Original Article

The effects of lateral head tilt on ocular astigmatic axis

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Abstract

Background: Compensatory ocular counter-torsion (COCT) is supposed to maintain the eyes aligned with the visual environment following head tilt. Because of some recent controversies the functional capacity of this phenomenon was defined according to the extent of induced astigmatic axis error following head tilt.

Materials and Methods: Objective autorefractometry was performed on 70 eyes with a regular astigmatism of ≥2D at vertical, right head tilt and left head tilt positions of 5°, 10°, 15°, 20° and 25°. Astigmatic axis error was calculated according to the difference between the defined axis at each tilted head position and the defined axis at the vertical head position. A tiltometer was used for this purpose to show the angle of head tilt without disturbing the process of refractometry.

Results: The mean astigmatic axis error was 3.2° ± 1.5° and 18.4° ± 4.2° at the head tilt angles of 5° and 25° respectively. The mean percentage of tilt angle compensation by COCT was 36% and 26% at the head tilt angles of 5° and 25° respectively. There was a direct relation between the head tilt angle and the induced astigmatic axis error (ANOVA, $P < 0.001$, 95% of confidence interval [CI]). Astigmatic axis error values at right head tilt were significantly lower than their corresponding values at left head tilt (ANOVA, $P = 0.04$ 95% CI).

Conclusion: Any minimal angle of head tilt may cause erroneous measurement of astigmatic axis and should be avoided during refraction. One cannot rely on the compensatory function of ocular counter-torsion during the refraction.

Key Words: Astigmatism, axis, compensatory ocular counter-torsion, head tilt, ocular torsion

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INTRODUCTION

Exact determination of the astigmatic axis is of utmost importance for the correction of astigmatism. Tilting of the patient's head during refraction may be ignored and could be considered to be less important, because of the presence of a phenomenon known as compensatory ocular counter-torsion (COCT) or ocular counter-roll (OCR). COCT includes intorsion of the eye on the side of the head tilt accompanied by extorsion of the contralateral eye.[1] The existence of

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COCT was universally well-accepted and a history of this phenomenon was published on 1985 by Simonsz.[2] Controversy raised about COCT when the absence of this phenomenon was mentioned by Jampel and Shi in their study at 2002. They believed that many previous reports on the presence of COCT had been faulty interpretation.[1] Kushner did not accept the conclusion of Jampel and Shi and stated that static COCT does occur after head tilt as most investigators believe in that and it is in the range of 5-10°.[3]

To define the safety margin of head tilt during refraction and indeed the functional capacity of COCT following head tilt, the extent of the induced astigmatic axis error was measured following lateral head tilt.

MATERIALS AND METHODS

A total of 78 eyes of 40 healthy individuals with a regular astigmatism of ≥2D were included in this study. Cycloplegic objective autorefractometry was performed for these patients by a high speed new generation auto refractometer (Topcon, RM.8800) at normal (vertical) head position, right head tilt positions of 5°, 10°, 15°, 20°, 25° and left head tilt positions of 5°, 10°, 15°, 20°, 25°. Astigmatic axis error was calculated according to the difference between the defined axis at each tilted head position and the defined axis at the vertical head position. Any change in the astigmatic axis following head tilt was considered as axis error and was attributed to the COCT defect. Patients were selected from the Out-patient Department of Farabi and Feiz Eye Hospitals Isfahan Iran during 2009-2010. Patients had a complete eye examination including retinoscopy and subjective refraction at the beginning. The included cases were patients with regular astigmatic refractive error and no apparent systemic or ocular disease. Patients with a defective ocular motility or strabismus, amblyopia, previous ocular surgery, previous ocular trauma, irregular astigmatism, dizziness and vertigo were not included. Uncooperative patients were excluded from the study. The process of this study was explained for patients and the included patients accepted to take part in this study. Cycloplegia was performed by using 1% tropicamide every 10 min for three times, autorefractometry was performed 10 min after the last drop of tropicamide. A tiltometer[4] was used for this study to be fixed over the patients head being able to show the head tilt angle without creating any disturbance in the process of autorefractometry at various head positions. The tiltometer is equipment for measuring the side-wise tilting angle of the head and is composed of two main parts. The horizontal part: an adjustable headband to be fixed around the patients head and the vertical part: a rotating pendulum being fixed at the center of a scaled circular display showing the tilt-angle in degrees [Figures 1 and 2]. After proper fixation and adjustment of the tiltometer over the patient's head in a vertical position, autorefractometry measurement was performed first in vertical head position, then at right head tilt angles of 5-25° and finally at left head tilt angles of 5-25°. In each, head position measurement was performed for the right eye and the left eyes respectively. Autorefractometry was performed as soon as a static alignment of the patient's eye and the instrument was maintained. In each head position the average value of axis was obtained after three consecutive measurements for each eye. The obtained data's were entered in SPSS 11.5 system and statistically analyzed by Student *t*-test and a repetitive ANOVA model.

