Contact Lens & Anterior Eye 37 (2014) 191–195

Contents lists available at ScienceDirect

Contact Lens & Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Evaluating the effect of splitting cylindrical power on improving patient tolerance to toric lens misalignment

Sandeep K. Dhallu, Amy L. Sheppard, James S. Wolffsohn*

Aston University, School of Life and Health Sciences, Ophthalmic Research Group, Birmingham B4 7ET, UK

ARTICLE INFO

Article history:
Received 28 April 2013
Received in revised form 2 September 2013
Accepted 31 October 2013

Keywords:
Toric
Intraocular lenses
Astigmatism
Misalignment
Misorientation

ABSTRACT

Purpose: Evaluating the impact of splitting toric power on patient tolerance to misorientation such as with intraocular lens rotation.
Setting: University vision clinic.
Methods: Healthy, non astigmats had +1.50D astigmatism induced with spectacle lenses at 90°, 135°, 180° and +3.00D at 90°. Two correcting cylindrical lenses of the opposite sign and half the power each were subsequently added to the trial frame misaligned by 0°, 5° or 10° in a random order and misorientated from the initial axis in a clockwise direction by up to 15° in 5° steps. A second group of adapted astigmats with between 1.00 and 3.00DC had their astigmatism corrected with two toric spectacle lenses of half the power separated by 0°, 5° or 10° and misorientated from the initial axis in both directions by up to 15° in 5° steps. Distance, high contrast visual acuity was measured using a computerised test chart at each lens misalignment and misorientation.
Results: Misorientation of the split toric lenses caused a statistically significant drop in visual acuity ($F = 70.341$; $p < 0.001$). Comparatively better acuities were observed around 180°, as anticipated ($F = 3.775$; $p = 0.035$). Misaligning the split toric power produced no benefit in visual acuity retention with axis misorientation when subjects had astigmatism induced with a low ($F = 2.190$, $p = 0.129$) or high cylinder ($F = 0.491$, $p = 0.617$) or in the adapted astigmats ($F = 0.120$, $p = 0.887$).
Conclusion: Misalignment of toric lens power split across the front and back lens surfaces had no beneficial effect on distance visual acuity, but also no negative effect.

1. Introduction

Pre-surgical corneal astigmatism of more than 1.50D exists in approximately 18–22% of patients awaiting cataract surgery [1–3]. With increasing levels of astigmatism, lower visual acuities are observed [3,4], therefore in order to optimise post-operative visual acuity corneal astigmatism should be corrected [1]. Currently, there are two main ways in which this astigmatic correction can be achieved; corneal/limbal relaxing incisions [5–9] or implantation of a toric IOL [2,6,9,10]. Incisional surgery relies heavily on the corneal healing response which can vary significantly between individuals, leading to greater unpredictability in refractive outcomes post-operatively [6,9]. Limbal relaxing incisions may be preferable to corneal relaxing incisions because they do not encroach as much onto the central cornea. They therefore rely less upon the subjects' specific corneal healing pattern meaning surgical outcomes can be predicted with greater accuracy [7]. A study comparing toric IOLs and limbal relaxing incisions found that the former produced residual astigmatism of less than or equal to 1.00D in approximately 90% of subjects compared to just 40% with limbal relaxing incisions. Additionally, toric IOLs were found to provide better contrast sensitivity under mesopic conditions at low spatial frequencies than limbal relaxing incisions and were therefore considered to be the superior form of correction in patients with mild to moderate astigmatism [1].

The invention of intraocular lenses represented a significant shift in modern cataract surgery techniques and allowed great advances in the distance acuity that could be reached after surgery. IOLs have undergone vast improvements over the last half century and current IOLs now have the ability to provide excellent uncorrected vision at both far and close distances. However, once implanted all IOLs are prone to tilt and decentration within the capsular bag, which can affect vision [11]. With toric IOLs, lens misorientation due to rotation or inaccurate positioning becomes an additional source of concern and is a frequently reported complication [10]. Small amounts of decentration or tilt have been reported to have a minimal effect on refraction [12]. Misorientation due to

* Corresponding author. Tel.: +44 1212044140; fax: +44 1212045142.
E-mail address: j.s.w.wolffsohn@aston.ac.uk (J.S. Wolffsohn).

1367-0484/$ – see front matter
http://dx.doi.org/10.1016/j.clae.2013.10.002

IOL rotation on the other hand has been found to play a much greater role, with reports indicating that this induces a hyperopic spherical change and reduces the power of the astigmatic correction [12,13].

Misorientation can occur for a number of reasons, for example surgical error resulting in inaccurate positioning of the IOL at the time of surgery [14] or post-operative rotation of the implanted IOL within the capsular bag [10,16]. Most IOL rotation is reported to take place within the first month of surgery [1] due to factors such as capsular bag size and capsulorhexis size; the commonest cause of late IOL rotation was found to be capsular bag shrinkage [15]. Interestingly, there appears to be a greater incidence of toric IOL rotation in patients with longer axial lengths [16]. The greater the cylinder power, the more essential accurate IOL placement becomes [10]. It has been stated that in general a 3% reduction in cylinder power occurs for every degree of toric intraocular lens rotation [3]. This is problematic since Leyland and colleagues [14] determined that 18% of plate haptic IOLs rotated by more than 30° three to six months after surgery, meaning in theory over one fifth of patients implanted with this type of toric IOL would receive inadequate astigmatic correction [17].

