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Scleral Lens Fitting in Keratoconus – Algorithms for Clinicians

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Abstract

Purpose. To present a structured, evidence-based clinical algorithm for scleral lens fitting in advanced keratoconus that integrates disease progression management, optical power optimization, and scleral asymmetry correction.

Material and Methods. This review synthesizes current evidence on scleral lens dynamics, keratoconus progression, high-powered lens management, and corneoscleral topography. The algorithm is built around three pillars: (1) a 100 micron progression safety margin, (2) strategic manipulation of back optic zone radius (BOZR) and diameter (BOZD) to optimize optical performance, and (3) management of scleral asymmetry using modern imaging. These concepts are integrated into distinct pathways for centered versus decentered ectasia.

Results. The algorithm provides a stepwise decision tree incorporating pre fitting assessments, foundational fit with central clearance of 200–300 µm (plus 100 µm for progressive disease), and over refraction to guide BOZR/BOZD manipulation for high powered lenses. Distinct pathways are outlined for centered ectasia (peripheral clearance management, oblate designs for high myopia with BOZD decreased for high myopia, and BOZR steepening with BOZD increase for high hyperopia) and decentered ectasia (optic zone decentration, quadrant specific modifications, and customized free form lenses). A troubleshooting protocol addresses common complications, and piggyback systems are discussed as a temporary rescue option.

Conclusion. Successful scleral lens fitting in advanced keratoconus requires a systematic, parameter driven approach that respects corneal and scleral topography, accounts for disease progression, and addresses refractive error through targeted BOZR/BOZD manipulation. The presented algorithm offers practitioners a structured framework to achieve reproducible outcomes and long term ocular health.

Keywords
Keratoconus, Scleral Lenses, Ectasia, BOZR, BOZD, Oblate Design, Anterior Segment OCT, Contact Lens Fitting Algorithm

Introduction

Keratoconus is a progressive corneal ectatic disorder characterized by stromal thinning (most commonly in the inferotemporal region), corneal protrusion, and irregular astigmatism, leading to significant visual impairment.[1,2,3,4] Traditionally considered noninflammatory,[5,6] emerging evidence links it to altered inflammatory mediators, suggesting underlying ocular inflammation.[7,8,9,10,11,12,13] Although bilateral, one eye is usually more severely affected.[14,15,16,17,18] It affects all sexes and ethnicities, often as an isolated condition but sometimes with other ocular or systemic diseases.[5]

Keratoconus remains a leading indication for corneal transplantation, yet the vast majority of patients can be successfully rehabilitated with contact lenses.[19,20] The evolution from corneal lenses to corneoscleral and fully scleral designs has broadened the range of available options for keratoconus management. Unlike corneal lenses that rest on the irregular ectatic surface – often inducing apical scarring or decentration[21] – scleral lenses vault the entire cornea, landing exclusively on the conjunctiva overlying the sclera.[22] This creates a post-lens tear reservoir that neutralizes 89 % of corneal astigmatism[23] while protecting the compromised epithelium and providing comfort.[22] Although corneal lenses were once considered the gold standard for managing corneal irregularities, the SCOPE survey revealed a significant shift in clinical preference: 42 % of clinicians now select scleral lenses as their primary choice, surpassing corneal lenses, which accounted for only 20 % of responses.[24] Importantly, scleral lenses have been shown to delay or eliminate the need for corneal transplantation in patients with keratoconus.[20,25,26]

Fitting scleral lenses, especially in advanced keratoconus, presents distinct challenges, including managing disease progression with a safe long-term strategy to prevent corneal touch as the cornea may continue steepening over time, accommodating decentered cones and rotational asymmetric sclera that can cause tilt, conjunctival compression, lens decentration, and midday fogging, and correcting significant refractive error (high minus or plus power) which affects lens mass, thickness, centration, and visual outcomes.[27,28,29,30,31]

