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Short communication

A topographical method to quantify scleral contact lens decentration

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ABSTRACT

Purpose: To describe a simple method to quantify scleral contact lens decentration using over-topography captured with a Placido ring videokeratoscope, and its repeatability.

Methods: Scleral lens over-topography (E300 videokeratoscope, Medmont) was measured on 10 healthy participants following 15 min of lens settling (16.5 mm total diameter ICD miniscleral, Capricornia). Horizontal and vertical lens decentration was quantified from the translation of the front optic zone relative to the pupil centre derived from ellipses manually fitted to tangential power over-topography maps using both a standard and normalised dioptric scale. Intrasession (different maps captured within the same measurement session), intraobserver (identical maps analysed by the same observer), and intertechqniue (standard or normalised tangential power scales) repeatability were calculated.

Results: The mean lens decentration was 0.62 ± 0.18 mm temporally and 0.91 ± 0.33 mm inferiorly. Lens decentration derived from tangential topography maps with a standard power scale were more repeatable (95% limits of agreement for intraobserver repeatability ± 0.07 mm and intrasession repeatability ± 0.15 mm) than measurements derived from normalised maps (95% limits of agreement for intraobserver repeatability ± 0.11 mm and intrasession repeatability ± 0.20 mm).

Conclusions: Scleral lens decentration can be reliably quantified using tangential power maps with a standard (fixed) scale captured during over-topography without the need for customised instrumentation or image analysis software. This method has a range of potential applications in research and clinical practice.

1. Introduction

Scleral contact lenses are prone to inferior, temporal, or inferotemporal decentration [1–3], and this is presumably due to a range of factors including the topography of the underlying sclera, the lens mass, and post-lens tear layer, gravitational, and eyelid forces. This decentration often results in post-lens tear layer thinning or lens bearing supero-nasally, which may lead to superficial corneal epithelial staining or erosions, lens awareness and discomfort, and reduced wearing time [4]. Optically, the non-uniform post-lens tear layer that arises due to lens decentration also induces a prismatic effect, and the mislocation of the anterior contact lens surface relative to the visual axis, introduces additional higher order aberrations, predominantly horizontal and vertical coma, that are not corrected by the post-lens tear layer [5]. Scleral lens decentration is a particularly important consideration when fitting multifocal lenses and designing customised lenses to correct both corneal and residual (internal) higher order aberrations [6–8].

Although scleral lens decentration is often observed clinically, particularly for a spherical haptic design fitted to a toric or asymmetric scleral shape, few studies have described techniques to quantify the direction and magnitude of scleral lens decentration. Sabesan et al. [7] used a digital camera focused at the pupil plane (captured simultaneously during wavefront aberrometry measurements) to quantify scleral lens decentration with respect to the pupil centre. This approach required the use of a surgical marking pen to highlight the edge of the optic zone and customised software for image analysis (measures of decentration could not be obtained due to insufficient image contrast in 18% of eyes). Marsack et al. [6] and Ticak et al. [8] described a similar process to quantify lens decentration using images of the lens on eye (with black alignment marks on the front surface) captured using a custom built imaging system (Modular Ophthalmic Measurement System) and analysed with customised software (with a reported accuracy of ± 0.02 mm). Vincent et al. [5] also described a repeatable technique to quantify lens decentration relative to the corneal normal (repeatability of ± 0.025 mm) using anterior segment optical coherence tomography which requires segmentation of the anterior lens and anterior corneal surface along the horizontal and vertical meridians, and determination of the location of the normal to each

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segmented surface, again using customised software.

While the above techniques are highly repeatable and suitable in a research setting, a technique that facilitates the reliable quantification of scleral lens decentration without the use of custom built instrumentation and additional software (and that does not require marking of the lens surface) is of potential use in clinical practice. In this paper, a simple method is presented to quantify scleral contact lens decentration (horizontal and vertical lens translation relative to the pupil centre) using over-topography captured with a Placido ring videokeratoscope during lens wear.

2. Methods

Scleral lens decentration was derived from over-topography data obtained during scleral lens wear in a prior study examining lens flexure [9]. This study was approved by the Queensland University of Technology human research ethics committee and followed the tenets of the Declaration of Helsinki and all participants provided informed consent. The participant characteristics, scleral lens parameters, and acquisition of over-topography maps have been previously described in detail. Briefly, ten healthy participants (nine study participants and one pilot study participant [9]) (mean age 26 ± 5 years, 7 female, 3 male and 7 Caucasian, 3 East Asian) with normal corneae and visual acuity (logMAR 0.00 or better) had over-topography measured after 15 min of lens settling (E300 Placdio ring videokeratoscope, Medmont, Melbourne, Australia). The lenses were soaked in conditioning solution (Boston Advance, Bausch and Lomb) for twenty-four hours prior to topography measurements and lubricating drops were applied in the case of reduced surface wettability.

