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Middle East Afr J Ophthalmol. 2015 Apr-Jun; 22(2): 233–237. PMCID: PMC4411623
doi: 10.4103/0974-9233.151884

Comparison of the Corneal Power Measurements with the TMS4-Topographer, Pentacam HR, IOL Master, and Javal Keratometer

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Abstract

Purpose:

The aim was to compare the corneal curvature and power measured with a corneal topographer, Scheimpflug camera, optical biometer, and Javal keratometer.

Materials and Methods:

A total of 76 myopic individuals who were candidates for photorefractive keratectomy were selected in a cross-sectional study. Manual keratometry (Javal Schiotz type; Haag-Streit AG, Koeniz, Switzerland), automated keratometry (IOL Master version 3.02, Carl Zeiss Meditec, Jena, Germany), topography (TMS4, Tomey, Erlangen, Germany), and Pentacam HR (Oculus, Wetzlar, Germany) were performed for all participants. The 95% limits of agreement (LOAs) were reported to evaluate the agreement between devices.

Results:

The mean corneal power measurements were 44.3 ± 1.59, 44.25 ± 1.59, 43.68 ± 1.44, and 44.31 ± 1.61 D with a Javal keratometer, TMS4-topographer, the Pentacam and IOL Master respectively. Only the IOL Master showed no significant difference with Javal keratometer in measuring the corneal power (P = 0.965). The correlations of the Javal keratometer with TMS4-topography, Pentacam, and IOL Master was 0.991. 0.982, and 0.993 respectively. The 95% LOAs of the Javal keratometer with TMS4-topography, Pentacam, and IOL Master were − 0.361 to 0.49, −0.01 to 1.14, and − 0.36 to 0.36 D, respectively.

Conclusion:

Although the correlation of Pentacam, TMS4-topography, IOL Master, and Javal keratometer in measuring keratometry was high, only the IOL Master showed no significant difference with the Javal keratometer. The IOL Master had the best agreement with Javal keratometry.

Keywords: Agreement, Corneal Power, Correlation, IOL Master, Pentacam, TMS4-Topographer

INTRODUCTION

Accurate measurement of corneal power is essential for refractive surgery, orthokeratology, contact lens fitting, and intraocular lens (IOL) power.[1,2] The Javal keratometer, corneal topographers, IOL Master, and

Pentacam are different devices for the measurement of the corneal power. Hence, it is important to determine the differences in measuring corneal power and curvature between these devices. The Javal (conventional) keratometer is the most common device for the measurement of corneal power because it is simple and fast to use and low cost. In addition, Javal keratometry is considered the gold standard for the measurement of corneal curvature.[3] An important limitation of the Javal keratometer, as a conventional keratometer, is that it only measures the power of the anterior cornea and estimates the mean power of the central cornea.[4] Available data indicate that no studies have been performed to compare the Javal keratometer as the gold standard with the Pentacam (Oculus Gmbh, Wetzlar, Germany), IOL Master (Carl Zeiss Meditec, Jena, Germany), and topography and to determine the limits of agreement (LOAs). However, a number of studies have compared corneal powers measured by the Atlas topographer (Carl Zeiss Meditec, Jena, Germany) and the IOL Master,[1] the Atlas topographer and a manual keratometer (Bausch and Lomb Inc., Rochester, New York, USA),[1] the IOL Master and a manual keratometer,[1] the Pentacam and two corneal topographers (TMS-2 and Keratron Scout),[5] the Pentacam and the IOL Master,[4,6] and the IOL Master and the Javal keratometer[7] which have all reported high correlations.

