Case report

Measuring Scleral Lens Vault with Accuracy – A Case Report

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Abstract:

Keratoconus is a non-inflammatory ocular pathology affecting the cornea's shape due to thinning and protrusion. This condition can be unilateral or bilateral with asymmetric presentation between both eyes. Refractive correction with spectacles is helpful in the initial stages; however, contact lenses play a significant role in the advance stages. Various options for contact lenses are available, and practitioners can use those depending upon the severity of the condition, shape of the cone, and other factors. Scleral lenses have gained popularity in recent years because they vault over the cornea and the limbus with no touch and land on the sclera. Caution is warranted on the amount of vault created between the scleral lens and the cornea; hence accurate measurement can be a valuable tool for practitioners' confidence in prescribing these lenses. This case presentation summarizes the use of Anterior Segment Optical Coherence Tomography (AS-OCT) to accurately measure the vault and finalize the lens fitting.

Key Words: *AS-OCT, corneal topography, cross-linking, Keratoconus, scleral lenses*

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Introduction:

Keratoconus is a non-inflammatory ecstatic disorder of the cornea causing corneal protrusion and thinning, resulting in poor vision because of irregular astigmatism [1]. Due to the anatomical and optical irregularities, it presents challenges to achieve the best visual outcome. Spectacles can be used at the early stage of keratoconus, while due to the higher-order aberrations (HOAs) in advance stages, specialty contact lenses may be required to reduce HOAs by masking the corneal irregularities. With a range of specialty contact lens options now available, including specialty soft, custom-made corneal gas permeable (GP), piggyback, hybrid and scleral lens, clinicians fit patients successfully.[2]

Scleral lenses were initially designed to correct myopia and irregular cornea and one of the most cited contact lens options for keratoconus management [3]. This is because scleral lenses provide stable fitting with improved comfort even in advanced cases of keratoconus. A recent survey shows that the use of scleral lenses has increased [4]. This could be because the lenses also allow individual customization to provide a maximum visual outcome. Incorporating technologies such as the anterior segment optical coherence topography (AS-OCT) helps clinicians to observe the fitting accurately and measure the vault accurately, thereby improving the clinicians' confidence in fitting these lenses [5].

Case Report

Initial visit

A 28-year-old Indian male presented to the contact lens clinic for a new contact lens fitting. He was diagnosed with keratoconus in both eyes and had undergone corneal cross-linking in both eyes eight years ago. He had no family history of keratoconus, and he had no known drug allergies. The patient was a student studying master's in accounting. He had been wearing Rose K lenses (infrequently) since he was diagnosed with the condition. He was unaware of the specific design and parameters of the lenses. He had last worn his lenses a week back. He had been wearing spectacles most of the time. The reason for infrequent contact lens wear was due to the low level of comfort even though the visual quality was good. He had read about scleral lenses online and had come with a particular interest to try scleral lenses for his condition.

On examination, his corrected distance visual acuity with his habitual correction was 6/18, improving to $6/18^{+2}$ in the OD and 6/12 with no further improvement with a pinhole in the OS. His habitual Rx measured using the focimeter was -2.50 -3.25 x 45 OD and ± -2.75 x 140 OS.

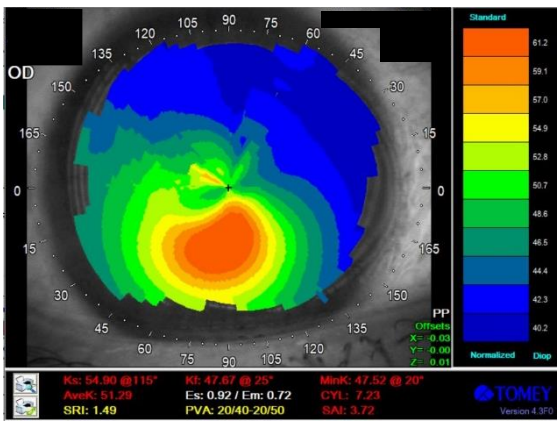
Extraocular motility was SAFE without pain or double vision. Pupils were equal, round, and reactive to light with no signs of relative afferent pupillary defect. Manifest refraction was -2.50 -3.25 x 30 OD and ± -2.75 x 140 OS with best-corrected distance visual acuity of 6/12 OD and 6/12 OS. Manifest refraction was noted to have a shift in the cylinder axis by 15 degrees for OD. Slit lamp biomicroscopy revealed the ocular adnexa's normal appearance, lids, lashes, conjunctiva, and cornea on both eyes with no clinical signs of keratoconus seen. No significant corneal staining was detected on staining the eye with 1mg Fluorescein Sodium LP moisten with normal saline. The tear breakup time (TBUT) was 8 sec OD and 9 sec OS. The patient's corneal thickness measured on the 3D OCT-1 Maestro AS-OCT was 442 microns on OD and 479 microns on OS.

