Comparison of ocular biometry profiles in urban and rural cataract candidates in eastern China

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Research article

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Abstract

Purpose: To compare ocular biometric parameters between urban and rural cataract patients in Shanghai, China.

Methods: A study of ocular biometry records from urban and rural hospitals was performed for cataract patients at least 50 years of age. The ocular biometrical parameters, which were measured with partial coherence laser interferometry (IOL Master, Zeiss), were axial length (AL), anterior chamber depth (ACD), radius of corneal curvature (K, including steep/flat/average K), astigmatism and axis. Only the right eye record of each patient was analysed.

Results: Ocular biometric data included 2839 urban patients (73.15 ± 9.54 years) and 2646 rural patients (73.64 ± 7.32 years). Mean AL, ACD and K were 24.35 ± 2.34 mm, 3.14 ± 0.58 mm, and 44.38 ± 1.52 D, respectively, in urban patients and 23.58 ± 1.70 mm, 3.08 ± 0.57 mm, 44.53 ± 1.50 D, respectively, in rural patients. The urban subjects had significantly longer axial lengths and deeper ACDs than rural subjects ($p < 0.01$). There was no significant difference in steep K, flat K and average K between the two groups. A total of 49.71% patients exhibited against-the-rule (ART) astigmatism, and there was a significant difference in the number of patients who exhibited with-the-rule (WRT) astigmatism (32.58%) and oblique astigmatism (17.71%).

Conclusions: We report biometry and astigmatism data in a large cohort of urban and rural subjects for the first time. In our study, a short AL, shallow ACD and axis turned in an ATR direction had higher prevalence rates in the rural subjects. This profile of ocular biometric data and corneal astigmatism will be helpful in planning for intraocular lens (IOL) power calculations and astigmatism correction in subjects in different locations.

Background

The expectations of both surgeons and patients are high for accurate refractive results after the phacoemulsification and intraocular lenses (IOLs) implantation surgery. One important key for these successful outcomes is obtaining accurate ocular biometric measurements preoperatively [1]. The basic ocular biometric characteristics include axial length (AL), anterior chamber depth (ACD), keratometric power (K) and corneal astigmatism (CA) [1]. The modern IOL power formula, which is based on the Gaussian model, predicts the effective lens position (ELP) by using these biometric parameters. With modern biometry and the new-generation IOL power formulas, the refractive outcomes in approximately 87% of patients are within ± 1.0 dioptre (D) of the intended target [2].

The specific AL, K and ACD averages according to the gender and race of patients in different areas may influence the accuracy of the IOL power calculation even when using the same formula. Studies concerning the distribution of ocular biometrics in different populations from Asian countries (Mongolia, Taiwan, Myanmar, Singapore and China) have been published [3-5]. In China, the comparable biometric data of interethnic variability in a large population-based study are still lacking.

The purpose of our study was to assess the distribution of AL and other ocular biometric parameters, as measured using the partial coherence laser interferometry (IOLMaster, Carl Zeiss Meditec, Germany), in the urban and rural populations of the municipality of Shanghai in eastern China.

Patients And Methods

Subjects

This study was approved by the ethics committee of the Shanghai Aier Hospital (Shanghai, China) and followed the tenets of the Declaration of Helsinki. Consecutive cataract patients scheduled for phacoemulsification and foldable IOL implantation were recruited in the urban location of Shanghai Aier Eye Hospital and in the rural location of Shanghai Jinshan Aier Eye Hospital between January 2018 and December 2018. Only patients aged over 50 years were included. Exclusion criteria included a history of ocular surgery, such as refractive surgery, corneal diseases, ocular inflammation and trauma; patients from other areas of China were also excluded. Routine eye slit-lamp and biometry examinations were performed before surgery. The procedures were fully explained to each patient, and they provided written informed consent.

Biometry examination

Ocular axial length (AL), anterior chamber depth (ACD), radius of corneal curvature (K, including steep/flat/average K), astigmatism and axis of the right eye were measured with the IOLMaster (Carl Zeiss Meditec, Germany, software version 5.4). The mean value of 5 measurements was used for each parameter. All patients were tested by the same experienced examiner. Keratometry, including flat keratometry (K1) and steep keratometry (K2), was recorded. The K value was calculated as the mean of K1 and K2.

