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Toric lens orientation and visual acuity in non-standard conditions

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ABSTRACT

Purpose: To evaluate and compare the effect of gravity and gaze direction on toric lens orientation and visual acuity (VA).
Method: This was a 14 subject, randomised, unmasked, non-dispensing study, relating to the effect of gaze direction and posture on toric lens orientation and VA. Four lens types were assessed: Acuvue™ Oasys® for Astigmatism (AOfA), Purevision® Toric (PVT), Air Optix® for Astigmatism (AOT) and Proclear® Toric (PCT). In the first part of the study, subjects were positioned on their side and once lenses had settled, VA was measured and photographs taken of the lens orientation position. In the second part, the subjects were positioned at a slit-lamp and video-recordings taken as they changed from the primary gaze position to the eight cardinal directions of gaze.
Results: In Part 1, all lenses rotated as a result of change in posture and head position. With subjects in a recumbent position mean rotation ranged from 11.0° with AOfA to 29.1° with PCT. The consequent mean reduction in VA ranged from 0.05 logMAR for AOfA to 0.15 logMAR for PVT and was significantly worse with PVT and PCT compared with AOfA ($P < 0.05$). In Part 2, lenses tended to show inferio-nasal rotation on upgaze and inferio-nasal rotation on downgaze. The AOfA lenses showed less rotation on inferio-nasal version than each of the other designs ($P < 0.005$). The AOT lenses showed significantly less rotation on superior-temporal version than PVT ($P = 0.01$).
Conclusion: Toric soft contact lens stability in extreme versions and postural positions can affect orientation and VA.

1. Introduction

The typical assessment of toric soft lenses involves the patient sitting upright at a slit-lamp and in front of a vertically oriented test chart with their eyes in the primary position, however this does not typify the range of eye movements and postural positions a person may adopt during a typical day of lens wear, particularly those activities that require abnormal body posture or various directions of gaze.

Over the years numerous studies have evaluated toric contact lenses in the 'upright world'. One study by Hanks even observed toric lens rotation in the 'up-side down world', which developed the 'water-melon seed principal' which claims that gravity has a limited effect on toric lens rotation [1]. Few studies have observed the rotational characteristics of a toric lens when the wearer is positioned horizontally and in particular the effect this has on visual performance. Observations of toric lens rotational stability have suggested that certain lenses would provide clearer, more stable vision than others [2]. However, until now, subjective VA measurements with toric lenses have been limited to the primary position. The purpose of this study was to evaluate and compare the influence of gravity and gaze direction on toric lens orientation and the effect that a different body posture has on VA.

2. Methods

Fourteen volunteer subjects took part in this randomised, unmasked, non-dispensing study, which compared the rotational characteristics of four different toric lens designs; Acuvue® Oasys™ for Astigmatism (AOfA), PureVision® Toric (PVT), Air Optix® for Astigmatism (AOT) and Proclear® Toric (PCT; Table 1). In Part 1, lens orientation and VA were assessed in the upright position and compared with those in a recumbent position. In Part 2, toric lens orientation was recorded in the eight cardinal directions of gaze.

PVT and PCT are both classic prism-ballasted designs with their thickest points close to the 6 o'clock position. The AOT lens is a modified prism-ballast design with the thickest points at 4 and 8 o'clock. AOfA has a similar 'accelerated stabilisation design' (ASD) as Johnson & Johnson's Acuvue® Advance™ for Astigmatism,

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Table 1
Study lenses.

	Manufacturer	Material	Water content (%)	Base curve (mm)	Diameter (mm)
ACUVUE® OASYS™ for astigmatism	Vistakon	Senofilcon A	38	8.55	14.5
PureVision® Toric	CooperVision	Balafilcon A	36	8.7	14.0
AIR OPTIX® Toric	Ciba Vision	Lotrafilcon B	33	8.7	14.5
Proclear® Toric	Bausch & Lomb	Omafilcon A	62	8.8	14.4

Table 2
Summary of analysis of variance (ANOVA) results.