RESULTS

A total of 70 eyes of 36 patients (including 36 female eyes and 34 male eyes) completed the study process and four patients were excluded because of poor

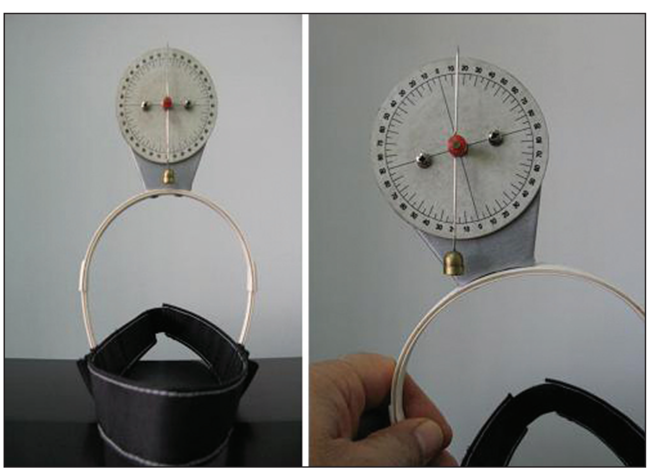
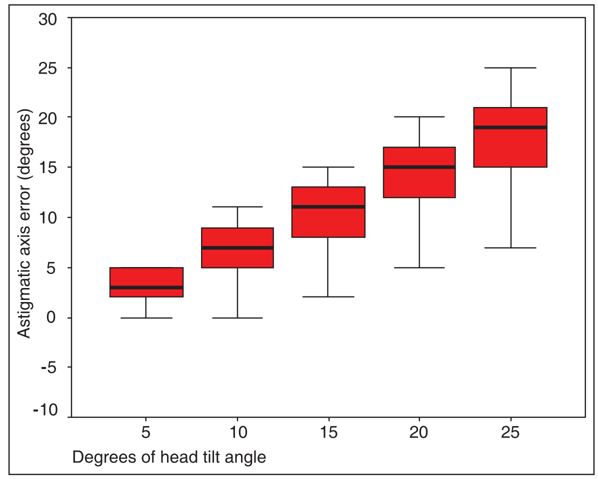


Figure 1: Tiltometer in vertical and tilted positions

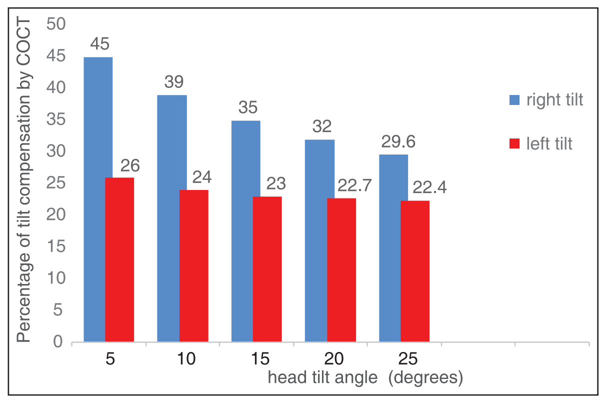
Figure 2: Status of tiltometer over the patients head during autorefractometry

co-operation. Some demographic characteristics of the study population are shown in Table 1.

