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Research Article
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Comparison of Manual and Automated Methods to Measure Position-Induced Ocular Cyclotorsion

Su-Yeon Kang, Jae-Won Lim, Hyo Myung Kim and Jong-Suk Song*

Department of Ophthalmology, Korea University College of Medicine, Seoul, South Korea

Abstract

Purpose: To evaluate position-induced ocular cyclotorsion with manual and automated methods and to compare the measurements of the two methods.

Setting: Department of Ophthalmology, Korea University College of Medicine, Seoul, Republic of Korea.

Methods: Position-induced ocular cyclotorsion was measured in 40 normal eyes using manual and automated methods. In the manual method, the subject was seated upright at the slit lamp, and the corneal limbus was marked at the 0- and 180-degree positions. Next, with the subject lying on the surgical table, ocular cyclotorsion was measured using a Mendez degree gauge (Katena Products Inc., Denville, NJ). In the automated method, new CRS Master™ with OcuLign™ eye registration (Carl Zeiss Meditec, Jena, Germany) was used.

Results: The mean values of ocular cyclotorsion were -0.53 ± 2.30 degrees with the manual method and 1.08 ± 2.61 degrees with the automated method (+: counterclockwise, -: clockwise). There was a significant difference between these two methods ($p=0.002$) and no significant correlation ($r=0.201$, $p=0.213$). On the Bland-Altman plots, the range of agreement between these two methods was 6.1 degrees, whereas the range of agreement between zero value which assumed there was no manually detectable cyclotorsion and automated measurements was 5.1 degrees; the range of agreement between zero value and automated method was 1 degree lower than the agreement range between manual and automated methods.

Conclusions: The current manual method, which has been used clinically to compensate for position-induced ocular cyclotorsion, is not correlated with automated method.

Keywords: Iris registration; Ocular cyclotorsion; Toric intraocular lens; Toric phakic IOL

As phakic intraocular lens (IOL) and cataract surgery technology have advanced, toric IOLs and toric phakic IOLs have been introduced to correct astigmatism and to provide postoperative spectacle independence. In order to obtain successful postoperative results with toric IOLs, careful preoperative evaluation should be done to determine astigmatism and IOLs should be aligned with the target axis. Furthermore, toric IOLs should be stable without rotation [1-3]. A 15-degree angle of error results in a 50% reduction in the magnitude of astigmatism corrected [4]. Therefore, manufacturers are making efforts to develop postoperatively stable toric IOLs, and surgeons are trying to place the axes of toric IOLs exactly on the astigmatism axis, because misalignment is the main problem with these lenses.

One of the reasons of errors regarding axis marking is position-induced cyclotorsion, which can occur when patients change from an upright position to a supine position [5-8]. These postural changes can induce a mean ocular cyclotorsional effect of 0.4 to 4.2 degrees (range 0 to 16 degrees) [5-7], depending on various methods for measuring ocular cyclotorsion. The degree of cyclotorsion has been measured indirectly using differences in Maddox double rod measurements [6], trial frame refraction [5], and video-keratography [9]. Swami et al. [7] measured the rotational position of 240 eyes of 169 patients who underwent treatment for myopic or hyperopic astigmatism with excimer laser. Immediately preoperatively, each eye was marked at the limbus with a marking pen at the 3- and 9-o'clock meridian positions, while the patient was fixating on a distant target in a seated position. Ocular cyclotorsion was measured on the supine patient immediately before beginning the laser exposure, mean ± standard deviation value was 4.1 ± 3.7 degrees. Another study by Becker et al. [10] measured with a more precise technique, binocular 3-dimensional infrared video-oculography. As a result, the range of cyclotorsion of the right and left eye was between 1.13 degrees excyclotorsion and 0.34 degrees incyclotorsion.

