Evaluation of Anterior Chamber Depth in 28,709 Adult Cataract Patients in China using Swept-Source Optical Biometry

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Abstract

Background: To create an anterior chamber depth (ACD) regression model for adult cataract surgery candidates from China, and to evaluate the distribution of their ocular biometric parameters.

Methods: The ocular biometric records of 28,709 right eyes of cataract surgery candidates who were treated at Aier Eye Hospitals in nine cities from 2018 to 2019 were retrospectively analyzed. All measurements were taken with IOLMaster 700. We included patients who were at least 40 years old and were diagnosed with cataract.

Results: The mean age of the patients was 68.6 ± 11.0 years. The mean values recorded were as follows: axial length (AL), 24.17 ± 2.47 mm; mean keratometry (Km) value, 44.09 ± 3.25 D; corneal astigmatism (CA), 1.06 ± 0.98 D; ACD, 3.02 ± 0.45 mm; lens thickness (LT), 4.52 ± 0.45 mm; central corneal thickness (CCT), 0.534 ± 0.04 mm; and white to white (WTW) corneal diameter, 11.64 ± 0.46 mm. The proportion of patients with long axial length (AL >25 mm) decreased with age. ACD, LT, AL, Km, WTW, and age were correlated. In the multivariate regression analysis of ACD, which included LT, AL, WTW, sex, Km, CCT, and age, there was a reasonable prediction with adjusted R^2 = 0.629.

Conclusions: The results show that high myopes are inclined to schedule cataract surgery at a younger age. LT and AL were found to be important factors that affect ACD. This study provides reference data for cataract patients from China.

Background

Modern cataract surgery has transformed from a rehabilitative procedure to a refractive operation. This can be attributed to the development of measuring devices, lens calculation formulas, surgical technology, and intraocular lenses. Accurate prediction of refractive outcomes after cataract surgery is crucial. When biometry is based on optical coherence interferometry (Zeiss IOLMaster), the error from anterior chamber depth (ACD) prediction amounts to approximately 42% of the total refractive prediction error [1]. Olsen [2] found that postoperative ACD is significantly predictable by a five-variable regression method that incorporates preoperative axial length (AL), ACD, keratometry (K), lens thickness (LT), and refraction. Therefore, it is essential to acquire the biometric characteristics of cataractous eyes to enable the utilization of precise ocular biometric parameters for accurate intraocular lens calculation.

Previous research has confirmed that female sex, older age, shorter AL, shallow ACD, and smaller LT were risk factors for angle closure [3]. These risk factors are also closely associated with elderly cataract patients.

To the best of our knowledge, there is no study of a large series of biometry measurements acquired with the IOLMaster 700 device in the existing literature. The purpose of this study was to create an ACD regression model for cataract surgery candidates aged 40 years or older, and to review and evaluate their biometry parameters. The results of this study may provide a new reference for cataract patients based on a large group of patients.

Methods

Study Population

The medical records of 28,709 cataract surgery candidates over a year period (October 2018 to October 2019) (11,753 men [40.9%] and 16,956 women [59.1%]) from the Aier Eye Hospitals in nine provincial capitals in China were reviewed retrospectively. Due to the retrospective nature of the study, the need for informed consent was waived. The retrospective study was approved by the Ethics Committee of Aier Eye Hospital and was performed in accordance with the Declaration of Helsinki.

The ocular parameters were measured with a non-contact swept-source optical biometer (IOLMaster 700, Carl Zeiss Meditec AG, Jena, Germany). The inclusion criteria were as follows: 1) patients diagnosed with cataracts; 2) patients who were 40 years or older; and 3) 3) patients with good quality measurements with the IOLMaster 700 The exclusion criteria were as follows: 1) patients who had complications with other eye diseases including corneal diseases or inflammatory eye diseases; and 2) patients who had a history of trauma or ocular surgery.

Device And Measurement

The IOLMaster 700 has a swept source optical coherence tomography (SS-OCT) scanning capacity with 1,050 nm laser infrared light and measures AL, ACD, LT, and central corneal thickness (CCT). The device can obtain OCT images of the macular and visualizes the measurement of the AL of the eye. The IOL Master 700 uses telecentric keratometry for K measurements. Corneal power is measured in two meridians: the greatest and least radii of curvature (K_1, K_2). Corneal astigmatism (CA) is calculated as the absolute difference between K_1 and K_2 values. Mean keratometry (Km) is the average of K_1 and K_2. It provides keratometry measurements in the central 2.5-mm zone and uses a refractive index of 1.3375 for the biometry parameters. ACD is measured from the corneal epithelium to the anterior lens surface [4]. A single capturing process can provide multiple measurements for each parameter. We controlled the quality of the measurements according to the device instructions. All patients were tested by experienced examiners. We selected measurements with a standard deviation of less than 20 microns.