This article synthesizes current evidence and clinical experience into a single, actionable algorithm. The three pillars of advanced keratoconus scleral fitting will be presented: the 100-micron progression safety margin, the manipulation of back optic zone radius (BOZR) and back optic zone diameter (BOZD) to reduce lens power and optimize optical performance, and the systematic management of scleral asymmetry using semi-quadrant-specific adjustments or free form scleral lenses. Finally, these concepts will be integrated into distinct pathways for centered versus decentered ectasia. A piggyback system as a therapeutic tool and a troubleshooting table for common complications, moving beyond trial-and-error toward a systematic, parameter-driven strategy, will also be discussed. The procedures described are not necessarily meant to be completed in a single visit or lens; rather, they represent sequential modifications to be implemented progressively throughout the lens-fitting process.

The Three Pillars of Fitting Scleral Lenses in Keratoconus

Pillar 1: The 100-Micron Progression Safety Margin

Keratoconus is a progressive disease. Even after corneal cross-linking, some eyes continue to steepen at a slow rate.[32] A scleral lens fitted with low apical clearance (< 200 µm) at dispense may develop focal corneal touch within a year as the cone elevates, leading to scarring and reduced visual acuity.[22,33] Conversely, excessive clearance (> 400 µm) may reduce oxygen delivery and cause different issues, including lens decentration and midday fogging.[31] The optimal balance is a target post-settling central clearance of 200–300 microns for stable keratoconus, with an additional ~100-micron safety margin for documented progressive keratoconus.

Patients fitted with the 100-micron progression safety margin require follow-up every six months to monitor disease progression and confirm no settling-induced touch. If the lens is touching the apex despite the initial safety margin, it should be replaced with one that offers greater vault.

Pillar 2: Manipulation of BOZR and BOZD to Reduce Lens Power and Optimize Optical Performance

Foundational Concept of Master Parameter Control: BOZR and BOZD Dynamics

While BOZR and BOZD are well recognized as crucial parameters in corneal lens fitting, their importance is often overlooked in scleral lens practice, where clinicians tend to focus primarily on lens sagittal values, elevation, and haptic alignment on the conjunctiva. However, successful scleral lens fitting also rests on understanding these two primary parameters and their reciprocal relationship. When clinicians struggle to adjust the haptic lens to resolve alignment issues, the root cause often lies in unaddressed problems at the corneal periphery and limbus. If these corneal peripheral and limbal zones are not properly managed, alignment issues will persist, manifesting as limbal congestion, conjunctival blanching, impingement, midday fogging, lens suction, conjunctival prolapse, lens decentration, and persistent discomfort.[29,30,31,34] Unlike empirical trial-and-error, a parameter-driven approach that deliberately manipulates BOZR and BOZD enables the clinician to predictably achieve the desired fit and optical outcomes in the peripheral cornea and over the limbus.

Manipulating BOZR and BOZD: Impact on Lens Fit

The interaction between BOZR and BOZD follows several predictable patterns, and they are summarized in Table 1. Steepening the BOZR (e.g., from 7.5 mm to 6.5 mm) decreases peripheral clearance and increases minus power. This maneuver is useful for centered cones with excessive peripheral clearance, where a moderate increase in power is acceptable, though it increases lens mass and may worsen decentra-

