# Intraocular lens calculation for aspheric intraocular lenses

Peter C. Hoffmann, MD, Christoph R. Lindemann, MD

**PURPOSE:** To evaluate the possible benefits of biometry and ray-tracing intraocular lens (IOL) calculation for aspheric aberration-correcting IOLs.

**SETTING:** Private eye clinic in Germany.

**DESIGN:** Retrospective consecutive case series.

**METHODS:** Eyes with 3 different aberration-correcting IOLs were reviewed. Before surgery, the axial length, corneal thickness, anterior chamber depth, crystalline lens thickness, and corneal radii were measured with the Lenstar biometer. Subjective refraction was taken 1 month after surgery. Okulix ray-tracing software (version 8.79) and the Hoffer Q, Holladay, and SRK/T formulas were used to calculate a prediction error based on preoperative biometry data, the given IOL, and the manifest refraction.

**RESULTS:** The study evaluated 308 eyes of 185 patients. The median absolute error was 0.28 diopters (D) for the Hoffer Q, 0.27 D for the Holladay, 0.28 D for the SRK/T, and 0.24 D for ray-tracing calculation. Using ray-tracing calculation, 95% of eyes were within $\pm$0.71 D of the predicted refraction as opposed to $\pm$0.85 D with the Hoffer Q, $\pm$0.82 D with the Holladay, and $\pm$0.84 D with the SRK/T.

**CONCLUSIONS:** Ray tracing based on biometry data improved IOL prediction accuracy over conventional formulas in normal eyes implanted with aberration-correcting IOLs. The number of outliers can also be reduced significantly.

**Financial Disclosure:** Neither author has a financial or proprietary interest in any material or method mentioned.

*J Cataract Refract Surg 2013; 39:867–872 © 2013 ASCRS and ESCRS*

In modern cataract surgery, aspheric intraocular lenses (IOLs) have become increasingly popular. Optics with a conic shape have the potential to significantly reduce the amount of spherical aberration in the eye, allowing higher contrast and acuity, especially under low light conditions.[1–3] However, the improved optical properties lead to less pseudoaccommodation and therefore increase the influence of defocus. It is therefore mandatory to predict the IOL power as precisely as possible.

Submitted: September 26, 2012.
Final revision submitted: December 22, 2012.
Accepted: December 31, 2012.

From Augenklinik Castrop-Rauxel, Castrop-Rauxel, Germany.

Corresponding author: Peter C. Hoffmann, MD, Münsterplatz 6, 44575 Castrop-Rauxel, Germany. E-mail: ph@augenklinik-castrop-rauxel.de.

Intraocular lens calculations with optical biometry and conventional formulas[4–6] yield very good results. However, all these formulas use calculations based on the Gullstrand eye model. This assumes a fixed ratio of anterior corneal curvature and posterior corneal curvature. The cornea is treated as a thin lens with a composite index of 1.3375 (or 1.3315 in the case of the Haigis formula). Systematic deviations are compensated for by so-called IOL constants that essentially modify the effective lens position (ELP). Although this leads to a correct result on average, it can deliver less precise results under certain conditions.

Newer eye models, such as that of Liou and Brennan,[7] describe the eye more accurately on average. Using ray-tracing technology, it is possible to work with the physical properties of the IOL and to take full advantage of crystalline lens data delivered by the Lenstar optical biometer (Haag-Streit) to improve prediction accuracy.[8,9]


Published by Elsevier Inc.
0886-3350/$ - see front matter
http://dx.doi.org/10.1016/j.jcrs.2012.12.037

The goal of this study was to evaluate whether ray-tracing calculation based on Lenstar measurements improve prediction accuracy in aspheric aberration-correcting IOLs compared with traditional formulas that are currently the gold standards of IOL calculation.

## PATIENTS AND METHODS

Eyes that had implantation of premium aspheric IOLs based on Lenstar optical biometry between January 2011 and June 2012 were reviewed retrospectively. All had routine cataract surgery without complications. Eyes with macular disease (eg, neovascular age-dependent maculopathy, macular hole, geographic atrophy, macular edema) and eyes with keratoconus, corneal grafts, corneal scars, or edema were excluded.

All surgical procedures were performed by 2 experienced surgeons using coaxial microphacoemulsification with 2.2 mm (P.C.H.) or 2.5 mm (C.R.L.) posterior limbal incisions placed temporally that were astigmatically neutral or near neutral as previously described.[10]

Preoperative diagnostics and IOL calculation were performed with the optical biometer software (version 3) as well as TMS5 tomography (Tomey) of both corneal surfaces. For comparison with traditional formulas, only biometer data were used as an input into the ray-tracing software (Okulix version 8.79, Tedics). A Lenstar data set includes the following information: axial length (AL), corneal thickness, internal anterior chamber depth (ACD), lens thickness, depth of vitreous cavity, retinal thickness, and corneal radii in the steepest and flattest meridians.

