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ORIGINAL RESEARCH

Corneal Surface Elevation and Thickness in Relation to the Fit of Rigid Contact Lenses in Keratoconus and After Corneal Cross-Linking

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Purpose: To determine if factors pertaining to corneal thickness and elevation were linked to the prescribed back optic zone radius and overall diameter in keratoconus (group I), and cross-linked keratoconus (group II), cases successfully fitted with rigid contact lenses.

Patients and Methods: A review of cases adapted to contact lens wear (Rose K™) and assessed using Pentacam™ (for corneal anterior surface topography, astigmatism, elevation, and topographic thickness variation) was undertaken to determine the significance of any correlation with comfort, lens usage, grading of keratoconus, corrected distance visual acuity (with glasses and contacts), refractive error, prescribed lens powers, back optic zone radius and overall diameter values were assessed.

Results: Chief findings were, comfort was rated highly, lenses were worn for more than 10 hours/day in 75% of cases. RCL corrected distance logMAR acuities (median, mode, inter-quartile ranges) were 0.11, 0.12 (0.08–0.13) and 0.08, 0.08 (0.06–0.11) in groups I and II, respectively. Multiple linear regression revealed significant correlations ($p<0.01$) between the [A] back optic zone radius, the thinnest value of corneal thickness (x1) and anterior corneal surface elevation (x2). The respective r^2 values were 0.471 in group I and 0.512 in group II. [B] overall diameter, x1 and x2. The respective r^2 values were 0.282 in group I and 0.505 in group II.

Conclusion: RCLs were well-tolerated in both groups. The r^2 values imply there is a 50% chance of correctly predicting the suitable back optic zone radius in both groups, a 50% chance of correctly predicting the overall diameter in group II and 28% in group I cases using just x1 and x2. The thinnest value of corneal thickness and anterior corneal surface elevation could be used to quickly select the BOZR and OD during RCL fitting. This has the potential to reduce chair-time, waste and improve efficiency.

Keywords: thinnest corneal thickness, lens radius and diameter

Introduction

An abundance of contact lens styles and designs have been advocated for the optimization of vision in keratoconus. These include rigid scleral and corneal lenses, soft flexible lenses, and hybrid combinations often referred to as "piggyback" lenses. The pros and cons of the diverse range of contact lenses currently available for vision correction, and maintaining comfort, in keratoconus are thoroughly discussed in some extensive recent reviews.[1–5] Fitting contact lenses to the novice or veteran keratoconus patient can be challenging. Keratoconus patients generally require more chair-time, several trial lenses may be used to reach an acceptable fit and power, and the lenses can be expensive.

The Rose K™ lens, approved by the FDA 1995, has been successful in providing both good vision and comfort in many cases of keratoconus cases.[6–10] In our experience this lens has also been useful in further improving visual acuity after cross-linking (CXL) in aggressive cases of keratoconus. Online video-based guidelines are available to facilitate the fitting of this lens.[11] However, independent studies based on hundreds of cases concluded the average number of trial

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lenses required to reach an optimum fit ranged from 1.7 to 3.4, and at times it was necessary to use 5 trial lenses to reach an optimum fit.[7,8,12,13]

Some investigators have issued their own guidelines for selecting the back optic zone radius (BOZR) of the Rose K lens to reduce chair-time and improve efficiency. The selection is based on estimating corneal curvature (SimK); but the advice ranges from selecting a BOZR that is either steeper, flatter, or same as mean SimK depending on the severity of the keratoconus.[2,7,8,14] Thus, the selection is directed by the fitter's grading of keratoconus.

Gupta et al[9] provided formulae for estimating the trial lens BOZR using SimK values obtained by Orbscan corneal topography over the central 3mm or 5mm optical zones of the cornea. More recently, Berjandy et al[15] generated equations for BOZR selection that depended on the flat and steep corneal radii, estimated by Javal keratometry, and corneal astigmatism. And video-keratoscopy has been advocated to estimate the BOZR and total diameter of the lens by considering the location, size and steepness of the cone.[2,16] The distorted corneal reflections are both difficult to interpret and measure during keratoscopy of the keratoconus eye. Besides the reliability of keratometry, the SimK estimation by video-keratoscopy in keratoconus is further impacted by factors such as eyelid pressure, tear film dynamics and the visual tasks undertaken by the patient immediately prior to ocular surface examination.[17–26]

