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ORIGINAL PAPER

Factors contributing to long-term refractive error after cataract surgery

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Abstract

Purpose To evaluate factors that may influence the direction and extent of long-term refractive error after cataract surgery.

Methods This was a retrospective observational study conducted across two private practices in Sydney, NSW, Australia. The study population consisted of patients who underwent cataract phacoemulsification surgery between January 1 and December 31, 2018. Patients who received cataract surgery combined with another procedure were excluded. Demographic and biometric data including anterior chamber depth (ACD), keratometry, central corneal thickness, axial length (AL) and lens thickness were obtained pre-operatively. Spherical equivalent (SEQ) refraction was measured at 2 months and 3 years after surgery and compared with target refraction. Factors associated with refractive error were analyzed.

Results This study included 221 eyes of 122 patients. A refractive error within 1.00 D was achieved in 217 eyes (98.2%) at 3 years post-operatively. Mean prediction error decreased significantly between 2 months and 3 years after surgery irrespective of whether eyes were more myopic ($p < 0.001$) or more hypermetropic than predicted ($p < .0001$). Pre-operative ACD and ACD-to-AL ratio were significantly associated with SEQ prediction error.

Conclusion After cataract surgery, refractive outcomes may be influenced by ACD and ACD-to-AL ratio. The pre-operative assessment of these risk factors may better inform IOL selection in individual patients. Prospective studies in a larger cohort are required.

Keywords Cataract surgery · Refractive error · Anterior chamber

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Introduction

The goals of cataract surgery encompass both improved visual acuity and the achievement of a post-operative refraction optimal for daily function [1]. In practice, while there is much variability in spherical equivalent (SEQ) refraction targets due to clinical judgment and patient preferences, useful SEQ

refraction is generally thought to lie between 0.00 D and −3.00 D. Schuster et al. have recommended a target refraction of −1.00 D to −1.50 D [2]. Post-operative myopia is associated with greater patient satisfaction with visual function, allowing for uncorrected near and distance vision suitable for most activities of daily living [3].

A successful refractive outcome is defined as within 1.00 D of target refraction, with guidelines suggesting that 85% of patients should be within this range after surgery [1]. The choice of intraocular lens (IOL) is largely dependent on pre-operative biometry, including keratometry, axial length (AL) and anterior chamber depth (ACD) [4]. Modern IOL formulas and surgical techniques, alongside the development of new ocular biometers [5], have enabled greater precision in SEQ prediction. Consequently, rates of post-operative refraction within 1.00 D of target have been achieved in up to 94% of patients in some studies [6].

While the difference between predicted and observed refraction has diminished over time, there are several factors that may contribute to poorer refractive outcomes [7]. In the current literature, these risk factors include older age, female gender, previous corneal refractive surgery and ocular comorbidity [4, 7, 8]. While existing studies have analyzed factors influencing mean prediction error, few have evaluated factors affecting the direction of refractive error. In addition, there are minimal data on refractive outcomes measured beyond 6 months [7, 8].

The purpose of this study was to evaluate the direction and extent of SEQ refraction prediction error in the short and long term after cataract surgery. This study also aimed to identify pre-operative factors that may affect refractive outcomes. Understanding these changes in refraction and associated risk factors may improve the individualization of IOL selection and allow surgeons to better inform and manage patient expectations after surgery.

Materials and methods

Study population

This retrospective study included patients who underwent cataract phacoemulsification surgery from January 1, 2018, to December 31, 2018. Inclusion criteria were patients operated on by a single ophthalmic surgeon (K.O.) who had cataract phacoemulsification using Alcon Constellation OZil IP system and 0.9-mm mini-flared 45-degree Kelman® phaco tip through a 2.75-mm temporal corneal incision. All patients received Alcon SN60WF IOL. Patients who received toric lenses or other lenses were excluded. Exclusion criteria were patients who had cataract surgery combined with another procedure or those where a superior corneal incision was used. Patients who did not achieve a post-operative best-corrected distance visual acuity of ≥ 6/9 were also excluded.

