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ORIGINAL RESEARCH

Predicting the refractive outcome and accuracy of IOL power calculation after phacoemulsification using the SRK/T formula with ultrasound biometry in medium axial lengths

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Purpose: To evaluate the accuracy of the SRK/T formula using ultrasound (US) biometry in predicting a target postoperative refraction of ±1.00D in eyes with medium axial length (AL) that underwent phacoemulsification.

Methods: The present study was a retrospective analysis, which included 538 eyes with an AL from 22.0 to 24.60 mm that underwent phacoemulsification and foldable intraocular lens (IOL) implantation (six different IOLs) in the bag. Preoperative AL was measured by US biometry and IOL power (IOLp) was calculated with the SRK/T formula. Patients had a complete ophthalmic examination, preoperatively and 1, 7, and 30 days after surgery. The achieved spherical equivalent (SE) and the prediction error (PE) were calculated. The prediction error was defined as the difference between attempted predicted target refraction and the achieved postoperative SE refraction. Statistical analysis was performed with SPSS V21.

Results: The mean age of the patients was 66.96±9.67 years, the mean AL was 23.29±0.62 mm, the mean K1 was 43.62±1.49D, the mean K2 was 43.69±1.53D, the mean IOL power was 21.066±1.464D, the mean attempted (predicted) SE was –0.178±0.266D, and the mean achieved SE was –0.252±0.562D. The mean PE (difference between predicted and achieved SE) showed a relatively hyperopic shift (mean ± standard deviation: 0.074±0.542D, ranging from –1.855 to 2.170D, P=0.001). A total of 93.87% of eyes were within ±1.00D of the PE and 92.75% of eyes within ±1.00D of achieved postoperative refraction. A total of 39 eyes (7.25%) had a refractive surprise. A total of 32 of 39 eyes were more myopic than –1.00D and 7 of them were more hypermetropic than +1.00D. There was no correlation between the mean PE and IOL type, AL, K1, K2, and IOLp. There were a positive statistically significant correlation between PE and age (r=0.095; P=0.028) and a negative statistically significant correlation between achieved SE and AL (Spearman's r=–0.125; P=0.04), and age (r=–0.141; P=0.01).

Conclusion: The IOLp calculation using the SRK/T formula with US biometry may demonstrate very good postoperative refractive outcomes in medium eyes with a few refractive surprises.

Keywords: axial length, biometry, cataract surgery, IOL power calculation, prediction error, SRK/T formula

Introduction

An accurate biometry and appropriate intraocular lens power (IOLp) formula selection in cataract surgery is very important for postoperative patient satisfaction.[1] Measurement, IOL calculation formula, IOL insertion, and lens constant's errors are the main sources of postoperative refractive errors.[2–13] Forty-three and sixty-seven percent of large refractive surprises are due to inaccurate preoperative measurement

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(axial length [AL] or keratometry). An error of 1 mm in measurement of AL leads to approximately an error of 2.88D in postoperative refractive error or 3.00–3.50D in calculation of IOLp (depending on the AL of the eye), and an error of 1D in keratometric reading (K) leads to approximately an error of 0.9–1.00D in calculation of IOLp.[2–6]

Third- and fourth-generation formulas are now the most preferred formulas.[7–16] The SRK/T (T for theoretical) is one of the third-generation formulas that was developed by Retzlaff et al, representing a combination of linear regression method with a theoretical eye model. This formula uses the A-constant to calculate the anterior chamber depth (ACD), using the retinal thickness and corneal refractive index. The ACD constant for SRK/T is provided by the manufacturer or calculated from the SRK-II A-constant by using the following formula: ACD = (0.62467× A) −68.747.[10,11,15]

Two biometry methods are presently in use: ultrasound (US) (contact/applanation, immersion, and immersion vector A/B-scan) and optical biometry (partial coherence interferometer). Partial coherence interferometry-based instruments, such as Zeiss IOL Master and Haag-Streit Lenstar, are most commonly used for IOLp calculation. IOL Master (IOLm) is regarded as the gold standard in optical biometry. However, US biometry remains the preferred method for measuring AL and calculating IOLp, due to familiarity with the technique and cost in developing countries or when measurements by optical biometry are inadequate due to dense ocular media such as mature or hypermature cataract, severe posterior capsular opacity, or a posterior segment abnormality such as vitreous hemorrhage or poor fixation.[17–24]

The purpose of this study was to evaluate the performance of the SRK/T formula using US biometry in predicting a target postoperative refraction of ±1.00D in eyes with medium AL after phacoemulsification and foldable lens implantation.