Statistical analysis

All data were recorded in Microsoft Excel spreadsheets. Statistical analysis was performed using SPSS PASW Statistics Version 18.0 software (IBM Corporation, Armonk, NY, USA). Distributions of normality of the ocular biometric parameters were checked with the Kolmogorov-Smirnov (K-S) test and were considered significantly different from normal when the p-value was less than 0.05. Differences between groups were compared using the t test or analysis of variance (ANOVA) for normally distributed variables and the Mann-Whitney U test for non-normally distributed variables. One-way analysis of variance and the Kruskal-Wallis test were respectively applied for the comparison of variance for normally and non-normally distributed data among the different age groups. A p-value less than 0.05 was considered statistically significant.

Results

Demographics of the study population:

A total of 5485 right eyes of 5485 participants (2839 eyes from urban areas, 2646 eyes from rural areas) were included in the study. Table 1 shows the patient demographics of all participants and also provides a comparison of the rural and urban populations. The population was stratified by age: 50–59 years (7.06% of the total population, mean age 55.57 ± 2.80 years; 60–69 years (22.92%, 65.07 ± 2.66 years); 70–79 years (44.23%, 74.40 ± 2.84 years); 80–89 years (24.54%, 83.10 ± 2.34 years); and 90+ years (1.26%, 92.10 ± 2.30 years). There were no significant differences between the age groups.

Distribution of ocular axial length characteristics

Figure 1 shows the distribution of ocular axial length in the whole population. The AL distribution (mean: 23.98 mm, median: 23.41 mm; range: 18.45–35.64 mm) was skewed toward the right (2.09), peaked with a kurtosis of 5.31 and had a significant Kolmogorov-Smirnov test for deviation from normality ($p < 0.01$).

In the urban group, the mean AL was 24.35 mm (median: 23.67 mm; range: 18.45–35.64 mm), and in the rural group, the mean AL was 23.58 mm (median: 23.23 mm; range: 19.87–33.92 mm), showing a statistically significant location-related difference ($p < 0.001$, Mann-Whitney U test).

In the urban group, the mean AL in women was 24.18 ± 2.48 mm (95% CI: 24.06–24.30 mm), and the mean AL in men was 24.61 ± 2.06 mm (95% CI: 24.49–24.73 mm), showing a statistically significant gender-related difference ($p < 0.001$). In the rural group, the mean AL in women was 23.40 ± 1.69 mm (95% CI: 23.32–23.49 mm), and the mean AL in men was 23.86 ± 1.66 mm (95% CI: 23.75–23.96mm), showing a statistically significant gender-related difference ($p < 0.001$). Mean AL was significantly longer in men than in women in both two groups (Table 2).

Distribution of ocular ACD characteristics

Table 2 shows the ACD distribution (mean: 3.11 mm, 95% CI, range 3.10–3.13 mm) which was not normal distribution in either group (urban: 3.14 ± 0.58 mm; rural: 3.08 ± 0.57 mm) or the whole population (Kolmogorov-Smirnov test, $p < 0.001$).

In the urban group, a decrease of ACD value was associated with increased age in men, women and in the combined group. A similar decrease of ACD value within a decade of age in different groups was also shown in the rural population. In first three age groups, there were significant differences of ACD between the different location populations. In the 80–89 years group and the 90+ years group, the differences were not significant between the two locations (Fig. 2).

Distribution of corneal K characteristics

The mean K of the overall population was 44.45 dioptres (D) (95% CI 44.41–44.49 D), and the distribution was right (positively) skewed (0.92) with kurtosis of 0.263 (K-S test, $p < 0.001$). As shown in Table 2, the mean K reading of the rural population (44.53 ± 1.50 D) was significantly different from that of the urban population (44.38 ± 1.52 D), $p < 0.001$. The mean K reading was also significantly different between the male and female populations in the urban area, rural area and combination groups.

In Table 3, the mean K reading was shown across age and location groups. There are significant differences in the K reading between the different age groups in the urban area population, while there are no significant differences in the K reading between the different age groups in the rural area population.

Distribution of corneal astigmatism (CA) characteristics

The CA distribution (mean, 1.07 ± 0.72 D) was skewed towards the positive (1.559) and peaked with kurtosis of 3.652 (K-S test, P < 0.001).

