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Analysis of ocular biometric parameters among candidates for cataract surgery

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引用:Zahra Sarlak,Masoud Khorrami-Nejad,Hamed Ghasemi,等. 白内障手术候选者的眼部生物特征参数分析. 国际眼科杂志, 2024,24(8):1186-1193.

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Received: 2023-10-15　　Accepted: 2024-04-10

白内障手术候选者的眼部生物特征参数分析

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摘要

目的:分析白内障手术候选人的眼部生物特征参数。

方法:横断面研究。纳入2017-01/2021-09就诊于伊朗德黑兰Farabi眼科医院的4 607例白内障患者(4 607眼)。使用IOLMaster 700评估眼轴(AL)、角膜曲率(Kf、Ks、Km)、前房深度(ACD)。根据AL分为22 mm<AL、22 mm≤AL≤25 mm和AL>25 mm组,根据ACD分为3.00 mm<ACD、3.00 mm≤ACD≤3.60 mm、ACD>3.60 mm组。

结果:患者平均年龄60.3±14.1(8-95)岁,女2 243例(48.69%),男2 364例(51.31%)。AL、ACD和平均角膜曲率范围分别为23.1-23.4 mm、3.1-3.2 mm和44.50-45.00 D。AL>25 mm组ACD平均值显著高于22 mm≤AL≤25 mm组和22 mm<AL组(P<0.001)。ACD>3.60 mm组的平均AL显著高于3.00 mm<ACD组和3.00 mm≤ACD≤3.60 mm组(P<0.001)。3.00 mm<ACD组和AL>25 mm组的Kf、Ks、Km均值显著高于ACD>3.60 mm组和22 mm<AL组(P<0.001)。

结论:AL长的白内障患者ACD更深,角膜更平坦;AL短的患者ACD较浅,角膜较陡。此外,深ACD患者的AL较长,角膜较平坦,浅ACD患者的AL较低,角膜较陡。

关键词:白内障;眼轴;前房深度;角膜曲率

Abstract

• AIM: To analyze ocular biometric parameters among candidates for cataract surgery.

• METHODS: This cross-sectional study was conducted on 4 607 cataract patients (4 607 eyes) in Farabi Eye Hospital, Tehran, Iran from January 2017 to September 2021. Axial length (AL), keratometry (Kf, Ks and Km), and anterior chamber depth (ACD) were assessed using IOLMaster 700. All eyes were categorized into three groups based on AL: short eyes (22 mm<AL), normal eyes (22 mm≤AL≤25 mm), and long eyes (AL>25 mm) and ACD as follows: low (3.00 mm<ACD), normal (3.00 mm≤ACD ≤3.60 mm) high (ACD>3.60 mm).

• RESULTS: The mean age of patients was 60.3±14.1 (range 8-95) years [2 243 (48.69%) female and 2 364 (51.31%) male]. The AL, ACD and mean keratometry ranges were 23.1 to 23.4 mm, 3.1 to 3.2 mm and 44.50 to 45.00 diopter (D), respectively. The mean amount of ACD in the long eyes group was significantly higher than the normal and short eyes group (P<0.001). The mean AL in the high ACD group was significantly higher than low and normal ACD patients (P<0.001). But the mean of Kf, Ks and Km in the low ACD and long eyes group was significantly higher than in high ACD and short AL groups (P<0.001).

• CONCLUSION: Those candidates with long eyes had deeper ACD with flatter cornea; while short eyes had shallower ACD with steeper cornea. Also, patients with high ACD had longer AL with flatter cornea, and patients with low ACD had lower AL with steeper cornea.

• KEYWORDS: cataract; axial length; anterior chamber depth; keratometry

DOI:10.3980/j.issn.1672-5123.2024.8.02

Citation: Sarlak Z, Khorrami-Nejad M, Ghasemi H, et al. Analysis of ocular biometric parameters among candidates for cataract surgery. Guoji Yanke Zazhi (Int Eye Sci), 2024, 24(8): 1186-1193.