Table 1: Master Parameter Control Matrix

Parameter Change	Primary Effect on Fit	Effect on Lens Power	Secondary Consequences	Clinical Application
Steepen BOZR (e.g., 7.5 mm → 6.5 mm)	Decreases peripheral clearance	Minus power: Increases lens power	• Increases lens mass/thickness • Increase negative spherical aberration • Can worsen decentration	Centered cones with excessive peripheral clearance where moderate minus power increase is acceptable
		Plus power: Decrease lens power	• Reduces lens mass/thickness • May reduce positive spherical aberration • May improve centration	• Keratoconus with high plus power • Centered cones with excessive peripheral clearance
Flatten BOZR (e.g., 6.5 mm → 8.0 mm)	Decreases minus power (or increase plus)	Increases peripheral clearance	• Reduces lens mass/thickness • May induce positive shift in spherical aberration • May improve centration	Primary strategy for high minus: Implement oblate design (must be paired with BOZD reduction)
Increase BOZD (e.g., 8.0 mm → 9.0 mm)	Increases peripheral clearance	No direct effect	• May slightly increase lens mass • Improves pupil coverage safety margin for large pupil	• Compensates for reduced peripheral clearance when steepening BOZR for high plus power • Improves pupil coverage in large pupils
Decrease BOZD (e.g., 8.0 mm → 7.0 mm)	Decreases peripheral clearance	No direct effect	• Reduces lens mass • **Risk:** Visual disturbance if edge encroaches on pupil	Primary strategy for managing peripheral clearance without altering power; Essential for oblate designs

tion. Flattening the BOZR (e.g., from 6.5 mm to 8.0 mm) decreases minus power while increasing peripheral clearance. However, flattening the BOZR always requires reducing the BOZD to compensate for the newly created excessive peripheral clearance. This is the core strategy for high myopia (oblate design).

Increasing the BOZD (e.g., from 8.0 mm to 9.0 mm) increases peripheral clearance without a direct effect on power. This adjustment compensates for reduced clearance when steepening the BOZR to reduce high-plus power. Decreasing the BOZD (e.g., from 8.0 mm to 7.0 mm) reduces peripheral clearance without altering power. This is the primary strategy for managing excessive peripheral clearance in centered cones and is essential for controlling clearance in oblate designs.

The High Myopia Paradox in Conventional Scleral Lens Fitting

In advanced keratoconus complicated by high myopia, conventional scleral lens fitting presents a significant clinical paradox. To achieve an adequate central vault on a steep cornea, the practitioner must select a relatively steep BOZR.[35] The optical consequence of this geometry is the generation of high minus power, often reaching –15.00 diopters or more. Physically, the lens becomes excessively thick at its center, which adds considerable mass. This heavy, thick lens tends to decenter more easily, reducing comfort and stability. Moreover, the high-minus power induces significant image minification, typically reducing the retinal image size and directly degrading both high- and low-contrast visual acuity.[35]

Oblate Geometry: Flipping the Paradigm

The oblate design offers a fundamental rethinking of scleral lens geometry for the highly myopic keratoconic eye. Unlike the prolate lens, which is steeper centrally and flatter peripherally, an oblate lens has a flatter central curve than its peripheral curves. By deliberately flattening the BOZR – for example, from 6.5 mm to 8.0 mm – the practitioner can maintain central vault not through central steepness but by strategically steepening the peripheral transition zone, which effectively „pinches" the lens, generating the necessary sagittal height to clear the cone apex without relying on a steep central curve. The flatter BOZR directly reduces the required minus power, which dramatically lowers lens mass, center thickness, and image minification. A reduction in BOZD is needed to reduce the peripheral clearance created by the flatter BOZR. Before implementing this approach, a scotopic pupil measurement is essential to determine the absolute minimum BOZD to avoid visual disturbance caused by encroachment of the optic zone edge. The oblate design thus transforms a problematic high minus lens into a more physiologically and optically tolerable device.

Managing High Plus Power: A Separate Challenge

Although less common, certain cases of keratoconus may require high plus power.[36] While high myopia has received considerable attention, high plus power presents an equally important but distinct challenge in scleral lens fitting for keratoconus.

In conventional scleral lens fitting for high plus power, a relatively flat BOZR is typically required to achieve the desired positive power. However, a flat BOZR increases peripheral clearance.

The solution for high plus power is to steepen the BOZR, which directly reduces positive power. This reduction in plus power has several important benefits: it decreases the lens center thickness, mass, and decentration. However, steepening the BOZR also decreases peripheral clearance, which can lead to peripheral corneal touch and limbal touch. Therefore, any significant steepening of the BOZR for high plus power may need to be accompanied by an increase in BOZD to counteract the reduction in peripheral clearance. This combination – steeper BOZR plus larger BOZD – maintains a safe peripheral vault while reducing the required plus power, resulting in decreased lens thickness and mass, better centration, and greater comfort.

