

The effect of head tilt on keratometric measurement using the IOLMaster

CY Park¹, JR Do¹, SH Kim¹, C-Y Lim²
and RS Chuck³

CLINICAL STUDY

Abstract

Purpose To investigate the effect of head tilt on keratometric measurement using the IOLMaster.

Methods Twenty-seven right eyes of 27 volunteers were examined using a manual keratometer (MK), automated keratometer (AK), and an IOLMaster. MK and AK measurements were performed in the upright head position, whereas IOLMaster measurements were performed in five different head positions (upright, 5° or 15° clockwise head tilt, and 5° or 15° counter-clockwise head tilt). The repeatability of IOLMaster was compared with MK and AK. The keratometric measurements (mean keratometric power, magnitude of astigmatism, and steep meridian) in different head positions were compared.

Results The IOLMaster showed good repeatability of keratometric measurement comparable to MK or AK. 15° and 5° clockwise head tilt resulted in 12.09 ± 9.51 (mean ± SD) ($P < 0.001$ vs upright) and 5.51 ± 5.97 (mean ± SD) degrees ($P < 0.001$) of clockwise rotation of steep meridian, respectively. 15° and 5° counter-clockwise head tilt resulted in 12.49 ± 7.07 (mean ± SD) ($P < 0.001$) and 6.08 ± 5.09 (mean ± SD) degrees ($P < 0.001$) of counter-clockwise rotation of steep meridian, respectively.

Conclusions The patient's head tilt (5° or 15°, clockwise or counter-clockwise) significantly changed the steep meridian of astigmatism measured using IOLMaster and the steep meridian generally shifted to the direction of head tilt. The importance of maintaining the upright head posture during IOLMaster measurement is demonstrated.

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Keywords: astigmatism; keratometry; head tilt; cyclotorsion; IOLMaster

Introduction

The recent popularity of toric intraocular lenses (IOLs) heightens concerns about the accuracy of preoperative astigmatism measurement. The accuracy of keratometry is very important in planning astigmatism correction.¹ Misalignment of toric IOLs can induce unexpected refractive outcomes after surgery.^{2–4} It is well known that eyes undergo cyclotorsional movement when changing from the sitting to the lying positions.^{5–7} The surgical procedure of astigmatism correction often begins with alignment and axis marking of eyes while sitting at the slit lamp. Various preoperative marking and surgical techniques^{8–10} have been introduced for precise positioning of toric IOLs, and a new intra-operative technology placing an angular scale display within the surgical microscope has recently been introduced to the market (SMI Surgery Guidance, SensorMotoric Instruments, Teltow, Germany). Manual keratometry, automated keratometry, and partial coherence interferometry are the most common instruments being used to measure keratometric values before cataract surgery. All of these instruments emphasize correct upright right head position during the measurement by supplying two marking points to level the right and left lateral canthi. However, a small misalignment is always possible even in experienced hands and head movement during the measurement can contribute further error. Torsional ocular movement usually compensates small head tilts, but not always.

In this study, we intentionally induced head tilts (5° and 15°) in clockwise and counter-clockwise directions during keratometric measurement by partial coherence interferometry, IOLMaster (Carl Zeiss Meditec, Oberkochen, Germany). We compared the

¹Department of Ophthalmology, Dongguk University, Ilsan Hospital, Koyang, South Korea

²Department of Medicine, Graduate School, Dongguk University, Seoul, South Korea

³Department of Ophthalmology and Visual Sciences, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA

Correspondence: CY Park, Department of Ophthalmology, Dongguk University, Ilsan Hospital, 814, Siksadong, Ilsan-dong-gu, Koyang, Kyunggido 410-773, South Korea. Tel: +82 31 961 7395; Fax: +82 31 961 7977. E-mail: oph0112@gmail.com

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obtained keratometric values (steep K, flat K, and the meridian of steep K) between the tilted and upright head positions.

Materials and methods

This study analyzed the measurement of right eyes of 27 volunteers (medical students of Dongguk University). This study followed the tenets of the Declaration of Helsinki and was approved by the institutional review board of Dongguk University, Ilsan Hospital.

Measurement device

Manual keratometry (Ker 200, Rodenstock, Dusseldorf, Germany), automated keratometry (Full Auto Ref-keratometer RK-F1, Canon, Tokyo, Japan), and IOLMaster were used for this study.

