CORRESPONDENCE

Wang-Koch axial length adjustment for the Holladay 2 formula in long eyes

Consistent hyperopic errors have been reported in long eyes whose axial lengths (ALs) were measured by A-scan, B-scan, or optical biometry.[1] This similarity in outcomes among the methods for measuring AL is anticipated because the optical path lengths measured by optical biometry were calibrated by regression to match ALs measured by immersion ultrasound.[2]

In a previous study,[3] we proposed a method of optimizing the AL to reduce hyperopic outcomes in patients with long eyes. We developed AL optimization formulas for 4 intraocular lens (IOL) power calculation formulas: Haigis,[2] Hoffer Q,[4] Holladay 1,[5] and SRK/T.[6] The purpose of this study was to develop an optimization equation for the Holladay 2[A] formula and compare it with the original Holladay 1 optimization formula (Wang-Koch Holladay 1 formula).

PATIENTS AND METHODS

Institutional Review Board approval was obtained for this study. Two datasets were included in this study. Dataset 1 comprised eyes with an AL greater than 25.0 mm that had cataract extraction and IOL implantation by the same surgeon (D.D.K.). Dataset 2 comprised eyes with an AL of 18.97 to 31.43 mm; 145 surgeons contributed cases.[7] Biometric measurements were performed with optical low-coherence reflectometry (OLCR) (Lenstar, Haag-Streit AG). One eye of each patient was included. The detailed inclusion criteria have been described.[3,7]

The development method of optimizing AL was described in a previous study.[3] Briefly, for each eye, the "optimized" or "ideal" AL (optimized-AL) that would produce a refractive prediction error of zero was back-calculated. The ALs for 2 formulas (Holladay 1 and Holladay 2) were optimized. Linear regression analysis in dataset 1 and nonlinear regression analysis in dataset 2 were used to assess the association between the optimized AL and the AL displayed on the OLCR (OLCR-AL). The optimized-AL values calculated using the Holladay 1 and Holladay 2 optimization equations developed in this study were compared to optimized-AL values calculated using the original Wang-Koch Holladay 1 formula.[3]

RESULTS

Dataset 1

Dataset 1 comprised 131 eyes. The mean age of the patients was 67 years $\pm$ 10 (SD) (range 44 to 93 years), and the mean AL was 26.52 $\pm$ 1.61 mm (range 25.01 to 30.98 mm).

The optimized-AL values with linear Holladay 1 and Holladay 2 formulas were highly correlated with the OLCR-AL (both $P < .001$) (Figure 1). The optimization equations are as follows:

Linear Holladay 1 optimized-AL $= 0.8048 \times$ (OLCR-AL) $+ 4.9195$

Linear Holladay 2 optimized-AL $= 0.8332 \times$ (OLCR-AL) $+ 4.2134$

Dataset 2

Dataset 1 comprised 18 501 eyes. Polynomial nonlinear regression results showed that AL adjustment was needed in eyes with an AL greater than 24.0 mm, and the optimization equations are as follows:

Polynomial for Holladay 1 optimized-AL $= 0.00005 \times$ (OLCR-AL)$^5 - 0.00709 \times$ (OCLR-AL)$^4 + 0.43205 \times$ (OCLR-AL)$^3 - 13.11626 \times$ (OCLR-AL)$^2 + 199.12386 \times$ (OLCR-AL) $- 1190.39848$

Polynomial for Holladay 2 optimized-AL $= -0.00012 \times$ (OLCR-AL)$^3 + 0.00329 \times$ (OLCR-AL)$^2 + 1.00104 \times$ (OLCR-AL) $- 0.32701$

Comparison with Original Wang-Koch Holladay 1 Formula

For Holladay 1 and Holladay 2, respectively, the mean differences between the ALs optimized using the new