Statistical analysis

To avoid correlation between the right and left eyes, only the right eye of each subject was used for statistical analyses. Data were processed with the SPSS software version 19.0 (IBM, USA). We performed a four-step analysis. First, we stratified the parameters according to sex and age groups. The study participants were classified into 5 groups based on age (40–49 years, 50–59 years, 60–69 years, 70–79 years, over 80 years). All eyes were divided into five groups based on AL; they were also categorized into five groups based on ACD. Second, the Mann-Whitney U Test was used to compare the ocular parameters according to sex and AL group. The chi-square test was used to compare the frequency distribution. Third, we evaluated the association between age and other ocular parameters using Spearman's correlation. Finally, we performed a multivariate analysis with ACD as the dependent parameter and all other parameters that were significantly associated with ACD as independent variables.

Variation inflation factors were calculated to investigate multicollinearity. All *P*-values were two-sided and considered statistically significant when the values were less than 0.05.

Results

A total of 28,709 patients, including 11,753 men (40.9%) and 16,956 women (59.1%) diagnosed of cataract, were selected according to our inclusion criteria. The mean age of the patients was 68.6 ± 11.0 years (range, 40–101 years). The mean values measured were as follows: AL, 24.17 ± 2.47 mm; Km, 44.09 ± 3.25 D; CA, 1.06 ± 0.98 D; ACD, 3.02 ± 0.45 mm; LT, 4.52 ± 0.45 mm; CCT, 0.534 ± 0.04 mm; and white to white (WTW) corneal diameter, 11.64 ± 0.46 mm. The details of the ocular characteristics of the right eyes stratified according to age groups are shown in Table 1. The subgroups and the distribution of AL and ACD are shown in Table 3. Figure 1 illustrates the percentage of patients in the AL groups stratified according to age. The proportion of patients with long AL (AL > 25 mm) decreased with age.

Table 1
Distribution of the ocular biometric parameters by age group

Parameter	Total	Age group (years)				
		40–49	50–59	60–69	70–79	80+
n (%)	28709	1932 (6.7%)	3658 (12.7%)	8720 (30.4%)	9888 (34.4%)	4511 (15.7%)
AL (mm)	24.17 ± 2.47	26.63 ± 3.40	24.98 ± 3.20	24.03 ± 2.39	23.75 ± 1.93	23.66 ± 1.58
Km (D)	44.09 ± 3.25	43.60 ± 3.10	43.91 ± 3.28	44.13 ± 3.20	44.19 ± 3.35	44.16 ± 3.16
CA (D)	1.06 ± 0.98	1.14 ± 0.93	1.01 ± 0.94	0.94 ± 0.88	1.08 ± 0.99	1.26 ± 1.13
ACD (mm)	3.02 ± 0.45	3.38 ± 0.41	3.21 ± 0.43	3.03 ± 0.44	2.95 ± 0.44	2.88 ± 0.41
LT (mm)	4.52 ± 0.45	4.17 ± 0.38	4.32 ± 0.43	4.50 ± 0.44	4.60 ± 0.43	4.70 ± 0.43
CCT (mm)	0.534 ± 0.04	0.533 ± 0.04	0.537 ± 0.04	0.534 ± 0.03	0.533 ± 0.04	0.533 ± 0.03
WTW (mm)	11.64 ± 0.46	11.83 ± 0.49	11.74 ± 0.46	11.63 ± 0.45	11.58 ± 0.45	11.60 ± 0.44

AL = axial length; Km = mean keratometry; CA = corneal astigmatism; ACD = anterior chamber depth; LT = lens thickness; CCT = central corneal thickness; WTW = white to white

Table 2
Mean value of biometric parameters published in previous studies

Study* (Date)	Country	Method	Eyes (n)	Age (y)	AL (mm)	ACD (mm)	LT (mm)
Our study	China	IOLMaster 700	28709	68.6 ± 11.0	24.17 ± 2.47	3.02 ± 0.45	4.52 ± 0.45
Ferreira[5] (2017)	Portugal	Lenstar	13012	69 ± 10	23.87 ± 1.55	3.25 ± 0.44	4.32 ± 0.49
Cui[6] (2014)	China	IOLMaster	6750	70.4 ± 10.5	24.07 ± 2.14	3.01 ± 0.57	-
Jivrajka[7] (2008)	USA	US immersion	795	74.37 ± 8.93	23.46 ± 1.03	2.96 ± 0.45	4.93 ± 0.56
Hoffer[8] (1993)	USA	US contact	600	69 ± 12	23.65 ± 1.28	-	4.63 ± 0.68
Hoffer[9] (1980)	USA	US contact	7500	72 ± 10	23.65 ± 1.35	3.24 ± 0.44	-

