Biometric error analysis after cataract surgery performed by residents, in patients with high myopia with SRK/T formula and Wang-Koch formula adjustment

Análise de erros biométricos após cirurgia de catarata realizada por residentes em pacientes com alta miopia com a fórmula SRK/T com ajuste pela fórmula Wang-Koch

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ABSTRACT

Objective: To evaluate intraocular lens power calculation and postoperative refractive errors in patients with high myopia undergoing cataract surgery, comparing predicted target refraction and actual postoperative refraction measured 30 days after surgery with SRK/T formula.

Methods: This retrospective analysis comprised 39 eyes of 31 patients undergoing cataract surgery through phacoemulsification with in-the-bag IOL implantation. Axial length was measured by partial coherence interferometry or immersion ultrasound biometry, with measurements greater than 26 mm and preoperative myopia greater than -6.0 D Manifest refraction was performed at the 1-month postoperative visit, and the spherical equivalent was analyzed.

Results: After analysis of 39 eyes of 31 patients undergoing cataract surgery with a mean axial length of 30.4 (standard deviation of 2.2) mm, the mean preoperative refractive spherical equivalent was -15.6 (standard deviation of 7.6) D, ranging from -24.0 to -13.4 D. At 30 days postoperatively, the mean spherical equivalent was -0.35 (standard deviation of 1.1) D, ranging from -2.4 to 2.50 D.

Conclusion: We encountered a correlation between the absolute refractive error and the dioptric power of the intraocular lens. Against expectations, in our study, ultrasound biometry yielded better results than the optical biometer device, probably due to the small number of patients undergoing optical biometry, suggesting that well-performed immersion biometry can still produce satisfactory results.

RESUMO

Objetivo: Avaliar os cálculos de potência da lente intraocular e os erros refrativos pós-operatórios em pacientes com alta miopia submetidos à cirurgia de catarata, comparando a refração-alvo prevista e a refração pós-operatória real medida 30 dias após a cirurgia com a fórmula SRK/T.

Métodos: Esta análise retrospectiva incluiu 39 olhos de 31 pacientes com cirurgia de catarata de facoemulsificação não complicada com implantação de lente intraocular na bolsa. Os comprimentos axiais foram medidos por biometria de coerência óptica ou ultrassônica (imersão), com medidas de *axial length* (AL) maiores que 26 mm em pacientes com miopia maior que -6.0 D. A refração manifesta foi realizada na consulta pós-operatória de 1 mês, e o equivalente esférico foi analisado.

Resultados: Após análise de 39 olhos de 31 pacientes submetidos à cirurgia de catarata com AL médio de 30,4 (desvio-padrão de 2,2) mm, o equivalente esférico refrativo médio pré-operatório foi de -15,6 (desvio-padrão de 7,6) D, variando de -24,0 a -13,4 D. Aos 30 dias de pós-operatório, o equivalente esférico médio foi de -0,35 (desvio-padrão de 1,1) D, variando de -2,4 a 2,50 D.

Conclusão: Encontramos uma correlação entre o erro refrativo absoluto e o poder dióptrico da lente intraocular. Contrariando as expectativas, em nosso estudo, a biometria ultrassônica apresentou melhores resultados que o biômetro óptico, provavelmente devido ao pequeno número de pacientes submetidos à biometria óptica, sugerindo que a biometria de imersão bem executada ainda pode produzir resultados satisfatórios.

INTRODUCTION

Pathological or high myopia (HM) is associated with a refractive error greater than or equal to 6 diopters (D) or an elongation of the axial length (AL) of at least 26 mm.[1,2] Several studies have estimated the prevalence of HM, with rates of 0.98% in the Beijing Eye Study,[3] 0.53% in Central India,[2] 2.7% in Europe,[4] and 8.4% in Singapore, among adults over 40 years of age.[5]

High myopia increases the risk of other eye conditions. For example, a significantly higher incidence of cataracts has been reported in HM eyes, which have faster disease progression than non-myopic eyes.[6]

Calculating intraocular lens (IOL) power in HM eyes remains challenging, often leading to unexpected postoperative refractive errors.[7,8] The main potential sources of error in IOL power calculation for HM eyes include AL measurement (due to posterior staphyloma), IOL constants, and the formula used to calculate IOL power.

