Scleral Profiles of Keratoconic vs. Normal Eyes:

Determining the Importance of Scleral Toricity in Fitting Scleral Lenses

Theodore Chow, M.Sc., Jason Jedlicka, OD, FAAO, Christopher Clark, OD, PhD

Indiana University School of Optometry, Bloomington, Indiana

INDIANA UNIVERSITY SCHOOL OF OPTOMETRY

INTRODUCTION

Keratoconus is a non-inflammatory disease of the cornea characterized by progressive corneal thinning and ectasia, resulting in corneal steepening, high-order aberrations, and irregular astigmatism. In many instances, these parameters collectively indicate the fitting of scleral lenses to optimize visual acuity and corneal health[1]. By vaulting over the entire cornea, the large diameter scleral lenses not only protect from apical corneal scarring, but are remarkably stable allowing for correction of both irregular astigmatism and, potentially, higher-order aberrations[2]. Paramount in the fitting of scleral lenses is aligning the haptic zone of the lens to the scleral profile. However, very little is known about the scleral profiles in normal eyes, let alone keratoconic eyes, as there is little normative data[3].

PURPOSE

The purpose of this study was to build upon a normative database by identifying differences in keratoconic vs. normal scleral profiles, specifically focusing on scleral toricity and steepest meridian. Indeed, we aimed to identify how differences in these scleral parameters may inform on optimal scleral lens fitting in challenging keratoconic eyes.

METHODS

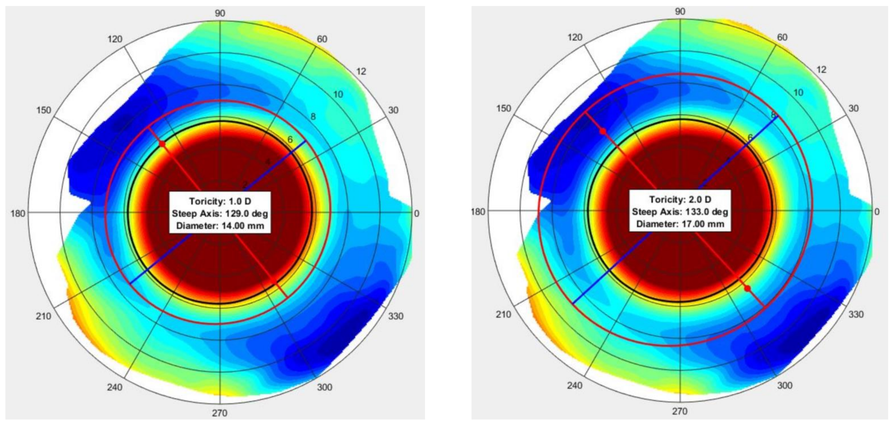
Demographics: The scleral profile of 22 keratoconic (10 OD and 12 OS) and 30 normal eyes (17 OD and 13 OS) were retrospectively analyzed using profilometry-based scleral topography (sMap3D, Visionary Optics).

Outcome Measures: Scleral toricity and steepest axes were compared between groups at four corresponding chord diameters: 14, 15, 16, and 17 millimeters. Groups were further subcategorized into with-the-rule (WTR), against-the-rule (ATR) and oblique astigmatism, defined as flattest meridians landing between 0 to 30 and 150 to 180 degrees, 60 to 120 degrees, and 31 to 59 and 121 to 149 degrees, respectively. Finally, to quantitatively analyze the amplitude of toricity by both magnitude and axis, we transformed the measured toricity into two power vectors. J_0 refers to cylinder power set at orthogonally 90 and 180 degree meridians, and J_{45} refers to cross-cylinder set at 45 and 135 degrees, representing oblique astigmatism.

