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Journal of Current Ophthalmology 29 (2017) 39−44
http://www.journals.elsevier.com/journal-of-current-ophthalmology

Original research

# The distribution of orbscan indices in young population

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Received 8 June 2016; accepted 6 August 2016
Available online 31 August 2016

**Abstract**

***Purpose***: To determine the distribution of anterior eye biometry indices, such as keratometry pachymetry, anterior chamber depth (ACD), pupil diameter, and corneal diameter, as measured by Orbscan instrument in a young Iranian population.
***Methods***: A cross-sectional study was conducted, and subjects were selected through multistage cluster sampling from the students of Mashhad University of Medical Sciences. Objective and subjective refraction were performed followed by Orbscan imaging.
***Results***: A total of 1330 subjects were selected, 1121 of which participated in the study. After applying the exclusion criteria, the final analysis was performed on the data of 1051 subjects. The mean age of the participants was 26.1 ± 3.2 years (19−34 years old). The mean ± SD and 95% confidence interval (CI) of maximum keratometry, minimum keratometry, pupil diameter, corneal diameter, ACD, and central corneal thickness was 44.5 ± 1.7 (44.4−44.6), 43.1 ± 1.6 (43.0−43.2), 4.3 ± 0.9 (4.3−4.4), 11.7 ± 0.4 (11.7−11.7), 3.7 ± 0.3 (3.6−3.7), and 550.5 ± 35 (548.4−552.6), respectively. After adjusting for age and the mean spherical equivalent (MSE), maximum keratometry, minimum keratometry, central corneal thickness, and the thinnest pachymetry were statistically significantly higher in female subjects ($P < 0.001$) whilst the corneal diameter and ACD were higher in male subjects ($P < 0.001$). The pupil diameter and ACD showed statistically significant changes with age ($P < 0.001$). The MSE was only correlated with maximum keratometry and ACD ($P < 0.001$).
***Conclusion***: In this study, the distribution of Orbscan measurements for the anterior segment parameters was reported in a large sample of the young Iranian population. Age, gender, and refractive error may affect the orbscan measurements.


*Keywords:* Orbscan; Gender; Age; Anterior segment; Iran

## Introduction

The increasing popularity of refractive surgery has meant that precise corneal and anterior segment biometry are more important than ever.[1] Among these indices, keratometry and corneal thickness are most frequently used by ophthalmologists in refractive surgery.[2] Many investigators have evaluated the normal values of important corneal indices by imaging devices in numerous studies over recent years.[3−6] These values help eye care practitioners to identify abnormal values in different devices and races and use alternative methods like IOL implantation due to the contraindication of laser refractive surgery.[7−9] The indices of anterior chamber depths (ACDs) are also important in IOL implantation, as a short ACD is considered a contraindication.[8,9] However, different cut-points of the abnormal values of ACD have been reported due to ethnic and measurement tools differences.[10−12] One useful instrument is the Orbscan (Bausch and

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Peer review under responsibility of the Iranian Society of Ophthalmology.

http://dx.doi.org/10.1016/j.joco.2016.08.003

Lomb, Rochester, USA) as it allows measurement of many anterior segment parameters. Many studies have investigated the agreement of this device with ultrasound techniques and Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) in measuring important corneal indices like its curvature and thickness.[13−18] Moreover, some studies have shown the role of the indices measured by this device in the diagnosis of keratoconus and its progress.[19−21] Since these devices require little time and are not expensive, they can also be used in screening programs and epidemiological studies.[3,10,22,23] Some investigators have reported the normal range of indices, but these values cannot always be used in a Middle Eastern population due to ethnic and racial differences. Some Orbscan indices were also reported in a Tehran eye study[3,10,22−24]; however, since the number of 20- to 40-year-old participants in the Tehran study was small, this current study was deemed useful so as to investigate the normal Orbscan indices in a young population with a larger sample size than the Tehran study.

## Methods

The target population of this cross-sectional study was students of Mashhad University of Medical Sciences in the northeast of Iran. Multistage cluster sampling was used to sample the subjects in each major proportionate to the total number of subjects in that major.

