# BETTER SOLUTIONS BY ACCURACY

Anterior segment diagnostics and biometry with the ANTERION.

BY OLIVER FINDL, MD, MBA; BJORN GJERDRUM, OD, PHD; KJELL GUNNAR GUNDERSEN, MD, PHD; AND DAMIEN GATINEL, MD, PHD

## A Device With Validated Precision and Accuracy

**Measurements taken with the ANTERION are comparable to those taken with the IOLMaster 700. | OLIVER FINDL, MD, MBA**

The ANTERION (Heidelberg Engineering; Figure 1) is a multimodal imaging platform that uses swept-source OCT for anterior segment examinations and measurements. This modular platform combines corneal topography and tomography, biometry, and IOL calculation for improved workflow efficiency. It has a fast acquisition time and eliminates the need to move patients between diagnostic devices. Additionally, ANTERION provides visual confirmation of all measurements.

### PRECISION

My colleagues and I compared measurements obtained with the ANTERION to those obtained with the IOLMaster 700 (Carl Zeiss Meditec). A total of 389 eyes with age-related cataract were included in the study.[1]

**Axial length.** The ANTERION and IOLMaster 700 produced mean values of 23.54 ±1.18 mm and 23.55 ±1.18 mm, respectively. The mean difference between the two devices (0.01 mm) would lead to a 0.03 D error, which can be considered negligible on the final refractive outcome. Both devices obtained AL measurements in all eyes enrolled in the study; however, 14 eyes required manual correction of retinal pigment epithelium peak, a function that is only available with the ANTERION.

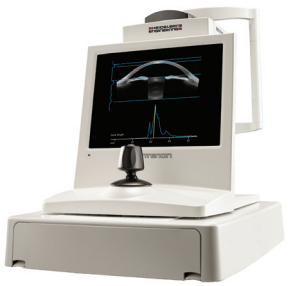

Figure 1. ANTERION is Heidelberg Engineering's platform optimized for the anterior segment.

**Keratometry.** The mean K readings were 7.82 ±0.26 mm and 7.80 ±0.26 mm for the ANTERION and IOLMaster 700, respectively. This difference was not clinically relevant and can be attributed to the various measurement zones used by each device.

**Anterior chamber depth.** ANTERION measures anterior aqueous depth whereas the IOLMaster 700 measures ACD. The mean ACD with the ANTERION was 3.20 ±0.42 mm, and it was 3.13 ±0.43 mm with the IOLMaster 700. Again, this difference was not clinically relevant.

**Lens thickness.** The mean lens thickness with the ANTERION and the IOLMaster 700 was 4.65 ±0.43 mm and 4.59 ±0.43 mm, respectively.

From this study, we determined that good agreement was found between the ANTERION and the IOLMaster 700 for all parameters that are critical to IOL power calculation.

### ACCURACY

We conducted another study comparing the repeatability of measurements with two swept-source OCT devices—the ANTERION and the IOLMaster 700—to the optical biometer Lenstar LS 900 (Haag-Streit). A total of 50 eyes were enrolled.[2]

**Axial length.** There was high repeatability with all three devices. In our hands, however, the ANTERION was slightly better than the Lenstar.

**Keratometry.** All three devices provided highly repeatable mean keratometry readings. The IOLMaster 700 was slightly superior for mean keratometry values, however, and the Lenstar produced slightly steeper keratometries. The within-subject standard deviation (Sw) was 0.083 for the IOLMaster 700, 0.018 for the ANTERION and 0.137 for the Lenstar.

**Anterior chamber depth.** Both swept-source OCT devices measured a slightly shallower anterior chamber depth (3.13 ±0.00 mm for the ANTERION and 3.06 ±0.03 mm for the IOLMaster 700) than the Lenstar (3.24 ±0.06 mm). Repeatability was also superior for the swept-source OCT devices (Sw: 0.004 for the ANTERION, 0.039 for the IOLMaster 700, and 0.134 for the Lenstar).

**Lens thickness.** Again, the Lenstar had the poorest reproducibility of the three devices. The Sw value was 0.037 for the ANTERION, 0.02 for the IOLMaster 700, and 0.180 for the Lenstar. This study showed that the ANTERION has a high repeatability and reproducibility of measurements, especially for axial length, anterior chamber depth, and lens thickness.