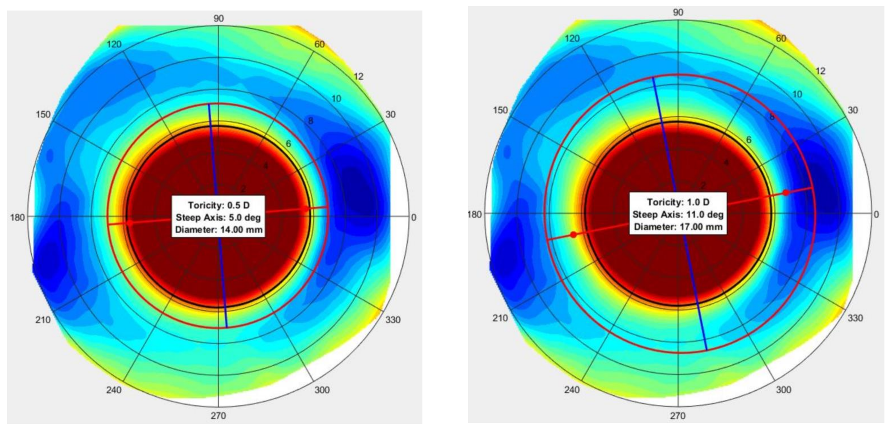
Statistical analysis: Univariate repeated measures ANOVA and student's t-tests were calculated using SPSS v24 (IBM, Chicago, IL).

RESULTS

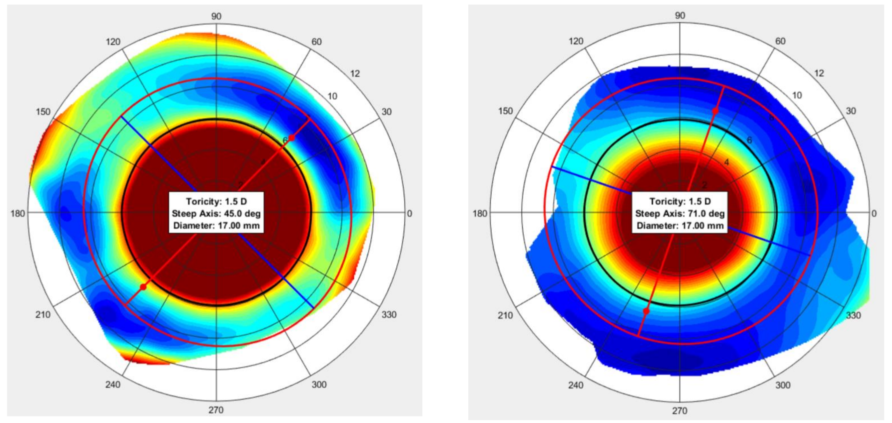
sMap Scleral Topography



Keratoconic patient showing 1.0D of oblique toricity at 14mm diameter (left) vs. 2.0D of oblique toricity at 17mm (right)