Since the project was designed for the evaluation of refractive errors and visual disorders, the sample size was calculated for a prevalence of 30% with a precision of 3% and type I error of 5%. The final sample volume, after considering a coefficient of 1.25 as the design effect and a non-response rate of 15%, considered 1300 samples.

The Ethics Committee of Mashhad University of Medical Sciences approved the study protocol, which was conducted in accord with the tenets of the Declaration of Helsinki. All participants signed a written informed consent (grant code: 910521).

The selected subjects were then formally invited to participate in the subjects through invitation forms. All the participants signed informed consent forms prior to entering the study. All examinations were performed in one fully equipped optometry clinic. The demographic data of the participants was collected through history- and symptoms-type questioning including such information as the family history of keratoconus, the history of allergy, and eye rubbing. All subjects received full eye examinations. An experienced optometrist evaluated refraction with an auto refractometer (TOPCON RM8800, Topcon Corporation, Tokyo, Japan) followed by retinoscopy with Heine Beta 200 (HEINE Optotechnic, Germany). Orbscan was used for imaging according to the manufacturer's instructions by an experienced operator. Only good quality images were used.

The indices of simulated keratometry, thinnest point of the cornea, central corneal thickness, pupil diameter, corneal diameter, and ACD were extracted from Orbscan data and analyzed.

Since the aim of this study was to determine the normal values in healthy participants, all individuals with a history of refractive surgery or any ocular surgery and those who used the contact lens were excluded from the study. Moreover, based on topographic and slit-lamp findings, keratoconic patients were also excluded.

The system was set to display the central ACD from the corneal epithelium.

Considering the high correlation of both eyes in Orbscan indices, analysis was only performed on the results of the right eye. In this study, the mean, standard deviation (SD), and 95% confidence interval (CI) of the evaluated indices are reported based on age and sex. Furthermore, for a more comprehensive descriptive report, the 5%, 25%, 50%, 75%, 95%, and 99% percentiles are also reported. The Kolmogorov−Smirnov test was used to evaluate the normality of the indices and the normal range calculated as the mean ± 2 SD. Multiple linear regression was used to investigate the correlation of this indices with age, sex, and refractive errors.

ANOVA was used to compare the average of Orbscan indices among the groups, and post hoc Scheffe was employed to demonstrate any difference between the groups. P value less than 0.05 was considered significant.

## Results

A total of 1330 subjects were selected, 1121 of which participated in the study. However, 37 subjects were excluded from the study due to the history of refractive surgery, 7 subjects due to use of the contact lens, and 26 subjects due to a definite diagnosis of keratoconus. Therefore, final analysis was performed on the data of 1051 subjects. Overall, 42.8% of the participants were male, and the mean age of the study population was 26.1 ± 3.2 years (range: 19−34 years).

The mean of spherical equivalent was −0.97 ± 2.58 (−14.5 to 13.25) diopters.

Table 1 shows the mean and 95% CI of minimum and maximum keratometry, ACD from the corneal epithelium, pupil diameter, corneal diameter, and the thinnest point of the cornea and central corneal thickness. Table 2 demonstrates the 5−99% percentiles of these indices along with the indexes of normal distribution. Table 3 presents the normal range of the evaluated indices based on mean ± 2 SD. The correlation of the evaluated indices with age, sex, and standard error (SE) were investigated a multiple model which showed that after adjusting with age and SE, the values of maximum keratometry, minimum keratometry, central corneal thickness, and the thinnest point of the cornea were significantly more in female subjects while the corneal diameter and ACD were larger in male subjects. The results of linear regression are presented in Table 4. Based on the findings of linear regression, only the pupil diameter and ACD were significantly correlated with age; as with each 1-year increase in age, the pupil diameter decreased by 0.03 mm, and the ACD shortened by 0.007 mm. Moreover, according to the results of this model, SE was only correlated with maximum keratometry and ACD. Table 5 shows the mean and standard deviation of

Table 1
The mean and 95% confidence interval (CI) of Orbscan indices in a young population of Iran.

