Xi et al. BioMedical Engineering OnLine (2025) 24:35
https://doi.org/10.1186/s12938-025-01364-x

BioMedical Engineering OnLine

RESEARCH Open Access

Analysis of preoperative ocular optical parameters in patients with cataract

Wenqun Xi[1], Xinhua Liu[1], Zhiqiang Ren[2], Xiaosheng Huang[1], Liangnan Sun[1], Ye Ye[1], Yanhua Zhao[1], Zhe Zhang[1*] and Kun Zeng[1*]

*Correspondence: whypotato@126.com; zengkun@sz-eyes.com

[1] Shenzhen Eye Hospital, Shenzhen Eye Medical Center, Southern Medical University, No. 18, Zetian Road, Futian District, Shenzhen, Guangdong Province 518040, People's Republic of China
[2] Department of Southern University of Science and Technology, 1088 Xueyuan Avenue, Nanshan District, Shenzhen, Guangdong Province 518055, People's Republic of China

Abstract

This study aims to evaluate the distribution of preoperative corneal parameters obtained using the Pentacam anterior segment analyzer in Chinese male and female patients with cataracts and to investigate the correlation between these parameters and related factors. Preoperative examination data of the eyes of 1,255 patients who underwent cataract surgery were retrospectively analyzed. The Pentacam AXL was used to extract preoperative corneal measurements, and the total corneal measurement data were analyzed. The average age of the patients was 52.9 ± 21.3 years. The mean simulated keratometry values and corneal curvature of total corneal refractive power were positively correlated with age (both $P < 0.01$). Spearman's correlation analysis revealed a positive association between age and anterior corneal spherical aberration, posterior corneal spherical aberration, and total corneal spherical aberration changes. A negative correlation was found between age and with-the-rule astigmatism, and it was positively correlated with the ratios of against-the-rule and oblique astigmatism. A significant between-eye correlation was observed regarding spherical aberration (Z40), horizontal coma (Z31), vertical coma (Z3-1), and horizontal trefoil (Z33). The corneal curvature in females was significantly steeper than that in males ($P < 0.01$). Corneal curvature, corneal spherical aberration, and corneal astigmatism were found to change with age. Additionally, we found physiological differences between the sexes. Individual measurements could be taken preoperatively to facilitate the development of personalized surgical plans. By identifying age- and gender-related corneal variations, this study enables more personalized cataract surgery planning, potentially improving refractive outcomes and reducing postoperative complications through tailored surgical techniques and intraocular lens selection.

Keywords: Cataract, Simulated keratometry, Total corneal refractive power, High-order aberration, Pentacam anterior segment analysis system

Introduction

Cataract is currently the second leading cause of visual impairment and the primary cause of blindness worldwide. Corneal curvature is a critical parameter for calculating the refractive power of an artificial lens. With the substantial increase in the number of cataract surgeries, a thorough and accurate assessment of corneal surface morphology and its changes is crucial for cataract treatment. Regarding studies on corneal curvature changes with age, Ma et al. [1] examined healthy Chinese individuals and reported gradual alterations in corneal morphology with age, with both anterior and posterior corneal curvature (K1 and K2) being positively correlated with age. According to research predictions, the number of individuals (aged 45–89 years) affected by any form of cataract will reach 240.83 million by 2050 [2]. There remain discrepancies between values obtained when measuring various biological indicators in patients with cataract, including the reference ranges that vary between measurements. Corneal curvature and the distribution of corneal astigmatism are important parameters in guiding the calculation of intraocular lens power in cataract surgery and determining the choice of surgical incisions. SimK is widely used in current clinical practice and is calculated using anterior corneal surface measurements and the presumption of a constant anterior–posterior corneal radius ratio. Early studies demonstrated that a conversion factor of 1.3375 was insufficient for converting the radius of curvature into the absolute refractive power of the cornea, which could lead to the overestimation of the corneal curvature measured by the SimK method. While age affects multiple ocular parameters due to physiological aging, the influence of sex on ocular biometry is more subtle, with corneal curvature being one of the few parameters showing a significant and consistent gender-based difference [3]. Wavefront aberration is generally considered a crucial indicator for assessing visual quality [4]. However, the parameters obtained in different tissues may vary according to factors such as geographic region, race, age, and differences in inclusion criteria [5]. For example, the anterior chamber volume and depth in males are typically greater than those in females [6]. Moreover, lens thickness tends to increase with age. Additionally, the anterior chamber depth has a negative correlation with age [7]. Nonetheless, there have been few epidemiological studies on patients with cataract, and the information is limited to local reports. Further, there have been limited biological parameters included in these studies [1, 8]. Therefore, with the development of personalized surgery, individual ocular biometry data are becoming particularly crucial.

In recent years, Total Corneal Refractive Power (TCRP) has gained interest among cataract and refractive surgeons. Based on the principle of ray tracing and incorporating data regarding corneal thickness and posterior corneal curvature, the Scheimpflug camera allows physical measurement of TCRP. This theoretically facilitates more accurate calculations [8].

