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Cataract & Refractive Surgery Today

PRECISION DIAGNOSTICS

Versatile technologies and tools designed for the ambitious surgeon.

Clinical Value and Use of the Eyestar 900's Cataract Suite

Best practices for using topography, Zernike analysis, and vision simulation in cataract surgery.

BY WARREN E. HILL, MD

Patients who present for a cataract surgery evaluation have often done their own research and are aware of basic options. For many, the focus is on spectacle independence without compromises. Surgical planning, especially when a premium IOL is involved, is crucial.

Today, we need more than axial length and keratometry to help our patients decide what type of IOL is best for them. The Cataract Suite of the Eyestar 900 (Haag-Streit) allows a comprehensive evaluation of almost any type of cataract, which can help surgeons review the suitability for a specific IOL and improve surgical planning and postoperative outcomes. Additionally, visual simulation can also be used to educate patients interactively about their condition and treatment options.

CLINICAL VALUE

Using swept-source OCT, the Eyestar 900 can penetrate almost any cataract to provide highly accurate axial measurements of the entire eye, from the cornea to the retina. There is also standard dual-zone reflective keratometry for highly accurate corneal power, 7.5 mm diameter topography with the Cataract Suite, and up to a 12 mm diameter with the Anterior Chamber Suite software option that incorporates the anterior and posterior corneal surfaces. B-scan imaging of the anterior chamber also includes the lens and an accurate assessment of tilt and decentration. These measurements allow the user to identify anatomical anomalies that may interfere with the surgical plan.

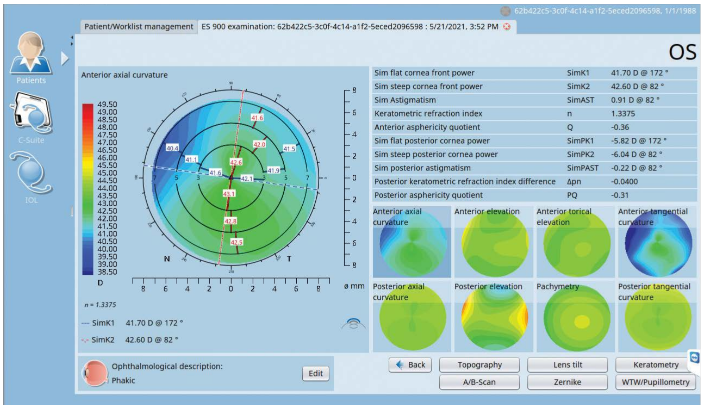

Figure 1. The bowtie on topography illustrates some bending and asymmetry in the astigmatism. Zone-based keratometry, however, can clearly quantify and depict the imperfections of the astigmatism, helping the surgeon in the decision-making process for the optimal IOL.

Other advantages of the Eyestar 900's Cataract Suite add to the device's clinical value, including a Zernike analysis and vision simulation. These will be the focus of this article, along with best practices for topography.

TOPOGRAPHY

The topographic maps of the Eyestar 900's Cataract Suite cover a 7.5-mm zone. The Anterior Chamber Suite incorporates data from the anterior and the posterior cornea and covers up to 12 mm.

Keratometry is a crucial feature in biometry, and the Eyestar can approach this in several ways. The first is standard keratometry based on an ellipsoid with flat and steep meridians perpendicular to one another. The Eyestar also uses zone-based keratometry, which incorporates up to four meridians—two steep and two flat and completely independent in terms of their orientation and power.

From a clinical perspective, zone-based keratometry allows surgeons to screen for signs of corneal pathologies that may limit visual potential. This form of keratometry can be used to identify regular and symmetrical astigmatism and validate standard reflective and simulated keratometry. The extra validation is especially helpful when considering candidates for toric and multifocal IOLs (Figure 1).

ZERNIKE ANALYSIS

Together, the Zernike polynomials are a valuable clinical tool used to describe wavefront aberrations of the cornea or the lens from an ideal shape that results in a loss of image contrast. The presence of third- and fourth-order aberrations can significantly impact the quality of vision due to a loss of contrast sensitivity. From the perspective of the ophthalmic surgeon, the third-order aberration coma is a form of irregular astigmatism that produces variable amounts of image duplication and displacement. Spherical aberration is a fourth-order aberration that produces a characteristic image, halo and glare. The mathematical construct of the Zernike polynomials qualifies these aberrations into values measured in microns, which can also be used for image sumulation and as part of our preoperative evaluation.

