Original article

Comparison of the corneal curvatures obtained from three different keratometers

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Abstract

Introduction: Keratometry forms an important component of the biometry for a calculation of the intraocular lens power and selecting a contact lens' parameters. **Objective:** To investigate the agreement between three different keratometers commonly used in an ophthalmology clinic. **Materials and methods**: In this prospective study, keratometry was performed using an IOL Master (IM), a manual keratometer (Man) and a autokeratometer (Top) in twenty five eyes of thirteen volunteer subjects. The average keratometry values and corneal astigmatism (J_{180} and J_{45} components) were computed and compared. The agreements between the instruments were analysed using the Bland Altman statistical method. The main outcome measures are average keratometry values and corneal astigmatism. **Results**: The mean of average keratometry values obtained from the IOL Master, manual keratometry and autokeratometry were 44.388 ± 1.430, 44.297 ± 1.425 and 44.220 ± 1.497 D, respectively. The mean difference in the average keratometry between the instruments were 0.31 ± 0.09 for IM and Man (p = 0.012), 0.14 ± 0.17 for IM and Top (p = < 0.001) and 0.29 ± 0.77 for Man and Top (p = 0.26). The mean differences in the J_{180} component of astigmatism were: 0.02 ± 0.11 for IM and Man, 0.02 ± 0.09 for IM and Top, and - 0.01 ± 0.11 for Man and Top. Similarly, for the J_{45} component, the mean differences were 0.02 ± 0.12 for IM and Man, 0.01 ± 0.13 for IM and Top and - 0.02 ± 0.10 for Man and Top. **Conclusion**: Average keratometry values obtained from different instruments vary significantly. The IOL Master consistently over-estimated the corneal power compared to the manual and the autokeratometer. All three instruments provided similar estimation of the corneal astigmatism.

Key- words: keratometer, keratometry, corneal astigmatism, cataract surgery

Introduction

A primitive form of the keratometer was invented approximately 250 years ago with an initial aim to investigate a change in corneal curvature during accommodation (Gutmark and Guyton, 2010). Since then the instrument has evolved with several modifications and improvements in its design and working principle. However, measuring the size of Purkinje image of a projected object produced from the front surface of the cornea has remained the fundamental basis. Subsequently, purposes of the technique have expanded enormously. Estimation of the corneal power and astigmatism in refractive and cataract surgery and contact lens fitting form the most significant clinical uses of a keratometer. In line with digitization of various objective clinical measurements, a variety of auto-keratometers have been introduced and have rapidly gained a

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widespread popularity among the clinicians and vision scientists. Since conventional keratometers measure central corneal curvature (up to 3.25 mm in diameter), topographical systems are preferred over the manual and autokeratometers for the purpose of the contact lens fitting and corneal refractive surgeries.

Various keratometers are commercially available for clinical use. Manual (e.g. B&L and Javel-Schiotz Keratometer), automated (eg various auto-keratorefractors, IOL Master) and devices for simulated keratometry (eg various corneal topographers) are the most common instruments. Since the working principles of different instruments vary, measurements are likely to differ from one to another. With an increasing trend of toric IOL implantation to correct pre-existing corneal astigmatism, precise determination of the strength and orientation of the corneal astigmatism is essential.

Though modern cataract surgery is a relatively simple procedure with arguably a high success rate, refractive outcome is not always as perfect as a surgeon or a patient would like to have. Existence of significant post-operative residual sphero-cylindrical refractive errors is not uncommon (Ale et al, 2012). Along with several factors (e.g. error in axial length measurement, inappropriate position of the implant, inaccuracy in formula used in calculating IOL and surgically-induced refractive changes (Norrby, 2008), inaccurate estimation of corneal power is one of the major sources of error (Olsen, 1986). Therefore, an accurate measurement of the corneal power is as important as the entire cataract surgical procedure.

Accuracy of various keratometers has widely been investigated and the results are equivocal. Many studies have demonstrated that commonly used instruments are equally reliable for clinical use (Manning and Kloess, 1997; Rosa et al, 2004; Shirayama et al, 2009; Symes and Ursell, 2011; Tennan et al, 1995, Vogel and Dick, 2001), whereas others found that the values are not interchangeable (Elbaz et al, 2007). For instance, an IOL master gives steeper corneal power than other forms of keratometers (Elbaz et al, 2007; Huynn, 2006).