Three different miniscleral lenses (hexafocon B) (Irregular Corneal Design, Capricornia Contact Lenses, Brisbane, Australia) were used in this study with the same aspheric back optic zone and central radius (7.46 mm), sagittal depth (4200 µm over a 15 mm chord), back vertex power (-1.00 D), front optic zone diameter (8 mm) and total diameter (16.5 mm), with varying central thickness values of 150 µm, 250 µm and 350 µm. Since all lenses had a fixed sagittal depth, corneal height data over a 10 mm chord was used to assess suitability for inclusion, and lenses were assessed using a slit lamp and optical coherence tomographer to ensure adequate corneal clearance.

2.1. Data analysis

Two different topography maps (measurement 1 and 2) were randomly selected from one measurement session (for either the 150 µm, 250 µm or 350 µm centre thickness lens) for each participant and were examined by a single observer. The topography maps were analysed to estimate the lens decentration relative to the pupil centre using two techniques with different dioptric scales based on the centre of; 1) the annular change in the standard tangential power map (default pre-defined dioptric scale of 35–50 D) and 2) the outermost annuli of change in the normalised tangential power maps (using an automatically adjusted dioptric scale which limits the upper and lower bounds of the scale to the maximum and minimum values within the topography map examined). The topographic changes observed in the tangential power maps are concentric with the edge of the front optic zone (Fig. 1). While axial power maps have been used previously to quantify corneal and scleral lens flexure [9,10], tangential power maps were chosen for this application since they more clearly highlight localised topographical variations.

Using the Medmont Studio software, an ellipse was manually fitted to the pupil and the region of topographical change in the tangential power maps concentric with the front optic zone of the lens (as shown in Fig. 1). The location of the centre of the pupil and front optic zone ellipse were extracted in polar coordinates (r [mm], theta [radians]), relative to the vertex normal and converted to Cartesian coordinates (x [mm], y [mm]). Scleral lens (front optic zone) decentration relative to the pupil centre was then calculated as the difference between the pupil and optic zone centres relative to the vertex normal (with positive values indicating temporal and superior decentration of the lens centre relative to the pupil centre). An ellipse was fitted to the second topography map twice (for both the standard and normalised scale techniques) (measurement 3 in Fig. 1) to allow the calculation of the intraobserver repeatability of lens decentration for each technique (agreement between measurements derived from the same topography map by the same observer). Similarly, the intrasession repeatability was determined by comparing measurements 1 and 2 (agreement between measurements derived from two different topography maps captured within the same measurement session by the same observer), and the intertechnique agreement was examined by comparing measurement 2 using the two techniques (agreement between measurements derived from the same topography map by the same observer using the two different tangential power scales).

2.2. Statistical analysis

The methods described by Bland and Altman were used to assess the intrasession and intraobserver repeatability and the intratechqniue agreement, by calculating the mean difference, the standard deviation of the mean difference and the 95% limits of agreement (LoA) [11]. Given the small sample size for repeatability analyses (n = 10), the exact 95% confidence intervals (considered as a pair) for the 95% LoA were also calculated [12]. This provides a conservative estimate of the true LoA (presented throughout this paper as the outer bounds of the exact 95% confidence intervals for the upper and lower 95% LoA). The outer bounds were calculated using a sample size of 10 participants (rather than the 10 paired [n = 20] data points presented as the horizontal and vertical decentration in Figs. 2 and 3).

3. Results

3.1. Intrasession repeatability (comparison of measurement 1 and 2)

3.1.1. Standard tangential power scale

The mean decentration derived from measurement 1 was 0.62 ± 0.18 mm temporally and 0.90 ± 0.36 mm inferiorly, compared to 0.62 ± 0.17 mm temporally and 0.93 ± 0.34 mm inferiorly for measurement 2 (measurements obtained from two different topography maps captured within minutes) (Table 1). Considering both horizontal and vertical decentration, the mean difference between the two measurements was 0.01 ± 0.08 mm (95% LoA -0.14 to 0.16 mm). The outer bounds of the 95% exact confidence intervals for the upper and lower 95% LoA were -0.28 to 0.30 mm (Fig. 2A).