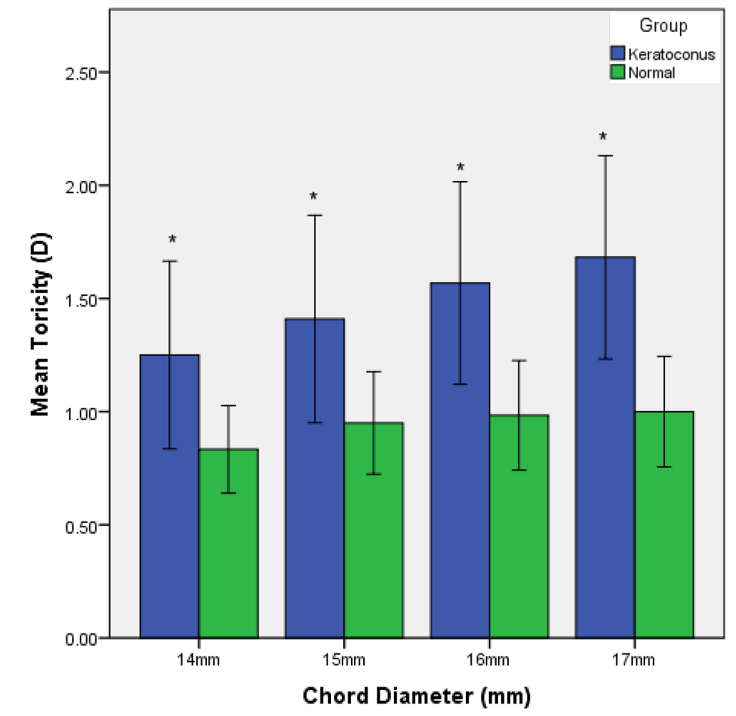


Healthy patient showing 0.5D of WTR toricity at 14mm diameter (left) vs. 1.0D of WTR toricity at 17mm (right)



Normal patient showing 1.5D of oblique toricity at 14mm diameter (left) vs. a keratoconic patient showing 1.5D of oblique toricity at 17mm (right)

Overall Differences in Scleral Toricity

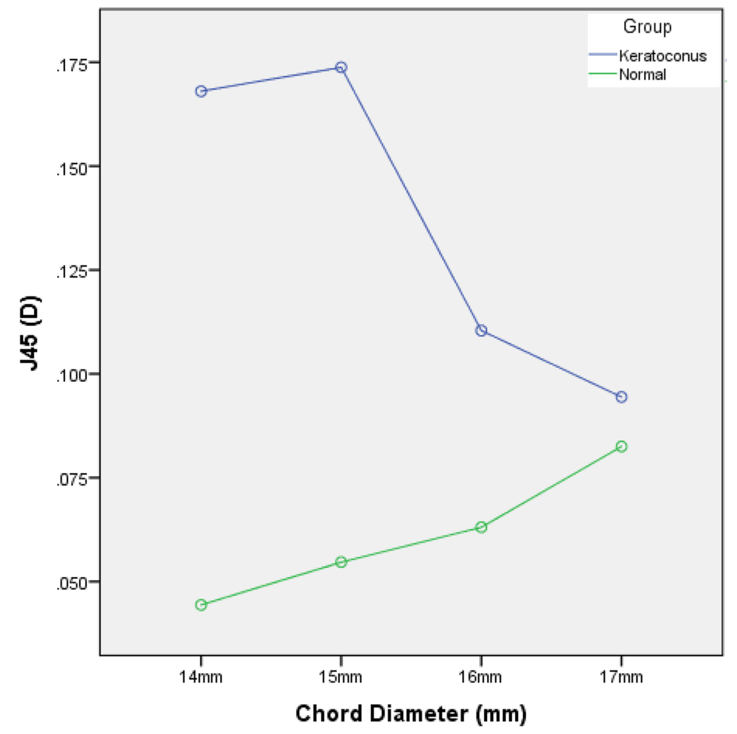


When comparing differences in scleral toricity between all keratoconic vs. all healthy individuals, we found that keratoconic patients had significantly greater astigmatism at each of the four chord lengths mentioned. Mean differences became more pronounced towards the peripheral sclera (at 17mm).

**p<0.05, Mean ± SEM*

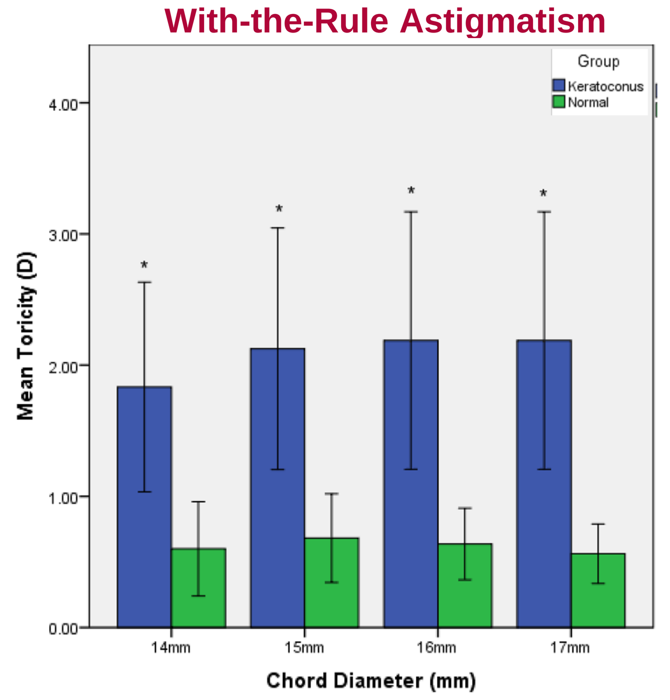
J_{45} Power Vector (for Oblique Astigmatism) Reveals an Interaction