	ANOVA		Paired tests					
	P-value	*F*	AOfA vs. PVT	AOfA vs. AOT	AOfA vs. PCT	PVT vs. AOT	PVT vs. PCT	AOT vs. PCT
Part 1								
Upright orientation	**0.0002**	7.50	**0.0035**	0.45	**0.0002**	**0.0054**	0.71	**0.0055**
Rotation	<**0.0001**	10.03	**0.0001**	**0.0034**	<**0.0001**	0.37	0.76	0.22
Upright VA	0.77	0.37						
Recumbent VA	**0.0066**	**4.94**	**0.013**	0.076	**0.015**	**0.038**	0.72	0.11
Change in VA	0.066	2.66						
Part 2								
Change in orientation with versions								
Superior	0.17	1.79						
Superior nasal	**0.011**	**4.51**	0.52	0.050	0.31	**0.014**	0.27	**0.0048**
Nasal	0.14	1.95						
Inferior nasal	0.76	0.39						
Inferior	0.33	1.19						
Inferior temporal	0.70	0.47						
Temporal	0.73	0.43						
Superior temporal	0.33	1.20						
Absolute change in orientation with versions								
Superior	0.23	1.54						
Superior nasal	0.71	0.46						
Nasal	0.077	2.55						
Inferior nasal	**0.0083**	**4.80**	**0.019**	**0.010**	**0.0058**	0.14	0.89	0.054
Inferior	0.54	0.73						
Inferior temporal	0.30	1.29						
Temporal	0.069	2.65						
Superior temporal	**0.013**	**4.29**	0.085	0.17	0.44	**0.0060**	0.20	0.053

which is claimed to reduce disruptive lid interaction by placing thick zones within the interpalpebral aperture.

Subjects were fitted with the toric contact lenses matched to their spectacle prescription and each lens type was assessed in both right and left eyes. Subjects were required to have distance sphere requirement in the range of −1.00 to −5.00DS and spectacle astigmatism in the range of −0.75 to −1.75D inclusive. The available axes at the time of the study were 10°, 90°, 180° and 170°. A tolerance of 5° was permitted when matching subject's spectacle axis of astigmatism to the available axes. The orientation markings of the lenses were enhanced using an ultra fine, non-toxic marker pen (Sharpies, Stanford, USA). In the case of PCT and PVT only the central toric marking was enhanced.

In Part 1, following a settling time of 15 min, subjects' VA was assessed in one eye, selected at random. A free-standing, externally illuminated, logMAR letter chart at 3 m was used for testing each lens in the upright position before subjects were asked to lie on their side with their head supported by a cushioned platform. Sufficient time was allowed for the lens to re-orientate to a settled position under the effect of gravity and lid interaction. VA was reassessed in this recumbent position with a similar chart orientated on its side in accordance with the subject's position. Where necessary a spherical trial lens was held in front of the eye to achieve best corrected VA.

In addition, a digital photograph was taken using a Nikon D1 digital camera (Nikon, Japan) of the final lens orientation position. Both eyes were photographed, with the lens of interest in the lower eye. The amount of lens rotation in the recumbent positioned was analyzed at a later stage using digital image (Paint Shop Pro v. 7.04, Corel Corporation, Canada) and digital protractor software (Pixel Port v.1.1, http://www.qwerks.com).

In Part 2 of the study, subjects were positioned at a slit-lamp in front of a chart with targets positioned 45° apart in the eight cardinal directions of gaze at an angle of approximately 40–45° from the primary direction of gaze (Fig. 1). Subjects were asked to blink naturally and then, after four blinks, to look at the 12 o'clock position for a period of four blinks before returning to the primary direction of gaze. If the lens appeared not to have rotated then four blinks were counted before they looked in the second direction (moving anti-clockwise) for four blinks and so on until they had covered all eight directions of gaze. The four blinks in the off-axis position took approximately 6 s to perform. If the lens showed rotation after looking into one of the off-axis directions of gaze, the patient was asked to continue blinking normally whilst looking in the primary position allowing the lens to settle back into its original orientation position. Lens movements were video recorded continuously using a Sony 3CCD Exwave HAD video recorder and Broadway computer software (Data Translation Inc., 1996/1997). Lens orientation position measurements were undertaken at a later stage from the video recording using video editing software (Ulead Video Studio 11, 2007, Corel Corporation) and the digital protractor.

Differences between the lens types were compared using repeated measurements analysis of variance (ANOVA). Where significant differences were found between lens types, least significant difference multiple pairwise comparisons were made.

