurements required of cataract surgery. Second, we now only have one device taking up space within our practice. For a listing of the technical specifications and measurement unit characteristics, see Tables 1 and 2.

The accuracy of corneal thickness measurements (ie, pachymetry), assessed with Scheimpflug technology, depends on the device being well aligned with the center of the cornea. Systems with a single Scheimpflug channel use a mathematical equation to estimate compensation for an off-center measurement; however, the only way to properly compensate for an off-center measurement is with Dual-Scheimpflug technology, like that featured on the GALILEI. As measuring is always favored over estimations, Dual-Scheimpflug systems are the preferred method for taking pachymetry measurements.

Figure 1. Placido-disc–based topography can be used to measure corneal curvature.

Figure 2. Scheimpflug technology can be used to calculate height information.
**QUESTIONS FOR A CLINICAL PRACTICE**

**Question No. 1:** What requirements do we, as cataract surgeons, have in our daily clinical practice for preoperative assessments? The list is relatively short:

- Corneal curvature;
- Keratometry (K) readings;
- Refractive power;
- Pachymetry; and
- Posterior corneal surface.

The only way to assess these parameters, however, is with a rotating Scheimpflug device. Unfortunately, measurements can be off-centered by as much as ±30 µm when using a Scheimpflug device with only one channel.

**Question No. 2:** What can we do about it?

We have three options:

- We can ignore it;
- We can try to estimate the necessary compensation; or
- We can measure it.

In my opinion, I would prefer to measure it. In order to do this, a second Scheimpflug channel is required. This second channel would allow us to measure the necessary compensation for pachymetry.

**Question No. 3:** Can’t a second Scheimpflug channel be added to an existing device? Our problems are not solved by simply building a device with a rotating dual-channel Scheimpflug. The reason is that the Scheimpflug technology has a severe problem handling corneal curvatures, especially in the center of the cornea—where it is most important. The central curvature deviation can be as high as ±1.00 D with a pure Scheimpflug system.

The only way to assess these parameters, however, is with a rotating Scheimpflug device. Unfortunately, measurements can be off-centered by as much as ±30 µm when using a Scheimpflug device with only one channel.

**Question No. 4:** How can we measure it? The simple answer is with a Placido-disc-based system, which is known for its accuracy of corneal curvature. The more complex answer, however, is that two components are needed to finally achieve an accurate assessment of the human corneal shape, a Scheimpflug system with two channels and a Placido-disc-based device.

**Question No. 5:** So we need two devices? In the past, the answer to this question would have been yes. But, luckily for us, Ziemer has built a single device that incorporates both Scheimpflug and Placido-disc technology into the same device, the GALILEI G6 Lens Professional.

**CONCLUSION**

The story does not quite end there, however. With the G6, Ziemer has now combined even more technology into the same device. By integrating optical coherence technology into the GALILEI G6, we can now perform biometry with this system as well. In this way, the G6 features everything a surgeon needs to accurately assess corneal anterior and posterior topography, pachymetry, and IOL power.

**THE BOTTOM LINE:**

The GALILEI G6 combines Placido-disc, Dual-Scheimpflug, and optical biometry technologies; everything a surgeon needs to assess corneal anterior and posterior topography, pachymetry, and IOL power.

---

**TECHNICAL SPECIFICATIONS**

| Placido disc: | 20 rings |
| Measurement speed: | 60 images in 1 second |
| Displayed map coverage: max. | 10 mm |
| DICOM compatibility: | Yes |
| Axial Length: | 45 mm (default 35 mm) |
| Lens Thickness: | 0.5 – 7 mm |
| Corneal radii: | 4.5 – 13.5 mm (25 – 75 D) |
| Anterior Chamber Depth: | 1 – 7 mm |
| White-to-White: | 6 – 14 mm |
| Pupillometry: | 0.5 – 10 mm |
| Interferometric resolution: | 5 µm |
| Eye length repeatability: | ± 25 µm |
| Pachymetry: | 250 – 800 µm (± 2 µm) |

**MEASUREMENT UNIT CHARACTERISTICS**

| Measuring principle: | Combination of optical A-Scan, Dual-Scheimpflug slit images, and Placido and top view images |
| Observation illumination: | NIR (near-infrared) LED 810 nm |
| Scheimpflug illumination: | Blue LED (UV-free) 470 nm |
| Placido illumination: | NIR (near-infrared) LED 750 nm |
| Biometry wavelength: | 880 nm |
| Image acquisition: | 3 HD CCD cameras |

*The GALILEI G6 Lens Professional is pending FDA approval and is not available for sale in the US. For some other countries, availability may be restricted due to local regulatory requirements. Please contact Ziemer for details.*
The Advantages of an All-in-One System

An interview with Han Bor Fam, MD.

1. WHAT ARE THE ADVANTAGES OF AN ALL-IN-ONE DEVICE?

Today, cataract surgery is a refractive procedure. Therefore, it needs the same thorough preoperative assessment required before corneal refractive surgery, whether incisional or laser. The GALILEI G6 Lens Professional* (Ziemer Ophthalmic Systems AG) is advantageous to use for preoperative screening of cataract patients as well as refractive surgery candidates because it encompasses both corneal tomography and an optical biometer in a single device. Below are four reasons why I prefer to use this device over the others on the market.

Convenience. Because the GALILEI G6 is capable of providing me with all of the preoperative data I need to perform successful surgery, the patient no longer has to move between several machines. This not only makes for a better patient experience, but it also improves my clinical workflow.

Cost. We can reduce operational costs, because additional machines are no longer required for preoperative assessment.

Physical space. The GALILEI G6 has a smaller footprint than some of the other diagnostic devices on the market, freeing up space for other uses.

Functionality. The GALILEI enables me to perform corneal tomography, wavefront analysis, pachymetry, and biometry for different purposes, including standard cataract surgery, cataract surgery with toric IOL implantation, planning limbal relaxing incisions (LRIs), and LASIK. These investigations are commonly required for refractive cataract surgery. The GALILEI, in a single machine, covers them all.