* First Author

US = A-scan ultrasound biometry; AL = axial length; ACD = anterior chamber depth; LT = lens thickness

Table 3
Distribution of ocular biometry parameters

Parameter	Number (%)
AL group	
< 22 mm	1840 (6.4%)
22–25 mm	21309 (74.2%)
25–27 mm	2221 (7.7%)
27–30 mm	1879 (6.5%)
≥ 30 mm	1460 (5.1%)
ACD group	
< 2.0 mm	413(1.4%)
2.0–2.5 mm	3000 (10.4%)
2.5–3.0 mm	9752 (34%)
3.0–3.5 mm	11223 (39.1%)
> 3.5 mm	4321 (15.1%)
AL = axial length; ACD = anterior chamber depth	

In this study population, the AL was statistically significantly longer in male subjects than in female subjects (24.39 mm versus 24.02 mm, $P < 0.001$). The ACD was significantly deeper in men than in women (3.12 mm versus 2.96 mm, $P < 0.001$). Men had a similar LT as women (4.53 mm versus 4.52 mm), and the difference was not statistically significant ($P = 0.178$). The Km was significantly higher in men than in women (44.59 D versus 44.44 D, $P < 0.001$). The WTW was significantly wider in men than in women (11.78 mm versus 11.54 mm, $P < 0.001$).

We also compared the ACD of the three AL groups (< 22 mm, 22–25 mm and ≥ 25 mm) and found that the differences between them were statistically significant ($P < 0.001$). The ACD of the patients in the group with AL < 22 mm was the shallowest (Fig. 2).

Correlation analysis revealed that age, AL, ACD, LT, Km, and WTW were all significantly correlated with each other ($P < 0.01$), and that ACD was highly correlated with LT ($r = -0.660$, $P < 0.001$) and AL ($r = 0.544$, $P < 0.001$). The complete matrix of the correlation is presented in Table 4. The relationship between ACD and LT, AL, and age is shown in scattergrams (Figs. 3–5).

Table 4
Matrix of Spearman correlation of biometric parameters

Parameter	Age	AL	ACD	LT	Km	WTW
Age	-	-0.180**	-0.284**	0.312**	0.059**	-0.133**
AL	-	-	0.544**	-0.212**	-0.420**	0.325**
ACD	-	-	-	-0.660**	-0.076**	0.300**
LT	-	-	-	-	0.015*	-0.047**
Km	-	-	-	-		-0.438**
AL = axial length; ACD = anterior chamber depth; LT = lens thickness; Km = mean keratometry; WTW = white to white.						
* P < 0.01						
**P < 0.001						

Variation inflation factors for variables were below 2, indicating that there was no clear evidence of multicollinearity. In the multivariate regression analysis of the final model, which included LT, AL, WTW, Km, sex, CCT, and age, there was a reasonable prediction with adjusted R^2 = 0.629 (Table 5).

Table 5
Optimal model coefficients of anterior chamber depth regression

Model	Unstandardized Coefficients		Standardized B	t	Sig.
	B	Std. Error			
(Constant)	1.457	0.067		21.625	< 0.001
LT	-0.625	0.004	-0.623	-163.633	< 0.001
AL	0.060	0.001	0.329	85.287	< 0.001
WTW	0.207	0.004	0.208	53.907	< 0.001
Sex	-0.107	0.003	-0.116	-30.853	< 0.001
Km	0.010	0.001	0.070	18.827	< 0.001
CCT	0.352	0.047	0.027	7.495	< 0.001
Age	0.001	0.000	0.028	7.149	< 0.001

ACD = anterior chamber depth; LT = lens thickness; AL = axial length; WTW = white to white; Km = mean keratometry; CCT = central corneal thickness; Std. = standard

Discussion

We reviewed and evaluated the biometry parameters of cataract surgery candidates and created an ACD regression model for predicting the refractive outcomes of cataract surgery. Optical biometry has been well accepted as the gold standard since the introduction of the IOLMaster optical biometer in 1999 [5]. As a newly available swept-source OCT-based optical biometry device, the IOLMaster 700 provides OCT imaging of the macula and visualizes the measurement of the AL of the eye. The repeatability and reproducibility of the swept-source optical biometer is excellent and its agreement with a standard biometer is very high; better lens penetration ability and more accurate AL measurements are obtained with the swept-source biometer than with the standard biometer [6]. The SS-OCT biometer showed better penetration in dense posterior subcapsular cataracts, measuring AL successfully in 96% of cases which possibly was a result of the reduced scattering and attenuation from ocular opacities by the 1055 nm light source used [7]. In the present study, ocular biometry was performed with the IOLMaster 700, which can capture all parameters in a single process. It is convenient for evaluating patients, especially elderly patients.