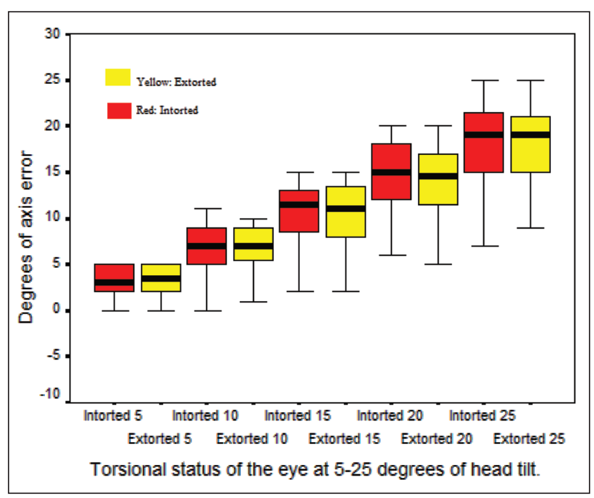
The mean age of the patients was 26.5 ± 10 (15-48) years. The multivariate test showed the main effect of tilt angle, tilt direction and right/left eye on the astigmatic axis error to be statistically significant. There was a direct relation between the head tilt angle and the induced astigmatic axis error (ANOVA, $P < 0.001$, 95% confidence interval [CI]). The mean astigmatic axis error was 3.2° ± 1.5° (from 0 to 5°) at 5° head tilt angle and 18.6° ± 4.2° (5-25°) at 25° head tilt angle. Graph 1 shows the ranges of axis error at the tilt angles of 5-25°. Astigmatic axis error values at right head tilt were significantly lower than their corresponding values at left head tilt (ANOVA, $P = 0.004$ 95% CI). Table 2 shows the mean values of astigmatic axis errors including the incyclotorsion and excyclotorsion errors for the right and the left tilt directions at the tilt angles of 5-25°. The mean percentages of tilt angle compensation by COCT after right and left head tilt are shown in Graph 2 and Table 3. The extent of astigmatic axis error in the incyclotorted eye was not necessarily equal with its corresponding value in the excyclototed sound eye (ANOVA: Main effect, $P = 0.031$, 95% CI, *t*-test: $P > 0.05$, 95% CI). Graph 3 shows the ranges of axis error in the intorted and extorted eyes at the tilt angles of 5-25°. The mean variation in astigmatic axis between the three measurements at the vertical head position was 1.20° ± 0.64° (from 0 to 3°); this variation was significantly lower than the mean astigmatic axis error of 3.2° ± 1.5° (from 0 to 5°) at 5° head tilt angle (*t*-test, $P < 0.001$ 95% CI).



Graph 1: Astigmatic axis error at head tilt angles of 5°-25° (ANOVA: $P < 0.001$)



Graph 2: Mean percentage of tilt compensation by compensatory ocular counter-torsion (COCT) in 5°-25° angles of head tilt



Graph 3: Astigmatic axis error in the intorted versus extorted eyes (*t*-student: $P > 0.05$)

DISCUSSION

According to the results of this study, lateral tilting of the head was accompanied by a significant error in astigmatic axis. Axis error was directly related to the angle of head tilt. Values of axis error were not symmetric for the right versus left head tilt directions and were found to increase during the test process. Axis error had a wide-range of variability with high standard deviation at each one of the tested head tilt angles. Since the axis error following head tilt was basically attributed to a COCT defect; therefore, COCT was found to be an unreliable phenomenon for the compensation of head tilt during refraction. in spite

Table 1: Demographic characteristics of the study population

Character	Eyes (70)	
	Right eye	Left eye
Number of eyes	36	34
Myopic eyes	28	26
Hyperopic eyes	8	8
Mean cylinder power (diopter)	3.2±1.16 D (2-6)	3.3±1.05 D (2-5.5)
Mean variation of astigmatic axis between the three measurements at vertical position	1.16°±0.71° (0°-2°)	1.23°±0.65° (0°-3°)

Table 2: Descriptive statistics of axis error at right and left head tilt position

Head tilt angle (degree)	Head tilt direction		*P* value, *t*-student
	Mean astigmatic axis error (degrees)		
	Right tilt	Left tilt	
5	2.7±1.5 From 0 to 5 Incyclotorsion OD: 2.8±1.4 Excyclotorsion OS: 2.6±1.6	3.7±1.5 From 0 to 5 Incyclotorsion OS: 3.8±1.6 Excyclotorsion OD: 3.7±1.5	0.012
10	6.1±2.3 From 0 to 10 Incyclotorsion OD: 6.0±2.1 Excyclotorsion OS: 6.1±2.5	7.6±2.7 From 0 to 10 Incyclotorsion OS: 7.5±2.6 Excyclotorsion OD: 7.7±2.8	0.010
15	9.7±3.4 From 2 to 15 Incyclotorsion OD: 10.0±3.4 Excyclotorsion OS: 9.4±3.5	11.5±3.1 From 2 to 15 Incyclotorsion OS: 11.7±3.3 Excyclotorsion OD: 11.4±2.8	0.037
20	13.5±3.7 From 5 to 20 Incyclotorsion OD: 13.8±3.9 Excyclotorsion OS: 13.3±3.6	15.4±3.5 From 7 to 20 Incyclotorsion OS: 15.3±3.5 Excyclotorsion OD: 15.5±3.5	0.05
25	17.6±4.2 From 5 to 25 Incyclotorsion OD: 17.8±4.3 Excyclotorsion OS: 17.4±4.1	19.2±4.2 From 7 to 25 Incyclotorsion OS: 19.7±3.9 Excyclotorsion OD: 18.8±4.4	0.054