2. HOW DOES THE GALILEI G6 SIMPLIFY YOUR SCREENING PROCESS?

The answer to this question has four significant points. First, the interface of the GALILEI G6 is very user-friendly, with single-button analysis for all measurements including axial length, keratometry (K), lens thickness, anterior chamber depth, and pachymetry. Second, diagnostic screening with Dual-Scheimpflug and Placido-disc–based corneal topography enables me to screen patients for keratoconus and corneal ectasia. It also alerts me to eyes that have previously undergone LASIK. Third, integration of total corneal pachymetry and corneal thickness measurements enables calculations for LRI placement and LASIK flaps and ablations; this is not included with conventional biometers. Fourth, I can use the GALILEI G6 to map the exact placement of a toric IOL, as it measures both anterior and posterior corneal astigmatism.

3. HOW DO YOU USE THE GALILEI G6 DURING YOUR SCREENING PROCESS?

I use the GALILEI for three main functions, and these are cataract surgery; LASIK; and detection of corneal pathologies including keratoconus, ectasia, and abnormal K readings. For cataract surgery, I use the GALILEI to measure axial length, anterior chamber depth, K readings, pachymetry (if placing LRIs), topography (if implanting a toric IOL), and higher-order aberrations (if implanting a premium IOL).

4. HOW DOES THE GALILEI G6 OPTIMIZE YOUR CLINICAL WORKFLOW?

Because the GALILEI G6 is an all-in-one device, I no longer need to use separate machines for most cases. The exception is cases requiring ultrasound biometry. Therefore, use of the GALILEI eliminates the need for excessive patient movement and, because the staff does not need to toggle between the user interfaces of multiple machines, it cuts down on training and time. Lastly, the GALILEI G6 improves my workflow because I can use it for both LASIK and cataract surgery patients.

5. WHAT ARE THE INDICATIONS FOR THE G6?

The GALILEI G6 can be used for preoperative assessment of both cataract and corneal refractive surgery patients. In those patients undergoing cataract surgery, I use the GALILEI G6 for optical biometry, including topography to measure total corneal astigmatism (in patients receiving a toric IOL); preoperative corneal aberrometry, and to determine placement of LRIs or astigmatic keratotomy incisions. I also use the device for post-LASIK IOL power calculation, post-LASIK ectasia monitoring, diagnostics and monitoring of corneal pathologies, postcataract refractive surprises to determine IOL position, and glaucoma preoperative assessment.

Han Bor Fam, MD, practices at the Tan Tock Seng Hospital, Singapore. Dr. Fam states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: Han_Bor_Fam@ttsh.com.sg.

THE BOTTOM LINE:

The interface of the GALILEI G6 is user-friendly, with single-button analysis for all measurements including axial length, keratometry, lens thickness, anterior chamber depth, and pachymetry.
Automated Detection Program for Subclinical Keratoconus

When selecting a refractive surgery procedure, identifying subclinical keratoconus remains one of the most challenging situations ophthalmologists face. The overlap of values between normal eyes and those with subclinical keratoconus in most of the parameters analyzed with topography and tomography does not allow the ophthalmologist to state with certainty to which category the eye belongs. Moreover, the amleness and complexity of data provided by current imaging systems represent a challenge of interpretation for the ophthalmologist. Therefore, decisions are often based upon personal experience and subjective recognition of patterns or empiric cutoff values that are not necessarily the same between imaging systems.

Using the GALILEI Dual-Scheimpflug Analyzer (Ziemer Ophthalmic Systems AG), we developed an automated screening program based on artificial intelligence for improving the sensitivity of subclinical keratoconus detection. In total, 56 parameters derived from topography, elevation maps, pachymetry, and wavefront were measured and included in the analysis for building a discrimination rule that could best distinguish subclinical keratoconus from a normal cornea.

METHOD

The aim of this study was to elaborate, with the help of an artificial intelligence system, a discrimination rule based on topographic, tomographic, and wavefront parameters for distinguishing normal corneas from subclinical keratoconus. A total of 221 eyes (142 patients) were enrolled in the study. All eyes were imaged with the GALILEI Dual-Scheimpflug analyzer, including 177 eyes of 95 patients with normal corneas and 47 contralateral eyes of patients with forme fruste keratoconus and with clinically evident keratoconus in the fellow eye (Figure 1).

For the purpose of our study, a normal cornea was defined as one with no clinical signs of keratoconus and no suggestive topographic or tomographic patterns of suspect keratoconus including asymmetric bowtie with a skewed radial axes, focal or inferior steepening, central keratometry greater than 47.00 D, or corneas thinner than 500 µm; forme fruste keratoconus was defined as topographically normal (no asymmetric bowtie, no focal or inferior steepening pattern and Klyce and Maeda indices <0.233) contralateral eyes of clinically evident keratoconus in the fellow eye.

ARTIFICIAL INTELLIGENCE SYSTEM: THE MACHINE-LEARNING CLASSIFIER

In this study, we used an artificial intelligence method for discriminating between normal corneas and those with forme fruste keratoconus that is based on an automated decision-tree induction algorithm. This method has been widely used in the fields of computer science and machine learning and has already been applied by others to medical diagnostic classification problems. One of the major advantages of this decision-tree classification method is its ease of interpretation and of understanding. Moreover, the classification-tree method builds its discriminating rule based on a logical sequence of conditional statements (ie, if A, then B). Another considerable benefit of classification by decision-tree induction is the automated selection
of variables that best discriminate your populations and discovery of cutoff values that reach the highest discriminating power. This ability to automatically find the most discriminant variables with their cutoff values is particularly relevant when dealing with extensive data and would not be possible without the help of an artificial intelligence method.

**STUDY FINDINGS**

The decision tree generated by the algorithm enabled us to identify forme fruste keratoconus with excellent performance (93.7% sensitivity, 97.2% specificity). Additionally, in contrast to the classical black box algorithms developed with other neural networks, this decision tree was transparent and easy to interpret. Therefore, it helped us to determine the most discriminant indices among the 56 parameters analyzed, along with their respective cutoff values. Thus, the posterior asphericity asymmetry index (AAI) with a cutoff value of 21.5 µm and the corneal volume at 30.8 mm³ were identified as the two most discriminant variables among the parameters incorporated in the analysis for differentiating between normal corneas and those with forme fruste keratoconus (Figures 2 and 3).