Methods

This retrospective review included 538 eyes of 362 patients who underwent a standardized small-incision phacoemulsification surgery and foldable IOL implantation in the bag through a 3.0–3.2 mm temporal clear corneal incision by a single surgeon (YK) with the same technique at Nisa Hospital from May 2005 to June 2012. Phacoemulsification was performed using Sovereign Compact Cataract Extraction System (Abbott Medical Optics Inc., Abbott Park, IL, USA). Six different IOLs were used: Softec 1 (Lenstec Inc., St Petersburg, FL, USA), Dr Schmidt (HumanOptics AG, Erlangen, Germany), Acriva (VSY Biotechnology, Istanbul, Turkey), AcrySof MA30AC (Alcon, Fort Worth, TX, USA) AlconSA60AT (Alcon), and Alcon AcrySof IQ (Alcon).

Exclusion criteria were the following: 1) eyes with AL <22.00 mm or >24.60 mm, 2) incomplete preoperative and postoperative data, 3) intraoperative and postoperative complications, 4) monocular patients, 5) pre-existing astigmatism >2.5D, 6) history of previous ocular surgery or injury, 7) presence of associated ocular pathologies (such as uveitis, zonular dialysis, corneal disease or dystrophy, glaucoma), and 8) diabetes mellitus with or without retinopathy.

Preoperatively, all patients underwent a full ophthalmologic examination, including measurement of uncorrected distance visual acuity, corrected distance visual acuity, intraocular pressure, simulated keratometry with an auto kerato-refractometer (Topcon KR 8000, Tokyo, Japan), slit-lamp biomicroscopy, and fundus examination. The AL was determined by A Scan ultrasonic biometer (EZ AB5500+ A-Scan/B-Scan; Sonomed Inc., Lake Success, NY, USA) with applanation technique under topical anesthesia before surgery in all eyes. The SRK/T formula was chosen to predict the IOLp calculation. The manufacturer's suggested A-constants were used for the IOL types. The goal in IOLp selection was to achieve a postoperative refraction of ±1.00D accurate. All examinations and calculations were performed by the same surgeon.

All patients had a record of the first day, first week, and about first month after the surgery. First month postoperative objective refraction of eyes culled from medical records was converted into spherical equivalent (SE), which was taken as the achieved postoperative refraction. Achieved postoperative refraction were compared with the attempted predicted preoperative refraction. The prediction error (PE) was calculated from the difference between the attempted predicted refraction and achieved postoperative refraction based on SE (PE = attempted predicted refraction-achieved postoperative refraction).

The retrospective study was approved by the Ethics Committee of Istanbul Medipol University (2015/346), and conducted in accordance with the tenets of the Declaration of Helsinki by obtaining written informed consent from all patients.

Statistical analysis

SPSS statistical software Version 21.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Parameters were analyzed as mean ± standard deviation. A test of the normality of the data distribution was performed using the

Kolmogorov-Smirnov and Shapiro-Wilk tests. Correlation analysis between the parameters was made using the Pearson's and Spearman's rank correlation coefficient depending on the normality of the data. Linear regression analysis was performed for the statistically significant correlation. Wilcoxon signed ranks test was used to calculate difference between attempted and achieved SE. The one-way analysis of variance (ANOVA) test was used to compare PE and the groups of different IOL types. The confidence interval was 95%, and $P<0.05$ was considered statistically significant.

