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Measurement of Cyclotorsional Eye Movement in Seated and Supine Positions with WaveScan and Infrared Camera on the LASIK Device

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Purpose: To quantify the cyclotorsion that occurs between upright sitting and supine positions in Taiwanese subjects. **Methods:** The Visx WaveScan Wavefront device was used to obtain images of 105 eyes (54 patients) when the patients were seated. An infrared camera was then mounted on the Visx Star S4 Excimer Laser System to obtain further images in the supine position. We compared the eye positions at the time of the wavefront measurement with those in the supine position to estimate the amount of cyclotorsion. **Results:** For all 105 eyes, the mean±SD cyclotorsional deviation was 2.6±2.0 degrees (right eye 2.4±3.8 degrees counterclockwise, left eye 2.7±2.9 degrees clockwise). Binocular excyclotorsion was the predominant trend, affecting 48 of 54 patients. **Conclusions:** The difference in cyclotorsional eye movement, measured with IR-Visx CV technology, was significant in the transition from seated to supine positions. The cyclotorsional deviation can be used to adjust the laser ablation algorithm to compensate for this rotational displacement.

Key words: cyclotorsion, LASIK (laser in situ keratomileusis), IR (iris registration)

INTRODUCTION

Eye movement and improper fixation can affect the outcome of laser refractive surgery, including in situ keratomileusis (LASIK). If the eye is not perfectly aligned with the delivery system as a laser pulse is delivered, the regions of tissue removed with each pulse will not line up properly with one another to form the desired ablation pattern or will line up off-center from the visual axis. The position of the center of the entrance pupil relative to the excimer laser axis can be determined with a video-tracking technique[1].

Residual astigmatism is a cause of suboptimal uncorrected visual acuity outcomes following LASIK. Residual astigmatism may result from an astigmatism induced during the treatment or from undercorrection of the preoperative astigmatism. The degree of torsion, as patients move from a seated to a supine position, has been measured indirectly using differences in double Maddox rod measurements[2], trial frame refraction[3], and videokeratography[4]. The theoretical effects of rotational and translational misalignment on refractive surgery have been documented[5,6].

There are two kinds of binocular cyclotorsion: incyclotorsion and excyclotorsion. Incyclotorsion occurs when the 12 o'clock position of the cornea rotates medially, whereas excyclotorsion occurs when the 12 o'clock position of the cornea rotates laterally. Cyclotorsional eye movement changes that occur as the subject moves from a seated to a supine position could be an important factor in the correction of astigmatism with refractive surgery. Before refractive surgery is performed, data on the refractive error are collected in a seated position, but patients are in a supine position when undergoing refractory surgery. If rotation is not properly compensated for, a significant negative impact on the outcome could result, especially if the surgery is wavefront guided. Using the Visx WaveScan Wavefront System (VISX Inc., Santa Clara, CA, USA), Chernyak observed a low to moderate amount of cyclotorsion between the seated and supine positions[7]. The purpose of this study was to determine the cyclotorsional deviations between the upright sitting and supine positions in Taiwanese subjects.

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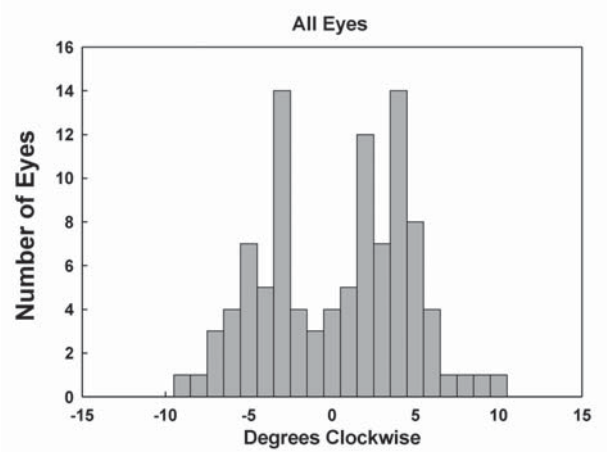

Fig. 1 Distribution of cyclotorsional eye rotation in all patients.