The posterior AAI is a quantitative indicator of the posterior surface asymmetry (Figure 4), which was first described by Arce in 2010. This index is calculated over the best-fit toric and aspheric (BFTA) reference surface, which was recently shown to improve the sensitivity of subclinical keratoconus detection when compared with the elevation analysis over the classical best fit sphere (BFS). Indeed, the shape of the BFTA reference surface, in contrast to the classical BFS, is built based on the mean toricity and eccentricity of the cornea, ultimately leading to a closer fit of the natural toric and aspheric corneal shape. Therefore, calculation of elevation relative to a BFTA would neutralize the influence of toricity and asphericity on the elevation pattern generated and would help to identify the first signs of asymmetry in elevation.

Although there is still debate over the first detectable sign of ectatic disease, whether it would be first an inferior steepening seen in the anterior surface with Placido-disc topography or subtle modifications of the posterior cornea detected by tomography, our findings—by selecting the posterior AAI as the most discriminant index for identifying forme fruste keratoconus—support the leading current hypothesis that ectatic disease may be first detectable at the level of the posterior surface.

**DISCUSSION**

Combining multiple corneal indices for detecting ectasia-susceptible corneas has been considered an interesting approach for improving the sensitivity and specificity of its detection and has already been successfully tested with various systems. By using the GALILEI Analyzer system for developing such screening tool, we could benefit from a thorough analysis of the corneal features with a single imaging system. A full range of corneal indi-
ces, such as those parameters derived from Placido-disc technology, Dual-Scheimpflug technology (including elevation and pachymetric indices), and wavefront, could be incorporated into the analysis for building our discriminating rule.

Since the results of this analysis and while waiting to further validate our findings in a larger sample size as well as in post-LASIK ectasia cases, we have adopted into our daily practice the discrimination rules generated by the software for screening our LASIK candidates. Therefore, we always first ensure that the posterior AAI is inferior to 22 µm before considering a candidate suitable for LASIK surgery. We also then check that the corneal volume is above 30.8 mm³ or has a thinnest point above 508 µm when the posterior AAI was within the adequate range.

CONCLUSION

Future combinations with other corneal properties such as corneal biomechanics has the potential to further improve the screening process for keratoconus and forme fruste keratoconus. However, this artificial intelligence system will undoubtedly help the clinician to improve the detection of mild ectatic corneas without requiring preliminary expertise in interpreting corneal imaging.

THE BOTTOM LINE:

The discrimination rules generated by Dr. Smadja’s software for screening LASIK candidates suggest that the posterior AAI is inferior to 22 µm before considering a candidate suitable for LASIK and that the corneal volume is greater than 30.8 mm³ or has a thinnest point above 508 µm when the posterior AAI is within the adequate range.
Keratoconus Screening
With the GALILEI

This device produces accurate posterior curvature measurements for precise keratoconus screening.

BY RONALD R. KRUEGER, MD

Keratoconus is a bilateral, corneal deformation due to biomechanical weakening that can interfere with normal vision. The traditional telltale sign is topographic asymmetry and steepening of the anterior corneal curvature on corneal topography. In many cases, the topographic asymmetry and steepening will be noted inferiorly, with associated corneal thinning. Since the biomechanical elasticity of the cornea cannot be measured well, in-vivo corneal topography has historically been the main diagnostic tool for keratoconus. As a general rule of thumb, the more irregular and steeper the anterior corneal curvature is, the more suspicious the examiner should be of keratoconus. However, diagnosing keratoconus is far from an exact science and tends to be a concurrence of symptoms, signs, and indices pointing toward changes in the shape and structure of the cornea.

Recently, Scheimpflug tomography has opened up additional areas that can be useful for detecting keratoconus. In addition to mapping the anterior corneal surface with topography, examiners can now measure the corneal thickness and map the posterior surface of the cornea with Dual-Scheimpflug tomography using the GALILEI (Ziemer Ophthalmic Systems AG). This technology can be used to determine whether the cornea is elevated and bulging forward relative to a best fit spherical or aspherical surface. It can also be used to compare the anterior and posterior

Figure 1. Humphrey Topography of both eyes (right, suspect keratoconus; left, obvious keratoconus).

Figure 2. Pentacam images of both eyes (A,B). A reasonable shape, thickness, and curvature on the front and back surface of the right eye (A).
surfaces of the cornea and detect the thinnest and thickest spots between both surfaces. This can be helpful to examiners, allowing them to validate the concerns of purely anterior topographic corneal irregularities. Scheimpflug tomography is especially integral to the diagnosis of keratoconus because, as a disease, it is believed to start more posteriorly than anteriorly.

**CASE STUDY**

The clinical importance of the GALILEI was remarkably obvious a few weeks ago as I examined a 56-year-old female with obvious keratoconus in one eye. The fellow eye looked fairly normal based on topography and tomography with the Pentacam (Oculus Optikgeräte GmbH); however, when I examined this normal-looking eye with the GALILEI, I noticed some abnormalities indicative of forme fruste keratoconus (Figures 1 through 5). Even if I had not used the GALILEI in this case, I would have still been suspicious of keratoconus in the fellow eye, given that it is a bilateral disease.

The challenge in this case is if I would only have seen the better of the two eyes and never had a reason to look at the keratoconic eye, would I have been able to distinguish that this was a potential keratoconus case with just topography or Pentacam tomography?
The importance of this case study is to emphasize the usefulness of the GALILEI. This technology is not over-diagnosing the corneal condition; rather, it adds sensitivity to our diagnosis. Because the GALILEI incorporates posterior corneal curvature maps and uses Dual-Scheimpflug tomography, it can detect the earliest signs of keratoconus. Forme fruste keratoconus is barely diagnosable, but it can be validated by looking at some of the most sensitive metrics that are available on the GALILEI.

My case reminds me of the recent work of Smadja et al., who studied the reference surfaces of 391 eyes as a best fit sphere (BFS) and as a best fit toric asphere (BFTA) to compare the discriminating ability of corneal elevation with the GALILEI Dual-Scheimpflug Analyzer. Of the eyes, 177 had normal corneas, 167 were keratoconic, and 47 had contralateral topographically normal corneas in patients with clinically evident keratoconus in the fellow eye. The aim of the study was to see if the GALILEI could distinguish a normal cornea from those with keratoconus or forme fruste keratoconus.