The Zernike wavefront analysis by the Eyestar 900 is highly useful for determining how individual and groups of aberrations impact visual quality. This feature can quantify the full range of aberrations, which can be converted into an easily understoond image simulation. Removing individual aberrations from an image simulation can be a powerful tool for demonstrating how correcting corneal astigmatism using a toric IOL improves vision. Removing all aberrations is an elegant way to demonstrate how the loss of

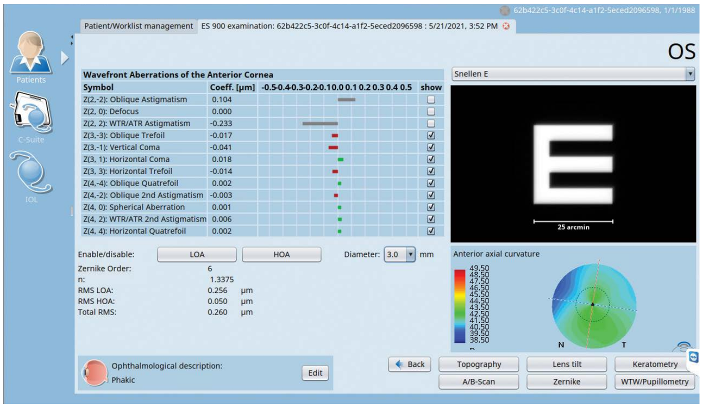

Figure 2. The Zernike wavefront analysis paired with an image simulation and a display of the anterior curvature map provides the eye care specialist with a versatile tool that can be used to demonstrate to the patient the improvement in visual quality following toric IOL placement. The influence of changing ambient light conditions may also be shown by adjusting the pupil diameter in real-time.

contrast from a highly irregular corneal surface can be dramatically corrected by a rigid gas permeable or scleral contact lens.

For patients who have previously undergone refractive surgery (eg, radial keratotomy, LASIK, PRK), image simulation is a useful way to show how an increase in spherical aberration and coma impacts visual quality. Image simulation can also show why certain options, such as a multifocal IOL, may not be a good choice.

Reviewing the wavefront analysis provides meaningful talking points when discussing IOL selection. It can help facilitate patient discussion as to why a certain IOL is better suited to them as an individual. The Zernike wavefront analysis also produces individual coefficients at different pupil sizes so that patients can get a feel for their vision in certain lighting conditions (Figure 2).

CONCLUSION

The Eyestar 900 is a comprehensive swept-source OCT device that provides simulated and zone-based keratometry and Zernike wavefront analysis to help us recommend the right IOL for our patients. In the age of increased patient demands, a device like the Eyestar 900 and its Cataract Suite continue to raise the bar for anterior chamber diagnostics that help us meet the needs of even the most demanding patients. ■

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Hill-RBF Calculator: More Data to Further Refine Outcomes

A new approach to optimum IOL prediction in any patient.

BY WARREN E. HILL, MD, AND ADI ABULAFIA, MD

It's no surprise that artificial intelligence (AI) is being steadily integrated into almost all areas of medicine. IOL power calculations are no exception. Hill-RBF (Radial Basis Function) is an advanced, self-validating method for IOL power selection that performs this task using AI-based pattern recognition.

PATTERN RECOGNITION

Since the introduction of IOLs, ophthalmology has struggled with accuracy for IOL power selection. This problem is primarily because the physical model does not always correspond to the predicted outcome. Additionally, there are millions of possible measurement combinations. Regrettably, no vergence formula or regression algorithm can consistently solve this problem at a level of accuracy we would all like to see.

