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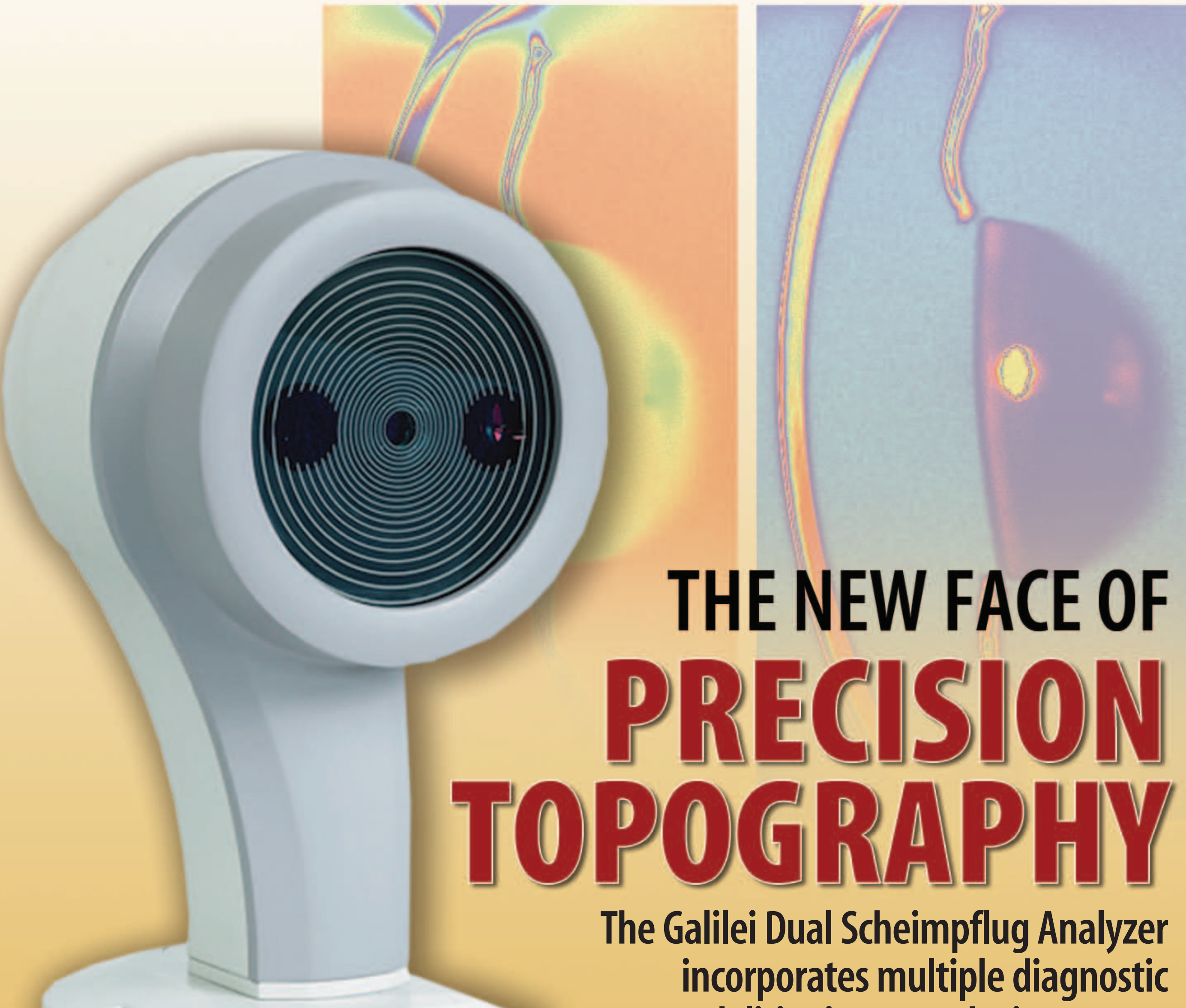
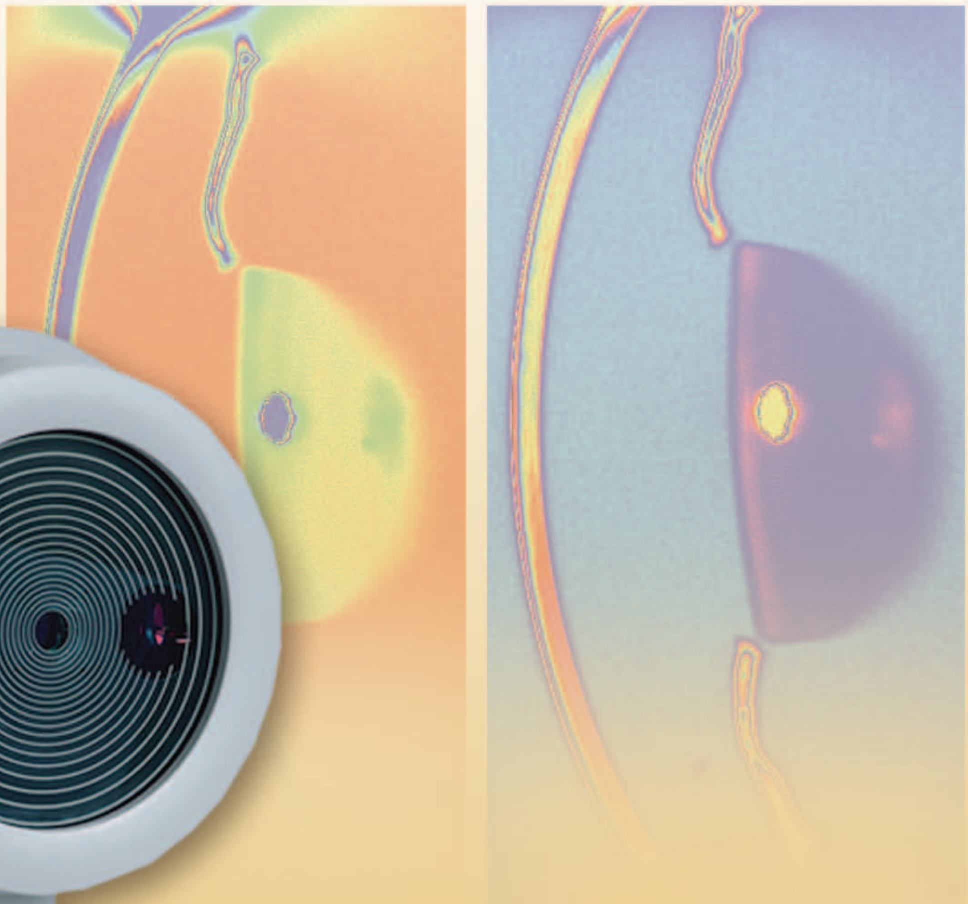


THE NEW FACE OF PRECISION TOPOGRAPHY

The Galilei Dual Scheimpflug Analyzer incorporates multiple diagnostic modalities into one device to map the cornea and anterior segment.

Sponsored by an educational grant from Ziemer Group.

THE NEW FACE OF PRECISION TOPOGRAPHY



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Enhanced Patient Screening and Reliable Outcomes

The Galilei's keratometry readings provide the same accuracy of outcomes in my refractive patients as in my cataract patients.

BY MICHAEL G. WOODCOCK, MD

In a little more than 1 year, I have taken more than 5,000 measurements with the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland). What I have found is that its keratometry (K) readings consistently provide the most accurate IOL power calculations. I started using the Galilei in my refractive patients, but I have found it invaluable for screening cataract patients as well. In fact, with the tightening of the global economy, I use the Galilei more often for cataract surgery, especially in my premium IOL patients.