| | Number of eyes | Max-K | Min-K | PD | WTW | ACD | CCT | CTTP |
|---|---|---|---|---|---|---|---|---|
| | | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) |
| 20–22 | 171 | 44.6 (44.3–44.9) | 43.1 (42.8–43.4) | 4.4 (4.3–4.6) | 11.7 (11.6–11.7) | 3.7 (3.7–3.7) | 551.2 (545.4–557) | 544 (538.3–549.8) |
| 23–25 | 293 | 44.4 (44.2–44.7) | 43 (42.8–43.2) | 4.4 (4.3–4.5) | 11.7 (11.7–11.8) | 3.7 (3.6–3.7) | 549.6 (546–553.3) | 542 (538.3–545.8) |
| 26–28 | 326 | 44.5 (44.3–44.7) | 43.2 (43–43.4) | 4.3 (4.2–4.4) | 11.7 (11.6–11.7) | 3.7 (3.6–3.7) | 551.3 (547.6–555.1) | 544.4 (540.5–548.2) |
| >28 | 261 | 44.4 (44.2–44.6) | 43.1 (42.9–43.3) | 4.2 (4.1–4.3) | 11.7 (11.7–11.8) | 3.6 (3.6–3.7) | 549.9 (545.6–554.3) | 542.9 (538.5–547.4) |
| Female | 601 | 44.7 (44.6–44.8) | 43.4 (43.2–43.5) | 4.3 (4.2–4.4) | 11.6 (11.6–11.7) | 3.6 (3.6–3.6) | 553.1 (550.5–555.6) | 546 (543.5–548.6) |
| Male | 450 | 44.0 (43.8–44.2) | 42.5 (42.4–42.7) | 4.4 (4.3–4.5) | 11.8 (11.8–11.9) | 3.7 (3.7–3.8) | 544.9 (541.1–548.6) | 537.3 (533.5–541.1) |
| Total | 1051 | 44.5 (44.4–44.6) | 43.1 (43–43.2) | 4.3 (4.3–4.4) | 11.7 (11.7–11.7) | 3.7 (3.6–3.7) | 550.5 (548.4–552.6) | 543.3 (541.2–545.5) |
| Kolmogorov–Smirnov | | 0.034 | 0.029 | 0.134 | 0.083 | 0.033 | 0.020 | 0.020 |
| P-value | | 0.008 | 0.052 | <0.001 | 0.048 | 0.010 | 0.200 | 0.200 |

Max-k: Maximum keratometry.
Min-k: Minimum keratometry.
PD: Pupil diameter.
WTW: White-to-white corneal diameter.
ACD: Anterior chamber depth.
CCT: Central corneal thickness.
CTTP: Corneal thickness at the thinnest point.

Table 2
The percentiles, Skewness, Kurtosis, and interquartile range (IQR) of orbscan indices in a young Iranian population.

| | Percentile | | | | | IQR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| | 05 | 25 | 75 | 95 | 99 | | | |
| Max-K | 41.80 | 43.30 | 45.60 | 47.20 | 49.00 | 2.30 | 0.351 | 0.962 |
| Min_K | 40.50 | 42.00 | 44.20 | 45.90 | 47.20 | 2.20 | 0.198 | 1.068 |
| PD | 3.20 | 3.70 | 4.70 | 6.20 | 7.60 | 1.00 | 1.596 | 4.249 |
| WTW | 11.10 | 11.40 | 11.90 | 12.30 | 12.80 | 0.50 | 0.342 | 1.332 |
| ACD | 3.18 | 3.49 | 3.83 | 4.12 | 4.31 | 0.34 | −0.035 | 0.209 |
| CCT | 496.00 | 526.00 | 573.00 | 608.00 | 633.00 | 47.00 | 0.019 | 0.083 |
| CTTP | 488.00 | 520.00 | 566.00 | 602.00 | 625.00 | 46.00 | 0.004 | 0.062 |

Max-k: Maximum keratometry.
Min-k: Minimum keratometry.
PD: Pupil diameter.
WTW: White-to-white corneal diameter.
ACD: Anterior chamber depth.
CCT: Central corneal thickness.
CTTP: Corneal thickness at the thinnest point.
IQR: Interquartile range.

minimum and maximum keratometry, ACD, corneal and pupil diameter, the thinnest point of the cornea, and the central corneal thickness based on the severity of refractive errors. Analysis of variance revealed that minimum and maximum keratometry and ACD had a significant difference among different types of refractive error.

