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Wang-Koch formula for optimization of intraocular lens power calculation: Evaluation at a Canadian center

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Purpose: To externally validate the Wang-Koch method for optimization of intraocular lens (IOL) formulas.

Setting: TLC Laser Eye Centre, Mississauga, Ontario, Canada.

Design: Retrospective case series.

Methods: Consecutive cataract patients with an axial length (AL) of 25.0 mm or longer were recruited. The predicted postoperative spherical equivalents (SEs) calculated from the Holladay 1 formula were compared with the 3-week postoperative SEs to yield prediction errors for Wang-Koch adjusted and unadjusted ALs. A mixed linear model was used to compare the proportion of eyes with a prediction error of ±0.25 diopter (D) or worse, ±0.50 D or worse, and ±1.00 D or worse between groups. The secondary outcomes of mean absolute error and median absolute error were also analyzed. A subgroup analysis was performed based on AL subgroups.

Results: Two hundred sixty-two eyes were selected for inclusion with a balanced sex distribution, a mean age of 62.49 years ± 9.13 (SD), and a preoperative AL of 26.49 ± 1.10 mm. Subgroup prediction error comparisons of ±0.50 D or worse favored unadjusted eyes with ALs between 25.0 mm and 26.0 mm (n = 105; $P < .001$), no difference in eyes with ALs between 26.0 mm and 27.0 mm (n = 91; $P = .43$), adjusted eyes with ALs between 27.0 mm and 28.0 mm (n = 36; $P = .003$), and adjusted eyes with ALs of 28.00 mm or longer (n = 30; $P < .001$).

Conclusion: The Wang-Koch adjustment should only be applied in eyes with ALs longer than 27.0 mm that have IOL power calculation with the Holladay 1 formula.

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Modern cataract surgery is an efficacious and safe procedure. Even though refractive outcomes after intraocular lens (IOL) implantation have improved considerably over time, patient expectations for increasingly precise postoperative refractive outcomes continue to increase.

Accuracy in the calculation of IOL power is necessary for realizing the desired postoperative refraction.[1] This accuracy is largely dependent on 3 factors: preoperative biometry data, the IOL power calculation formula, and the quality control of the manufacturer's IOL power. The axial length (AL) derived from preoperative biometry is one important determinant of eventual IOL refractive power.[2] Specifically, a study of ultrasound (US) biometry using the Binkhorst formula[3] found that 54% of all errors in predicted refraction could be attributed to AL measurement errors, whereas only 8% of errors occurred because of corneal power measurement inaccuracies. Thirty-eight percent of errors were caused by flaws in the estimation of postoperative anterior chamber depth (ACD). Resultantly, accurate measurement of AL is likely the most meaningful method to improve IOL power prediction.[4]

In eyes with long ALs, IOL formulas might not consistently produce accurate results. In 89 long eyes with ALs greater than 24.5 mm, Hoffer[5] showed that the Holladay 1 formula[6] produced the lowest mean absolute error (MAE) of 0.41 diopter (D) ± 0.31 (SD) when compared with the SRK I,[7] SRK II,[8] SRK/T,[9] and Hoffer Q formulas.[5] Nonetheless, hyperopic error can be found after IOL implantation in long eyes. Wang et al.[10] have hypothesized

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that this hyperopic error is attributable to (1) as AL increases, inaccurate estimation of ACD in the determination of effective lens position; (2) in optical biometry, a single value used for the refractive index that converts optical path length to AL, despite a different refractive index of vitreous because of vitreous liquefaction in long eyes; and (3) in US biometry, inaccurate measurement of AL in the presence of posterior staphylomata, which are common in long eyes.[10] They note that in long eyes, surgeons have targeted for a myopic postoperative refraction of −1.00 D or −2.00 D with the understanding that there might be hyperopic surprises. Several approaches have been suggested in response to this unexpected hyperopia, including specialized IOL constants or the adjustment of AL. For instance, the Haigis IOL formula uses specialized constants that have been recommended for use in low dioptric positive and negative IOLs.[11] It is important to note that newer Gaussian-based formulas, such as the Barrett formula,[12] do not use specialized constants or AL adjustment in long eyes.[10]

The adjustment of measured ALs has been suggested as another method to correct for systemic inaccuracies in long eyes.[13,14] In 2011, the Wang-Koch method for optimization of IOL formulas with long ALs was developed and validated.[10] Upon validation of the Wang-Koch approach, the authors found that the mean numerical errors with optimized ALs were significantly reduced compared with the mean numerical errors with partial coherence interferometry (PCI) (IOLMaster 500, Carl Zeiss Meditec AG) ALs (IOLs >5.0 D: unadjusted mean numerical error range 0.27 to 0.68, adjusted range −0.10 to −0.02; IOLs ≤5.0 D: unadjusted range 1.13 to 1.87, adjusted range −0.21 to 0.01, $P < .05$ for all analyses). The optimized ALs were highly correlated to the ALs produced by PCI (R^2 from 0.960 to 0.976) and a significantly smaller proportion of patients was left hyperopic postoperatively. Nonetheless, it is currently uncertain whether similar conclusions could be reached in patient samples of different demographic and clinical characteristics. As such, we aimed to externally validate the Wang-Koch formula at a Canadian treatment center.

