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RESEARCH ARTICLE

Corneal Curvature Measurements Utilizing a New Swept-source Optical Coherence Tomography Tomey OA-2000® and Comparison With IOL Master® 500 in Pterygium Patients

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ABSTRACT

Introduction: *Corneal curvature (CC) is an important anterior segment parameter. This study compared CC measurements conducted with two optical devices in pterygium eyes.*

Methods: *Sixty pterygium eyes of 30 patients were enrolled in this study. CC was measured three times with the optical biometer and topography-keratometer Tomey OA-2000 (Tomey Corporation, Nagoya, Japan), then with partial optical coherence interferometry (PCI) IOL Master 500 (Carl Zeiss Meditec, Dublin, CA) and data were statistically analysed.*

Results: *The measurements revealed in a mean CC of 43.86 ± 1.57 D with Tomey OA-2000 and 43.84 ± 1.55 D with IOL Master. Distribution of data is normal, and no significance difference in CC values was detected (P = 0.952) between the two devices. Correlation between CC measurements was highly significant (r = 0. 99; P < 0.0001). The mean difference of CC values between devices was 0.017 D and 95% limit of agreement was -0.088 to 0.12. Duration taken for measurements with the standard biometer IOL Master was longer (55.17 ± 2.24 seconds) than with Tomey OA-2000 (39.88 ± 2.38 seconds) in automatic mode. Duration of manual measurement with Tomey OA-2000 in manual mode was shorter (28.57 ± 2.71 seconds).*

Conclusion: *In pterygium eyes, CC measured with Tomey OA-2000 and IOL Master showed similar values, and high correlation was observed between these two devices. This shows that both devices can be used interchangeably. Tomey OA-2000 is better in terms of faster to operate and has its own topography systems.*

Keywords: *Pterygium; Corneal Curvature; IOL Master 500; Tomey OA-2000; Corneal Topography*

INTRODUCTION

Measurements of anterior segment parameter such as corneal curvature are clinically important especially for contact lens fitting, cataract surgery and other refractive surgery (Kim et al., 2015; Savini et al., 2016; Wang et al., 2017) (Kim et al, 2015; Savini et al, 2016; Wang et al, 2017). Moreover, the configuration of the corneal curvature has a well-known role in refractive errors and corneal abnormalities such as keratoconus and pellucid marginal degeneration (PMD). Our aim was to compare and analysed CC values and testing duration measured with the gold standard optical biometer, IOL Master (Carl Zeiss Meditec, Dublin, CA, USA) and swept-source optical coherence tomography (SS-OCT) Tomey OA-2000 (Tomey Corporation, Nagoya, Japan) in pterygium patients.

MATERIALS AND METHODS

This study comprised sixty (60) pterygium eyes of 60 patients who came to tertiary ophthalmic centre in East Coast of Malaysia. CC measurements with Tomey OA-2000 and IOL Master were taken by a single observer. All measurements were performed with pupil not dilated pupil. The following served as exclusion criteria: any anterior eye segment pathology found during slit-lamp examination, dilated pupil and any history of previous corneal and/or intraocular surgery. The study was performed in compliance with Declaration of Helsinki and approved by the university research committee (IIUM/310/G13/4/4-125).