According to Scheffe post hoc analysis, there was a statistically significant difference in minimum ($P = 0.023$) and maximum keratometry ($P < 0.001$) readings between myopes and emmetropes. ACD was also significantly different between different levels of refractive errors ($P < 0.05$).

## Discussion

The mean keratometry was 43.7D in this study, 43.5D in the Tehran study[22] on individuals aged 20–29, and 43.7D in a study from Thailand.[25] Other studies have also reported similar mean values. Evaluation of other studies[26,27] reveals that the distribution of keratometry is almost similar worldwide.

In this study, the mean pupil diameter was 4.3 mm under photopic conditions. Since the pupil diameter changes in different ambient lighting conditions, it is difficult to compare this variable with studies that have used devices other than Orbscan. The mean pupil diameter was 4.09 mm in the Tehran[28] study and 3.87 mm in a report by Hsieh et al.[29] Yazici

Table 3
The mean ± 2 standard deviations (SD) (normal range) of orbscan indices in a young Iranian population.

| | Number of eyes | Max-K | Min-K | PD | WTW | ACD | CCT | CTTP |
|---|---|---|---|---|---|---|---|---|
| 20–22 | 171 | 41.15–48.03 | 39.76–46.44 | 2.44–6.36 | 10.94–12.42 | 3.19–4.19 | 474.16–628.28 | 467.48–620.6 |
| 23–25 | 293 | 40.87–48.03 | 39.52–46.56 | 2.58–6.18 | 10.92–12.52 | 3.10–4.22 | 485.68–613.60 | 476.98–607.10 |
| 26–28 | 326 | 41.07–47.95 | 39.94–46.42 | 2.51–6.15 | 10.89–12.45 | 3.09–4.21 | 482.06–620.62 | 473.79–614.95 |
| >28 | 261 | 41.06–47.70 | 39.99–46.15 | 2.36–6.04 | 10.85–12.59 | 3.07–4.17 | 478.44–621.4 | 470.25–615.65 |
| Female | 601 | 41.35–48.03 | 40.22–46.50 | 2.52–6.08 | 10.90–12.38 | 3.08–4.16 | 483.79–622.31 | 475.85–616.21 |
| Male | 450 | 40.49–47.49 | 39.21–45.85 | 2.40–6.36 | 10.96–12.68 | 3.19–4.27 | 475.55–614.15 | 467.26–607.38 |
| Total | 1051 | 41.04–47.92 | 39.82–46.38 | 2.48–6.16 | 10.90–12.50 | 3.09–4.21 | 480.83–620.15 | 472.73–613.89 |

Max-k: Maximum keratometry.
Min-k: Minimum keratometry.
PD: Pupil diameter.
WTW: White-to-white corneal diameter.
ACD: Anterior chamber depth.
CCT: Central corneal thickness.
CTTP: Corneal thickness at the thinnest point.

Table 4
The association of Orbscan indices with age, gender, and spherical equivalent according to multiple linear regression analysis.

| | Coefficient (95% CI) | P-value |
|---|---|---|
| **Maximum keratometry** | | |
| Age (year) | −0.01 (−0.04−0.02) | 0.426 |
| Gender (male/female) | 0.70 (0.48−0.92) | <0.001 |
| Spherical equivalent (diopter) | −0.08 (−0.12−0.04) | <0.001 |
| **Minimum keratometry** | | |
| Age (year) | 0.01 (−0.02−0.04) | 0.701 |
| Gender (male/female) | 0.83 (0.63−1.04) | <0.001 |
| Spherical equivalent (diopter) | −0.02 (−0.06−0.02) | 0.321 |
| **Pupil diameter** | | |
| Age (year) | −0.03 (−0.05−0.01) | 0.001 |
| Gender (male/female) | −0.08 (−0.20−0.04) | 0.173 |
| Spherical equivalent (diopter) | −0.01 (−0.03−0.02) | 0.643 |
| **White-to-white corneal diameter** | | |
| Age (year) | 0 (−0.01−0.01) | 0.836 |
| Gender (male/female) | −0.18 (−0.23−0.12) | <0.001 |
| Spherical equivalent (diopter) | 0.01 (0.0−0.02) | 0.086 |
| **Anterior chamber depth** | | |
| Age (year) | −0.01 (−0.01−0) | 0.012 |
| Gender (male/female) | −0.11 (−0.14−0.07) | <0.001 |
| Spherical equivalent (diopter) | −0.01 (−0.02−0.01) | <0.001 |
| **Central corneal thickness** | | |
| Age (year) | −0.07 (−0.72−0.57) | 0.823 |
| Gender (male/female) | 8.19 (3.66−12.72) | <0.001 |
| Spherical equivalent (diopter) | −0.04 (−0.85−0.77) | 0.928 |
| **Corneal thickness at the thinnest point** | | |
| Age (year) | 0 (−0.66−0.66) | 0.999 |
| Gender (male/female) | 8.73 (4.14−13.31) | <0.001 |
| Spherical equivalent (diopter) | −0.21 (−1.03−0.61) | 0.618 |