A gradual descending trend in average age was reported in five studies of patients who underwent cataract surgery (Table 2) [8–12]. To minimize selection bias, we compared the proportion of patients under 70 years of age in our study and with those of Cui's [10] studies, which represented the cataract surgery scenario in China 10 years ago (July 2007 and June 2011). Both studies included cataract candidates scheduled for phacoemulsification, most of whom came from the urban area. The result, which indicated that there was a higher ratio of cataract patients under 70 years of age currently than there was 10 years ago, was statistically significant (χ^2 = 199.008, P< 0.001). Over the last 10 years, the development of phacoemulsification and femtosecond laser-assisted cataract surgery [13, 14] and the popularity of functional intraocular lenses [15, 16] have advanced cataract surgery in China, leading to better visual outcomes. Urban Chinese cataract patients in the present study tended to choose surgical treatment earlier than cataract patients did 10 years ago, a decision which could improve their quality of life.

In present study, more female patients scheduled cataract surgery than male patients (59.1% versus 40.9%). This finding is almost identical to those of previous published studies [9, 17] (60% versus 40%). Furthermore, female patients presented for surgery at a slightly older age than male patients (mean: 68.8 years versus 68.4 years, P= 0.005). This is similar to the results of Jivrajka's report (mean: 75 years versus 73 years), which considered that women had a longer life expectancy than men [9]. Moreover, some studies showed that women exhibit a higher prevalence of some types of cataract than men [18, 19]. Freeman [20] suggested that a potentially modifiable factor in cataractogenesis may be a woman's exposure to postmenopausal estrogen. This partially explains the sex-related differences in the rates of cataract surgery. Moreover, we believe that elderly women are more concerned about their eye health and are more likely to undergo surgery than elderly men. This needs to be confirmed by further research.

In the present study, female patients presented for surgery with a shorter average AL (mean 24.02 mm versus 24.39 mm, P< 0.001) and shallower ACD (mean 2.96 mm versus 3.12 mm, P< 0.001) than male patients. This echoes the findings of other studies of cataract patients in different countries [21–23]. Some studies showed that body height is positively correlated with AL and ACD; taller persons tended to have longer ALs and deeper ACDs than shorter people, and men are generally taller than women [9, 24, 25]. The sex-related differences in the ALs and ACD measured in the present study may be attributed to the association between ocular dimensions and stature. Further, this is consistent with the higher incidence of primary angle closure (PAC) in women than in men [3, 26]. Research confirms that the female sex, older age, shorter AL, shallow ACD, and larger LT are risk factors for angle closure [3, 26]. These risk factors are closely associated with elderly cataract patients.

In the present study, the mean AL was 24.17 ± 2.47 mm; this result is similar to those of previous reports by Yu [27] (24.38 ± 2.47 mm) and Huang [28] (24.32 ± 2.42 mm). We found that AL was negatively correlated with age (r = -0.180 P< 0.001) (Table 5). The longest mean AL was in the 40–49 years age group (26.63 ± 3.40 mm); this mean AL is longer than that of Cui's report (25.97 ± 3.53 mm) [10]. This may be because our study population had a higher proportion of eyes with a longer AL (AL > 26 mm) than the population in Cui's study [10] (14.7% versus 11.9%). This is especially apparent in the 40–49 years age group in our study, in which the proportion was as high as 52.1%. The proportion of eyes with AL > 25 mm decreased with age (Fig. 1). This corroborates Jivrajka's supposition that high myopia with increased AL predisposes to the development of cataract at a younger age [9]. On the contrary, newer lens formulas and adjustments/transformations are now available to reduce postoperative predictive error in high myopes [29, 30]. Furthermore, the levels of satisfaction and spectacle independence experienced by high myopes were reasonably high after implantation of multifocal or trifocal intraocular lens [15, 31]. Since these outcomes enhance the confidence of high myopes, they are more inclined to schedule cataract surgery at a younger age.

In the present study, the proportion of eyes with short ALs (AL < 22 mm) was 6.4%, which is similar to that of other studies [10, 28]; the proportion of eyes with shallow ACDs (ACD < 2.5 mm) was 11.8%. The refractive status of a patient with a shallow ACD and a short AL after cataract surgery would tend toward a myopic shift. Conversely, a patient with deep ACD and long AL would move toward a hyperopic shift, which was related to the postoperative ACD change [32]. The relative change in ACD after phacoemulsification is larger in short eyes than in normal and long eyes [33]. Melles found that the Barrett Universal Formula had the lowest mean absolute prediction error for eyes with short AL and shallow ACD [34]. This guided us toward choosing the suitable formula for these kinds of patients.