Just as in my case example, Smadja et al found that the most sensitive indicator for keratoconus detection was not on the anterior, but posterior surface. We concluded that the use of BFTA elevation parameters significantly improved the ability to discriminate between normal corneas and those with forme fruste keratoconus (P = .01).

PERSONAL USE

At the Cole Eye Institute of the Cleveland Clinic, we have had the GALILEI G4 for approximately 2 years. The most important way we use this technology is for screening refractive surgery patients. It is the best technology to determine who potentially has keratoconus, who is suitable for refractive surgery, and, if they are, to decide between PRK and LASIK.

Owning and using the GALILEI differentiates us from other practices in our area that only use corneal topography in the diagnosis and screening of keratoconus. We also have a Humphrey topographer (Carl Zeiss Meditec) and even a Pentacam, but the GALILEI is the additional check that we need when we feel that there is something disconcerting or suspicious about the maps generated with the other two systems. We like that the GALILEI can provide more detail and more advanced metrics than the other devices do.

One of the newer metrics we have adopted was recently published, again by Smadja et al., using an automated decision-tree analysis. This is the best way to systematically screen which indices are most sensitive and specific as part of larger decision tree, which can be simplified to even a pruned decision tree of only one or two indices.

In this study, the posterior aspheric asymmetry index (AAI) was noted to be the most sensitive and specific. This index is simply determined by viewing the posterior BFTA referenced elevation map and determining the difference between the magnitude of the most elevated and most depressed points on this posterior surface. When the difference is greater than 21.5 µm in magnitude and there is associated thinning and even anterior elevation in the same region as the most posterior elevated point, then the eye has forme fruste keratoconus unless proven otherwise.

Finally, we have started using the GALILEI postoperatively to reassess patients who had questionable maps preoperatively, but in whom we proceeded with surgery. Using it this way, we can see if there are any changes to the posterior curvature and magnitude of the AAI after surgery that may suggest there was a biomechanical shift in the cornea, indicated by a forward bulge in the cornea’s posterior surface.

So far, as reported in a previous study, we have only seen transient increases that stabilize after 1 to 3 months, but this kind of comparative analysis may be useful in better understanding the corneal biomechanics associated with LASIK and the real signs and risk factors for post-LASIK ectasia. 

CONCLUSION

When assessing a patient for refractive surgery and there is even a hint of asymmetric topographic steepening, I assess the patient with Dual-Scheimpflug tomography to look at the anterior and posterior corneal surface shapes and corneal thickness maps for greater detail. I specifically look at the posterior elevation map using a BFTA shape to measure the difference in magnitude between the greatest point of elevation in one area and the greatest point of depression in another. When this magnitude is greater than 21.5 µm and associated with thinning and anterior steepening, I am concerned that there may be weakness in the cornea, and I discourage the patient from LASIK. If there are no other apparent risk factors and a low correction, I may consider PRK surgery. The advantage of the GALILEI is that we can identify these subtle findings as potential areas of corneal weakness at its earliest stages, allowing me to screen out forme fruste keratoconus with more confidence than I can with other devices.

Ronald R. Krueger, MD, is Medical Director of the Department of Refractive Surgery, Cole Eye Institute, Cleveland Clinic Foundation. Dr. Krueger states that he has no financial interest in the products or companies mentioned. He may be reached at tel: +1 216 444 8158; e-mail: krueger@ccf.org.


THE BOTTOM LINE:
The advantage of the GALILEI is that examiners can identify potential weaknesses in the cornea at their earliest stages, allowing timely detection of forme fruste keratoconus.
Avoiding Visual Complaints With Premium IOLs

The total corneal wavefront must be evaluated to achieve success with multifocal and toric IOLs.

BY CARLOS G. ARCE, MD

The total corneal wavefront, produced by light rays that cross the cornea, can be calculated and decomposed in Zernike polynomials or aberrations only by devices able to assess data from both the anterior and posterior corneal surfaces. Higher-order aberrations (HOAs) may be assessed either in microns or diopters and can be separated individually, by order, or as an overall index like the root mean square (RMS).

Iatrogenic or pathologic modification of the shape of the corneal surface induces specific changes in the eye’s normal corneal wavefront, and abnormal corneal HOAs cause loss of quality of vision. All available diagnostic devices assess eye or corneal HOAs aligned to the pupil center. However, most surgeries and applications are aligned to the first Purkinje and not to the pupil center, thus creating some conflict and limitation to the interpretation and utility of the wavefront data.

This article demonstrates how we can use total corneal HOAs to our advantage, in order to avoid visual complaints with premium IOLs.

SPHERICAL ABERRATION

The most studied corneal HOA is the spherical aberration. The amount of spherical aberration in an eye is related to the refractions of central and peripheral light rays as they strike the cornea. Positive spherical aberration means that peripheral rays are bent more in front of central rays; negative spherical aberration means that peripheral rays are not bent enough and focus beyond the central rays. Both produce defocused images, either toward the inside or the outside. Zero spherical aberration means that all central and peripheral light rays focus at the same point of the optical axis; in these cases, images are in sharp focus.

In all eyes, total spherical aberration increases with age due to changes in the crystalline lens, but corneal spherical aberration does not change in normal corneas.1-3 Corneas that have previously undergone refractive surgery or have experienced pathologic changes on their surfaces, however, have a variable spherical aberration outside the normal range. Average spherical anterior or posterior corneal surfaces studied with the GALILEI (Ziemer Ophthalmic Systems AG) have a Q factor ($\varepsilon^2$) around 0.00 and spherical aberration between 0.25 to 0.30 $\mu$m. The $\varepsilon^2$ is an index of corneal surface shape and correlates well with the total corneal spherical aberration (Figure 1). Thus, when corneal surfaces are aspheric ellipsoid prolate, the negative Q or the positive $\varepsilon^2$ (similar value, opposite sign) increase and the corneal spherical aberration becomes less positive ($\mu$m).

Ideally, aspheric corneas with anterior $\varepsilon^2$ around 0.60 have 0.00 $\mu$m of spherical aberration; hyperprolate corneas with higher anterior $\varepsilon^2$ have negative spherical aberration. On the other hand, when aspheric corneal surfaces become less prolate or oblate, then the $\varepsilon^2$ decreases and the spherical aberration becomes more positive (in $\mu$m).