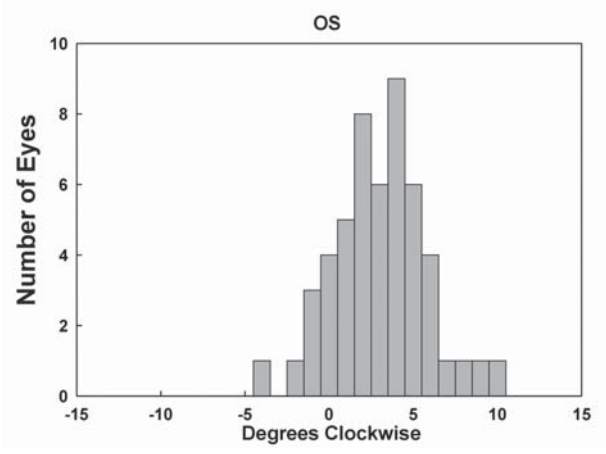

Fig. 2 Distribution of cyclotorsional eye rotations in left eyes.

METHODS

We prospectively evaluated 105 eyes (52 right eyes and 53 left eyes) of 54 patients, between August and December, 2005. Institutional review board approval and informed consent for the procedure were obtained. The patients were not interested in refractive surgery, and three participants had undergone LASIK previously. The cohort comprised men and women ranging in age from 20 to 30 years. Patients were eligible to be included in the study if they were at least 20 years of age, were free of ocular disease, and had a best spectacle-corrected visual acuity of 20/20 or better. Patients had a full orthoptic examination to rule out hidden pareses or palsies. Their refractive errors ranged from +2.0 to -7.0 diopters (D), with up to 3.0 D of astigmatism. All the participants were Taiwanese.

The limbus of all eyes was marked at 3 o'clock, and 9 o'clock with a disposable sterile gentian-violet surgical pen, while the patient was asked to fix on a distant target in a seated position under a slit-lamp. A cross was marked at the center of the nasal bridge at the same time. A slit-lamp examination was performed with horizontal and vertical beams and the precise positions of the marks were verified. Double Maddox rod tests were used to determine if positionally induced ocular cyclotorsion occurred when a patient moved from a seated to a supine position. Double Maddox rod tests were performed twice, while the patients viewed a fixation light at a distance of seven feet in both the seated and supine positions. Before the Visx WaveScan Wavefront device was used to obtain images of 105 eyes (54 patients) in a seated position, the positions of eyes were corrected according to the marks at the limbus. Before the patients were lowered to a supine position to obtain further images with the Visx Star S4 Excimer Laser System, the positions of their eyes and heads were confirmed according to the marks at the limbus and the nasal bridge. Finally, we compared the eye position at the time of the wavefront measurement with that in the supine position to estimate the amount of cyclotorsion.

RESULTS

To estimate the change in the cyclotorsional angle from one device to the other, an image of each eye was taken by each device. These images were compared to determine the amount of cyclotorsion.

The rotational eye movements of all eyes in the study are shown in Fig. 1. The range of cyclotorsional eye rotations was between 10 degrees clockwise and 9 degrees counterclockwise. For all 105 eyes, the mean $\pm$ standard deviation (SD) cyclotorsion was 2.6 ± 2.0 degrees.

Figure 2 shows the distribution of the cyclotorsional eye rotations for the right (OD) eyes. Figure 3 shows the data for the left (OS) eyes. The positive x-axis corresponds to the clockwise rotational direction from the observer's point of view. The graphs show that most patients experienced excyclotorsion, and the mean values of the rotation were: OD, 2.4 degrees counterclockwise (SD=3.8 degrees, 52 eyes); OS, 2.7 degrees clockwise (SD=2.9 degrees, 53 eyes). Both values are significantly different from zero using the t test: OD, $t=4.4$, $P < 0.01$, degrees of freedom (df) $=102$; OS, $t=6.8$, $P < 0.01$, $df=104$.