Corneal tomography provides details of objectively measured corneal characteristics that bypass the operator error associated with subjective evaluation of corneal characteristics. Corneal tomography carries the potential to offer objective details of other corneal parameters that may be useful in selecting the BOZR and/or diameter of the lens in keratoconus. Factors that are relatively more stable and less likely to change during tomographic assessment. For example, corneal thickness and surface elevation. A preliminary, unpublished, in-house study suggested there may be a link between the thinnest corneal thickness (TCT) value, anterior corneal surface elevation (ACSE) and the finally prescribed Rose K BOZR and diameter. This anecdotal evidence implied TCT and ACSE, regardless of the topographic location, could be useful objective determinants for selecting BOZR and diameter. The aim of this study was to conduct an audit of cases successfully fitted with Rose K lenses and determine if the prescribed BOZR and overall diameter (OD) were associated with pre-and post-fitting factors such as refractive error, best corrected distance visual acuity (CDVA), initial grading of the keratoconus, power of contact lens prescribed, comfort, daily usage and objective factors such corneal anterior surface astigmatism, TCT and ACSE.

Materials and Methods

Study Design

This was a retrospective, observational, study consisting of chart review of keratoconus patients that underwent corneal assessment using Pentacam™ and successfully adapted to daily wear of Rose K lenses for more than 6 months. All patients had been fitted with lenses, and managed, by highly experienced clinicians. The review was conducted at Eye Clinic Svjetlost in Sarajevo, the study was approved by the Ethics committee at the Eye Clinic Svjetlost and the tenets of the Helsinki agreement were followed throughout. Signed consent had been obtained from all patients after they were fully informed about the procedures, risks and benefits. All patients had been examined fitted with contact lenses and followed up by the same clinical team, given permission to use their anonymized data.

Patient Selection

The records of keratoconus patients prescribed Rose K lenses between October 2020 and May 2023 that underwent anterior OCT assessment, had successfully adapted to daily wear of lenses without discomfort for no less than 6 months without need to replace lenses, were accessed for review. Records of patients with central corneal scarring, history of ocular surgery apart from CXL, severe infection or other ocular disease were excluded.

Two-hundred and eighty-five charts were reviewed, and cases were separated into two groups I) Keratoconus wearing Rose K lenses and II) Keratoconus cases previously treated with cross-linking (CXL) more than one year previous and subsequently fitted with Rose K lenses for additional improvement of visual acuity. These cases had been fitted with Rose K lenses by one member of the team (SG) no less than 10 weeks after CXL when the best spectacle correction had stabilized (changes of no more than ±0.50D in the sphere and ±0.50D in the cylinder between successive postop checkups).

The reasons for, and more precise details of, the CXL procedure in the Group II cases are fully described elsewhere.[27] Cross-linking had been performed in accordance with the Dresden protocol by a single ophthalmologist (AB).

Only data from right eyes were selected from bilateral cases. The data recorded from the records were as follows.

Patient-Related

Patient age, gender, best corrected distance visual acuity (CDVA with spectacles and contact lenses) and grade of keratoconus. All patients were self-described as Caucasian. In every case, the CDVA was recorded using the same chart (Clear Chart 2 Digital Acuity Systems, Reichert™) during subjective refraction and the final prescribed contact lens power was determined by refracting over the best fitting lens after correcting for back vertex distance.

In CXL cases, the grade of keratoconus prior to cross-linking was recorded. Keratoconus was graded from 0-to-4 according to the "A, B, C, D" staging system advocated by Belin et al and fully explained elsewhere.[28]

Patient's self-assessment of the comfort experienced during contact lens wear was evaluated on a 0-to-5 visual analogue scale (where 0=very poor, 1=poor, 2=not good, 3=satisfactory, 4=good and 5=very good) like those proven useful in pain studies.[29,30] In addition, each patient recorded the total number of hours their lenses were worn each day, at 1 week, 3 and 6 months.

Pentacam

A single factory calibrated, and regularly serviced, Pentacam device was used on all occasions. The data harvested from Pentacam were corneal surface topography, including SimK values, anterior surface astigmatic power (difference between maximum and minimum SimK values) and details describing anterior corneal surface elevation (ACSE), topographic pachymetry, including value of lowest corneal thickness (TCT), prior to contact lens fitting.

CL Related Data

All details of the final lens prescribed including BOZR, OD and power were retrieved for analysis. The contact lens fits were facilitated with a set of 26 Rose K trial lenses with BOZR ranging from 5.1 to 7.6 mm in 0.1 mm increments, diameters varying from 8.50 to 9.20mm and a range of powers.