In this study, we sought to investigate if commonly used three types of keratometers produce clinically interchangeable measurements. The instruments compared in the current study included a manual keratometer (Bausch & Lomb), Topcon RK-7100 auto-keratorefractor (Topcon Inc, Japan) and IOL Master 500 (Zeiss Meditec).

Materials and methods

The study followed the tenets of the Declaration of Helsinki. After obtaining informed consent, thirteen healthy volunteers were prospectively recruited at Peninsula Eye Hospital, Redcliffe, Queesnland, Australia. Keratometry using the aforementioned three devices was performed in 26 normal eyes. A brief description of working principles of the instruments tested in this study is as follows.

The IOL master (Zeiss Meditec) is a conventional automated keratometry device that projects six spots of light in a hexagonal array and analyses the reflection off the front corneal surface to finally determine the corneal curvature. It measures the curvature at 2.3 to 2.5 mm diameter (depending on the corneal curvature) from the corneal apex. This is one of the most popular keratometers among the ophthalmic practitioners in Australia. The Bausch & Lomb keratometer (Bausch & Lomb, Rochester) is a one-position manual keratometer which is capable of measuring two meridians simultaneously. The instrument uses the principle of fixed object and variable image. It employs an image doubling by means of axially movable horizontal and vertical prisms. A four-aperture Scheiner disc improves focusing accuracy and easier adjustment of distance. Topcon auto-keratometer projects a ring through an annular collimating lens onto a 3 mm diameter central region of the cornea. Another image of the mire reflection is projected onto a photodetector system. From the light distribution on the photodetector, a built-in computer calculates the corneal radii. All these instruments use a standard refractive index of 1.3375.

In this study, keratometry values were obtained in dioptres, directly from the instruments. Corneal powers of the two principal meridians were averaged for analysis. Keratometric astigmatism was represented into the absolute form (plus cylinders) and transformed into rectangular coordinate system J_{180} and J_{45} which elegantly allows the simultaneous analysis of the strength and orientation (axis) of astigmatism (Thibos and Horner, 2001).

Statistics: Multiple comparisons of the corneal powers obtained from different devices were performed using paired *t*-test. A *p*-value less than 0.05 were considered statistically significant. Agreement between the devices was tested using Bland Altman analysis (Bland and Altman, 1986).

Results

Among the total, four subjects were males and nine females. The mean (SD) age of all the subjects was 32 ± 4.61 years. Out of the 26 sample eyes, an eye (amblyopic) was excluded from the study as it produced unreliable measurement due to poor fixation.

Table 1: Mean (SD) of average corneal power as measured by different devices.

Device	N	Mean K ± SD	SE Mean
IM	25	44.39 ± 1.43	0.29
Man	25	44.30 ± 1.43	0.29
Top	25	44.22 ± 1.50	0.30

N – sample size, SD – standard deviation, SE – standard error. IM – IOL Master, Man - Manual, Top – Topcon.

The means of keratometry values were 44.388 ± 1.430, 44.297 ± 1.425 and 44.220 ± 1.497 D as measured by IOL Master, Manual keratometer and autokeratometer, respectively (Table 1). The IOL Master showed slightly steeper corneal curvatures compared to other two methods whereas the autokeratometer yielded the lowest average keratometry values.

Table 2: Mean, standard deviation (SD), 95% confidence interval (CI) and p-values of differences between the keratometry values obtained from the three instruments

Difference between*	Mean ± SD of difference	95% CI of difference	*p*
IM – Man	0.09 ± 0.21	0.028 to 0.204	0.012
IM – Top	0.17 ± 0.14	0.111 to 0.225	<0.001
Man – Top	0.08 ± 0.24	-0.044 to 0.152	0.260

*IM – IOL Master, Man - Manual, Top – Topcon

Statistically significant differences in the mean of the average between IM and Man (p=0.012), and IM and Top (p=<0.001) were observed. There was no statistical difference between the mean of differences obtained from the Man and the Top (p=0.26). The difference was highest between IOL Master and autokeratometer (Table 2).