Although a small angle of cyclotorsion will not significantly affect postoperative results, larger rotational errors can lead to worse outcomes after treatment for astigmatism. To compensate for ocular cyclotorsion, preoperative marking is done at the 0- and 180-degree positions on the corneal limbus under slit lamp biomicroscopy. This provides a horizontal reference line during the intra operative period when the patient is in a supine position [7]. However, this technique might not be sufficient to achieve precise optical results [11]. To the best of our knowledge, there have been no published articles discussing if this manual method is accurate. In the present study, we compared this manual method with an automated method, which captures an iris image and precisely measures cyclotorsion during corneal refractive surgery.

Patients and Methods

This observational study was conducted in the Department of

***Corresponding author:** Jong-Suk Song, MD, PhD, Department of Ophthalmology, Guro Hospital, Korea University College of Medicine, 80, Guro-dong, Guro-gu, Seoul, 152-703, South Korea, Tel: 82-2-2626-3178; Fax: 82-2-857-8580; E-mail: crisim@korea.ac.kr

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Ophthalmology, Korea University College of Medicine. We evaluated 40 eyes in 20 volunteers who had no evidence of ocular disease. The study adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of Anam Hospital of Korea University. Informed consent was obtained from all participants.

Position-induced ocular cyclotorsion was measured in all patients using both manual and automated methods. The new CRS Master™ with OcuLign™ eye registration (Carl Zeiss Meditec, Jena, Germany) was used as an automated method. After photopic and scotopic iris images were scanned with the subject in the seated position on the operative bed of the excimer laser machine, the subject's head position was adjusted to check for possible cyclotorsion. The limbus and pupil were registered using a WASCAR analyzer (Figure 1A). Cyclotorsion and eyeball deviation to the x- and y-axis were measured by comparing this data with the iris image captured in the supine position (Figure 1B). The angle of rotation was automatically displayed on a computer screen; a positive value indicates that the eye was rotated counterclockwise (excyclotorsion for right eye and incyclotorsion for left eye), and a negative value indicates that the eye was rotated clockwise (incyclotorsion for right eye and excyclotorsion for left eye). The measurement unit was 0.1 degree.

In the manual method, the patient was seated upright at the slit lamp, instructed to gaze at a distant target, and the corneal limbus was marked at the 0- and 180-degree positions using a toric reference marker (AE-2793S, ASICO) with a marking pen, guided by the horizontal slit beam (Figure 2A). The subject was then laid on the surgical table, where head position was aligned and the 0- and 180-degree positions were marked again. Ocular cyclotorsion, which was the difference between two horizontal lines, was measured using a Mendez degree gauge (Katena products Inc., Denville, NJ) calibrated every 10 degrees (Figure 2B).

In order to block the influence of automated measurements on manual measurements, the order of measurement was as follows: we first registered iris and pupil images using the WASCAR analyzer, and then manually marked the 0- and 180-degree positions of the limbus at the slit lamp. On the surgical table of the MEL 80 excimer laser (Carl Zeiss Meditec, Jena, Germany), we first measured ocular cyclotorsion manually with the Mendez degree gauge and then evaluated it using the automated method.

Statistical Analysis

The paired *t* test was used to analyze differences between the manual and automated methods for the measurement of ocular cyclotorsion. Pearson's correlation analysis was used to evaluate correlations between the two methods. *P* values <0.05 were considered to be statistically significant. The Bland-Altman analysis was used to assess agreement between the two methods. Bland-Altman plots show the differences between the two methods plotted against the mean of the two methods. The range of agreement is defined as 1.96 SD, and if this value is not clinically important, the two methods may be used interchangeably [12].