INTRODUCTION

Cataract is a leading cause of visual impairment worldwide[1]. With the increase in life expectancy of populations, progressive aging of the world population is expected and this is linked to the increase in the incidence and prevalence of cataract worldwide[2]. The only type of treatment for cataract is surgery. Phacoemulsification is the most commonly used and efficient surgical technique for the treatment of cataract and it is often effective in restoring vision[3].

As cataract surgery has evolved, expectations for refractive results continue to increase. Advancements in technology have helped to deliver these expectations to provide new ways to measure ocular dimensions in preparation for cataract surgery[3]. Accurate biometric measurements of cataractous eyes are therefore essential. Precise measurement of ocular biometric parameters including ocular axial length (AL), keratometry, anterior chamber depth (ACD), and corneal diameter before cataract surgery is decisive for acquiring the precise degree of implanted intraocular lens (IOL) to control the postoperative diopter (D) to accomplish satisfactory postoperative refractive outcomes and enhance the visual quality for cataract patients[4]. Partial coherence interferometry, through its pioneering and precise measurement of ocular parameters, can quantify preoperative corneal astigmatism and predict the residual corneal astigmatism after the cataract surgery[5].

There are numerous studies of preoperative ocular biometric and corneal astigmatism data on cataract patients in European, American, African, Latin American, and Asian populations[6-48] and two studies from the Middle East with small numbers of Iranian patients recruited[23,30]. However, as ocular biometric parameters vary with gender, age, and ethnicity and are different among different populations[11,14,32,43-47,49], the epidemiological analysis of ocular biometric and corneal astigmatism data of cataract patients in the Middle East with a large group of patients has yet to be explored. Therefore, the aim of this study was to evaluate the distribution and analysis of ocular biometric parameters, and determine the prevalence of ocular biometry parameters and corneal astigmatism before phacoemulsification in cataract patients in Tehran, Iran, to present a reference for improving cataract surgical procedures, designing an IOL to meet eye characteristics of Iranian population, and providing some information regarding distribution of ocular biometry parameters including their relationships.

As mentioned, according to the available literature and published articles, race has been found to influence biometry measurements. This particular article, conducted in Iran with a significantly large patient population, is the first of its kind in this region. As a result, it can serve as a valuable reference for future studies conducted in the same area.

SUBJECTS AND METHODS

Ethical Approval This study was approved by the institutional ethics committee of the Tehran University of Medical Sciences and followed the tenets of the Declaration of Helsinki. Institutional review board of the Tehran University of Medical Sciences approved the study.

Subjects A total of 4 602 cataract patients (4 602 eyes) hospitalized in a tertiary care hospital, the Farabi Eye Hospital, Tehran, Iran were included in this study between January 2017 and September 2021. Consecutive cataract patients scheduled for phacoemulsification were recruited at the Farabi Eye Hospital. Exclusion criteria included a history of ocular surgery (*e.g.*, refractive surgery and intra-ocular surgery), corneal diseases, ocular inflammation, pterygium, corneal pathology, and traumatic IOL dislocation. A full ophthalmologic examination was performed before the cataract surgery, including visual acuity, refractive error measurement, tonometry, slit lamp evaluation, and dilated fundus assessment.

Biometry Examination Partial coherence interferometry is a broadly used method due to its superior accomplishment in the measurement of ocular biometry values. Therefore, ocular AL, keratometry values, and ACD of each cataract-affected eye were assessed with a non-contact swept-source optical biometer, the IOLMaster 700 (Carl Zeiss Meditec, Germany). Keratometry was performed in two meridians: that is, flat keratometry (Kf) and steep keratometry (Ks). The K value was calculated as the mean of Kf and Ks.

The patients were firstly divided into two groups on the basis of gender and then different parameters of age, AL, ACD, Kf, Ks, mean keratometry, and corneal astigmatism were assessed between males and females. All eyes were subsequently stratified into three groups based on AL[50] as follows: short eyes (22 mm<AL), normal eyes (22 mm ≤ AL ≤ 25 mm), and long eyes (AL > 25 mm) and then different parameters of age, ACD, Kf, Ks, mean keratometry, and corneal astigmatism were assessed among these three groups. The patients were also divided based on ACD as follows: low (3.00 mm<ACD), normal (3.00 mm ≤ ACD ≤3.60 mm), and high (ACD>3.60 mm) and compared in the aforementioned way[50]. Patients were classified in 4-year steps, from 16 to 96 years. All ocular optical biometry measurements were performed by two experienced optometrists between 8:00 a.m. and 13:00 p.m. in the same room.