SUM OF THE CORNEAL AND IOL SPHERICAL ABERRATIONS

After cataract surgery, the total spherical aberration is the sum of the corneal spherical aberration and the IOL’s spherical aberration. Therefore, the preoperative total corneal spherical aberration can be used to select the best spherical or aspheric IOL in accordance to what the practitioner decides is best for the eye after cataract surgery (Figure 2).
Presently, IOLs are available as spherical, with spherical aberration of 0.20 to 0.30 µm, or as aspheric, with spherical aberration of either 0.00 µm or between -0.11 and -0.27 µm. Since the shape of normal corneal surfaces ranges from spherical to aspheric prolate, the range of normal total corneal spherical aberration goes from 0.00 to around 0.30 µm, and implantation of a spherical IOL would increase their positive spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.

While aspheric-neutral IOLs keep the preoperative corneal spherical aberration, aspheric IOLs with negative spherical aberration compensate for the normal positive corneal spherical aberration. This creates an eye with a total spherical aberration closer to 0.00 µm and, as a result, with sharper vision when refraction is plano or best corrected.

Eyes with oblate corneas, like those after myopic LASIK, PRK, or radial keratotomy, have higher positive spherical aberration and, therefore, spherical IOLs are not the best option. Results with aspheric-neutral IOLs are good when a negative target refraction is wished, and aspheric-negative IOLs reduce the higher positive spherical aberration the eye already has. On the other hand, aspheric IOLs with negative spherical aberration are not appropriate for eyes with hyperprolate corneas and negative spherical aberration, like those that have previously undergone hyperopic or presbyopic spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.

While aspheric-neutral IOLs keep the preoperative corneal spherical aberration, aspheric IOLs with negative spherical aberration compensate for the normal positive corneal spherical aberration. This creates an eye with a total spherical aberration closer to 0.00 µm and, as a result, with sharper vision when refraction is plano or best corrected.

Eyes with oblate corneas, like those after myopic LASIK, PRK, or radial keratotomy, have higher positive spherical aberration and, therefore, spherical IOLs are not the best option. Results with aspheric-neutral IOLs are good when a negative target refraction is wished, and aspheric-negative IOLs reduce the higher positive spherical aberration the eye already has. On the other hand, aspheric IOLs with negative spherical aberration are not appropriate for eyes with hyperprolate corneas and negative spherical aberration, like those that have previously undergone hyperopic or presbyopic spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.

While aspheric-neutral IOLs keep the preoperative corneal spherical aberration, aspheric IOLs with negative spherical aberration compensate for the normal positive corneal spherical aberration. This creates an eye with a total spherical aberration closer to 0.00 µm and, as a result, with sharper vision when refraction is plano or best corrected.

Eyes with oblate corneas, like those after myopic LASIK, PRK, or radial keratotomy, have higher positive spherical aberration and, therefore, spherical IOLs are not the best option. Results with aspheric-neutral IOLs are good when a negative target refraction is wished, and aspheric-negative IOLs reduce the higher positive spherical aberration the eye already has. On the other hand, aspheric IOLs with negative spherical aberration are not appropriate for eyes with hyperprolate corneas and negative spherical aberration, like those that have previously undergone hyperopic or presbyopic spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.

While aspheric-neutral IOLs keep the preoperative corneal spherical aberration, aspheric IOLs with negative spherical aberration compensate for the normal positive corneal spherical aberration. This creates an eye with a total spherical aberration closer to 0.00 µm and, as a result, with sharper vision when refraction is plano or best corrected.

Eyes with oblate corneas, like those after myopic LASIK, PRK, or radial keratotomy, have higher positive spherical aberration and, therefore, spherical IOLs are not the best option. Results with aspheric-neutral IOLs are good when a negative target refraction is wished, and aspheric-negative IOLs reduce the higher positive spherical aberration the eye already has. On the other hand, aspheric IOLs with negative spherical aberration are not appropriate for eyes with hyperprolate corneas and negative spherical aberration, like those that have previously undergone hyperopic or presbyopic spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.

While aspheric-neutral IOLs keep the preoperative corneal spherical aberration, aspheric IOLs with negative spherical aberration compensate for the normal positive corneal spherical aberration. This creates an eye with a total spherical aberration closer to 0.00 µm and, as a result, with sharper vision when refraction is plano or best corrected.

Eyes with oblate corneas, like those after myopic LASIK, PRK, or radial keratotomy, have higher positive spherical aberration and, therefore, spherical IOLs are not the best option. Results with aspheric-neutral IOLs are good when a negative target refraction is wished, and aspheric-negative IOLs reduce the higher positive spherical aberration the eye already has. On the other hand, aspheric IOLs with negative spherical aberration are not appropriate for eyes with hyperprolate corneas and negative spherical aberration, like those that have previously undergone hyperopic or presbyopic spherical aberration. In such cases, the normal practice has been to select an IOL with slightly more positive power, allowing a myopic target postoperative refraction. Monovision is well tolerated by these eyes, probably because the area of less confusion of the Sturm conoid coincides with the peripheral rays whenever the central rays are focused on the retina.
refractive surgery or that have keratoconus. In these cases, aspheric-neutral or spherical IOLs are a better selection.

**COMA**

The asymmetric shape of corneal surfaces is represented in best fit toric aspheric (BFTA) elevation maps and may be quantified with the Kranemann-Arce (K-A) Index, also called the aspheric asymmetric index (AAI). This index is the differential value between the maximum positive and the minimum negative elevation point in BFTA maps of the GALILEI (Figure 3).

Asymmetry of corneal surfaces can follow the steeper or flatter axis of astigmatism and can even be oblique to it. Furthermore, the asymmetric shape of the anterior surface may have a different orientation and value, usually smaller, than the asymmetry on the posterior corneal surface.

An asymmetric corneal surface shape correlates well with the total corneal coma (Figure 4), which is the induced star-like dispersion of light rays not focused at the optical axis causing a variation in magnification over the entrance pupil. In refractive or diffractive IOLs, coma is also dependent on wavelength and, therefore, may be perceived as chromatic aberration.