The histograms of the frequency distribution of corneal astigmatism for all location groups are shown in Figure 3. Corneal astigmatism of 0.51–1.00 D was the most common range of values in both urban and rural areas (35.7% and 33.0%, respectively). In rural areas, the next most common ranges were 0.0–0.50 D (22.4%), 1.01–1.50 D (22.1%) and 1.51–2.0 D (13.0%), while for urban areas, the next most common ranges were 1.01–1.50 D (23.1%), 0.0–0.50 D (21.1%) and 1.51–2.0 D (13.0%).

A total of 49.71% patients exhibited against-the-rule (ART) astigmatism, which was significantly different from with-the-rule (WRT) astigmatism (32.58%) and oblique astigmatism (17.71%). The prevalence of WTR corneal astigmatism decreased with increasing age, while the prevalence of ATR corneal astigmatism rose. The trend of ART/WTR changing across age group was more obvious in the rural population than the urban (Fig. 4).

Discussion

Our study evaluated the ocular biometric data characteristics in Shanghai urban and rural populations by using a partial coherence laser interferometry (PCI). PCI is widely used in clinical work due to its highly accurate and reproducible measurements. The accuracy of the biometric data leads to accurate calculations of IOL power. Previous studies have investigated the characteristics of biometric data of different race populations, such as southern Chinese [6], Latin American [7], Malay [8], Indian [9] and Western populations [10]. To our knowledge, this is the first biometry study that focuses on urban and rural cataract patients in China.

We demonstrated that the biometry parameter, such as AL, ACD, K and CA, was distributed non-normally in the general investigated population (all participants), in the different location populations (urban versus rural) and in the gender populations (male versus female), respectively.

The AL data in our study was positively skewed and showed significant kurtosis, as reported in the Reykjavik Eye Study [11] and the studies by Fotedar [12] and Chen [13]. In the combination/general population, mean AL was 23.98 ± 2.09 mm, which was similar to the results of the study in southern China by Cui et al. (24.07 ± 2.14mm) [6]. But the mean AL in urban areas was about 0.8 mm longer than that in rural areas (24.35 ± 2.34 mm versus 23.58 ± 1.70 mm, respectively). Mean AL in Shanghai was similar to Yu's study (24.38 ± 2.47 mm) from central China [14] and Huang's study (24.32 ± 2.42 mm) from western China[15], but was clearly longer than other AL studies using PCI [8-10], which investigated other ethnicities, such as European (23.43 ± 1.51 mm) [10], Latin American (23.8mm) [7], Malay (23.55mm) [8] and Mongolian (23.13 ± 1.15 mm) [4].

Yu [14] and Huang [15] had investigated the inhabitants in Wuhan and Chengdu urban areas, respectively, which are similar in latitude to Shanghai. All of these cities belong to the reaches of the Yangtze River. For other Chinese inhabitants in urban southern China, on the reaches of Zhu River, and other Asian countries, mean AL is shorter than for those living in Shanghai. Obviously, AL parameters were related to ethnicity and environment. There was no previous study that involved the local urban and rural populations. We found the AL of the urban population to be longer than that of the rural population. We propose that the urban population may be exposed to more near work and become more myopic with a longer AL than the rural population. As for the gender factor, we found that men had a longer AL than women, which is consistent with findings from previous studies [6, 12, 15]. These disparities reflect the different physical conditions between the sexes.

We found that the ACD was deeper in a younger, male, urban population than it was in an older, female, rural population. The first two findings were similar to other studies [4, 12, 16]. The trend of ACD variance with sex was attributed to differences of male and female anatomy, particularly height. The depth of the ACD often decreased with an increase in age-related lens thickness, which can be observed in any gender or race [4, 12, 16]. In comparison to European (3.11 ± 0.43mm) [10], Austrian (3.10mm) [12] and Latin American studies (3.41± 0.35 mm) [7], the mean ACD depth is shallower in Shanghai and Jinshan. Previous studies found that elderly Asian women were more likely to develop acute angle-closure glaucoma due to factors of sex and race, which is similar to the results of Chinese population studies from Cui (3.01 ± 0.57mm) [6] and Chen (3.03 mm) [13]. However, other investigators, like Huang (3.08 ± 0.47 mm)[15] and Yu (3.15 ± 0.48mm) [14], found a deeper ACD than we did. Long axial length myopia is often consistent with a deeper ACD, while short axial length hyperopia is consistent with a shallower ACD. The percentage of eyes with a long axial length in the population will influence the mean ACD; therefore, when comparing the mean ACD in different Chinese studies, researchers should consider adjusting for the effects of myopia.

