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Accuracy of Intraocular Lens Calculation Formulas

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Purpose: To compare the accuracy of intraocular lens (IOL) calculation formulas (Barrett Universal II, Haigis, Hoffer Q, Holladay 1, Holladay 2, Olsen, and SRK/T) in the prediction of postoperative refraction using a single optical biometry device.

Design: Retrospective consecutive case series.

Participants: A total of 13 301 cataract operations with an AcrySof SN60WF implant and 5200 operations with a SA60AT implant (Alcon Laboratories, Inc., Fort Worth, TX).

Methods: All patients undergoing cataract surgery between July 1, 2014, and December 31, 2015, with Lenstar 900 optical biometry were eligible. A single eye per patient was included in the final analysis, resulting in a total of 18 501 cases. We compared the performance of each formula with respect to the error in predicted spherical equivalent and evaluated the effect of applying the Wang–Koch (WK) adjustment for eyes with axial length $>$25.0 mm on 4 of the formulas.

Results: For the SN60WF, the standard deviation of the prediction error, in order of lowest to highest, was the Barrett Universal II (0.404), Olsen (0.424), Haigis (0.437), Holladay 2 (0.450), Holladay 1 (0.453), SRK/T (0.463), and Hoffer Q (0.473), and the results for the SA60AT were similar. The Barrett formula was significantly better than the other formulas in postoperative refraction prediction ($P < 0.01$) for both IOL types. Application of the WK axial length modification generally resulted in a shift from hyperopic to myopic outcomes in long eyes.

Conclusions: Overall, the Barrett Universal II formula had the lowest prediction error for the 2 IOL models studied. *Ophthalmology 2017;■:1–10 © 2017 by the American Academy of Ophthalmology*

The prediction of refractive outcomes after cataract surgery has steadily improved, with more recent intraocular lens (IOL) power formulas generally outperforming those of prior generations.[1,2] Yet there is still considerable debate about which formula provides the most accurate refractive prediction. Because no single formula has been shown to be highly accurate across a range of eye characteristics, some authors have suggested that cataract surgeons should use different formulas for eyes of varied ocular dimensions.[3,4]

During the study period, by provider or patient preference, 145 surgeons most frequently used an AcrySof SN60WF or SA60AT IOL (Alcon Laboratories, Inc., Fort Worth, TX) for uncomplicated cataract surgery. Although both of these IOL models are made of hydrophobic acrylic and have anterior asymmetric biconvex designs (where the front surface has stronger power), the SN60WF has a yellow chromophore, has an aspheric posterior surface (with nominal negative asphericity of −0.2), and is available in powers of 6.0 to 30.0 diopters (D),[5] whereas the SA60AT has no chromophore, has a spheric posterior surface, and includes IOL powers of 6.0 to 40.0 D.[6]

Our study was designed to address 4 main questions: (1) Of the currently popular IOL calculation formulas (Barrett Universal II, Haigis, Hoffer Q, Holladay 1, Holladay 2, Olsen, and SRK/T), which is the most accurate when evaluating the error in predicted postoperative spherical equivalent including eyes of all ocular dimensions? (2) What is the accuracy of the various formulas when evaluating short, medium, and long eyes? (3) What is the extent of bias within each formula for different biometric dimensions of the eye (anterior chamber depth, axial length, corneal curvature, and lens thickness) that lead to imperfect predictions? (4) Does the use of the Wang–Koch (WK) axial length adjustment for the Haigis, Hoffer Q, Holladay 1, and SRK/T formulas in long eyes lead to improved outcomes?

Methods

Kaiser Permanente Northern California is a large multiprovider medical plan providing comprehensive health care services to a diverse population of approximately 4 million patients.

Consecutive patients who underwent uncomplicated cataract surgery with an implantation of the 2 most commonly used IOLs at our institution (SN60WF or SA60AT) from July 1, 2014, to December 31, 2015, were eligible. A total of 145 surgeons contributed cases, and surgery was performed by clear cornea temporal incision phacoemulsification. All patients were measured preoperatively with the Lenstar 900 (Haag-Streit AG, Koeniz, Switzerland). Manifest refraction was performed at a 1-month postoperative visit with an optometrist. The study was performed under institutional review board approval and conformed to the tenets of the Declaration of Helsinki.