### POSTOPERATIVE AXIAL LENGTH

We also studied the differences between pre- and postoperative axial length with the ANTERION and IOLMaster 700 (unpublished). A total of 50 eyes with different stages of cataract were included in the study.

There was a slight difference in pre- and postoperative axial length for both devices,

but it was smaller with the ANTERION (0.08 vs 0.07 mm). We noticed a slight correlation between the grade of cataract, where the difference was greater the denser the cataract was.

## CONCLUSION

The ANTERION is highly precise and accurate. The measurements taken with the ANTERION were comparable with those taken with the IOLMaster 700, with only very small differences between devices.

1. Fisus AD, Hirnschall ND, Findl O. Comparison of 2 swept-source optical coherence tomography–based biometry devices. *J Cataract Refract Surg.* 2021;47(1):87-92.
2. Fişuş AD, Hirnschall ND, Ruiss M, Pilwachs C, Georgiev S, Findl, O. Repeatability of 2 swept-source OCT biometers and 1 optical low-coherence reflectometry biometer. *J Cataract Refract Surg.* 2021;47(10):1302-1307.

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# Biometry in Normal and Difficult Eyes

**Clinical experience and case presentations. | KJELL GUNNAR GUNDERSEN, MD, PHD**

Modern lens surgery is now considered to be a refractive procedure. Accurate biometry therefore is a prerequisite for good postoperative outcomes, both for normal and difficult eyes. In my clinical experience, swept-source anterior segment OCT (Figure 2) is the optimal way to achieve accurate and reproducible biometric measurements in all eyes.

## NORMAL EYES

My colleagues and I are conducting a pilot study of 41 eyes of 21 patients to compare the ocular biometry measurements taken with two swept-source OCT devices, the ANTERION (Heidelberg Engineering) and Argos (Alcon), and the Lenstar LS 900 (Haag-Streit). At baseline, the mean age of patients in this ongoing study was 76.0 ±6.1 years (range, 62–91 years), the mean preoperative keratometry (K) was 43.70 ±1.95 D (range, 38.80–48.60 D), and the mean preoperative keratometric astigmatism was 0.95 ±0.57 D (range, 0.20–2.17 D). The mean IOL power implanted in eyes was 20.30 ±3.10 D (range, 12.50–24.50 D). A toric IOL was implanted in 78% of patients.

Thus far, we have analyzed our results from the 5- to 6-week follow-up visit. Mean uncorrected and corrected distance visual acuity were 0.07 ±0.1 (range, 0.5–1.2) and -0.02 ±0.05 (range, 0.9–1.5), respectively. The mean spherical equivalent was 0.21 ±0.35 (range, -0.63 to 0.88), and the mean postoperative cylinder was -0.52 ±0.34 (range, -1.75 to 0.00 D). About 63% and 40% of eyes were within ±0.25 and ±0.50 D of intended refraction, respectively.

Most impressively, the mean refractive prediction error (ie, the difference between the calculated and actual postoperative refractive error) with the Barrett True K formula was lowest on the ANTERION. The largest predictive errors, both arithmetic and absolute, were with the combination of Argos and Barrett True K, followed by the Lenstar and Barrett. This difference is not significant in such a small cohort. It is, however, a clear trend. We also looked at the results in eyes that received a low-powered toric IOL. Both the postoperative refractive cylinder and the uncorrected contrast sensitivity were significantly better with toric IOLs when swept-source OCT was used for optical biometry measurements.

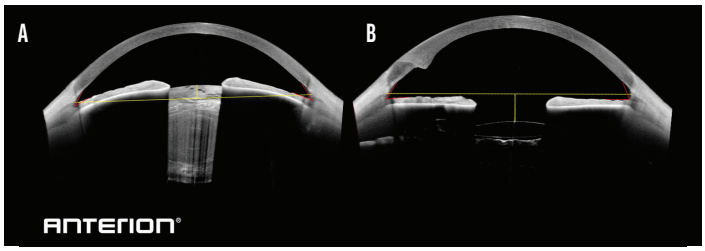


Figure 2. OCT images of an eye before (A) and after (B) cataract surgery, including selected measurement overlays for anterior chamber angle, spur-to-spur distance, and lens vault.