As for the differences in ACD between the urban and rural populations, we presume it was also caused by the myopia ratio in these two groups. Xu et al. had demonstrated that myopic refractive error was significantly associated with younger age and an urban region [17]. Because our study was based on cataract surgery candidates who had not been correctly evaluated with their refractive error status, no advanced refractive error corrected analysis about the relationship between and biometry was performed. In He's study, however, refractive error was strongly correlated with axial length and anterior chamber depth by using the multivariate models [18]. The differences in ACD may be strongly related to the AL distribution in the two populations.

In our study, we found that 44.18% of the overall population had 1.0 D or more corneal astigmatism, which is higher than other Chinese population results. Chen [19] reported that 41.3% of the eyes studied had presented a corneal astigmatism equal to or higher than 1.0 D while Cui and Yu reported 43.9% and 43.5%, respectively [6, 14]. Two other Chinese studies showed a higher percentage of eyes with over 1.0 D astigmatism than our study (Yuan 47.27%, Guan 45.46%) [20, 21]. We speculate that the difference between these studies is caused by two factors: first, these studies focused on a larger age range than our study, and second, these studies recruited many cases that included both eyes, which may increase the statistical power of a test, thereby increasing the likelihood of detecting true significant effects.

In our study, we found that the proportion of eyes in urban areas that had a corneal astigmatism of 1.0 D or greater was 41.9%, which was less than the proportion in rural areas (45.9%). We also found the astigmatism axis turned to the ATR direction with age. This trend of ATR increasing as subjects grow older has been proven by many previous investigations. However, a higher percentage of ATR astigmatism was found in the rural population than in the urban population. In the population with 1.0 D or more astigmatism in urban areas, 42.25% of patients had WTR and 46.16% had ATR. In rural areas in the same population, 23.14% of patients had WTR and 67.05% had ATR. Previous studies have demonstrated a higher percentage of ATR astigmatism in an Asian population (49.7% in our study, 53.2% in Cui's study and 62.2% in a Thailand population) [6, 22] than in Western populations. There are many factors that influence whether the astigmatism axis direction turns with-the-rule or against-the-rule, such as ethnicity, anatomy, eyelid morphology and the effects of intraocular pressure on the curvature of the cornea. The reasons that have led to the difference in prevalence of ATR in various locations still needs to be investigated further. Cataract surgeons should consider using more toric IOLs in rural populations than in urban populations.

Our study has some limitations. First, the study was clinic-based and may not be representative of the entire population. Second, the relationship between biometric features and refraction was not evaluated due to the cloudy crystalline lens of the cataract patients. There were also missing measurements, such as the white-to-white, central corneal thickness, lens thickness and vitreous chamber depth. Finally, social status, education and occupation were not recorded in our study.

In conclusion, we report biometry and astigmatism data in a large cohort of urban and rural subjects for the first time. In our study, the rural subjects were more likely to have a short AL, shallow ACD and an axis turned in an ATR direction. This profile of ocular biometric data and corneal astigmatism will be helpful in planning IOL power calculations and astigmatism correction in patients who live in different locations.

Declarations

Conflict of interest statement

All the authors have no conflicts of interest.

Consent to Publish

Not applicable

Availability of data and material:

All data supporting our findings can be found in this article.

Author Contributions:

Conceived and designed the experiments:Xu Chen, Hui Liu. Performed the experiments:Hui Liu,Jianheng Liang, Kunqiao Wei. Analyzed the data: Hui Liu. Contributed reagents/materials/analysis tools: Zhuyun Qian. Wrote the paper:Hui Liu. Critical revision of the manuscript:Xu Chen, Zequan Xu.