Results

The study comprised 40 eyes in 20 patients (3 men and 17 women). The mean patient age was 29.40 ± 4.72 years (range 23 to 43 years). The iris-registration function was successfully performed in all 40 eyes using eye registration technology. The absolute mean values of cyclotorsion were 1.32 ± 1.94 degrees (range 0 to 5.0 degrees) with the manual method and 2.27 ± 1.65 degrees (range 0 to 6.6 degrees) with

(A)
(B)

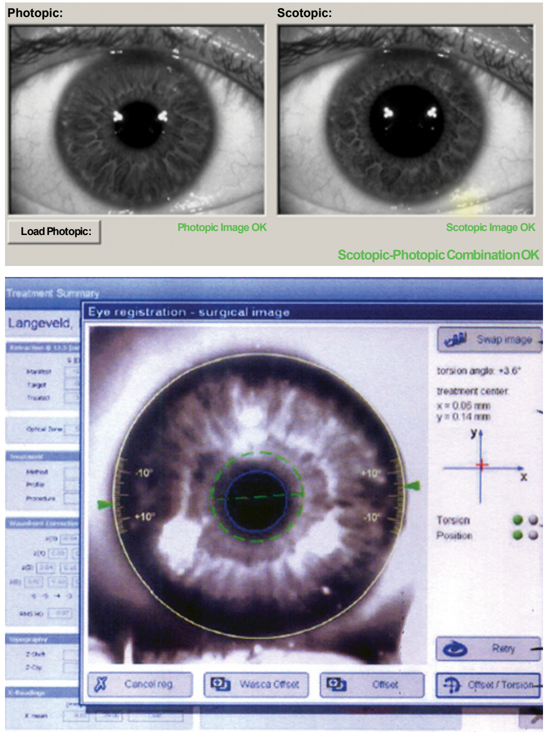

Figure 1: The automated method to measure position-induced cyclotorsion. The new CRS Master™ with OcuLign™ eye registration (Cark Zeiss Meditec, Jena, Germany) was used as an automated method. **(A)** Photopic and scotopic iris images were scanned with the subject in the seated position, the limbus and pupil were registered using a WASCAR analyzer. **(B)** Cyclotorsion and eyeball deviation to the x- and y-axis were measured by comparing this data with the iris image captured in the supine position.

(A)
(B)

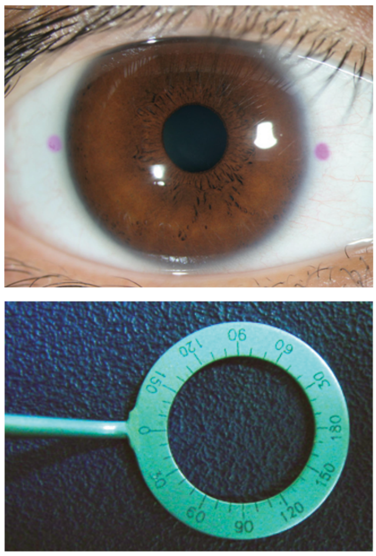

Figure 2: The manual method to measure position-induced cyclotorsion. **(A)** The patient was seated upright at the slit lamp, and the corneal limbus was marked at the 0- and 180-degree positions using a marking pen. The subject was then laid on the surgical table, where head position was aligned and the 0- and 180-degree positions were marked again. **(B)** Ocular cyclotorsion, which was the difference between two horizontal lines, was measured using a Mendez degree gauge (Katena products Inc., Denville, NJ) calibrated every 10 degrees.

the automated method. There was a statistically significant difference between the absolute mean values of the two methods (p=0.03, paired *t* test). Six eyes (15%) had a deviation of 5 degrees or more in the manual method, and four eyes (10%) had a deviation of 5 degrees or more in the automated method.

For the manual method, the mean value of cyclotorsion was -0.53 ± 2.40 degrees (range -5 to 5.0 degrees) clockwise: 0.4 ± 2.28 degrees (excyclotorsion) in the right eye and -1.45 ± 1.96 degrees (excyclotorsion) in the left eye. With the automated method, the mean value of ocular cyclotorsion was 1.08 ± 2.61 degrees (range -3.8 to 6.6 degrees) counterclockwise: 1.54 ± 2.01 degrees (excyclotorsion) in the right eye and 0.61 ± 3.08 degrees (incyclotorsion) in the left eye. There was a statistically significant difference between the mean values of the two methods (p=0.002, paired *t* test). Pearson's correlation analysis showed no significant correlation between the manual and automated methods (r=0.201, p=0.213) (Figure 3). The Bland-Altman plot showed that the mean difference in measurements between the two methods (automated minus manual methods) was 1.6 degrees ± 3.1 (SD), and the range of agreement was 6.1 degrees (Figure 4A).