## BIOMETRY IN DIFFICULT EYES

Some of the most difficult eyes to achieve accurate biometry for are post-LASIK eyes, short and long eyes, eyes with an irregular cornea (eg, keratoconus, prior corneal graft, and removed LASIK flap), and eyes with advanced cataracts. In these cases, a ray-tracing method can provide accurate measurements (for more on this topic, see the next article, "Ray Tracing for Post-LASIK Patients"). Below is a case example in which the OKULIX IOL calculation method was used.

A 63-year-old man presented with stable keratoconus OU. At the precataract evaluation, refraction was -4.00 -2.50 x 45° with a visual acuity of 0.7 OD and -1.25 -0.50 x 45° with a visual acuity of 0.6 OS. Mean preoperative keratometry was 41.85 and 46.32 D OD and OS, respectively, and there was 5.98 D astigmatism at 137° OD and 9.61 D @ 39° OS. The axial length in the eyes was 24.82 and 24.60 mm, respectively.

Using the data from the OKULIX software, a 15.00 D IOL with 7.50 D of toricity was implanted OD and a 14.00 D IOL with 10.00 D of toricity was implanted OS. The postoperative refraction was similar in both eyes, and at 5-weeks postoperative the patient reported never seeing better uncorrected in bright light and reading well with only simple plus lenses.

## CONCLUSION

Optical biometry with the ANTERION is reliable both clinically and scientifically. Furthermore, this device has future potential to be used with epithelial mapping.

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# Ray Tracing for Post-LASIK Patients

**A better approach to IOL calculations. | BJØRN GJERDRUM, OD, PHD**

The most challenging population in which to perform accurate IOL calculations is post-LASIK patients. Traditional formulas such as the SRK/T, Holladay II, and Barrett Universal II use keratometry to predict the postoperative refractive outcome. In normal eyes, these formulas produce reliable results. In post-LASIK eyes, however, this method is erroneous because refractive surgery alters the corneal curvature. The use of these formulas therefore often leads to significant unintended postoperative refractive errors, mainly an under- or overestimation of the required IOL power in eyes that had previous myopic and hyperopic refractive surgery, respectively.

Alternatively, post–laser vision correction (LVC) formulas can be used, such as the Double-K, Haigis-L, Wang-Koch-Maloney, and Barrett True K. Although these formulas provide more accurate outcomes in post-LASIK eyes compared to traditional formulas, they are all theoretical formulas that either require historical measurements or use a no-history/regression analysis or an assumed posterior corneal power to predict the total corneal power. They also rely on paraxial assumptions. Such correctional assumptions are not accurate for the human eye.

Another option for IOL calculations in post-LVC eyes is to use ray tracing. This method uses exact calculations based on Snell's law for single rays at varying radial distances. Ray tracing does not incorporate any paraxial assumptions. The accuracy, however, is dependent on the availability and accuracy of the data. Today, a device such as the ANTERION (Heidelberg Engineering), which combines corneal topography and tomography, biometry, IOL calculation, anterior chamber and angle assessments, and high-resolution imaging into one device, can help to provide the most complete and accurate data needed to produce excellent IOL power calculations. The ANTERION offers a comprehensive suite of established IOL formulas and provides an interface to OKULIX, an IOL calculation method using ray tracing to calculate the optimal IOL power. ANTERION's high data quality can make the biggest differences in challenging eyes, including those that have undergone refractive surgery as well as in short eyes and in eyes with unusual corneal geometry and corneal pathologies.

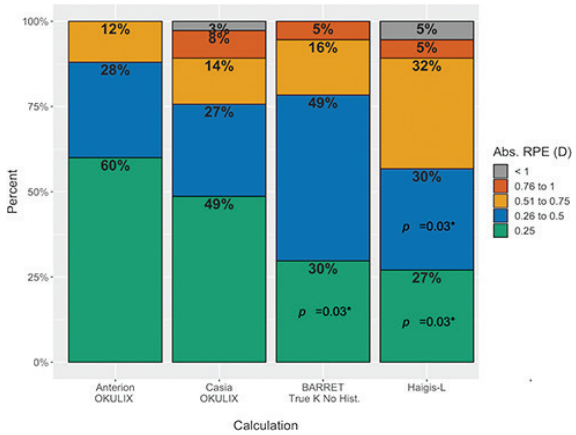


Figure 3. Comparison of the absolute refractive prediction error between different IOL calculation methods in patients with a history of previous myopic laser vision correction. The combination ANTERION + OKULIX showed the highest percentage of eyes within ±0.25 D, and all eyes were within ±0.75 D.