On the other hand, Hill-RBF uses pattern recognition, which is independent of the effective lens position. Via this approach, IOL power is accurately calculated regardless of the eye's

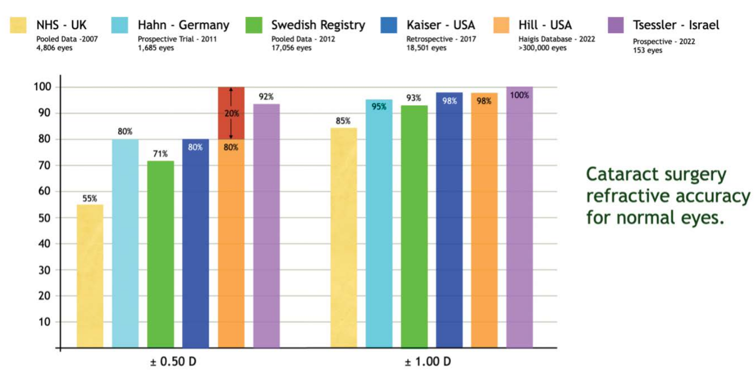

Figure 1. Results from six significant studies show that, on average, cataract surgeons are within ±0.50 D of the intended refraction in 80% of routine cases.[1-6]

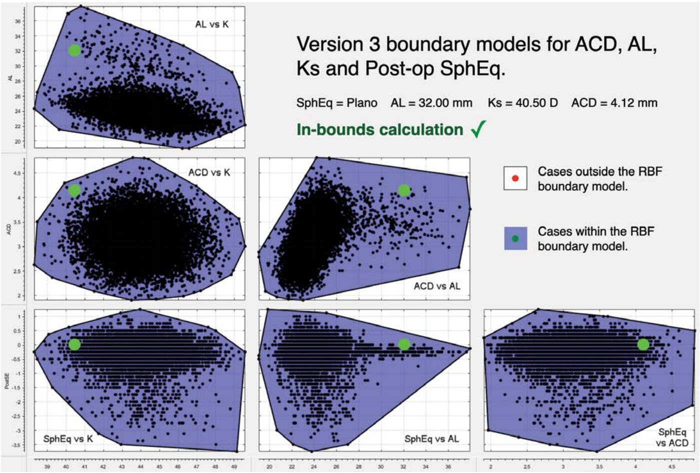

Figure 2. Graphic illustrating the concept of boundary models. The data for this case represents a highly unusual eye with extreme axial myopia, flat keratometry, and a very deep anterior chamber. Despite these highly unusual preoperative measurements, the calculation with Hill-RBF version 3.0 would still be in-bounds and have a 90% chance of being within ±0.50 D of the target spherical equivalent.

axial length (AL) and configuration of the anterior segment. Compared to standard IOL calculation formulas, one additional advantage of Hill-RBF is that data are continuously acquired from 40 high-quality surgical sites worldwide. For each new version, additional information is added, validated, and then re-fit to the AI model, improving its accuracy's overall breadth and depth.

NEW PREOPERATIVE MEASUREMENTS

Hill-RBF is available to use free of charge at www.RBFcalculator.com. The latest version of the calculator (version 3.0), released in December 2020, uses a highly refined data set that now incorporates the new parameters of lens thickness (LT), white-to-white (WTW), central corneal thickness (CCT), and gender, improving accuracy even for unusual anterior segments. Hill-RBF is also available on the Lenstar and Eyestar (both from Haag-Streit).

IMPROVED ACCURACY

For normal eyes, on average, cataract surgeons are within ±0.50 D of the intended spherical equivalent for 80% of cases. In comparison, some more experienced surgeons obtain an accuracy between 84% and 90% of patients. When the accuracy of the intended refraction is lowered to ±1.00 D, typically 98% of cases are within the range (Figure 1).

As the size of the AI database increases, not only does the overall accuracy increase, but the number of out-of-bounds cases also decreases. For version 3 of Hill-RBF, the number of out-of-bounds cases for the typical surgeon has now dropped to 2.5%. For version 3, the range of calculation accuracy was also increased for biconvex IOLs up to +34.00 D and meniscus design IOLs down to -5.00 D.

The best accuracy for version 3 is when all eight variables have been entered: AL, keratometry (K), ACD, LT, CCT, WTW, target spherical equivalent, and gender. The calculation also can be carried out with slightly less accuracy if the LT, CCT, and gender are omitted.