To supply this critical basic information, the Pentacam AXL for anterior segment analysis is used to evaluate the characteristics and distribution of preoperative corneal biological parameters in patients with cataract. It is stated that Pentacam AXL demonstrates high agreement with measurements from other methods, which was quantitatively assessed using Spearman's correlation analysis. The agreement was found to be strong (Spearman's $\rho = 0.85$, $p < 0.001$), indicating a high level of consistency between the Pentacam AXL measurements and those from previous studies. This demonstrates that the Pentacam AXL provides reliable measurements that are comparable with other established methods [9–11]. The results of such analysis can inform the establishment of individualized surgical plans based on patient-specific corneal characteristics in clinical practice, allowing for satisfactory visual quality post-operation. Therefore, this study aimed to assess the distribution of preoperative corneal biological parameters among patients with cataract in Shenzhen, China, and to explore their association with risk factors.

Results

Comparison of the anterior corneal surface and whole cornea curvatures in right eyes

Flat axis curvature (k1), steep axis curvature (k2), and mean corneal curvature (km) of the simulated keratometry (SimK), as well as total corneal refractive power (TCRP) of the right eye, were assessed for normal distribution in 1,255 patients with a mean age of 52.9 ± 21.3 years (Table 1). Given their non-normal distribution, a Wilcoxon signed-rank test was applied. There was a significant difference in all corneal k1, k2, and km values between SimK and TCRP. Age was positively correlated with the km values of both the SimK (correlation coefficient r = 0.56199) and TCRP (r = 0.25064) (both, $P < 0.01$) (Fig. 1).

Comparison of higher-order aberrations in the anterior corneal surface of right eyes across different age groups

Comparison of corneal spherical aberrations in the right eyes across different age groups revealed variations in the spherical aberrations of the anterior surface, posterior surface, and total cornea increased with age. There were significant among-group differences in spherical aberrations on the anterior surface, posterior surface, and total cornea ($P < 0.001$). Furthermore, Spearman's correlation analysis demonstrated a positive correlation between these parameters and age (Table 2).

Comparison of astigmatism axis changes in right eyes across different age groups

The proportion of with-the-rule astigmatism showed a decreasing trend as age increased, whereas oblique astigmatism showed a notable increase in the 40–60 years group, which plateaued in patients aged > 60 years. Meanwhile, ATR astigmatism showed a notable increase in patients aged 40–60 years and continued to increase in patients aged > 60 years before it eventually stabilized (Fig. 2).

Comparison of higher-order aberrations in the anterior corneal surface between both eyes

A significant correlation was observed between spherical aberration (Z40, r = 0.79881), horizontal coma (Z31, r = -0.59467), vertical coma (Z3-1, r = 0.74806), and horizontal trefoil (Z33, r = -0.37542) between the eyes. There was no significant between-eye correlation of the total HOA (r = 0.72091) and oblique trefoil (Z3-3, r = 0.51390) (Fig. 3)."

Relationship between corneal curvature and sex

The mean km of both the SimK and TCRP were found to be larger in females than in males. The corneal curvatures in females were significantly steeper than those in males ($P < 0.01$) (Fig. 4).

Discussion

We used the Pentacam instrument to measure and compare SimK and TCRP, specifically analyzing flat axis curvature, steep axis curvature, and mean corneal curvature. Significant differences were observed between SimK and TCRP values.

Table 1 Corneal characteristics of the right eyes in 1,255 patients with cataract

Variable stratified	Eyes (%)	Simulated keratometry (SimK)			Total corneal refractive power (TCRP)			Axial distribution of astigmatism, eyes (%)		
		k1	**k2**	**Km**	**k1**	**k2**	**km**	**With-the-rule**	**Against-the-rule**	**Oblique**
Age										
20–40	427 (34.02)	42.56 ± 1.47	44.77 ± 1.74	43.63 ± 1.49	42.40 ± 1.46	44.46 ± 1.65	43.43 ± 1.45	361 (84.54)	33 (7.73)	33 (7.73)
41–60	315 (25.10)	42.95 ± 1.58	43.95 ± 1.75	43.44 ± 1.61	43.01 ± 1.63	44.01 ± 1.74	43.51 ± 1.63	187 (59.37)	83 (26.35)	45 (14.29)
61–80	373 (29.72)	43.63 ± 1.50	44.52 ± 1.61	44.07 ± 1.52	43.82 ± 1.58	44.80 ± 1.66	44.31 ± 1.57	155 (41.55)	148 (39.68)	70 (18.77)
Over 80	140 (11.16)	43.59 ± 1.39	44.61 ± 1.49	44.09 ± 1.38	43.82 ± 1.37	45.02 ± 1.49	44.42 ± 1.37	41 (29.29)	69 (49.29)	30 (21.43)
Sex										
Male	578 (46.06)	42.88 ± 1.59	44.31 ± 1.77	43.58 ± 1.58	42.88 ± 1.65	44.30 ± 1.72	43.59 ± 1.59	346 (59.86)	149 (25.78)	83 (14.36)
Female	677 (53.94)	43.27 ± 1.52	44.61 ± 1.63	43.93 ± 1.48	43.35 ± 1.62	44.69 ± 44.69	44.02 ± 1.55	398 (58.79)	184 (27.18)	95 (14.03)
Test $statistic_1$		39.87	14.95	13.21	67.88	17.87	33.69	218.7531		
Test $statistic_2$		19.69	10.03	16.51	26.21	17.36	23.95	0.3145		

