

Comparison of Keratometric Values Using Javal Keratometer, Oculus Pentacam, and Orbscan II

Hassan Hashemi, MD¹ • AbbasAli Yekta, PhD^{2,3} • Hadi Ostadimoghaddam, PhD^{2,3}
Reza Norouzirad, MSc⁴ • Mehdi Khabazkhoob, MSc⁵

Abstract

Purpose: To compare Orbscan II and Pentacam keratometry readings in terms of their agreement with a manual Javal type keratometer

Methods: In this retrospective study, records of patients who had refractive surgery were reviewed. We extracted data of 765 eyes which had keratometry with the Javal keratometer; of these, 577 had Orbscan II and 200 eyes had Pentacam acquisitions. Minimum (min-K) and maximum (max-K) keratometry readings and keratometric astigmatism with the latter two devices were compared with Javal.

Results: Correlation coefficients for Javal and Orbscan II in measuring min-K and max-K were $r=0.916$ and $r=0.913$, respectively ($p<0.001$). The 95% limits of agreement (LoA) between Javal and Orbscan II was 1.17-1.20 D for min-K and 1.22-1.24 D for max-K. The coefficients for Pentacam and Javal min-K and max-K readings were very high ($r=0.943$ and $r=0.962$). The 95% LoA between Pentacam and Javal in measuring min-K and max-K were 0.51-0.99D and 0.72-0.99D, respectively. The correlation between Pentacam and Javal measurements of keratometric astigmatism was stronger than that for Orbscan II and Javal ($r=0.973$ and $r=0.800$); the 95% LoA was 0.55-0.76D for Pentacam and Javal, and 1.14-1.19D for Orbscan II and Javal.

Conclusion: According to this research, Orbscan II and Pentacam had high correlation and agreement with Javal-keratometer in determining keratometric values. Nevertheless, the results obtained from Pentacam showed better agreement and stronger correlation with Javal as compared with Orbscan II. It seems that Pentacam is a suitable substitute for Javal to perform keratometry in normal eyes.

Keywords: Keratometry, Orbscan II, Pentacam, Javal-keratometer

Iranian Journal of Ophthalmology 2014;26(1):3-10 © 2014 by the Iranian Society of Ophthalmology

-
1. Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, Iran
 2. Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran
 3. Refractive Error Research Center, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran
 4. Dezfoul University of Medical Sciences, Dezfoul, Iran
 5. Department of Epidemiology, Faculty of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received: October 3, 2013

Accepted: January 21, 2014

Correspondence to: Mehdi Khabazkhoob, MSc

Department of Epidemiology, Faculty of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Email: khabazkhoob@yahoo.com

Financial disclosures: None

Introduction

Keratometry, or the measurement of corneal curvature and power, is an essential part of an ophthalmic work up. Topographic maps and keratometry readings have applications in determining corneal health and diagnosing corneal ectasia.¹⁻⁴ Keratometry readings are also used to prescribe appropriate contact lenses and calculate the power of intraocular lenses before cataract surgery.^{5,6} Therefore, it is important to ensure the accuracy of its measuring devices. Keratometry is commonly done with manual Javal type keratometers which are the gold standard.⁷ With this device, the principle of reflection is used for measuring the slope of the corneal surface, from which, the radius of curvature and corneal power are calculated. However, its use has some limitations because it follows certain assumptions and measures the corneal shape from only two points. The new generation of computerized videokeratographers employs the projection method to perform topography and determine corneal power. In these devices, the real shape of the cornea is obtained via determining the elevation of numerous points. Orbscan II (Bausch & Lomb) and Pentacam (Oculus) are two examples of such devices. Many studies have examined these devices in terms of their measurements of the central corneal thickness and their agreement with the gold standard ultrasound.⁸⁻¹² Considering the increasing popularity of these devices,¹³ it seems necessary to check the accuracy of other indexes measured with these devices using traditional gold standard devices. Both Orbscan II and Pentacam generate simulated keratometry readings, however, few studies have been conducted in this field. This study was designed to compare keratometric measurements of Orbscan II and Pentacam with those of a manual keratometer. Should results be in favor of their interchangeability, the preoperative work-up time and the number of tests can be reduced for most patients?

