A comparative study of Pentacam indices in various types and severities of refractive error in candidates for photorefractive keratectomy (PRK) surgery

Ghazal Maraghechi¹, Habib Ojaghi²*, Firouz Amani¹, Amin Najafi²

Author Affiliations
1. Department of Medical Education, School of Medicine, Ardabil Azad University, Ardabil, Iran
2. Department of Surgery, School of Medicine and Allied Medical Sciences, Ardabil University of Medical Sciences, Ardabil, Iran
3. Department of Community Medicine, School of Medicine and Allied Medical Sciences, Ardabil University of Medical Sciences, Ardabil, Iran

*Corresponding Author:
Habib Ojaghi,
Department of Surgery,
School of Medicine and Allied Medical Sciences,
Ardabil University of Medical Sciences, Ardabil, Iran.
E-mail: habibojaghi@yahoo.com

ABSTRACT
This study aimed to specify Pentacam indices in patients who suffered from different types of refractive error and underwent photorefractive keratectomy (PRK) surgery. It is a descriptive cross-sectional study carried out on 1125 patients (2215 eye samples) who underwent PRK surgery in the Noor Surgical Center of Ardabil, Iran, over a 5 year period (2014–2018). A particular checklist was provided to patients, which consisted of demographic data, pachymetry test, keratometry, refractive error, corneal-thickness indices, and corneal surface area indices. The data were analysed using the statistical analysis package of IBM® V25. The mean age of the participants in this study was 28.48±6.82 years, and the ratio of women to men was 66.4%. It was observed that the differences between angle, volume, the depth of the anterior chamber, IV A, and ISV were significant (P=0.00) when compared to each other in all types of refractive errors. High myopes had significantly higher Kmax front than low myopes (P=0.00). In astigmatism patients, the Kmax in front of the cornea in extreme type was significantly higher than in moderate (P=0.00) and high (P=0.01) types. High myopes had significantly lower Rmin than mild myopes (P=0.02), and extreme astigmatism had significantly lower Rmin than high (P=0.014) and moderate types (P=0.013). The data from this study revealed that in patients undergoing PRK surgery, some Pentacam indices could be related to some types of refractive errors, and in some of these indices, there are statistically significant differences between different severities of refractive errors. Therefore, their preoperative evaluation is very important.

KEYWORDS: refractive error, hyperopia, astigmatism, myopia, PRK, Pentacam indices.

INTRODUCTION
Given the prevalence of refractive error, photorefractive keratectomy (PRK) surgery has been the most common non-emergency eye treatment option in the last two decades. The procedure of these types of surgeries consists of correction of astigmatism, hyperopia, and myopia and the decrement of spectacles dependence and reduction of dependence on contact lenses [1–4].

However, ophthalmologists face numerous challenges in identifying patients at risk for postoperative complications. These complications mainly include ectasia, undercorrection, and over-correction [5, 6]. Therefore, the errors induced from corneal indices measurement could be minimised using diagnostic instruments such as a Galilei analyzer, ultrasonography, Orbscan corneal topography, and Pentacam system. The Pentacam system is among the most prevalent instruments used in this regard [7]. One of the most crucial steps in achieving a suitable therapeutic strategy to prevent PRK complications is to measure corneal parameters accurately.

Consequently, in refractive surgery, the initial basis for diagnostic tests is determining the topographic design for different types of refractive errors. In addition, in every country, there is a need for a comprehensive database on the characteristics of the components of the visual system because of the effect of geographic and racial factors. The present study aimed to examine and compare various Pentacam indices in patients with different types and severities of refraction error who underwent the PRK surgical procedure at Noor ophthalmology clinic in Ardabil, Iran, for 5 years from the beginning of 2014 until the end of 2018.
MATERIAL AND METHODS

The present study is a descriptive cross-sectional study of patients who underwent PRK surgery between 2014 and 2018 (3 years) at Noor Surgery Center in Ardabil, Iran (a private ophthalmology practice setup). The sampling was done using the census method, based on which 1125 patients were selected, and finally, 2215 eyes were examined. The data of patients consisting of demographics (age and gender), keratoconus (KCN) classification, pachymetric, keratometric, and refractive data were obtained based on the records of patients and then included in a detailed checklist. A skilled surgeon (Ojaghi H) examined the patients before the operation and then performed the operation. A new Canon RK-F2 Full Auto Ret-Keratometer made in Tokyo, Japan was used to perform a refraction test 30 minutes after instilling two drops of cyclopentolate 5 minutes apart. The data obtained from examining the eye using a Pentacam scanner (Oculus Instruments, Wetzlar, Germany) includes corneal topography, corneal pachymetry, and assessment of the anterior chamber angle (ACA). Anterior chamber depth also included corneal thickness.