Source: Gjerdrum B, Gundersen KJ, Lundmark PO, Aakre BM. Refractive precision of ray tracing IOL calculations based on OCT data versus traditional IOL calculation formulas based on reflectometry in patients with a history of laser vision correction for myopia. *Clin Ophthalmol*. 2021;15:845-857.

## SOFTWARE OVERVIEW

OKULIX uses full-aperture ray tracing to capture the pupil size and manufacturer-provided IOL data like corneal radii, refractive index, asphericity, and lens thickness. Rather than using effective lens position, OKULIX predicts the geometrical IOL position based on the axial length, anterior chamber depth, and lens thickness. There's no need for personalized lens constants. The software can incorporate anterior and posterior corneal tomography and corneal thickness. When these measurements are available, the calculation is independent of patient history. Rather than calculating the IOL power for a theoretical best focal point, OKULIX calculates the power that will provide the smallest simulated foveal image. In this way, it also accounts for spherical aberrations.

The OKULIX calculation software shows the predictive procedural refraction in terms of the best focus, which is used for surgery planning, as well as the procedural refraction for the paraxial calculation. The difference between these two values represents the spherical aberrations. The software also calculates the predictive geometrical postoperative anterior chamber depth.

## STUDY RESULTS

We compared the refractive precision of OCT ray-tracing IOL calculations with the ANTERION and Casia 1000 (Tomey) to post-LVC IOL calculation achieved with the Barrett True K and Haigis-L with the Lenstar LS 900 (Haag-Streit).

A total of 37 eyes of 20 patients who had previously undergone laser vision correction for myopia were included in the results. The correlatiton between two eyes of a patient were accounted for. The mean age of patients was 57 years, and the mean planned LVC correction was for -3.70 D myopia (range, -10.00 to -1.60 D). The mean power of the implanted IOL was 20.30 D (range, 15.00–24.50 D). About 65% of patients received a toric IOL.

We determined that the OKULIX calculation based on the ANTERION data had the lowest mean refractive prediction error. This was statistically significantly different from all three other calculations, including the OKULIX calculation with the Casia data. Further, the ANTERION OKULIX calculation was the only one that had no outliers on the whiskers box plot, which is about 1.5 standard deviations.

The ANTERION OKULIX calculation also had the lowest mean absolute prediction error, but this was only statistically different from the Haigis-L calculation. About 60% of eyes were within ±0.25 D with the ANTERION OKULIX calculation, 49% with the Casia OKULIX calculation, and 30% and 27%, respectively, for the two formulas based on the reflectometry. The percentages for both these formulas were significantly different from the ANTERION OKULIX calculation. About 88%, 76%, 79%, and 57% of eyes were within ±0.50 D of the intended target with the ANTERION OKULIX, Casia

OKULIX, Barrett, and Haigis-L calculations, respectively. Only with the ANTERION OKULIX calculation were all the eyes within ±0.75 D (Figure 3).

## CONCLUSION

Ray tracing is a better approach to IOL calculations, especially in post-LVC eyes. This method takes individual measurements, is independent of ocular history, and avoids the need for personalized lens constants. Of the IOL calculation methods we have studied, ray tracing with the ANTERION OKULIX provided the best arithmetic mean absolute prediction error with the lowest range of refractive error. About 60% of eyes were within ±0.25 D of the refractive target at 3 months postoperative.

1. Gjerdrum B, Gundersen KJ, Lundmark PO, Aakre BM, Refractive precision of ray tracing IOL calculations based on OCT data versus traditional IOL calculation formulas based on reflectometry in patients with a history of laser vision correction for myopia. *Clin Ophthalmol*. 2021;15:845-857.