Table 3: Mean percentage of tilt compensation by compensatory ocular counter-torsion (COCT) at 5°-25° angles of head tilt

Head tilt angle (degrees)	Head tilt side		*P* value, *t*-student
	Mean percentage of tilt compensation at right tilt %	Mean percentage of tilt compensation at left tilt %	
5	45±30	26±30	0.000
10	39±23	24±27	0.004
15	35±23	23±20	0.010
20	32±18	22.7±17	0.052
25	29.6±17	22.4±17	0.326

COCT: Compensatory ocular counter-torsion

of obtaining COCT amplitudes of up to 20° following a 25° angle of head tilt, the compensatory function of this phenomenon was not adequate and consistent even at the small head tilt angle of 5°.

Adler believed that ocular torsional movements were completely compensatory for head tilt and degrees of ocular counter-torsion would be equal to the degrees of head tilt, maintaining the ocular torsional orientation with the visual environment. He credits Nagel as formulating that belief.[5,6] Schworm *et al.* at 2002 used the infrared three-dimensional video oculography technique and showed a consistent ocular counter-role corresponding to the amount of head tilt in all subjects being tested at the head tilt angles of 15°, 30° and 45°. The relative amount of COCT ranged between 13% and 22% of the actual head tilt, decreasing with increasing head tilt.[7] The study by Jampel and Shi, at 2002 raised some controversy; they used two miniature video cameras and a fiber optic light source for detection of this phenomenon and concluded that no COCT exist in any stabilized head tilt position, COCT occurs only during head tilt and periodic torsional eye movements occurs during head tilt.[1] In a literature review at 2004, Kushner mentioned that although the methodology of studies varied, the results of all found that the partial compensatory counter-torsion present after head tilt in the range of 10-30%.[3] In another study, Pansell *et al.* used a sclera search coil technique and found that during the static head tilt position of 30° the average COCT gain was 28 ± 8% of the tilt angle.[8] Sverkersten *et al.*, found that the visually induced COCT is not maintained and slowly drifts back toward the initial reference position.[9]

The relative amount of head tilt compensation by COCT in this study was 36 ± 30% and 26 ± 17% at the head tilt angles of 5° and 25° respectively. The obtained COCT values in this study are compatible with the results of previous studies in spite of being measured in the manner of refraction rather than video or search coil. High variability of axis error following head tilt in this study is attributed to the high variability of COCT and could be explained Based on the slow drift back of COCT and periodic rotational eye movements after head tilt. The axis error values were probably dependent on the cyclotorsional status of the eye at the moment of autorefractometery.

One explanation for the significant asymmetry in axis error between the right and the left head tilt directions of this study could be the reduction of compensatory function of COCT during the test process [Table 3], since the entire patients begun the test with the right head tilting, completed the right head tilt test positions and then continued the test at the left head tilt positions.

Some cyclotorsional compensation discrepancy between the two eyes following head tilt in this study is compatible with the dissociated hysteresis of static ocular counter role in human being reported by Palla *et al.*[10]

CONCLUSION

This study showed that in-spite of the presence of COCT after head tilt, any minimal head tilt can cause erroneous astigmatic axis measurement and should be avoided during refraction. One cannot rely on the compensatory function of COCT during refraction.

As a rule the patient's head is held in a vertical position during ocular refraction. Vertical alignment of the patients head is best estimated by the examiner when confronting face-to-face with the patient. Vertical position of the patients head is hard to be defined by the examiner when the patients head is located behind the refractometry instruments. Vertical positioning of the patients head behind the auto refractometers is mostly defined through the instruments monitor by having the patent's pupils at the same horizontal level; in patients with orbital asymmetry struggle for having an alignment through the monitor of the instrument will be accompanied by erroneous tilting of the patients head. Pre-alignment of the patients vertical head position with tiltometer is suggested to help the examiner to monitor the head position during the process of refraction and improve the accuracy of astigmatic axis determination.

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