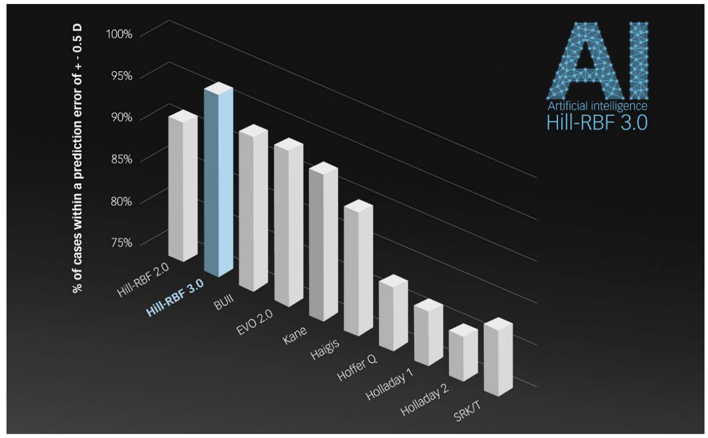

Figure 3. Results of a recent study of 153 eyes by Adi Abulafia, MD, and colleagues showed that Hill-RBF 3.0 performed significantly better than its predecessor. It further showed best prediction in the comparison. *(Tsessler M, Cohen S, Wang L, Koch DD, Zadok D, Abulafia A. Evaluating the prediction accuracy of the Hill-RBF 3.0 formula using a heteroscedastic statistical method.* J Cataract Refract Surg. *2022;48(1):37-43.)*

ACCURACY VALIDATION

In a retrospective multicenter study of 459 consecutive patients of IOL power calculation performed with Hill-RBF, a ±0.50 D accuracy was achieved in 91% of all eyes (AL, 20.97–29.10 mm), 92.2% of normal eyes (AL, >22.5 mm and <25.0 mm), 98.4% in eyes with axial myopia (AL, >25.0 mm), and 84.5% in eyes with axial hyperopia (AL, <22.5 mm). The mean absolute error for each group was 0.29, 0.30, 0.20, and 0.32 D, respectively.

BOUNDARY MODEL ACCURACY PREDICTION

After entering the required measurements by biometry, a target spherical equivalent, and some basic information about the IOL, including its lens constant, Hill-RBF will accurately determine the recommended IOL power. A feature unique to this calculation method is that it will also predict the postoperative refractive accuracy. This is possible due to the ability to sample the accuracy edge of six pair-wise boundary models, such as AL versus ACD or central corneal power versus the target spherical equivalent (Figure 2). For Hill-RBF, the ±0.50 D accuracy edge is set at a 90% level. If all preoperative measurements fall within each of the six pair-wise boundary models, the calculation is termed in-bounds. However, if any preoperative measurements fall outside one or more boundary models, the user is flagged, and an out-of-bounds calculation is indicated. An in-bounds indication suggests a 90% chance of sufficient data for a ±0.50 D accuracy. A quick way to be outside one of the boundary models is to select an unusual target spherical equivalent, such as +3.50 D. It is doubtful that there are an adequate number of cases within the AI database with an observed, highly hyperopic refractive outcome.

The Hill-RBF method has been optimized using Lenstar data. Aside from the online calculator, Hill-RBF is also available within the Lenstar and the Eyestar biometers. The online calculator may also be used with biometry data from other devices. By using this free calculator, surgeons can improve their confidence with IOL power calculation parameters for eyes with both in- and out-of-bound measurements. Additionally, Hill-RBF enables surgeons to identify unusual cases at a glance when an out-of-bounds indication appears. When this happens, a meaningful preoperative conversation begins with the patient to alert them that some unique aspect of their eye(s) may preclude a predictable result.

CONCLUSION

Ophthalmology is experiencing a convergence of technologies for IOL power selection that are helping all of us achieve better outcomes. Many methods now produce excellent results. However, the method with the greatest sensitivity and flexibility will end up as the leader. Haag-Streit has been firmly committed to ongoing research in this area for more than a decade (Figure 3). ■

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How the Eyestar 900 Can Improve Workflow

Clinical experience in a busy practice.

BY PASCAL IMESCH, MD

Individualized patient care and optimized workflow are crucial factors for the success of any practice. One way that I have been able to achieve both is by incorporating the Eyestar 900 (Haag-Streit; Figure), a fully automated swept-source OCT device that has diagnostic applications for both cataract and refractive surgery. As a surgeon who works in a busy practice, I need a versatile diagnostic tool that produces results both quickly and accurately to improve my workflow.

ADVANTAGES

I have used the Eyestar 900 for approximately 1 year. Several advantages aid in improved workflow.