Statistical Analysis Data analysis was performed with SPSS version 24 (IBM Inc., Chicago, USA) using the Kolmogorov-Smirnov test to determine the normal distribution of the variables. After confirming the normal distribution of the parameters, parametric tests were performed. Continuous variables were expressed as the mean ± standard deviation. Independent samples *t*-test was used to compare biometric parameter differences between the male and female study groups. One-way analysis of variance (ANOVA) was applied to compare the variables between the different AL and ACD study groups. Histogram plots with normal curves were drawn for continuous data such as age, AL and ACD. *P*-value of less than 0.05 was considered statistically significant.

RESULTS

In this study, the mean age of patients was 60.3±14.1 (range 8-95) years. The most prevalent age range was 64 to 68 years, followed by 68 to 72 and 60 to 64 years. The less frequent age range was <16 and >96 years of age, which included only 14 and 5 patients. The distribution of age in patients candidate for the cataract surgery is shown in Figure 1. In this study, 2 243 (48.69%) of cataractous patients were female and 2 364 (51.31%) were male. Ocular biometric characteristics of Iranian cataractous patients, stratified by sex, are reported in Table 1. Although the mean AL and ACD in males was significantly higher than in females ($P<0.001$), all keratometry readings (except corneal astigmatism) in females were higher than in males ($P<0.001$).

The distribution of AL in patients candidate for the cataract surgery is shown in Figure 2. The most prevalent AL range was 23.1 to 23.4 mm, followed by 22.8 to 23.1 and 22.5 to 22.8 mm. According to the definition of AL in this study, short, normal and long eyes were found in 423 (9.18%), 3 828 (17.97%) and 356 (7.73%) patients, respectively (all $P<0.001$). Descriptive statistics of age, ACD, corneal astigmatism and keratometry in cataractous patients in different AL groups are stated in Table 2. As shown in this table, the mean ACD in the long eyes group was significantly higher than the normal and short eyes group ($P<0.001$). On the other hand, the mean amount of Kf, Ks, Km and corneal astigmatism in the short eyes group was significantly higher than two other groups ($P<0.001$).

Table 1　Ocular biometric characteristics of the cataract patients stratified by sex　$\bar{x}\pm s$

Parameters	Female	Male	Total	P^a
Number	2 243	2 364	4 607	
Age(y)	60.7±13.7	59.9±14.5	60.3±14.1	0.049
AL (mm)	23.3±1.60	23.6±1.30	23.42±1.48	<0.001
ACD (mm)	3.10±0.43	3.21±0.44	3.15±0.44	<0.001
Flat keratometry(D)	44.32±1.84	43.59±1.84	43.95±1.87	<0.001
Steep keratometry(D)	45.38±1.95	44.64±1.94	45.00±1.98	<0.001
Mean keratometry(D)	44.85±1.84	44.11±1.84	44.47±1.88	<0.001
Corneal astigmatism(D)	1.05±0.89	1.05±0.90	1.05±0.89	0.856

[a]Two independent sample t-test. AL: Axial length; ACD: Anterior chamber depth.

Table 2　Distribution of age, anterior chamber depth, corneal astigmatism and keratometry in cataractous patients in different axial length groups　$\bar{x}\pm s$

Parameters	Short eyes (22 mm<AL)	Normal eyes (22≤AL≤25 mm)	Long eyes (AL>25 mm)	Total	P^a
Number	423	3 828	356	4 607	
Age (y)	61.6±13.9	60.8±13.8	53.8±15.5	60.3±14.1	<0.001
ACD (mm)	2.79±0.46	3.16±0.40	3.52±0.45	3.15±0.44	<0.001
Flat keratometry (D)	45.69±1.76	43.87±1.65	42.67±2.72	43.95±1.87	<0.001
Steep keratometry (D)	46.87±1.72	44.86±1.75	44.29±3.06	45.00±1.98	<0.001
Mean keratometry (D)	46.28±1.67	44.36±1.65	43.48±2.83	44.47±1.88	<0.001
Corneal astigmatism (D)	1.19±0.95	0.98±0.82	1.62±1.28	1.05±0.89	<0.001

[a]One-way ANOVA; AL: Axial length; ACD: Anterior chamber depth.