Data and Statistical Analysis

Data were logged up on an Excel spread sheet and checked to determine the significance of any,

a. Differences between the two groups (where appropriate, Mann–Whitney *U*-test or unpaired *t*-test) in relation to i) contact lens comfort, ii) number of hours lenses were worn per day, iii) grade of keratoconus vi) refractive error (best spectacle sphere and cylindrical correction), v) best corrected logMAR distance visual acuity with spectacles (CDVAs) and finally prescribed contact lens (CDVAc), vi) TCT, vii) ACSE.
b. Association (where appropriate Spearman's rho, Pearson correlation, Mann–Whitney *U*-test or unpaired *t*-test) between finally prescribed lens BOZR and OD with i) contact lens comfort, ii) number of hours lenses were worn per day, iii) grade of keratoconus vi) refractive error (best spectacle sphere and cylindrical correction), v) CDVAs and CDVAc, vi) TCT, vii) ACSE, viii) age and gender. The analysis was extended to include anterior corneal surface astigmatism and the power of prescribed contact lens.

Depending on the outcome of this analysis, the data would be further investigated to determine if models could be constructed (linear and/or multiple regression) to predict the BOZR and/or OD based on objective quantitative measurements of TCT and ACSE and corneal surface astigmatism prior to lens fitting. Non-parametric tests were applied when data were not normally distributed (Kolmogorov–Smirnov test for normality). Associations were considered statistically significant when $p<0.05$ and, where appropriate, this was adjusted for the Bonferroni correction.

Results

Complete sets of data were found for 124 keratoconus (39 female, 85 male, age range 15–63 years) and 42 post-CXL cases (10 female, 32 male, age range 17–40 years). The main details of patient age, refractive errors, CDVA, comfort scores, daily usage, initial grading of keratoconus, final prescribed contact lens characteristics, corneal astigmatism, TCT and ACSE are shown in Table 1. There were significant differences between the two groups regarding age, average diameter of lens prescribed and initial grading of keratoconus. However, these were rendered insignificant after applying the Bonferroni correction except for the grading. In both groups, there were no significant associations between patient age and gender with BOZR or OD (p>0.05).

The significance of any correlations between prescribed lens BOZR and OD with initial grade of keratoconus, refractive error, CDVA, TCT, ACSE, corneal surface astigmatism, comfort and hours of daily lens wear are shown in Table 2.

All associations were significant except for; in the keratoconus group, i) BOZR and corneal surface astigmatism, ii) OD, refractive and corneal surface astigmatism; and in the post-CXL group i) BOZR, refractive cylinder, corneal surface astigmatism, CDVA and CL power ii) OD, refractive cylinder, corneal surface astigmatism and CDVA.

In both groups, the BOZR and OD values were significantly correlated with initial grade of keratoconus, spherical component of the refractive error, TCT and ACSE.

Figures 1A and B show the trends between BOZR, TCT and ACSE. Figures 2A and B show the trend between OD, TCT and ACSE.

After considering various permutations, multiple linear regression revealed significant associations between log BOZR, log TCT and ACSE; log OD, TCT and ACSE in the keratoconus group (n=124). Similarly, in the post-CXL

Table 1 Key results of the Audit

	***Keratoconus* (n=*124*)**	***Post-CXL*(n=*42*)**	***p***
Age(years)	*31.1 (±9.5, 29.4–32.8)*	*29.9 (±4.9, 25.-28.4).*	*0.01*
Sphere (D)	*−3.11 (4.66, −20.00 to +4.00)*	*−2.26 (3.40,-13.00 to +3.00)*	*>0.05*
Cylinder(D)	*−3.35 (2.48,-12.00 to 0.00)*	*−2.65 (1.94,-7.00 to 0.00)*	*>0.05*
Corneal astigmatism(D)	*−3.79 (2.52,-17.10 to 0.00)*	*−3.91 (2.04,-11.8 to −0.20)*	*>0.05*
CDVAs	*0.29, 0.30 (0.23–0.34)*	*0.30, 0.17 (0.13–0.47)*	*>0.05*
CDVAc	*0.11, 0.12 (0.08–0.13)*	*0.08, 0.08 (0.06–0.11)*	*>0.05*
TCT	*443 (75.9, 219–586)*	*430 (39.59, 345–512)*	*>0.05*
ACSE	*61.56 (39.94, 6.00–183)*	*68.79 (22.63, 26.0–114.0)*	*>0.05*
Back optic zone radius (mm)	*6.97 (0.67, 5.10–8.20)*	*6.85 (0.41, 5.90–7.60)*	*>0.05*
Overall Diameter (mm)	*9.00 (0.34, 8.50–10.40)*	*8.87 (0.16, 8.70–9.20)*	*0.02*
CL power (D)	*−6.80 (5.42,-25.00 to +5.75)*	*−6.37 (3.46,-14.00 to 1.50)*	*>0.05*
Comfort	*5.0, 5.0 (5.0–5.0)*	*5.0, 5.0 (5.0–5.0)*	*>0.05*
HDLW	*10, 10 (10–12)*	*10, 10 (10–12)*	*>0.05*
Grade of keratoconus	*2.0, 3.0 (2.0–3.0)*	*2.25, 2.0 (2.25–3.50)*	*<0.01*