Large kappa distance or misaligned aspheric IOLs tend to induce increased coma that may be clinically significant in patients who receive a multifocal IOL. Increased K-A index and coma have been linked with visual complaints in patients with keratoconus and after implantation of toric, aspheric multifocal, or multifocal IOLs. According to the experience of several Brazilian surgeons, diffractive aspheric multifocal IOLs should not be implanted in eyes with vertical or horizontal total corneal coma greater than ±0.50 µm and kappa distance larger than 0.45 mm. Similarly, refractive aspheric multifocal IOLs with the largest diameter in its first central optical ring would be contraindicated in eyes with kappa distance larger than 0.75 mm. The GALILEI automatically calculates the kappa distance between the pupil center and the first Purkinje.

Toric IOLs are implanted along the steepest axis of astigmatism; however, they are not specifically designed to compensate for coma derived from any asymmetry in the corneal surface’s curvature, power, or shape. Ideal
eyes for toric IOL implantation are those with a symmetric corneal shape and little coma. Better results with these IOLs have been observed when coma is parallel or 90° from the steepest axis of astigmatism.

**TREFOIL, QUATREFOIL, AND OTHER HOAs**

The higher the HOA, the more complicated the specific shape it depicts with greater detail. Increased abnormal trefoil and quatrefoil correspond well with wavy shape of wavefront and can cause visual complaints. Nevertheless, more studies are needed to confirm the link between specific HOAs and halos, glare, starbursts, lack of contrast sensitivity, and other symptoms that reduce the quality of vision.

Irregular, wavy, folded, or wrinkled corneal surfaces can be detailed on anterior or posterior BFTA maps with green, yellow, and blue zones of different sizes. These abnormal surfaces are commonly found in corneas that have previously undergone radial keratotomy, penetrating or lamellar keratoplasty; those with asymmetric keratoconus, pellicud marginal degeneration, or postoperative ectasia (Figure 5); corneas that had a small ablation zone or misaligned laser treatment; dry eyes, or with subepithelial viral infiltrates; and those that have Fuchs dystrophy, subclinical edema, anterior or posterior dystrophies, scars, or leucomas. The surfaces of these corneas have been related with increased total corneal trefoil, quatrefoil, and other HOAs, especially in the presence of a larger pupil.

On the other hand, multifocal IOLs may be apodized diffractive IOLs with Fresnel-like prisms in their surfaces or refractive IOLs with multiple zones for near or far. These IOLs are potential producers of third-, fourth-, and higher HOAs. The commercial literature for these IOLs usually explains that the lens produces scattering of light rays; it does not mention HOAs to justify postoperative visual complaints. In fact, we do not know how much trefoil or quatrefoil are induced by the variety of multifocal IOLs available on the market. While each manufacturer claims that its offering of IOLs is better accepted by the eye, there is also contradictory unpublished data suggesting which IOLs are better received than others.

We presently recommend not to implant multifocal IOLs when a cornea has more than average +2.00 SD of HOAs. In the presence of more than ±0.50 µm of coma, more than ±0.40 µm of trefoil, more than ±0.30 µm of quatrefoil, and more than ±0.20 µm of fifth-order aberrations, toric and multifocal IOLs should probably not be implanted. More studies are needed to confirm these preliminary cut-off values that presently serve as a guide for our decisions.

**CONCLUSION**

Total eye and corneal HOAs are related to visual complaints; however, they have been usually studied using RMS and other unspecific values. In order to better understand the origin of visual complaints, we must study each HOA individually. Today, there is still little evidence of how much HOAs the available IOLs produce. Most commercial literature is dedicated to marketing only the spherical aberration induced by spherical and aspheric IOLs.

In short, multifocal and toric IOLs with sophisticated optics should not be implanted in eyes with irregular corneal surfaces and increased HOAs detected by devices like the GALILEI. Matching the HOAs induced by an IOL to the total corneal HOAs in the eye would help to reduce the postoperative complaints that reduce the quality of vision. On the other hand, preoperative third- and fourth-order total corneal HOAs should be used to determine the best patients for toric and multifocal IOL implantation.

Carlos G. Arce, MD, is in private practice in Campinas, Brazil. Dr. Arce states that he is consultant to Ziemer Group and contributed to the development of applications with the Galilei; however, he has no commercial interest in the products mentioned. He may be reached at e-mail: carlos@arce.med.br.

4. Arce CG. Corneal shape and HOAs may be used to distinguish corneas with keratoconus. Paper presented at: the ESCRS annual meeting. Paris; September 2010.
7. Ibrahim F, Hepsen IF, Bilen NB, Arce CG. The correlation between the quality of vision and refractive, topographic, pachymetric, and aberrometric data in eyes with keratoconus. [Submitted for publication 2013.]

---

**THE BOTTOM LINE:**

Multifocal and toric IOLs with sophisticated optics should not be implanted in eyes with irregular corneal surfaces detected by devices like the GALILEI. Matching the HOAs induced by an IOL to the total corneal HOAs in the eye would help to reduce the postoperative complaints that reduce the quality of vision.
Total Corneal Astigmatism for Toric IOLs

An interview with Douglas D. Koch, MD.

1. WHAT IS YOUR OPINION OF THE NEW GENERATION OF IOL POWER CALCULATION FORMULAS?

In the early days of IOL power calculation, we had two types of formulas, early theoretical (e.g., Binkhorst) and regression formulas—empiric formulas generated by retrospectively averaging a large body of clinical results. The most well-known of the regression formulas are the SRK and the SRK II, and, although they were easy to use, they often resulted in power errors.

Today, these formulas have been replaced with sophisticated theoretical IOL power calculation formulas that are based on geometrical optics and require much more precise data than regression formulas did. The best-known theoretical formulas are the so-called third-generation SRK-T, Holladay 1, Hoffer-Q; the fourth-generation Holladay 2 and Haigis; and what we might call the fifth-generation Olsen and Barrett. Theoretical IOL power calculation formulas use a variety of biometric data to calculate effective lens position, which remains perhaps the largest source of error.

2. WHAT IS THE ROLE OF THE GALILEI (ZIEMER OPHTHALMIC SYSTEMS AG) IN PRODUCING ACCURATE IOL POWER CALCULATIONS?

By using ray tracing, the GALILEI can provide measurements of total corneal power—that is both anterior and posterior corneal powers as well as corneal thickness. This helps us to determine things such as the variability of corneal curvature on the front of the cornea—in other words all of the aberrations and how they might affect the final image, as well as the variability of corneal curvature on the posterior cornea. I believe that the latter is going to prove to be very important.