Methods

In this retrospective study, we reviewed records of refractive surgery candidates who underwent surgery in 2008 and 2009. The data required for this study was extracted from patients' preoperative records. We included patients who had at least one record of

keratometry with the Javal keratometer and one acquisition with Orbscan II or Pentacam in their preoperative examinations. Moreover, the spherical refractive error was between -8 and +3 D and astigmatism was less than 3 D in all selected patients in the study.

For each participant, keratometry on both eyes was done with a manual Javal keratometer (Haag-Streit), Pentacam HR (Oculus) and Orbscan IIz (Bausch & Lomb), following the manufacturers' instructions. All measurements were done by a single optometrist.

Measurement techniques

The manual Javal keratometer operates based on the concept of fixed image size and variable object size. Depending on the dioptric power of the cornea, the keratometer focuses on four points in the 3-4 mm zone (3.2 mm apart on a 44-D cornea) of the central anterior cornea and the minimum keratometry (min-K), maximum keratometry (max-K), and their axes can be read on the device after the mires are aligned subjectively. The device is highly accurate for regular spherocylindrical surfaces, but is of limited value in testing irregular corneas.¹⁴

The Pentacam HR is a computerized corneal topographer equipped with a rotating digital Scheimpflug camera. It collects elevation data from 25,000 points to construct a 3 dimensional image of the anterior segment of the eye. In addition to elevation, curvature, and corneal thickness maps, the system displays simulated keratometry readings as the Kf (flat) and Ks (steep) which are equivalent to the min-K and max-K, respectively.¹⁵

Bausch and Lomb Orbscan IIz corneal analysis system was used to perform Orbscan, which is a multidimensional system and provides a complete analysis of the corneal surface. It uses developed Placido discs. The slit light beams are emitted at an angle of 45° to the eye. Twenty slit light beams from the left and 20 slit light beams from the right side are projected on the cornea. It takes images from 9000 point in two time ranges of 0.75 seconds. Orbscan evaluates all corneal curvatures. Keratometry reading by Orbscan are simulated.

The collected data included min-k reading or the dioptric equivalent of the radius of curvature of the flat meridian, the max-K or the dioptric equivalent of the radius of curvature of the steep meridian, and keratometric astigmatism (dif-K) which was calculated as the difference between max-K and min-K with each device.

Statistical analysis of this study was conducted by SPSS, V 11.5. The mean differences between Orbscan II and Pentacam readings of min-K and max-K were determined using paired *t*-test. Pearson correlation coefficients were used for showing the correlation between Orbscan II and Pentacam measurements of min-K, max-K, and dif-K with Javal readings. To demonstrate inter-device agreement, Bland and Altman graphs with 95% limits of agreement (LoA) was used where horizontal and vertical axes indicated the average of a variable with two devices and the inter-device difference for the variable, respectively. The 95% LoA was calculated as "Mean \pm 1.96x standard deviation" of the inter-device difference.

Ethical considerations

Data was collected anonymously and data was extracted based on codes. The project was approved by the Ethics Committee of Noor Eye Hospital.