Note: Test $statistic_1$ and test $statistic_2$ refer to the F value and χ^2 value, respectively. Significant differences were observed ($P < 0.05$) except for the axial distribution of astigmatism stratified by age

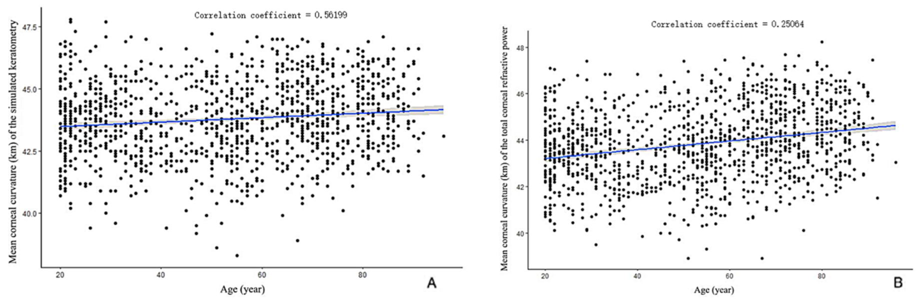

Fig. 1 Comparison of the correlations between the curvature of the anterior corneal surface and the whole cornea and age. **A** Simulated keratometry; **B** Total corneal refractive power. Age was positively correlated with the mean corneal curvature (km) of both SimK (**A**) and TCRP (**B**), with a significant correlation observed for both ($P < 0.01$)

Table 2 Comparison of higher-order aberrations in the anterior corneal surface of right eyes across different age groups

Age group (years)	Anterior surface (μm)	Posterior surface (μm)	Total cornea (μm)
20–40	0.189	−0.146	0.146
41–60	0.282	−0.139	0.252
61–80	0.341	−0.119	0.338
Over 80	0.354	−0.108	0.362
Spearman's correlation coefficient	0.50	0.43	0.57
P	<0.001	<0.001	<0.001

Note: Data were tested for normality using the Kolmogorov–Smirnov test. Since the data followed a normal distribution ($p > 0.05$ for all variables), analysis of variance (ANOVA) was applied for group comparisons

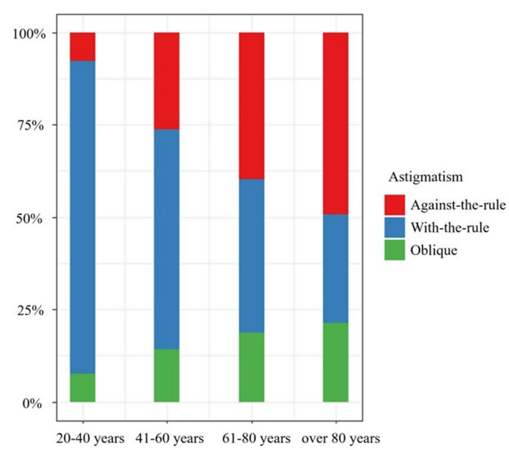

Fig. 2 Astigmatism axis changes among different age groups

Previous research comparing SimK and Pentacam HR ray-tracing found that SimK values were 0.40–0.60 D higher than TCRP [14]. Savini et al. [15] reported that this discrepancy depends on the anterior–posterior corneal radius ratio. In our study, mean corneal curvature assessed using SimK and TCRP showed significant variation. As age increased, both SimK and TCRP exhibited a gradual rise in mean corneal curvature.