Data collection

Basic demographic data were collected on patient age and sex. All patients underwent comprehensive ophthalmic examination 1 week prior to surgery, and at 2 months and 3 years post-operatively. At each examination, ocular parameters including keratometry, ACD, AL, central corneal thickness (CCT), and lens thickness (LT) were measured using IOL Master 700 (Carl Zeiss, Germany). Keratometry was recorded as the flat meridian of the anterior corneal surface ($K1$) and the steep meridian of the anterior corneal surface ($K2$). Target SEQ was defined as the average of the refraction predicted by the SRK/T, Haigis, Holladay 2 and Barrett Universal II IOL formulae.

Refractive power was preliminarily assessed with an autorefractor and then definitively measured using subjective refraction. Subjective refraction was performed for all patients at every follow-up. SEQ was calculated as the sum of the sphere power and half of the cylinder power. Refraction prediction error was calculated as achieved refraction minus target refraction. All measurements and assessments were conducted by the same ophthalmic surgeon.

Statistical analysis

All data were analyzed using IBM SPSS Statistics, version 26.0 (IBM Corp, Armonk, NY). Demographic data were analyzed using descriptive statistics. The paired t test was used to assess differences in refraction prediction error at 2 months and 3 years after surgery. Logistic regression was used when mean prediction error was dichotomized. Odds ratios (OR) were obtained using the chi-square test.

A p value less than 0.05 was considered statistically significant.

Ethical approval

This study was approved by the Human Research Ethics Committee of the Northern Sydney Local Health District and was conducted in accordance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants.

Results

A total of 122 patients were eligible for inclusion in this study, with cataract surgery performed in 221 eyes (115 (52.0%) left eyes, 106 (48.0%) right eyes). Mean patient age was 67.54 ± 7.07 years. The sex distribution of eyes was 129 (58.4%) female and 92 (41.6%) male. The mean IOL used was 19.31 ± 4.43 D. A refractive outcome within 1.00 D of target was achieved in 218 eyes (98.6%) at 2 months and 217 eyes (98.2%) at 3 years post-operatively. The distribution of SEQ prediction error at 2 months and 3 years is shown in Fig. 1 and Fig. 2, respectively.

In patients who were more myopic than predicted at 2 months ($n = 113$, 51.1%), mean refraction prediction error was −0.29 ± 0.25 D (Fig. 3). When reassessed at 3 years post-operatively, mean refraction prediction error was −0.15 ± 0.36 D. This change was statistically significant ($p < 0.001$, paired t test).

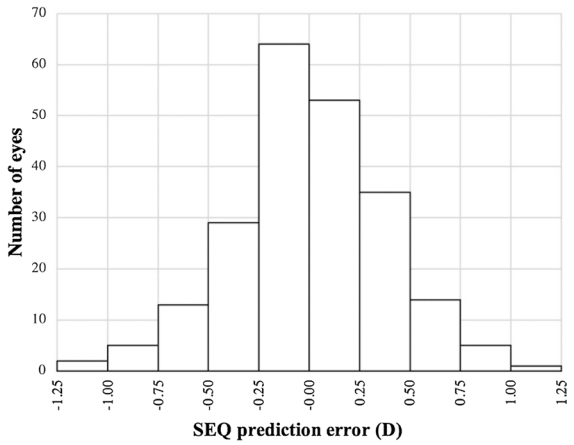

Fig. 1 Histogram showing the distribution of SEQ prediction error at 2 months post-operatively. Abbreviations: SEQ = spherical equivalent

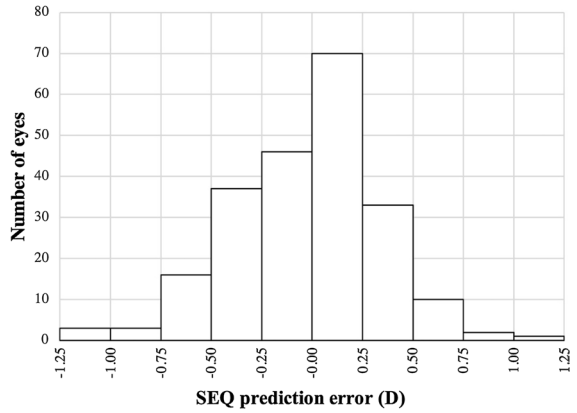

Fig. 2 Histogram showing the distribution of SEQ prediction error at 3 years post-operatively. Abbreviations: SEQ = spherical equivalent

In patients who were more hypermetropic than predicted at 2 months ($n = 108$, 48.9%), mean refraction prediction error was 0.30 ± 0.26 D (Fig. 4). When reassessed at 3 years post-operatively, the mean refraction prediction error was 0.10 ± 0.35 D. This change was also statistically significant ($p < 0.001$, paired t test).