The following rules were used to specify refractive astigmatism and anterior and posterior corneal astigmatism based on the steep axis of corneal astigmatism. Based on previous studies, with-the-rule (WTR) astigmatism is between 0°–30° or 150°–180°, against-the-rule (ATR) astigmatism is between 31°–120°, and oblique astigmatism (OA) is between 60°–120°, and oblique astigmatism (OA) is between 31°–59° or/and 121°–149° [8, 9].

The amount of corneal astigmatism was determined using the following formula [10]:

\[
\text{Corneal astigmatism} = \text{maximum keratometry (K1)} - \text{minimum keratometry (K2)}
\]

Refractive error was divided based on intensity levels and myopia was categorized into four levels as follows:

1. Mild myopia: When the amount of lens power (sphere) is less than 3.00 diopters;
2. Moderate myopia: When the amount of lens power (sphere) is between 3.00 to 6.00 diopters;
3. High myopia: When the amount of lens power (sphere) is between 6.25 to 9.00 diopters;
4. Extreme myopia: When the amount of lens power (sphere) is more than 9.00 diopters [11, 12].

Hyperopia was categorized into three levels as follows [13]:

1. Low hyperopia: When the amount of lens power (sphere) is up to +2 diopters;
2. Moderate hyperopia: When the amount of lens power (sphere) is between 2.25 and 4.74 diopters;
3. High hyperopia: When the amount of lens power (sphere) is more than 5.00.

Based on its severity, astigmatism was categorized as follows:

1. Mild astigmatism: When its degree is less than 1 diopter;
2. Moderate astigmatism: When its degree is between 1 to 2 diopters;
3. High astigmatism: When its degree is between 2.25 to 4 diopters;
4. Extreme astigmatism: When its degree is more than 4 diopters [12].

Inclusion criteria included stable refraction with a change of less than 0.5 diopters (D) of myopia, hyperopia, and astigmatism in the last 6 months and age ≥18 years at the time of surgery. Patients with a history of HSV (herpes simplex virus) keratitis, blepharitis, immunosuppressive diseases, uncontrolled diabetes, corneal scar, severe dry eye, herpes keratitis, uveitis, cataract, and people with thin corneas (thickness less than 480 µm or expected postoperative residual stromal thickness (RST) less than 300 µm) were excluded from the study.

Statistical analysis

The data of the present study were analysed using SPSS software version 25.0. In the majority of tables and graphs, the index of dispersion (variance, standard deviation, range) and the central tendency (mean, median, mode) descriptive statistics were used. In addition, student’s t-test, Pearson correlation coefficient, and one-way analysis of variance (ANOVA) were used to perform analytical statistics. A p-value less than 0.05 was considered statistically significant (typically P<0.05).

RESULTS

Our study was carried out on 1125 patients (2215 eye samples) who underwent PRK surgery with a female to male ratio of 66.4% and mean age of 28.4±6.82 years (ranging from 18 to 52 years, median of 27 years, and mode of 24 years) among which 1111 participants were right eyes (50.2%). The score of the sphere ranged from -10.75 and +7.50 diopters with a mean of -3.39±2.55D, and refractive astigmatism ranged from 0–6 diopters with a mean of -1.03±1.12D. The spherical equivalent among samples ranged from -10.75 and +7.50 diopters with a mean of -3.91±2.50D.

Figure 1 represents the frequency and percentage of refractive astigmatism in accordance with the steepest meridian in the studied samples. In our study, the most prevalent type of refractive astigmatism was with-the-rule (WTR) astigmatism (76.3%).

In 82.7% of participants (1832 individuals), the anterior corneal astigmatism was WTR followed by ATR (7.2%; 160 eyes) and oblique (10.1%; 223 eyes) (Figure 2).

As observed from Figure 3, in 93.4% of cases (2069 eyes), the posterior corneal astigmatism was type WTR, followed by ATR (2%; 44 eyes) and oblique (4.6%; 102 eyes).

Tables 1 and 2 represent the anterior chamber indices and keratometric indices, including anterior and posterior corneal surface areas (Av/Pa) (k1, k2, and kmax). The mean posterior corneal astigmatism is -0.34±0.18D, and mean anterior corneal astigmatism is -1.11±1.14D.

The data from Pearson’s correlation coefficient test showed a strong direct significant association (P=0.00, r=99%) between the thinnest location and the pachymetry of the apex. Myopia was observed in 85.73% of eye cases (1899 eyes), astigmatism in 10.57% (234 eyes), and hyperopia in 3.7% of them (82 eyes).