The mean ACD in the present study was 3.02 ± 0.45 mm. The ACD tended to be shallower in older patients and shorter eyes and was negatively correlated with LT. The mean LT was 4.52 ± 0.45 mm and tended to be larger in older patients and in shorter eyes. These findings are consistent with the findings of other studies [8, 9, 35]. These results confirm Hoffer's [8] mechanism of emmetropization: the lens thins (or decreases in power) as the eye gets longer (myopic) and thickens (or increases in power) as the eye gets shorter (hyperopic). The Km in the present study was 44.09 ± 3.25 D and tended to be greater in shorter eyes, which is also in line with the mechanism of emmetropization.

Based on the standardized coefficients of ACD multivariate regression analysis, LT is the main factor that affects ACD, and is followed by AL (Table 6). Adjusted $R^2 = 0.629$ means that 62.9% of the variance could be explained by this model. A study of an elderly Chinese population showed that approximately one in five people aged 50 years and over developed some form of angle closure over a 10-year period, and reported best cut-off values of 2.60, 4.72, and 22.92 mm for ACD, LT, and AL, respectively, in predicting incident PAC [26]. In the present study, the mean ACD of patients in the 60–69 age group was 2.55 mm when the AL was < 22 mm (Fig. 2), and it tended to be shallower with age. Therefore, combined with our ocular data, elderly cataract patients with AL < 22 mm are at a high risk of having PAC. Cataract surgery is effective for lowering the intraocular pressure of normal patients or glaucoma patients [36, 37]. Therefore, we recommend early surgery for elderly cataract patients, especially those with short AL, to minimize the risk of PAC.

This study has certain limitations. First, the data from the nine hospitals do not completely represent the ocular parameters of the overall population in China. Second, we need to collect more information about anthropometric characteristics, education, occupation, income, and the type of intraocular lens, and evaluate the correlations among them. We will conduct more research to improve on the findings of the analyses.

In summary, we collated data on the ocular biometric parameters of cataract surgery candidates in China, compared them, analyzed their correlations, and created an ACD regression model. We found that urban

Chinese patients in this study tended to choose surgical treatment earlier than cataract patients did 10 years ago. We also found that high myopes are inclined to schedule cataract surgery at a younger age. These findings confirm the development and improvement of cataract surgery in China. According to the ACD multivariate regression model, LT and AL are the main factors that affect ACD. Elderly cataract patients, especially those with AL < 22 mm, may be at a high risk of having PAC. We recommend that their cataract surgery be scheduled earlier.

Abbreviations

ACD: anterior chamber depth; AL: axial length; K: keratometry; LT: lens thickness; SS-OCT: swept source optical coherence tomography; CCT: central corneal thickness; CA: corneal astigmatism; Km: mean keratometry; WTW: white to white

Declarations

Ethics approval and consent to participate

The retrospective study was approved by the Ethics Committee of Aier Eye Hospital and was performed in accordance with the Declaration of Helsinki. Due to the retrospective nature of the study, the need for informed consent was waived.

Consent for publication

Not applicable.

Availability of data and materials

All the data supporting the conclusion of this article is included within the article.

Competing interests

The author declare that they have no competing interests.

Author's contributions

QL participated in the collection of data, performed the statistical analysis and drafted the manuscript; YW participated in its design and critically revised the manuscript; HT participated in the collection of data and revised the manuscript; XF participated in the collection of data and revised the manuscript. All authors read and approved the final manuscript.

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Figures

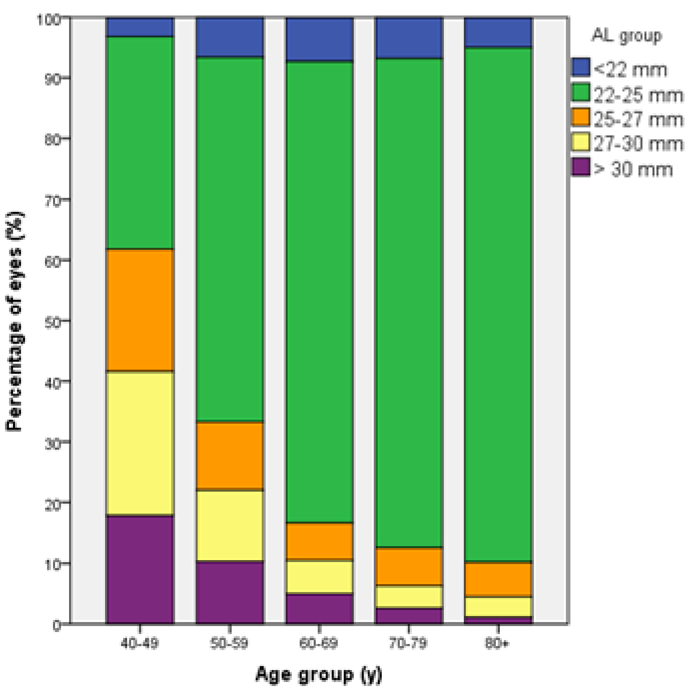

Figure 1

Stacked histogram comparing the percentage of eyes in different AL groups by age groups. AL= axial length