To my knowledge, the Galilei is the only topographer that gives the true calculated K reading—the power reading—based on the internal and external surfaces of the cornea. We no longer have to rely on estimated K readings; we can directly measure both corneal surfaces to calculate keratometry, thus translating into greater accuracy for IOL power calculations.

Before I began using the Galilei, most of my patients underwent multiple sources of keratometry, including automatic, manual, and topographic keratometry prior to undergoing lens surgery. Despite our best efforts, occasional postoperative refractive errors of 1.00 D still occurred. Premium IOL patients required an enhancement for these outcomes, which was costly for my practice.

I now measure K readings with the Galilei for all my cataract surgery procedures, specifically looking at the simulated K readings and the central 4-mm true power of the Galilei. If there is more than 0.25 D difference between the manual average keratometry and the Galilei's simulated value, the patient must undergo further evaluation prior to IOL calculation. In approximately 95% of the repeat measurements, my staff and I find simple technician errors that we then correct prior to surgery. Whenever the values for the simulated and true total powers vary, I will choose an IOL power that somewhat favors the K reading from the true power calculation. Coupled with the accuracy of the IOLMaster (Carl Zeiss Meditec, Inc., Dublin, CA) for axial length, our postoperative mean absolute power for all premium IOLs is 0.36 D (standard deviation, 0.49 D). When the K reading is accurate, there is a strong chance that we will hit our target.

For cataract surgery with premium IOLs, the importance of accurate initial measurements is paramount. These patients demand high-quality results; avoiding the need for LASIK enhancement saves everyone time and expense. The current Galilei software (Version 4.0) provides even better capture rates with built-in messages to alert the user to possible acquisition errors that might affect accuracy.

PATIENT SCREENING

What are the mandatory parameters for accurate patient screening? The device must (1) accurately provide both the power and the axis of astigmatism, (2) correct for alignment errors, and (3) recognize when focus and alignment are inadequate for reliable measurements. With the introduction of dual Scheimpflug cameras and software to compensate for decentration errors, the Galilei has become an instrument without rival in the quest for a better keratometer. I previously considered manual calibrated keratometry as the gold standard of care; however, the Galilei is now my new standard. Its dual Scheimpflug technology provides more valid data compared with single Scheimpflug devices.

MORE VALUABLE IN THE FUTURE

Recently, I have seen a rise in the number of radial keratotomy and LASIK patients presenting to my practice for cataract surgery or refractive lensectomy. Prior to the introduction of the Galilei, my staff and I would calculate IOL power in the usual ways: the historical method of lens power calculations as well as by performing a hard contact lens over-refraction. As of recently, I have noted that the central Galilei's true K readings are more accurate for IOL power in these more difficult cases. I find that I am hitting closer to the intended outcomes now that I have another way to estimate the power of the postrefractive cornea.

Version 4.0 of the software does not allow the user to define the area of regard for true power measurement; however, future versions will permit the user to do so. This will allow more predictability by matching the average power of the postrefractive patient's own pupil rather than a set 4-mm optical zone. I also look forward to a histogram of the average powers over a user-defined zone for the evaluation of postoperative image quality with different IOL technologies.

Patients are never disappointed to find out that I offer the most accurate and the best technology available. Providing high-quality care is the best way for me to grow my business. To me, the Galilei is to keratometry what the IOLMaster is to axial length measurements. This is why, in my opinion, the Galilei is worth the investment. ■

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Keratometry and IOL Calculations

We may soon arrive at a time when IOL calculations are performed following exact optical calculations—with real measurements of all optical elements and without any fudge factors.

BY JAIME ARAMBERRI, MD

In the pseudophakic model, the IOL has a relationship with two other refracting planes: the spectacle and the cornea (Figure 1). The cornea, of course, is the most powerful surface; correctly measuring its surface and calculating its optical properties is crucial for any IOL calculation. In fact, these are probably two of, if not the most important steps in building an accurate and reliable IOL calculation.

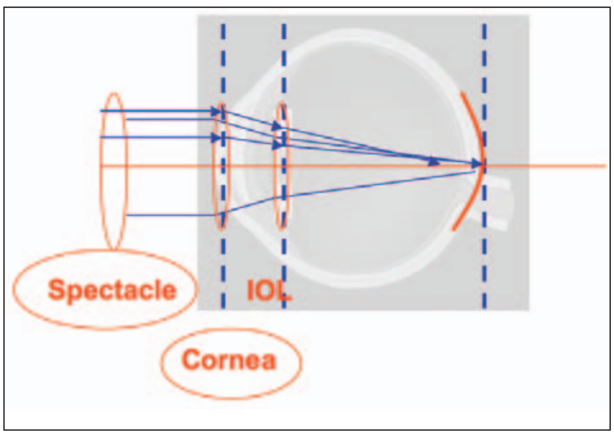

Figure 1. In the pseudophakic eye model, the IOL combines with the spectacle and the cornea.

ANTERIOR CORNEA: PRECISION

Anterior corneal power has been measured using reflexion-based technologies for the last 150 years. Keratometers (manual and automatic) and Placido-based topographers analyze the image of a known object and measure the curvature radii with different levels of assumptions. Because the difference between air and the corneal tissue's index of refraction is high (0.376), any small error will significantly affect the final refraction. The surgeon must remember two relationships: 0.1 mm of error in anterior curvature radius translates into 0.65 D of error in simulated keratometry (SimK), and 1.00 D of error in keratometry becomes 1.00 D of error in pseudophakic refraction.

Precision in anterior radius measurement is mandatory to achieve good IOL power predictions. Because they measure more points in the central cornea, topographers and tomographers are less precise than autokeratometers. However, in ongoing research into repeatability, we have

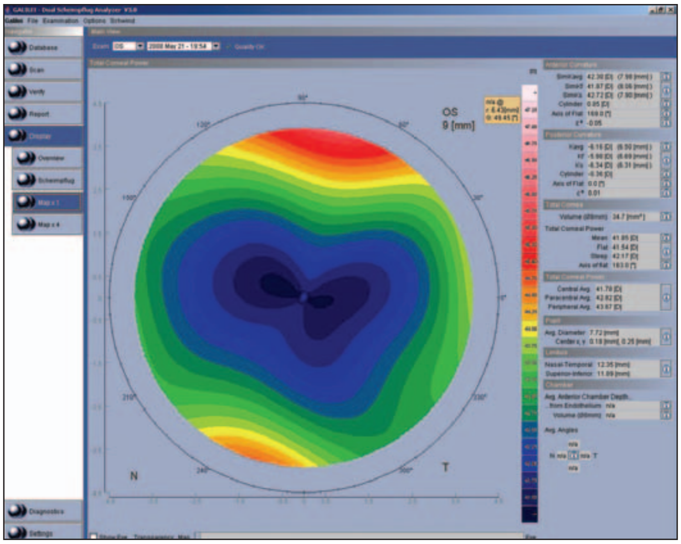

Figure 2. Example of patient data obtained with the Galilei Dual Scheimpflug Analyzer.

seen that the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland) performs with a standard deviation of 0.07 D, similar to that of the IOLMaster (Carl Zeiss Meditec, Inc., Dublin, CA) and the KR-8000 (Topcon; Tokyo, Japan). Additionally, this figure was similar for eyes that underwent LASIK or PRK as well as normal eyes. This impressive precision is probably the consequence of the double data source of images—Placido disc and dual Scheimpflug (Figure 2). For the first time, we can use a corneal tomographer SimK number in the IOL power calculation that does not increase the final prediction variance. Also, this fact is unaffected by previous corneal surgery.