In 56.5% of cases, myopia was moderate, followed by 27.96% mild myopia, 14.69% of cases with high myopia, and 0.85% with extreme myopia. Also, 6%, 47.6%, and 46.4% of hyperopic eyes had low, moderate, and high hyperopia, respectively. In 20.8% of cases, astigmatism was extreme, in 54.7% high, 24.7% moderate, and 0% mild.

Based on the location of the focal lines in relation to the retina, the percentages of the astigmatism types were as follows: 63.24% were compound (148 cases), 25.64% simple (60 cases), and 11.12% were mixed (26 cases).

Based on the data presented in Table 3, the association of refractive errors of myopia, hyperopia, and astigmatism with Rmax, IHA, IVA, ISV, AC depth, angle, cornea volume, Kmax front, chamber volume, and mean thinnest location indices is significant. However, the association of refractive errors with the
Figure 1. Frequency and percentage of various types of astigmatism.

Figure 2. Different types of anterior corneal astigmatism (frequency and percentage).

Figure 3. Different types of posterior corneal astigmatism (frequency and percentage).
### Table 1. Keratometric indices.

|                     | Keratometric indices | Mean±SD  | Range     |
|---------------------|----------------------|----------|-----------|
| **Anterior cornea** |                      |          |           |
| K1                  | 43.09±1.52           | 37.8–48.5|
| K2                  | 44.39±1.52           | 39.7–50.1|
| Kmean               | 43.73±1.45           | 39.2–49  |
| Astigmatism (K2-K1) | -1.16±1.34           | -6.1–4.9 |
| Kmax                | 44.84±1.58           | 40.3–54.4|
| **Posterior cornea**|                      |          |           |
| K1                  | -6.09±0.24           | (-7.2)–(-5.4) |
| K2                  | -6.44±0.27           | (-7.5)–(-5.6) |
| Kmean               | -6.26±0.24           | (-7.3)–(-5.6) |
| Astigmatism (K2-K1) | -0.34±0.18           | -1.1–0.4 |

### Table 2. The data achieved from the corneal pachymetry technique and anterior chamber indices.

| Indices                              | Range         | Mean±SD          |
|--------------------------------------|---------------|------------------|
| Apex pachymetry (µm)                 | 434–687       | 534.26±32.04     |
| Thinnest location pachymetry (µm)    | 429–680       | 531.27±32.48     |
| Cornea volume (mm³)                  | 49.5–76.2     | 59.64±3.61       |
| Chamber volume (mm³)                 | 94–336        | 201.62±35.13     |
| Anterior chamber depth (mm)          | 2.67–6.68     | 3.78±0.30        |
| Anterior chamber angle (degree)      | 15.1–79.5     | 37.94±6.21       |

SD – Standard deviation.

### Table 3. The association of various types of refractive error with Pentacam indices.

| Pentacam indices | Refractive errors Mean±SD | P-value |
|------------------|---------------------------|---------|
|                  | Myopia n=1899 (85.73%)    |         |
|                  | Astigmatism n=234 (10.57%)|         |
|                  | Hyperopia n=82 (3.70%)    |         |
| AC Depth         | 3.80±0.28                 | 3.72±0.39| 3.38±0.31| 0.00    |
| Chamber volume   | 204.52±33.78              | 191.75±34.25| 156.95±35.07| 0.00    |
| Angle            | 38.27±6.13                | 36.76±6.36| 33.62±5.79| 0.00    |
| ISV              | 15.79±4.95                | 26.75±7.82| 19.91±8.29| 0.00    |
| IVA              | 0.10±0.06                 | 0.12±0.05| 0.14±0.09| 0.00    |
| IHA              | 3.04±12.386               | 4.109±3.327| 3.850±2.986| 0.00    |
| IHD              | 0.005±0.009               | 0.007±0.003| 0.007±0.004| 0.08    |
| KI               | 1.020±0.031               | 1.019±0.018| 1.015±0.019| 0.247   |
| CKI              | 1.007±0.006               | 1.007±0.005| 1.006±0.005| 0.20    |
| Cornea volume    | 59.72±3.59                | 59.11±3.80| 59.26±3.21| 0.006   |
| Pachy apex       | 534.39±31.99              | 530.94±33.56| 540.52±27.69| 0.059   |
| Thinnest location| 531.42±31.87              | 527.04±34.22| 536.23±27.51| 0.048   |
| Rmin             | 7.539±0.286               | 7.439±0.268| 7.665±0.272| 0.00    |
| Kmean front      | 44.80±1.54                | 45.42±1.63| 44.19±1.94| 0.00    |
| Prog_max         | 0.685±0.128               | 0.688±0.130| 0.672±0.101| 0.62    |
| Prog_avg         | 0.953±0.125               | 0.960±0.129| 0.929±0.117| 0.156   |
| Prog_min         | 1.180±0.177               | 1.191±0.168| 1.157±0.150| 0.329   |