Since there was no correlation between the manual and automated methods, we tried to determine if the manual method was useful for measuring ocular cyclotorsion. We used zero value instead of manual measurements for the Bland-Altman plot, which assumed there was no manually detectable cyclotorsion. The Bland-Altman plot showed that the range of agreement between zero value and the measurements obtained using the automated method was 5.1 degrees, which was 1 degree lower than the agreement range between the manual and automated methods (Figure 4B).

Discussion

Axial misalignment may be responsible for residual astigmatism after toric IOL implantation or laser refractive surgery. Possible causes of axis misalignment include incorrect preoperative refraction, misalignment of the patient's head or the laser beam, cyclotorsion of the eye, and movement of the eye during laser treatment [13]. Among these factors, ocular cyclotorsion has been investigated in many previous studies. At the beginning, imprecise devices such as Maddox double rod testing, trial frame refraction, or portable automated keratometry were used to detect cyclotorsion [5,6,13]. Now, however, iris registration technology is being utilized to precisely measure position-induced ocular cyclotorsion [14]. These new devices can automatically display the amount of ocular cyclotorsion by comparing two iris images captured in both the seated and supine positions. However, this updated technique has been applied only to laser refractive surgery so far, not to toric IOL implantation surgery.

With respect to IOL implantation, the current method used to compensate for ocular cyclotorsion is to mark a horizontal reference line at the 0- and 180-degree positions of the limbus. According to the horizontal reference line, we determined the axis of the toric IOL intraoperatively, with the patient in the supine position. Even though we have been using this manual method routinely, its effectiveness has not been proven. In the present study, we used the manual method to measure the amount of ocular cyclotorsion and compared the results with the measurements obtained using the automated method. The mean value of cyclotorsion and the absolute mean value were

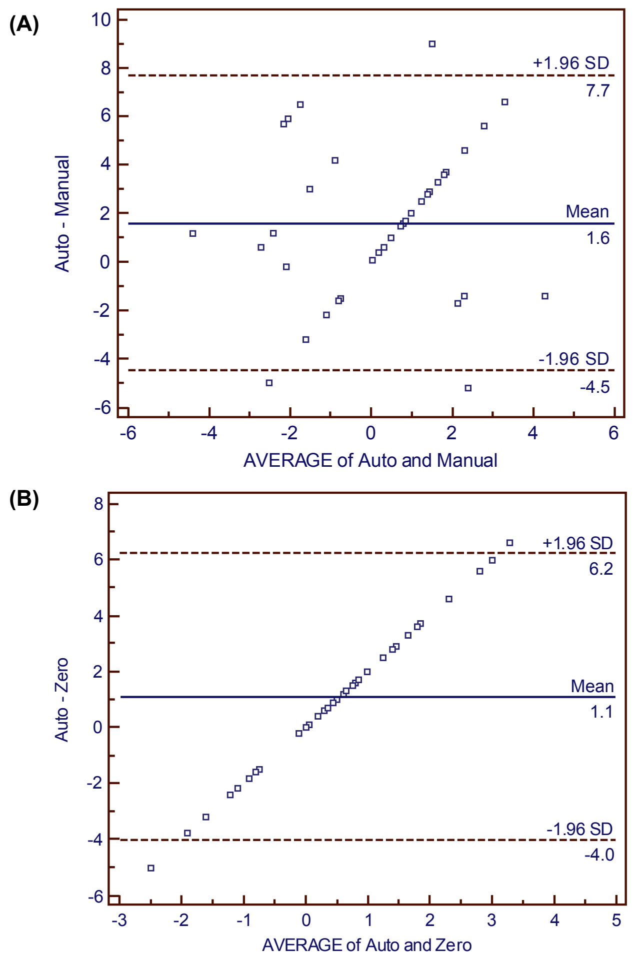

Figure 4: (A) Bland-Altman plot showing the difference between the automated and manual methods. The mean difference in measurements was 1.6 ± 6.1 degrees, and the range of agreement was 6.1 degrees. **(B)** Bland-Altman plot showing the difference between zero value and the measurements obtained using the automated method. The range of agreement was 5.1 degrees, which was 1 degree lower than the agreement range between the manual and automated methods.