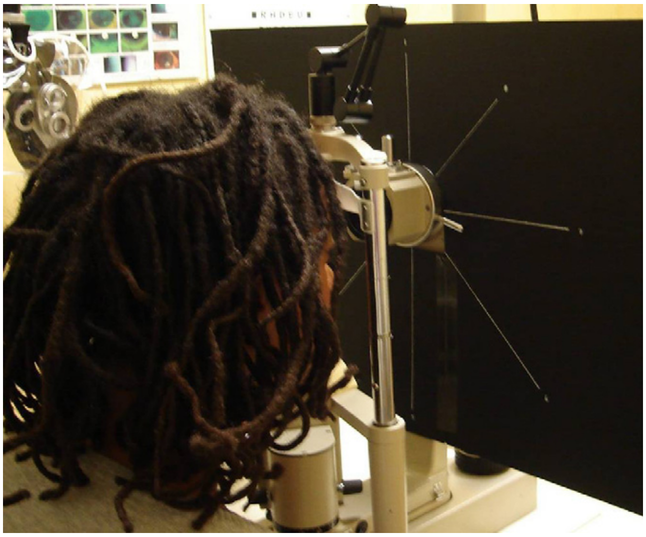

Fig. 1. Slit-lamp set-up for cardinal directions assessment.

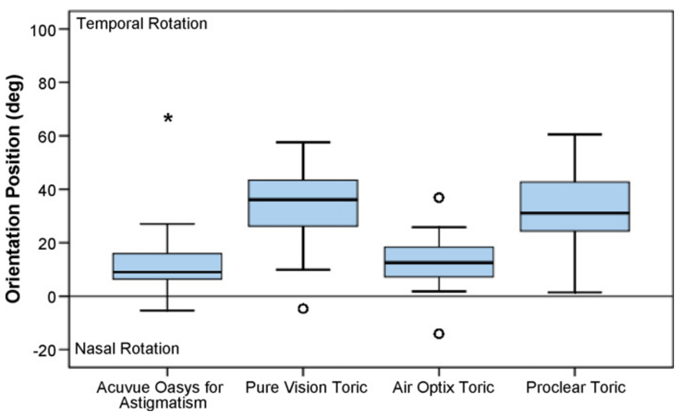

Fig. 2. Orientation position. Box and whisker plot showing the median (black line in box), quartiles (box), outliers (+), and extreme values (*).

A Pearson correlation was used to test for associations between rotation and change in VA. A *P*-value of 0.050 or less was regarded as statistically significant

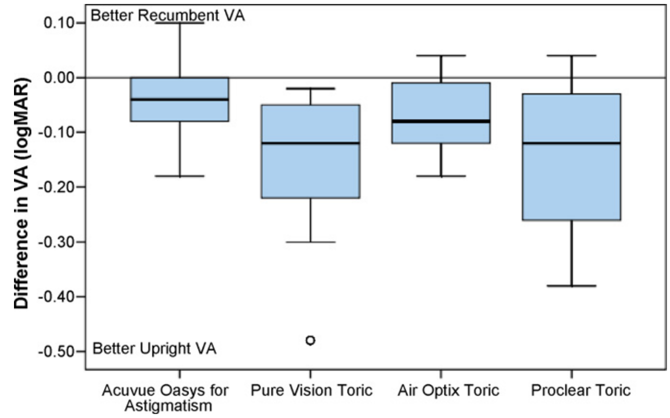

Fig. 3. Change in VA. Box and whisker plot showing the median (black line in box), quartiles (box), and outliers (o).

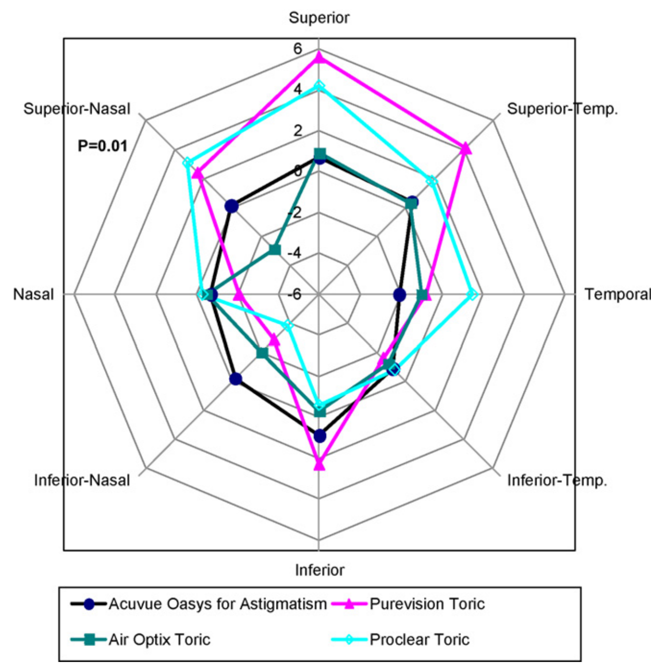

Fig. 4. Mean change in orientation with versions (0 = no change; +ve indicates inferior-nasal rotation; −ve indicates inferior-temporal rotation, *P*-values indicates significant difference by ANOVA).