Notes: The mean (±sd, 95% CI) values are shown for parametric data. Median, mode (inter-quartile ranges) values are shown for non-parametric data. The p-values note the significance of any differences between the two groups. Grade of keratoconus (0–4) classified according to "ABCD" scale.[27]

Abbreviations: CDVAs, best spectacle corrected logMAR visual acuity prior to contact lens fitting; CDVAc, best contact lens corrected logMAR visual acuity at follow up; TCT, thinnest corneal thickness (μ); ACSE, anterior corneal surface elevation (μ); D, diopters. HDLW, hours of daily lens wear.

Table 2 Correlations Between Prescribed Back Optic Zone Radius Overall Lens Diameter and Other Clinical Factors

	Keratoconus (n=124)	**Post-CXL(n=42)**
Back optic zone radius (mm)		
Grade of keratoconus	$r_s = -0.656$, $p<0.01$	$r_s = -0.458$, $p<0.01$
Sphere (D)	$r^2 = 0.260$, $p<0.01$	$r^2 = 0.480$, $p<0.01$
Cylinder (D)	$r^2 = 0.128$, $p<0.01$	$r^2 = 0.006$, $p>0.05$
Corneal astigmatism(D)	$r^2 = 0.039$, $p>0.05$	$r^2 = 0.001$, $p>0.05$
CDVAs	$r_s = -0.598$, $p<0.01$	$r_s = -0.261$, $p>0.05$
CDVAc	$r_s = -0.411$, $p<0.01$	$r_s = -0.08$, $p>0.05$
TCT	$r^2 = 0.392$, $p<0.01$	$r^2 = 0.359$, $p<0.01$
ACSE	$r^2 = 0.380$, $p<0.01$	$r^2 = 0.330$, $p<0.01$
CL power (D)	$r^2 = 0.726$, $p<0.01$	$r^2 = 0.084$, $p>0.05$
Comfort	$r_s = 0.133$, $p>0.05$	$r_s = -0.012$, $p>0.05$
HDLW	$r_s = -0.187$, $p=0.04$*	$r_s = -0.059$, $p>0.05$
Overall Diameter (mm)		
Grade of keratoconus	$r_s = -0.643$, $p<0.01$	$r_s = -0.438$, $p<0.01$
Sphere (D)	$r^2 = 0.151$, $p<0.01$	$r^2 = 0.404$, $p<0.01$
Cylinder (D)	$r^2 = 0.015$, $p>0.05$	$r^2 = 0.002$, $p>0.05$
Corneal astigmatism	$r^2 = 0.000$, $p>0.05$	$r^2 = 0.012$, $p>0.05$
CDVAs	$r_s = -0.543$, $p<0.01$	$r_s = -0.259$, $p>0.05$
CDVAc	$r_s = -0.363$, $p<0.01$	$r_s = -0.140$, $p>0.05$
TCT	$r^2 = 0.216$, $p<0.01$	$r^2 = 0.286$, $p<0.01$
ACSE	$r^2 = 0.226$, $p<0.01$	$r^2 = 0.367$, $p<0.01$
CL power (D)	$r^2 = 0.309$, $p<0.01$	$r^2 = 0.186$, $p<0.01$
Comfort	$r_s = 0.105$, $p>0.05$	$r_s = -0.041$, $p>0.05$
HDLW	$r_s = -0.176$, $p>0.05$	$r_s = -0.059$, $p>0.05$