The principles and development of the ray-tracing software have been described.[11–13] The software can be used with the same input data as conventional formulas; however, additional information can be used to refine the model. This includes Lenstar optical path data of the anterior segment as well as corneal tomography with different devices (Placido, Scheimpflug, anterior segment optical coherence tomography [AS-OCT]).

The following aspheric aberration-correcting (as opposed to aberration-neutral) IOLs were implanted: iMics1 (Hoya), Acrysof IQ (Alcon), Tecnis 1-piece (Abbott Medical Optics). Although the exact physical properties of the IOLs are not disclosed by the manufacturers, it is known that the Tecnis IOL has the strongest negative spherical aberration followed by the Acrysof IQ and the iMics1.

The measure of success was the prediction error, defined as the difference between achieved and predicted spherical equivalent (SE) manifest refraction. The manifest refraction was obtained by subjective refraction 1 month after surgery according to DIN 58220.[14] The distance from the patient's head to the acuity chart was 6 m (20 ft).

The subjective refraction was performed as follows: First, the uncorrected acuity was taken. Second, the patient was refracted with spherical lenses until the best spherical glass was found and acuity could not be improved. Third, a cross cylinder ($\pm$0.5 D or $\pm$1.0 D depending on acuity) was applied at 0 degree, 90 degrees, 45 degrees, and 135 degrees. If there was subjective improvement in any of these axes, the patient was offered 2 choices by flipping the cross cylinder along its handle and adjusting the axis in decreasing steps. After the cross-cylinder examination, a final spherical adjustment was performed with the help of a red–green balance chart. Final refraction was reached when there was red–green balance or slight green overweight. All refractions were performed by 1 of 4 experienced ophthalmologists.

The difference between the SE of this refraction and the SE as predicted by the formula or the ray-tracing software was defined as the prediction error. The median, mean, and standard deviation were calculated. The median and mean absolute error were also evaluated after adjusting offsets and constants to a mean prediction error of zero.

The Hoffer Q,[15] Holladay,[16] and SRK/T[17] formulas were used for comparison. For each type of IOL, the specific formula constants were optimized to obtain a mean prediction error of 0.0 D.

The ray-tracing software was set up to import a Lenstar data set. Posterior curvature was configured according to the model of Liou and Brennan,[7] the asphericity Q was set to $-0.16$ ($-0.18$ in the Liou and Brennan model), and the pupil was assumed to be 3.0 mm in diameter in the iris plane. All calculations were performed for the best focus, which was defined according to the International Organization for Standardization (ISO 11979-2)[18] for each meridian by the ray that intersects the pupil plane at a distance of

$$d = 0.5 \times \sqrt{2} \times p$$

where $p$ is the pupil diameter. The postoperative IOL position was estimated by averaging 2 algorithms based on (1) AL only and (2) ACD and crystalline lens thickness biometry data, which have been described in detail.[8,19]

To evaluate statistical significance, the Wilcoxon parameter-free matched-pair test and Prism 5.0b software (Graphpad Software) were used.

The various formulas were used with the actual constants recommended in the User Group for Laser Interference Biometry database[A] and the Okulix version 8.79 software out of the box. Because there was a systematic offset for all IOLs in all formulas and all but 1 IOL in the ray-tracing software, the offset for each IOL was adjusted to 0.0 D so as not to compare constants but rather the real potential of the algorithms.

## RESULTS

The study reviewed 308 eyes of 185 patients; 117 patients (63.2%) were women. The median age of the patients was 73 years (range 39 to 87 years). The mean corrected distance visual acuity was 0.04 $\pm$ 0.10 logMAR (SD) (range 0.3 to $-0.2$ logMAR).

The mean implanted IOL power was 21.06 $\pm$ 3.80 D (range 8.0 to 31.5 D). The iMics1 IOL was implanted in 67 eyes, the Acrysof IQ IOL in 82 eyes, and the Tecnis IOL in 159 eyes.

Table 1 shows the overall results. Systematic offsets were corrected for all formulas and the ray-tracing calculation. When using the ray-tracing software and Lenstar crystalline lens data, the median absolute prediction error improved by 9% to 14% depending on the formula. Furthermore, the number of eyes with prediction outside the $\pm$1.00 D boundaries was from 7 (2.3%) to 1 (0.3%). No eye had an absolute prediction error of more than 1.50 D.

The differences in absolute error were highly significant between the ray-tracing software and the SRK/T