Determining head posture and measurement

Measurements began with the manual keratometer (MK). The examinee was instructed to place their chin on the chin rest and appose their forehead to the forehead rest of the MK. Next, the lateral canthi of both eyes were aligned to the instrument's eye level markers. Three points (nose tip, dorsum of the nose, and mid-glabella) were marked with a marking pen. A straight line was drawn on transparent commercial tape (Scotch, 3M, St Paul, MN, USA) and attached to the face between the marked points. After measuring with MK, automated keratometer (AK), and IOLMaster at zero-degree rotation, the examinee was asked to tilt the head. A protractor and thread and pendulum bob attached to the forehead rest were used to determine rotation angle with respect to the marked face midline. IOLMaster measurements were performed at four head tilt positions (5° and 15°, clockwise and counter-clockwise). All measurements with MK, AK, and IOLMaster were performed in triplicate.

Analysis of astigmatism change with head tilt

The magnitude of measured astigmatism was compared in each head position. The meridian of astigmatism was analyzed as follows; if the change of meridian was in the same direction as head tilt, the change of meridian had positive value in degrees; if the change of meridian was in the opposite direction of head tilt, then the change of meridian had negative value in degrees.

Statistical analysis

Statistical analysis was performed using SPSS software (version 20.0, SPSS Inc., Seoul, South Korea). Normality

of data was assessed by the Shapiro–Wilk test. Paired *T* test was used to compare two related samples. *P*-values less than 0.05 were considered to be significant.

To determine the repeatability of measurement by each device, intraclass correlation coefficient (ICC) was calculated for the three repeated measurements. ICC valued greater than 0.90 signify high repeatability.

Results

All 27 subjects (22 male and 5 female) completed the measurement with good compliance. The age of subjects was 26.48 ± 3.24 (mean \pm SD) (range 22–34).

MK, AK, and IOLMaster all showed good repeatability in measurement of keratometric powers (mean keratometric power and magnitude and meridian of corneal astigmatism) (Table 1).

Mean keratometric values measured higher with IOLMaster (43.33 ± 0.91 D, mean \pm SD) than with AK (42.82 ± 0.99 D) ($P < 0.001$). However, mean keratometric values measured with MK (42.89 ± 0.90 D) showed no difference compared with IOLMaster or AK (Table 2). The magnitude of astigmatism measured higher with AK (1.97 ± 1.10 D) than with MK (1.80 ± 1.08 D) ($P = 0.002$) and IOLMaster (1.83 ± 1.05 D) ($P = 0.005$). However, the meridian of astigmatism showed no significant difference between the different measurement instruments.

Head tilt either clockwise or counter-clockwise affected the meridian of astigmatism significantly (Table 2). Head tilt changed the meridian of astigmatism in the same direction of head tilt; 15° and 5° clockwise tilt resulted in $12.09 \pm 9.51^\circ$ (range -15.33 – 24.67) ($P < 0.001$ vs upright) and $5.51 \pm 5.97^\circ$ (-3.66 – 17.67) ($P < 0.001$ vs upright) clockwise rotation of meridian, respectively; 15° and 5° counter-clockwise tilt resulted in $12.49 \pm 7.07^\circ$ (-11.33 – 22.66) ($P < 0.001$ vs upright) and $6.08 \pm 5.09^\circ$ (-5.67 – 18.66) ($P < 0.001$ vs upright) counter-clockwise rotation of astigmatism meridian, respectively (Figures 1 and 2). Personal variation existed as evidenced by some outliers in Figures 1 and 2.

However, the mean keratometric power and magnitude of astigmatism were not affected by head tilt on either clockwise or counter-clockwise direction (Table 2).