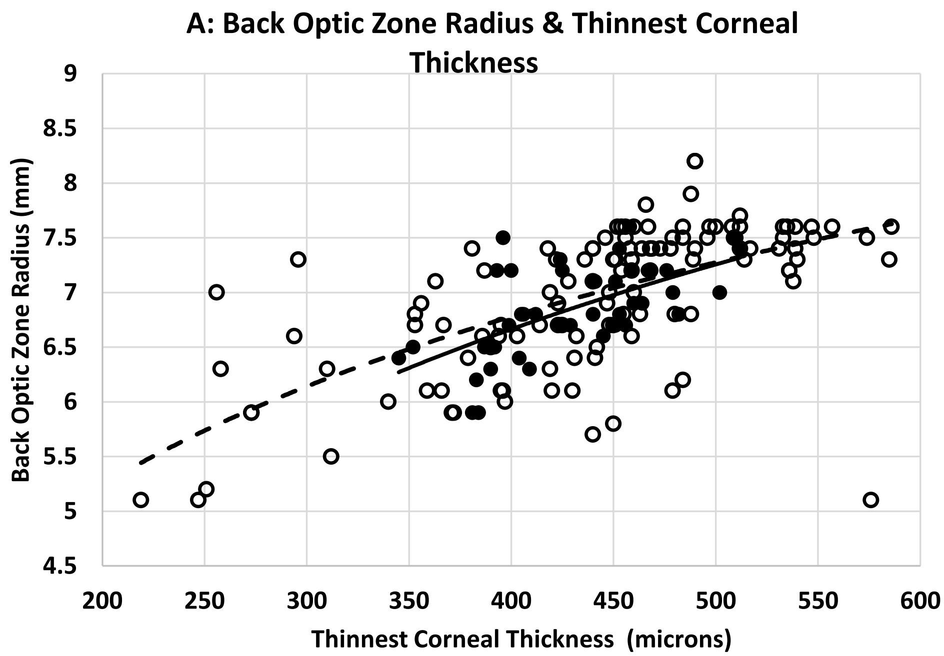
Notes: The square of the respective Pearson correlation co-efficient [r] for parametric factors, the Spearman's rho (r_s) for non-parametric factors and respective p-values are shown. The comfort scores were recorded at no less than 6 months after wearing lenses. *The significance was rejected after application of Bonferroni correction.

Abbreviations: CDVAs, best spectacle corrected logMAR visual acuity prior to contact lens fitting; CDVAc, best contact lens corrected logMAR visual acuity at follow up; TCT, thinnest corneal thickness (μ); ACSE, anterior corneal surface elevation (μ); D, diopters. HDLW, hours of daily lens wear.

group (n=42) significant associations were revealed between log BOZR, log TCT and log ACSE; log OD, log TCT and log ACSE. The expressions representing these associations are shown in Table 3.

Discussion

In both groups the CDVA was better with rigid contact lenses (RCLs) compared with glasses. This was an expected result confirming more recent reports focused on keratoconus.[31,32] The CDVA, either with glasses or RCLs, correlated with the



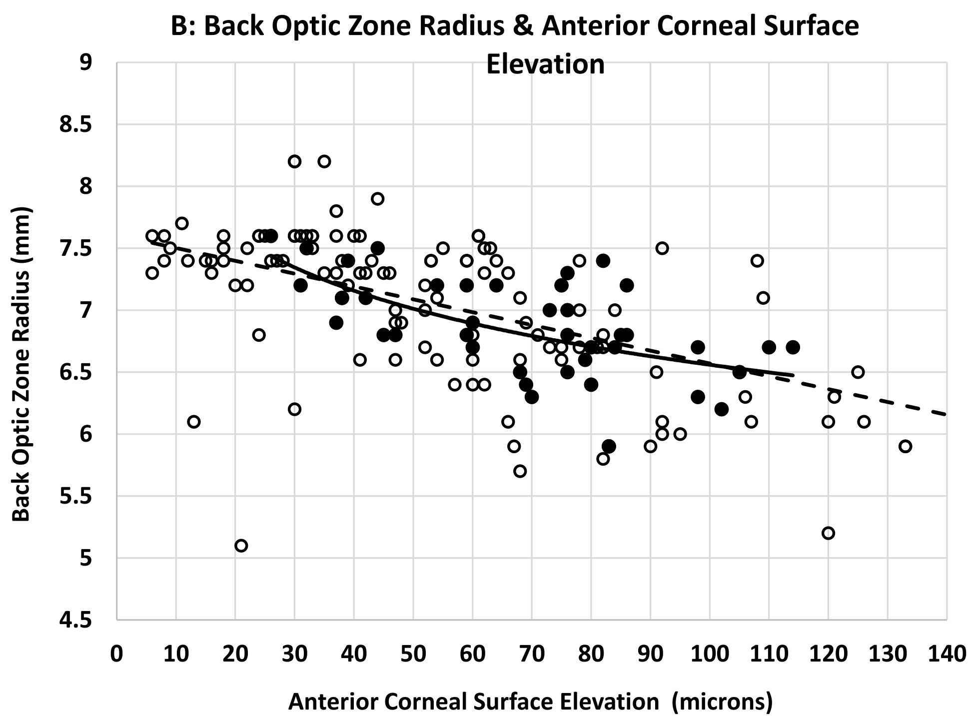


Figure 1 RCL back optic zone radius, thinnest corneal thickness (**A**) and anterior corneal surface elevation (**B**).