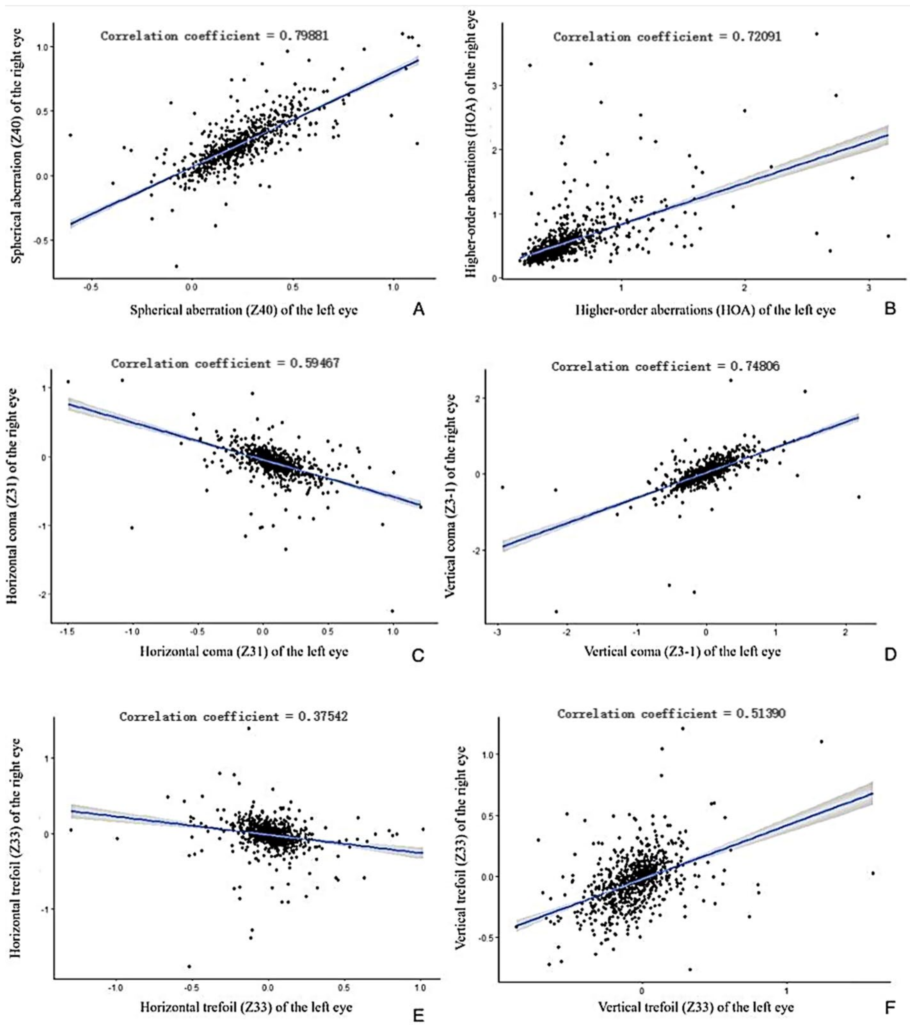

Fig. 3 Correlation of high-order aberrations on the anterior corneal surface between both eyes. **A** Spherical aberration (Z40). **B** Higher-order aberrations (HOA). **C** Horizontal coma (Z31). **D** Vertical coma (Z3-1). **E** Horizontal trefoil (Z33). **F** Vertical trefoil (Z3-3). Significant correlations were observed for spherical aberration, horizontal coma, vertical coma, and horizontal trefoil ($P < 0.01$), while no significant correlation was found for vertical trefoil (Z3-3)

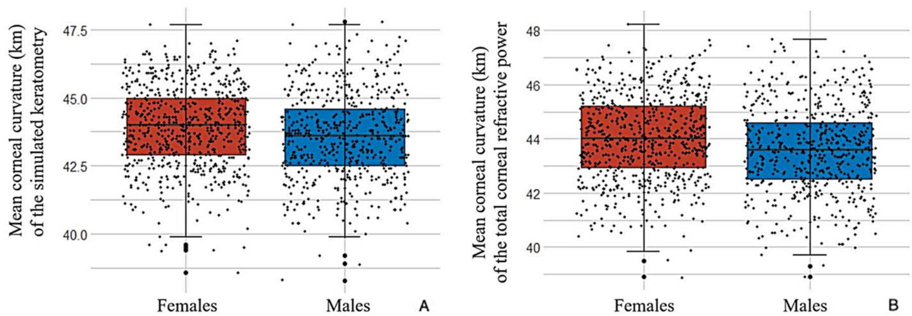

Fig. 4 Relationship between corneal curvature and sex. **A** Relationship between simulated keratometry and sex. **B** Relationship between total corneal refractive power and sex

Linear regression indicated that the SimK-TCRP discrepancy decreased with age, at a rate of 0.00965 per year.

Prior studies [16] confirm that anterior and posterior corneal surfaces undergo significant changes with aging. Our findings align with these reports, revealing that corneal curvature increases with age, primarily due to anterior corneal surface modifications. Hashemi et al. [17] noted that anterior surface changes were more pronounced than posterior ones, supporting our inference that total corneal curvature shifts are predominantly driven by anterior corneal surface alterations.

The average anterior corneal spherical aberration (0.276 ± 0.165 μm) in this study is consistent with findings from Elkitkat et al. ($+0.26 \pm 0.12$ μm), Beiko et al. (0.274 ± 0.089 μm), and Wang et al. in Chinese patients. Anterior spherical aberration increased with age, while posterior spherical aberration declined, leading to an overall rise in total corneal spherical aberration. This suggests that the posterior corneal surface may play a compensatory role in balancing corneal aberrations [18]. Unlike previous studies [19, 20], our results showed a substantial proportion of eyes with negative spherical aberration, possibly due to differences in patient demographics or cataract severity.