Speed. The device provides precise measurements and imaging data of the whole eye, from the cornea to the retina. In addition to cornea-to-retina biometry, the Eyestar 900 delivers topographic assessment of the anterior and posterior corneal surfaces and visualization of the anterior chamber, including the lens. The entire measurement process, including topography, keratometry, and axial length, takes only about 40 seconds for both eyes.

Ease of use. Measurements with the Eyestar 900 can be easily delegated to a technician and performed just after autorefraction and endothelial cell measurements. Another nice thing is that most technicians do not require additional training to operate the device because it is intuitive to use.

Data can be displayed in multiple ways. All the basic measurements for both eyes can be displayed on the same screen in one view, and more detailed measurements can be displayed as separate reports. It's easy and intuitive to adapt view on the Eyestar 900 to display the proper measurements. For instance, I can switch to cataract mode to interpret the A- and B-scans.

Updated functionality. The latest software uses dual-zone reflective keratometry to provide precise keratometry and

Figure. The Eyestar 900 has diagnostic applications for both cataract and refractive surgery.

astigmatism measurements that are compatible with existing IOL formulas. It also integrates the asymmetry of the astigmatism into keratometry measurements and provides all the different maps that I need to analyze keratometry readings, allowing me to fully document the status of the entire eye and quickly and reliably diagnose diseases.

The updated software of the Eyestar 900 also incorporates Zernike polynomials, which is a great feature and something I use with every cataract patient. (Editor's note: For more on Zernike polynomials, see the article by Warren E. Hill, MD, on pg 2.) The aberration coefficients may be reviewed as groups (lower- and higher-order) or independently and the pupil size adjusted, which are great tools to use when explaining to patients how they could benefit from different IOLs. The root-mean-square of the higher-order aberrations, usually in a 4-mm pupil, can be used to evaluate if patients would be suitable for a premium lens.

The Eyestar 900 also can be used to assess lens tilt, which is another helpful tool for determining patients' candidacy for premium IOLs.

Small footprint. One thing that I really like about the Eyestar 900 is its small footprint. It can fit on the table next to an endothelial camera or autorefractometer.

A better patient experience. Because of the device's small footprint and intuitive software, patients have a better preoperative experience. The patient can sit in one spot rather than moving around to different devices, and they don't even have to switch from one eye to the other. Everything is operated by a touchscreen. Additionally, the software provides audible feedback when the measurement is completed successfully or if a repeat measurement is required. I have to say, however, that there is little to no need for repeat measurements with the Eyestar 900 because it is that accurate.

CONCLUSION

The fast acquisition time of the Eyestar 900 combined with its intuitive software helps improve workflow efficiency. I can delegate the measurements to my technicians and be assured that the data are accurate and precise. This device is a huge benefit in my busy practice. ■

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Precision OCT With the Eyestar 900

A device comparison.

BY GIACOMO SAVINI, MD

Precision measurements are crucial for cataract surgical planning. Coupled with effective patient counseling to set realistic expectations, proper diagnostic testing leads to greater patient satisfaction. My colleagues and I recently conducted a study to evaluate the repeatability of measurements with the Eyestar 900 (Haag-Streit) and compare it to two other diagnostic devices, the IOLMaster 700 (Carl Zeiss Meditec) and the Argos (Movu).

A total of 56 unoperated eyes of 56 patients who presented for a preoperative workup for cataract or corneal refractive surgery or were healthy volunteers were included in the prospective study. Exclusion criteria included the presence of or suspected keratoconus; a prior dry eye diagnosis; history of corneal disease, trauma, or other ocular surgery; and contact use in the past month. One eye of each patient was randomly selected. In each eye, three consecutive scans with the Eyestar 900 and one with both the IOLMaster 700 and Argos were performed in a random order.

RESULTS

In our study, which has been accepted for publication in the *Journal of Cataract and Refractive Surgery*, high repeatability and good to high agreement was achieved for all measurement parameters and among the three optical biometers, respectively.

Comparison to the IOLMaster 700. The mean values for keratometry (K) including K1, K2, and average K; anterior chamber depth (ACD); axial length (AL); and lens thickness (LT) as measured by the Eyestar 900 were not statistically significantly different compared to those measured by the IOLMaster 700. The two devices revealed excellent agreement for all axial measurements including AL, ACD, and LT; good agreement for K values; and moderate agreement for corneal astigmatism, central corneal thickness (CCT), and corneal diameter (CD). CCT and CD measurements with the Eyestar 900 were slightly higher than those with the IOLMaster 700.