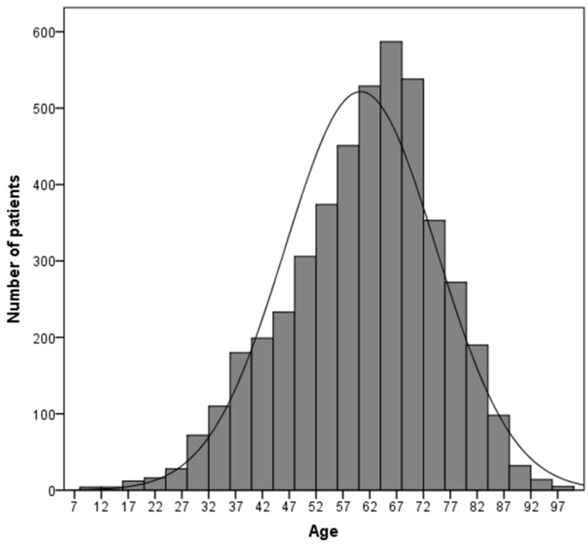

Figure 1　Distribution of age in the cataract surgery candidate patients.

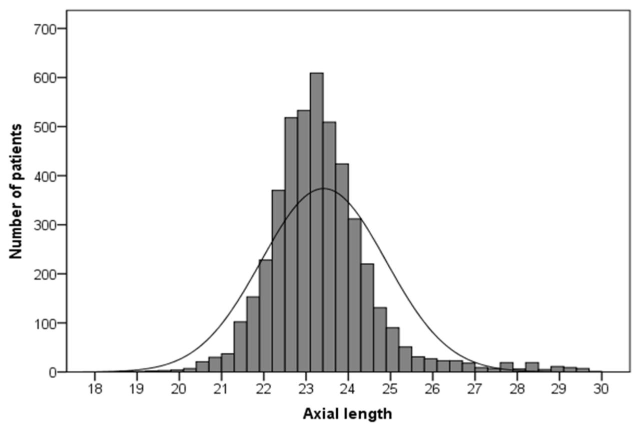

Figure 2　Distribution of axial length in the cataract surgery candidate patients.

The distribution of ACD in the cataract surgery candidates is shown in Figure 3. The most prevalent ACD range was 3.1 to 3.2 mm followed by 3.0 to 3.1 and 3.2 to 3.3 mm. Based on the definition of ACD, low, normal and high ACD were found in 1 571 (34.10%), 2 357 (51.16%) and 679 (14.74%) patients, respectively ($P < 0.001$). Descriptive statistics of age, AL, corneal astigmatism and keratometry in cataractous patients in different ACD groups are reported in Table 3. The mean of AL in the high ACD group was significantly higher than low and normal ACD patients ($P<0.001$). But the mean of Kf, Ks, Km in the low ACD group was significantly higher than two other groups ($P<0.001$).

In Figure 4, the distribution of mean keratometry in the cataract surgery candidates is shown. The most prevalent mean keratometry range was 43.50 D to 44.00 D followed by 44.50 D to 45.00 D and 44.00 D to 44.50 D.

DISCUSSION

This study investigated the ocular biometry parameters in cataract surgery candidates in Iran. Patients were in the age range of 8-95 years, mostly between 64-68 years, with a mean age of 60.3±14.1, which was lower than the mean age in many other studies[7,11,17,23,37,51-52], indicating the higher prevalence of cataract among the less older population in Iran as compared to other countries, which can be attributable to various factors as, metabolic and lifestyle factors, hypercholesterolemia, and excessive fuel exposure[53-55]. Moreover, this pathology was more prevalent among male than female (51. 3% *vs* 48. 7%), agreeing with some studies[30,56-57] and inconsistent with other studies[11,16,21,23,37,52,58-62].