The advances in IOL calculation formulas and increased surgeon expectation for accurate IOL calculations especially for toric IOLs now require devices that can measure both corneal surfaces and also measure posterior corneal astigmatism.[1] However, a study[1] of toric IOLs implantation reported that corneal astigmatism prediction error by the devices that only measure anterior corneal astigmatism including IOL Master, Lenstar (Haag-Streit AG, Koeniz, Germany), Atlas corneal topographer, and manual keratometer was only 0.5-0.6 D for with-the-rule astigmatism, while it was 0.57 D for the Galilei Placido-dual Scheimpflug analyzer (Ziemer Ophthalmic Systems AG, Port, Switzerland) which measures both anterior and posterior corneal astigmatism. This value was even less for against-the-rule astigmatism.[1]

However, there are numerous devices that measure only the anterior corneal surface, and it is important to determine the agreement of various devices. This is important because all the devices are often available hence, determining the agreement between devices can allow the estimation of values derived between different devices. In this report, our objective was to compare the Javal keratometer with topography, the Pentacam, and the IOL Master and to determine the agreement between devices.

MATERIALS AND METHODS

In this cross-sectional study, which was conducted between October 2011 and July 2012, 76 otherwise healthy individuals who were candidates for photorefractive keratectomy (PRK) refractive surgery for myopia were examined at Farabi Hospital, Tehran, Iran. Persons with a history of ocular or systemic diseases, ocular surgery, corneal problems, and those aged above 40 years were excluded from examinations. Keratometric measurements of both eyes were performed with a manual keratometer (Javal Schiotz Type, Switzerland), the Haag-Streit keratometer, the IOL Master (version 3.02, Carl Zeiss, Meditec, Jena, Germany), the TMS4-topographer (Tomey Erlangen, Germany), and the HR Pentacam (Oculus, Wetzlar, Germany). For each device, K_{min}, K_{max}, and K_{mean} were calculated. The central 3-mm values were used for the topographer and the Pentacam.

We obtained keratometry readings with the Pentacam via equivalent keratometry. The data were analyzed with SPSS version 20 software (IBM Inc., Chicago, Illinois, USA). Descriptive statistics including the mean readings of the four devices along with their standard deviations were calculated. The correlation of the devices and their correlation coefficients were calculated using the Pearson coefficient. A paired *t*-test was used to evaluate the difference between devices. Finally, the agreement between devices was determined with the 95% LOAs and Bland-Altman plots. $P < 0.05$ indicated statistical significance.

This study was approved by the Ethics Committee of the Optometry Department of the faculty of rehabilitation affiliated with Tehran University.

All the participants signed informed consent forms, and the examinations were free of charge. The anonymity of the participants was ensured, and the examinations had no side-effects for the participants.

RESULTS

In this study, both eyes of 76 individuals were evaluated. There were 16 (21.1%) males. The mean age of the participants was 27.05 ± 4.25 years (range: 19-39 years).

The correlation of the left and the right eye

There was a statistically significant correlation between eyes of the same patient [Table 1] ($P < 0.001$). The paired *t*-test indicated no significant difference in the results of the left and the right eye among all the devices. Therefore, the analysis of the agreement between devices was performed on the right eye.

Javal keratometer and topography

The mean corneal power was 44.3 ± 1.59 D with the Javal keratometer and 44.25 ± 1.50 D with the TMS4-topography [Table 2]. The paired *t*-test demonstrated a statistically significant difference in the mean corneal power between the keratometer and TMS4-topography ($P = 0.010$) [Table 3]. There was a high correlation between the corneal powers obtained by the Javal keratometer and TMS4-topography ($P < 0.001$; Pearson's correlation coefficient = 0.991) [Figure 1 and Table 4]. The 95% LOAs of the two devices were − 0.36 to 0.49 [Figure 2].

The Javal keratometer and the Pentacam

Table 2 presents the results of the mean corneal power measured by the Pentacam. The paired *t*-test showed a statistically significant difference in the mean corneal power measurements with the Pentacam and the Javal keratometer ($P < 0.001$) [Tables 2 and 3], but their correlation was high ($P < 0.001$, $r = 0.982$) [Figure 3]. Figure 4 shows the agreement of the Javal keratometer and the Pentacam. The 95% LOAs of the Pentacam and Javal keratometer were from − 0.01 to 1.14.