Results

Totally, 538 eyes (270 [50.2%] right eyes and 268 [49.8%] left eyes) of 362 patients were included in the study. A total of 178 (49.17%) of them were females and 184 (50.83%) were males. The mean age of the patients was 66.96±9.67 years (range 40–90 years), the mean AL was 23.29±0.62 mm (range 22.01–24.57 mm), the mean K1 was 43.62±1.49D (range 39.75–47.50D), the mean K2 was 43.69±1.53D (range 39.25–47.50), the mean IOLp was 21.066±1.464D (range 16.00–25.00), the mean attempted (predicted) value was –0.178±0.266D (range –0.90–1.00D), and the mean achieved postoperative SE was –0.252±0.562D (range –2.50 to 1.625D). A total of 92.75% of the eyes were within ±1.00D of the achieved postoperative SE. Unpredicted refraction outside ±1.00D was found in 39 (7.25%) eyes; 32 (82.05%) of them were more myopic than –1.00D and 7 (17.95%) of them were more hyperopic than +1.00D. The mean PE was 0.074±0.542D (range –1.855 to 2.170D), and the difference showed a little tendency toward hyperopic shift (P=0.001). The majority of the eyes (93.87%) were within ±1.00D of the PE. PE was more myopic than –1.00D in 10 eyes (1.86%) and more hyperopic than +1.00D in 23 eyes (4.275%) (Table 1 and Figure 1).

Table 1 Distribution of the prediction error (difference between attempted and achieved SE) in medium eyes using SRK/T formula and ultrasound biometry (n=538)

Range of SE (D)	n	%
Within ±0.25	208	38.66
Within ±0.50	374	69.51
Within ±1.00	505	93.87
>+1.00 (more hyperopic than predicted)	23	4.275
≥+1.50	9	1.67
≥+2.00	2	0.37
More myopic than predicted –1.00	10	1.86
More myopic than –1.50	2	0.37

Abbreviations: D, diopter; n, number of operated eyes; SE, spherical equivalent.

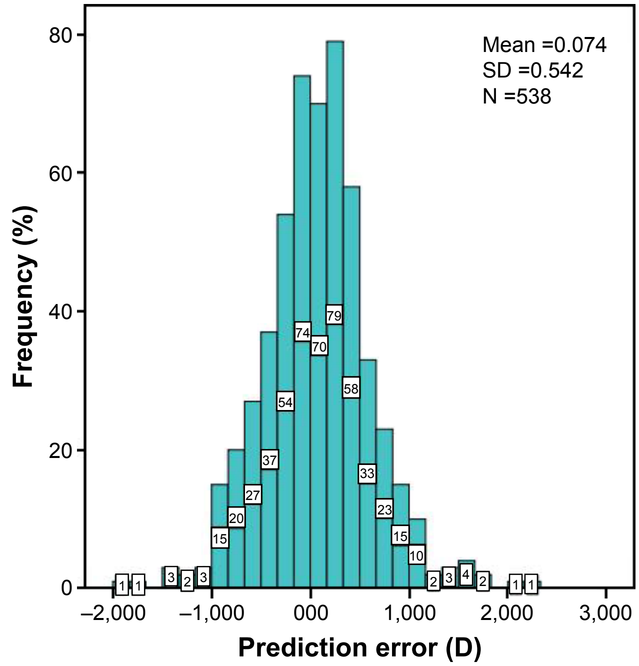

Figure 1 Histogram shows the frequency of prediction error.
Abbreviation: SD, standard deviation.

The results for the prediction accuracy are detailed in Table 1.

The frequency of PE is shown on histogram in Figure 1.

In this study, different IOLs were implanted in the bag based on availability and the surgeon's choice. The distribution of IOLs was as follows: Softec 1 IOL (n: 402; 74.7%), Dr Schmidt IOL (n: 75; 13.9%), Acriva IOL (n: 53; 9.9%), Alcon IQ IOL (n: 4; 0.7%), Alcon SA60 AT IOL (n: 3; 0.6%), and Alcon MA30 IOL (n: 1; 0.2%). The mean PE was 0.089±0.544 for Softec 1 IOL, 0.080±0.581 for Dr Schmidt IOL, 0.0067±0.426 for Acriva IOL, –0.66±0.471 for Alcon IQ, and –0.070±0.600 for Alcon SA60 AT. No statistically significant differences were found between types of IOLs and PE (P=0.069; with one-way ANOVA test).