Comparison to the Argos. The differences between measurements with the Eyestar 900 and the Argos were statistically significant for all tested parameters except for astigmatism. The mean AL was slightly but significantly higher with the Eyestar 900 than the Argos (24.10 ±1.27 mm vs 24.07 ±1.23 mm, respectively) due to the subgroup of eyes with long ALs (> 25 mm). The mean AL in all other eyes was nearly identical between the Eyestar 900 and Argos (23.60 ±0.82 mm and 23.59 ±0.79 mm, respectively). For mean K values (K1, K2, and average K), CD, ACD, and LT, the Eyestar 900 provided lower values compared to the Argos. Except for the statistically significant difference in mean AL in long eyes, agreement between the Eyestar 900 and Argos was excellent; in fact, it was better than that observed with the IOLMaster 700 for most parameters except CD.

Discussion. Based on our results, we believe that the Eyestar 900 could be considered almost interchangeable to the IOLMaster 700. Although there was a statistically significant difference for CCT and CD, the differences were unlikely to be clinically significant. Additionally, the Eyestar 900 produced measurements that were in agreement to those taken with the Argos and better than agreement between the Eyestar 900 and IOLMaster 700 for most parameters, including K, ACD, and LT.

CONCLUSION

The Eyestar 900 is a nice addition to our daily practice. In the study presented in this article, the repeatability of the measurements taken with the device were highly reliable and in good agreement with the measurements from other proven diagnostic technologies. The Eyestar 900 has quickly become a crucial part of our preoperative examination and assists in providing more precise and customized results for patients. ■

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Case Report: Congenital Aniridia

A customized treatment was possible thanks to novel measurements and calculations with the Eyestar 900.

BY DAVID GOLDBLUM, MD, FEBO

A 40-year-old woman with congenital aniridia was referred to me for a cataract surgery consultation.

On presentation, she had bilateral polar posterior cataracts, amblyopia, foveal hypolplasia, borderline ocular hypertension, and astigmatism. The patient was also experiencing symptoms of dry eye disease, another common comorbidity in patients with aniridia. Preoperative imaging with the Eyestar 900 (Haag-Streit) is shown in Figure 1.

The biometry measurements, also taken with the Eyestar 900, both showed that both eyes had a short axial length (22.11 mm OD and 22.19 mm OS) and a very shallow anterior chamber (ACD; 2.21 mm OD and 2.24 mm OS; Figure 2). Both corneas were also flat.

This article details the possible use of the Eyestar 900 powered by EyeSuite analysis software to measure the lens diameter. It also demonstrates how collaboration with Haag-Streit helped to produce a successful outcome in a challenging case.

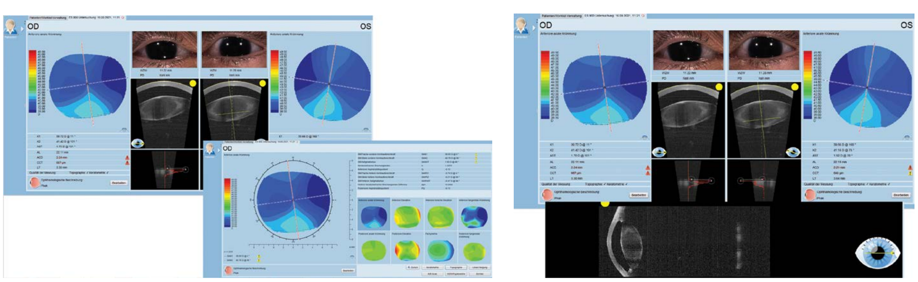

Figure 1. Preoperative imaging in the right and left eyes with the Eyestar 900.

SURGICAL PLANNING

The patient was scheduled for bilateral cataract surgery and implantation of a CustomFlex ArtificialIris Fiberfree (HumanOptics) and capsular tension ring—a standard practice for me in eyes with congenital aniridia—in her left eye first.

IOL power. The IOL chosen was a Vivinex XC1 (Hoya Surgical). In this case, the IOL power calculations for the closest target refraction to emmetropia with the Eyestar 900 for the left eye varied from 29.00 D with the SRK/T to 30.50 D with the Hoffer Q. The Hill-RBF and Barrett and Haigis formulas showed IOL powers of 29.50 and 30.00 D, respectively. I selected a lens power of +29.50 D for the left eye that resulted in a spherical equivalent (SE) of -0.375 D and calculations according to Hill-RBF was a SE of -0.04 D.