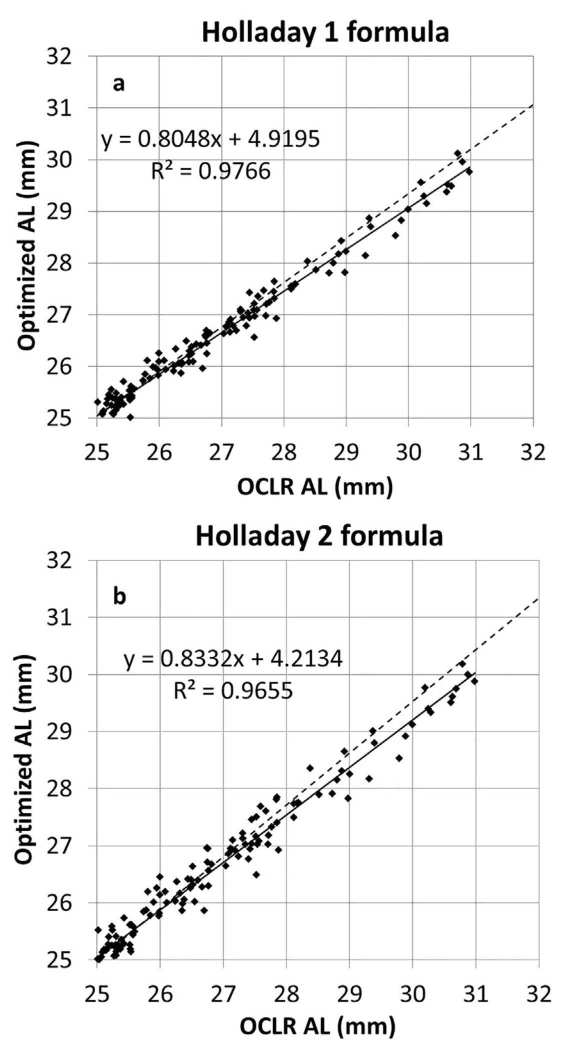

Figure 1. Correlation of OLCR AL and optimized AL for Holladay 1 (*a*) and Holladay 2 (*b*) with R^2 values of 0.977 and 0.966 (both $P < .001$) in dataset 1. For comparison, dashed lines for the nonlinear regression Holladay 1 and Holladay 2 equations from dataset 2 were added in the figures (AL = axial length; OLCR = optical low-coherence reflectometry).

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Table 1. Comparison of optimized AL using Holladay 1 and Holladay 2 optimization formulas developed in this study and those using the original Wang/Koch Holladay 1 formula.

	Optimized AL (mm) with Formulas					Difference in Optimized AL (mm)*			
OCLR AL (mm)	Wang/Koch Holladay 1[3]	Linear Holladay 1	Linear Holladay 2	Nonlinear Holladay 1	Nonlinear Holladay 2	Linear Holladay 1	Linear Holladay 2	Nonlinear Holladay 1	Nonlinear Holladay 2
24.00	NA	NA	NA	24.00	24.00	NA	NA	NA	NA
25.00	24.99	25.44	25.46	25.02	24.95	0.04	0.06	0.03	−0.04
26.00	25.82	25.84	25.88	25.92	25.90	0.03	0.06	0.10	0.08
27.00	26.65	26.65	26.71	26.78	26.83	0.00	0.06	0.13	0.18
28.00	27.48	27.45	27.54	27.63	27.75	−0.02	0.07	0.15	0.27
29.00	28.30	28.26	28.38	28.48	28.66	−0.05	0.07	0.18	0.35
30.00	29.13	29.06	29.21	29.34	29.55	−0.07	0.08	0.21	0.42
31.00	29.96	29.87	30.04	30.20	30.43	−0.09	0.08	0.24	0.47
32.00	30.79	NA	NA	31.05	31.30	NA	NA	0.26	0.50
33.00	31.62	NA	NA	31.88	32.14	NA	NA	0.26	0.52
34.00	32.45	NA	NA	32.69	32.98	NA	NA	0.24	0.53
35.00	33.28	NA	NA	33.48	33.79	NA	NA	0.21	0.52
36.00	34.11	NA	NA	34.30	34.59	NA	NA	0.19	0.48

AL = axial length; NA = data not available; OCLR = optical low coherence reflectometry
*Linear and nonlinear Holladay 1/2 − Wang/Koch Holladay 1

optimization equations and the original Wang-Koch Holladay 1 formula were −0.02 ± 0.05 mm (range −0.09 to 0.05 mm) and 0.04 ± 0.03 mm (range 0.00 to 0.09 mm) in dataset 1 and 0.18 ± 0.07 mm (0.03 to 0.26 mm) and 0.36 ± 0.18 mm (−0.04 to 0.53 mm) in dataset 2 (Table 1).