Kuroda et al. [21] suggested that nuclear cataracts cause local refractive changes, increasing higher-order aberrations. These changes may explain the observed variation in corneal spherical aberration, as nuclear cataracts alter wavefront aberration. Our methodology, which did not classify eyes based on lens opacity type, may have contributed to the divergence from previous findings [22].

Corneal spherical aberration significantly influences visual quality. Aspheric intraocular lenses (IOLs) aim to counteract these aberrations, targeting a postoperative whole-eye aberration of 0–0.1 μm for optimal visual outcomes [19, 23]. However, our study highlights substantial individual differences in corneal spherical aberration among cataract patients, suggesting that a standardized correction value may not be suitable for all cases. Factors such as pupil size, stromal pocket condition, and postoperative artificial lens positioning [24] contribute to patient-specific variations in visual outcomes. This may explain why some patients remain dissatisfied with vision quality despite aspheric IOL implantation.

Given these findings, preoperative measurement of corneal spherical aberration is crucial for selecting appropriate aspheric IOLs. A personalized approach considering multiple patient factors may improve postoperative vision and enhance overall satisfaction.

Age-related changes in corneal astigmatism are well-documented, with studies indicating a shift from with-the-rule (WTR) to against-the-rule (ATR) astigmatism over time [25]. Our study corroborates these findings, showing a decline in WTR astigmatism and an increase in ATR and oblique astigmatism with advancing age. These shifts align with previous research [8, 25] and emphasize the importance of incorporating age-related astigmatic changes into surgical planning.

Koch et al. [26] proposed that younger individuals benefit from posterior corneal astigmatism compensating for anterior corneal astigmatism. However, as age progresses, anterior astigmatism shifts toward ATR, potentially leading to under-correction if only anterior corneal curvature is considered. Additional factors, such as changes in eye wall tension, eyelid pressure, and extraocular muscle traction, may also contribute to age-related refractive alterations [27]. Our results suggest that corneal astigmatism is dynamic and should be carefully evaluated when planning cataract surgery, particularly in older patients.

Our study analyzed higher-order aberrations (HOAs) in 873 patients and found significant interocular correlations for spherical aberration (Z40), horizontal coma (Z31), vertical coma (Z3-1), and horizontal trefoil (Z33). These findings support prior research indicating moderate-to-high correlation in corneal HOAs between both eyes [28, 29]. However, total HOA and oblique trefoil (Z3-3) did not show a significant interocular relationship, suggesting variability in individual wavefront aberration profiles.

HOAs significantly influence retinal image quality and visual perception [4, 30]. Prior studies suggest that nuclear cataracts increase coma and spherical aberration, while posterior subcapsular cataracts primarily affect trefoil aberrations [31, 32]. Similar to previous research [28, 29], we did not stratify HOA analysis by cataract type, which may explain discrepancies in interocular correlation findings.

Kim et al. [33] reported that nuclear cataract-induced HOAs could cause retinal triple imaging, contributing to visual disturbances. Wang et al. [28] found that anterior corneal surface HOAs exhibit mirror symmetry between eyes, which may help preserve binocular vision despite corneal irregularities. Tear film stability also plays a role in HOA fluctuations [34, 35], as an uneven tear film can increase wavefront distortions. Given the lack of effective surgical methods for reducing HOAs [36], preoperative assessment remains essential for optimizing refractive outcomes.

Our study revealed that corneal curvature, as measured by SimK and TCRP, were observed to be lower in male patients compared to female patients. These findings align with previous research, indicating that female corneas tend to be steeper than male corneas ($P < 0.01$). Similar to other physiological differences, sex-related variations in ocular structure may contribute to distinct refractive outcomes [37, 38].

Although age broadly affects multiple ocular parameters, sex-related differences are often more subtle and inconsistent across studies. Corneal curvature remains one of the most reliably documented sex-dependent parameters, whereas other biometric variations (e.g., axial length, lens thickness) tend to show smaller or less consistent differences. Notably, males typically exhibit longer axial lengths and flatter corneal curvatures compared to females [39].

These findings highlight the need to consider sex differences in preoperative surgical planning. Traditional IOL power calculation formulas do not account for sex-specific variations, yet even minor corneal modifications can lead to substantial changes in refractive power. Implementing sex-adjusted methodologies could enhance postoperative visual acuity predictions and improve surgical outcomes.

While this study provides valuable insights, certain limitations should be acknowledged. As a retrospective study, potential selection bias cannot be entirely excluded. However, since patient selection, surgical treatment, and postoperative follow-up were not influenced by artificial criteria, the impact of selection bias is likely minimal. Additionally, since our research is based on hospital-based clinical data, the findings may not be fully representative of the broader Chinese population. A larger-scale, community-based epidemiologic survey would be needed to validate these results.