Although a statistically significant positive correlation was found between PE and age (r=0.095; P=0.028), no statistically significant correlation was found between PE and AL, K1, K2, and IOLp (Figure 2A). There was a statistically significant negative correlation between achieved postoperative SE and age (r=–0.141; P=0.01), and AL (r=–0.125; P=0.04) (Figure 2B and C). There was no correlation between achieved postoperative SE and K1, K2, and IOLp. These correlations were analyzed by using linear regression. r^2, t, and P were 0.010, 2.355, and 0.019, respectively, for the regression analysis between PE and age; 0.019, –3.222, and 0.001, respectively, for achieved

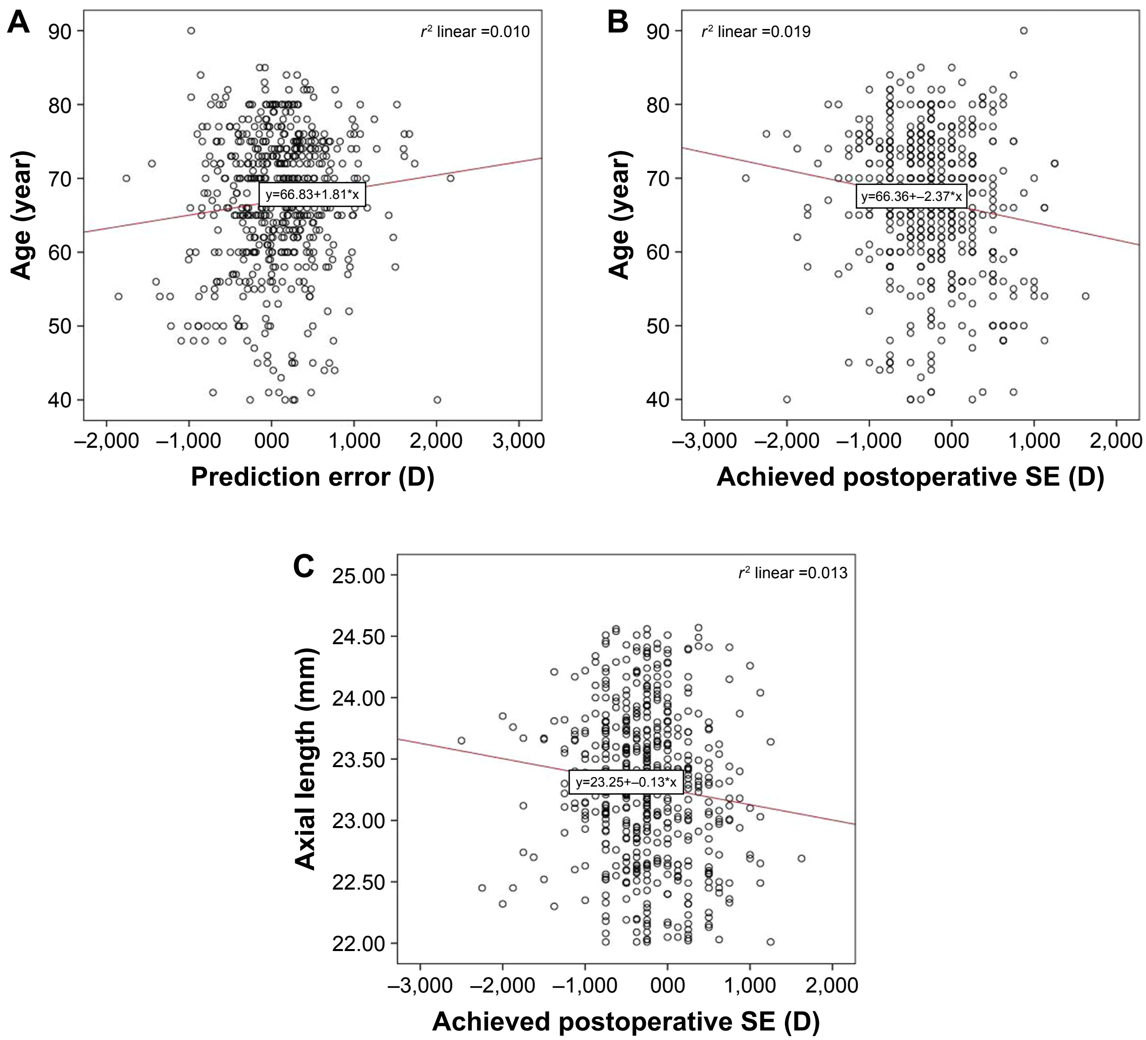

Figure 2 (**A**) Scatter plot of prediction error versus age; (**B**) achieved postoperative SE versus age; (**C**) achieved postoperative SE versus AL.
Abbreviations: AL, axial length; D, diopter; SE, spherical equivalent.

postoperative SE and age; and 0.013, –2.631, and 0.009, respectively, for achieved postoperative SE and AL. *P*-values were lower than 0.05 (statistically significant) and r^2 values were very close to zero.