The predominant tendency in this study (48 of 54 patients) was excyclotorsion (positive x-axis). In contrast, four

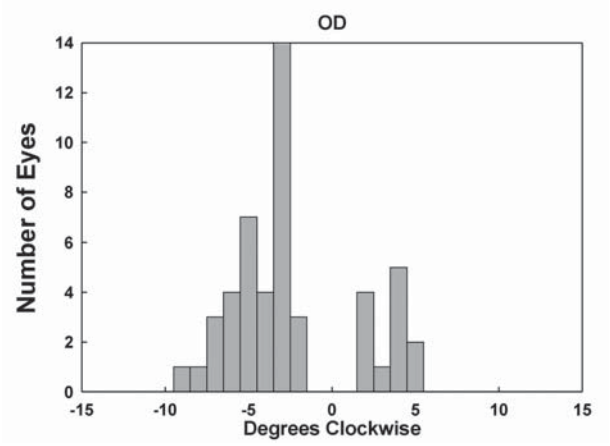

Fig. 3 Distribution of cyclotorsional eye rotations in right eyes.

patients exhibited incyclotorsion and two patients exhibited no cyclotorsion. The mean value for excyclotorsion was 2.7 degrees (SD=2.9 degrees, 96 eyes). The value is statistically significantly different from the null hypothesis (t=4.6, $P < 0.01$, df=102). Because head motion was eliminated from the computation, the results show significant excyclotorsion occurs when a patient moves from a sitting to a supine position.

DISCUSSION

In this study, 86 eyes (81%) experienced more than two degrees of cyclotorsion between the WaveScan measurement and the Visx Star S4 Excimer Laser System reading. Twenty-eight eyes (29%) experienced more than five degrees of cyclotorsion. These patients may have benefited from the appropriate corresponding rotation of the laser treatment table.

There are many laser-based vision correction companies moving away from traditional spherocylindrical corrections and toward customized corrections, which also address high-order wavefront aberrations of the eye. As the ablation patterns used in treatments become more complex and more specific to the individual, the importance of the precise registration of these patterns on the cornea increases. Small amounts of cyclotorsion should not affect the outcomes of surgery, but rotations of more than two degrees could introduce significant postsurgical aberrations[8,9]. Accurate compensation for this phenomenon will ensure that the potential of customized ablations to produce better results from those achieved using conventional ablations is not limited by cyclotorsional eye movement. The degree of cyclotorsion as patients move from an upright to a supine position has been measured indirectly using differences in double Maddox rod measurements[2], trial frame refraction[3], and videokeratography[4]. In our study, the measurement of cyclotorsional eye movement between seated and supine positions, when measured with the double Maddox rod test, was not statistically significant. The data were similar to the results of a previous study by Smith and Talamo in 1995[2]. The data collected with double Maddox rod tests (subjective method) showed no significant difference between the two measurements made in the seated and in the supine positions. However, the data collected with the WaveScan device (objective method) showed a significant difference between the two measurements made in the seated and in the supine positions.

Farah and coworkers demonstrated an improvement in visual outcomes following toric LASIK using corneal marking. Swami et al. suggested that marking the cornea can be used to decrease misalignment of the axis of correction, thereby improving the outcome after toric hyperopic or myopic LASIK[5].

According to published data and our measurements, possible causes of this excyclotorsion (two degrees) in the final visual outcomes of patients include rotation of the head and body under the laser, ocular torsion caused by the vestibular system, and the unmasking of cyclophoria[5]. The average deviation observed in this study is similar to the measurements made by Chernyak[7], with a shift of 2.0 degrees from a seated to a supine position. However, our deviation was smaller than the deviation of 4.1±3.7 degrees that was measured by Swami et al.5 with the LADARVision tracking system (Alcon Summit Autonomous, Orlando, FL, USA). The results of this study suggest that marking the cornea could be used to decrease the misalignment of the axis of correction, thereby improving the outcome after LASIK.

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