POSTERIOR CORNEA: REAL MEASUREMENT

Posterior corneal surface power can be calculated from the anterior radius using the value 1.3375, or the standard index of refraction. This is how keratometers and topographers calculate SimK, which represents the average of total central power, just measuring the anterior surface. It has been known for a long time that this number overestimates the true corneal power. More accurate SimK calculations may be obtained using other index of refraction values, such as 1.3315 or 1.333, both of which have been tried in the literature. The 1.3375 value has worked well for contact lens adaptation and IOL power calculations because this inaccuracy, being systematic, can be corrected by compensating for the bias. However, the Achilles heel of this calculation is that it is based upon one main assumption: Anterior-to-posterior radii ratio is constant. This means that the steepness of the posterior cornea is proportional to the anterior cornea, with a normal value of around 1.21. Any cornea with a different ratio will make the SimK calculation with an arbitrary index of refraction erroneous.

In the last couple of years, we have seen many corneas that have an abnormal ratio. The postrefractive surgery cornea is the main example: After myopic LASIK or PRK, the anterior radius of curvature becomes higher (flatter), and the posterior radius remains unchanged, thus increasing the anterior-to-posterior ratio value. After radial keratotomy, the ratio increases in a lower magnitude, because there is some posterior flattening as well. After hyperopic corneal surgery, the change is opposite, and the ratio decreases. In irregular corneas (eg, keratoconus, scars), the ratio can change as well.

The only way to overcome this limitation is to measure the posterior radius of curvature and use this real number (not calculated from anterior radius) in the IOL power calculation. Once both radii are known, ray tracing can be performed to determine the optical properties of that cornea. Paraxial calculations can give a simple central power value, and more complex exact calculations can display lower- and higher-order aberrations of the total cornea.

The Galilei performs precise measurement of the posterior cornea, with a high repeatability index of 0.11 D using the Bland-Altman coefficient. It shows a similar value before and after corneal refractive surgery. We can rely on this parameter, forgetting fudge factors to achieve accurate IOL calculations in abnormal corneas. Moreover, the software calculates total central power by means of ray-tracing calculations.

CONCLUSION

The Galilei shows a robust ability to measure both anterior and posterior curvature radii with high levels of precision. This allows us to calculate IOL power accurately in those cases where SimK assumptions are broken, such as in the eyes with postrefractive surgery corneas, keratoconus, and ectasia.

I am sure that in the near future, these real numbers—obtained from measurement and not calculation—will be used in ray-tracing tools to achieve accurate calculations. In this scenario, precision will be limited only by the variance of biometric devices and algorithms that predict pseudophakic anterior chamber depth. The Galilei will be a tough contender in this race. ■

Jaime Aramberri, MD, practices in San Sebastian, Spain. He acknowledged no financial interest in the products or companies mentioned herein. Dr. Aramberri may be reached at jaimearamberri@telefonica.net.

Posterior Corneal Power in IOL Calculations

The Galilei predicts IOL power for normal patients as well as the IOLMaster does.

BY LI WANG, MD, PhD; MARIKO SHIRAYAMA, MD; AND DOUGLAS D. KOCH, MD

IOL power calculations play a large role in the success of the surgery. In the event of an IOL miscalculation, residual refractive errors may compromise the outcome and lead to patient dissatisfaction. The first step in producing optimal outcomes is to find out from the patient what his visual goal is for surgery. Once we know this, the second step is to use the proper IOL calculation.

Recently, we conducted a retrospective study to determine the accuracy of topography devices in IOL power calculations for normal eyes and eyes with prior myopic LASIK/PRK. In normal patients, we compared the IOL calculation accuracy with the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland) to the Humphrey Atlas corneal topographer and the IOLMaster (both manufactured by Carl Zeiss Meditec, Inc., Dublin, CA).

Seventy-five eyes of 62 patients who underwent phacoemulsification with implantation of the SN60WF IOL (Alcon Laboratories, Inc., Fort Worth, TX) were included. Five different corneal power values were evaluated: (1) simulated keratometry (SimK; performed with the Galilei); (2) average total corneal power steep and flat meridians over a 1- to 4-mm diameter (TCP Meridian; performed with the Galilei); (3) average total corneal power over the central 4-mm zone (TCP central; performed with the Galilei); (4) SimK (performed with the Atlas); and (5) corneal power (performed with the IOLMaster).

Using the Holladay 1 formula to determine the IOL power, predicted refractions with these five corneal powers were calculated; refractive prediction errors were determined by comparing the predicted refractions with the actual refraction obtained 3 to 4 weeks postoperatively. The surgeon factor was optimized for each corneal power. The accuracy of IOL calculations using these corneal power values was determined by calculating the mean absolute prediction error and percentage of eyes with refractive prediction error within 0.50, 1.00, and 1.50 D.

In 63 eyes after wavefront-guided LASIK or PRK, we evaluated the accuracy of the IOL calculation using corneal power measured with the Galilei. We used several values provided by the device, the primary ones being (1) corneal powers derived from the anterior corneal surface only, which included SimK and axial curvature central average; these measurements are obtained from combined information from the Placido rings and the Scheimpflug image, and (2) corneal powers calculated using the ray-tracing function, which included the average of the steep and flat meridians and the average of the central 4-mm zone.

The clinical history method was considered the gold standard. We calculated prediction error by subtracting the clinical history method from the corneal power

TABLE 1. CORNEAL POWER MEASUREMENTS

Corneal power measurement	Mean corneal power Mean ±SD (range)
Galilei SimK	43.74 ±1.21 D (41.00-46.60)
Galilei TCP Meridian	43.36 ±1.25 D (40.70-46.80)
Galilei TCP Central	43.37 ±1.28 D (40.70-46.80)
IOLMaster	43.87 ±1.22 D (41.10-47.50)
Atlas SimK	43.85 ±1.24 D (41.10-47.00)

TABLE 2. MEAN ABSOLUTE PREDICTION ERRORS

Corneal power measurement	Optimized surgeon factor	Absolute prediction error (D) ±SD (range)
Galilei SimK	1.77	0.39 ±0.31 (0.00–1.43)
Galilei TCP Meridian	1.53	0.41 ±0.32 (0.01–1.55)
Galilei TCP Central	1.57	0.42 ±0.33 (0.02–1.57)
IOLMaster	1.82	0.37 ±0.30 (0.00–1.32)
Atlas SimK	1.84	0.39 ±0.34 (0.00–1.70)

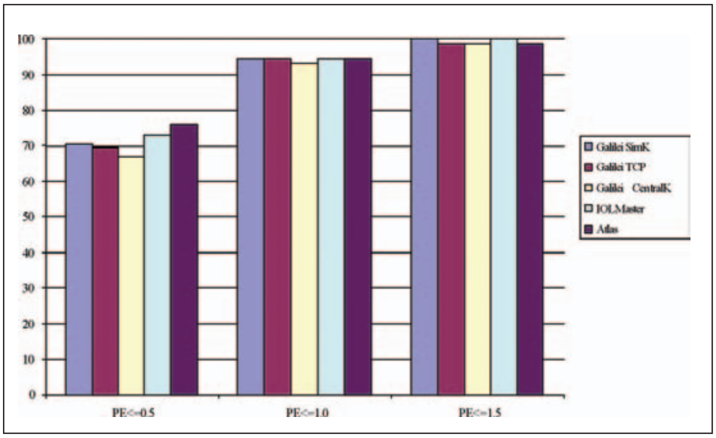

Figure 1. Percentage of eyes with refractive prediction errors within 0.50, 1.00, and 1.50 D.