The horizontal visible iris diameter (HVID) measured was 11mm on OD and OS, while the pupil size was 4.5mm on OD and OS under normal room illumination.

Corneal topography examination was performed using Tomey TMS-4 Topographic Modelling System (Tomey Co., Ltd., Nagoya, Japan). The results were the baseline topography values shown in Figures 1 and 2. On performing keratoconus screening on Tomey TMS-4, it showed 77.2% severity in OD and 82.9% severity according to Smolek / Klyce Screening. The Amsler's – Krumeich classification for keratoconus can be classified as Stage II for OD and Stage III for OS.

The options for vision correction for this patient based on the condition included:

- Spectacles
- Soft toric lenses / Customized soft toric lenses
- Rose K2 NC lens design
- Scleral lenses



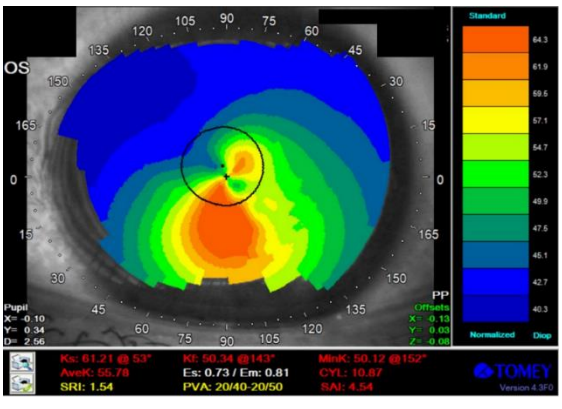


Figure 1

Figure 1: Corneal topography measured using Tomey TMS-4 Topographic Modelling System (Tomey Co., Ltd., Nagoya, Japan). Figure 1 shows the right eye's axial map, and Figure 2 shows the left eye's axial map. This shows that the left eye was more affected compared to the right eye.

Since the patient was not comfortable with his own Rose K lenses, it was decided to fit him with Rose K2 XL, the corneo-scleral lens design. Based on the recommended fitting guide, the initial lens parameters were calculated as shown in Table 1

Table 1: Parameters of the initial trial lens based on fitting guide.

Parameter	**OD**	**OS**
Base Curve	6.90 mm	6.70 mm
BVP	-7.00 D	-9.00 D
TD	14.60mm	14.60 mm

Trial #1

The lenses were inserted on both the eyes are the fitting evaluation was performed after 15-20 minutes of adaption time. The lenses were filled with normal saline before insertion. The dynamic fitting assessment a post blink movement of about 1-1.5mm on both eyes. The fluorescein pattern of the right and left eye is shown in Figures 2a and 3a, respectively. Figure 2a shows the right eye lens's fluorescein pattern was too flat as there was a central touch seen just at the cone apex position, while Figure 3a shows the left eye lens's fluorescein pattern flat to the optimum amount of fluorescein.

AS-OCT was performed using the 3D OCT-1 Maestro to measure the tear layer, referred to as vault. This showed that the vault was extremely low for the right eye (46 microns) shown in figure 2b, whereas it was near to adequate for the left eye (179 microns), as shown in figure 3b. There was also a large clearance zone at the lens's edge inferiorly due to excessive edge lift for both eyes.

These findings concluded that the fitting was very flat for the right eye, and it was optimum to flat for the left eye. Hence, both lens base curve was steeped. The parameters of Trial 2 are shown in Table 2.