The Javal keratometer and the IOL Master

The mean difference between the Javal keratometer and IOL Master was not statistically significant ($P = 0.965$) [Table 2]. There was a high correlation between corneal powers measured by the Javal keratometer and the IOL Master ($P < 0.001$, $r = 0.993$) [Figure 5, Table 4]. The 95% LOAs were − 0.36 to + 0.36. The Bland-Altman plot is presented in Figure 6.

DISCUSSION

The outcomes of is study indicate that although there was a significant correlation between the Javal keratometer and other devices in this study, there were significant differences between the Javal keratometry and corneal topography, and between the Javal keratometer and the Pentacam. In addition, there was a strong correlation between the IOL Master and the Javal keratometer, (the mean difference between devices was 0.001 ± 0.18 D). The Javal keratometer and the Pentacam had the largest mean difference (0.57 ± 0.29 D) [Table 2]. The difference between these devices results from differences in the measuring principles.[8] We used the Javal keratometer in this study that is a manual keratometer that uses two keratometry mires along the main meridians of the cornea. The corneal power is determined using the reflection from these illuminated mires from the central 3.4 mm of the cornea. The device uses a refraction index of 1.3375.[9] In topography, to estimate the central 3-mm curvature, 7-8 Placido rings are used.[10] In the IOL Master, six light spots are projected onto the cornea in a hexagonal pattern, and measurement is performed in a 2.3 mm radius.[9] The Pentacam is a Scheimpflug camera used for corneal imaging.[9] Equivalent keratometry values from the Pentacam are generated using measurements of the anterior and posterior corneal values in the central 3 mm.[1]

Another difference is that the Pentacam uses a refractive index of 1.376 for the cornea in equivalent *K* while the other devices use a refractive index of 1.3375.[9] This difference in the refractive index for equivalent *K* in the Pentacam may cause a significant difference compared to other devices. Additionally, the resolution of the imaging in the central 3 mm of the cornea and the mechanism of the estimation of the power based on the Scheimpflug mechanism may be responsible for the difference in results. A study by Visser *et al.*,[9] reported significant differences in the equivalent *K* values and the keratometry values of the IOL Master (automated keratometry), topography (simulated keratometry [SimK]), and the Javal keratometer (manual keratometry).

The Javal keratometer and corneal topography showed a high correlation, however, the significant differences between results may be due to the number of reflected corneal spots, the reconstruction mechanism or the estimation of corneal power. Other comparative studies of topography and keratometry, have shown a strong correlation of the Atlas topographer and the manual topographer (Bausch and Lomb Inc., Rochester, New York, USA) in measuring the corneal power.[1] SimK values determined from the data points on mires 7, 8, and 9 of videokeratography were significantly correlated with the measurements obtained by conventional keratometry.[5] The IOL Master and keratometry not only show a significant correlation but also do not show significant differences. These findings indicate the interchangeability of the results of the IOL Master and keratometry. Despite the differences in the number of data points and axis of imaging, the estimation of corneal power between devices yields similar values. A study of the IOL Master and manual keratometry[1] has reported a strong correlation in the measurement of the corneal power. Additionally, preoperative measurements of PRK patients indicate a strong correlation between the IOL Master and Javal keratometer.[11] Another study comparing the IOL Master and Javal keratometer also showed a very strong correlation of corneal power between devices.[7]

A study of toric lens implantation based manual keratometry data or dual-zone autokeratometry from the Lenstar LS 900 biometer reported no significant difference between manual and autokeratometry.[2] Other studies have reported that the results of manual and autokeratometry are comparable.[2]

The results of our study indicated that Pentacam, placido disk based corneal topography, and Javal keratometry present different measurements of corneal power. This difference should be considered when the measurement of central corneal power is clinically important, such as for IOL power calculation, toric IOL power calculation and contact lens fitting. Changes in the cornea due to refractive surgery, keratoconus, orthokeratology, or other surgery or pathology may result in even more differences between these devices. A study[12] compared the manual keratometry values with SimK readings of two topographers (Dicon and Atlas) before using the Ortho K lens and 1 month after beginning lens use; although there were no significant differences in the corneal power between the steep and flat meridians of the cornea before using the lens, significant statistical and clinical differences were observed between keratometry and topography 1 month after using the Ortho K lens.