Discussion

In this study, MK, AK, and IOLMaster showed overall good repeatability of keratometric measurement (magnitude and meridian). The mean keratometric power was measured higher with IOLMaster than with MK or AK. The astigmatic power was measured higher

Table 1 Astigmatism reproducibility results by manual keratometer, automated keratometer, and IOLMaster

	ICC (95% CI)					
	IOLMaster					
	MK	AK	15 CCW	5 CCW	Upright	15 CW
Km	0.979 (0.961–0.989)	0.987 (0.975–0.993)	0.993 (0.988–0.997)	0.942 (0.892–0.971)	0.999 (0.998–0.999)	0.981 (0.965–0.991)
Astigmatism magnitude	0.998 (0.996–0.999)	0.994 (0.989–0.997)	0.991 (0.982–0.995)	0.979 (0.960–0.989)	0.997 (0.995–0.999)	0.990 (0.981–0.999)
Astigmatism meridian	0.971 (0.946–0.985)	0.892 (0.798–0.946)	0.989 (0.980–0.995)	0.991 (0.984–0.996)	0.982 (0.967–0.991)	0.986 (0.973–0.993)

Abbreviations: AK, automated keratometer; CCW, counter-clockwise; CI, confidence interval; CW, clockwise; ICC, intraclass correlation coefficient; Km, mean keratometric value [(Kflat + Ksteep)/2]; MK, manual keratometer.

Table 2 Measurement data of keratometry by manual keratometer, automated keratometer, and IOLMaster

	IOLMaster					
	MK	AK	15 CCW	5 CCW	Upright	15 CW
Km (diopters) Mean ± SD (range)	42.89 ± 0.90 (41.54–44.67)	42.82 ± 0.99 (41.33–44.96)	43.28 ± 0.93 (41.93–45.27)	43.29 ± 0.88 (41.87–45.11)	43.33 ± 0.91 (41.85–45.14)	43.27 ± 0.89 (41.80–45.29)
Astigmatism magnitude(diopters) Mean ± SD (range)	1.80 ± 1.08 (0.13–5.53)	1.97 ± 1.10 (0.67–6.25)	1.79 ± 1.11 (0.43–5.76)	1.87 ± 1.11 (0.61–5.88)	1.83 ± 1.05 (0.58–5.80)	1.79 ± 1.10 (0.16–5.76)
Astigmatism axis (degrees) Mean ± SD (range)	89.84 ± 21.89 (58.00–130.67)	88.31 ± 8.60 (64.67–111.00)	102.39 ± (15.74 65.67–132.67)	95.80 ± 12.44 (66.33–130.00)	90.31 ± 11.07 (58.00–114.00)	84.23 ± 11.90 (54.67–115.67)

Abbreviations: AK, automated keratometer; CCW, counter-clockwise; CW, clockwise; Km, mean keratometric value [(Kflat + Ksteep)/2]; MK, manual keratometer.