Recently we have come to realize how important posterior corneal curvature is for astigmatism, and I think we are going to find out that it is important for IOL calculation as well. Those are the two very special and unique features of using ray tracing and a device that can capture the back of the cornea. I think that the GALILEI is really the future of what we want to do in lens calculations.

3. WHAT IS THE BAYLOR NOMOGRAM FOR TORIC IOL CALCULATIONS?

The Baylor nomogram is a regression nomogram for toric IOL power calculations that provides a way to compensate for the against-the-rule astigmatism added to the refraction by the posterior surface of most corneas. It was created by compiling a large body of posterior corneal astigmatism measurements taken with the GALILEI, as well as data from a clinical study. Prior to our studies, these data had not been correlated to the use of toric IOLS. We looked at how the posterior cornea alters the selection of toric IOLS and created the nomogram to aid in selection of a toric IOL in cases for which an accurate posterior corneal measurement is not possible.

My goal is for the Baylor nomogram to have a very short lifespan, eventually becoming obsolete and replaced by direct measurements of anterior and posterior curvature: astigmatism and mean curvature.

4. DO YOU SEE THAT HAPPENING IN THE FUTURE WITH ANY OF THE AVAILABLE TECHNOLOGIES?

Yes, I do. I think technologies such as the GALILEI will enable us to measure the posterior corneal curvature before surgery and, in so doing, we will be able to get a comprehensive measurement of total corneal astigmatism. This will allow us to select our toric IOL appropriately based solely on that.

The posterior cornea, in almost every case, is steep vertically. Because the posterior cornea is a minus lens, that vertical steepness creates refractive astigmatism that is against-the-rule, meaning the corneal power is greater along the horizontal meridian. The GALILEI is designed to help surgeons more accurately select the toric IOL and prevent what is commonly occurring: over-correcting eyes that have with-the-rule astigmatism and under-correcting eyes that have against-the-rule astigmatism.

5. HOW CAN THE CALCULATION OF TOTAL CORNEAL ASTIGMATISM HELP IN THE CALCULATION OF TORIC IOL POWER?

The cornea contributes to astigmatism, and it almost always creates net refractive power along the horizontal meridian. If you do not take that into account—if you
implant a toric IOL in a patient whose anterior astigmatism is vertically oriented—you are likely to over-correct them with the selected toric IOL power. Conversely, if the patient has corneal astigmatism with greater power along the horizontal meridian than along the anterior cornea, then you are likely to under-correct them with your toric IOL and also with your corneal relaxing incision (Figure 1).

6. HOW DID THE GALILEI HELP YOU TO IMPROVE TORIC IOL CALCULATION?

The GALILEI is the device that has pointed out to me these interesting findings about the posterior cornea and the differences that are present as a function of what kind of astigmatism the anterior cornea has. It is also striking to see that there is not a big difference in the posterior cornea with age, which is very different than what happens with the anterior corneal surface.

In corneas that are steep vertically on the anterior surface, the greater the astigmatism on the front, the greater the steepness on the back. Therefore, the posterior cornea increasingly compensates for the anterior astigmatism as it increases. What we found using the GALILEI is that the posterior corneal astigmatism in an eye with 3.00 or 4.00 D of with-the-rule astigmatism can sometimes be as high as 0.80 D. We did not find the opposite in patients with against-the-rule astigmatism on the front surface of the cornea, however. In those patients whose corneas are steep horizontally, the posterior corneal curvature did not change much as that curvature increased.

7. ARE THERE ANY OTHER CASES FOR WHICH THE GALILEI IS USEFUL?

The GALILEI is also useful in patients who have unusual situations, for instance those who have had prior corneal refractive surgery such as PRK or LASIK. In these patients, the corneal curvature—and particularly the anterior corneal astigmatism—is no longer predictive of the posterior corneal astigmatism. This makes it all the more important to measure the posterior corneal astigmatism directly with the GALILEI. Likewise, in patients who have unusual conditions such as keratoconus, the posterior cornea can be very atypical. Here, again, it is important to measure the posterior corneal astigmatism to obtain the posterior corneal power, because there may be some surprises in that regard too.

Douglas D. Koch, MD, is a Professor and the Allen, Mosbacher, and Law Chair in Ophthalmology at the Cullen Eye Institute of the Baylor College of Medicine in Houston. Dr. Koch states that he has received research support from Ziemer and consults with Abbott Medical Optics Inc. and Alcon. He may be reached at tel: +1 713 798 6443; e-mail: dkoch@bcm.tmc.edu.

THE BOTTOM LINE:

By using ray tracing, the GALILEI can provide measurements of total corneal power. This includes anterior and posterior corneal powers and corneal thickness.
Planning a Procedure With LRIs

Preoperative measurements with the GALILEI and incision creation with the FEMTO LDV is a winning combination.

BY BOJAN PAJIC, MD, PhD, FEBO

We have entered a time in cataract surgery when patients expect precise refractive results and maximal visual quality postoperatively. Therefore, it is increasingly essential to transform our procedures from simple phacoemulsification with implantation of a monofocal IOL to refractive cataract surgery with implantation of a premium IOL.

The surgical transformation does not stop there, however, and today it is not uncommon for us to further customize cataract surgery to meet our patients’ demands. For instance, we can now target astigmatism correction at the time of cataract surgery using limbal relaxing incisions (LRIs). I prefer to do so using the GALILEI (Ziemer Ophthalmic Systems AG) for preoperative measurements and the FEMTO LDV (Ziemer Ophthalmic Systems AG)** for incision creation. This combination has proved to provide my patients with the exceptional postoperative results that they are aiming for.

PREOPERATIVE MEASUREMENTS

Various biometers and diagnostic systems are available on the market today. However, I find the usefulness of the GALILEI far outweighs that of other technologies. In short, this is because I can take many different measurements in one scan, alleviating time and boosting patient compliance (Figures 1 through 4). Also, using the GALILEI allows me to be more predictive of and gives me a better chance to adequately diagnose potential problems with the cornea before surgery. For one example of a case in which I detected keratoconus with the GALILEI, please see the sidebar, Keratoconus Detection With the GALILEI.