Third-generation formulas (Holladay 1, SRK/T, and Hoffer Q) and fourth-generation formulas (Haigis and Holladay 2) have been most widely studied.

A new-generation formula (Barrett Universal II) is available for commercial use and has shown promising performance IOL power calculation.[8]

This study evaluated IOL power calculations and postoperative refractive errors in patients with HM undergoing cataract surgery by comparing the predicted target refraction and the actual postoperative refraction measured 30 days after surgery and to compare results with optical and ultrasound biometer.

The objective of this study was to evaluate intraocular lens power calculation and postoperative refractive errors in patients with high myopia undergoing cataract surgery, comparing predicted target refraction and actual postoperative refraction measured 30 days after surgery with SRK/T formula with optical and immersion biometry.

METHODS

All patients who underwent uncomplicated cataract surgery with IOL implantation (MA60AC, Alcon Laboratories, Inc., Fort Lauderdale, FL, United States; MA60MA, Alcon Laboratories, Inc., RayOne Aspheric, Rayner Intraocular Lenses, Ltd, Worthing, UK; or SN60WF, Alcon Laboratories, Inc.) at *Unidade Paulista de Oftalmologia*, an ophthalmology clinic in São Paulo, Brazil, from January 1st, 2015, to December 31, 2019, were eligible.

Third-year residents specializing in cataract surgery performed all surgeries. Surgery was performed by phacoemulsification through a temporal clear cornea incision using the Sovereign Compact system (Abbott Medical Optics, Santa Ana, CA, United States). Institutional review board approval was obtained for this study.

Selection criteria

The inclusion criteria were AL of more than 26.0 mm (with preoperative myopia greater than -6.0 D) and cataract extraction through phacoemulsification with in-the-bag IOL implantation through a 2.75-mm clear corneal incision located temporally or superiorly. Patients were excluded if they had a keratometric cylinder >4.0 D, a history of previous intraocular surgery or postoperative complications, preexisting ocular conditions that could influence postoperative refraction (such as keratoconus, corneal scarring, endothelial dystrophy, retinal detachment, and macular edema), invalid biometry, or missing postoperative refractive information.

The patients had biometric measurements by partial coherence interferometry (IOLMaster 500, Software V5.4 and above; Carl Zeiss Meditec, Inc., Dublin, CA, USA) or immersion ultrasound biometry (OcuScan RxP; Alcon Laboratories, Inc., Fort Worth, TX, USA), depending on device availability. Preoperatively, the optical biometer (OB) device was used for both AL and keratometry measurements. Postoperatively, AL was measured by immersion ultrasound biometry, and keratometry was performed using an auto kerato-refractometer (KR-8900; Topcon Co., Tokyo, Japan).

Manifest refraction was performed at the 1-month postoperative visit with an ophthalmologist, and the spherical equivalent was analyzed.

Formula calculations

We performed spherical equivalent formula predictions with the open-source SRK/T formula.[9] As suggested by Wang et al., based on the association of many of the theoretical "thin-lens optic" formulas with hyperopic outcomes in long eyes, AL measurements in these eyes should be adjusted to offset this potential error. To this end, applying the Wang-Koch (W-K) AL adjustment for the Haigis, Hoffer Q, Holladay, and SRK/T formulas to eyes over 25.0 mm is recommended. In the present study, we used the first linear version of (W-K) adjustment in all cases using the formula 1.[9,10]

$$\text{SRK/T optimized AL} = 0.8981 \times \text{IOLMaster AL} + 2.5637 \quad \text{Formula 1}$$

We analyzed the preoperatively planned target and the actual spherical equivalent measured 30 days after surgery to estimate the postoperative absolute refractive error. We determined the biometric error as the difference between the actual spherical equivalent outcome and the predicted spherical equivalent (target).

Statistical analysis

We tested the normality of data distribution by the Shapiro-Wilk test. We used Pearson's correlation coefficient to determine the correlation between quantitative variables. We used Student's t-test for paired samples to compare formula absolute prediction errors. We analyzed the data in STATA 11 SE and set the level of statistical significance at $p \leq 0.05$ for all analyses.

RESULTS

We analyzed 39 eyes of 31 patients who underwent cataract surgery. The mean AL was 30.4 (standard deviation [SD] 2.2) mm, ranging from 27.0 to 34.7 mm.