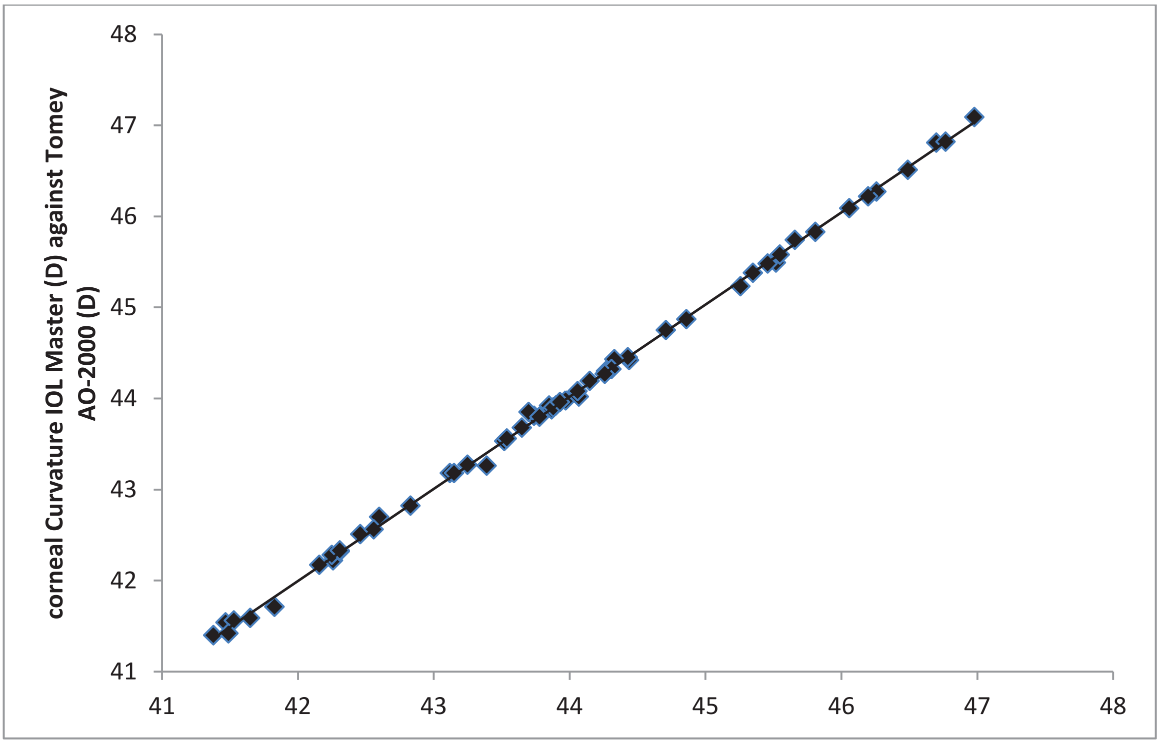

Figure 1. Corneal curvature (CC) values measured with Tomey AO-2000 (Tomey Corporation, Nagoya, Japan) (x axis) and with IOL Master (Carl Zeiss Meditec, Dublin, CA, USA) (y axis). Significant correlation was observed (Pearson's r = 0.99; P < .0001).

First, the central CC was measured three times on each eye using a new optical biometer, Tomey OA-2000 based on SS-OCT. External corneal measurement was set as the device's CC adjustments, means corneal curvature was defined as within 2.5 mm central cornea. The external CC was determined automatically by the built-in image analysis software. Subsequently, automatic partial optical interferometry IOL Master (Version 5.4, Carl Zeiss Meditec, Dublin, CA, USA) measurements were taken three times. The mean of three values of Tomey OA-2000 and IOL Master data were used for statistical analysis. The duration of patient data entry and of the actual measurement process to printout were calculated.

Statistical analysis was performed using MedCalc for Windows statistical software (Version 17.2, MedCalc Software, Mariakerke, Belgium). Data were described as mean ± standard deviation (SD), range and 95% confidence interval (CI) for the mean. The normality of continuous variables was determined with the Kolmogorov-Smirnov test. The variables showed normal distribution (P = 0.200 for CC measured with Tomey OA-2000 and for IOL Master, P = 0.200). Differences in values between groups were obtained using independent 2 sample t-test and a P value of 0.05 was considered as the level of significance. The association between groups was described by Pearson's correlation of rho (r). Bland-Altman plots were created to estimate the agreement between the tested methods and 95% limits of agreement was calculated as the mean ± 1.95 SD of the difference. The difference in duration time wasereas measured in seconds.

RESULTS

The mean age of patients was 26.63 ± 2.46 years (range: 22 to 33 years; 95% CI: 26.00 to 27.27). The mean of CC measured was 43.86 ± 1.57 D (range: 41.40 to 47.09 D; 95% CI: 43.45 to 44.24 D) with Tomey OA-2000 and 43.84 ± 1.55 D (range: 41.38 to 46.98 D; 95% CI: 43.44 to 44.24 D) with IOL Master. Difference in values of CC was not significant (P = 0.952) between the two devices, and significant correlation was observed between the two devices (r = 0.99; P < 0.0001) (Figure 1).

The mean difference of CC values between devices was 0.017 D and 95% limit of agreement was -0.088 to 0.12 (Figure 2). Duration taken for measurements with the gold standard biometer IOL Master was longer (55.17 ± 2.24 seconds) than with Tomey OA-2000 (39.88 ± 2.38 seconds) in automatic mode. Duration of manual measurement with Tomey OA-2000 in manual mode was the shortest (28.57 ± 2.71 seconds).