All patients undergoing cataract surgery should undergo preoperative screening with biometry, topography, and keratometry. With the first-generation GALILEI, topography and keratometry were standard, and I used a separate device to perform biometry. Now with the GALILEI G6 Lens Professional,* however, biometry is also available and I can measure axial length, topography, and keratometry in the same scan, which takes only a few seconds.

The GALILEI’s pachymetry maps help me to precisely plan surgery before the patient even enters the operating room. One distinct advantage is that I can use these maps to plan laser-assisted cataract surgery as well as the placement of limbal relaxing incisions (LRIs) for astigmatism correction. These incisions are easily created with the FEMTO LDV, which can create up to three arc-shaped incisions for astigmatism correction of up to 10 mm in diameter (Figure 5). Automated construction of LRIs is more reproducible than manual LRI construction, and using the laser for construction can allow complete control of the position and angle as well as increased precision in the dimension and depth of the incisions. The same laser module can be used for the creation of clear corneal incisions for cataract surgery.
All in One

Patient Selection for LRI

In general, patients with 1.00 to 1.50 D of astigmatism are best treated with LRIs. Because each patient’s eye and visual demands are unique, it is crucial to plan surgery on an individualized basis. I use the GALILEI G6 to plan LRI placement because, by combining Dual-Scheimpflug tomography with Placido-disc tomography, it produces the most complete and fully integrated dataset of corneal measurements including high-definition pachymetry, astigmatism, and corneal curvature.

The GALILEI G6 also provides me with a comprehensive analysis of pre- and postoperative astigmatism and higher-order aberrations (HOAs). Lastly, the precise pachymetry data and high-definition elevation maps provide exact characterization and biomechanical corneal modeling to improve my surgical planning of LRI placement as well as the safety of the procedure.

Conclusion

There are many reasons why the GALILEI G6 has become my diagnostic device of choice. For starters, I can obtain various measurements including optical biometry, high-definition topography, and anterior segment tomography with the same device. Additionally, I like that I can use the GALILEI for femtosecond cataract applications including LRIs.

Bojan Pajic, MD, PhD, FEBO, is a Consultant in the Division of Ophthalmology, Department of Clinical Neurosciences, University Hospitals of Geneva, Switzerland; president of the Swiss Eye Research Foundation, Medical Director of the Eye Clinic ORASIS, Reinach, Switzerland; and a Surgeon and a member of the Board of Specialized Hospital VIDARORASIS Swiss at the Eye Hospital VIDAR-ORASIS Swiss, University of Novi Sad, Faculty of Physics, Novi Sad, Serbia. Dr. Pajic states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: bpajic@datacomm.ch.

*The GALILEI G6 Lens Professional is pending FDA approval and is not available for sale in the US. For some other countries, availability may be restricted due to local regulatory requirements. Please contact Ziemer for details.

**The Ziemer FEMTO LDV Z Models are FDA cleared and CE Marked and available for immediate delivery. For some countries, availability may be restricted due to local regulatory requirements. Cataract procedures are not approved in the United States and in some other countries. Please contact Ziemer for details.

Figure 3. Results screen of the GALILEI G6: Scans and maps.

Figure 4. Results screen of the GALILEI G6: Images.

Figure 5. Planning for LRIs with the FEMTO LDV.

Figure 6. Keratoconus detection with the GALILEI.

Patient A presented with an advanced cataract and visual acuity of 0.05. Preoperatively, we performed biometry with the IOLMaster (Carl Zeiss Meditec), the Lenstar (Haag-Streit), and the GALILEI G6. Although the eye appeared normal on biometries from the first two devices, with the G6, keratoconus was detectable.

At that moment, everything we had planned for cataract surgery in this 70-year-old woman changed. Because of her advanced age, we questioned the use of corneal collagen crosslinking (CXL) before cataract surgery and, in the end, decided to delay surgery and watch for keratoconus progression. If we had missed the diagnosis and proceeded with cataract surgery, her visual outcomes would have been poor. Now she is stable and has a visual acuity of 0.8; she is satisfied with her results.

Another therapy strategy is to first perform cataract surgery, using the steep part of the cornea for entrance, followed by CXL 6 weeks later.

The GALILEI G6 provides all of the data I need to create LRIs successfully and reproducibly, including precise pachymetry and pre- and postoperative calculation and visualization of astigmatism and HOAs. When used in combination with the Femto LDV, the GALILEI G6 ensures that I provide my patients with the best visual outcomes possible after cataract surgery.

Bojan Pajic, MD, PhD, FEBO, is a Consultant in the Division of Ophthalmology, Department of Clinical Neurosciences, University Hospitals of Geneva, Switzerland; president of the Swiss Eye Research Foundation, Medical Director of the Eye Clinic ORASIS, Reinach, Switzerland; and a Surgeon and a member of the Board of Specialized Hospital VIDARORASIS Swiss at the Eye Hospital VIDAR-ORASIS Swiss, University of Novi Sad, Faculty of Physics, Novi Sad, Serbia. Dr. Pajic states that he has no financial interest in the products or companies mentioned. He may be reached at e-mail: bpajic@datacomm.ch.
FOR REFRACTIVE AND CATARACT SURGERY

Reaching a new level in corneal tomography
Patented Dual Scheimpflug system provides highly accurate pachymetry and ray-tracing, even when the measurement is decentred.

The only true solution
Placido and Scheimpflug for highly accurate pachymetry, elevation and curvature data – in all eyes.

Iris-based eye motion compensation
Have confidence in your follow-up measurements with realignment of maps in 3-D.

One platform, one solution.
We simplify the daily workflow in your clinic with an all-in-one solution, from refractive to cataract surgery.

Only the GALILEI G4 unites Placido and Dual Scheimpflug technologies in one measurement. With the GALILEI G4, you get highly precise measurements for posterior and anterior curvature, pachymetry, Total Corneal Power, Total Corneal Wavefront and the anterior segment of your patient’s eye. The new GALILEI G4, for first-class clinical results. The GALILEI G4 is a modular platform, which can be upgraded according to your needs. Learn more on galilei.ziemergroup.com.