3. Results

3.1. Influence of gravity

In Part 1, the ANOVA (Table 2) indicated significant differences in orientation between lenses even in the normal upright position ($P = 0.0035$). Therefore, in order to compare lenses in the recumbent position, the change in orientation (rotation) from the upright position was calculated. The PCT lenses showed the greatest mean rotation from the upright position while the AOfA lenses showed the least (Fig. 2). The ANOVA indicated significant differences in rotation ($P < 0.0001$) and *post hoc* testing indicated that the three prism-ballasted lenses showed significantly more rotation than the ASD design ($P \leq 0.003$). The AOfA lenses rotated on average 11.0° relative to the upright orientation position compared with 29.1° for PCT, 28.7° for PVT, and 26.5° for AOT.

There were no significant differences in VA with the four lens types measured in the upright position, however, there were significant differences in the recumbent position ($P = 0.007$). The mean reduction in VA in the recumbent position ranged from 0.05 logMAR (2.5 letters) with AOfA to 0.15 logMAR (1.5 lines) with PVT and PCT (Fig. 3). Mean VA in the recumbent position was significantly worse for two of prism-ballasted lenses (PVT, PCT) compared with the ASD design and the other prism-ballast design (AOT).

The correlation coefficient for rotation and change in VA was not statistically significant ($R = -0.25$, $P = 0.08$, $n = 50$).

3.2. Influence of gaze

Overall, in Part 2 there were few significant differences with regard to orientation in different directions of gaze. In general, it was found that all lens types tended to rotate nasally (+ve) with superior versions and temporally (−ve) with temporal, nasal and inferior versions (Fig. 4). Since the direction of rotation is not relevant to the effect on vision, the absolute change in orientation was also calculated for each movement (Fig. 5). The mean change in orientation ranged from 3.0° with AOfA to 9.5° with PCT. The

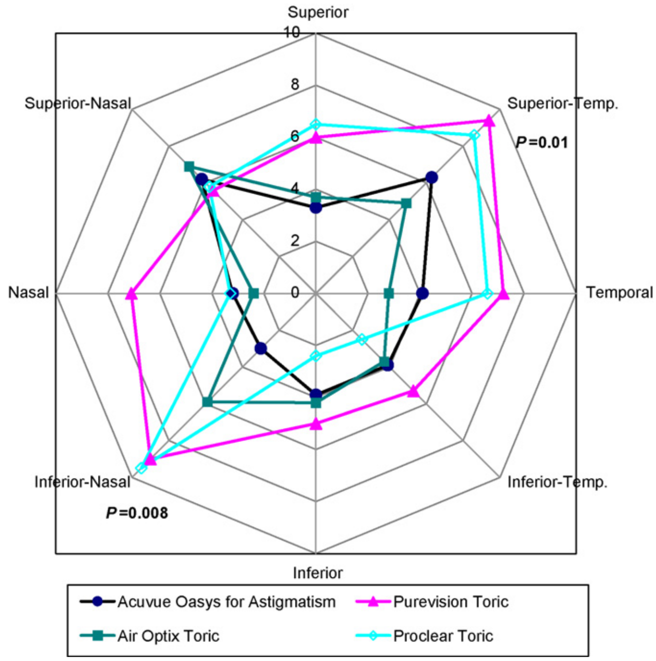

Fig. 5. Mean absolute change in orientation with versions (*P*-values indicated significant difference by ANOVA).

ANOVA indicated significant differences in absolute orientation in two of the eight directions of gaze: inferior-nasal and superior temporal ($P \leq 0.01$). With inferior-nasal gaze, the change in orientation was significantly greater with the three prism-ballasted lenses than the ASD design ($P \leq 0.02$). With superior-temporal gaze, the change in orientation was significantly greater with PVT than the AOT ($P = 0.01$).