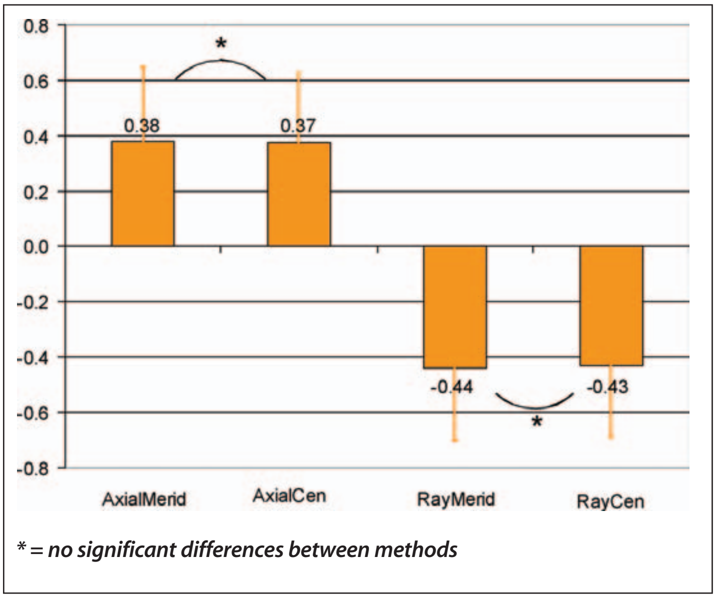

Figure 2. Prediction errors using corneal powers derived from anterior corneal surface only (AxialMerid and AxialCen), and corneal powers using the ray-tracing method (RayMerid and RayCen).

obtained from the Galilei. When the prediction error is positive, you get a hyperopic surprise; if it is negative, you get a negative surprise.

RESULTS

In normal eyes, the corneal power values measured by these devices are listed in Table 1. The mean absolute prediction errors ranged from 0.37 to 0.42 D (Table 2). There were no statistically significant differences among groups. Although the IOLMaster-derived mean absolute prediction error was slightly more accurate than the Galilei- and Atlas-derived data, the highest mean difference in mean absolute prediction error between the methods was less than 0.05 D. All corneal power measurements produced predicted refractive error within 1.00 D in more than 93% of the eyes (Figure 1).

In eyes with prior LASIK or PRK, the average corneal power estimate (from the anterior corneal surface) was overestimated by 0.37 to 0.38 D on average, indicating hyperopic surprise in the majority of eyes. Corneal powers derived from the ray-tracing method underestimated corneal power by -0.43 to -0.44 D. The absolute values of the differences between these Galilei values and historically derived values are modest when compared with what has been reported with other approaches (Figure 2).

CONCLUSION

The accuracies of IOL calculation using these five different corneal power measurements, including measurements by ray tracing through the anterior and posterior curvatures with the Galilei, were highly predictable for normal patients. The Galilei predicts IOL power for normal patients as well as the IOLMaster does.

In patients who have undergone LASIK or PRK, we recommend using the total corneal power measured by ray tracing for calculating IOL power. With a nomogram adjustment, this has become one of our most accurate methods for these calculations. The formula incorporating this nomogram adjustment has been incorporated into the IOL power calculator that is available on the ASCRS Web site, and we recommend that Galilei owners use it as one of their primary methods of calculating IOL power in these challenging cases.

The Galilei has become an important tool for us for all of our IOL calculations. ■

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Practical Experience and Clinical Results

In a high-volume refractive center, the Galilei is the best option for a diagnostic imaging tool.

BY MAURO ZUPPARDO, OD, PhD

Last year, Primavista opened an additional refractive center; at the same time, we also purchased the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland). This device has become an essential part of our practice; we use it to document the anterior and posterior segment of the more than 3,500 patients who visit our office for excimer laser or intraocular refractive laser procedures. We also use the Galilei as our primary means for measuring corneal pachymetry pre- and postoperatively, to evaluate the extent and depth of corneal opacities, to design anterior lamellar keratoplasty procedures, and to determine the correct parameters for each excimer laser ablation we perform. The Galilei is a dynamic diagnostic tool that aids us in evaluating the effectiveness of laser refractive surgery on a patient-by-patient basis.

We also have experience using the Orbscan topographer (Bausch & Lomb, Rochester, NY); however, we noticed a big difference between the corneal pachymetry of the Galilei and the diagnostic results of the Orbscan. Therefore, when we perform customized ablations, our choice for diagnostic imaging is always the Galilei, because it provides more data points. In comparison, the Orbscan has approximately 9,000 data points to the Galilei's approximately 122,000 points. The more accurate our calculation, the better chance we have of avoiding corneal ectasia.

WHY SWITCH TO THE GALILEI?

There are many reasons why we decided to implement the overall use of the Galilei at our practices. Among the chief reasons are its precision, accuracy, and repeatability. The Galilei's pachymetric precision is 3 µm. It also provides accurate and repeatable imaging of the anterior and posterior chamber surfaces, user-guided edge detection, dual Scheimpflug imaging, and the mergence of Scheimpflug and Placido images.

The inclusion of dual Scheimpflug imaging in the Galilei technology provides outstanding accuracy in pachymetry, allowing accurate curvature measurements. In our centers, we implant a lot of Intacs (Addition Technology, Inc., Irvine, CA). After insertion of the implant, we must ensure the precision of the curve. The lateral resolution of the Galilei (4 µm) is an incredibly accurate measurement of the curve. Overall, its precision is unmatched by other diagnostic imaging tools.

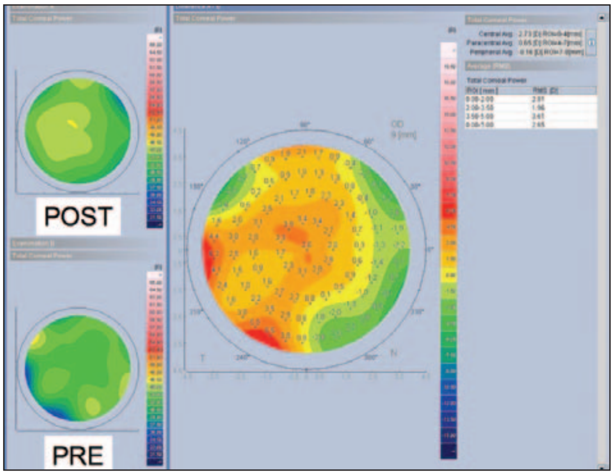

Figure 1. An eye's total corneal power at 3 months.

Because the anterior and posterior elevation maps correlate nicely, we know that the Galilei also has a good eye tracker. This eye-tracker system detects and compensates for eye movements that occur in between image capture. Without good motion compensation, we lack the ability to gather accurate data. What is nice about this eye-tracker technology is that it singles out a unique patch on the iris and tracks its displacement throughout all of the images. This is done on the x, y, and z axes. The Galilei may also add a second iris patch, located on the opposite side of the iris, to identify and correct cyclotorsional movement. Using the eye tracker allows treatments to be accurate and repeatable.

Resolution is also of great concern for diagnostic imaging. The axial resolution (1 µm) of the Galilei is based on a subpixel edge detection algorithm. The accuracy of the edge's position is approximately 1/20th of a pixel. Additionally, the lateral resolution is based on a pattern-matching algorithm; it is used

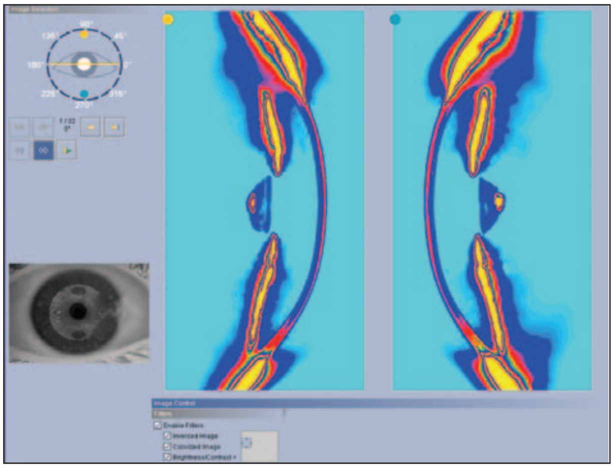

Figure 2. An example of image control.

for motion correction of the Scheimpflug scans before the scans are registered to the anterior and posterior surfaces.