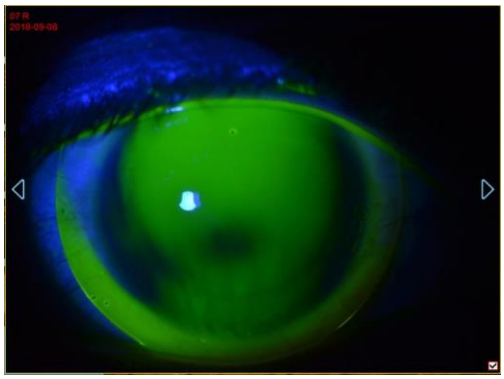


Figure 2a

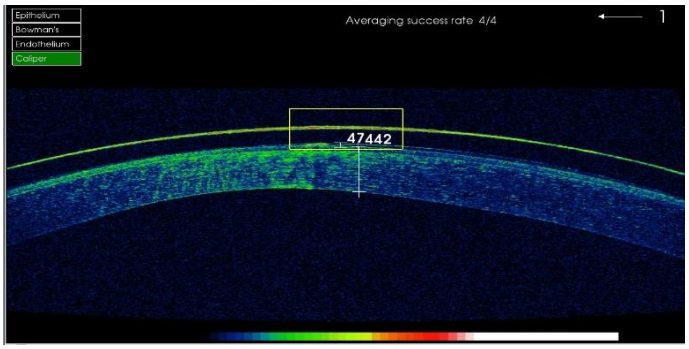


Figure 2b

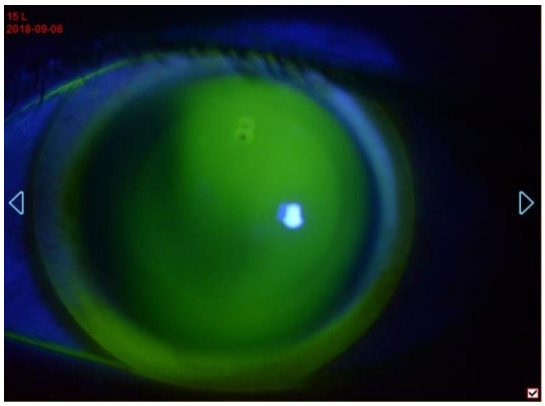


Figure 3a

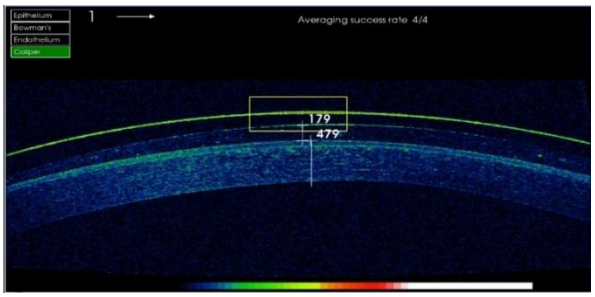


Figure 3b

Figure 2 and 3: Fluorescein pattern for the right eye is seen in figure 2a, and corresponding AS-OCT is seen in figure 2b, which shows touch at the cone apex and a low vault, respectively, indicative of a flat fit. Figure 3a shows the left eye's fluorescein pattern with the corresponding AS-OCT seen in Figure 3b showing a feathery touch with near to adequate vault indicative of an optimum to flat fit.

Table 2: Parameters of the lens for Trial 2

Parameter	**OD**	**OS**
Base Curve	6.60 mm	6.60 mm
BVP	-10.00 D	-10.00 D
TD	14.60mm	14.60 mm

Trial # 2

Based on the parameters in Table 2, lenses were inserted in both eyes, and fitting was assessed after 15-20 minutes of lens insertion. The dynamic fitting assessment a post blink movement of about 0.50 to 1mm on both eyes. The fluorescein pattern of the right and left eye is shown in Figures 4a and 5a, respectively showing an acceptable fluorescein pattern for both eyes.

AS-OCT was performed using the 3D OCT-1 Maestro to measure the tear layer, referred to as vault. This showed that the vault was acceptable for both eyes with these lenses. The vault was for the right eye was 258 microns (Figure 4b), and the left eye was 247 microns (Figure 5b). The edge lift was asymmetric between the vertical and horizontal meridian, specifically in OD; however, no modifications were made to the edge profile for both the eyes.