Results

In this study, we used data from 765 eyes which had keratometry with Javal; 577 of them had Orbscan II and 200 had Pentacam readings. Of the enrolled patients, 33.6% were male. The type of surgery was laser in situ keratomileusis (LASIK) in 354 eyes (46.3%)

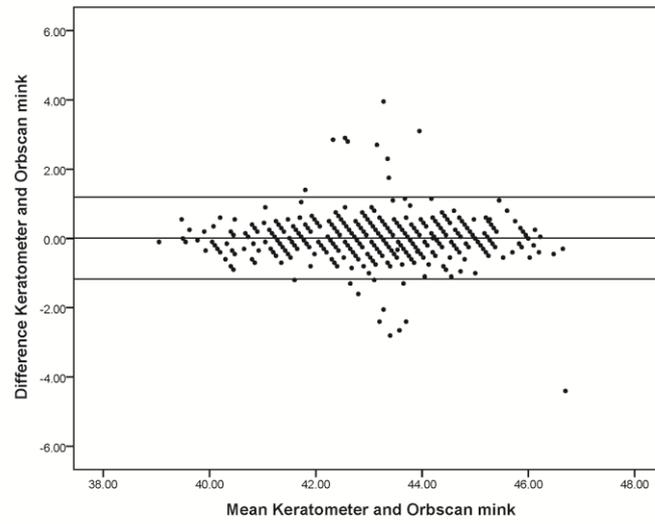
and photorefractive keratectomy in 411 (53.7%) eyes. Table 1 shows the mean min-K, max-K, and dif-K with the three devices.

Javal and Orbscan

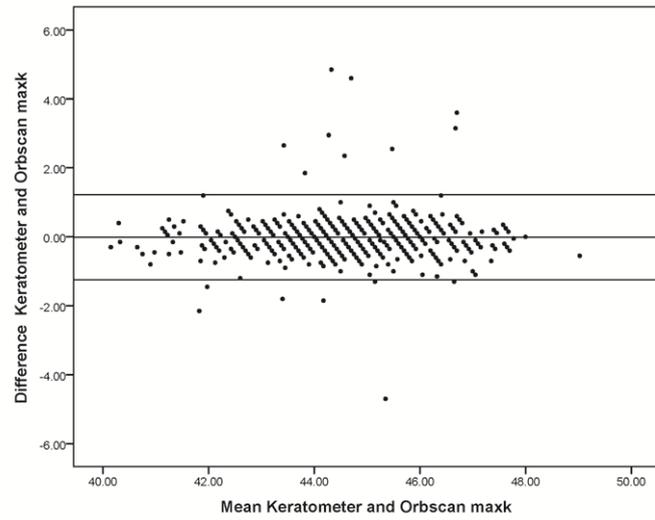
The correlation between Javal and Orbscan II in min-K, max-K, and dif-K measurements were $r=0.916$, $r=0.913$, and $r=0.800$, respectively ($p<0.001$); mean inter-device differences for min-K ($p=0.641$), max-K ($p=0.382$), and dif-K ($p=0.127$) were not statistically significant. Table 2 shows the mean difference between the two devices in terms of the studied variables. Figure 1 illustrates the agreement between these two devices using the Bland-Altman plots. The 95% LoA between these two devices were 1.17-1.20 diopter (D) and 1.22-1.24 D for min-K and max-K, respectively, and -1.19-1.14 D for dif-K. Table 3 presents the equations obtained from linear regression for deriving Javal readings from Orbscan II.

Javal and Pentacam

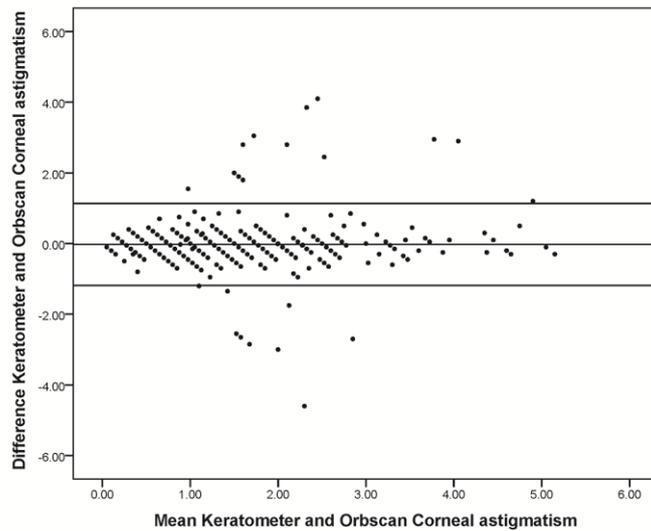
The correlation between Javal and Pentacam was quite high for min-K ($r=0.962$, $p<0.001$), max-K measurements ($r=0.943$, $p<0.001$), and dif-K ($r=0.937$, $p<0.001$). Analysis with paired *t*-test showed statistically significant differences between min-K, max-K, and dif-K measurements with these two devices ($p<0.001$) (Table 2). Figures 1 and 2 illustrate the inter-device agreement. The 95% LoA in measuring min-K and max-K were 0.51-0.99 D and 0.72-0.99 D, respectively. The 95% LoA for dif-K was -0.76-0.55 D. Table 3 contains results of linear regressions for Pentacam and Javal.