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Tables

Table-1: Demographic features of the present study population

Age/Location		Shanghai(urban)	Jinshan(rural)	Total(%)
ALL	Patients(Eyes)	2839	2646	5485
	Age	73.15±9.54	73.64±7.32	73.29±8.56
50-59	Eyes	330.00	57.00	387 (7.06)
	Age	55.58±2.83	55.51±2.63	55.57±2.80
60-69	Eyes	601	656	1257 (22.92)
	Age	64.95±2.72	65.17±2.62	65.07±2.66
70-79	Eyes	1072	1354	2426 (44.23)
	Age	74.48±2.88	74.34±2.81	74.40±2.84
80-89	Eyes	786	560	1346 (24.54)
	Age	83.11±2.36	83.08±2.32	83.10±2.34
>90	Eyes	50.00	19.00	69 (1.26)
	Age	92.02±2.35	92.32±2.19	92.10±2.30

Table-2: Sex distribution of ocular biometric parameters

Location/Gender		Mean ± SD					
		AL	ACD	Astigmatism	K		
					K-mean	K1	K2
Rural and Urban	All(5485)	23.98±2.09	3.11±2.09	1.07±0.72	44.45±1.51	43.92±1.54	44.98±1.58
	M(3360)	24.25±1.91	3.20±0.58	1.06±0.70	44.00±1.49	43.47±1.51	44.53±1.55
	F(2125)	23.81±2.17	3.05±0.57	1.07±0.73	44.74±1.16	44.20±1.49	45.27±1.53
	P value	<.001	<.001	>.1	<.001	<.001	<.001
Jinshan(rural)	All(2676)	23.58±1.70	3.08±0.57	1.09±0.73	44.53±1.50	43.98±1.54	45.07±1.55
	M(1030)	23.86±1.66	3.17±0.57	1.08±0.68	44.04±1.42	43.50±1.47	44.58±1.46
	F(1616)	23.40±1.69	3.03±0.57	1.10±0.76	44.84±1.46	44.29±1.50	45.39±1.53
	P value	<.001	<.001	>.1	<.001	<.001	<.001
Shanghai(urban)	All(2839)	24.35±2.34	3.14±0.58	1.04±0.70	44.38±1.52	43.86±1.53	44.90±1.60
	M(1095)	24.61±2.06	3.24±0.58	1.04±0.72	43.96±1.54	43.44±1.54	44.29±1.63
	F(1744)	24.18±2.48	3.08±0.57	1.05±0.70	44.64±1.45	44.12±1.47	45.17±1.52
	P value	<.001	<.001	>.1	<.001	<.001	<.001

ACD anterior chamber depth；AL axial length;K1 keratometric in flat meridian;K2 keratometric in steep meridian;M Male;F Female

Table-3: Descriptive statistics of mean K reading in 5 age groups

Age Group (Y)	K (D) mean ± SD	
	Shanghai(urban)	Jinshan(rural)
50-59	44.11±1.57	44.52±1.75
60-69	44.56±1.50	44.44±1.55
70-79	44.40±1.57	44.56±1.51
80-89	44.29±1.46	44.54±1.38
>=90	45.10±0.97	44.39±1.75
P value	<0.001	0.43

K mean keratometry, D diopter, SD standard deviation

Table-4: Patient Ocular biometric data compared with other published studies

Paremeters		Yu JG[14]	Cui Y[6]	Guan Z[19]	Yuan X[20]	Huang Q[15]	Pan CW[9]	Fotedar R[12]	Warrier S[3]	Shufelt C[7]
Location		Central China	Southern China	Eastern China	Northern China	Western China	Singapor	BMES	Myanmar	Los Angele
Eyes		3209	6750	1430	12449	6933	3400	1321	1498	5588
Age(y)	Mean±SD	70.51±9.81	70.4±10.5	72.27±11.59	69.80±11.15	NR	NR	NR	NR	NR
	Range	32,95	40,101	16,98	30,97	50,98	40,83	>=59	>=40	>=40
Keratometry(D)	K1-mean ± SD	43.75±1.59	43.57±1.69	43.57±1.56	43.93±1.67	NR	43.95	43.38	NR	NR
	K2-mean ± SD	44.84±1.65	44.69±1.69	44.64±1.65	45.08±1.73	NR	44.7	NR		
	K-mean ± SD	44.29±1.58	44.13±1.63	NR	NR	44.23±1.66	NR	NR		
AL(mm)	Male	24.38±2.47	24.28±2.08	NR	NR	24.79±2.48	23.68±1.06	23.75	23.12	23.65±0.94
	Female		23.90±2.18			23.88±2.27	23.23±1.10	23.2	22.54	23.18±1.02
ACD(mm)	Male	3.15±0.48	3.08±0.59	NR	NR	3.16±0.47	3.19±0.36	3.16	2.86	3.48±0.34
	Female		2.96±0.55			3.01±0.47	3.10±0.35	3.06	2.29	3.36±0.34