Discussion

Various theoretical and regression IOL calculation formulas have been used since Fedorov et al in 1967.[25] However, there is no consensus as to which formula is the best.[26] Today, third-generation formulas such as the Holladay 1, the Hoffer Q, and the SRK/T; fourth-generation formulas such as the Holladay 2, the Haigis, and the Olsen; and newer formulas are the most commonly used in all eyes. They work well and provide similar results in eyes with medium AL.[7–13]

We sought to evaluate the performance of the SRK/T formula using US biometry after phacoemulsification in 538 eyes with medium AL and to share our experience. One of the most important results of our study was a prediction accuracy of 38.66% for refractive errors of ±0.25D, 69.51% for refractive errors of ±0.50D, and 93.87% for refractive errors of ±1.00D (Table 1). PE is also known as deviation from intended refraction and the difference between the preoperative predicted refraction and the achieved postoperative refraction. It is known that a negative mean PE indicates a tendency for myopic refractive outcomes, whereas a positive mean indicates a tendency for hyperopic refractive outcomes.[21] We found that PE showed a slight tendency toward hyperopic shift with PEs of 0.074±0.541D. PE was more hyperopic than +1.00D in 23 eyes (4.275%) and more myopic than –1.00D in 10 eyes (1.86%). Two eyes (0.37%) had a difference of more than +2.00D in PE (Table 1).

These results were similar to previous studies and even better than those for the target predictive refraction within ±1.00D. Aristodemou et al[14] used an unselected data set of

1677 cases to compare the formulas of SRK/T, Holladay, SRK-II, Hoffer, and Binkhorst II. For errors <0.5D, the outcome was 50% and for errors <1.00D the outcome was 80% with SRK/T formula. This study included a large group of cases with different ALs from different surgical centers and different surgeons using different IOLs.

Sanders et al[11] used a data set of 990 unselected cases using different IOLs from multiple surgeons and reported outcomes of 29%, 79%, and 95.3% with SRK/T formula for <0.5D, 1.00D, and 2.0D, respectively (76% of the patients had ALs between ≥22 and <24.5 mm and the authors reported 81% of cases within ±1.00D). For unselected cases, the SRK/T and Holladay formulas were considered as the best.

Hoffer[7] published a cataract surgery series including 450 cases (325 of them had medium AL). All cataract operations were performed by a single surgeon and only one IOL type was implanted (nonfoldable, polymethylmethacrylate [PMMA]) through a large incision. In that study, the mean PE was 94.8% for Holladay 1, 93.2% for Hoffer Q, and 94.5% for SRK/T formula within ±1.00D in 325 eyes with medium ALs (from 22.0 to 24.5 mm). Hoffer reported that SRK/T, Holladay, and Hoffer Q formulas were statistically similar and better than SRK-II with ALs >26.00 mm.

Olsen and Gimbel[12] reported that the mean PE was 0.41±0.91D (range −2.28 to +2.96D) for ALs of 22.5–24.5 mm and PE was within ±1.00D in 87% of cases with short, medium, and long ALs (range 18.92–37.45 mm). Eleven different IOL types from six different companies with different A-constants and IOL designs were used in their study.

Lagrasta et al[27] showed a prediction accuracy of 24% for refractive error within ±0.25D, 55% for refractive error within ±0.50D, and 91% for refractive error within ±1.00D using SRK/T formula with US biometry in 33 eyes of 33 patients with medium ALs (22.2–24.5 mm). The mean attempted predicted SE was −0.431±0.181D (range −0.02 to −0.72D), the mean achieved postoperative SE was −0.220±0.732D (range +1.75 to −1.625D), and the mean PE was 0.211±0.708D (range −1.07 to 2.33D). In that study, four types of AcrySof IOLs were implanted in the bag through a sutureless 3 mm incision.