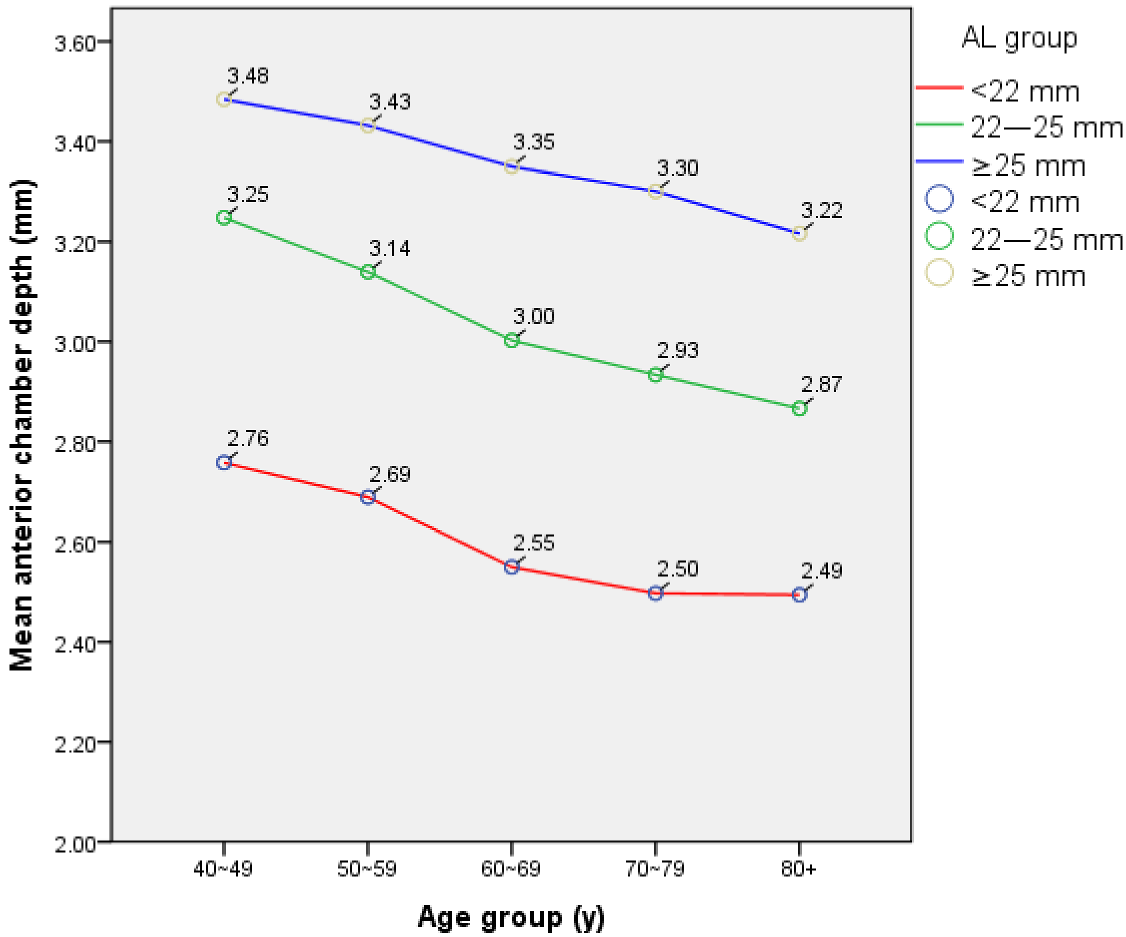

Figure 2

Distribution of anterior chamber depth (ACD) across age groups with data markers stratified according to three axial length (AL) groups. The ACD tended to be shallower in older patients and shorter eyes.