Interestingly, when analyzing the J_{45} power vector, which accounts for meridian and amplitude, there was a significant interaction between groups for the J_{45} vector representing oblique astigmatism, $F(3, 150) = 2.93$, $p = 0.036$. As chord diameter increases, the difference in oblique astigmatism between groups becomes equivalent. Given this interaction, we decided to further analyze differential scleral toricity across type of astigmatism.

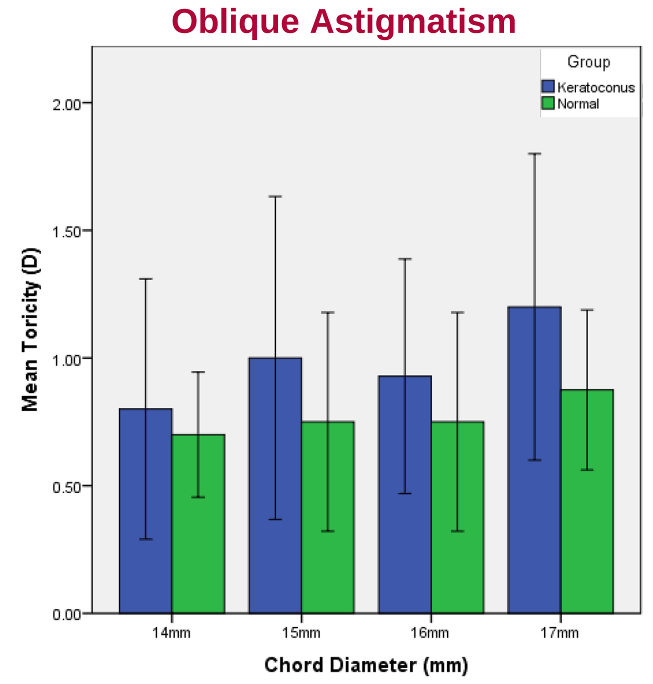


Differences in Scleral Toricity as a Function of Astigmatic Type

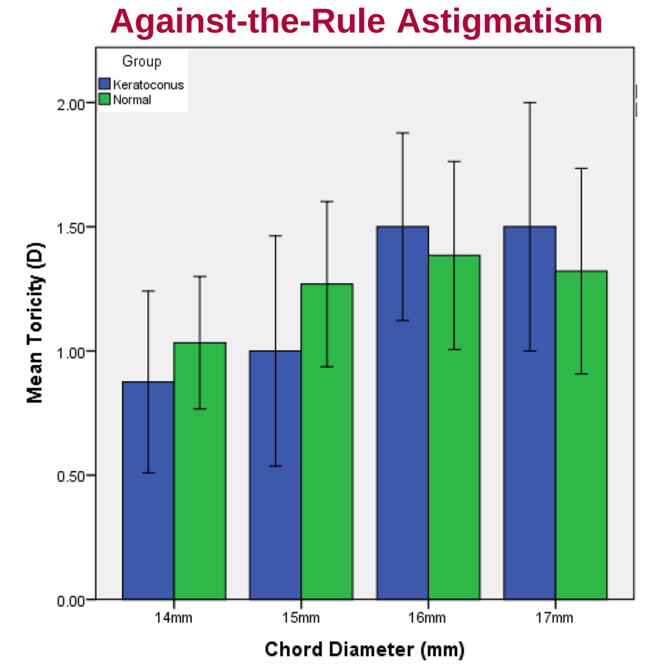
With-the-Rule Astigmatism



Oblique Astigmatism



Against-the-Rule Astigmatism



The significantly greater degree of scleral toricity in keratoconic individuals is shown here to be largely the effect of WTR toric individuals (*p<0.05). Indeed, the power vector, J_0 representing WTR astigmatism, also exhibited significant differences in toricity between keratoconic and normal individuals (although this was only significant at 14mm).

Scleral Toricity (D) at Varying Chord Diameters

Keratoconus	14mm	15mm	16mm	17mm
*WTR (n=9)	1.83 ± 1.20	1.94 ± 1.33	2.06 ± 1.36	2.06 ± 1.40
ATR (n=8)	0.88 ± 0.52	1.00 ± 0.65	1.31 ± 0.70	1.50 ± 0.65
Oblique (n=5)	0.80 ± 0.57	1.10 ± 0.82	1.10 ± 0.55	1.30 ± 0.76
All (n=22)	1.25 ± 0.97	1.41 ± 1.08	1.57 ± 1.05	1.68 ± 1.06
Normal				
*WTR (n=10)	0.60 ± 0.57	0.65 ± 0.58	0.60 ± 0.46	0.55 ± 0.37
ATR (n=15)	1.03 ± 0.52	1.13 ± 0.67	1.23 ± 0.75	1.30 ± 0.75
Oblique (n=5)	0.70 ± 0.27	1.00 ± 0.35	1.00 ± 0.35	1.00 ± 0.35
All (n=30)	0.83 ± 0.53	0.95 ± 0.62	0.98 ± 0.66	1.00 ± 0.67

Values are displayed as Mean Diopters ± Standard Deviation.
*p<0.05; mean difference in scleral toricity of WTR keratoconic patients vs. normal adults. Mean differences were significant for all four chord diameters.

SUMMARY