The final model ($r^2 = 0.006$, $p < 0.001$) contained two variables that were significantly associated with the direction of prediction error. These variables were pre-operative ACD ($p < 0.001$) and pre-operative ACD-to-AL ratio ($p < 0.001$). Variables that were not statistically significant were age, sex, and the pre-operative ocular parameters AL, K1, K2, LT and CCT.

Eyes with a pre-operative ACD-to-AL ratio less than 0.13 were more likely to be more myopic than predicted at 2 months (OR = 1.14, 95% CI [1.02, 1.27], $p = 0.017$, chi-square test) and at 3 years (OR = 1.13, 95% CI [1.00, 1.26], $p = 0.044$, chi-square test). Similarly, eyes with a pre-operative ACD less than 3.5 mm were more likely to be more myopic than predicted at 2 months (OR = 1.19, 95% CI [1.07, 1.32], $p < 0.001$, chi-square test) and at 3 years (OR = 1.16, 95% CI [1.05, 1.29], $p = 0.050$, chi-square test).

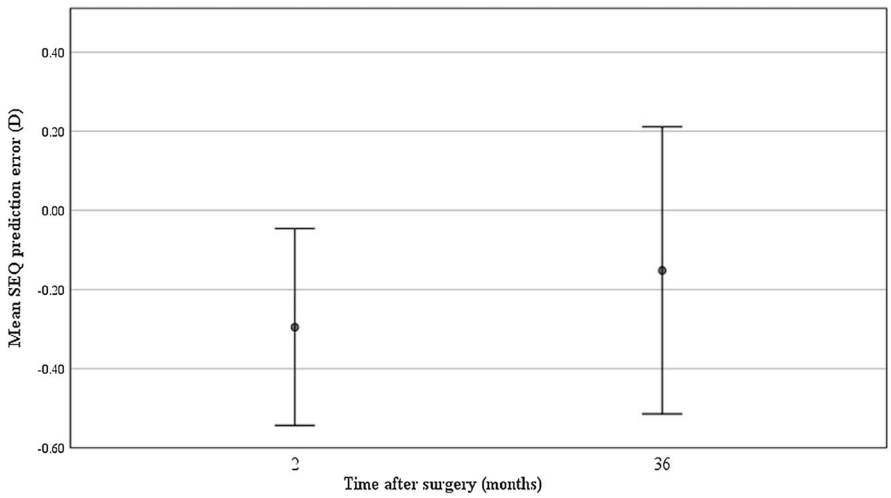

Fig. 3 Mean SEQ prediction error in eyes that were more myopic than predicted. Vertical bars denote SD. Abbreviations: SEQ = spherical equivalent; SD = standard deviation