Notes: Associations for keratoconus (empty circles) and post-CXL cases (filled circles). The best fits are shown as broken lines for keratoconus and solid lines for post-CXL. NB, some data points overlap. For keratoconus the association between thinnest corneal thickness (TCT) and back optic zone radius (BOZR) is best represented by LogBOZR = 0.336.logTCT - 0.103 (r^2=0.403, n=124, p<0.01); association between anterior corneal surface elevation (ACSE) and BOZR is best represented by BOZR = 7.607–0.010.ACSE (r^2=0.380, n=124, p<0.01). The corresponding associations for post-CXL are LogBOZR = 0.395.logTCT −0.472 (r^2=0.366, n=42, p<0.01) and LogBOZR = 2.319–0.095.logACSE (r^2=0.342, n=42, p<0.01).

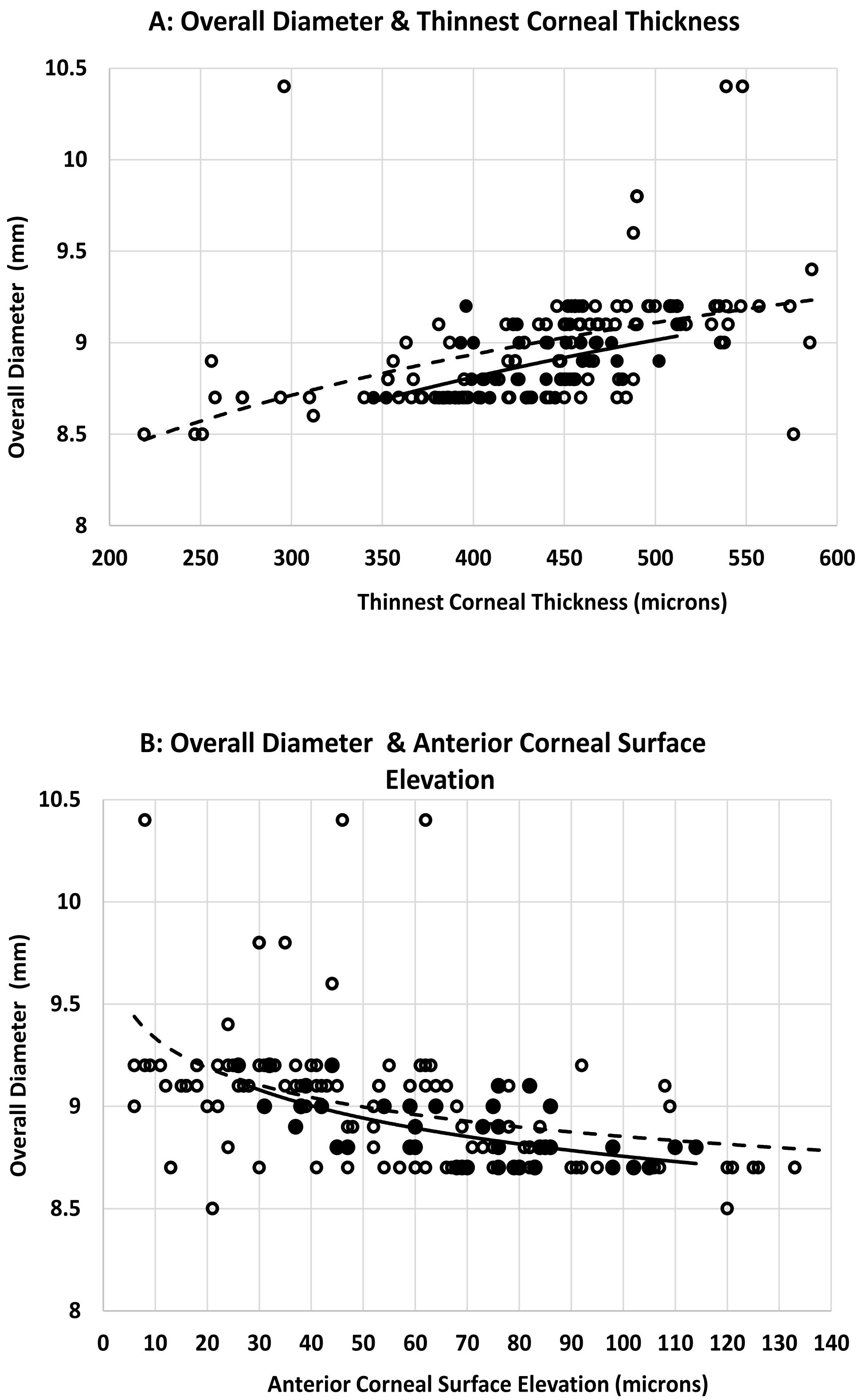


Figure 2 RCL overall diameter, thinnest corneal thickness (**A**) and anterior corneal surface elevation (**B**).