Another limitation is the lack of stratification based on cataract type. Variations in nuclear, cortical, and posterior subcapsular cataracts may influence certain corneal parameters, such as HOAs and spherical aberration. Future studies could explore these distinctions to refine surgical approaches further.

Despite these limitations, our study presents novel findings on the distribution of preoperative corneal morphological parameters in Chinese patients with cataract. This is the first large-scale analysis using the Pentacam instrument to assess ocular biometric variations by age, sex, and interocular correlation. Our results offer valuable insights for cataract surgery planning and may help refine patient-specific surgical strategies.

We observed significant age-related changes in corneal curvature, spherical aberration, and astigmatism, as well as notable sex differences in corneal parameters. Additionally, interocular correlations in HOAs suggest that binocular vision may compensate for asymmetrical corneal aberrations. These findings emphasize the need for personalized surgical planning to optimize postoperative visual outcomes in cataract patients.

Methods

Participants

The study was conducted following the tenets of the Declaration of Helsinki. The study involved human participants and was approved by the Institutional Review Board of Shenzhen Eye Hospital (2023KYPJ065). Written informed consent for participation was not required for this study in accordance with the national legislation and institutional requirements.

In this retrospective case series study, clinical data of patients with cataract across various age groups who attended our hospital between June 2020 and March 2023 were collected. The right eyes of patients who met the inclusion criteria were chosen for observation and analysis. The left eyes of the same patients were included in the study for comparison and correlation analyses involving both eyes. A total of 1,255 right eye cases were included, along with 873 cases involving both eyes; accordingly, we included 1,255 patients (2,128 eyes). The reason for the difference in the number of cases (873 vs. 1,255) is that not all patients had complete bilateral data available for analysis. Some patients had only one eye meeting the inclusion criteria, or data for the contralateral eye were incomplete or unavailable due to technical or clinical reasons (e.g., poor quality scans, prior surgery, or other ocular conditions in the contralateral eye). Additionally, the study sample comprised 578 male eyes and 677 female eyes. The patients were categorized into four groups based on age: Group A (20–40 years, 427 cases), Group B (41–60 years, 315 cases), Group C (61–80 years, 373 cases), and Group D (>81 years, 140 cases).

The inclusion criteria were as follows: (1) satisfactory compliance, an ability to cooperate until completion of the Pentacam examination; (2) absence of other eye diseases; (3) absence of prior eye surgery; and (4) cases wherein the Pentacam for anterior segment analysis passed the quality status assessment.

The exclusion criteria were as follows: (1) conditions such as glaucoma, dry eye syndrome, and high myopia; (2) patients with a history of myopic laser surgery; (3) contact lens users; (4) patients who underwent keratoplasty; and (5) patients with various corneal diseases.

Measurement method

Preoperative optical biometry was performed using the Pentacam AXL software (version 1.21r43) in all cases. The Pentacam AXL is based on Scheimpflug imaging technology and ray tracing principles, which allow for a comprehensive analysis of the anterior segment of the eye. The device uses a red LED light to automatically locate the corneal apex, followed by a blue slit light source (wavelength 475 nm) to illuminate the cornea. The camera, tilted at 45°, rotates 360° to capture a series of oblique cross-sectional images of the cornea. These images are then reconstructed to generate a three-dimensional model of the anterior segment, providing detailed information about corneal curvature, thickness, and other relevant parameters.

Simulated Keratometry (SimK)

SimK refers to the refractive power (or curvature) of the anterior corneal surface. It is calculated based on the curvature of the anterior cornea, typically measured along the flat (k1) and steep (k2) meridians. The mean corneal curvature (km) is derived from these values. SimK assumes a fixed ratio between the anterior and posterior corneal curvatures, which is a standard approach in clinical practice for estimating corneal refractive power [12].

Total corneal refractive power (TCRP)

TCRP represents the total refractive power of the cornea, taking into account both the anterior and posterior corneal surfaces. Unlike SimK, TCRP is calculated using ray tracing technology, which considers the actual path of light through the cornea. This method incorporates data on corneal thickness and the curvature of both the anterior and posterior corneal surfaces, providing a more accurate measurement of the cornea's total refractive power [13].

The Pentacam AXL automatically measures both SimK and TCRP, along with other relevant parameters, such as corneal astigmatism, higher-order aberrations, and corneal thickness. These measurements are crucial for preoperative planning in cataract surgery, particularly for intraocular lens (IOL) power calculation and the selection of appropriate surgical techniques.

The examination was performed on the pupil under dark room conditions. During pre-examination, patients were instructed to blink to maintain a uniform distribution of the tear film to minimize error. The patients were advised to keep both eyes wide open and fixate on a flashing red light. Upon focusing, the machine automatically reconstructed the three-dimensional structure of the anterior segment using 25 frames of Scheimpflug images.