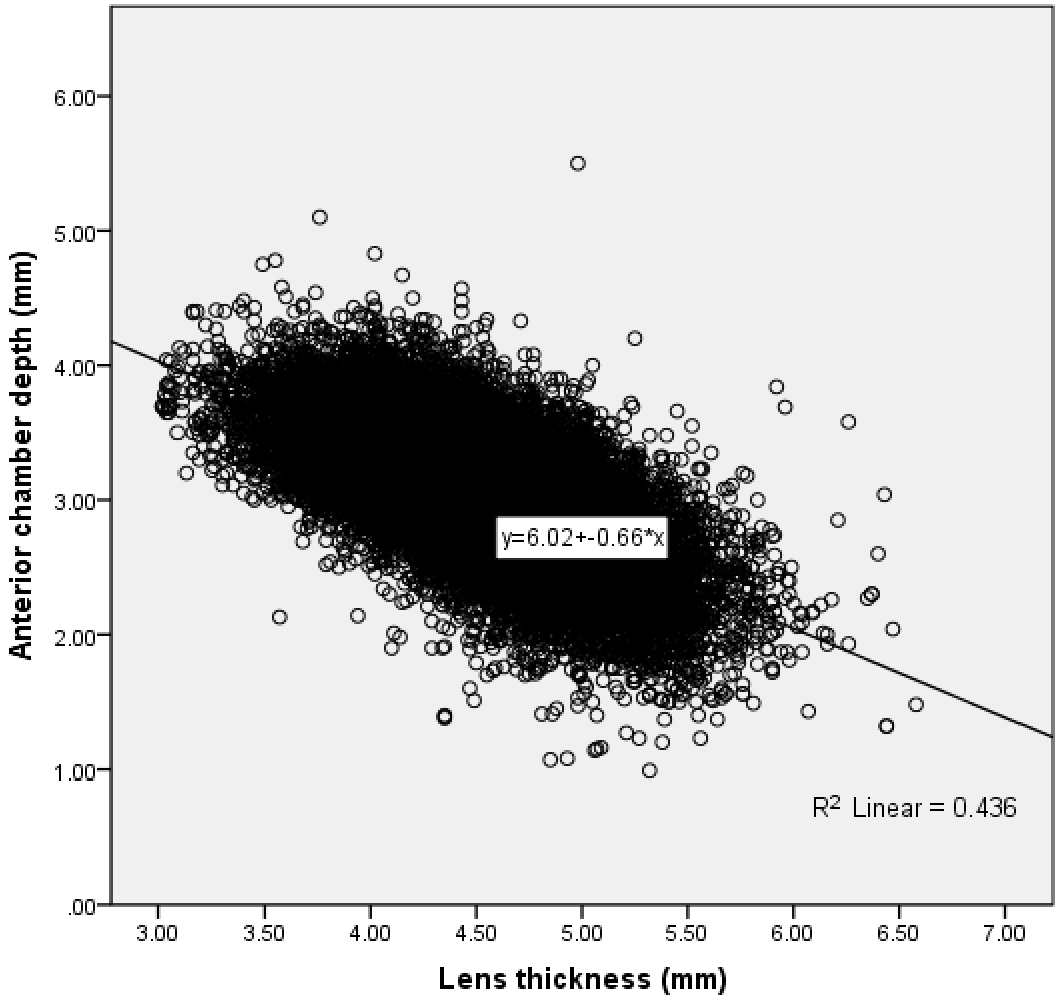

Figure 3

Scattergram showing the relationship between lens thickness and anterior chamber depth.