Notes: Associations for keratoconus (empty circles) and post-CXL cases (filled circles). The best fits are shown as broken lines for keratoconus and solid lines for post-CXL. NB, some data points overlap. For keratoconus the association between thinnest corneal thickness (TCT) and overall diameter (OD) is best represented by LogOD = 0.0002.TCT + 2.096 (r^2=0.229, n=124, p<0.01); association between anterior corneal surface elevation (ACSE) and OD is best represented by LogOD = 2.224–0.0004.ACSE (r^2=0.239, n=124, p<0.01). The corresponding associations for post-CXL are LogOD = 0.102.logTCT + 1.563 (r^2=0.288, n=42, p<0.01) and LogOD = 2.309–0.030.logACSE (r^2=0.404, n=42, p<0.01).

Table 3 Least Squares Expressions, Resulting from Multiple Linear Regression, Between Prescribed Back Optic Zone Radius, Overall Lens Diameter, TCT and ACSE

	Least Squares Expressions	r^2
Keratoconus (n=*124)*	log BOZR = 0.217 log TCT - 8.8×10^{-4} ACSE + 0.675 [eq.1]	*0.471*
	log OD = 1.3×10^{-4} TCT - 2.8×10^{-4} ACSE + 2.155 [eq.2]	*0.282*
Post-CXL (n=*42)*	log BOZR = 0.291 log TCT - 0.067 log ACSE + 0.437 [eq.3]	*0.512*
	log OD = 0.066 log TCT - 0.02 log ACSE + 1.886 [eq.4]	*0.505*

Notes: The square of the respective Pearson correlation co-efficient [r] is shown for each expression. The respective p-values were <0.01. The comfort scores were recorded at no less than 6 months after wearing lenses. For eq.1, the $r^2_{log\ TCT}$ and r^2_{ACSE} values were 0.404 and 0.376. For eq.2, the r^2_{TCT} and r^2_{ACSE} values were 0.229 and 0.239. For eq.3 the $r^2_{log\ TCT}$ and $r^2_{log\ ACSE}$ values were 0.366 and 0.344. For eq.4, the $r^2_{log\ TCT}$ and $r^2_{log\ ACSE}$ values were 0.297 and 0.433.
Abbreviations: BOZR, back optic zone radius (mm); OD, overall lens diameter (mm)TCT, thinnest corneal thickness (μ); ACSE, anterior corneal surface elevation (μ).

selected BOZR and OD in keratoconus but not in the post-CXL cases. It is not abundantly clear why this difference occurred. The difference may be related to differences in corneal surface topography and overall corneal optics. Proposing a reason for the difference at this stage would be purely speculative. However, the difference could be related to the specific design of the CXL protocol.

There was no difference between the two groups with respect to comfort and daily lens usage. Lim & Vogt reported, 65% of keratoconus patients wore lenses for up to 12 hours/day and 87% achieved CDVA of 20/30 (equivalent to logMAR 0.18) or better.[33] The hours of daily lens wear in our cases compare well with the previous finding, but the CDVA values with RCLs were slightly better than values reported by Lim & Vogt. The differences may be associated with differing RCL designs. Edrington et al reported there was no association between contact lens fitting characteristics and patients' comfort ratings in keratoconus.[34] The current study found this occurred in keratoconus and post-CXL cases.

There were significant differences between the two groups with respect to age, initial grading of keratoconus, mean OD of the lenses prescribed. The post-CXL cases tended to be younger, initially presented with more advanced and severe keratoconus, and required slightly smaller lenses compared with the non-CXL keratoconus cases. There was no significant difference in the mean BOZR value between the two groups, but keratoconus eyes required larger lenses. For any RCL design, the sagitta of the back surface is dependent upon both the BOZR and OD values. This suggests that post-CXL cases require not only smaller lenses, but lenses with smaller sagitta values. However, the differences in OD became insignificant after applying the Bonferroni correction.

The grade of keratoconus was negatively associated with BOZR and OD in both groups. This was not a surprise finding because a higher grading is generally associated with a more protruding, hence steeper, cornea. Satisfactory lens fittings were achieved with relatively smaller lenses when the grade of keratoconus was relatively higher. The higher the grade, the lower the BOZR and OD. Interestingly, neither BOZR nor OD correlated with corneal astigmatism. The corneal surface astigmatism was not a factor influencing the finally prescribed BOZR or OD.

In the keratoconus group, flatter and larger lenses were generally associated with numerically lower refractive errors, higher CDVA values and contact lens powers. Similar trends occurred in the post-CXL group, but there were no significant correlations with CDVA. The BOZR and OD values correlated with CDVA, with either glasses or RCLs, in the keratoconus group. The BOZR and OD values predict the likely CDVA in keratoconus, but not after CXL. The lack of statistical significance in the post-CXL group may be the result of a lower number of cases (42) compared with 124 in the keratoconus group.