The mean preoperative refractive spherical equivalent was -15.6 (SD of 7.6) D, ranging from -24.0 to -13.4 D. At 30 days after surgery, the mean spherical equivalent was -0.35 (SD of 1.1) D, and it ranged from -2.4 to 2.50 D. As expected, the spherical equivalent improved significantly after cataract surgery ($p < 0.001$).

Patients had biometric measurements by two different methods (immersion biometry and OB). We evaluated the mean biometric error for each group separately. Of 39 eyes, 29 underwent immersion biometry, and 10 underwent optical biometry. The mean absolute refractive error was 0.2 (SD of 1.1) with immersion biometry and 0.71 (SD of 1.1) with optical biometry, with no statistical significance in either group ($p = 0.363$ and $p = 0.254$, respectively) (Table 1).

Table 1. Results with two different biometers

Absolut error *versus* refractive target				
Biometer	Refractive absolute error	Target	Postoperative equivalent	p-value
Immersion (n = 29)	0.20 ± 1.1	-0.76 ± 0.5	-0.56 ± 1.1	0.363
IOL Master (n = 10)	0.71 ± 1.1	-0.67 ± 0.3	0.2 ± 0.6	0.254

Results expressed as mean ± standard deviation.
IOL: intraocular lens.

We used the SRK/T formula in this study and applied the W-K adjustment. The mean absolute error for the SRK/T formula was 0.48 (SD of 1.3), which was statistically significant ($p = 0.026$) (Table 2).

Three types of lenses were used: MA60AC (6 eyes), MA60MA (29 eyes), and SN60WF (4 eyes). The absolute refractive error was not significantly different ($p = 0.045$).

Table 2. Results with SRK/T formula

Formula	Refractive absolute error	Target	Postoperative equivalent	p-value
SRK/T (n = 39)	0.48 ± 1.3	-0.78 ± 0.5	-0.31 ± 1.2	0.026

Results expressed as mean ± standard deviation.

Intraocular lens power significantly correlated with absolute refractive error ($r = -0.6$; $p < 0.01$). An increasing IOL power was correlated with a decreasing absolute refractive error.

DISCUSSION

Cataract surgery in patients with HM is challenging from preoperative planning to post-operative results. Intraocular lens power calculation is only partially accurate in these patients for several reasons, including the low accuracy of AL measurements.[11] In our study, AL was measured by immersion ultrasound biometry and partial coherence interferometry. Ultrasound measurements may be a problem mainly in patients with posterior staphyloma because AL can be measured to the depth of the staphyloma rather than the fovea. Studies have shown that partial coherence interferometry provides more accurate AL measurements because the patient fixates along the direction of the measuring beam without the need for cornea contact or indentation.[1,3,6] Keratometry measured with the OB device is more accurate than an auto keratometer.[10-16]

Moreover, HM is still associated with an unwelcomed hyperopic outcome with various biometric formulas.[12-14]

Another potential source of error is that measurements with the OB device are made from the corneal vertex to the retinal pigment epithelium. In contrast, ultrasound measurements are made from the anterior corneal vertex to the inner limiting membrane. This difference in measurement is accounted for by mathematically transforming the OB measurement into an immersion ultrasound-equivalent measurement.[14] However, in HM's eyes, these adjustments are inaccurate.[15] This statement agrees with Wang et al.,[9] who added that vitreous liquefaction in HM eyes might have a different refractive index, leading to an erroneous conversion into AL. They stated that optical coherence biometry has a systematic error that increases linearly with an increasing AL, and based on that, they proposed a method for optimizing AL formulas that reduced the percentage of hyperopic results,[9] which we used in the present study.

In the present study, we analyzed 39 HM eyes. As expected, the mean postoperative spherical equivalent was significantly lower, indicating that cataract surgery could correct myopia in these patients. Also, the mean absolute error was compared between two biometers (immersion biometer and OB), and the immersion biometer was not inferior to the OB, yielding even slightly better results. This may be explained by a well-trained team in ultrasound biometry and the small sample size. Therefore, it is possible that, if well performed, immersion biometry can still be successfully used in places where OB is not yet available (a common scenario in low- and middle-income countries).[17-23]

We used the SRK/T formula in this study for two reasons: first, it was used in all cases with ultrasound biometry measurements, as it does not measure anterior chamber depth (ACD), which is necessary to calculate the Haigis formula; and second, because some surgeons, despite the availability of the OB data, preferred to use the SRK/T formula (of note, in our clinic, most surgeons thought that the SRK/T formula was the most appropriate one for HM eyes). These reasons prompted us to conduct the present research.