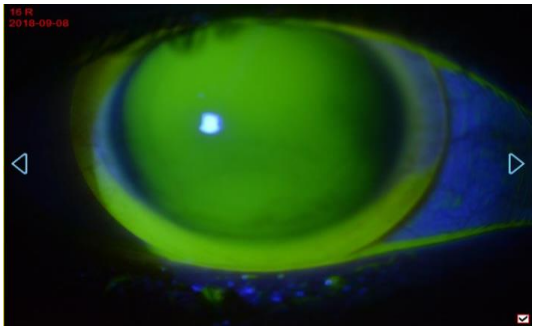


Figure 4a

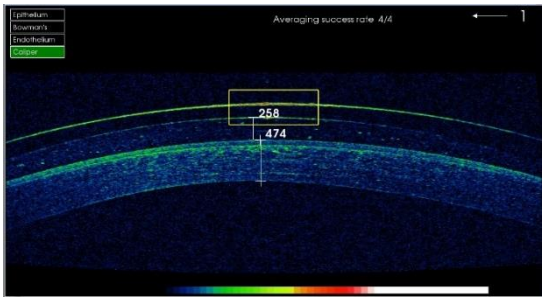


Figure 4b

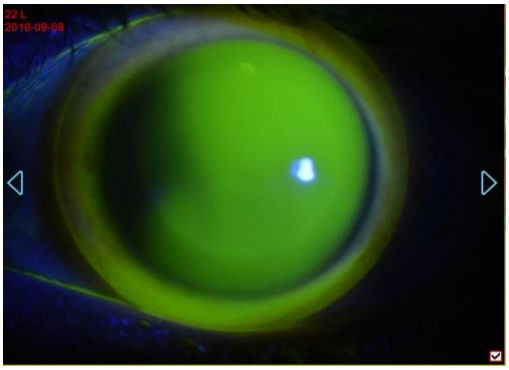


Figure 5a

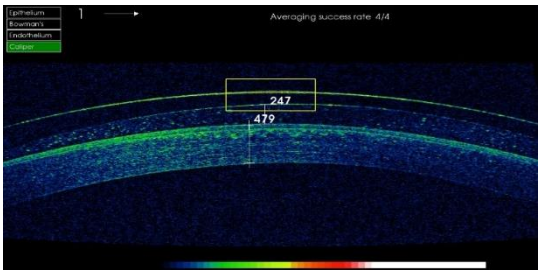


Figure 5b

Figure 4 and 5: Fluorescein pattern for the right eye is seen in figure 7a, and corresponding AS-OCT is seen in figure 7b, which shows acceptable fitting with adequate vault, respectively. Figure 8a shows the left eye's fluorescein pattern with the corresponding AS-OCT seen in figure 8b, which also shows acceptable fitting with an adequate vault. Both eye fitting is accepted.

These findings obtained with trial 2 indicated that the fitting was acceptable. Over-refraction was then performed on both eyes, which showed +0.50 -1.75 x 145 OD and +0.50 -1.50 x 140 OS with vision improving to 6/6 on both eyes monocularly. The parameters of the final lens ordered for the patient are shown in Table 3.

Table 3: Final lens parameters ordered for the patient.

Parameter	**OD**	**OS**
Material	Boston XO2	
Base Curve	6.60 mm	6.60 mm
BVP	-9.50 / -1.75 x 145	-9.50 / -1.50 x 140
TD	14.60mm	14.60 mm
Edge profile	Standard	Standard

Lens Dispensing Visit

The patient came to the clinic for his lens collection. The patient was taught lens insertion, removal, lens handling. The fitting assessment was carried with the lenses, and the fitting obtained was like the fitting which was finalized before lens ordering Distance visual acuity with lenses was $6/7.5^{+2}$ on OD and 6/7.5 on OS. The patient was comfortable, and the lenses were dispensed. His subsequent follow-up was scheduled a week later.