These clinical nuances do not offer a practical solution for selecting a suitable lens during the fitting process. Alternatively, as demonstrated in Figures 1 and 2 and the expressions in Table 3, in both groups the corresponding TCT and ACSE values were strongly associated with the finally prescribed BOZR and OD. Eqs 1–4 provide options for selecting the trial lens BOZR and OD values on occasions when traditional procedures are not satisfactory. For example, for TCT & ACSE values of 440μ and 60μ, eqs 1 and 2 predict BOZR and OD values of 6.98mm and 8.98mm and the respective values according to eqs 3 and 4 are 6.92mm and 8.93mm. Thus, it would be prudent to select a BOZR of 7.00mm and OD of 9.00mm in keratoconus and 6.90mm and 8.90mm in post-CXL for evaluation when all else fails.

Figures 1A and B show low BOZR values are linked to thinner, more surface elevated, corneas. It is reasonable to expect relatively thin corneas to be more elevated. Eqs 1 and 3 feature correlation coefficient values that are higher for TCT than ACSE. Eqs 2 and 4 feature correlation coefficient values that are higher for ACSE than TCT. Therefore, when the selection of the RCL proves difficult using more traditional methods, then the TCT could be used to help select the BOZR and ACSE help select the OD.

The r^2 values in eqs 1 and 3 indicate there is a 50% chance of correctly predicting the BOZR of the RCL using the TCT and ACSE values, and the remaining variation is attributed to other factors. The best fit equations in Figure 1A imply that ignoring ACSE values reduces the chances of correctly predicting the BOZR to 40%. Turning to OD, eqs 4 and 2 imply that about 50-to-72% of the variation in the OD can be attributed to other factors besides TCT and ACSE values but ignoring TCT raises this range to around 57-to-76%. The best fit equations resulting from single linear regression, as noted in Figures 1 and 2, estimate BOZR and OD values that are generally within ±0.1mm of those resulting from multiple linear regression predictions. However, glancing over Figures 1A and 2A, the data points diverge away from the best fit lines for TCT values <325µ and >500µ. These outliers are interesting because none had undergone CXL. Incidentally, the cases where TCT >500µ were mainly graded as 0 or 1 and would, traditionally, have been classified as sub-clinical cases of keratoconus. In Figures 1B and 2B, the data points are more cohesive when ACSE >70µ suggesting other factors are more influential when ACSE is <70µ. The measurement of corneal front surface curvature marks the start of contact lens fitting. So, it comes as no surprise that correlations between characteristics of the lens back surface and corneal curvature are high and provide models for selecting the first trial lens during the fitting.[2,9,15,16,35] Bhatoa et al[36] used the FITSCAN software (for Orbscan II) to predict the required BOZR in keratoconus and compared the results with the habitual prescribed BOZR. There was reasonable agreement between the two sets of BOZR values though FITSCAN tended to provide a slightly flatter fit. Mandathara et al[37] also used FITSCAN and reported the predicted BOZR values were, on average, 0.22 mm higher (ie flatter) compared with the final prescribed values using the preferred diagnostic method. Practitioners are expected to use their own judgement when fitting lenses in keratoconus and post-CXL, though apical touch is preferred in over 85% of cases.[38] Nevertheless, eqs 1–4 are evidence based, objectively derived, models that offer alternatives for the selection when the preferred procedure is unfruitful.

Conclusion

In keratoconus and post-CXL, the fitting characteristics of prescribed RCLs are associated with the initial grading of keratoconus though post-CXL cases tend to require slightly smaller lenses. The CDVA is linked to the fitting characteristics in keratoconus but not in post-CXL. Several trial lenses are used when attempting to achieve an acceptable RCL fit in keratoconus. The objectively derived TCT and ASCE values harvested prior to RCL fitting could be used to select both the BOZR and OD of the trial lens. This has the potential to assist in the decision-making process and improve efficiency.

Ethics Approval and Informed Consent

The study was approved by the presiding Ethics Committee. The tenets of the Helsinki agreement were followed throughout. Signed informed consent was obtained from all patients after fully explaining all the procedures, risks, and benefits.

Author Contributions

Each author made a significant contribution to the work reported. Contributions with respect to study conception, design, execution, data collection, analysis, interpretation, drafting, revising or reviewing the article and giving the final approval of the version to be published, agreeing on the journal to which the article will be submitted and agreeing to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work. None of the authors have any financial interest in any of the products or procedures mentioned in this paper. The study was self-financed.

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