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Prediction of Postoperative Intraocular Lens Position with Angle-to-Angle Depth Using Anterior Segment Optical Coherence Tomography

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Purpose: To evaluate the accuracy of a new formula for predicting postoperative anterior chamber depth (ACD) with preoperative angle-to-angle (ATA) depth using anterior segment (AS) optical coherence tomography (OCT) and to compare it with established methods.

Design: Retrospective consecutive case series.

Participants: Three hundred four eyes (276 patients) implanted with acrylic intraocular lenses (IOLs) were divided randomly into a training set (152 eyes) and a validation set (152 eyes).

Methods: Based on the training set data, the postoperative ACD measured 1 month after surgery was analyzed via multiple linear regression analysis with 5 preoperatively measured variables: ATA depth, ATA width, preoperative ACD measured with AS OCT, axial length (AL), and corneal power. A new regression formula for predicting postoperative ACD was developed using the results of the stepwise analysis. In the validation set data, the coefficients of determination (R^2) between the measured postoperative ACD and the predicted postoperative ACD obtained using the new formula were compared with those obtained using the Sanders-Retzlaff-Kraff theoretic (SRK/T) and Haigis formulas. The absolute prediction errors were compared with each formula.

Main Outcome Measures: Postoperative ACD, median absolute prediction error of postoperative ACD, and ocular biometric parameters.

Results: In the training set, ATA depth yielded the highest standard partial regression coefficient value, indicating that ATA depth is the most effective parameter for predicting postoperative ACD. The new regression formula was developed with 3 variables; ATA depth, preoperative ACD, and AL. In the validation set, the postoperative ACDs of the new formula, the SRK/T formula, and Haigis formula were predicted with R^2 of 0.71, 0.36, and 0.55, respectively, and the medians of the absolute prediction errors were 0.10 mm, 0.65 mm, and 0.30 mm, respectively. The absolute prediction error with the new formula was significantly smaller than those obtained with the SRK/T and Haigis formulas ($P < 0.0001$).

Conclusions: The new formula with 3 preoperative parameters—ATA depth, preoperative ACD, and AL—predicted postoperative ACD more accurately than the SRK/T and Haigis formulas. It may be possible to improve the accuracy of IOL power calculation using an improved postoperative ACD prediction with the ATA depth measured by AS OCT. *Ophthalmology 2016;■:1–7 © 2016 by the American Academy of Ophthalmology*

Cataract surgery is the most common ophthalmic surgery,[1,2] and the postoperative refractive error associated with this procedure is an important clinical consideration because it directly affects the patient's quality of life. Postoperative refractive error is mainly dependent on 4 factors: corneal power (K), axial length (AL), intraocular lens (IOL), and postoperative anterior chamber depth (ACD).[3–5] Corneal power and AL can be measured before surgery. However, without an accurate prediction of the postoperative ACD, it is not possible to achieve the optimal final refraction with certainty. It has been reported that approximately 5% to 20% of patients needed a refractive correction of more than 1 diopter (D) after cataract surgery.[6,7] Furthermore, approximately 40% of the postoperative refractive error results from imprecise prediction of the postoperative ACD or the postoperative IOL position.[3–5]

Various IOL power formulas have been developed to overcome the problem of inaccurate postoperative ACD prediction. The third-generation formulas are the Holladay 1,[8] Sanders-Retzlaff-Kraff theoretic (SRK/T),[9] and Hoffer Q.[10] They all use AL and K for the prediction of postoperative ACD and the subsequent IOL power calculation. The Haigis formula,[11] a fourth-generation formula, uses AL and preoperative ACD to predict postoperative ACD. The formula does not require

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K values. Additionally, Olsen[12] developed a thick lens formula using AL, ACD, crystalline lens thickness, corneal radius, and preoperative refraction in a prediction formula for postoperative ACD.

Recently, several techniques have been developed for imaging the anterior segment (AS) of the eye in vivo. Anterior segment optical coherence tomography (AS OCT) allows noncontact, cross-sectional imaging of the AS, including the anterior chamber angle,[13,14] and it is in widespread use for the clinical diagnosis and treatment of AS diseases.[15–24] The use of customized software allows even better imaging, specifically of the angle. When measuring the lens vault[19,24] or ACD[17,18,20–23] with AS OCT, the angle-to-angle (ATA) depth can be measured as the perpendicular distance between the posterior corneal surface and the intersection point of a line joining both angle recesses on the cross-sectional horizontal image with the corneal vertex. The authors hypothesized that the ATA depth may be useful for predicting postoperative ACD, because the ATA depth could not change after phacoemulsification and IOL implantation. The purpose of this study was to evaluate ATA depth assessed using AS OCT as a predictor of postoperative ACD and to establish the new formula for predicting postoperative ACD using AS OCT.