If you perform topography, for example, you are faced with several maps to review. We can control the reproducibility of these maps with the resolution. For most diagnostic examinations, the standard acquisition resolution is 15 scannings on 360° of the cornea and one Scheimpflug acquisition on each 24° of camera rotation. With the Galilei, it is possible to increase this figure, which in turn allows a more precise patient exam and also closer estimates the shape of the cornea after laser ablation is performed. When you enlarge the resolution, more data becomes available. Figure 1 shows an example of a patient's total corneal power at 3 months.

I have used resolutions of between six and 60 acquisitions (ie, one acquisition from 60° to 6° of the camera's rotation) with the Galilei. Each map is similar; the only difference between maps is the amount of visible astigmatism. Therefore, the variety of resolutions provides us with more precise anterior and posterior elevation. In the case of customized ablations, I have found that using more examinations—both pre- and postoperatively—is beneficial. We perform multiple exams in the same eye, using different resolutions.

OPTICAL DENSITY

The Galilei also integrates a new diagnostic tool into its profile: optical densitometry. In a nutshell, this tool deciphers the patient's degree of corneal opacity by calculating the intensity of the incident and transmitted rays. I am also an optometrist, so it is extremely important to me that the patient's cornea is clear. You can perform all kinds of surgery; however, if the postoperative cornea is unclear, you will have poor results, including loss of contrast sensitivity. The Galilei is the only tool to measure and control the optical density in two distinct manners, meaning it measures it at the x and y axes. Additionally, we can compare the patient's degree of corneal opacity pre- versus postoperatively.

Optical density is an important parameter to define the optical quality of the cornea. We are studying optical density in relation to pathology and corneal surgery procedures. For example, after collagen crosslinking of the cornea for keratoconus, we indirectly control the follow-up of the treatment through the variation of optical density. After subtractive excimer laser treatment, we observed an increase of light transmission (ie, decrease of optical density).

Another advantage of the Galilei is you can control each image by filtering its color (Figure 2). This function allows the surgeon to zoom in on corneal images, thus observing any changes in the corneal opacities. The color will change in the presence of a corneal opacity; you can visualize the differences more readily when you use the filtering function.

CONCLUSION

We choose the Galilei because of the benefits we have seen in our patients' pre- and postoperative exams. Preoperatively, we analyze the posterior corneal surface, which allows us to identify and exclude patients who are contraindicated for surgery. Those include patients with preclinical or forme fruste keratoconus. We also use the Galilei to determine the postoperative shape of the cornea. Prior to LASIK, its pachymetry map locates the thinnest corneal points; before implantation of phakic IOLs, it determines the anterior chamber's depth. Postoperatively, we use the Galilei's dual Scheimpflug analyzer to evaluate the ablation and its effect on the corneal tissue. It is also used to analyze regression as well as determine the presence of complications.

The Galilei is the most accurate diagnostic measurement of corneal elevation, curvature, and pachymetry. Because this device combines two rotating Scheimpflug cameras with a Placido-ring–based technology, 3-D analysis of the anterior segment, by only rotating 180°, is extremely accurate. The dual-Scheimpflug imaging is capable of delivering the most accurate pachymetry data available.

The Galilei is the ideal diagnostic tool for a high-volume refractive center, such as Primavista, which performs approximately 30 to 50 examinations per day. Its use in routine refractive cases, as well as complex cases, is vital to the success of our practice. The biggest advantages of the Galilei are certainly its precision, repeatability, and image quality. ■

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Dual Scheimpflug Advantageous in Second-Opinion Patients

In candidates with irregular corneas, we show them a pictorial graph and a corneal printout to explain the contraindication for LASIK.

BY RAJESH KHANNA, MD

As a refractive specialist, I see a lot of patients who are seeking second opinions. I like to use the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland) to ensure that not only the patient's central pachymetry spread is good, but also that the pachymetry spreads over the entire corneal surface. There are two subtle signs that LASIK may not be a viable option for a certain case: (1) there is a big difference in the pachymetric readings in the superior and inferior cornea; or (2) the thinnest point of the cornea is displaced inferiorly.

I typically perform 100-µm thin-flap LASIK; however, if either subtle sign is present, I do not hesitate to switch to a surface ablation procedure. I also use Intacs (Addition Technology, Inc., Irvine, CA) as an alternative to LASIK in corneas that show signs of forme fruste keratoconus.

The greatest advantage of the Galilei is that it provides real data—topographic and pachymetric maps—simultaneously. I am somewhat obsessive-compulsive with my measurements, performing repeat ultrasound pachymetry. It is amazing how the Galilei and corneal pachymetry correlate almost every time, within 1 µm of each other. Therefore, the Galilei can also be used as a screening tool. The Galilei also provides the anterior and posterior elevation of the cornea. Another big advantage is that I am able to show my patients their cornea. In the case of an individual who is a poor candidate for LASIK but has been told elsewhere that he is a good candidate, we can show him the pictorial graph to help explain his contraindication.

I also implant presbyobia-correcting IOLs. The Galilei images an early cataract; I can explain to my patients where the presbyopic implants will be placed because the dual Scheimpflug's color picture shows the iris, lens, and cornea. Patients' understanding and acceptance is higher, because you can show them this live animation of their own eye.

GOOD CORRELATION

Before the Galilei, I used the Orbscan topographer (Bausch & Lomb, Rochester, NY) on thousands of patients. The data never seemed to accurately correlate with ultrasound results—perhaps because it does not use true data points. I stopped using the Orbscan because I found topography more helpful. When I learned of the Galilei, which uses both technologies, I decided to try it. The Galilei provides a good correlation between topography and ultrasound. If I have to place Intacs, it scans the depth of the cornea at different points, thus providing the optimal incision depth.

I have been using the Galilei for approximately 3 years. At that time, I was only relying on topography and corneal pachymetry. I was seeing many cases of post-LASIK ectasia that were referred from other practices. Even though we knew pachymetry was a good predictor of ectasia, I decided it was time to invest in a technology that allowed me to avoid ectasia in my patients as well as manage borderline patients more effectively.

When I was looking into what technology to purchase, I did a demo on several machines. I found the Galilei to be the most reliable. Additionally, the engineers of the Galilei visited my clinic, providing me with valuable information on its principles. I am a passionate surgeon, and I want to do the best for my patients. I could see that same kind of passion from those engineers.

CASE PRESENTATION

I have multiple offices, but I only have the Galilei in one office. In one instance, the topographer showed subtle differences in the superior and inferior cornea. Although things looked OK to proceed, I still was not convinced that I should perform LASIK. Before deciding to proceed or switch to surface ablation, I asked that the patient visit my other office so that I could use the Galilei. Patients are always reluctant to travel, but I am glad he agreed. When we looked at his cornea on the Galilei, it picked up more LASIK contraindications, especially the superior/inferior pachymetry difference and displacement of the thinnest point. I therefore performed surface ablation.

When we use corneal pachymetry with nine or 10 test points, it is accurate enough to screen 98% of patients; however, that 1% to 2% of patients who have a subtle discrepancy that we may not catch is enough to make the switch to the Galilei. The thinnest point is easily missed when you screen for it manually. The more knowledge we acquire and apply using such machines makes us better physicians and makes surgery safer for our patients.