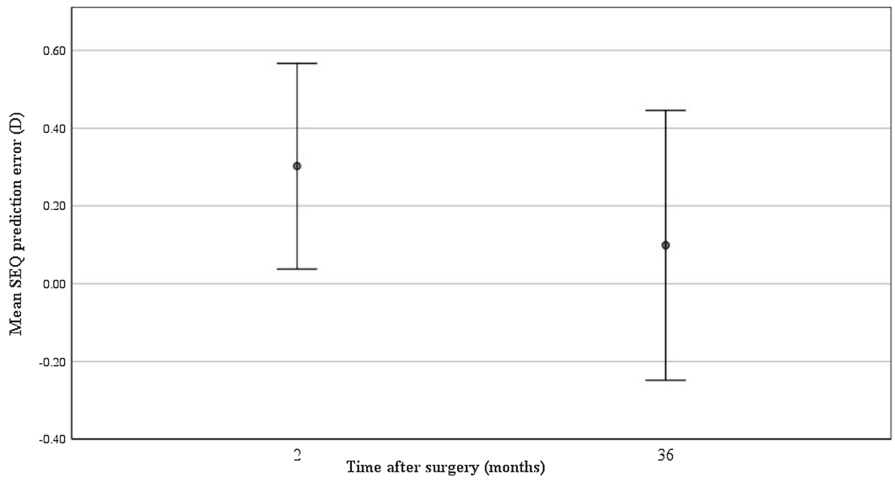

Fig. 4 Mean SEQ prediction error in eyes that were more hypermetropic than predicted. Vertical bars denote SD. Abbreviations: SEQ = spherical equivalent; SD = standard deviation

Discussion

This study evaluated the direction and extent of refraction prediction error occurring 3 years after cataract phacoemulsification surgery. We identified significant differences in the refraction prediction error calculated at 2 months and 3 years post-operatively, with measured refraction generally approaching target refraction during the study period. Therefore, if IOL exchange is requested by the patient for refractive surprise at 2 months, our results suggest that the possibility of longer-term refractive change should be first considered.

The proportion of patients achieving post-operative SEQ within 1.00 D of predicted SEQ was higher than in previous cohorts [1, 9]. In addition, the mean refraction prediction error observed in our study population was lower than has been documented in some studies [7, 10], which may be a reflection of improved biometry assessment and modern surgical techniques [8]. Similarly to the existing literature, we identified no significant difference in refractive outcomes between male and female eyes [7]. While poorer visual outcomes in women have been noted in the literature, these results have been inconsistent within cohorts or were based on subjective visual function as opposed to formal SEQ assessment [4, 8]. In concordance with other studies [7, 8, 11], we did not identify any significant impact of age, IOL power, and pre-operative AL, K1, K2, AL and CCT on the

prediction error observed at 2 months and 3 years post-operatively.

Importantly, our study reports significant associations between refraction prediction error and pre-operative ACD and ACD-to-AL ratio. These findings suggest that a refractive outcome that is more myopic than predicted is associated with a lower ACD and ACD-to-AL ratio. These results were consistent at 2 months and 3 years after surgery. A shallower ACD has been correlated with a greater degree of change after surgery [12], which is thought to affect IOL calculations due to an underestimation of relative post-operative ACD change [13, 14]. When planning target post-operative SEQ to optimize long-term visual functionality, it may be preferable to aim for a less myopic target refraction in eyes with shallower anterior chambers and lower ACD-to-AL ratios.

One strength of our study was the availability of complete pre-operative biometric data, which allowed for analysis of all ocular parameters that may influence SEQ prediction. This is in contrast to larger, multicenter databases where such information was unavailable [7, 8]. In addition, the patients included in this study were followed up for a minimum of 36 months after cataract surgery, enabling calculation of long-term prediction error. Furthermore, all biometry measurements, surgeries and refraction assessments were performed by a single surgeon using the same equipment, reducing the risk of bias from measurement error and inter-observer variability.

Limitations of the present study include its retrospective nature and relatively small sample size. Data were not obtained on other variables that have been associated with refractive outcomes, such as pre-operative visual acuity [7, 8, 15], ocular comorbidity [7, 16], and previous corneal refractive surgery [17]. Consequently, the impact of these factors was unable to be assessed. Further, as both eyes from some patients were included, there is the potential for inter-eye correlation bias [18]. Finally, as ACD-to-AL ratio is a novel risk factor that has not been reported to influence post-operative refraction, further studies to confirm this finding are warranted.

Conclusion

Between 2 months and 3 years after cataract surgery, the difference between predicted and observed refraction decreased significantly, with eyes approaching target refraction irrespective of the initial direction of prediction error. Eyes with shallower pre-operative ACD and lower ACD-to-AL ratio had a greater likelihood of being more myopic than predicted. This information may be useful when planning target refraction for individual patients and should be considered prior to IOL exchange for post-operative refractive error.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by NL and KO. The first draft of the manuscript was written by NL, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethics approval This study was approved by the human research ethics committee of the Northern Sydney Local Health District.

Consent to participate Informed consent was obtained from all individual participants included in the study.

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