Selection Criteria

Our selection criteria generally followed the recommendations of a recent editorial by Hoffer et al[7] regarding best practices for studies of IOL formulas, namely, the use of optical biometry, the inclusion

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of only 1 eye from each study subject, and the exclusion of patients with less than 20/40 best-corrected vision. In addition, we required a keratometric cylinder less than 4.0 D, lens thickness measurement of at least 2.50 mm, and refraction within the 2-week to 4-month postoperative period. Patients with a history of corneal disease or refractive surgery were excluded. Cases with a postoperative absolute refractive error greater than 2.0 D were reviewed, and 24 cases were excluded because of apparent measurement errors. If both eyes were eligible and the postoperative visual acuity was unequal, the eye with the better visual acuity was selected. If both eyes were eligible and the visual acuity was equal, the first eye was selected if the patients had surgery on separate dates. A random eye was chosen if immediate sequential bilateral surgery was performed. An overview of the selection criteria is shown in Figure 1. Exclusion of patients with corneal or refractive surgery, invalid biometry, missing postoperative refractive information in the 2-week to 4-month postoperative period, or worse than 20/40 vision resulted in a total of 27 191 eligible eyes. Selection of a single eye per patient produced 13 301 study eyes for the SN60WF IOL and 5200 study eyes for the SA60AT.

Formula Calculations

Spherical equivalent formula predictions and lens constant optimizations were performed in collaboration with Haag-Streit, who has licensed versions of the proprietary Barrett Universal II

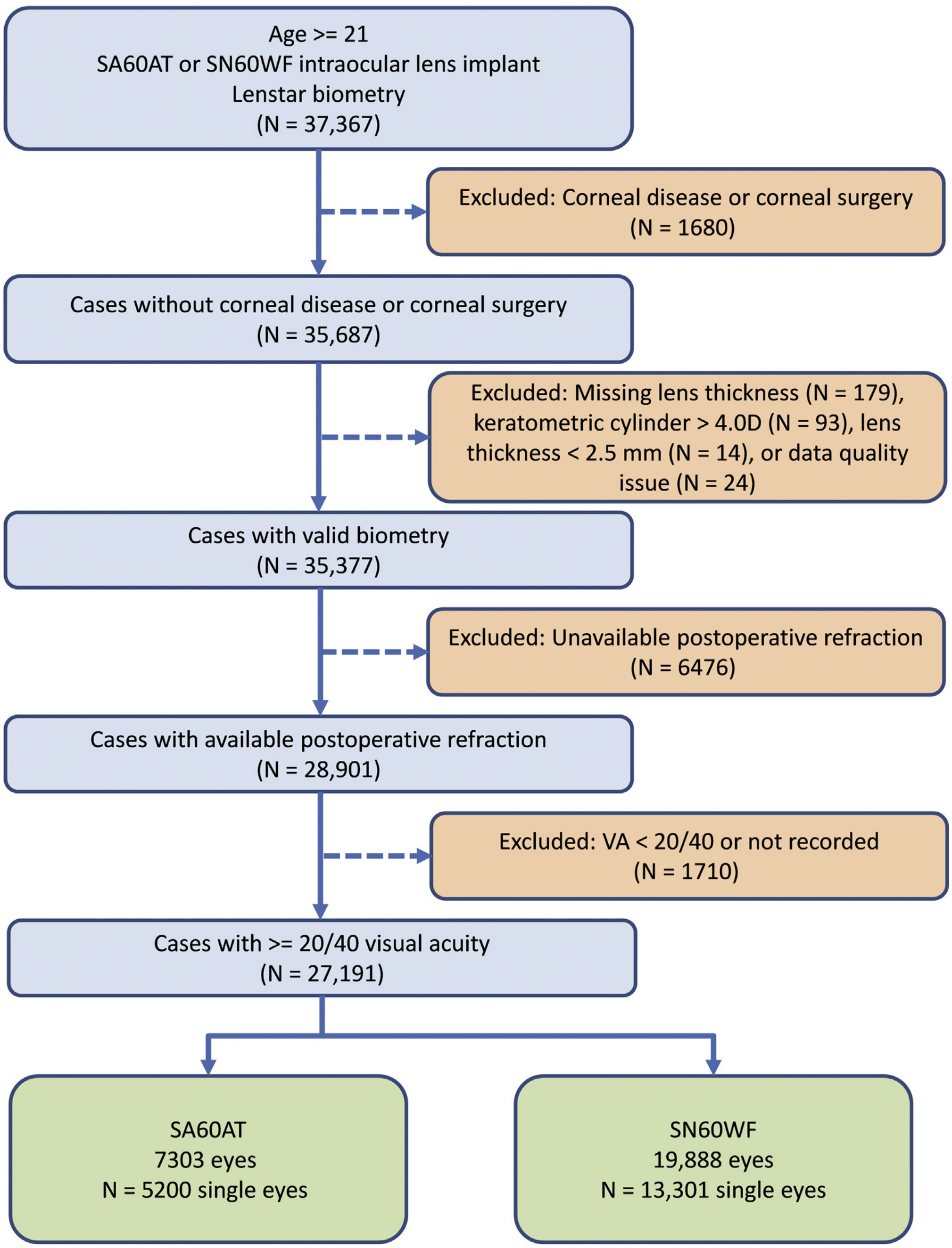

Figure 1. Selection criteria overview. VA = visual acuity.