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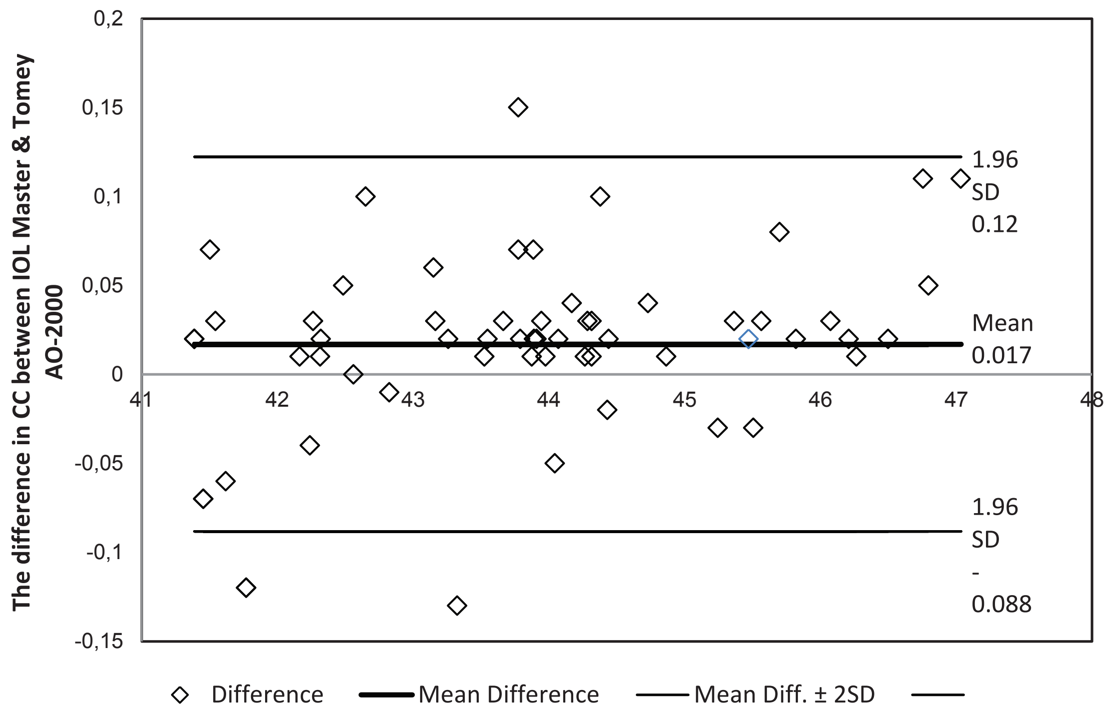

Figure 2. Bland-Altman plots of the difference in corneal curvature (CC) values between IOL Master (Carl Zeiss Meditec, Dublin, CA, USA) and Tomey AO-2000 (Tomey Corporation, Nagoya, Japan) against their mean. Mean difference of CC values between devices was 0.017 D and 95% limits of agreement was -0.088 to 0.12. SD = standard deviation

DISCUSSION

Accurate measurement of anterior segment structure is important for diagnosing and intervene diverse ocular pathologies such as cataract, glaucoma, post-operative control, and refractive surgery such as laser in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) (Khairat et al., 2013)(.Khairat et al, 2013). The values of corneal power, corneal astigmatism, anterior chamber depth (ACD) and corneal thickness are important in calculating intraocular lens (IOL) in cataract patients (Wang et al., 2017)(Wang et al, 2017). Errors in the measurement of these parameters prior to surgery might result in post-surgical refractive error. Hence, reducing these errors will ensure the success of the refractive surgery (McAlinden and Moore, 2010; Mcalinden, 2012). (McAlinden and Moore, 2010; McAlinden, 2012).

Manual keratometer is considered as the gold standard method for keratometric measurements in normal eyes. However, it has its own limitation. They assume the corneal curvature in normal is spherical (Tennen, Keates and Montoya, 1995; Holzer, Mamusa and Auffarth, 2009; Jafarzadehpur et al., 2015)(Tennen, Keates and Montoya, 1995; Holzer, Mamusa and Auffarth, 2009; Dehnavi et al, 2015) and these devices cannot determine the refractive power of the posterior corneal surface11. However, as technology advances, new imaging techniques have been developed.