Razmju *et al*.[11] noted a significant difference between the IOL Master and Javal keratometer (Gm 300, CSO, Milano, Italy) after PRK although there was no significant differences before PRK and the measurements for both devices had a strong correlation.

A limitation of our study was that did no access to the Lenstar, as a very important device, for autokeratometry. Additionally, if there were a lack of data for SimK for the Pentacam, hence we could not compare it to the Javal keratometer.

We suggest that these devices should be compared in corneas with high corneal cylinder, abnormal corneas, or postrefractive surgery corneas, to determine whether their readings are interchangeable in cases such as contact lens fitness.

Other limitations of this study include not performing this study in the normal population and healthy participants. Additionally, the lack of randomization is another limitation.

CONCLUSION

Although the correlation of Pentacam, TMS4-topography, IOL Master, and Javal keratometer in measuring keratometry was high, only the IOL Master showed no significant differences with Javal keratometry values. The IOL Master had the best agreement.

Footnotes

Source of Support: This Project is Funded in Part by the Noor Ophthalmology Research Center

Conflict of Interest: None declared.

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Figures and Tables

Table 1

	Javal-Schiotz keratometer	TMS4-topographer	Pentacam	IOL Master
Pearson correlation	0.979	0.975	0.958	0.982

IOL: Intraocular lens, TMS: Topographic modeling system

Correlation between keratometry of the right and left eyes measured by four devices

Table 2

	Mean	SD	Minimum	Maximum
Javal-Schiotz keratometer	44.30	1.59	40.63	48.10
TMS4-topographer	44.25	1.64	40.69	48.83
Pentacam	43.68	1.44	40.30	46.50
IOL Master	44.31	1.61	40.79	48.08

SD: Standard deviation, IOL: Intraocular lens, TMS: Topographic modeling system

Mean and SD of keratometry by IOL Master, Javal keratometer, topography, and Pentacam