M – Mean; SD – standard deviation; ACD – anterior chamber depth; Rmin – minimum radius of curvature; Prog_max – pachymetric progression index minimum; Prog_avg – pachymetric progression index average; Prog_min – pachymetric progression index maximum; KI – keratoconus index; CKI – central keratoconus index; IHD – index of height decentration; IHA – index of height asymmetry; IVA – index of vertical asymmetry; ISV – index of surface variance.
thinnest location was weak. Moreover, the association of refractive errors with indices of pachymetry, including K1, K2, IHD, Progfront, Progast, and Progmax, was not significant.

Table 4 shows the relationship between Pentacam indices in various types of refractive errors. For instance, the differences in angle, volume, IVA, ISV, and anterior chamber depth were significant (p=0.00) compared to each other in all types of refractive errors (except for the comparison of IVA between hyperopia and astigmatism with p=0.057).

Table 5 shows the relationship between Pentacam indices and different severities of refractive errors. The difference in mean±SD of the Kmax front between severities in both myopia (p=0.003) and astigmatism (p=0.00) is significant. The intra-group analysis demonstrated that, in myopes, only high myopes had significantly higher Kmax front than low myopes (p=0.00). In astigmatism, all three groups had significant differences, and maximum keratometry (Kmax) was significantly higher in extreme type in comparison with moderate (p=0.00) and high (p=0.01) type and in high astigmatism than moderate types (p=0.02). The AC depth in myopes was significantly higher than that of astigmatism and hyperopia, and in astigmatism it was significantly higher than hyperopes (all three p=0.00). However, in intra-group variance analysis, the differences between different refractive error severities in AC depth were not significant.

In the anterior chamber volume analysis, only moderate myopia had a significantly higher volume in comparison with the mild myopia(p=0.019), and only in astigmatism, moderate types had higher anterior chamber angle in comparison with the high (p=0.012) and extreme (p=0.024) types.

The ISV of moderate myopes was significantly higher compared with the mild types (p=0.00), and high myopes had a significantly higher ISV in comparison with ISV of moderate and mild types (p=0.00). Besides, the ISV of high astigmatism was significantly higher compared with moderate types (p=0.00), and the ISV of extreme astigmatism was significantly higher in comparison with high and moderate types (p=0.00).

In the analysis of asymmetric variables of the cornea, only extreme astigmatism had significantly higher IVA and IHA than moderate types (p=0.001 and p=0.035, respectively).

Eventually, high myopes had significantly lower Rmin than mild myopes (p=0.02). Also, extreme astigmatism had significantly lower Rmin than high (p=0.014) and moderate (p=0.00) types, and high astigmatism had significantly lower Rmin than moderate types (p=0.013). In other indices, the differences between different severities of refractive errors in terms of Pentacam indices were not significant.

DISCUSSION

In our study, the participants ranged from 18–52 years with a mean age of 28.48±6.82, and 66.4% were female. The mean spherical equivalent of the participants' eyes was -3.91±2.50D. Moreover, the prevalence of myopia was the highest (83.73%), followed by astigmatism (10.57%) and by hyperopia (3.70%). As reported by Seyed Javad Hashemian et al. [14], 91.95% of the 2673 cases who were screened for refractive surgery were detected with myopia.

In another study, Heydari et al. [15] showed that 94.2% of 400 studied eyes had myopia as the most serious vision problem, and the least was hyperopia with a percentage of 3.3%. In their study, the mean spherical equivalent was -3.29±2.27D, which is in line with the data achieved in our study. These results could be justified by the better response of myopia to PRK compared with the other types of refractive errors. In our study, the mean posterior and anterior corneal K were -6.09±0.24D and 43.09±1.52D, respectively. Moreover, the mean posterior and anterior corneal K were -6.42±0.27D and 44.39±1.52D, respectively. In addition, the association of the Kmax front with the refractive errors was significant, and the mean Kmax front was 44.84±1.58D (Tables 1–5).