D diopter, K1 flat keratometry, K2 steep keratometry, K mean keratometry, SD standard deviation, AL axial length, ACD anterior chamber depth, NR not reported;

Figures

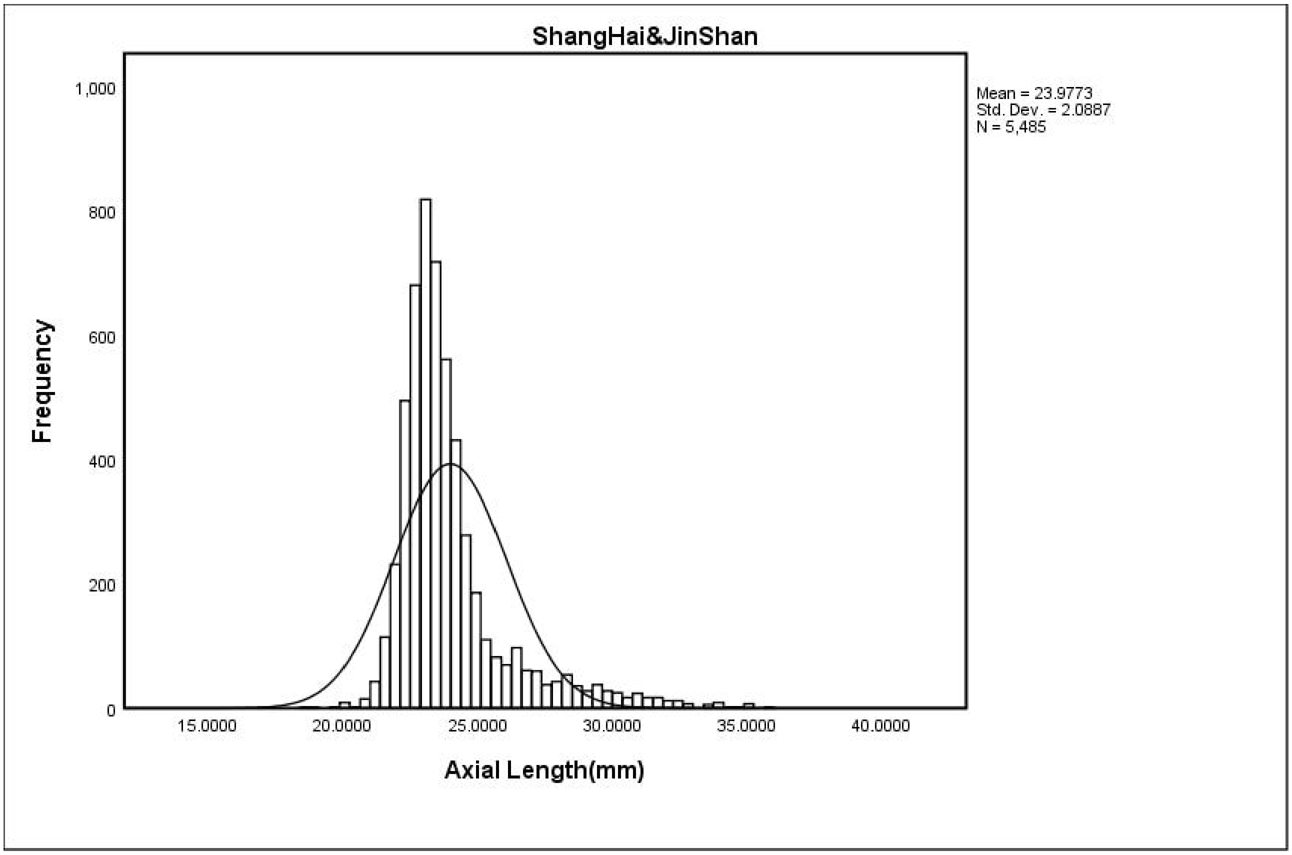

Figure 1