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# SCORE: An Algorithm for Ectasia Screening

**Optimized for use with the ANTERION. | DAMIEN GATINEL, MD, PHD**

Post-LASIK ectasia is the most dreaded complication after refractive surgery. Evidence-based screening tools can be used successfully, but some are considered controversial because they do not incorporate the latest advances in diagnostics. In attempt to improve our detection capacities, my colleagues and I set out to devise a simple, efficient, and objective algorithm for ectasia screening. The Screening Corneal Objective Risk of Ectasia (SCORE) Analyzer is AI software designed to aid in clinical decision-making and detecting form fruste (asymmetrical) keratoconus and ectasia. The SCORE software will be integrated into the ANTERION Ectasia Display by Heidelberg Engineering. The expected release is spring 2022.

## BACKGROUND AND DESCRIPTION

Several topographical parameters can discriminate for ectasia, including corneal thinning from the periphery to the center, irregularity at 3 mm, vertical decentration of the thinnest point, and differences between central and thinnest pachymetry and mean inferior and superior keratometry measured 5 mm from the vertex. No indice should be used independently to screen for ectasia because each one alone cannot differentiate, with sufficient sensitivity and specificity, normal from irregular corneas. Taken collectively, like with SCORE, however, they can be used to produce a sensitive and specific diagnostic test for both form fruste keratoconus and ectasia.

SCORE uses 12 of the most discriminant indices for ectasia. The software can classify ectasia according to the degree of similarity with corneas that are likely to progress to ectasia. The algorithm is based on measurements from 265 patients split into two groups—a control group of 189 eyes with at least 4 years of documented unremarkable history for ectasia and a keratoconus group of 76 eyes with forme fruste keratoconus. The normal eyes of the control group were matched with the least-affected eye of patients with asymmetrical keratoconus (ie, one eye with frank keratoconus and the other eye with minor abnormalities but within the classical topographic limits of detection).

In our experience, SCORE can detect about 75% of the corneas that are at risk for post-LASIK ectasia. The graphic user interface of the investigational ANTERION Ectasia Display is shown in Figure 4.

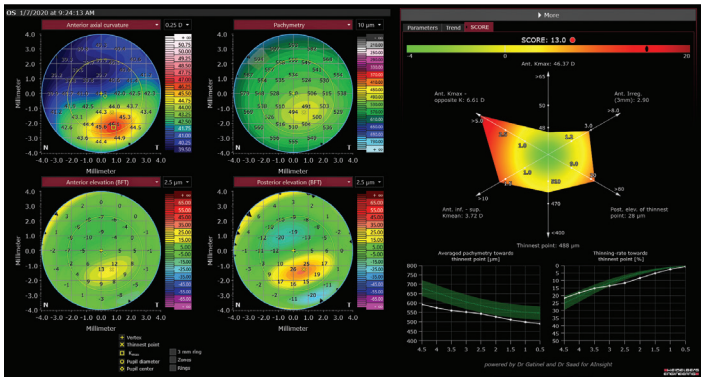


Figure 4. ANTERION Ectasia Display showing customizable corneal maps and SCORE. The SCORE tab presents the SCORE value, a radar map and pachymetry diagrams (powered by Dr. Gatinel and Dr. Saad). The SCORE value consists of different parameters that describe the magnitude of corneal steepening, thinning, and asymmetry to assist clinicians in detecting and monitoring ectatic changes. *(The image shows investigational software that is currently under development.)*

The measurements are combined in a linear discriminant function, and all relevant metrics are multiplied by a coefficient to discriminate form fruste keratoconus from normal corneas.

ANTERION Ectasia Display includes different corneal maps that can be customized. The SCORE tab includes the SCORE value and diagrams for average pachymetry and the thinning rate toward the thinnest point. The lower the curves, the more discriminant of ectasia. The software's RADAR map also allows direct and intuitive visualization of values for some of the parameters used for the SCORE. The score is shown as a value; a normal cornea is scored as -0.5 or below.

## CONCLUSION

The ANTERION Ectasia Display is currently under development and is expected to be released in spring 2022. Our SCORE formula has been optimized for use with the ANTERION. The incorporation of this software will improve the quality of the corneal measurements obtained with the device and will provide modern methods for screening for keratoconus and other ectatic diseases. ■

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