3.1.2. Normalised tangential power scale

The mean decentration derived from measurement 1 was 0.60 ± 0.25 mm temporally and 0.93 ± 0.36 mm inferiorly, compared to 0.65 ± 0.19 mm temporally and 0.89 ± 0.34 mm inferiorly for measurement 2 (Table 1). Considering both horizontal and vertical decentration, the mean difference between the two measurements was 0.04 ± 0.10 mm (95% LoA -0.16 to 0.23 mm). The outer bounds of the 95% exact confidence intervals for the upper and lower 95% LoA were -0.33 to 0.41 mm (Fig. 2C).

3.2. Intraobserver repeatability (comparison of measurement 2 and 3)

3.2.1. Standard tangential power scale

The mean decentration derived from measurement 2 was 0.62 ± 0.17 mm temporally and 0.93 ± 0.34 mm inferiorly, compared to 0.62 ± 0.17 mm temporally and 0.93 ± 0.34 mm inferiorly for measurement 3 (a repeated measurement from the same topography map used in measurement 2) (Table 1). Considering both horizontal and vertical decentration, the mean difference between the two

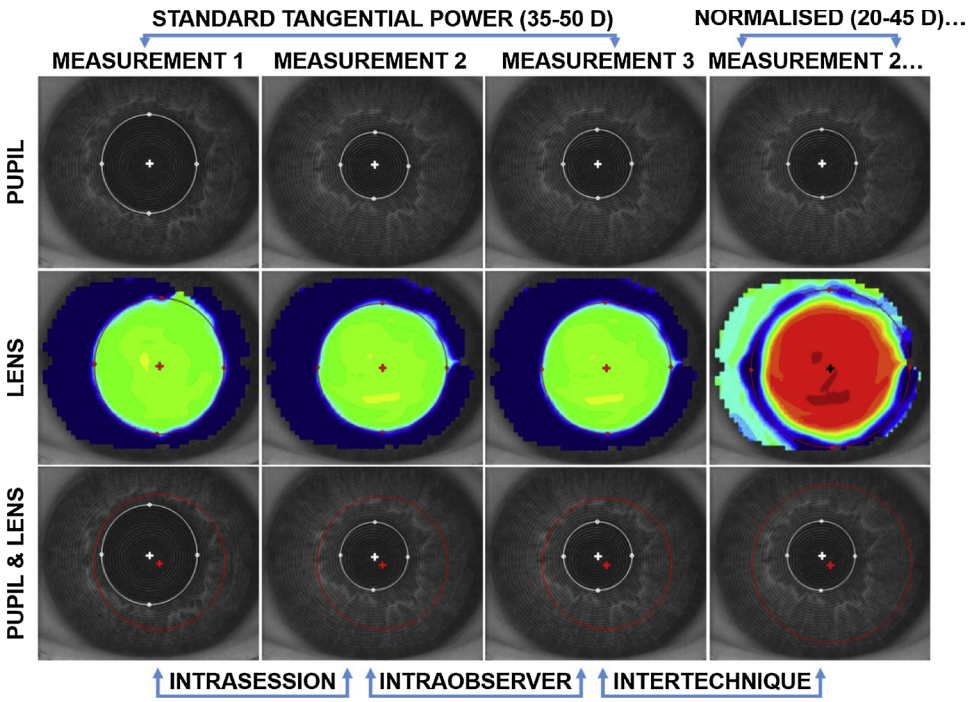

Fig. 1. Schematic of the method used to quantify decentration of the centre of the scleral lens front optic zone from the pupil centre. An ellipse was fitted to the pupil outline (white line, top panels) and the region of topographical change in the tangential power map concentric with the scleral lens front optic zone (red line, middle panels). The bottom panels display both the pupil and region of topographic change concentric with the scleral lens front optic zone and the ellipse centres (white and red cross). Two different over-topography maps within the same measurement session were compared for intrasession repeatability (measurement 1 and 2), and the same topography map was analysed twice (measurement 2 and 3) to evaluate intraobserver repeatability. The intertechnique repeatability was calculated by comparing decentration measurements derived from measurement 2 using the standard and normalised dioptric power scales.

measurements was 0.00 ± 0.03 mm (95% LoA -0.06 to 0.07 mm). The outer bounds of the 95% exact confidence intervals for the upper and lower 95% LOA were -0.12 to 0.13 mm (Fig. 2B).