The recorded measurements included the flat axis curvature (k1), steep axis curvature (k2), and mean corneal curvature (km) of the anterior corneal surface and the whole cornea of the examined eye. Corneal astigmatism and its axis were extracted from the anterior surface of the cornea. The type of corneal astigmatism was determined based on the orientation of the steep axis: with-the-rule astigmatism $90 \pm 30°$, against-the-rule (ATR) astigmatism $0 \pm 30°$, and oblique astigmatism for orientations in between. Higher-order aberrations within a 6-mm diameter of the anterior corneal surface were recorded, including total higher-order aberrations (HOA), horizontal coma (Z31), vertical coma (Z3-1), horizontal trefoil (Z33), vertical trefoil (Z3-3), and spherical aberration (Z40). All examinations were conducted by the same professionally trained technician.

Stratification by gender

In addition to stratifying by age, we also conducted analyses based on gender to examine potential differences in corneal parameters between male and female patients. Comparisons were made between the groups using the appropriate non-parametric tests, as described for the age comparisons. The results of these comparisons are summarized in Table 1, where "Test statistic_1" represents the age based startification, whlie "Test statistic_2" represents gender-based stratification.

Statistical analysis

All statistical analyses were performed using the SAS 9.4 software. The Kolmogorov–Smirnov test, combined with graphical methods, was used to test the normality of data distribution. The normality test confirmed that the higher-order aberration (HOA) data were normally distributed ($p > 0.05$ for all variables). Given this, analysis of variance (ANOVA) was applied to compare HOA values across different age groups. Spearman's correlation analysis was used to analyze the correlation between two continuous variables. The significance level was set at $\alpha = 0.05$.

Acknowledgements
We thank all the participants in the study.

Author contributions
W.X，K.Z. and X.L. performed the conception and design of the study. Data was collected and analyzed by W.X., Y.Z., X.H., L.S., Z.R., and Y.Y. together. Manuscript was drafted by W.X.，Z.Z.， and K.Z. Z.Z., and K.Z. acquired the funding for the study. All authors revised the manuscript and have read and agreed to the publication of the manuscript.

Funding
This work was supported by the Shenzhen Science and Technology Program under grant number JCYJ20220530153604010.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was conducted following the tenets of the Declaration of Helsinki. The study involved human participants and was approved by the Institutional Review Board of Shenzhen Eye Hospital (2023KYPJ065). Since the whole study was a retrospective study, when the data were collected, there was no artificial selection bias due to different groups in the process of patient selection, surgical treatment, and postoperative follow-up observation. Written informed consent was obtained from the patient for participation in this study.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Received: 2 December 2024 Accepted: 3 March 2025
Published online: 16 March 2025

References

1. Ma R, et al. Changes in corneal morphology with age in Asian population: a multicenter study of 30,618 cases. Adv Ther. 2021;38:5763–76.