In the present study, the mean AL was 23.42±1.48, which was consistent with studies conducted in Australia[14], Germany[17], California[59], and Iran[62] and inconsistent with number of studies conducted in Iran[30,61], Turkey[51], Los Angeles[32], and South Africa[57]; the mean AL was greater in the present study. This difference between results may originate from using different devices to measure the AL. In two studies conducted in Northeast Iran (2016) and in Los Angeles (2005) contact ultrasound was used to measure the AL[30,32], which results in shorter measurements in comparison to the results from optical biometers, *e.g.*, the IOLMaster[14]. In a study scoping adult population in Shahroud, a city in the north part of Iran, Hashemi[61] (2012) used the LenStar to measure ocular biometry parameters and reported its results to be useful in selecting an appropriate formula for IOL power calculation in cataract patients. The reported mean AL was shorter than that in the present study, whereas a study in Portugal on patients with cataracts showed that the LenStar

Table 3 Distribution of age, anterior chamber depth, corneal astigmatism and keratometry in cataractous patients different anterior chamber depth groups $\bar{x}\pm s$

Parameters	Low (3.00 mm<ACD)	Normal (3.00≤ACD≤3.60 mm)	High (ACD>3.60 mm)	Total	P^a
Number	1 571	2 357	679	4 607	
Age (y)	62.9±13.6	59.9±13.5	55.5±16.0	60.3±14.1	<0.001
AL (mm)	22.81±1.10	23.52±1.37	24.45±1.87	23.42±1.48	<0.001
Flat keratometry (D)	44.22±1.85	43.85±1.76	43.65±2.22	43.95±1.87	<0.001
Steep keratometry (D)	45.27±1.89	44.89±1.84	44.77±2.52	45.00±1.98	<0.001
Mean keratometry (D)	44.74±1.81	44.37±1.75	44.21±2.32	44.47±1.88	<0.001
Corneal astigmatism (D)	-1.05±0.89	-1.03±0.85	-1.13±1.01	-1.05±0.89	0.063

[a]One-way ANOVA. ACD: Anterior chamber depth; AL: Axial length.

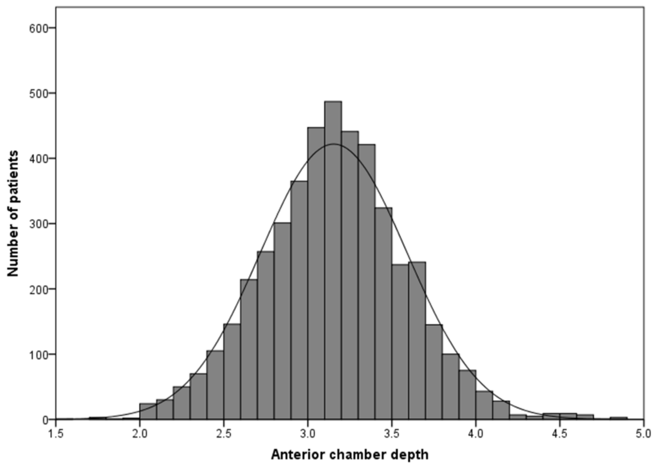

Figure 3 Distribution of anterior chamber depth in the cataract surgery candidate patients.

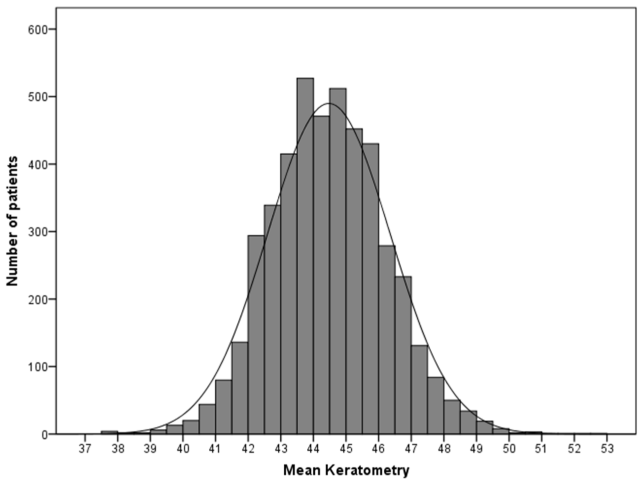

Figure 4 Distribution of mean keratometry in the cataract surgery candidate patients.