Overall Scleral Profile: The scleral profile, as measured by the sMap3D, indicates greater toricity in the scleras of keratoconic patients. As such, there may be a need for more toric haptics when fitting keratoconic patients in scleral lenses relative to normal eyes.

With-the-Rule Astigmatism: Interestingly, this toric haptic zone differential may apply only to patients exhibiting WTR astigmatism. In such eyes, scleral toricity in keratoconic patients are consistently greater than normals, but especially at the shorter chord diameters (14mm). This is confirmed with the J0 power vector, showing the greatest difference in toricity occurring at the 14mm chord length, with progressively equivalent toricities between keratoconic vs. normal patients towards the periphery.

Against-the-Rule and Oblique Astigmatism: Patients with ATR and oblique astigmatism failed to show any significant differences in toricity across any chord lengths. Nevertheless, the significant interaction at the J45 vector (oblique cylinder) hinted at a trend towards equivalent toricities between the two groups – again, towards the larger, more peripheral chord diameters (17mm)

CONCLUSIONS

Special consideration must be given towards fitting scleral lenses on keratoconic patients exhibiting WTR astigmatism, especially in the 14mm and 15mm diameters. Indeed, toric haptics would address the greater toricity found in these patients, ensuring comfortable and stable scleral lens fitting.

REFERENCES

1. van der Worp, E. A Guide to Scleral Lens Fitting [monograph online]. Forest Grove, OR: Pacific University; 2010. Available from: http://commons.pacificu.edu/mono/4/.
2. Yoon G, Johns L, Tomashevskaya O, Jacobs DS, Rosenthal P (2010) Visual benefit of correcting higher order aberrations in keratoconus with customized scleral lenses. ARVO poster; 3432
3. Morrison, S. The importance of scleral shape. Contact Lens Spectrum. 2016 June.