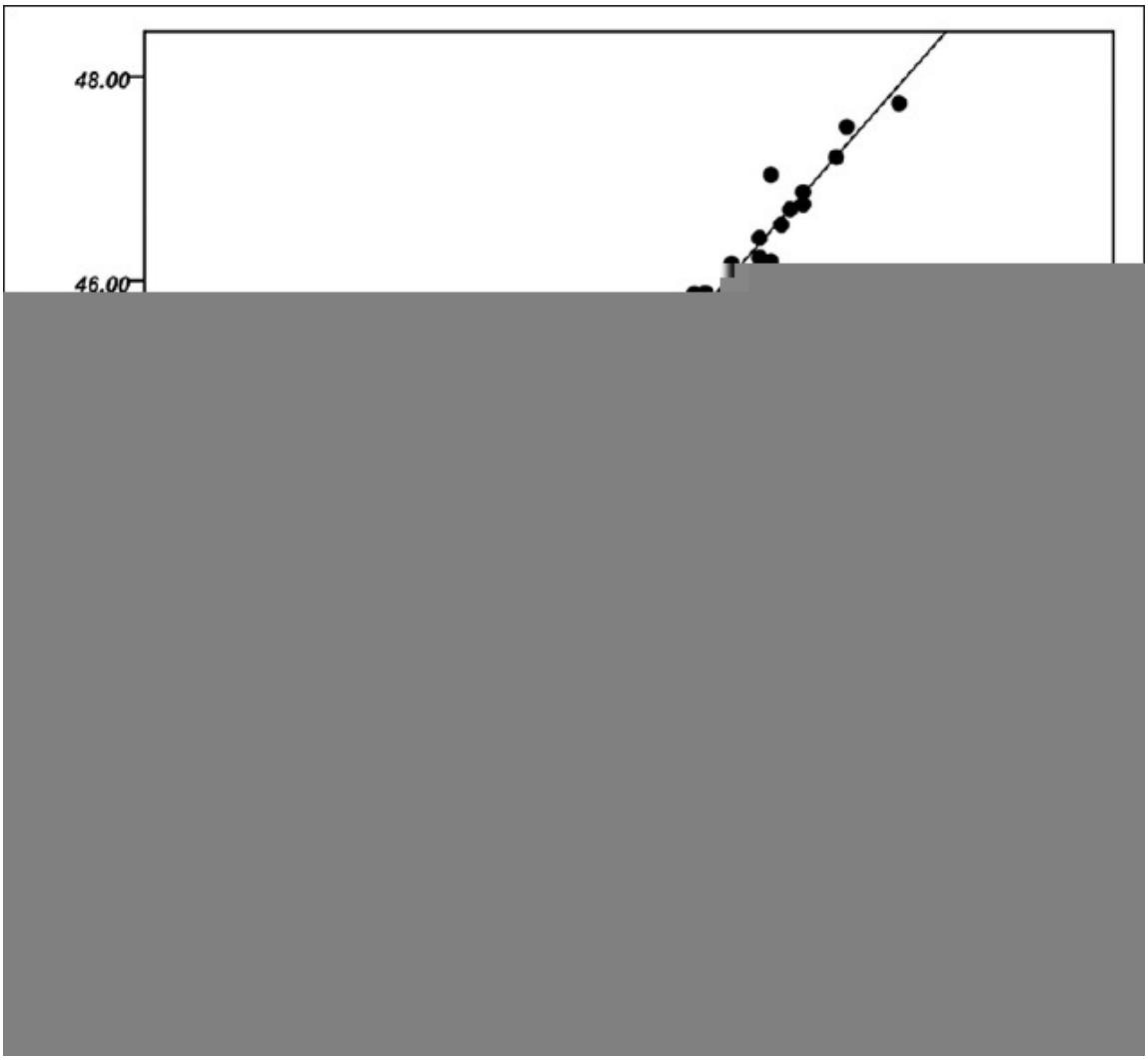
Table 3

	Paired differences±SD (95% CI)	*P*
Javal-Schiotz keratometer and TMS4-topographer	0.07±0.22 (0.017–0.12)	0.010
Javal-Schiotz keratometer and Pentacam	0.57±0.29 (0.49–0.64)	<0.001
Javal-Schiotz keratometer and IOL Master	0.001±0.18 (−0.042 to 0.044)	0.965

P<0.05 was considered statistically significant. SD: Standard deviation, CI: Confidence intervals, IOL: Intraocular lens, TMS: Topographic modeling system

Paired differences between Javal-Schiotz keratometer, TMS4-topographer, Pentacam, and IOL Master