Table 3: J_{180} and J_{45} components of the corneal astigmatism measured by different keratometers (n = 25)

Method	J_{180}		J_{45}	
	Mean ± SD	SE	Mean ± SD	SE
IOL Master	0.24 ± 0.34	0.07	0.31 ± 0.52	0.10
Manual	0.25 ± 0.46	0.09	0.28 ± 0.30	0.06
Topcon	0.26 ± 0.30	0.06	0.30 ± 0.43	0.09

Absolute keratometric astigmatism is given in Figure 1. Table 3 shows the mean (SD) of J_{180} and J_{45} components of the corneal astigmatism. The mean differences in these astigmatic components between the instruments can be seen in Table 4. Statistically, all instruments produced identical astigmatic errors.

Table 4: Differences in mean, standard deviation (SD), 95% confidence interval (CI) and p-values of J_{180} and J_{45} components (n = 25). IM – IOL Master, Man - Manual, Top – Topcon.

Methods	J_{180}			J_{45}		
	Mean diff ± SD	95% CI	*p*	Mean diff. ± SD	95% CI	*p*
IM-Man	-0.02 ± 0.11	-0.24-0.21	0.89	0.02 ± 0.12	-0.21-0.26	0.84
IM-Top	-0.02 ± 0.09	-0.20-0.16	0.82	0.01 ± 0.13	-0.26-0.28	0.95
Man-Top	-0.01 ± 0.11	-0.22-0.21	0.97	-0.02 ± 0.10	-0.22-0.19	0.88

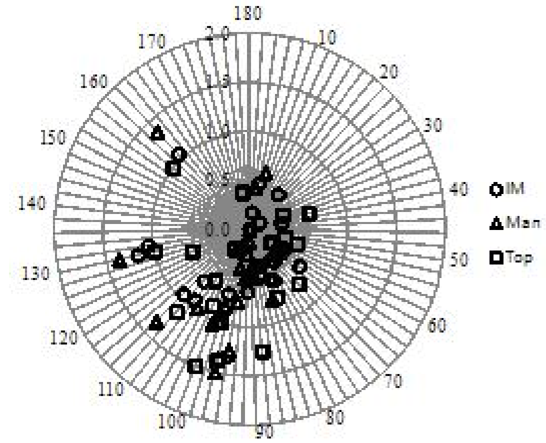
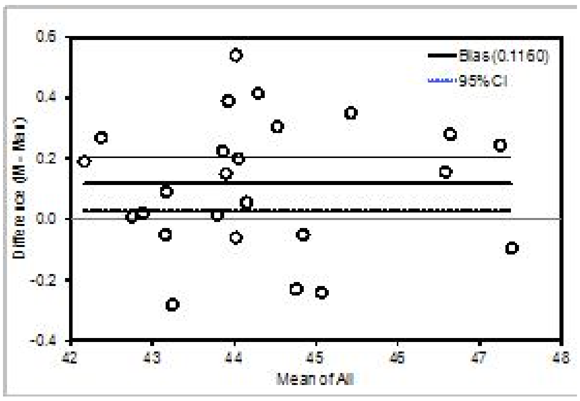


Figure 1: Absolute astigmatism obtained from three keratometry methods: IM – IOL Master, Man – manual keratometer and Top - Topcon



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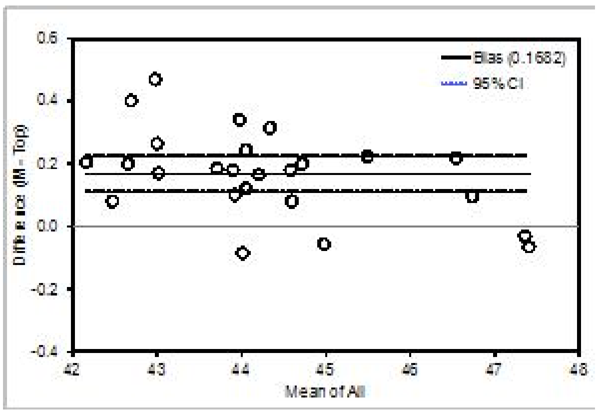