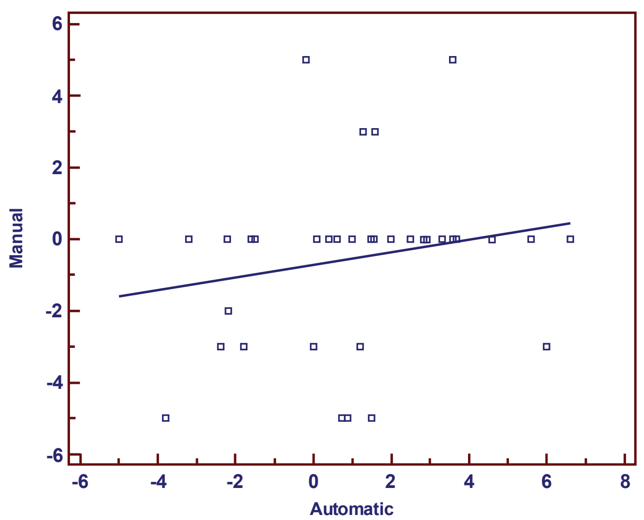

Figure 3: Scatterplot of position-induced ocular cyclotorsion with the automated and manual methods (r=0.201, p=0.213).

statistically different from each other, and there was no significant correlation between the two methods. Furthermore, when we assumed there was no manually detectable cyclotorsion and used zero value instead of manual measurements for the Bland-Altman plot, we found that the automated method showed better agreement with zero value instead of the manual method value. This seems to indicate that preoperative marking is not useful.

In this study, the absolute mean value of cyclotorsion was 2.27 ± 1.65 degrees, and a total of 4 eyes (10%) had a deviation of 5 degrees or more with the automated method. Kim el al. [17] measured positionally induced cyclotorsion using iris registration technology and reported similar results: the mean cyclotorsion was 2.67 ± 1.65 degrees and 13% of eyes had cyclotorsion greater than 5 degrees. Two or three degrees of cyclotorsion seem to be difficult to detect with the current manual method, because the Mendez degree gauge, which is used in the manual method, is calibrated every 10 degrees. Furthermore, it is difficult to mark a horizontal line at the 0- and 180- degree positions at the slit lamp without an error of a few degrees. Hence, the current manual method used in toric IOL implantation seems to be inaccurate and may be unhelpful. Furthermore, imprecise limbal marking may induce more axis misalignment. Therefore, in order to improve the efficacy of toric IOLs, more precise technology should be developed and applied to implantation.

The present study has a few limitations. The first is the relatively small sample size: 40 eyes (20 subjects) is a relatively small sample to elucidate the correlation between the two methods. The second is the fact that we measured the amount of ocular cyclotorsion with the manual method according to the horizontal reference line. However, in clinical toric IOL implantation, the amount of cyclotorsion is not measured with this technique, though the axis of the toric IOL is determined based on the reference line. Finally, the manual method we compared here is not the most precise one. In practice, other efforts to improve the accuracy of the manual methods including using the bubble level marker which aids in aligning with the horizontal axis and the toric axis marker with a scale of 5 degrees.

In conclusion, the mean cyclotorsion value was different to a statistically significant degree between the measurements obtained with the manual and automated methods, and there was no significant correlation. The manual method, which has been used clinically to compensate for position-induced ocular cyclotorsion, may not be precise, and near perfect manual methods need to be developed and compared with more precise automated methods.

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