Distribution of axial length in the total shanghai population

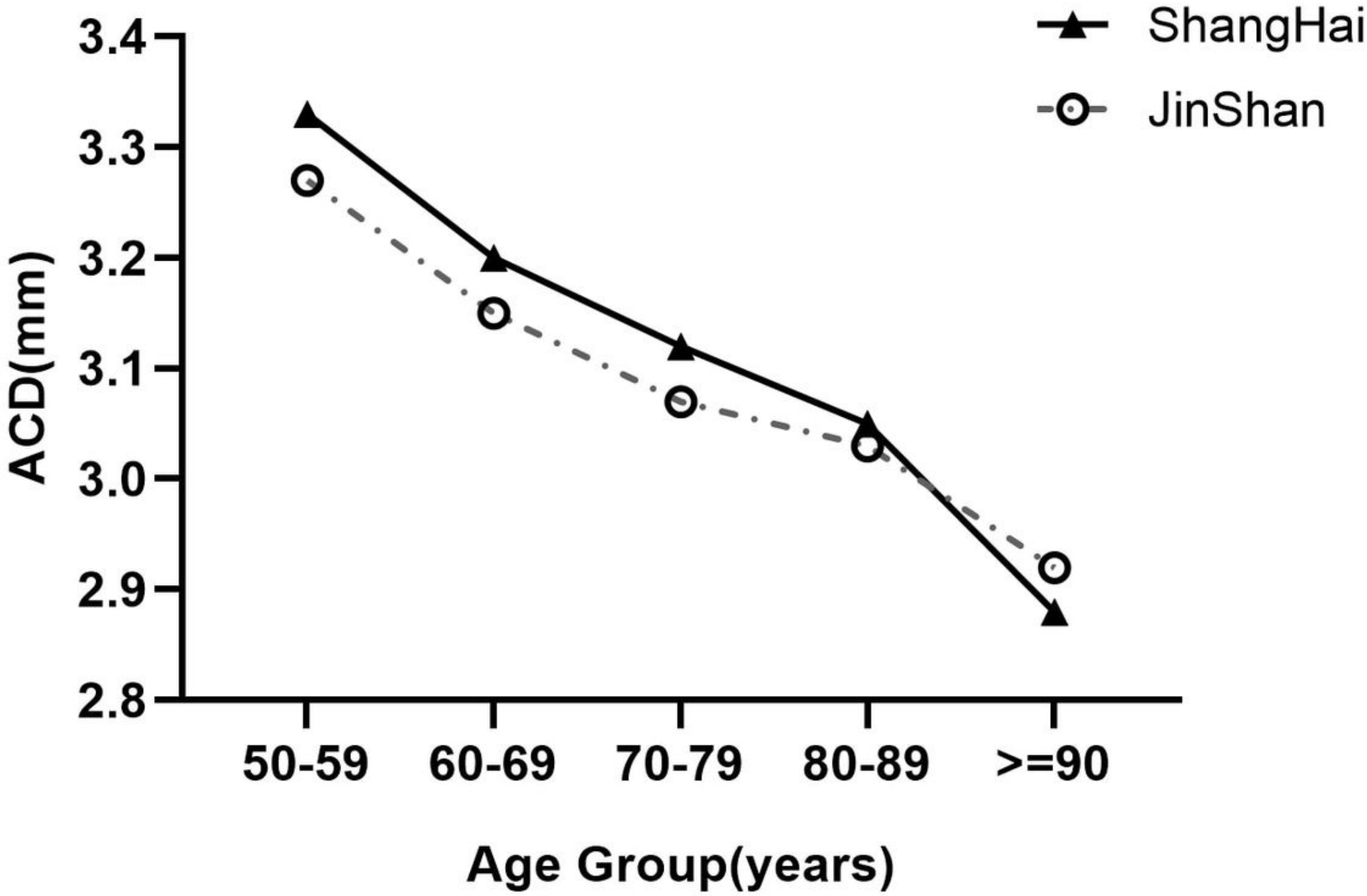

Figure 2

Distribution of ACD in Shanghai and Jinshan populations in all age groups

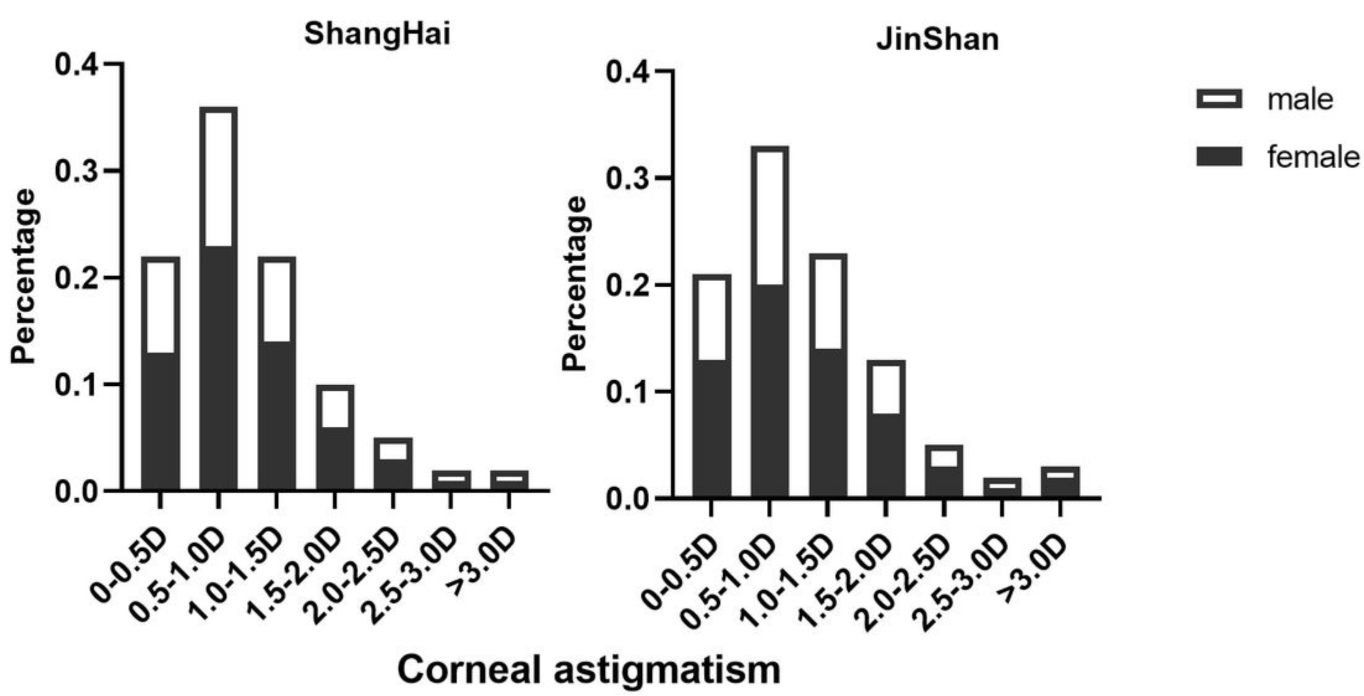