Based on the data from this study, it was observed that the mean Kmax front for hyperopia and myopia was 44.19±1.94D.
|                        | Myopia |       |       |       | Hyperopia |       |       |       | Astigmatism |       |       |       |       |
|------------------------|--------|-------|-------|-------|-----------|-------|-------|-------|-------------|-------|-------|-------|-------|
|                        | Mild n=531 | Moderate n=1073 | High n=279 | Extreme n=16 | P-value | Low n=5 | Moderate n=39 | High n=38 | P-value | Moderate n=58 | High n=128 | Extreme n=48 | P-value |
| K_max front (D)        | 44.63±1.49 | 44.81±1.54 | 45.05±1.56 | 44.81±1.50 | 0.003 | 43.70±2.05 | 44.09±2.21 | 44.36±1.64 | 0.70 | 44.75±1.53 | 45.44±1.59 | 46.20±1.52 | 0.00   |
| Cornea volume (mm³)    | 59.57±3.54 | 59.76±3.73 | 59.76±3.16 | 61.27±2.87 | 0.25 | 59.64±2.82 | 58.47±2.85 | 58.99±3.63 | 0.781 | 58.72±3.60 | 59.36±3.89 | 58.94±3.83 | 0.543  |
| Chamber volume (mm³)   | 201.12±33.58 | 206.32±34.58 | 204.88±31.80 | 190.81±25.10 | 0.011 | 149.40±27.66 | 158.33±33.11 | 156.52±38.40 | 0.865 | 198.27±35.33 | 192.10±33.38 | 192.66±35.45 | 0.510  |
| AC depth (mm)          | 3.785±0.273 | 3.816±0.284 | 3.802±0.283 | 3.650±0.223 | 0.028 | 3.342±0.244 | 3.413±0.282 | 3.356±0.348 | 0.699 | 3.832±0.526 | 3.704±0.357 | 3.655±0.280 | 0.049  |
| Angle (degree)         | 38.49±6.091 | 38.40±6.124 | 37.45±7.233 | 36.41±5.034 | 0.055 | 35.66±3.017 | 33.57±5.922 | 33.39±5.987 | 0.717 | 38.97±5.484 | 36.15±6.663 | 35.74±6.023 | 0.009  |
| ISV                    | 14.87±4.562 | 15.68±4.890 | 17.86±5.398 | 17.93±2.112 | 0.00 | 19.60±4.979 | 17.87±6.817 | 22.05±9.549 | 0.085 | 19.00±4.120 | 26.83±5.112 | 35.89±7.247 | 0.00   |
| IVA                    | 0.10±0.043 | 0.10±0.058 | 0.11±0.093 | 0.10±0.038 | 0.142 | 0.168±0.031 | 0.176±0.046 | 0.162±0.125 | 0.080 | 0.10±0.040 | 0.12±0.052 | 0.14±0.048 | 0.001  |
| IHA                    | 2.91±2.343 | 3.02±3.234 | 3.30±2.677 | 3.45±2.458 | 0.149 | 2.60±2.867 | 3.43±2.609 | 4.44±3.298 | 0.209 | 3.25±2.668 | 4.21±3.468 | 4.86±3.497 | 0.04   |
| R_min (mm)             | 7.56±0.340 | 7.53±0.261 | 7.50±0.262 | 7.54±0.255 | 0.034 | 7.74±0.377 | 7.70±0.256 | 7.67±0.275 | 0.329 | 7.52±0.261 | 7.43±0.261 | 7.31±0.242 | 0.00   |

Table 5. Comparing Pentacam indices based on refractive severity.

- **K_max front** – maximum keratometry of anterior cornea; **D** – Diopter; **R_min** – minimum Radius of curvature; **AC depth** – anterior chamber depth; **IHA** – index of height asymmetry; **IVA** – index of vertical asymmetry; **ISV** – index of surface variance.
and 44.80±1.54D, respectively. In a similar study by Hashemi et al. [16], who evaluated anterior chamber criteria regarding the refractive status of patients, 203 eye samples were divided into three groups (hyperopia, myopia, and emmetropia), and those with a myopic disorder were divided into four subgroups. Based on their study, it was observed that 83% of samples were detected with myopia. However, in contrast to the data of our study, the differences in refractive errors and $K_{max}$ Front were not significant ($p=0.1$), with a mean of 44.3±2.2D for myopia and 45.03±1.44D for hyperopia. Although there was no difference between the $K_{max}$ front in the hyperopia and myopia, the $K_{max}$ front in the myopia was higher than the hyperopia. The lack of mentioned difference could be explained by the higher powers of myopic eyes when compared with the hyperopes, which is to some extent due to the high corneal power in myopes.