In recent years, techniques on assessing anterior segment have rapidly evolved, with new devices based on Scheimpflug imaging such as Pentacam HR (Hashemi and Mehravaran, 2007, 2010)(Hashemi and Mehravaran, 2007; Hashemi and Mehravaran, 2010) and Galilei Dual Scheimpflug Analyzer (GDSA)(Ziemer Group, Port, Switzerland) or rapid anterior segment ocular coherence tomography (AS-OCT) such as Visante (Carl Zeiss Meditec, Dublin, CA, USA) combined with previously established biometry methods including slit scanning Orbscan (Bausch and Lomb Inc., Rochester, NY, USA), partial coherence interferometry (PCI) IOL Master (Carl Zeiss Meditec, Dublin, CA, USA) and very high frequency ultrasound Artemis (Ultralink, LLC, St. Petersburg, FL,USA). These devices provide tremendous information regarding the corneal curvature and other anterior segment structure such as ACD with an advantage of being non-contact and user-friendly ((Twa, M.D., Coral-Ghanem, C. & Barth, 2003; Barkana et al., 2005; Huynh, Son C.; Mai, Tung Q.; Kifley, Annette; Wang, Jie Jin; Rose, Kathryn A.; Mitchell, 2006; Shirayama et al., 2009; Bandyopadhyay et al., 2010; Sheppard and Davies, 2010; Nakakura et al., 2012; Bueno-Gimeno et al., 2013)Twa, Coral-

Table 1. Comparison of CC Measurements With IOLMaster and Other Ocular Biometry in the Literature

Authors	Device 1	Device 2	Differences in CC (D)	*LoA	*r*	*P*-value
Elbaz et al	Pentacam	IOLMaster	- 0.471	2.01		< 0.01
Whang et al	Manual Keratometer	IOLMaster	- 0.160	1.80		0.007
Whang et al	Pentacam	IOLMaster	- 0.07	2.26		0.156
Mehravaran et al	Javal	IOLMaster	- 0.18	0.96	0.988	
Mehravaran et al	Topcon	IOLMaster	- 0.03	0.58	0.994	
Mehravaran et al	IOLMaster	EyeSys	0.45	0.47	0.968	
Mehravaran et al	IOLMaster	Pentacam	0.35	0.71	0.992	

*LoA: Limits of Agreement
r: correlation

Ghanem and Barth, 2003; Barkana et al, 2005; Huynh et al, 2006; Shirayama et al, 2009; Sheppard and Davies, 2010; Salouti et al, 2010; Bandyopadhyay et al, 2010; Nakakura et al, 2012; Bueno-Gimeno et al, 2013).

The aim of this study was iswas to compare CC measurements with Tomey OA-2000 compared to widely used gold standard IOL Master. To the best of our knowledge, this is the first study to measure and compare CC measurements between these two devices in pterygium patients. IOL Master has been regarded as the gold standard in anterior segment measurement (Rosa et al., 2006; Norrby, 2008; Holzer, Mamusa and Auffarth, 2009; Chen, Hirnschall and Findl, 2011; Nakakura et al., 2012; Huang et al., 2017)(Rosa et al, 2006; Norrby, 2008; Holzer, Mamusa and Auffarth, 2009; Chen, Hirnschall and Findl, 2011; Nakakura et al, 2012; Huang et al, 2017) and in measurement of CC as illustrated in Table 1. This study shows that CC measurement with Tomey OA-2000 is slightly overestimate compared to IOL Master 500, although it was not statistically significant (P = 0.952). The difference could happen due to the nature of pterygium itself which directly affecting the anterior corneal curvature as the pterygium irregular surface would induce unwanted excess of corneal astigmatism.

However, it should be noted that IOLMaster use 6 light spots in 2.5 (Rosa, 2011)mm (Rosa et al, 2011) radius close to the optical axis, while Tomey OA-2000 measures CC using a placido disc-based topography with nine rings, each with 256 points in a 5.5 mm of central cornea. This could explain the reason of differences in measurement of CC. Hence, these results can be interpreted from three (3) perspectives. Firstly, both instruments proved able to measure CC in both normal and disease eye such as pterygium. Secondly, Tomey OA-2000 proved to be quick and reliable in measuring CC in pterygium eye, even though pterygium can easily disturb tears stability (Bandyopadhyay et al., 2010; Ozsutcu et al., 2014)(Ozsutcu et al, 2014; Bandyopadhyay et al, 2010). Lastly, this study proved that measurement of CC can be taken in different classification of pterygium while not affecting its statistical significance.