Figure 3

Distribution of corneal astigmatism in the total shanghai population

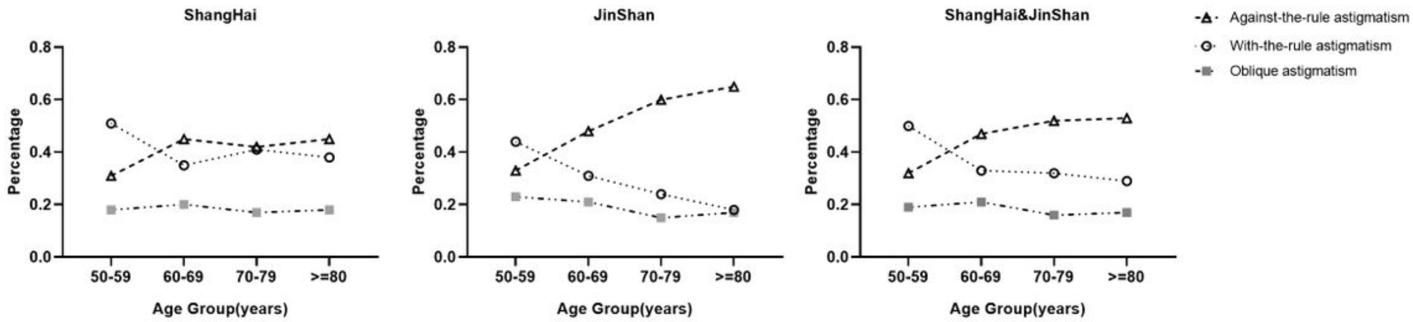

Figure 4

Percentages of with-the-rule, against-the-rule, and oblique corneal astigmatisms in the 4 groups