In our study, the average thickness of cornea at thinnest and apex locations were 531.279±32.48 µm and 534.261±32.04 µm, respectively. There was a substantial significant association between the mentioned variables ($P=0.00$). However, the association of these two variables with refractive errors was not statistically significant. In their study, Mohammadi et al. [17] revealed a significant association between refractive error and corneal thickness in hyperopes. In another study by Mahmoud et al. [18], a significant association was reported between the severity of myopia and the central corneal thickness (CCT). However, these two studies mentioned above contradict our study; Hashemi et al. [16] observed no significant association between the thinnest location and corneal thickness with refractive errors. In another study, a mean of 549.5±33.6 µm was reported for CCT, while the association of CCT with refractive errors was not significant [19].

In addition, Fam et al. [20] reported no significant association between CCT and the degree of myopia in their study. The data in our study correspond with the findings of the three studies mentioned above and some other studies in which the association of CCT and refractive errors was not significant [21–23]. The association between refractive errors and corneal thickness could be explained by geographical or racial differences in various populations.

Our study revealed that the association of anterior chamber indices and refractive errors is statistically significant, as, in the analysis of AC depth and volume, there was a significant difference between hyperopia with both myopia and astigmatism and also between astigmatism and myopia (Table 4). Intra-group analysis of cornea volume demonstrated a significant difference only between astigmatism and myopia. Our study revealed that patients in the myopia group had the highest amount of angle, chamber volume, and AC depth. Furthermore, there was a significant relationship between different severities of refractive errors and anterior chamber indices.

In their study, Razmjoo et al. [24] showed that the depth, volume, and the mean anterior chamber angle in patients undergoing PRK surgery were 207±50 mm³, 3.29±0.4 mm, and 39.7±5.2°, respectively. Another study by Hashemi et al. [16] demonstrated that the association of angle, anterior chamber volume, and anterior chamber depth with refractive errors was significant. Based on their data, the anterior chamber depth and volume in the myopes had the highest values of data. However, there was no significant association between refractive errors and cornea volume ($p>0.05$). A study consisting of 149 patients (297 eye samples) using Pentacam indices observed that 242 eye samples had the highest prevalence rate of myopia, and the association of pachymetric and anterior chamber indices with all refractive errors was significant ($p<0.05$). Moreover, the participates in the myopia group had the highest depth and volume of the anterior chamber and the lowest values of corneal vol-
the anterior corneal surface were significantly higher. Contrary to the data achieved from our study, some of the previous studies revealed that ATR and WTR was the most prevalent type of posterior and anterior corneal astigmatism, respectively [35–38].

The data presented in a study by Miyake et al. [38] revealed no significant association between ACA and PCA, which is in contrast with the results of our study. Moreover, in their study, the most common types of astigmatism were ATR astigmatism in the posterior cornea and WTR in the anterior cornea with 91% and 68%, respectively. The reported differences in the data achieved from various studies could be due to the differences in various types of posterior and anterior astigmatism based on different geographical areas and races or may be because of the availability of unknown cases which should be investigated with more detail in further studies. Eventually, one of the advantages of the present study was that all preoperative clinical and paraclinical examinations were performed only by one surgeon and a Pentacam device. Our study had no specific limitation.

CONCLUSION

The data in this study revealed that, in patients who underwent PRK surgical procedure, Pentacam indices, including surface zone indices, anterior chamber indices, and keratometric indices, may differ on the severity and types of refractive errors. Furthermore, it should be noted that a more desirable outcome from refractive surgery could be obtained through a more accurate and effective examination of the anterior and posterior cornea.

ACKNOWLEDGMENTS

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

The study was approved by the biomedical research ethics committee of Ardabil Azad University (NO: 1191010197203).

Consent to participate

Written informed consent was obtained from participants in this study.

Authorship

HO designed the study, HO, GM, FA and AN conducted the study. HO and GM wrote the paper. FA performed the statistical analysis of the study. All authors read and approved the final manuscript.