Methods

The study was designed as a retrospective consecutive case series and was approved by the Institutional Review Board of the National Hospital Organization, Tokyo Medical Center. Informed consent was obtained from each patient. Each patient was treated in accordance with the tenets of the Declaration of Helsinki. All patients were recruited from the National Hospital Organization, Tokyo Medical Center, from July 2012 through August 2015. The exclusion criteria for the study were as follows: previous AS or posterior segment surgery, history of ocular trauma, presence of significant ocular comorbidities, unreliable or undetectable preoperative biometric measurements, IOL implantation outside the capsular bag, and dislocated IOL.

All patients underwent routine preoperative and 1-month postoperative ophthalmic examinations comprising a corrected distance visual acuity measurement using a Landolt C chart, slit-lamp examination, keratometry, intraocular pressure measurement, and funduscopy. Axial length and K were measured using partial coherence interferometry (IOLMaster 500; Carl Zeiss Meditec, Dublin, CA). The surgical technique comprised a 2.2-mm corneal incision and phacoemulsification with the implantation of an IOL (AcrySof Toric IOL, SN6A T3-T6; Alcon, Fort Worth, TX) in the bag after a circular capsulorrhexis in all cases. All surgical procedures were performed under topical anesthesia by the same experienced surgeon (T.N.).

Anterior Segment Optical Coherence Tomography Imaging and Analysis

A swept-source AS OCT instrument (SS-1000; Tomey Corp, Nagoya, Japan) was used to obtain the AS imaging.[13,25,26] This instrument uses a super-luminescent diode light source at a wavelength of 1310 nm. The axial and transverse resolutions are approximately 10 μm and 30 μm, respectively. To capture the image, the pupil was dilated with a mixture of 0.5% tropicamide and 0.5% phenylephrine hydrochloride administered via eye drops. All subjects underwent imaging with AS OCT performed in a dark room (light intensity, 0.3 lux) by a trained technician who was masked with regard to the clinical data. The angle analysis protocol was used, in which 128 radial B-scans are obtained, each with 512 A-scans (16-mm scan length). This allowed 360° imaging of the entire AS in 2.4 seconds. During the imaging, the patient fixated on an internal fixation target.

The measurement was performed along the vertex normal. The images were centered on the corneal vertex defined as the cross-point of the vertex normal and anterior corneal surface. The horizontal image was obtained in each eye studied, with the nasal and temporal angles at 0° and 180°, respectively. The images were processed using customized software by 2 of the authors (S.G., K.H.) who were blind to the clinical data. The only observer input was to determine the location of the 2 angle recesses on the AS OCT images, and then the ATA depth was calculated automatically. Interevaluator intraclass correlation coefficients for preoperative ATA depth (0.986), postoperative ATA depth (0.964), preoperative ACD (0.999), and postoperative ACD (0.997) showed good agreement.

The parameters measured with AS OCT (Fig 1) were defined as follows. Angle-to-angle depth was defined as the perpendicular distance between the posterior corneal surface and a line drawn between the anterior chamber angle recesses on nasal and temporal sides of the horizontal AS OCT scans. Angle-to-angle width was defined as the distance between the anterior chamber angle recesses on nasal and temporal sides of the horizontal AS OCT scans. Preoperative ACD was defined as the distance between the posterior corneal surface and the anterior lens surface. Corneal thickness was defined as the distance between the anterior corneal surface and the posterior corneal surface. Postoperative internal ACD (ACD_i) was defined as the distance between the posterior corneal surface and the anterior IOL surface. Postoperative external ACD (ACD_e) was defined as the distance between the anterior corneal surface and the middle point of the IOL. Because postoperative ACD_e is defined as the distance from the anterior surface of the cornea to the center of the IOL for the thin lens formulas, the postoperative ACD_e was

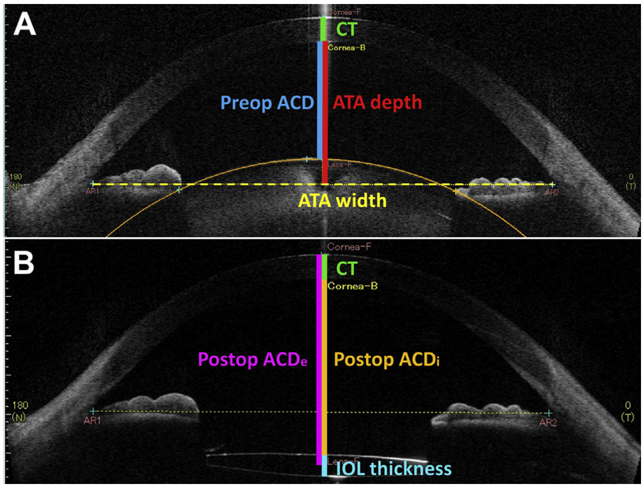

Figure 1. Measurement of anterior segment parameters via anterior segment optical coherence tomography images (**A**) before and (**B**) after cataract surgery. ACD = anterior chamber depth; ACD_e = external anterior chamber depth; ACD_i = internal anterior chamber depth; ATA = angle-to-angle; CT = corneal thickness; IOL = intraocular lens; postop = postoperative; preop = preoperative.