In the right eye, again the IOL power calculations varied from 29.00 D to 30.50 D. For this eye, the SRK/T

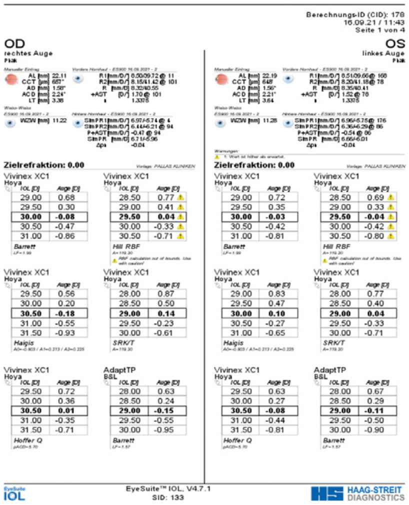

Figure 2. Biometry measurements with EyeSuite Software.

calculation produced an IOL power of 29.00 D, the Hill-RBF an IOL power of 29.50 D, the Barrett an IOL power of 30.00 D, and the Haigis and Hoffer Q an IOL power of 30.50 D. I selected an IOL power of +30.00 D that resulted in a SE of +0.25 D and calculations according to Barrett was a SE of -0.08 D.

Artificial iris implantation. I usually prefer the ArtificialIris to be implanted in the sulcus. For eyes with congenital aniridia, however, I like to implant it in the capsular bag to avoid touching the ciliary structures and decrease the risk for inflammation and glaucoma. Implantation in the capsular bag requires some extra work because the implant should fit perfectly in the capsular bag. If too small, the pupil will be decentered inferiorly; if the chosen size is too large, the implant might become folded and damage the capsule.

To determine the perfect size of the implant, I worked with Haag-Streit to manually measure the diameter of the lens capsule. In the case of a complete aniridia, no obstruction on the OCT imaging is present. Hence, the lens can be imaged from equator to equator. By using the Eyestar's OCT scans of the patient's eye, I outlined the lens capsule (Figure 3) in all radial scans and sent the images to the company to determine the diameter. Haag-Streit then calculated from these radial scans the average diameter to be 9.84 mm in the right lens and 9.64 mm in the left. I trephined the ArtificialIris to 9.5 mm for implantation in the capsular bag. An interesting fact to note: The average normal lens weighs 220 mg (including the capsular bag). The IOL in the chosen power weighs 20 mg, the capsular tension ring weighs 1 mg, and the 9.5-mm ArtificialIris weighs 30 mg, for a total implanted weight of 51 mg—well below the natural weight of the crystalline lens. Therefore, the zonules should not be stressed.

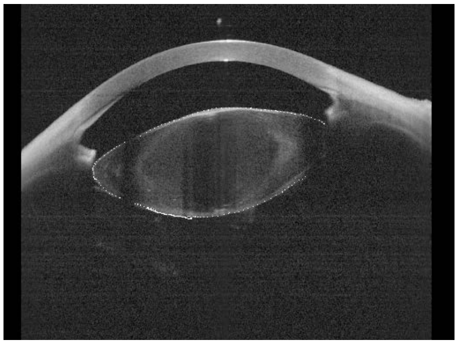

Figure 3. Professor Goldblum outlined the lens capsule so that Haag-Streit could calculate the diameter.

POSTOPERATIVE RESULT

Immediately after surgery, the patient experienced ocular hypertension with a peak of 28 mm Hg that was managed with a short-term prescription for IOP-lowering drops. She regained her normal visual acuity of 0.3 (preoperative 0.1), which she was happy with.

Several weeks after cataract surgery and ArtificialIris implantation, the patient returned for a cosmetic bilateral ptosis procedure. Figure 4 shows the final result.

Figure 4. The final postoperative result after bilateral ptosis.

CONCLUSION

Working with Haag-Streit in a unique way to help to customize the surgical procedure for this patient with congenital aniridia was a rewarding experience. Trephinating the artificial iris in the capsular bag avoided having to implant the device in the sulcus as well as touching the ciliary structures. In the end, this approach decreased the risk for glaucoma and inflammation. ■

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