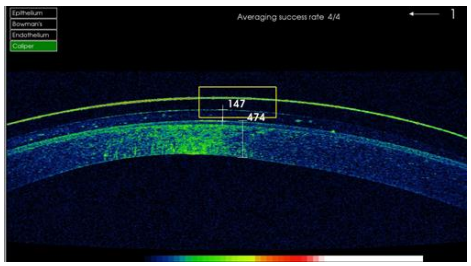
Follow Up # 1

After about three and a half months, the patient returned to the clinic as he had to travel for his internship. The patient was regularly in touch via WhatsApp and reported that he had no problems in comfort and the vision was good. He was wearing the lenses most of the days for more than twelve hours without any problems.

The patient had worn the lenses for about five hours during this follow-up visit. Distance visual acuity with the lenses was $6/6^{-3}$ on OD and $6/7.5^{+2}$ on OD. An over-refraction of +0.50D was found, but it did not change the best-corrected visual acuity at a distance as well as near. The fitting assessment showed adequate lens movement of about 0.5mm to 0.75mm and an acceptable fluorescein pattern on both eyes.

AS-OCT was performed using the 3D OCT-1 Maestro to measure the tear layer, referred to as vault. This showed a decrease in the vault compared to the final lens fitting. The vault was for the right eye was 147 microns (Figure 6), and the left eye was 158 microns (Figure 7).

There were no signs of any corneal staining or conjunctival indentation on ocular examination post lens removal; hence no modifications were made, and the patient was recommended to follow up every three months.



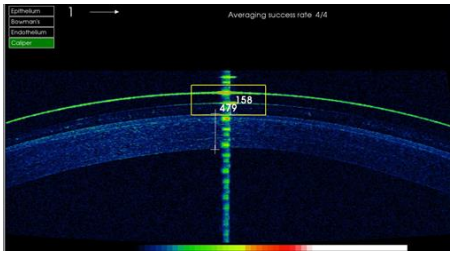


Figure 6 Figure 7

Figure 6 and 7: AS-OCT for OD (Figure 6) and OS (Figure 7) performed using the 3D OCT-1 Maestro on follow-up showing reduction of vault compared to the finalized fitting vault.

Discussion:

The prevalence of keratoconus varies depending upon the geographic location, diagnostic criteria, and the study population.[6] The prevalence in a clinic-based population study showed approximately 1 in 100 patients who visited a cornea specialist center in Malaysia.[7] Keratoconus clinically presents in patients in their teenage years or early twenties. A study reported that most keratoconus patients seen university hospital in Jordan were between the age of 20 to 24 years old (mean age of 25.9 years).[8] Their main complaints are progressive blur vision and distortion secondary to myopia and astigmatism. Glare resulting due to photophobia and monocular diplopia could also be a presenting symptom. Various ocular signs involving a different layer of the cornea can be seen based on the stage of the disease, commonly seen scissors reflex during retinoscopy, Fleischer's ring within the epithelial layer, and Vogt striae within the stroma. Munson's sign, which is the protrusion of the lower lid during down gaze, can be seen in the disease's advanced stage. Hydrops can be seen due to the spontaneous teas in the ruptured Descemet's membrane.

Corneal mapping using a topographer can be a valuable diagnostic tool for detecting sub-clinical keratoconus and monitoring the disease's progression. A topographic classifier using eight indices to diagnose keratoconus is available.[9] Different topographic devices provide additional information through various features to help clinicians detect keratoconus at an early stage. This will help determine the contact lens design and parameters and help clinicians decide on other strategies such as collagen cross-linking (CXL), intrastromal corneal ring segments, phakic intraocular lenses, and others to slow down the progression of the disease.[10]

Keratoconus was classified using the Amsler-Krumeich (AK) system for grading proposed by Mark Amsler in 1947. This was based on keratometry (central anterior corneal curvature) and optical pachymetry (apical thickness). The AK system has limited usefulness due to modern imaging, which allows for detecting the disease at a much earlier stage. Placido -based corneal topography is still widely used; however, there is a drawback as it completely ignores the posterior cornea. The new Berlin ABCD classification system was introduced by the Oculus Pentacam (Oculus GmbH, Wetzlar, Germany) to overcome this shortcoming.[11] The ABCD criteria is also used to monitor the progression of keratoconus, and a study states that corneal cross-linking would effectively stabilize the progression of keratoconus as per the ABCD criteria.[12] Keratoconus can also be classified using a statistical approach into five levels reported to be free from subjective considerations using the Simulated keratometry (SimK), Central K, Cone location and magnitude index (CLMI), Higher-Order root mean square (Ho RMS), logBC, and coma.[13]