3.2.2. Normalised tangential power scale

The mean decentration derived from measurement 2 was 0.65 ± 0.19 mm temporally and 0.89 ± 0.34 mm inferiorly, compared to 0.65 ± 0.17 mm temporally and 0.91 ± 0.33 mm inferiorly for measurement 3 (Table 1). Considering both horizontal and vertical decentration, the mean difference between the two measurements was 0.01 ± 0.06 mm (95% LoA -0.10 to 0.12 mm). The outer bounds of the 95% exact confidence intervals for the upper and lower 95% LOA were -0.21 to 0.22 mm (Fig. 2D).

3.3. Intertechnique agreement (comparison of standard and normalised map techniques)

Data summarising the different decentration values derived using the two techniques are presented in Table 1 for the three difference measurements. However, the data used to calculate the limits of agreement between the two techniques included data from measurement 2 only since this showed the greatest discrepancy. Considering both horizontal and vertical decentration, the mean difference between the two techniques was -0.04 ± 0.06 mm (95% LoA -0.16 to 0.09 mm). The outer bounds of the 95% exact confidence intervals for the upper and lower 95% LoA were -0.27 to 0.20 mm (Fig. 3).

4. Discussion

This paper describes a simple method to quantify the magnitude and direction of scleral contact lens decentration using a Placido ring videokeratoscope to capture measures of central over-topography during lens wear. A similar approach has been described previously to evaluate the location of the central optic zone of soft and rigid corneal multifocal lenses relative to the pupil [13,14], however, the method described in this paper extends upon this qualitative technique by manually fitting an ellipse to both the pupil and topographical changes in the tangential power map concentric with the edge of the front optic zone, from which the decentration of the centre of the optic zone relative to the pupil centre can be calculated.

Averaged across each topography map (including repeated measures) and each measurement technique (standard and normalised tangential topography maps), the group mean decentration observed in the ten participants was 0.62 ± 0.18 mm temporally (range 0.19 to 0.98 mm) and 0.91 ± 0.33 mm inferiorly (range 0.41 to 1.65 mm) after 15 min of lens wear. This is in broad agreement with other studies reporting inferior and temporal decentration ranging from 0.1 to 0.27 mm horizontally and 0.15 to 0.88 mm vertically for a range of lens designs, lens diameters, wearing times, and methods to quantify decentration [5,7,8]. In a previous study examining the temporal dynamics of 16.5 mm diameter Irregular Corneal Design trial lenses [5], less decentration was observed compared to the current study (0.20 mm or less on average), which may be due to differences in the scleral topography of the participants in each study, and the differences in the lens design (lenses used in the current study had a fixed sagittal depth).

As anticipated, the intraobserver repeatability (repeated measurements of the same standard tangential map, 95% LoA of ± 0.07 mm) was significantly better than the intrasession repeatability (agreement between two different standard tangential maps within the same measurement session, 95% LoA of ± 0.15 mm). This suggests that this topographical method is slightly less repeatable than previously described methods (repeatability of ≤ ± 0.025 mm) using customised instrumentation and software [5,7,8], but is reasonably robust to short-term fluctuations in pupil size and anterior lens surface topography which vary within and between a series of topography images. While this approach may not be suitable for customised lenses designed to correct higher order aberrations, for which optimum alignment of the optic zone with the pupil is critical, it may be a useful approach to quantify the magnitude and direction of lens decentration for different scleral lens designs trialled, or following lens modifications, in clinical practice. In particular, this approach may be useful to assess the centration of multifocal scleral lenses, or to locate the pupil centre and dimensions relative to the optic zone centre for tinting purposes.

While the intertechnique agreement was reasonable (95% LoA ± 0.13 mm), using the standard dioptric scale (35–50 D) for the tangential power map yielded better intrasession and intraobserver repeatability than the normalised scale technique, most likely due to the less ambiguous change in the topography of the tangential power