A



B



C

Figure 1. Bland-Altman plots demonstrating 95% limits of agreement between Orbscan II and Javal manual keratometer in measuring the minimum keratometry (A), maximum keratometry (B), and corneal astigmatism (C)

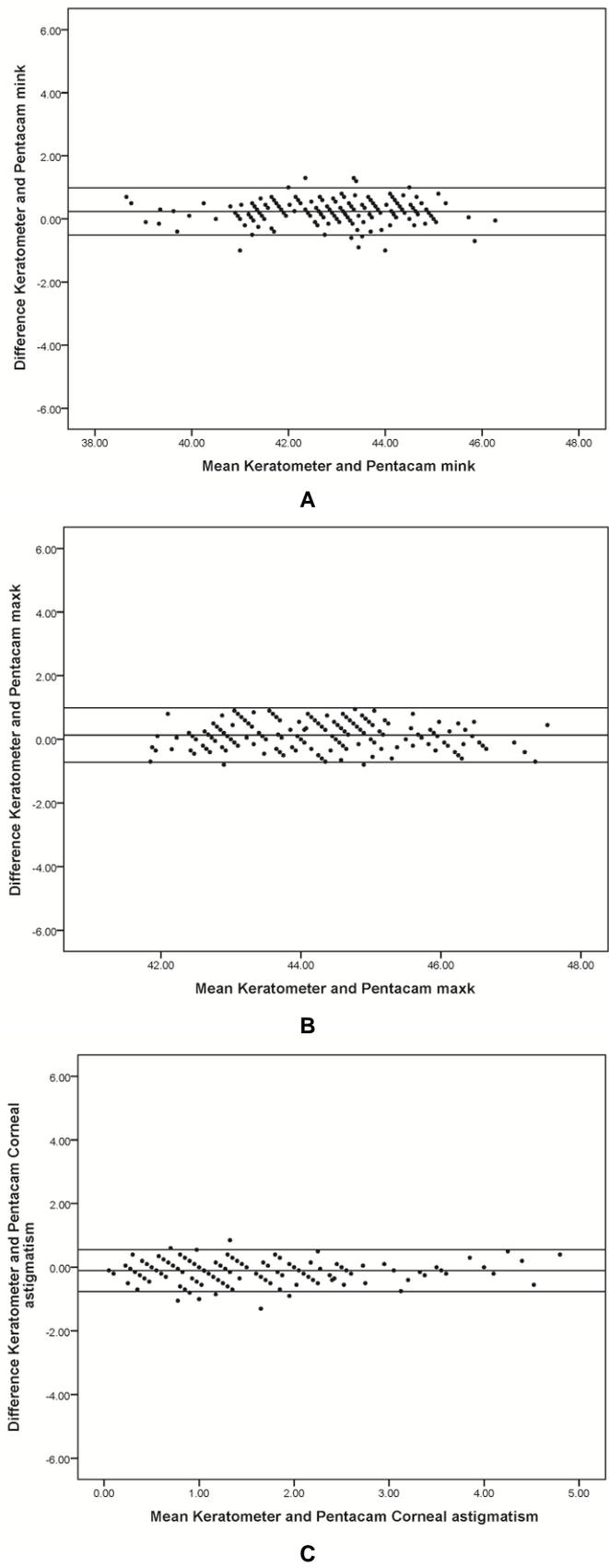


Figure 2. Bland-Altman plots demonstrating 95% limits of agreement between Pentacam and Javal manual keratometry in measuring the minimum keratometry (A), maximum keratometry (B), and corneal astigmatism (C)