Contraindications for Power-Adjusting Strategies

Despite their advantages, both oblate (high-minus) and steepened BOZR (high-plus) strategies have limitations. For high minus, the most important contraindication is a large scotopic pupil diameter exceeding 6.5 mm. Because the oblate design relies on a reduced BOZD, the optic zone edge may encroach on the pupil under low-light conditions, causing significant edge glare, halos, or other disturbing visual phenomena.[29,34] In such patients, a conventional steep BOZR with a larger BOZD remains the preferred approach, accepting the higher minus power and its associated minification as a necessary trade-off to avoid disabling night-vision symptoms.

For high plus power, the main limitation is that steepening the BOZR may not be feasible in eyes with extremely steep corneas, where the required BOZR would be impractically small. In these cases, alternative strategies include accepting higher plus power with a flatter BOZR and larger BOZD.

Pillar 3: Management of Scleral Asymmetry

Research using corneoscleral topography has revealed several key patterns in keratoconic eyes. There is a positive correlation between corneal irregularity and scleral asymmetry; in essence, a more irregular cornea predicts a more irregular sclera.[37] A study has shown that the keratoconic eye has a much more asymmetrical corneoscleral profile than the healthy eye, especially in moderate-to-advanced disease.[38] The report also found that scleral steepening tends to mirror corneal steepening.[38] Similarly, another study reported significant differences in sagittal height variation across meridians between ectatic and normal eyes.[39] A strong correlation emerged between the magnitude of cone decentration and the level of scleral asymmetry, indicating that greater cone displacement predicts more pronounced scleral contour abnormalities in advanced disease.[39]

This relationship in earlier-stage keratoconus, where cone decentration is less pronounced, was later explored.[37] It has been found that a moderate correlation exists between cone decentration and scleral toricity, suggesting that disease severity affects the extent to which cone position predicts scleral shape. The study also showed that when a corneal meridian steepens, the corresponding scleral semi-meridian steepens as well.[37] However, the reverse did not hold – corneal flattening did not predict scleral flattening. Additionally, the angle between the steepest and flattest regions of the sclera varies significantly from patient to patient, meaning that corneal measurements alone cannot reliably determine the optimal toric lens design.[37]

Another report examined whether habitual lens wear alters corneoscleral shape by comparing three severity-matched keratoconus groups (lens-naive, corneal lens wearers, and scleral lens wearers) against healthy emmetropic controls.[40] The findings showed that both types of contact lens wear induced localized shape changes in the peripheral cornea and sclera, and keratoconic eyes had significantly steeper peripheral corneas and scleras than healthy eyes. Among the keratoconus groups, scleral lens wearers exhibited the highest degree of scleral asymmetry.[40] This suggests that a scleral lens with a spherical landing zone will likely result in uneven tissue compression across quadrants in these patients.

Bottom Line

Several consistent patterns emerge from this body of literature.

- First, keratoconic eyes demonstrate a highly asymmetric corneoscleral profile compared to healthy eyes.
- Second, as keratoconus progresses, the sclera not only becomes steeper but also more irregular, particularly in the same semi-meridians where corneal steepening occurs.
- Third, the peripheral cornea and sclera are significantly steeper in keratoconus than in normal eyes.
- Fourth, corneal topographic data can offer useful clues about the presence and location of scleral asymmetry, especially the steepest scleral angle.
- Fifth, in moderate-to-advanced disease, the degree of cone decentration may serve as a clinical indicator of underlying scleral asymmetry.