Corrêa et al[28] conducted a retrospective review in 81 patients with AL of 22–25 mm using the SRK/T formula and US biometry and presented residual refractive errors within ±0.50, between ±0.51 and ±1.25D, between ±1.26 and ±2.00D, and within ±1.25D in 40.7%, 35.7%, 9.87%, and 76.4% of patients, respectively.

Hubaille et al[29] compared the preoperative target ametropia, calculated with the SRK/T formula, with the postoperative refraction after extracapsular extraction by phacoemulsification and implantation of different posterior chamber lenses (nonfoldable PMMA lens, PMMA-copolymer foldable lens, and acrylic foldable lens) in a retrospective review. They found the error within ±0.75D in 78% and ±1.00D in 88% of cases.

Rajan et al[30] conducted a prospective study in 100 patients who underwent phacoemulsification. Patients were randomized to undergo biometry by either IOLm or the applanation US. The preoperative mean AL was 23.47±1.1 mm (range 20–27.6 mm) in the partial coherence laser interferometry (PCLI) group and 23.43±1.2 mm (range 20.1–27 mm) in the US group. The mean absolute error (MAE) in the US group was 0.62±0.40D. Eighty-seven percent of patients were within ±1.00D in the PCLI group as compared to 80% in the US group (*P*=0.24). The eyes that underwent PCLI had increased tendency for a hyperopic shift (65%), when compared to eyes in the US group (50%).

Bhatt et al[31] reported that 71.3% of eyes were within ±1.00D, 37.5% of eyes were within ±0.50D, and 18.8% of eyes were within ±0.25D with predictions made by using US biometry and SRK/T formula in their retrospective study including 421 eyes of 304 patients. The mean PE was −0.43±0.84D for IOLm and −0.60±0.87D for US biometry.

Narváez et al[32] compared the four formulas (Hoffer Q, Holladay 1, Holladay 2, and SRK/T) in 643 eyes with different ALs using immersion US biometry and found no difference in accuracy between them in four subgroups of ALs. In that study, the MAE was 0.52±0.43D (range 0.00–2.49) in 437 eyes with medium AL (22.0–<24.49 mm) using SRK/T formula.

One of the most important sources of error in ultrasonic biometry is the measurement of the shorter AL, which is caused by excessive pressure on the cornea. This error results in a postoperative myopic refractive surprise.[2–6] In our study, 92.75% of eyes were within ±1.00D of the achieved postoperative SE and this is a quite high rate. However, 39 eyes (7.25%) had a refractive surprise. A total of 32 (82.05%) of 39 eyes were more myopic than −1.00D and 7 (17.95%) of them were more hyperopic than +1.00D. Although all biometric measurements were performed by the same doctor with a high biometry experience, it is thought that the most probable error source is the AL measurement error.

We found a positive statistically significant correlation between PE and age (*P*=0.028), but no statistically significant correlation between PE and AL, IOLp, IOL types, K1, and K2. Additionally, we found a negative statistically significant correlation between AL and achieved postoperative SE (P=0.004; as AL increased, achieved postoperative SE decreased). A negative statistically significant correlation between achieved postoperative SE and age was also found (P=0.01; as age increased, PE decreased) (Figure 2A–C). Since the r^2 (0–1) found in the regression analyzes we made to demonstrate the power of the relationship between the parameters were far away from 1 (ie, 100%), it was concluded that the significant correlation between each two variables ($P<0.005$) alone was not sufficient to explain the model.

The strengths of the study are the large sample size, uniformity of the biometric date, same surgery technique, single surgeon and use of one formula. The advantage of using one formula is that the postoperative results can be compared with the preoperative prediction.

The weaknesses of the study are retrospective nature, six different IOL types, different A-constant for the IOL type, use of only one formula (SRK/T) for the IOLp calculation (due to the lack of comparability of different formulas), and use of only one biometry technique.

Conclusion

The results of our study showed that the SRK/T formula is an accurate and a good option to predict the refractive error after phacoemulsification and foldable IOL implantation in eyes with medium AL. The mean PE showed a little tendency toward hyperopic shift. As in our study, a few refractive surprises can be observed. Therefore, all parameters for IOLp calculation should be measured accurately and especially ultrasonic biometry should be done carefully.

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Disclosure

The authors report no conflicts of interest in this work.

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