Table 1. Mean and standard deviation of minimum keratometry, maximum keratometry and keratometric astigmatism (dif-K) in diopters, as measured in this study with three devices

	Javal Mean±SD	Orbscan II Mean±SD	Pentacam Mean±SD
min-K (diopter)	43.15±1.45	43.24±1.48	42.93±2.66
max-K (diopter)	44.5±1.45	44.6±1.52	44.31±1.42
dif-K (diopter)	1.35±0.96	1.36±0.92	1.52±1.03

SD: Standard deviation, min-K: Minimum keratometry, max-K: Maximum keratometry

Table 2. Mean and standard deviation of differences between Javal-Orbscan II and Javal-Pentacam paired measurements of minimum keratometry, maximum keratometry and keratometric astigmatism (dif-K) in diopters

	Javal and Orbscan II N=577 Mean±SD	Javal and Pentacam N=200 Mean±SD
min-K	0.01±0.60	0.24±0.38
max-K	-0.01±0.63	0.13±0.44
dif-K	-0.03±0.59	-0.11±0.33

SD: Standard deviation, min-K: Minimum keratometry, max-K: Maximum keratometry

Table 3. Linear regression equations for predicting Javal keratometry readings from Orbscan II and Pentacam measurements of minimum keratometry, maximum keratometry and keratometric astigmatism (dif-K) in diopters

min-K	4.07+0.91 (min-K by Orbscan)
min-K	1.56+0.97 (min-K by Pentacam)
max-K	3.21+0.93 (max-K by Orbscan)
max-K	4.00+0.91 (max-K by Pentacam)
dif-K	0.20+0.84 (dif-K by Orbscan)
dif-K	0.00 +0.93 (dif-K by Pentacam)

min-K: Minimum keratometry, max-K: Maximum keratometry

Discussion

Javal-type manual keratometers are used in ophthalmological centers across the globe for measuring the corneal curvature.¹⁶ It has been evaluated and approved in terms of its repeatability, and has been regarded as the gold standard in comparative studies.⁷ Development of corneal imaging devices has paved the way for comparing the results of new devices with those of the traditional gold standard devices and for evaluating their accuracy and reliability. Orbscan II and Pentacam are corneal imaging devices and various studies have examined their performances; nevertheless, most of them have merely focused on the evaluation of central corneal thickness and elevation

values.^{9-11,17} Although their keratometric measurements have been analyzed in various articles¹⁸⁻²⁰ and some have reported high repeatability for these devices, there are few comprehensive studies on the agreement of Orbscan II and Pentacam with Javal in terms of their measurements of simulated keratometry readings which was the topic of interest in this study.

As a main objective of this study, we determined correlations between Orbscan II and Javal in measuring min-K, max-K, and dif-K, and inter-device differences. Since this difference is a sum of positive and negative values, it seems better to decide on the accuracy of Orbscan II keratometry

measurements by considering their correlation and agreement with Javal readings. The minimum correlation coefficient for Orbscan II and Javal readings was 0.9, which indicates a high correlation between these two devices. However, the min-K and max-K with these two devices varied within a range of 2.4 D in 95% of cases, and inter-device differences were equal to or more than 2.5 D in 5.0% of cases. Leyland showed a close agreement between Orbscan II and Javal in a study on normal individuals.²¹ Such results may suggest favorable keratometric performance for Orbscan II; however, as shown in figure 1 and table 2, differences may not be clinically acceptable, and in some cases, the device may have a difference of up to 4.5 D with Javal. This is of special importance when readings are used for calculating the power of intraocular lenses, because such differences can lead to significant error. This also has implications for the diagnosis of corneal disease such as keratoconus as well as preoperative work-up for refractive surgery for which keratometry readings are used as diagnostic and eligibility criterion, respectively.