TIPS FOR PROPER USE

One of the most important principles to follow in order to provide the best results and the maximum benefit for patients is to thoroughly understand whatever machine you use. Make sure that your technicians understand it as well.

Patients must not move during preoperative measurements. The eye should also be well lubricated to give the best output. The Galilei assists the user by pointing out the accuracy of the measurements. It also interprets the data and makes analysis user friendly. Rather than repeating measurements and wondering why you are not getting good results, follow these steps from the start. Additionally, perform measurements in a semi-darkened room. These tips have helped us decrease the time required to take pictures from 10 to 15 minutes to 2 to 3 minutes.

One of the biggest challenges we will face in the near future is post-LASIK patients who will come in for presbyopia-correcting IOLs. To measure the central corneal keratometry is challenging, and then applying the correct formula is even more challenging. The Galilei will make these measurements easier. ■

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User Tips: Improve Your Results With the Galilei

Learn how to properly administer the patient examination.

BY CARLOS G. ARCE, MD

One of the most exciting attributes of the Galilei Dual Scheimpflug Analyzer (Ziemer Group, Port, Switzerland) is its capacity to integrate two technologies into one imaging tool. The Galilei uses three cameras—one capturing the front view and two Scheimpflug cameras—thus combining the double Placido image of the anterior surface with multiple Scheimpflug slit-lamp images of the anterior segment. In this article, I present simple and practical tips we have learned during the last 2 years working with the Galilei.

TIPS FOR OBTAINING QUALITY EXAMS

Like with any technology, there is a learning curve with the Galilei. The exam is more difficult to perform in corneas with an irregular anterior surface, advanced keratoconus or keratoglobus, stromal opacities (more than 20% to 25% of optical densitometry), or scars, in post-transplant corneas, and in the presence of intracorneal segments or inlays.

The use of topical anesthetics may reduce blepharospasm in patients with photophobia or ocular diseases. Additionally, lubricant eye drops are beneficial in dry eyes to avoid poor-quality Placido images. However, a dense

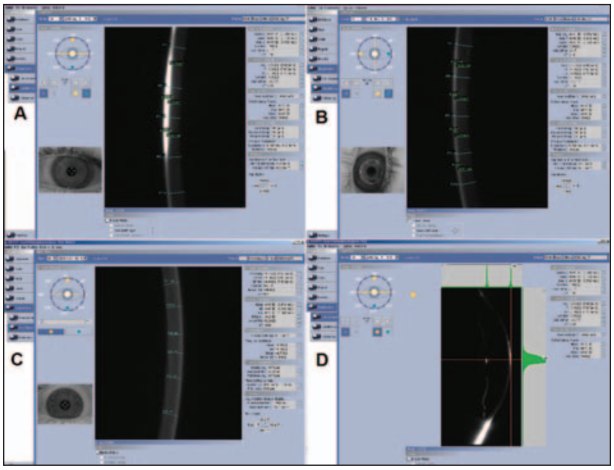

Figure 1. Eye metrics of horizontal (A) and vertical (B) Scheimpflug images. Automatic pachymetry (C) and densitometry (D) in corneal opacities.

solution may produce distorted Placido rings, forcing the surgeon to wait until the tear film stabilizes. Last, the heavy use of eye drops may produce a meniscus above the lower lid margin, introducing artifacts on the map images.

Soft or hard contact lenses placed on the eye may produce better Placido and/or Scheimpflug images and may help to assess the depth (Figure 1A and B) or densitometry of corneal lesions and the position of intracorneal implants.

The Galilei allows the surgeon to verify the quality of the exam. Anterior surface data may still be obtained with good Placido and poor Scheimpflug quality; however, an exam with good Scheimpflug but low Placido quality may fail to display curvature or elevation maps. In this event, a pachymetry map may still be produced. Therefore, do not discard the exams until you have reviewed them and verified what data were saved. Also important are the automatic thickness (Figure 1C), corneal densitometry (Figure 1D), and anterior segment metrics that can be obtained directly from Scheimpflug images—even when traditional maps are unavailable.

Because eyelash and upper lid shadows may produce artifacts in the Scheimpflug image, use the first horizontal slit from the bottom (blue spot) to measure distances and verify the densitometry of the cornea and the lens.

TIPS FOR CENTERING THE EXAMINATION

Centering the red cross with the four white dots reflected on the corneal surface will avoid falsely aligned, asymmetric, or irregular images. There are several useful signs to identify a decentered examination. For instance, if the red cross is aligned and the pupil looks eccentric, the eye may have an important Kappa angle.

The alignment of any surgery to the line of vision or pupil may be reviewed using the transparency map. A thinnest point located within the center of the pupil means that the ablation in myopic LASIK or PRK used the pupil as the center of the ablation. This alignment will remain even if the exam was misaligned.

The pupil centroid and the thinnest point should be within 1 mm of each other. Keratoconus should be suspected if the thinnest point of a clear cornea is less than 500 µm and is located beyond 1 mm. A distance greater than 3 mm may signify an artifact or be the byproduct of corneal scars.

MAPS AND IMAGES

Profiles. The Galilei Version 4.01 software introduces more customization for maps and data. It has four reports, including the classic refractive, keratoconus, wavefront, and IOL power reports. To preserve your preferences, create a profile before setting up the maps. The most usual presentation of maps is with the 9-mm aperture, with the pupil and thinnest point outlined. Many practitioners include four rings of numeric values located at 1.0, 2.0, 2.75, and 3.5 mm from the map center. My suggestion is to change these numbers to 1.0, 2.0, 3.0, and 4.0 mm. I prefer to use custom scales so that colors resembling traffic lights (ie, green, yellow, and red) correspond to a well-defined value.

Custom views. With this option, Galilei is the first technology to analyze the anterior and posterior curvature in the same screen, with appropriate noninverted and inverted scales, respectively. A suggestion is to set up several maps to obtain practical results. First, establish anterior and posterior axial curvature and best-fit sphere (BFS) elevation maps (Figure 2A). A second map may include the instantaneous anterior and posterior curvature and best-fit toric asphere (BFTA) elevation (Figure 2B). Additionally, another map may depict elevation maps based on the BFS, best-fit asphere (BFA), or BFTA of both surfaces (Figures 3 and 4).

Color scales. Anterior curvature maps' scales default to steps between 0.25 and 1.50 D; posterior curvature maps from 0.05 to 0.50 D. Pachymetry maps have steps from 5 to 50 µm; elevation maps from 2.5 to 25 µm. Colors are distributed at the top and bottom scales, beginning from a fixed value located at the second green step on the anterior (43.50 D) and posterior (-6.00 D) curvature scales. The zero value is located at the yellow step of elevation scales (Figure 3A). The smallest and largest steps in pachymetry scales are useless in practical terms.