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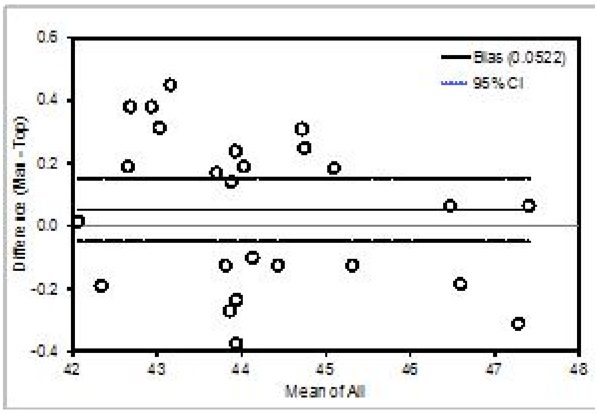
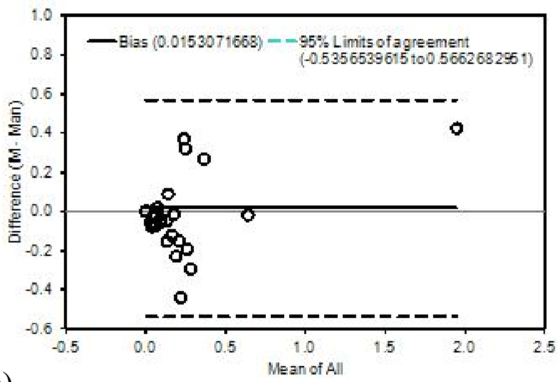


c)

Figure 2: Bland Altman mean difference plot for agreement between a) IM – Man i.e. IOLMaster minus Manual; b) IM – Top i.e. IOLMaster minus Topcon and c) Man – Top i.e. Manual minus Topcon keratometry for average keratometry values.



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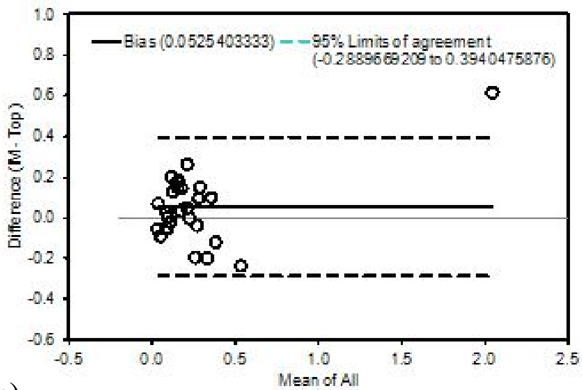

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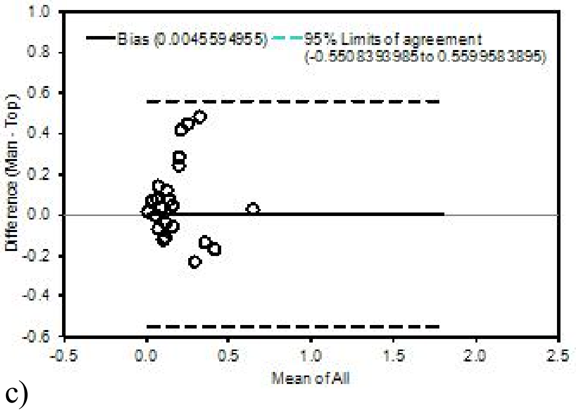
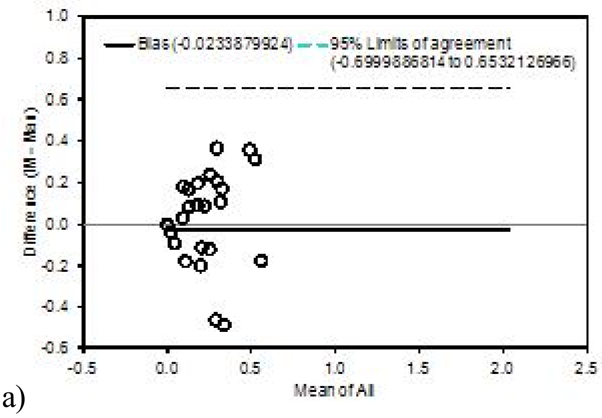


c)

Figure 4: Bland Altman mean difference plot for agreement between a) IM – Man i.e. IOLMaster minus Manual; b) IM – Top i.e. IOLMaster minus Topcon and c) Man – Top i.e. Manual minus Topcon keratometry for J_{180} component of the astigmatism