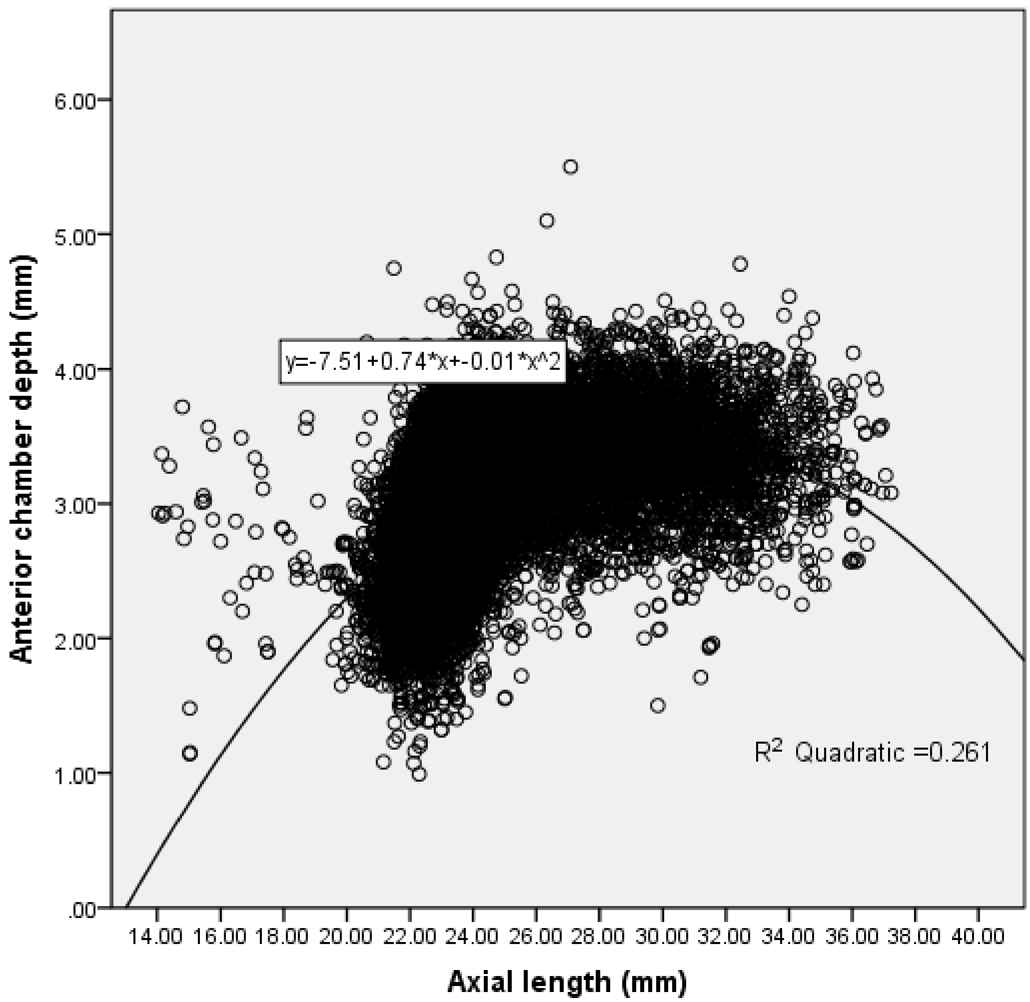

Figure 4

Scattergram showing the relationship between axial length and anterior chamber depth.

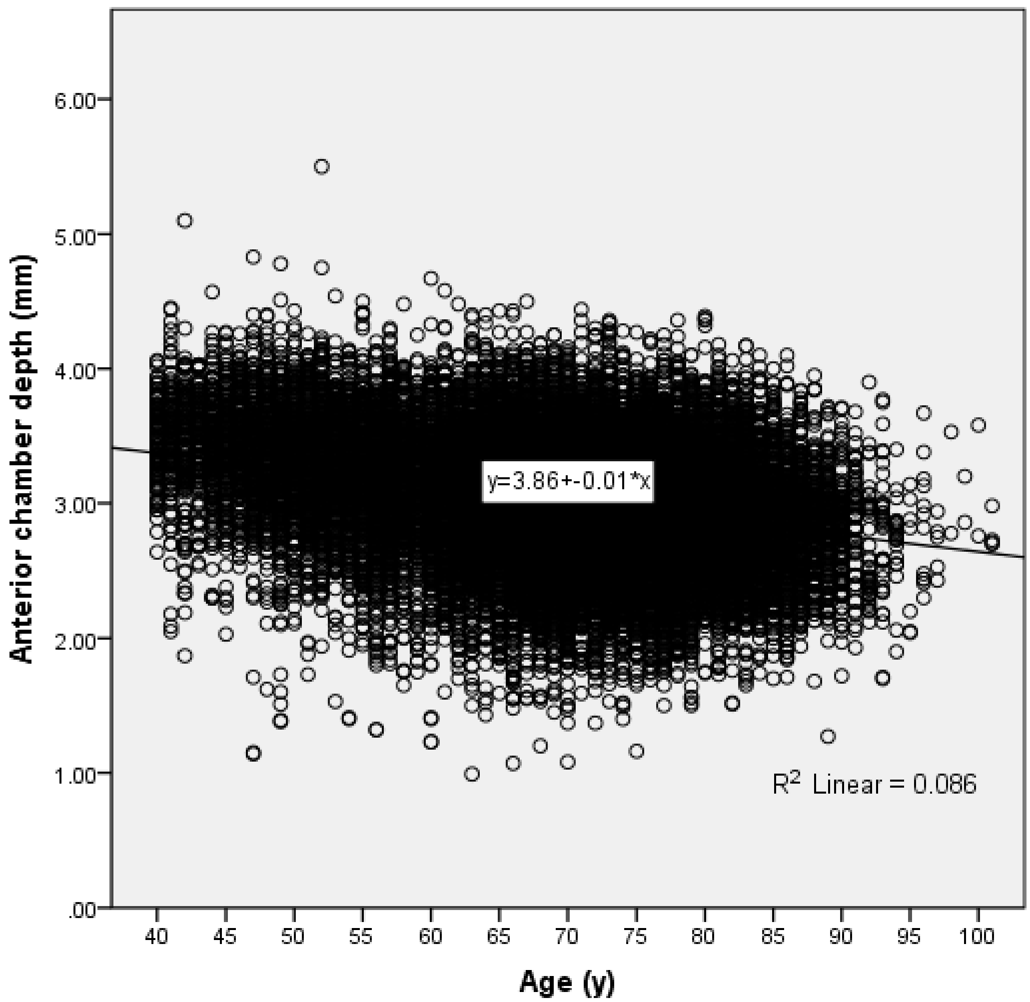

Figure 5

Scattergram showing the relationship between age and anterior chamber depth.