PATIENTS AND METHODS

In this single-center retrospective case series, consecutive patients with ALs greater than 25.0 mm having cataract surgery were recruited from TLC Laser Eye Centre, Mississauga, Ontario, Canada. Cataract surgery was assisted by a femtosecond laser or performed manually by 5 experienced surgeons from July 1, 2012, to July 31, 2015. This study adhered to the tenets of the Declaration of Helsinki and was approved by a local Institutional Review Board. Patients were included if they had preoperative optical biometry data and a predicted postoperative spherical equivalent (SE) as calculated by the Holladay 1 formula.[6] In addition, included patients were required to have a postoperative SE examination 3 weeks after cataract surgery. To increase homogeneity, patients were only included if they received 1 of the 4 most common implanted IOLs (ie, Acrysof IQ Toric SN6AT2-9 and Acrysof IQ SN60WF [both Alcon Laboratories, Inc.] and Tecnis ZCB00 and Tecnis Toric ZCT100-400 [both Abbott Medical Optics, Inc.]). The lens constants that were used at the treatment center were as follows: (1) Acrysof IQ Toric SN6AT2-9 = 1.96, (2) Acrysof IQ SN60WF = 1.85, (3) Tecnis ZCB00 = 2.00, and (4) Tecnis Toric ZCT100-400 = 2.00. In addition, eyes that had a corrected distance visual acuity (CDVA) worse than 20/40 at 3 weeks postoperatively were excluded.

Preoperatively, all included patients had anterior and posterior segment evaluations and biometry measurements. The Lens Opacities Classification System III[15] was used to grade all included cataracts. The target IOL power was calculated by the Holladay 1 formula and was measured with PCI in all patients. The Wang-Koch adjustment for the Holladay 1 formula was used to optimize measured, unadjusted ALs. The predicted postoperative SE using the Holladay 1 formula was computed using PCI for unadjusted ALs and adjusted ALs.

Patients were examined 1 day and 3 weeks postoperatively. At each follow-up visit, a complete slitlamp evaluation, applanation tonometry, and CDVA measurements were performed. The prediction errors for adjusted ALs and unadjusted ALs were then computed as the difference between the postoperative actual refractive outcome and the predicted refraction. A hyperopic refractive prediction error is denoted by a positive value in the prediction error.

Following the recommendations of an editorial by Hoffer et al.,[16] the primary endpoint of this study was the proportion of eyes with a prediction error of ±0.25 D or worse, ±0.50 D or worse, and ±1.00 D or worse. The MAE and median absolute

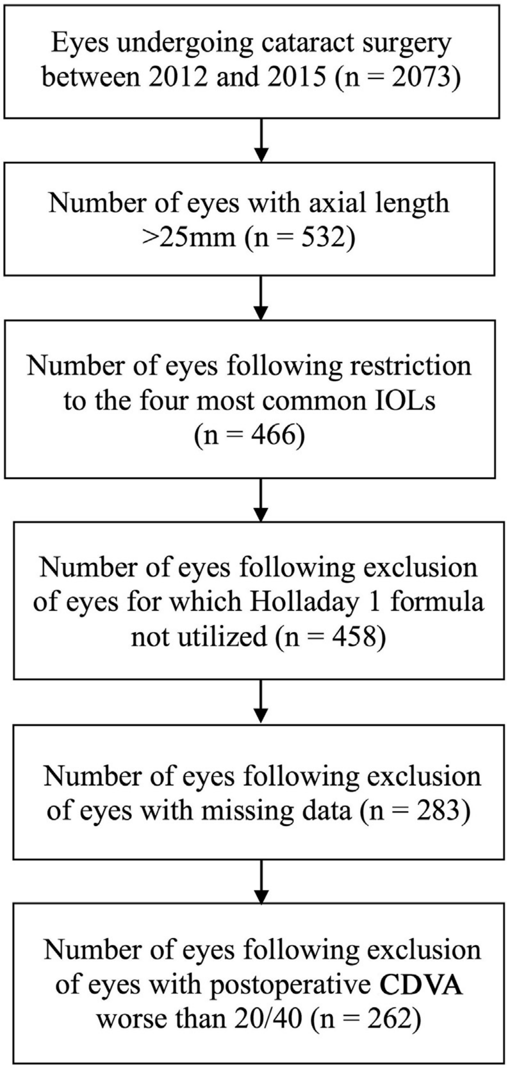

Figure 1. Flowchart for inclusion of study eyes.