and IOLMaster do not have much difference in the measurement of the AL[11]. On the other hand, the number of male was higher in the present study compared to other studies[23,32,61-62], considering that the mean AL is longer in male than in female[7,11,14,16-17,23,30,32,52,59,61-63], this can be a cause of this difference. Moreover, patients in the presents study were younger compared to other studies[23,30,51,62], but still consistent with the present study, since in these studies younger individuals had longer mean AL. Another cause of this difference can be age. It seems in the study conducted in South Africa[57], in which the mean age of the patients was significantly lower than the present study (28.15 *vs* 60.30) and the majority of the patients were male, other factors such as race and data measurement techniques were among the causes of lower mean AL as compared to the present study. It is worth noting that their research subjects were not patients with cataracts. The mean AL in the present study was lower than studies conducted in Cuba[52], South China[7], central China[37] and Europe[6,16,58]. Given that the IOLMaster was used to measure the AL in the present and aforementioned studies, the difference between the results seems to exist probably due to racial differences in study populations in various parts of the world. Studies have shown that genetic factors, race, and environmental factors are the most important causes of the variation in AL measurements[7,23,61]. Some studies have mentioned the role of height, job, social status, and the amount of near work in causing the difference in the measurements of AL in different societies[61,63]. Hoffman attributed the differences in the measurements of the AL to differences in calibration of the IOLMaster in different studies[17], which has not been mentioned in other studies. In the present study, the AL in 83.09% of the participants was within the defined normal range (23.1-23.4).

The mean keratometry in the patient population under investigation was 44.47±1.88 D, which was slightly lower than the mean keratometry obtained from the latest study conducted in Iran[62] and higher than the majority of studies in Europe [6,11,58] and other parts of the world[7,37,52]. Other than the race, the difference in data measurement methods was a potential cause of the difference in mean keratometry between the study conducted in Los Angeles[32] and the present study (43.72 *vs* 44.47). In the Los Angeles study, the autorefractometer was used for keratometry measurement, in which the measured corneal power was lower than that measured by the IOLMaster[52]. Moreover, in the present study, female had steeper cornea than male, which was consistent with the findings of other studies[7,11,17,21,32,52,58,62]. According to Mohammadi *et al*[23], the sex-dependent difference in corneal dioptric power can be due to changes in sex hormone levels. Some studies attributed steeper cornea in female to the emmetropization phenomenon and related it to shorter AL in female[7,56,63]. The mean keratometry of 43.50-44.00 D had the highest prevalence in the population under investigation.

The mean prevalence of astigmatism in the present study was 1.05±0.8, which was slightly higher than values reported by some similar studies[7,17,51]. Moreover, the mean prevalence of astigmatism in the present study was higher in female than male, a finding observed in other studies[11,23]. Two studies conducted in India and Western China (2020) investigated the prevalence of corneal astigmatism in patients with cataracts. Both studies attributed the difference in the prevalence of astigmatism in different societies to age, sex, genetic, measurement tools, and environmental factors[21,56]. However, Hoffman and Hütz[17] (2010) reported that the prevalence of corneal astigmatism was only slightly age-dependent. Moreover, the difference in biometric parameters among male and female can be attributed to the difference in sex hormone levels[23,58]. The mean prevalence of astigmatism in individuals with longer AL (>25 mm) was higher than the two other groups ($P<0.001$). In the aforementioned study the prevalence of astigmatism was higher among individuals with the AL equal to or longer than 26 mm.