Figure 1

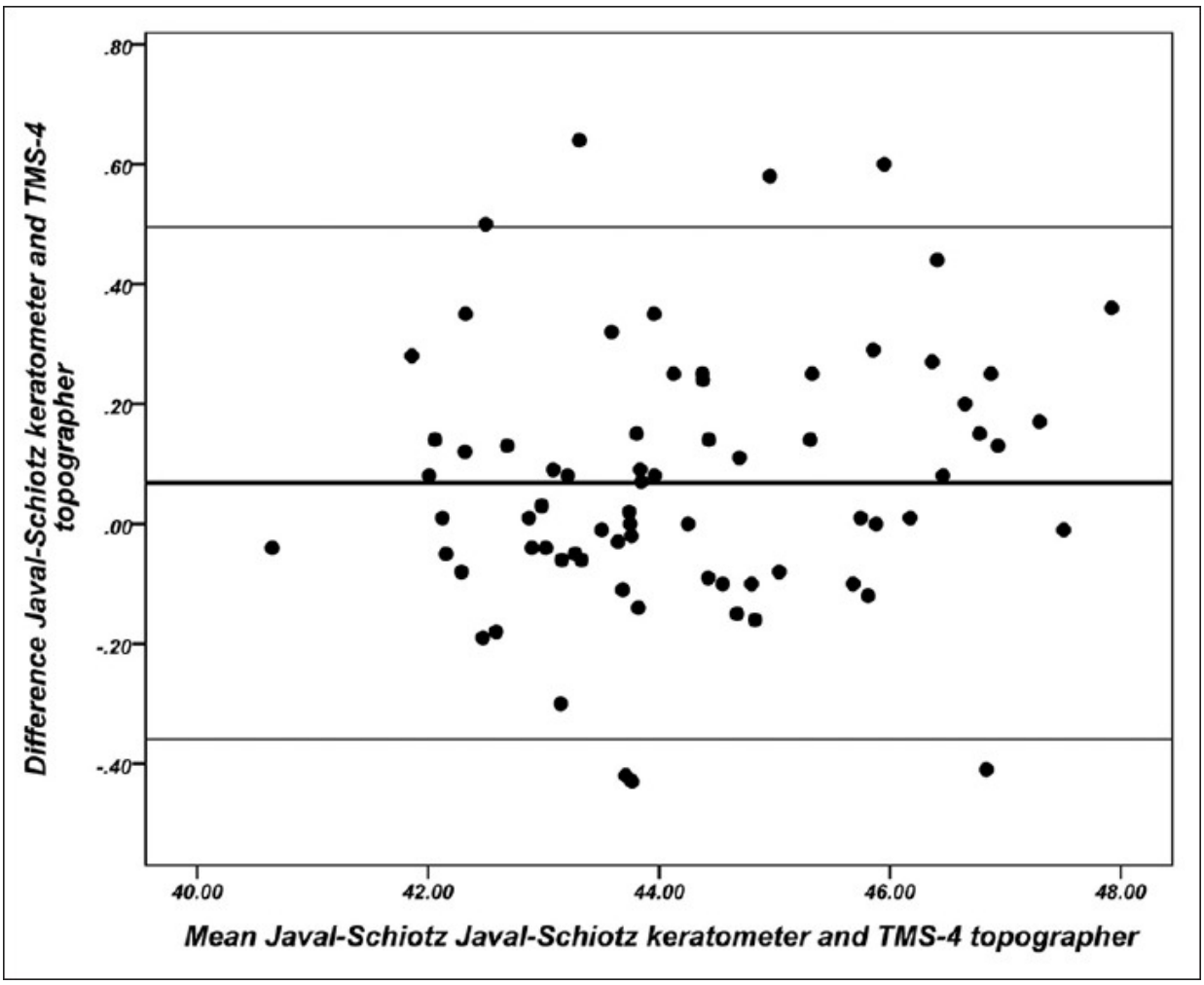


Correlation between Javal-Schiotz keratometer and TMS4-topographer measurements of corneal power (diopters)