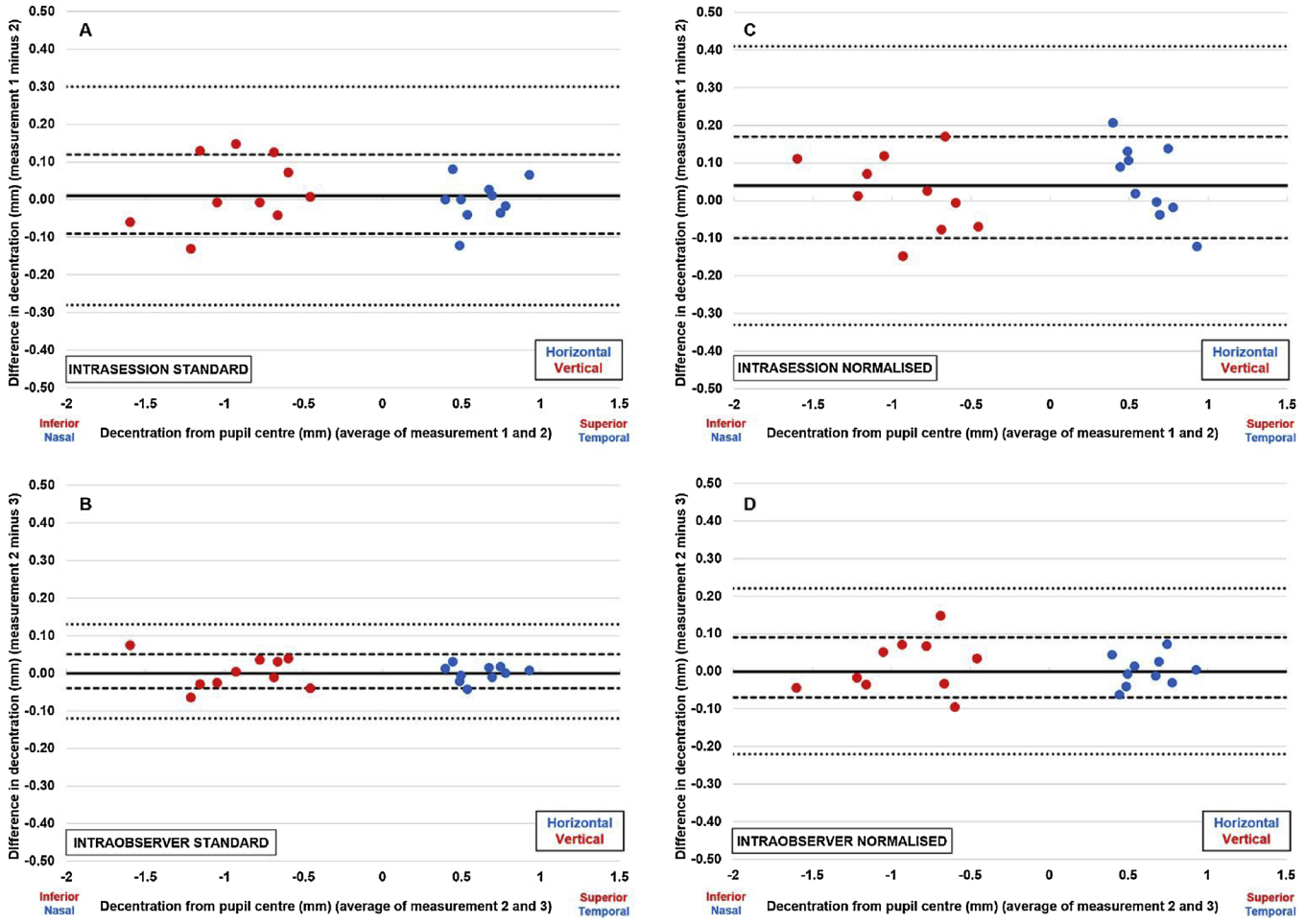

Fig. 2. Bland-Altman plot of intrasession (A and C) and intraobserver (B and D) repeatability for the standard and normalised techniques: the difference in scleral lens front optic zone decentration from the pupil centre as a function of the average scleral lens front optic zone decentration from the pupil centre. Vertical decentration (red) and horizontal decentration (blue) data points are presented separately. Negative values on the x-axis indicate inferior and nasal lens decentration. The solid black line represents the mean difference, the dashed lines represent the 95% LoA, and the dotted lines represent the outer bounds of the 95% exact confidence intervals around the 95% LoA.