The mean ACD in the present study was different from other studies assessing biometry parameters; being higher than some[7,30,52,59,61-62] and lower than some other[11,16,32,57]. Height, age, sex, race, refractive error, and ACD measurement devices, play a role in this issue[7,30]. For example, the number of male was higher in the present study than other studies[7,23,52,59,61-62]; consistent with the majority of aforementioned studies, the mean ACD was higher in male than female[7,11,17,23,52,61], which can be a cause of these differences. A study in Western China[63] showed that differences in the ACD between male and female can be attributed to the factor of height, since male are taller, they have greater ACD too. Moreover, the mean age of patients in the presents study were younger than the mean age of some other studies[7,23,30,52,59,62]. But consistently, younger individuals had greater mean ACD in both our study and literature; thus age can be another cause of this difference. Studies have shown that shallower ACD in older individuals, compared to younger people, is due to the crystalline lens thickness, which increases with aging[7,63]. The present study did not investigate the crystalline lens thickness and its changes with aging. The mean AL in the present study was greater than values reported in similar studies[6-7,52]; whereas, the mean ACD in the present study was lower than the mentioned studies. According to Hoffman and Hütz[17], ACD anatomy can be independent of the AL. The mean ACD was greater in the present study than in the studies conducted by Sedaghat *et al*[30] and Hashemi *et al*[61]. Sedaghat *et al* used contact ultrasound to measure the ACD which led to results

Table 4 Summary of the studies assessing biometry $\bar{x}\pm s$

Country, region and race	Author	Year of publish	Mean keratometry(D)	Mean AL(mm)	Mean ACD(mm)
Cuba	Hernández-López *et al*[52]	2021	44.04±1.77	23.52±1.59	3.02±0.44
Iran	Jamali *et al*[62]	2021	44.51±1.72	23.36±1.55	3.09±0.40
Indonesia	Ernawati *et al*[60]	2020	-	23.81±1.46	3.25±0.70
Western China	Huang *et al*[63]	2018	44.23±1.66	24.32±2.42	3.08±0.47
A founder population of European ancestry	Hilkert *et al*[16]	2018	43.37±1.39	23.86±0.95	3.65±0.41
Portugal	Ferreira *et al*[11]	2017	43.91±1.71	23.87±1.55	3.25±0.44
In black South Africans	Mashige and Oduntan[57]	2017	-	23.05±0.98	3.21±0.37
Central China	Yu *et al*[37]	2017	44.29±1.58	24.38±2.47	3.15±0.48

AL: Axial length; ACD: Anterior chamber depth.

lower than the measurements made by the IOLMaster[7,59]. Hashemi *et al* used the LenStar to measure biometric parameters of the eyes and ACD, which produce greater ACD than the IOLMaster[11,52], so it seems shallower ACD measurements in Hashemi's study compared to our study is affected by factors other than measurement tools. The mean age of the patients in Hashemi's study was lower than in the present study (50.90 *vs* 60.30) years. As a result, this difference cannot be attributed to age and thus the higher number of female than male (2 825 *vs* 2 044) in Hashemi's study can be the only reason. In another study, Hashemi *et al*[64] measured the participants' ACD using Orbscan. The mean ACD in Hashemi's study was lower than in the present study (2.79 *vs* 3.15) mm. Participants' mean age was significantly lower (40.6 *vs* 60.3) years, and the number of female was more than male. Considering shallower ACD in female and older people, this difference between the two studies seems to exist due to the difference in sex and measurement method. Hashemi reported that the measured ACD with Orbscan was similar to ultrasonography methods (data regarding some of the relevant studies is summarized in Table 4). Totally, 51.16% of the individuals had ACD within the normal range (3.00-3.60) mm. To conclude, such factors as age, sex, race, and ocular biometric parameters measurement tools are the most important factors that are different in various parts of the world.

This study did not investigate the effect of other factors, such as height, social status, lifestyle, and refractive errors, and the relationship of these factors with ocular biometry parameters, which can be addressed in future studies.

Also, AL is found to be influenced by the time of the measurement[65]. But there exist controversies in anterior segment parameters. Read *et al*[65] stated ACD undergoes significant diurnal changes, while Xu *et al*[66] found no significant changes in anterior segment parameters measured in different times during a 24-hour time. Noteworthy, both studies were conducted in young populations. We didn't assess diurnal variations in biometry measurements, appoint to be an again addresses in future studies.

This study, along with similar studies provides ophthalmologists with a normative reference of data from ocular biometric parameters to enable them to calculate the IOL power and select appropriate formulas to calculate it for patients who are candidate for cataract surgery. Among candidates for cataract surgery, long eyes had deeper ACD with flatter cornea; and short eyes had shallower ACD with steeper cornea. Also, patients with high ACD had longer AL with a flatter cornea and patients with low ACD had lower AL with a steeper cornea.

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