4. Discussion

The relatively large amounts of rotation seen with two of the prism-ballasted lenses, with subjects in the recumbent position, had a greater impact on VA than with the ASD lens (AOfA). This reduction in VA can be predicted from the calculation of the expected induced astigmatism from this rotation (Fig. 6). The induced astigmatism for the average rotation noted in this study with PVT (29°) is approximately equivalent to the mean cylinder power of the lenses themselves (−0.90D) and, furthermore, is at an oblique axis. The mean reduction in VA of one and a half lines was consistent with this. Lenses of relatively low cylinder power were used in this study (−0.75D, −1.25D); an even greater effect on vision might be expected with lenses of higher cylinder power. Ocular cyclorotation might be expected to partially compensate for change in posture, however, this has been found to be relatively small: ∼10% of head tilt [3].

A novel method for assessing lens orientation in different directions of gaze was used in this study. With varying gaze positions, the two traditional prism-ballasted lenses, PVT and PCT, tended to show greater rotation than the other two lens types. They showed the greatest rotation on upgaze, which tended to induce inferior-nasal rotation. This is to be expected with those lenses that show inferior temporal-rotation on normal gaze, since, freed from the influence of the bottom lid, rotate to the zero position under the influence of gravity [4]. PVT, in particular,

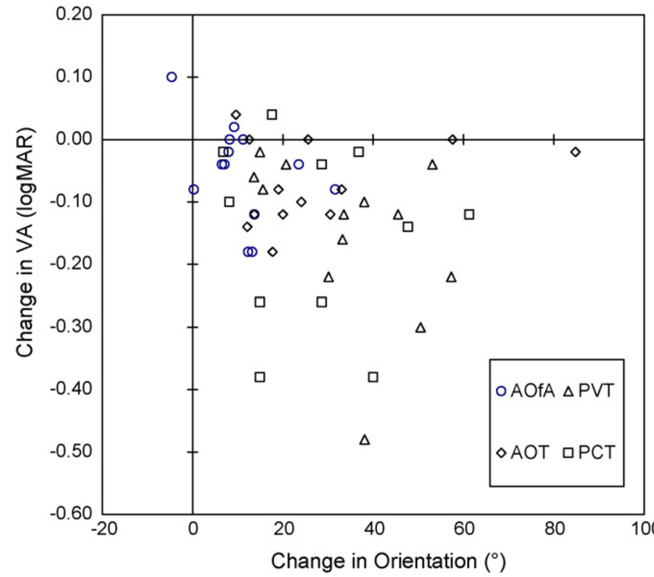

Fig. 6. Scatter plot of difference in VA from upright to recumbent position.

showed on average of nearly 10° of rotation following the superior-temporal gaze direction; it is notable that this corresponds to the change in gaze when looking in a rear-view mirror when driving.

All three prism-ballasted lenses tended to rotate in the inferior-temporal direction following inferior-nasal versions. Prism-ballasted lenses showed on average significantly more absolute rotation following this gaze direction compared with the ASD lenses. This has an implication for reading when both eyes tend to point in this direction. A study by Zikos et al., which compared Acuvue Advance for Astigmatism with SofLens® 66 Toric lenses, across a range of natural viewing conditions, found similar findings with the prism-ballasted lens showing more infero-temporal-rotation across a range of tasks, and the ASD lens showing more nasal orientation. The same study found that, for reading tasks, the ASD lens maintained stable orientation closer to the zero reference than the prism-ballasted lens [4].

In conclusion, this study has noted differences in visual performance between soft toric lenses when used in varying activities. The findings may help to explain some of the visual complaints reported by toric soft lens wearers and suggest that the visual demands arising from patients' occupation and leisure activities should be taken into account when fitting toric soft lenses.

Acknowledgement

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References

[1] Hanks AJ. The watermelon seed principle. Cont lens Forum 1983;8(9):31–5.
[2] Young G, McIlraith R. Clinical evaluation of factors affecting soft toric lens orientation. Optom Vis Sci, in press.
[3] Collewijn H, Van der Steen J, Ferman L, Jansen TC. Human ocular counterroll: assessment of static and dynamic properties from electromagnetic scleral coil recordings. Exp Brain Res 1985;59:185–96.
[4] Zikos GA, et al. Rotational stability of toric soft contact lenses during natural viewing conditions. Optom Vis Sci 2007;84:1039–45.