CI: Confidence interval.

et al[30] and Cosar et al[31] reported that the mean pupil diameter was 4 mm in individuals aged 21−32 years who were candidates for refractive surgery and had otherwise normal eyes using Orbscan. In general, the results presented in this study suggest that the mean pupil diameter is a little larger in this age range when compared to other studies, which should be considered in Iranian patients seeking refractive surgery.

The corneal diameter was 11.7 mm in our study and 11.77 mm in a similar age group in the Tehran study.[32] It was reported 11.78 mm by Baumeister et al,[33] 11.6 mm by Srivannaboon et al,[34] 11.84 by Kohnen et al,[35] and 11.7 mm by Rufer et al,[36] which are almost similar. The ACD was 3.7 mm in our study and 3.02 mm in the Tehran[10] study. The ACD measured by Orbscan ranges from 2.5 mm in individuals from Tehran aged 60 years or more to 3.61 mm in a report by Rabsilber et al.[37]

ACD in this study was deeper compared to previous studies. The major reason for this difference can be attributed to the difference in the calculation method of ACD, as in some studies, such as the Tehran Eye Study, the ACD was calculated from corneal endothelium. On the other hand, the mean refractive error in this study shifts toward myopia, and higher myopia can be another reason for deeper ACD in this study. As mentioned earlier, the central corneal thickness was 550 μ in this study. This index has been measured by different devices in different studies; however, 95% of the study population fell in the range of 480.83−620.15. The reports on the central corneal thickness vary from 508μ in 14- to 51-year-old Australians[38] to 579μ in children from Singapore.[39] Different studies have shown that the difference in central corneal thickness among different races is considerable,[40,41] which results in different normal ranges in various parts of the world.

In this study, like previous studies, keratometry was significantly steeper[22] and the central cornea was significantly thicker in females, while the anterior chamber[42−44] was significantly deeper and the corneal diameter[32] was significantly larger in males. The majority of the reports on central corneal thickness mostly contradict our findings in this regard and suggest that the central cornea in significantly thicker in males.

Table 5
Mean and standard deviation (SD) of Orbscan indices in a young population of Iran according to severity of refractive errors.