2. Song P, Wang H, Theodoratou E, Chan KY, Rudan I. The national and subnational prevalence of cataract and cataract blindness in China: a systematic review and meta-analysis. J Glob Health. 2018;8:010804.
3. Shao X, et al. Age-related changes in corneal astigmatism. J Refract Surg. 2017;33:696–703.
4. Zhang X, Zhou J, Li H, Lu J, Liang S. Analysis of the changes and possible reasons in aberrations before and after surgery in patients with concomitant exotropia. Comput Intell Neurosci. 2022;2022:5207553.
5. Chen W, et al. Prevalence of corneal astigmatism before cataract surgery in Chinese patients. J Cataract Refract Surg. 2013;39:188–92.
6. Kyei S, et al. Age- and sex-related differences in the measures of anterior segment parameters in a myopic clinical sample using Pentacam Scheimpflug tomography. Int Ophthalmol. 2022;42:1573–80.
7. Meng J, et al. Lens thickness and associated ocular biometric factors among cataract patients in Shanghai. Eye Vis. 2021;8:22.
8. Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. Ophthalmology. 2018;125:169–78.
9. Muźyka-Wozniak M, Oleszko A. Comparison of anterior segment parameters and axial length measurements performed on a Scheimpflug device with biometry function and a reference optical biometer. Int Ophthalmol. 2019;39:1115–22.
10. Haddad JS, Barnwell E, Rocha KM, Ambrosio R Jr, Waring GO. Comparison of biometry measurements using standard partial coherence interferometry versus new Scheimpflug tomography with integrated axial length capability. Clin Ophthalmol. 2020;14:353–8.
11. Taroni L, Hoffer KJ, Barboni P, Schiano-Lomoriello D, Savini G. Outcomes of IOL power calculation using measurements by a rotating Scheimpflug camera combined with partial coherence interferometry. J Cataract Refract Surg. 2020;46:1618–23.
12. Sinjab MM. Corneal tomography in clinical practice (Pentacam system): basics and clinical interpretation. JP Medical Ltd.; 2021.
13. Pan C, Tan W, Savini G, Hua Y, Ye X, Xu W, Yu J, Wang Q, Huang J. A comparative study of total corneal power using a ray tracing method obtained from 3 different Scheimpflug camera devices. Am J Ophthalmol. 2020;216:90–8.
14. Næser K, Savini G, Bregnhøj JF. Corneal powers measured with a rotating Scheimpflug camera. Br J Ophthalmol. 2016;100:1196–200.
15. Savini G, Hoffer KJ, Lomoriello DS, Ducoli P. Simulated keratometry versus total corneal power by ray tracing: a comparison in prediction accuracy of intraocular lens power. Cornea. 2017;36:1368–72.
16. Jiang Y, et al. Distribution and internal correlations of corneal astigmatism in cataract patients. Sci Rep. 2021;11:11514.
17. Hashemi H, Asgari S, Emamian MH, Mehravaran S, Fotouhi A. Age-related changes in corneal curvature and shape: the Shahroud eye cohort study. Cornea. 2015;34:1456–8.
18. Zhang X, Ma JH, Xi X, Guan L. Characteristics of corneal high-order aberrations in adolescents with mild to moderate myopia. BMC Ophthalmol. 2020;20:465.
19. Beiko GHH, Haigis W, Steinmueller A. Distribution of corneal spherical aberration in a comprehensive ophthalmology practice and whether keratometry can predict aberration values. J Cataract Refract Surg. 2007;33:848–58.
20. Amorim-de-Sousa A, Vieira AC, González-Méijome JM, Queirós A. Age-related variations in corneal asphericity and long-term changes. Eye Contact Lens. 2019;45:99–104.
21. Kuroda T, et al. Wavefront analysis in eyes with nuclear or cortical cataract. Am J Ophthalmol. 2002;134:1–9.
22. McLellan JS, Marcos S, Burns SA. Age-related changes in monochromatic wave aberrations of the human eye. Invest Ophthalmol Vis Sci. 2001;42:1390–5.
23. Schrecker J, Langenbucher A, Seitz B, Eppig T. First results with a new intraocular lens design for the individual correction of spherical aberration. J Cataract Refract Surg. 2018;44:1211–9.
24. Khan S, Rocha G. Cataract surgery and optimal spherical aberration: as simple as you think? Can J Ophthalmol. 2008;43:693–701.
25. Wu Z, Liu C, Chen Z. Prevalence and age-related changes of corneal astigmatism in patients undergoing cataract surgery in Northern China. J Ophthalmol. 2020;2020:6385098.
26. Koch DD, et al. Contribution of posterior corneal astigmatism to total corneal astigmatism. J Cataract Refract Surg. 2012;38:2080–7.
27. Namba H, et al. Age-related changes in astigmatism and potential causes. Cornea. 2020;39(Suppl 1):S34–8.
28. Wang L, Dai E, Koch DD, Nathoo A. Optical aberrations of the human anterior cornea. J Cataract Refract Surg. 2003;29:1514–21.
29. Castejón-Mochón JF, López-Gil N, Benito A, Artal P. Ocular wave-front aberration statistics in a normal young population. Vision Res. 2002;42:1611–7.
30. Hughes RP, Vincent SJ, Read SA, Collins MJ. Higher order aberrations, refractive error development and myopia control: a review. Clin Exp Optom. 2020;103:68–85.
31. Rocha KM, et al. Higher-order aberrations of age-related cataract. J Cataract Refract Surg. 2007;33:1442–6.
32. Takabayashi N, Hiraoka T, Kiuchi T, Oshika T. Influence of decorative lenses on higher-order wavefront aberrations. Jpn J Ophthalmol. 2013;57:335–40.
33. Kim A, et al. Wavefront analysis of eyes with cataracts in patients with monocular triplopia. Ophthalmic Physiol Opt. 2006;26:65–70.
34. Rhee J, et al. A systematic review on the association between tear film metrics and higher order aberrations in dry eye disease and treatment. Ophthalmol Ther. 2022;11:35–67.
35. Yang L, et al. Effect of intense pulsed light on anterior corneal aberrations and quality of vision in patients with evaporative dry eye. Photobiomodul Photomed Laser Surg. 2021;39:185–95.

36. Gulmez M, Tekce A, Kamıs U. Comparison of refractive outcomes and high-order aberrations after small incision lenticule extraction and wavefront-guided femtosecond-assisted laser in situ keratomileusis for correcting high myopia and myopic astigmatism. Int Ophthalmol. 2020;40:3481–9.
37. Hashemi H, et al. The distribution of keratometry in a population based study. J Curr Ophthalmol. 2021;33:17–22.
38. Chen X, Huang Y, Chen H, Liu L. Distribution and characteristics of ocular biometric parameters among a Chinese population: a hospital-based study. Ophthalmol Ther. 2023;12:2117–31.
39. De Bernardo M, et al. Biometric parameters and corneal astigmatism: differences between male and female eyes. Clin Ophthalmol. 2020;14:571–80.

Publisher's Note