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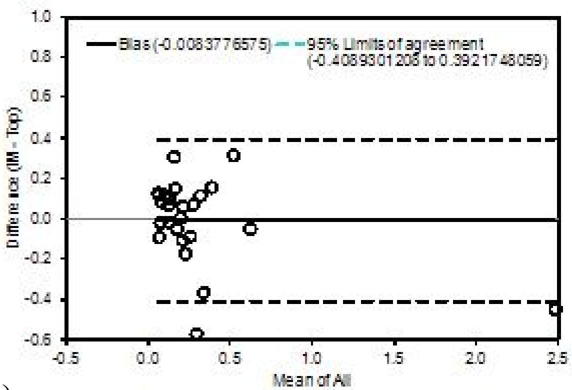

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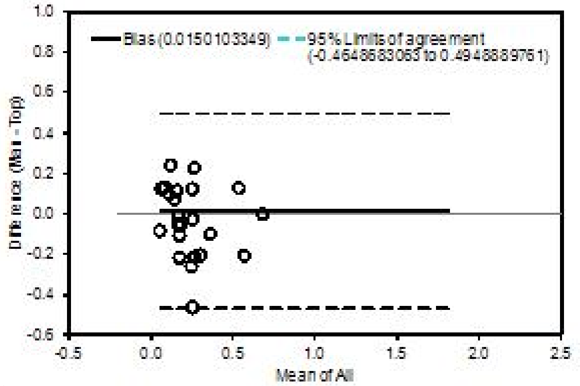

c)

Figure 5: Bland Altman mean difference plot for agreement between a) IM – Man i.e. IOL Master minus Manual; b) IM – Top i.e. IOLMaster minus Topcon and c) Man – Top i.e. Manual minus Topcon keratometry for J_{45} component of the astigmatisma)

Discussion

Amid significant improvement in axial length measurement techniques such as partial coherence interferometry and immersion ultrasound, keratometry remains an important source of error in ocular biometry and IOL power calculation (Olsen, 2007). Accurate measurement of the corneal astigmatism (strength and axis) is extremely important as an error may give rise to improper determination of the toric IOL strength thereby inducing unwanted residual astigmatism. Principally, all keratometers measure the curvature of the pre-corneal tear film. Unstable tear film has been shown to create errors larger than 0.60D (Erdelyi et al, 2006). Hence, a regular and stable tear film is a pre-requisite for accurate measurement.

Several studies have demonstrated high repeatability and accuracy of various keratometers including automated, topographical and manual methods for the purpose of IOL calculations (Shirayama et al, 2009; Symes and Ursell, 2011; Tennan et al, 1995) whereas others questioned the accuracy of each (Elbaz et al, 2007). Using the Bland Altman method (Bland and Altman, 1986) of evaluating inter-device agreement, we compared keratometry data obtained from the three most commonly used instruments in an ophthalmology clinic for the purpose of IOL power calculation. We found statistically significant differences (p = <0.01) between the mean of the average keratometry values measured by IOL Master and manual and IOL master and autokeratometer; the IOL Master produced consistently steeper values by an average of 0.2 D which is smaller than the differences reported previously. Elbaz *et al* (2007) found a difference of 0.42 D. Similarly, Huynh *et al* (2006), in their six-year old subjects, reported a difference of 0.29 D between the IOL master and to RK-F1 (Canon Inc, Japan) autokeratometer. Interestingly, the difference in the mean of average keratometry values between the manual and autokeratometry (0.08D) was statistically insignificant (p = 0.26) in the current study.

Estimation of the corneal astigmatism is one of the most important components of cataract surgery. Calculation of the cylindrical power of a toric IOL and orientation of the implant axis is solely dependent on the keratometry. In the current study, all three instruments agreed well in estimating the corneal astigmatism (Fig 2 and 3). Mean of the difference in corneal astigmatism did not exceed 0.02D for any pair of comparisons made which is clinically as well as statistically insignificant.

Though the sample size in this study is relatively small, our results are consistent with the previous reports; a study with a larger sample would verify the findings. Based in the results of the current and prior studies, a pertinent question that arises in relation to keratometry is whether inter-instrument difference is clinically significant. Roughly, every 0.25 D defocus clinically declines the Snellen's acuity by a line, which indicates that the inter-device differences in keratometry may potentially compromise the postoperative visual result.

Conclusion

We conclude that the average keratometry values obtained by the three instruments tested are not interchangeable. However, all three instruments provided similar estimation of the corneal astigmatism.

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