| | Number of eyes | Max-K | Min-k | PD | WTW | ACD | CCT | CTTP |
|---|---|---|---|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| High myopia (more than −6.0D) | 155 | 44.86 ± 1.76 | 43.17 ± 1.64 | 4.25 ± 0.98 | 11.63 ± 0.42 | 3.67 ± 0.27[b] | 552.79 ± 36.82 | 546.65 ± 36.79 |
| Moderate myopia (−3.1D to −.0D) | 422 | 44.58 ± 1.64 | 43.24 ± 1.56 | 4.36 ± 0.84 | 11.7 ± 0.39 | 3.68 ± 0.27[b] | 548.65 ± 35.87 | 541.63 ± 36.32 |
| Low myopia (−0.5D to −3.0D) | 373 | 44.37 ± 1.66 | 43.02 ± 1.63 | 4.34 ± 0.99 | 11.72 ± 0.39 | 3.64 ± 0.28[b] | 550.54 ± 33.36 | 542.9 ± 34.0 |
| Emmetropia (−0.49 to 0.49) | 73 | 43.84 ± 1.68[a] | 42.79 ± 1.64 | 4.25 ± 0.83 | 11.72 ± 0.44 | 3.61 ± 0.26[b] | 555.21 ± 33.47 | 547.25 ± 33.5 |
| Low Hyperopia (+0.5D to +2.0D) | 21 | 43.39 ± 1.97[a] | 42.31 ± 1.87 | 4.33 ± 1.15 | 11.72 ± 0.34 | 3.47 ± 0.28 | 552.9 ± 29.62 | 545.38 ± 31.46 |
| Moderate hyperopia (+2.1D to+4.0D) | 4 | 44.48 ± 2.21 | 42.28 ± 2.04 | 3.88 ± 0.46 | 11.78 ± 0.57 | 2.98 ± 0.34 | 561.5 ± 37.68 | 555 ± 42.31 |
| High hyperopia (more than +4.0D) | 3 | 45.47 ± 7.11 | 44.37 ± 6.84 | 3.43 ± 1.24 | 11.53 ± 0.74 | 3.40 ± 0.44 | 539.33 ± 31.09 | 533.67 ± 35.56 |
| ANOVA; P-value | | <0.001 | 0.024 | 0.457 | 0.426 | <0.001 | 0.678 | 0.672 |

Max-k: Maximum keratometry.
Min-k: Minimum keratometry.
PD: Pupil diameter.
WTW: White-to-white corneal diameter.
ACD: Anterior chamber depth.
CCT: Central corneal thickness.
CTTP: Corneal thickness at the thinnest point.
[a] Significant differences when compared to high myopia (ANOVA, Post Hoc Tests, Scheffe).
[b] Significant differences when compared to moderate HYPEROPIA (ANOVA, Post Hoc Tests, Scheffe).

There was statistically significant inter-gender difference in mean central corneal thickness in this study; however, this difference was about 10 micron which does not seem to be clinically significant. Other previous studies like the Tehran Eye Study also did not report significant inter-gender differences in central corneal thickness. Many investigations have shown that the corneal diameter and ACD are larger in males. The ACD is part of the axial length, and there is a direct correlation between these two indices. For this reason, as reported by previous studies, men have a longer axial length than women.[42–44] During emmetropization, some of the changes in the axial length are compensated by the cornea; therefore, shorter eyes (i.e. in females) are expected to be steeper in compensation. Therefore, the reason for higher keratometry in females in this study could be the shorter axial length.

In this study, the changes of the pupil diameter and the ACD were significantly correlated with age; a significant decrease was observed in both, with an increase in age. The Tehran study and the study conducted by Hsieh also reported that the corneal diameter decreased with age. The changes in the corneal diameter are V-shaped throughout life; the corneal diameter increases from birth to puberty and then decreases. Netto has also confirmed this relationship. Therefore, considering the age range of our participants, the corneal diameter is expected to decrease with age.

The decrease in ACD with age is also reported by a number of studies, as well[45–47] although these studies mostly evaluated the elderly population, and few have investigated the changes of the ACD in a young population. Previous studies have reported that due to the growth of the eye until the second decade of life,[48,49] there is an increase in the axial length which results in a deeper anterior chamber, and that the axial length decreases after the age of 40 which might be the result of ocular atrophy.[5,50] However, as mentioned earlier, we noticed that the ACD decreased mildly with age in the 19- to 34-year-old participants of our study. The authors believe that these changes may result from the lens changes and its thickening in this age group.

Similar to previous studies, it was noticed that the anterior chamber was deepest in high myopic patients,[37] which is due to the longer axial length in these individuals. Moreover, as expected, the myopic individuals had flatter keratometry.

The present study has some strengths and limitations. The most important strength of this study is that it evaluates a large sample of young individuals using Orbscan. With respect to the fact that most of the refractive surgery candidates belong to this age group, the results of this study can be used as a reference. However, this study has several limitations; we only used Orbscan for measurements. Also, other biometric components of the eye were not evaluated. In addition, the data is limited to the students of one province in Iran.

In conclusion, in this study, the distribution of Orbscan measurements for the anterior segment parameters was reported in a large sample of the young Iranian population. Age, gender, and refractive error may affect the orbscan measurements.

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