There is therefore a need to improve the rotational stability of toric IOLs or to introduce a mechanism to compensate for the effect of toricity caused by lens rotation, as this would give patients better vision and allow surgeons greater flexibility. Several design strategies have been developed in order to increase lens stability and therefore reduce intracapsular lens rotation [6,10], however there is still uncertainty as to which type of IOL design confers better rotational stability [15]. This study evaluates a novel idea for compensating for the rotational effects of a toric IOL. This involves separating the toric power of an IOL by splitting the astigmatic power between both the front and back surfaces of the IOL, as opposed to across just one surface, in order to assess whether this provides a beneficial effect that could be incorporated into toric IOLs in order to minimise the impact of any lens rotation on visual acuity. In theory with such a design the maximum toric power would be spread over a wider angular subtense, perhaps reducing the power loss with rotation away from the axis of peak astigmatism. Most toric IOLs are made with one spherical surface and one toric surface. It has been suggested that this can cause a disparity between the images and object magnifications in different meridians in the case of corneal astigmatism. Bitoric IOLs may have the additional advantage of eliminating this image distortion and therefore offer an advantage over standard toric IOLs [12].

The axis of astigmatism can be categorised as with-the-rule, against-the-rule and oblique. It is believed that with-the-rule astigmatism aids with distance vision while against-the-rule astigmatism improves reading vision and so should not be treated as aggressively as oblique astigmatism [18]. To test the effect that misaligning split toric power has on patient tolerance with each of type of astigmatism this study induced astigmatism at 90°, 135° and 180° as well as determining the effect of toric power and adaptation.

2. Method

Participants were required to have no more than three dioptres of astigmatism, be free of any active eye disease, not taking ocular or systemic medications with known ocular side effects and to not have had ocular surgery within the last three months. Contact lens wearers were required to remove their lenses at least twelve hours before any tests were carried out. Thirty-one healthy subjects with a mean age of 26.4 ± 8.3 years and with best corrected Snellen acuity of 6/9 or better gave informed consent to take part in the study. The study was approved by the Institutional Ethics Committee and the research conformed to the tenets of the Declaration of Helsinki. The subjects were split into two subgroups, 16 subjects with limited astigmatism <0.75D and an adapted astigmatic group ($n = 15$) with ocular toricity from −1.00 to −3.00 D (mean −1.27 ± 0.54DC).

2.1. Induced astigmatism cohort

Subjects underwent a refractive examination to ensure they were wearing the most accurate sphero-cylindrical distance prescription maximising the positive power while retaining the best possible distance visual acuity and a measurement of their best corrected visual acuity was taken at this point. An additional cylindrical lens was added in to the trial frame over their distance prescription in order to induce astigmatism in these subjects; a +1.50D cylindrical lens (low) was added at 90°, 135° and 180° and +3.00D (high) at 90° in a random sequence. Two forward facing correcting cylindrical lenses each of either −0.75D or −1.50D were then added to the trial frame aligned with each other, misaligned by 5° or by 10° in a randomised order. These lenses were placed at the angle of the induced astigmatism and misorientated in a clockwise direction by a total of 15° in 5° steps. The position of the two −0.75D/−1.50D cylindrical lenses for each lens misalignment and misorientation is shown in Table 1.

2.2. Astigmatic cohort

Subjects with astigmatism between −1.00 and −3.00D had their own astigmatism corrected using two cylindrical lenses of half the power each. These two cylindrical lenses were placed at the angle of the subjects' astigmatism and misorientated either side by up to 15° in 5° steps; the lenses were again separated (misaligned) by 0°, 5° and 10° at each of these axes. This was done to enable evaluation of the effects of adaptation on rotational tolerance by comparing subjects with a moderate toric component to their prescription against those in whom the astigmatism had just been induced. All measurements were taken on one eye only.

Distance visual acuity was measured on a digital logarithmic progression chart on all subjects (TestChart 2000Pro, Thomson Software Solutions, London, UK) with the letters randomised between presentations. Each letter read correctly was scored as 0.02logMAR and subjects were encouraged to guess if unsure.

2.3. Statistical analysis

All data were collected in an Excel database (Microsoft Office 2007). Data were analysed using SPSS for Windows (version 20.0, SPSS Inc.). A one-sample Kolmogorov–Smirnov test revealed that the visual acuity data was normally distributed (Kolmogorov–Smirnov $Z = 1.206$, $p = 0.109$). Therefore visual acuity with each axis and astigmatic power misalignment was compared by repeated measure analysis with posthoc tests applied when the overall significance was $p < 0.05$.

3. Results

3.1. Induced astigmatism cohort

3.1.1. +1.50D of astigmatism induced at 90°, 135° and 180°

Misorientation of the split toric lenses caused a statistically significant drop in visual acuity ($F = 70.341$; $p < 0.001$; Fig. 1). There was also a statistically significant change in visual acuity with axis ($F = 3.775$; $p = 0.035$). Comparatively lower visual acuities were recorded at 90° than at 180° as expected. Misalignment of the toric power split between the two lenses, however, did not result in a statistically significant better visual acuity compared to no separation ($F = 2.190$, $p = 0.129$).