REFERENCES

1. Read SA, Collins MJ, Garway LG. A review of astigmatism and its possible genesis. Clin Exp Optom. 2007 Jan;90(1):5-19. doi: 10.1111/j.1444-0988.2007.00112.x.
2. Ojaghi H, Moghadam R, Ahari SS, Bahadoram M, Amani E. Amblyopia Prevention Screening Program in Northwest Iran (Ardabil). Int J Prev Med. 2016 Mar 1;7:45. doi: 10.4103/2008-7802.173887.
3. Najafi A, Ojaghi H, Zahiriyan Moghadam T, Sharigi A. Prevalence of Types of Corneal Astigmatism before Cataract Surgery. International journal of Pharmaceutical Research. 2020;12(2):303-11. doi: 10.31838/ ijpr.2020.12.02.00844.
4. Yekta A, Fotouhi A, Hashemi H, Dehghani C, et al. Prevalence of refractive errors among schoolchildren in Shiraz, Iran. Clin Exp Ophthalmol. 2010 Apr;38(3):292-8. doi: 10.1111/j.1442-9071.2010.02247.x.
5. Randleman JB, Woodward M, Lynn MJ, Stulting RD. Risk assessment for ectasia after corneal refractive surgery. Ophthalmology. 2008 Jul;115(7):137-50. doi: 10.1016/j.ophtha.2007.03.073.
6. Schweitzer C, Roberts CJ, Mahmoud AM, Collin J, et al. Screening of forme fruste keratoconus with the optical wavefront analysis. Invest Ophthalmol Vis Sci. 2010 May;51(5):4290-3. doi: 10.1167/iovs.09-3680.
7. Hashemian MN, Ojaghi H, Mohammadpour M, Jahanbarn M, et al. Femtosecond laser accurate keratometry for the correction of postkeratoplasty high astigmatism in keratotomy. J Res Med Sci. 2017 Feb 16;22:17. doi: 10.4103/1735-1955.200627.
8. Khurana A, Khurana AK, Khurana B. Theory and practice of optics and refraction, 2nd edition, Elsevier India; 2014.
9. Wang LL, Wang W, Han XT, He MG. Influence of severity and types of astigmatism on visual acuity in school-aged children in southern China. Int J Ophthalmol. 2018 Aug;11(11):1377-1383. doi: 10.3980/j.issn.2223-3959.2018.08.20.
10. Schuster AK, Pfeiffer N, Schulz A, Hoehn R, et al. Refractive, corneal and ocular residual astigmatism: distribution in a German population and age-dependency - the Gutenberg health study. Graefes Arch Clin Exp Ophthalmol. 2017 Dec;255(12):2493-2501. doi: 10.1007/s00417-017-3775-x.
11. American Optometric Association. Optometric clinical practice guideline care of the patient with myopia. 1997;437:6314-7881.
12. Kaimbo DKK. Astigmatism - definition, etiology, classification, diagnosis and non-surgical treatment. Astigmatism e Optics, Physiology and Management Intech. 2012;59-74. doi: 10.5722/13012.
13. Moore BD, Augsburger AR, Ciner E, Cockrell D, et al. Optometric clinical practice guideline: care of the patient with hyperopia. American Optometric Association. 1997:1-29.
14. Hashemian SJ, Soleimani M, Forouatan A, Jokhodhani M, et al. Ocular higher-order aberrations and mesopic pupil size in individuals screened for refractive surgery. Int J Ophthalmol. 2012;5:222-5. doi: 10.3980/jissn.issn.2223-3959.2012.02.21.
15. Heidari Z, Mohammadzadeh M, Moghaddas M, Jafarzadehpour E, et al. Correlation between Refractive, Corneal and Residual astigmatism in refractive surgery candidates. Journal of Mazandaran University of Medical Sciences. 2014;23(10):38-43.
16. Hashemi M, Fardarjani KG, Aghal GH, Aghdam KA, Gordzil A. Anterior segment study with the Pentacam Scheimpflug camera in refractive surgery candidates. Middle East Afr J Ophthalmol. 2013 Jul-Sep;20(3):212-6. doi: 10.4109/0974-9233.114795.
17. Mohammad A, Jafarzadehpour E, Rafer M. Corneal Thickness, Corneal Curvature and Refractive Errors of University Student in Arek. Journal of Arak University of Medical Sciences. 2013;16(8):85-91.
18. AlMahmoud T, Priest D, Munger R, Jackson WB. Correlation between refractive error, corneal power, and thickness in a large population with a wide range of anisotropia. Invest Ophthalmol Vis Sci. 2011 Mar 16;52(3):1235-42. doi: 10.1167/iovs.10-4549.
19. Koucheki B, Mehravararam S, Hashemi H. Correlation between central corneal thickness and refractive indices in a laser refractive surgery population. Iranian journal of ophthalmology. 2010;22(4):43-8.
20. Fan H, Bow AC, Baskaran M, Lim KL, et al. Central corneal thickness and its relationship to myopia in Chinese adults. Br J Ophthalmol. 2006 Dec;90(12):1451-3. doi: 10.1136/bjo.2006.101170.
21. Lekouk M, Aimpon P, Navaneentarakul P, Bumrungradwatt S, et al. The correlations between Central Corneal Thickness and age, gender, intracocular pressure and refractive error of aged 12-60 years old in rural Thai community. J Med Assoc Thai. 2005 Nov;88 Suppl 3:S175-9.
22. Pederson L, Hjortdal J, Elders N. Central corneal thickness in high myopia. Acta Ophthalmol Scand. 2005 Oct;83(3):359-42. doi: 10.1111/j.1600-0420.2005.00081.x.
23. Price FW Jr, Koller DL, Price MO. Central corneal pachymetry in patients undergoing laser in situ keratomileusis. Ophthalmology. 1999 Nov;106(11):2216-20. doi: 10.1016/S0161-6420(99)90564-8.
24. Razmjoo H, Fahidzadeh S. Comparison of central thickness in candidates for photorefractive keratectomy (PRK), using three methods, Orbscan II, Pentacam, and ultrasound. Journal of Isfahan Medical School. 2017;35(417):1-13.
25. Mrutura C, Muthmann F, Yamazaki E, Campos M. Anterior ocular segment study with the Scheimpflug rotational camera in refractive surgery candidate. Acta Ophthalmologica Belg. 2011;74(2):130-4.
26. Alrajhi LS, Bokhary KA, Al-Saleh AA. Measurement of anterior segment parameters in Saudi adults with myopia. J Ophthalmol. 2013 Jul-Sep;20(3):212-6. doi: 10.4103/1735-1995.114795.
27. Chang CK, Lin JT, Zhang Y. Correlation analysis and multiple regression formulas of refractive errors and ocular components. Int J Ophthalmol. 2019 May 10;12(5):490-81. doi: 10.18240/ij.2019.05.28.
28. Foster PJ, Broadway DC, Hayat S, Leman R, et al. Refractive error, axial length and anterior chamber depth of the eye in British adults: the EPIC-Norfolk Eye Study. Br J Ophthalmol. 2010 Jul;94(7):827-30. doi: 10.1136/bjo.2009.163899.
29. Yuan Y, Zhang Z, Zhu J, He X, et al. Responses of the Ocular Anterior Segment and Refraction to 0.5% Tropicamide in Chinese School-Aged Children of Myopia, Emmetropia, and Hyperopia. J Ophthalmol. 2015;2015:612728. doi: 10.1155/2015/612728.
30. Hashemi H, Khabazkhoob M, Ezamian MH, Shariati M, et al. Association between Refractive Errors and Ocular Biometry in Iranian Adults. J Ophthalmic Vis Res. 2015;10(3):214-20. doi: 10.4103/2008-322X.170340.