As shown in the results, mean difference between Javal and Pentacam were higher than those between Javal and Orbscan II. In spite of this, Pentacam-Javal correlations in measuring min-K and max-K were stronger than that between Orbscan II and Javal. Shamma et al²² Compared Pentacam with an autokeratometer; they reported a correlation coefficient of 0.945 and comparable accuracy for routine intraocular lens power calculation, but inter-device agreement was not computed. In our study, the 95% LoA indicated better agreement with gold standard for Pentacam than for Orbscan II. It would be interesting to know how this inter-device agreement compares to test-retest agreement with each device, and this can be addressed in further studies.

Other comparative studies of Pentacam and Orbscan II have shown better results with Pentacam in measuring the corneal thickness and corneal elevation as well.^{8,9,23-25} The difference seems to arise from the imaging methods of the two devices, the camera angle, and the illumination path of projected slits. Pentacam evaluates 25 or 50 slit images of the corneal surface and provides more information about the central cornea in

comparison to Orbscan II. Overall, as comprehensive, user friendly, non-contact optical corneal topography systems, Pentacam appears to be a better choice than Orbscan II and can be used with less concern for possible differences with gold standard devices. This issue could be of special interest for epidemiological studies where such systems can provide a constellation of corneal information with minimum time consumption and patient discomfort.

The present study had some strong and weak points. The most important strength of this study is that it evaluated the agreement of the devices using a large sample size. However, not performing this study in the normal population and healthy participants is its major weak point. Moreover, lack of random sampling in this study should be regarded as another weak point of this study.

Conclusion

Based on these findings, although both Orbscan II and Pentacam demonstrated strong correlations and small differences with Javal in terms of keratometry readings, results of agreement analyses were more in favor of Pentacam in this regard. In clinical situations where anterior segment data such as corneal thickness is needed in addition to keratometry readings, Pentacam alone can serve as a reliable device. Further studies in other patient populations are suggested.

References

- Holladay JT. Keratoconus detection using corneal topography. *J Refract Surg* 2009;25(10 Suppl):S958-62.
- Li X, Yang H, Rabinowitz YS. Keratoconus: classification scheme based on videokeratography and clinical signs. *J Cataract Refract Surg* 2009;35(9):1597-603.
- Hashemi H, Roshani M, Mehravaran S, Parsafar H, Yazdani K. Effect of corneal thickness on the agreement between ultrasound and Orbscan II pachymetry. *J Cataract Refract Surg* 2007;33(10):1694-700.
- Dastjerdi MH, Hashemi H. A quantitative corneal topography index for detection of keratoconus. *J Refract Surg* 1998;14(4):427-36.
- Shirayama M, Wang L, Koch DD, Weikert MP. Comparison of accuracy of intraocular lens calculations using automated keratometry, a Placido-based corneal topographer, and a combined Placido-based and dual Scheimpflug corneal topographer. *Cornea* 2010;29():1136-8.