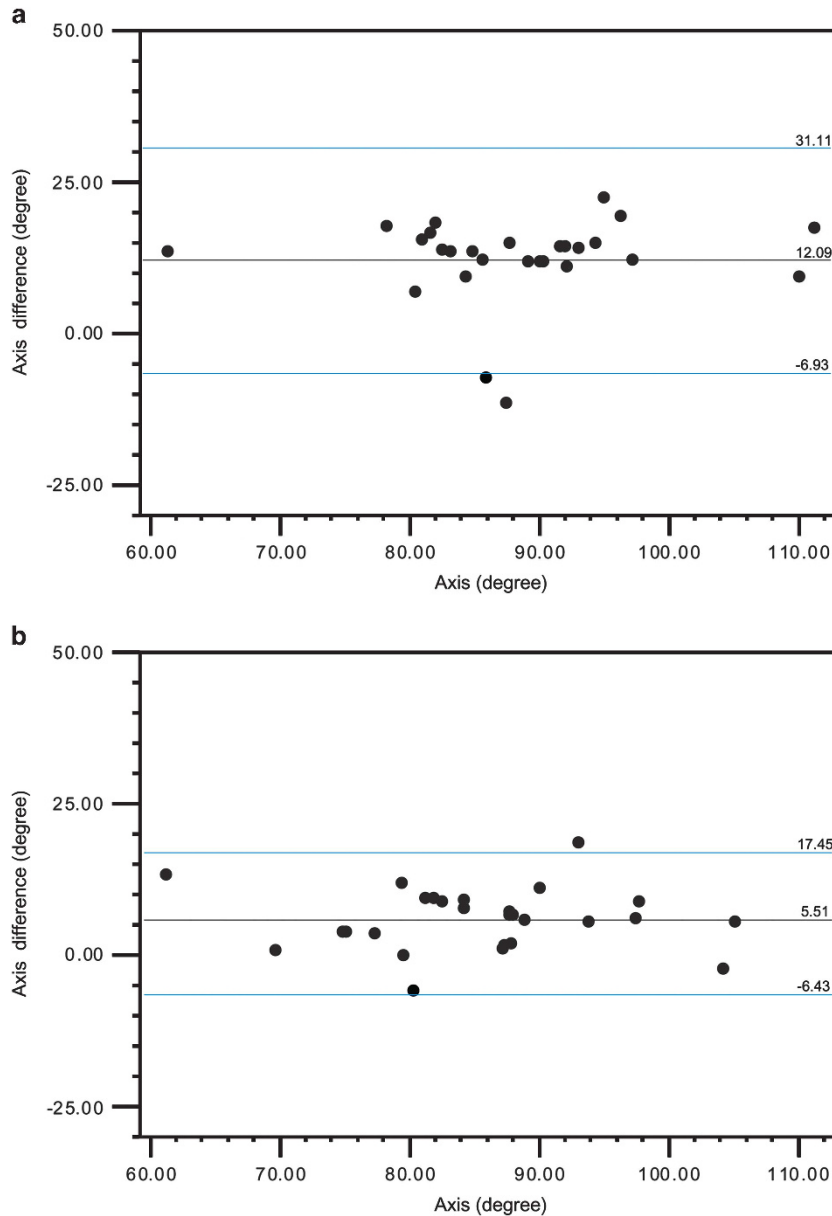


Figure 1 Bland–Altman plots show differences in astigmatism meridian between upright head position and clockwise head tilt. (a) Clockwise head tilt, 15°. (b) Clockwise head tilt, 5°. Mean difference and 95% limit of agreement (mean \pm 2 SD of the difference) are represented by the three horizontal solid lines. If the change of meridian is in the same direction as that of the head tilt, the change of meridian has positive value and vice versa.

with AK than with MK or IOLMaster. However, the meridian of astigmatism was not significantly different between instruments. Head tilt when measuring IOLMaster either in clockwise or counter-clockwise direction resulted in the rotation of astigmatic meridian in the same direction.

The precision in measurement of axial length by partial coherence interferometry technology, integrated automated keratometry function, and ease of operation are stated advantages of IOLMaster for standard

biometry before cataract surgery.^{11–15} The astigmatism measurement (meridian and power) by IOLMaster was not different from measurement using MK in our and others' studies.¹⁶ However, the higher measurement of mean keratometric power with IOLMaster than with AK has previously raised concerns.¹⁷ Therefore, it is always necessary to optimize IOLMaster calculating formulae by reviewing first series of surgical outcomes, because IOL power calculation output by the IOLMaster is based on its measurement.¹⁸