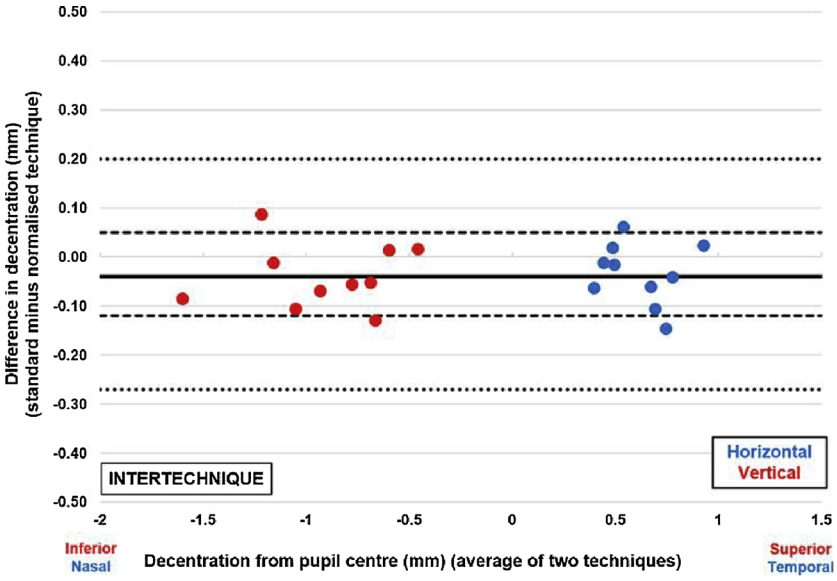

Fig. 3. Bland-Altman plot of intertechnique repeatability: the difference in scleral lens front optic zone decentration from the pupil centre (standard minus normalised technique) as a function of the average scleral lens front optic zone decentration from the pupil centre (average of the standard and normalised technique) for the same over-topography maps. Vertical decentration (red) and horizontal decentration (blue) data points are presented separately. Negative values on the x-axis indicate inferior and nasal lens decentration. The solid black line represents the mean difference, the dashed lines represent the 95% LoA, and the dotted lines represent the outer bounds of the 95% exact confidence intervals around the 95% LoA.

Table 1
The group mean horizontal and vertical lens decentration derived using the two techniques (standard and normalised tangential power maps) from three measurements.

	Technique			
	Standard		Normalised	
Measurement	Horizontal (mm)	Vertical (mm)	Horizontal (mm)	Vertical (mm)
1	0.62 ± 0.18	−0.90 ± 0.36	0.60 ± 0.25	−0.93 ± 0.36
2	0.62 ± 0.17	−0.93 ± 0.34	0.65 ± 0.19	−0.89 ± 0.34
3 (2 repeated)	0.62 ± 0.17	−0.93 ± 0.34	0.65 ± 0.17	−0.91 ± 0.33

Positive values denote temporal and superior lens decentration.

map concentric with the optic zone (Fig. 1). That is, the point at which the tangential power of the anterior scleral lens surface reduces below the lower 35 D standard scale threshold (approximately 3 mm from the optic zone centre) is more apparent. Therefore, a single central tangential topography map using the standard fixed scale (without map pasting to generate a composite map or customising the tangential power scale) provides a reliable method of quantifying scleral lens decentration. However, the analysis presented in the current paper only considers a single lens design and the optimum tangential power scale to reliably estimate the centre of the front optic zone may vary with lens design, the magnitude of lens flexure, or lens wettability.

Given the optic zone diameter of many scleral contact lenses is 8–10 mm, some level of decentration is acceptable and the optical correction will still cover the pupil under scotopic lighting conditions. However, optimum centration is critical for customised higher order aberration corrections, multifocal optics, and significantly mislocated pupils (e.g. physiological, traumatic, or post-operative corectopia). Pullum suggests decentring the optic by 1–1.5 mm nasally to improve overall lens centration and minimise rotation [15], however, customised optic zone decentration may improve visual outcomes compared to a fixed offset value since significant between subject variations were observed in the current study (maximum between subject variation of 0.8 mm horizontally and 1.2 mm vertically) and previous work (maximum intersubject variation of 0.6 mm horizontally and 1.4 mm vertically after 8 h of lens wear) [5]. While decentring the optic zone to align with the pupil may improve visual outcomes during scleral lens wear, other modifications may also be required if the decentration results in an unacceptable lens fit (e.g. excessive movement or edge lift) such as; fitting a smaller diameter lens, a toric, quadrant specific or customised back surface haptic zone, or minimising lens thickness (lens mass).

5. Conclusion

The method described in this paper allows reliable quantification of scleral lens optic zone decentration relative to the pupil centre (95% LoA ± 0.07 mm) using over-topography measurements acquired from a Placido ring videokeratoscope and manufacturer provided software without the need for customised anterior eye photography, imaging processing software, optical coherence tomography, or markings applied to the contact lens surface. This method has a range of potential applications in scleral lens research and clinical practice.

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