31. Huseynova T, Abdulaliyeva F, Lanza M. Comparison of Scheimpflug imaging parameters between steep and keratoconic corneas of Caucasian eyes. Clin Ophthalmol. 2016;10:603-8. doi: 10.2147/OPTH.S102683.

32. Ho JD, Liou SW, Tsai RJ, Tsai CY. Effects of aging on anterior and posterior corneal astigmatism. Cornea. 2010 Jun;29(6):632-7. doi: 10.1097/ICO.0b013e3181c2963f.

33. Koch DD, Ali SF, Weikert MP, Shirayama M, et al. Contribution of posterior corneal astigmatism to total corneal astigmatism. J Cataract Refract Surg. 2012 Dec;38(12):2080-7. doi: 10.1016/j.jcrs.2012.08.036.

34. Nemeth G, Berta A, Lipecz A, Hasan Z, et al. Evaluation of posterior astigmatism measured with Scheimpflug imaging Cornea. 2014 Nov;33(11):1214-8. doi: 10.1097/ICO.0000000000000238.

35. Feizi S, Naderan M, Ownagh V, Sadeghpour F. Distribution of the anterior, posterior, and total corneal astigmatism in healthy eyes. Int Ophthalmol. 2018 Apr;38(2):481-491. doi: 10.1007/s10792-017-0483-9.

36. Adani F, Khorrami-Nejad M, Aghazadeh Amiri M, Hashemian H, et al. Characteristics of Posterior Corneal Astigmatism in Different Stages of Keratoconus. J Ophthalmic Vis Res. 2018;13(1):3-9. doi: 10.4103/jovr.jovr_217_16.

37. Dezaklyshian R, Gharemani RM, Ghorbani SM, Tahataheed SM, Mohammadi NM. Evaluation of anterior, posterior, and total corneal astigmatism in normal subjects. Journal of Isfahan Medical School. 2017;35(450):1382-8.

38. Miyake T, Shimizu K, Kamiya K. Distribution of posterior corneal astigmatism according to axis orientation of anterior corneal astigmatism. PLoS One. 2015 Jan 27;10(1):e0117194. doi: 10.1371/journal.pone.0117194.