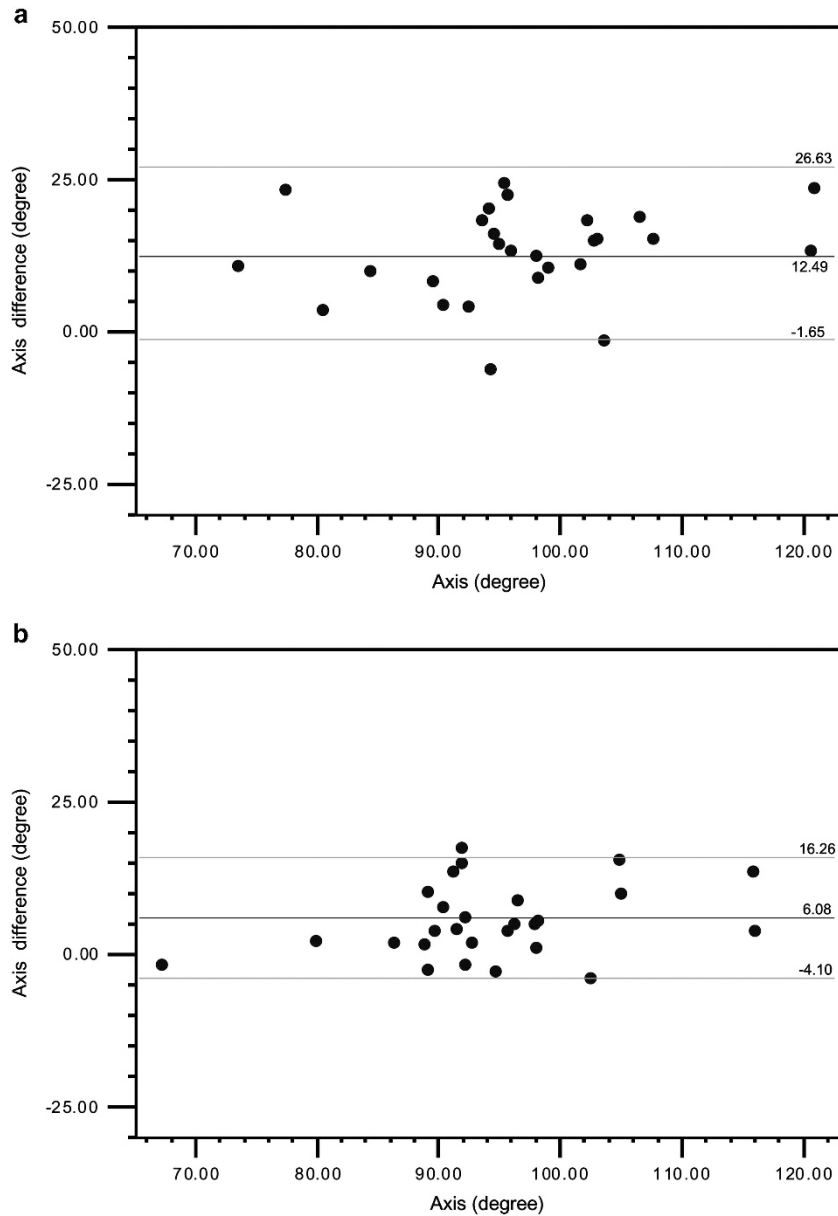


Figure 2 Bland–Altman plots show differences in astigmatism meridian between upright head position and counter-clockwise head tilt. (a) Counter-clockwise head tilt, 15°. (b) Counter-clockwise head tilt, 5°. Mean difference and 95% limit of agreement (mean \pm 2 SD of the difference) are represented by the three horizontal solid lines. If the change of meridian is in the same direction as that of the head tilt, the change of meridian has positive value and vice versa.

It is interesting that head tilt during IOLMaster measurement significantly changed the astigmatic meridian but had little effect in keratometric power (mean and astigmatism). The possible effect of head tilt on keratometric axis measurement is anticipated. However, torsional eye movements may or may not have sufficiently compensated the head tilt. No previous reports about the effect of head tilt on keratometry measurement by IOLMaster have been reported to our

knowledge. Our results indicated that the compensatory effect was insufficient and this resulted in significant changes of astigmatic meridian in most eyes in our study. It is probable that the fixation target of the IOLMaster is not strong enough to induce complete compensatory torsional eye movement. It is also noteworthy that head tilt had little effect on mean keratometric power measurement, and hence, the IOL power calculation for non-toric IOLs.

An increasingly common clinical implication of incorrect astigmatic meridian measurement is incorrect toric IOL implantation. Theoretical analysis predicts a steady loss of astigmatism correction as a toric IOL rotates more and more off axis. The relationship is fairly linear from 0° to 30°, where the correction drops to essentially zero.¹⁹ The misaligned toric IOL not only causes reduction of astigmatism correction but also results in both rotation of the astigmatic meridian and change of the refractive spherical equivalent.⁴ Optical quality is also compromised and modulation transfer function decays to ~50% due to increased aberration when a toric IOL rotates from 0° to 5°.²

A limitation of our study was the relatively small number of cases (27 eyes); however, considering the good repeatability of keratometric measurement by IOLMaster and the low *P*-values, we believe our study is sufficient to demonstrate the effect of head tilt on astigmatism meridian measurements by IOLMaster.

In summary, our study found a significant effect of head tilt on astigmatism meridian measurement using IOLMaster. Based on our results, we recommend that a cautious approach is necessary to avoid inadvertent head tilt when measuring preoperative keratometric data by IOLMaster, especially for toric IOL implantation. In cases of patients who have asymmetric lateral canthi or severe dermatochalasis obscuring the lateral canthal areas, more attention may be necessary to maintain upright head alignment.

Summary

What was known before

- Cyclotorsional movement of eye may compensate the accidental head tilt during IOLMaster measurement and may maintain the main axis of astigmatism constantly.

What this study adds

- Head tilt during the IOLMaster measurement resulted in the significant rotation of axis of astigmatism in the same direction.

Conflict of interest

The authors declare no conflict of interest.

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