A small step is generally used to increase the sensibility of asymmetric signs and increase the chances of noting a bow-tie pattern in the curvature map. However, over a shorter range of values, the extreme blue or red colors are achieved faster. A larger step increases the range of values

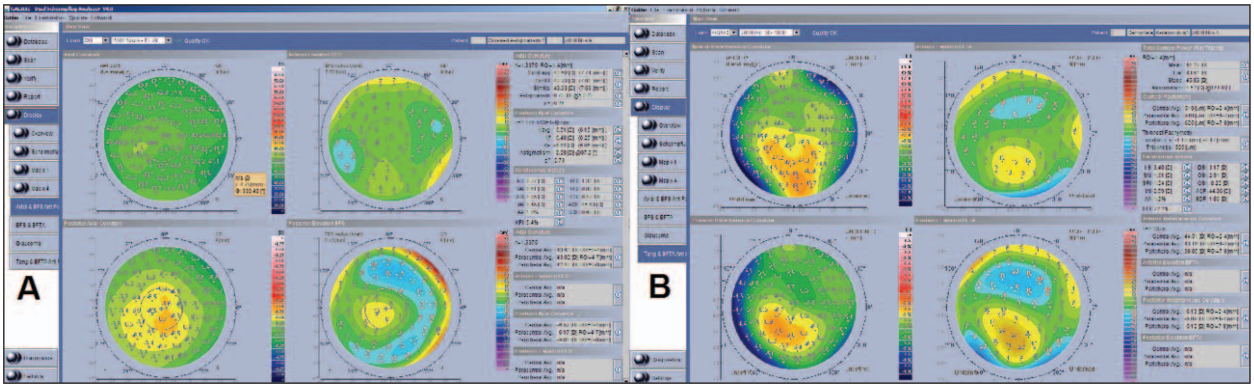

Figure 2. A custom map (x4) (A) showing a small, normal range of against-the-rule anterior astigmatism (axial map, top left); an almost spherical anterior BFS elevation pattern (top right); a borderline with-the-rule posterior astigmatism (axial map, bottom left); and a central borderline posterior BFS elevation (bottom right). The keratoconus prediction index was 5.4%. A custom map (x4) (B) shows a pellucid-like anterior instantaneous pattern (top left); an inferior posterior steepening (instantaneous map, bottom left); and a vertical aspheric asymmetry of both anterior and posterior BFTA elevation (right) that correlates with the 0.94 µm (0.72 D x 87°) vertical coma found in the wavefront report. The keratoconus prediction index was 22.2%, and the thinnest point was 505 µm.

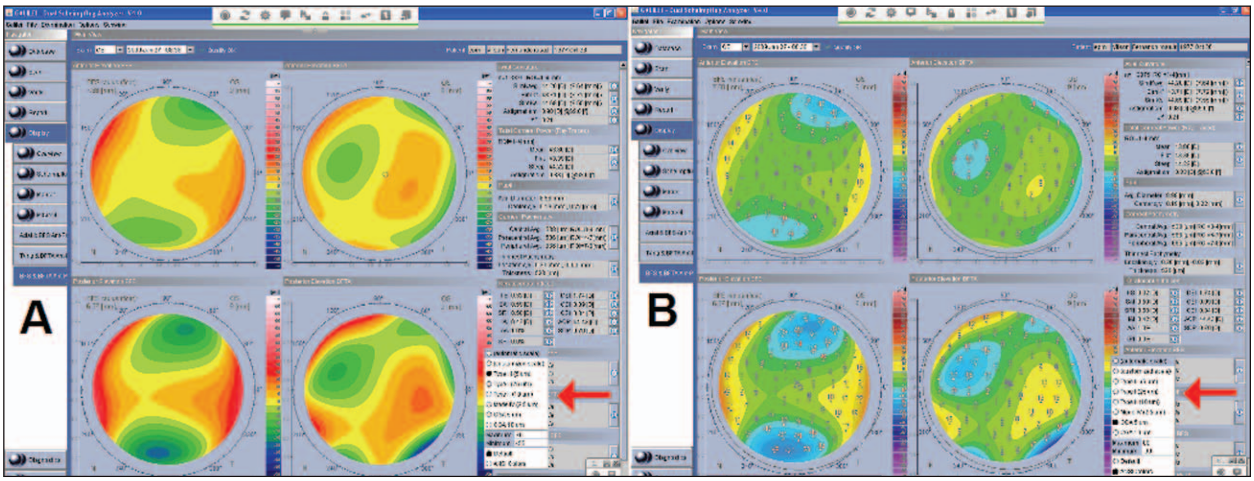

Figure 3. In the default style color distribution (A), the zero is fixed in the only one yellow step of both anterior and posterior BFS (right) and BFTA elevation (left) scales, indicated with an arrow. In the ANSI style (B) with a customized 5-µm scale, indicated with an arrow, the zero is fixed in the second green step, facilitating the interpretation of these maps.

shown in the map; be cautious, because typical patterns are easily missed. Therefore, modifying the size of the steps produces a change in the map's color, independent of the fact that the value of each point remains the same.

Colors should not guide the interpretation of maps when traditional absolute and relative scales are used. However, the green step range habitually relates to a normal value in curvature and pachymetry and the zero in elevation maps; yellow steps mean already positive values.

I modified the default color settings of the Galilei by using custom scales I created in the settings menu. You can also type in a maximum and minimum value in the color bar close to the maps. In my setting, I use a borderline value fixed in the second yellow step instead of a normal value fixed in the second green step. By this simple strategy, green, yellow, and red has a defined meaning: Green means proceed with surgery, yellow means proceed with caution, and red is a contraindication to surgery.

This custom traffic light color distribution fixes the second yellow step with the borderline values of the anterior curvature maps (47.00 D), posterior curvature maps (-6.75 D), and pachymetry map (500 µm)—all three with the default style scale. For both anterior and posterior elevation maps (15 µm), the color scale suggested by the American National Standards Institute (ANSI) is better.

The six green steps on the default style scale—the last appearing as an emerald green-blue color—are within the normal range of anterior curvature (40.00 to 45.00 D, with

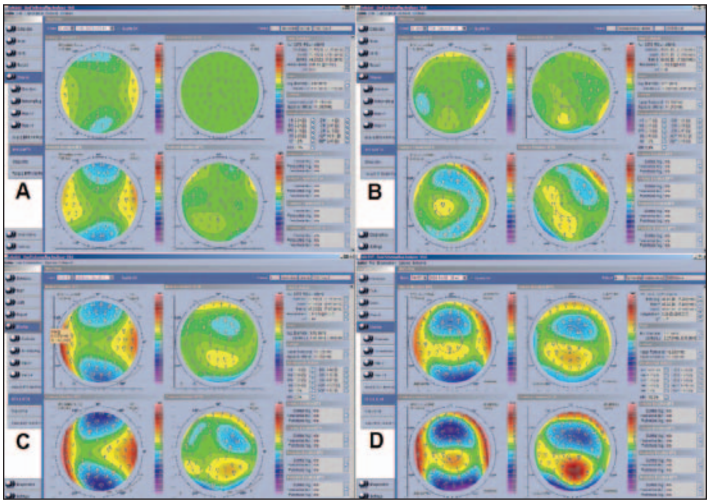

Figure 4. Anterior and posterior BFS elevation maps (left) of a toric aspheric cornea with a typical horizontal green bridge. The respective BFTA elevation maps (right) have an almost complete uniform green pattern (A). The same cornea from Figure 2A has a symmetric aspheric anterior surface with an almost green anterior BFTA elevation map (top right) and an asymmetric aspheric posterior surface (bottom right) (B). An astigmatic cornea has BFS elevation maps (left) with darker blue zones and both anterior and posterior BFTA elevation maps (right) with vertical asymmetry (C). Keratoconus and 100% keratoconus prediction index shows increased elevation, high astigmatism, and vertical asymmetry on both BFS and BFTA elevation maps (D).

1.00 D steps) and posterior curvature (-6.25 to -5.00 D, with 0.25 D steps) and corneal thickness (530 to 605 µm, with 15-µm steps). The three green 5-µm steps on the ANSI-style scale reflect the elevation data fitted closer to the respective referential surface. Although the first and second yellow steps still signify normal values, they are the first sign of caution, because they are close to the borderline. The orange-to-red color steps indicate steep (≥ 48.00 D and ≤ -7.00 D), thin (≤ 485 µm), or positive (≥ 20 µm) elevation values, which are considered abnormal. The blue range of color steps represents the opposite range, meaning flat (≤ 39.00 D and ≥ -4.75 D), thick (≥ 620 µm), or negatively elevated (≤ -20 µm) values .