Moreover, many studies have proven that IOLMaster automated keratometric values are slightly steeper than manual keratometer, automated keratometer and Pentacam (Barkana et al., 2005; Huynh, Son C.; Mai, Tung Q.; Kifley, Annette; Wang, Jie Jin; Rose, Kathryn A.; Mitchell, 2006; Elbaz et al., 2007; Hashemi and Mehravaran, 2007, 2010; Shirayama et al., 2009; Kheirkhah et al., 2012; Khairat et al., 2013; Mehravaran et al., 2014; Wang et al., 2017) .(Barkana et al, 2005; Huynh et al, 2006; Hashemi and Mehravaran, 2007; Elbaz et al, 2007; Shirayama et al, 2009; Hashemi and Mehravaran, 2010; Khairat et al, 2013; Mehravaran et al, 2014; Wang et al, 2017). Variations in measurement of CC between devices were due to coverage area or size of measurement is smaller in IOLMaster (2.5mm) compared to other devices (ranges from 3.5mm to 9 mm). Moreover, due to the fact that corneal curvature are naturally flatter towards the periphery, devices which able to measure wider area would give rise to lower CC measurements due to wider gap between flattest and steepest corneal toricity. The difference between these two devices (IOLMaster vs. Tomey OA-2000) is the latter has its own topography system. Topography system is essential for corneal mapping especially in refractive surgery such as LASIK and corneal surface disorders.

Specifically, preceding studies have reported on measurement of CC in pterygium patient using both placido-disc (Altan-Yaycioglu et al., 2013; Vives, 2013)(Vives et al, 2013; Altan-Yaycioglu et al, 2013) and Scheimpflug-based (Kheirkhah et al., 2012) (Kheirkhah et al, 2012; Kheirkhah et al, 2012) corneal topographic system. Generally, previous works (Kheirkhah et al., 2012; Altan-Yaycioglu et al., 2013; Vives, 2013) (Kheirkhah et al, 2012; Kheirkhah et al, 2012; Vives et al, 2013; Altan-Yaycioglu et al, 2013) reported increase of CC measurement with increasing of size or extension. However, it should be noted that these topographic system were mainly covers approximately 5-5.5 mm of central cornea except for Scheimpflug system which can reach 9-12 mm. In pterygium patients, there is a need for measurement of CC to be measured in separate segments as this signifies its progression. In light with the present study, it is proved that measurement of CC can be taken with optical-based K-reading instrument (Tomey OA-2000) in disease eye as it able to segregate CC profile based on corneal coverage (2, 2.5 and 3 mm). Nonetheless, it would have been better if types of pterygium distribution can be determined based on K-reading gained through topographic image.

With regards to Tomey AO-2000, this present study found that it able to complete a full corneal scan faster than IOLMaster. This could happen due to three (3) reasons. Firstly, difference in the algorithms for edge for corneal detection could lead to delay in IOLMaster and secondly, the dissimilarity of the light source for image acquisition between the devices, which could affect the scanning speed and image quality. Tomey AO-2000 employs swept-source laser which able to scan up to 1000 scans per second while IOLMaster employs infrared as its light source. Lastly, availability of automated search functions in Tomey OA-2000 which automatically detects a measurable point, and it able to perform ten consecutive scans per measurement without the need for realignment. Hence, this could explain of Tomey OA-2000 fast data acquisitions compared to IOLMaster.

This present study only assessed the corneal curvature based on the 2.5 mm radius close to the optical axis between these two devices in patients with pterygium. Due to limited number of pterygium eyes, different results may obtain with bigger samples with considerations of the extension of pterygium and also it's other morphology. It is recommended that more parameters with various anterior eye pathologies should be evaluated between these two devices.

CONCLUSION

The SS-OCT Tomey OA-2000 and the IOL Master yield comparable data in measurement of CC in pterygium eyes. Data obtained with these two optical devices are interchangeable and the correlation between these two devices is excellent with Tomey OA-2000 has an advantage as being a full stand-alone anterior segment diagnostic instrument and easier to operate compared to IOL Master.

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