6. Srivannaboon S, Rakpanichmanee T, Cheng AC, Fam HB. Estimation of posterior corneal power for IOL calculation after myopic LASIK. *J Refract Surg* 2008;24(9):946-51.
7. Tennen DG, Keates RH, Montoya C. Comparison of three keratometry instruments. *J Cataract Refract Surg* 1995;21(4):407-8.
8. Jonuscheit S, Doughty MJ. Regional repeatability measures of corneal thickness: Orbscan II and ultrasound. *Optom Vis Sci* 2007;84(1):52-8.
9. Ho T, Cheng AC, Rao SK, Lau S, Leung CK, Lam DS. Central corneal thickness measurements using Orbscan II, Visante, ultrasound, and Pentacam pachymetry after laser in situ keratomileusis for myopia. *J Cataract Refract Surg* 2007;33(7):1177-82.
10. Hashemi H, Mehravaran S. Central corneal thickness measurement with Pentacam, Orbscan II, and ultrasound devices before and after laser refractive surgery for myopia. *J Cataract Refract Surg* 2007;33(10):1701-7.
11. Lackner B, Schmidinger G, Pieh S, Funovics MA, Skorpik C. Repeatability and reproducibility of central corneal thickness measurement with Pentacam, Orbscan, and ultrasound. *Optom Vis Sci* 2005;82(10):892-9.
12. Iskander NG, Peters NT. Orbscan versus ultrasound. *J Cataract Refract Surg* 2004;30(2):293.
13. González-Pérez J, González-Méjome JM, Rodríguez Ares MT, Parafita MA. Central corneal thickness measured with three optical devices and ultrasound pachometry. *Eye Contact Lens* 2011;37(2):66-70.
14. Khurana AK. Theory and practice of optics and refraction. Chennai, India: Elsevier India; 2008.
15. Swart TC. Pentacam. In: Agarwal A, Agarwal A, Jacob S, editors. *Dr Agarwal's textbook on corneal topography: Including Pentacam and anterior segment OCT*. New Delhi, India: Jaypee Highlights Medical Publishers, INC; 2010. p. 117-36.
16. Lam AK, Chan CC, Lee MH, Wong KM. The aging effect on corneal curvature and the validity of Javal's rule in Hong Kong Chinese. *Curr Eye Res* 1999;18(2):83-90.
17. Yekta AA, Hashemi H, KhabazKhoob M, Dostdar A, Mehravaran S, Heravian J, et al. Comparison of central corneal thickness measurements with Pentacam, Orbscan II, and ultrasound pachymeter. *Iranian Journal of Ophthalmology* 2009;21(2):51-7.
18. KhabazKhoob M, Hashemi H, Yazdani K, Mehravaran S, Yekta A, Fotouhi A. Keratometry measurements, corneal astigmatism and irregularity in a normal population: the Tehran Eye Study. *Ophthalmic Physiol Opt* 2010;30(6):800-5.
19. Módis L Jr, Szalai E, Kolozsvári B, Németh G, Vajdas A, Berta A. Keratometry evaluations with the Pentacam high resolution in comparison with the automated keratometry and conventional corneal topography. *Cornea* 2012;31(1):36-41.
20. Norrby S. Pentacam keratometry and IOL power calculation. *J Cataract Refract Surg* 2008;34(1):3; author reply 4.
21. Leyland M. Validation of Orbscan II posterior corneal curvature measurement for intraocular lens power calculation. *Eye (Lond)* 2004;18(4):357-60.
22. Shammas HJ, Hoffer KJ, Shammas MC. Scheimpflug photography keratometry readings for routine intraocular lens power calculation. *J Cataract Refract Surg* 2009;35(2):330-4.
23. Bourges JL, Alfonsi N, Laliberté JF, Chagnon M, Renard G, Legeais JM, et al. Average 3-dimensional models for the comparison of Orbscan II and Pentacam pachymetry maps in normal corneas. *Ophthalmology* 2009;116(11):2064-71.
24. Ha BJ, Kim SW, Kim SW, Kim EK, Kim TI. Pentacam and Orbscan II measurements of posterior corneal elevation before and after photorefractive keratectomy. *J Refract Surg* 2009;25(3):290-5.
25. Rosa N, Lanza M, Borrelli M, Polito B, Filosa ML, De Bernardo M. Comparison of central corneal thickness measured with Orbscan and Pentacam. *J Refract Surg* 2007;23(9):895-9.