A variety of contact lens options are available for patients with keratoconus ranging from soft toric contact lenses to scleral contact lenses. The lens selection depends on various factors such as the corneal topography, previous experience with contact lenses, visual demand requirement, to name a few.[14]

A well-fitted scleral lens must fulfill these three criteria: vaulting over the cornea and limbus, ensuring a proper landing zone over the sclera with adequate tear exchange underneath the lens. This will ensure maintaining good corneal physiology.[15] The Rose K XL lenses were developed by Paul Rose and have been studied in patients with irregular corneas showed that these lenses provided qualitative as well as a quantitative visual function along with high degrees of patient comfort and satisfaction.[16]

The initial lens was selected for this patient based on the manufacturer's Rose K2 XL fitting guideline. After computing the mean K from the topography results, the lenses were selected, which was 6.58mm in OD and 6.05mm in OS. Hence, looking at the practitioner guidelines' initial base curve of the trial lens was 6.90mm for OD and 6.70mm for OD.

Generally, a five-step fitting approach is suggested for a scleral lens, including diameter selection, clearance (vault measurement), landing zone fit, lens edge assessment, and asymmetrical back surface design. Lens vault and landing zone can be clinically observed through the slit lamp – with and without fluorescein. This is done by comparing the slit width of the space between the lens and the cornea (vault) with the known thickness from either the

contact lens thickness or the corneal thickness. However, this is an approximation. It has been reported that an approximate underestimation by 50 microns would be there when measuring vault with slit lamp compared to the ultrasound measurements.[17] AS-OCT is a valuable tool to accurately measure the vault allowing clinical to modify the sagittal height to obtain the required vault.[18,19]

AS-OCT has numerous research and clinical applications for glaucoma[20], refractive surgeries[21], corneal transplants[22], pachymetry[23], corneal diseases[24], and many more[25]. The use of AS-OCT has now been expanded for pre-and post-contact lens assessment (especially specialty contact lens fittings and custom designing of large diameter scleral lenses).[26–28] This is because it allows to measure the tear layer (vault) accurately and look at the interaction between the lens edge and the sclera. AS-OCT is, therefore, a useful tool to observe how the parameter change affects the lens fitting, as discussed in this case presentation.

The 3D OCT-1 Maestro is a noncontact SD-OCT. It is a fully automated instrument that captures 50,000 axial scans per second. A study comparing the OCT model across seven centers and the measurements were reliable in normal healthy individuals.[29] It is also understood that the scleral lens, once dispensed, usually continues to settle in the first or second month of lens wear. Appropriate measurements can help measure these changes accurately and be used to assess the vault and clinical performance of the scleral lens over time.[30] A review article published reports that an OCT imagining is the most accurate and repeatable corneal vault estimate. [31]

The central clearance (vault) for the patient was seen to be reduced after about three and a half months of wear in both eyes by nearly 100 microns. A study that compared the change in vault during scleral lens wear with AS-OCT after 1 hour and 4 hours of wear reported a significant reduction in the vault after 4 hours of lens wear with an average reduction of 125 microns in the ectasia group using the PROSE lenses.[32] Another study also reports similar findings with three different lens designs.[33] Both the studies suggested that a sufficient amount of time should be allowed before finalizing the fit (4 hours to 8 hours), and it was also reported that larger diameter lenses had more significant changes than smaller diameter lenses. In clinical practice, one should select the fit with a slighter higher than required vault to the account of the lens settling over time.

A study compared how varying degrees of corneal clearance of scleral contact lenses affect visual acuity and comfort in corneal ectasia patients. The results demonstrated that variation in

the central clearance did affect the vision and comfort. Increased clearance may not provide the best vision.[33] This could be why the vision improved by a couple of letters on the follow-up visit for this patient compared to the dispensing visit.

Conclusion

In conclusion, AS-OCT would be a valuable tool in lens choice, accurately measuring the vault of the lens over the cornea and monitoring it over time and looking at the landing of the scleral lens edge over the sclera. All these would help clinicians to modify and alter the fitting of the lens as desired with confidence.

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