PEARLS AND POINTERS

Using the default style of colors, an all-green anterior or posterior curvature map reflects a surface within the normal range. More spherical surfaces have a uniform color pattern; aspheric surfaces have a typical pattern with concentric rings that change color progressively. A central small bow-tie or a circular cooler zone surrounded by concentric rings of warmer colors at the periphery indicates an oblate aspheric surface (ie, postmyopic LASIK). If the central zone color is warmer and cooler colors are noted at the periphery, the anterior surface is prolate (ie, normal or keratoconus).

The presence of a bow-tie pattern indicates astigmatism close to the step size of the scale or larger. Asymmetric curvatures are represented by a bow-tie, where one zone has a warmer color and/or is larger than the other. To detect initial asymmetry of curvature, a yellow zone is unnecessary, because in the default style setting, the green range has several steps. Vertical asymmetry has a larger inferior warmer zone; horizontal asymmetry has a larger temporal warmer zone, sometimes resembling the letter D.

Sometimes, the Galilei shows a bow-tie pattern filled with cooler colors (flattest axis) instead of the typical bow-tie pattern with warmer colors (steepest axis). Inexperienced surgeons may confuse the kind of astigmatism if only guid-

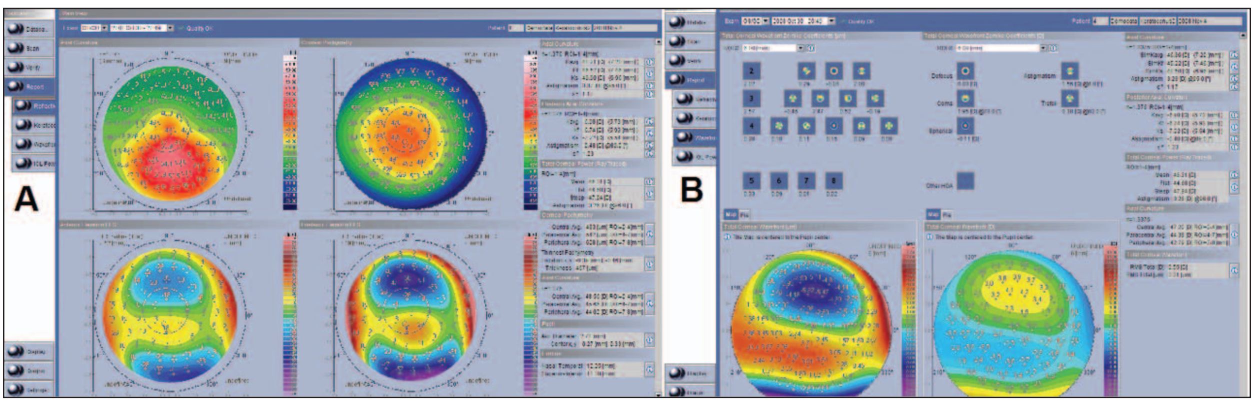

Figure 5. The refractive report (A) of the same keratoconus patient in Figure 4D shows the axial map (top left) with seven colors 1.00 D steps beyond the first yellow, indicating a steepest zone of around 53.00 D. The pachymetry map (top right) shows a central area with three orange 15-µm steps beyond the first yellow, indicating a thinnest paracentral zone of around 470 µm. The wavefront report (B) shows vertical (2.47 µm) and horizontal (0.52 µm) coma (1.95 D x 78°).

ed by the position of the apparent bow-tie.

Interpreting elevation maps is easier with the ANSI colors if they follow the shape of the surface used to compare the data. For example, a toric anterior surface with low-to-moderate with-the-rule astigmatism (Figure 4A) shows a BFS elevation map with the typical green horizontal band at the center, with a trend to yellow at the 3- and 9-o'clock positions (flattest axis) and two zones with light blue at the 6- and 12-o'clock positions (steepest axis). If high astigmatism is present without keratoconus, the peripheral blue zones are darker (Figure 4C), and the center remains green within the normal range. If there is a chance of keratoconus or ectasia, the paracentral zone or the center itself is yellow. In more advanced cases, the center is orange or red (Figure 4D), with a peninsula or an island pattern. Asymmetric surfaces may be represented by a vertical displacement of the horizontal band and/or by a difference in the tone of the peripheral blue zones. Alternatively, the pattern will be mostly green (Figure 4B) when the surface is close to a sphere.

A normal posterior surface usually shows a BFS elevation map with a green horizontal (with-the-rule) band (Figure 4A). A spherical posterior surface with a whole green pattern is rare. Normal patterns do not have any yellow zones at the center. Suspect corneas (Figure 4B) or an astigmatic posterior surface (Figure 4C) may have yellow central or paracentral zones at the posterior BFS elevation maps before they appear on the anterior BFS elevation maps. The change from a band pattern to a peninsula (Figure 4B) or island pattern, and/or to warmer colors (Figure 4D) is a sign of steepening of the posterior surface and may also suggest progression to keratoconus or ectasia.

An ideal aspheric corneal surface with similar or different uniform main meridians tends to have a green BFA or BFTA map, respectively (Figures 4A and 4B) with all elevation values close to zero. However, if a meridian is asymmetric, the map (Figure 4B through 4D) has one zone leaning to the yellow-red side as the opposite zone does to the light blue-violet side. This classic pattern of asymmetry correlates with the positive or negative corneal coma found in the wavefront report of the Galilei (Figure 5).

Most useful pachymetric scales have 15- or 20-µm steps, with the normal central thickness represented in one of the green steps (530 to 605 µm or 540 to 640 µm, respectively). Thicker values are already blue. Normal corneas have a classic pachymetric pattern of concentric rings with a warmer color at the center. With the traffic light color distribution, any yellow zone, especially if dislocated temporoinferiorly, will immediately raise concern, because the thickness is around the 500-µm limit.

Due to the uniform and progressive thickening, the normal peripheral cornea usually has a thickness close to the last blue shade (680 µm in the 15-µm scale and 740 µm in the 20-µm scale). The differential pachymetric measurement (peripheral average minus the central average) used to be between 150 and 200 µm (10 color steps). A map with fewer steps is related to a cornea with more uniform thickness. Alternatively, more color steps means a steeper slope —an early sign of keratoconus—especially if the thinnest point begins with a color beyond the orange (ie, thickness of less than 500 µm). To better recognize initial keratoconus, the ideal pachymetric default style scale should perhaps have few more blue or violet steps, reducing the number of pink steps at the other side of the color bar. Although the normal cornea is thicker at the top than at the bottom, significant differences in color on both sides seems to be another sign of alert, representing an asymmetric progression of thickness. Presently, probably the most sensible way to evaluate asymmetrical thickness is by measuring the distance of the thinnest point from the pupil's center.

CONCLUSION

I prefer to use the traffic light color distribution, because it gives intuitive meaning to colors. The red signifies steep, thin, or high; it may indicate a contraindication to refractive surgery. Yellow is close to the accepted borderline values of normality, suggesting caution during the decision process and an alert sign for possible changes from normality to pathology. Green indicates the normal range of parameters. Last, blue means flat, thick, or deep, and should orientate a search as to why this condition was achieved. The Galilei's maps have a clear color guide when using scales with the traffic light color distribution. More details about these customized scales are available upon request.

Color patterns, differences, distribution, and location on maps are important signs that may indicate pathologic status, the beginning of an asymmetry, or a normal cornea. The synergy and understanding of these concepts applied in the Galilei have already made my interpretation of exams easier and faster. It has improved the grade of diagnostic confidence at our eye clinic. ■

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