Bang et al.[13] showed that the Haigis formula was the most accurate in predicting postoperative refraction, followed by the SRK/T formula; however, the Barrett Universal II formula was not included in their study. Abulafia et al.[8] showed that the Barrett Universal II, Haigis, and Holladay 1 formulas had the best prediction refraction results. In a recent study, Zhou et al.[17] showed that the Barrett Universal II formula had the lowest absolute refractive error for HM eyes. However, the SRK/T and Haigis formulas had a similar proportion, higher than that of the Holladay and Hoffer Q formulas. In addition, the accuracy of the SRK/T formula was similar to that of the Haigis formula.[18]

An effective lens position assumption and the IOL constant adopted are essential factors in the prediction error.[18,19] Third-generation formulas (such as Hoffer Q, Holladay 1, and SRK/T) assume short eyes will have shallower ACDs, whereas long eyes will have deeper ACDs. However, the Haigis and Barrett Universal II formulas (fourth-generation formulas) use the measured ACD value in addition to the other measurements, making these formulas theoretically more advantageous. Other studies have recommended optimizing IOL constants separately for the positive-diopter and negative-diopter IOL ranges by using the User Group for Laser Interference Biometry (ULIB) project framework.[20-25]

To enhance predictability in HM, some authors suggest that surgeons should empirically reserve -0.75 to -3.0 D for patients with HM to avoid the expected postoperative hyperopic outcomes.[24] Additionally, these patients should know they might still need spectacles after surgery.

Based on these guidelines, we found that, the mean predicted target refraction ranged from -0.55 (SD, 0.2) to -0.78 (SD, 0.5) D in the patients selected for this study. When analyzing the final postoperative results, the mean actual spherical equivalent outcome ranged from -0.82 (SD, 0.9) to 0.52 (SD, 1.3) D. We could observe that, even in high refractive errors, satisfactory correction was achieved, resulting in a postoperative refractive error compatible with improved quality of life.

In the present study, we found a significant correlation between the absolute refractive error and the dioptric power of the IOL; the higher the IOL power, the smaller the absolute refractive error. This finding is consistent with previous studies.[16,17,22] Also, we could compare patients who used OB vs. immersion biometry, having their lenses calculated by the SRK/T formula. Other comparisons, such as between formulas (SRK/T vs. Haigis) and between lenses, were impaired due to the small sample size, making it difficult to achieve meaningful results. In the ophthalmology setting in Brazil, obtaining data from patients with axial myopia undergoing cataract surgery is still challenging in the conduction of more in-depth analyses on biometric errors and ways to reduce them.

Our study has some limitations, such as the lack of predictability of the effective lens position, causing a less accurate biometric value. This happened because we did not use an OB in all cases. We also have limitations in our sample size and the lack of more accurate formulas for the reasons above. Another bias in our study is that surgeons in training performed capsulorhexis, which could lead to more inaccurate sizes of capsulorhexis, affecting the refractional final result.[25,31]

It is more challenging to achieve the predicted refractive outcome in HM eyes than in emmetropic eyes. We should choose a biometric formula suitable for HM to reduce this error, such as the SRK/T, Haigis, or Barrett Universal II formulas. The OB device is generally preferable to ultrasound biometry, but well-performed immersion biometry can still produce satisfactory results.

We encountered a correlation between the absolute refractive error and the dioptric power of the IOL. Contrary to expectations, in our study, ultrasound biometry yielded better results than the Optic biometer device, probably due to the small number of patients undergoing optical biometry. We should calculate individualized IOL constants and optimize AL, as proposed by Wang et al.[9]

CONCLUSION

We encountered a correlation between the absolute refractive error and the dioptric power of the intraocular lens. Ultrasound biometry yielded better results than the optical biometer device, probably due to the small number of patients undergoing optical biometry, suggesting that well-performed immersion biometry can still produce satisfactory results.

AUTHORS' CONTRIBUTION

Substantial contribution to conception and design: Andre Beckencamp, Daniel Diniz da Gama, Bernardo Kaplan Moscovici, Caio Regatieri.

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