DISCUSSION

In dataset 1 comprising eyes with an AL greater than 25.0 mm, a linear relationship was observed between the optimized-ALs and the OLCR-ALs. There were minimal differences in optimized-ALs calculated using the new linear optimization equations for the Holladay 1 and Holladay 2 formulas or the original Wang-Koch Holladay 1 formula, with a maximum absolute difference 0.09 mm. To prevent hyperopic outcomes, the Wang-Koch Holladay 1 formula is aggressive and slightly myopic results may occur.[7–9]

In dataset 2 comprising eyes with an AL ranging from 18.97 to 31.43 mm, nonlinear regression analysis in the whole dataset showed that AL adjustment was needed in eyes with an AL greater than 24.0 mm. The AL adjustments using the nonlinear equations are different for Holladay 1 and Holladay 2 formulas and are less aggressive than the Wang-Koch Holladay 1 formula. Because the mean prediction error is zero using the nonlinear equations, there is an equal probability of myopic and hyperopic prediction errors. Therefore, when using the nonlinear equations, we recommend targeting for mild myopia (≤−0.25 D) to reduce the risk for a hyperopic result. Further studies are needed to evaluate the accuracy of these optimization formulas.

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OTHER CITED MATERIAL

A. Holladay JT. Holladay IOL Consultant Software & Surgical Outcomes Assessment. Bellaire, TX, Holladay Consulting, 2015 Available at: http://www.hicsoap.com. Accessed July 2, 2018

ERRATA

In the October 2018 article, “Wang-Koch axial length adjustment for the Holladay 2 formula in long eyes” (J Cataract Refract Surg. 2018 Oct;44:1291-1292):

1. Corrected Table 1.
2. Polynomial equations with more digits after the decimal:
   a. Polynomial for Holladay 1 optimized-AL $= 0.0000462655 \times (\text{OCLR-AL})^5 - 0.0070852534 \times (\text{OCLR-AL})^4 + 0.4320542309 \times (\text{OCLR-AL})^3 - 13.1162616532 \times (\text{OCLR-AL})^2 + 199.123862943 \times (\text{OCLR-AL}) - 1190.3984759734$
   b. Polynomial for Holladay 2 optimized-AL $= -0.0001154786 \times (\text{OCLR-AL})^3 + 0.0032939472 \times (\text{OCLR-AL})^2 + 1.001040305 \times (\text{OCLR-AL}) - 0.3270056564$

Table 1. Comparison of optimized AL using Holladay 1 and Holladay 2 optimization formulas developed in this study and those using the original Wang/Koch Holladay 1 formula.

OCLR AL (mm)	Optimized AL (mm) with formulas					Difference in optimized AL (mm)*			
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28.00	27.48	27.45	27.54	27.63	27.75	−0.02	0.07	0.15	0.27
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31.00	29.96	29.87	30.04	30.20	30.43	−0.09	0.08	0.24	0.47
32.00	30.79	NA	NA	31.05	31.30	NA	NA	0.26	0.50
33.00	31.62	NA	NA	31.88	32.14	NA	NA	0.26	0.52
34.00	32.45	NA	NA	32.69	32.98	NA	NA	0.24	0.53
35.00	33.28	NA	NA	33.48	33.79	NA	NA	0.21	0.52
36.00	34.11	NA	NA	34.30	34.59	NA	NA	0.19	0.48

AL = axial length; NA = data not available; OCLR: optical low coherence reflectometry
*Linear and nonlinear Holladay 1/2 – Wang/Koch Holladay 1

In the September 2018 article, “Effect of phenylephrine 1.0%–ketorolac 0.3% injection on tamsulosin-associated intraoperative floppy-iris syndrome” (J Cataract Refract Surg 2018; 44:1103–1108), there is an error in an author’s name. The correct name is Nariman Nassiri, not Nissiri Nariman as printed.

The author list should be corrected as follows: Steven M. Silverstein, MD, Viren K. Rana, MS, Robert Stephens, PhD, Larry Segars, PharmD, DrPH, Joseph Pankratz, MS, Shivani Rana, Mark S. Juzych, MD, MHSA, Nariman Nassiri, MD, MPH