Table 4

Correlation of keratometry with four devices

Figure 2

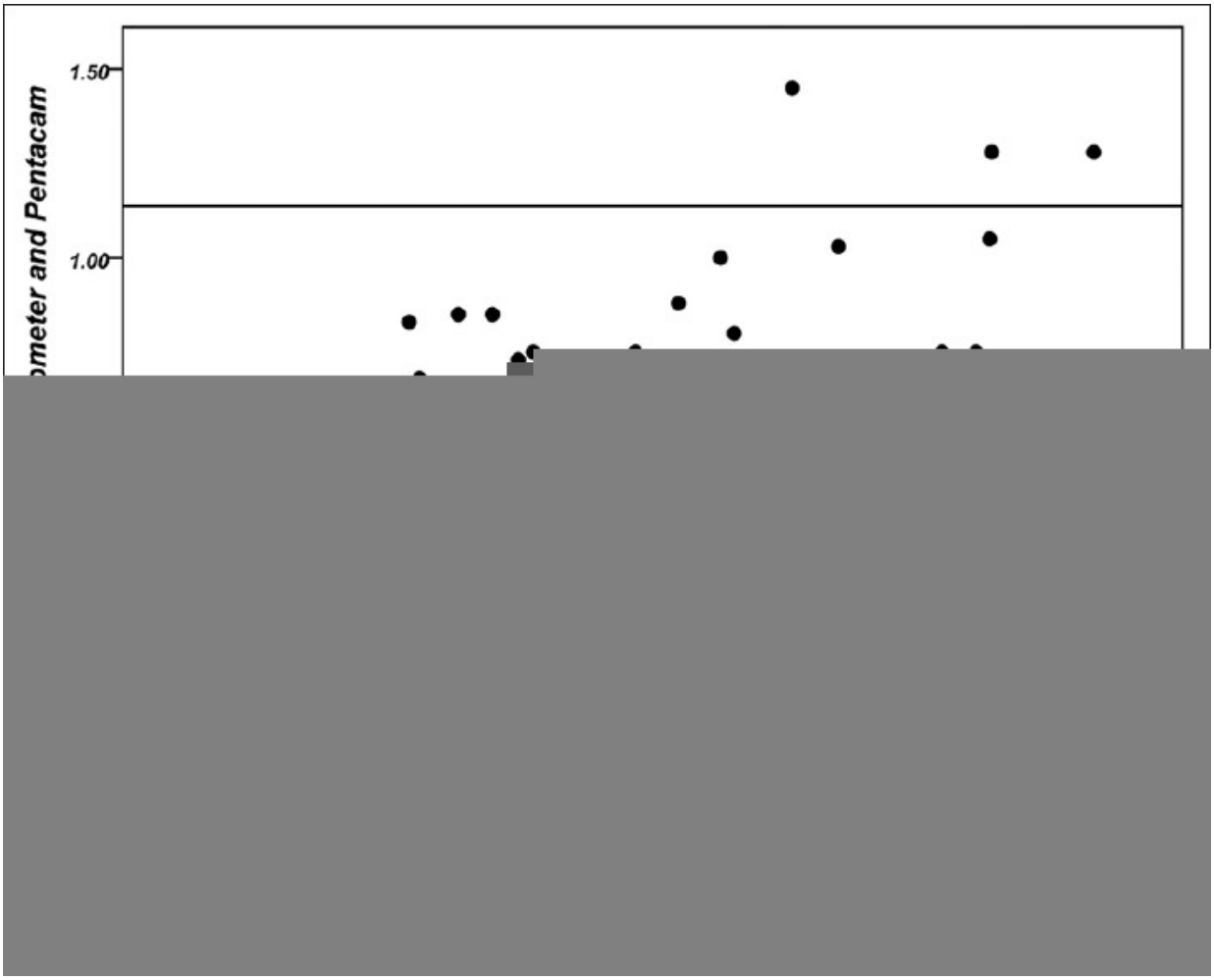


Bland-Altman plots demonstrating 95% limits of agreement between Javal-Schiotz keratometer and TMS4-topographer in measuring corneal power (diopter)

Figure 3

Correlation between Javal-Schiotz keratometer and Pentacam measurements of corneal power (diopters)

Figure 4



Bland-Altman plots demonstrating 95% limits of agreement between Javal-Schiotz keratometer and Pentacam in measuring corneal power (diopters)

Figure 5

Correlation between Javal-Schiotz keratometer and IOL master measurements of corneal power (diopters)

Figure 6

Bland-Altman plots demonstrating 95% limits of agreement between Javal-Schiotz keratometer and IOL master in measuring corneal power (diopters)