Clinical Implications for Scleral Lens Fitting

These anatomical insights carry direct practical consequences for the scleral lens practitioner. The presence of cone decentration should raise suspicion of concomitant scleral asymmetry and prompt consideration of a quadrant-specific or customized landing zone design, rather than relying on a symmetric spherical or toric haptic. Furthermore, when fitting scleral lenses in advanced keratoconus, the lens periphery may need to be steeper than conventional fitting norms would suggest to align with the naturally steeper scleral contour characteristic of this disease. Failing to account for these regional variations risks poor lens centration, focal conjunctival compression, reduced wearing time, and suboptimal visual outcomes.[31]

Comprehensive Clinical Algorithm: Centered Versus Decentered Ectasia

The following stepwise algorithm synthesizes the key principles outlined in the preceding sections into a practical, clinical decision tree for fitting scleral lenses in advanced keratoconus. The algorithm begins with essential pre-fitting assessments, including slit lamp examination to detect clinical signs such as Fleischer's ring, Vogt's striae, corneal scarring, and epithelial changes that may influence lens selection and clearance targets, and corneal topography and tomography to identify cone location, maximum keratometry (Kmax), thinnest pachymetry, and documentation of disease progression over the preceding 12 to 24 months. Scotopic pupil diameter must be measured, as it determines the minimum acceptable BOZD to avoid edge glare. Corneoscleral profilometry is also crucial for assessing scleral asymmetry, reducing chair time and lens reorders. A manifest refraction is necessary to estimate lens power and determine whether high myopia or high hyperopia is present, guiding the choice between flat and steep BOZR strategies. Based on these data, the practitioner first achieves a foundational fit with appropriate central clearance and establishes the 100 micron progression safety margin. A rigid lens is then applied, and an over refraction is performed to determine whether manipulation of the BOZR or BOZD is required for high-powered lenses. The fitting then branches into distinct pathways for centered versus decentered ectasia. The algorithm concludes by troubleshooting common complications and outlining long-term follow-up, and is presented in Tables 2–4 and Figure 1.

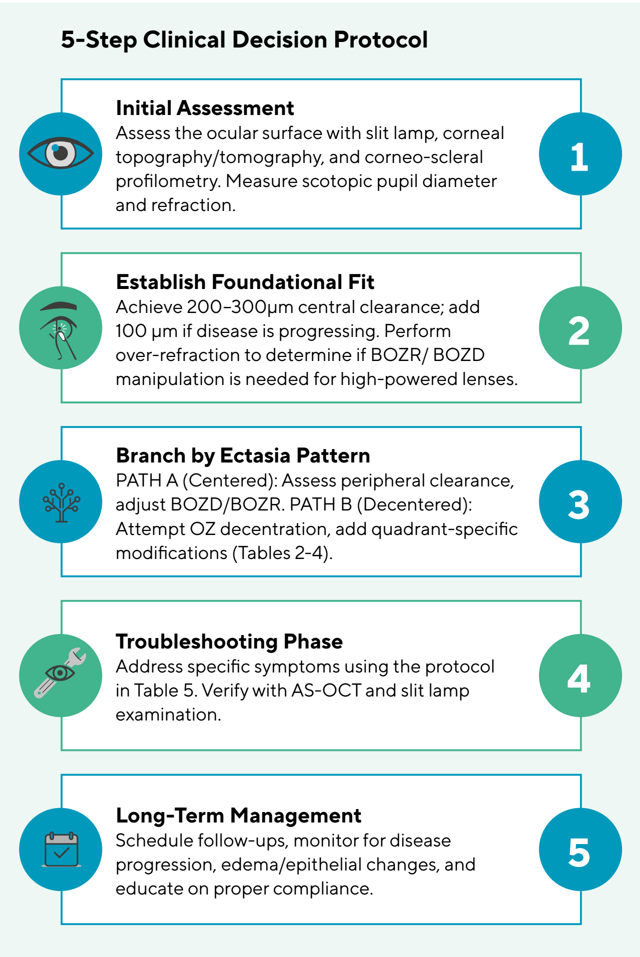

Figure 1: Scleral Lens Fitting Algorithm for Ectasia

Pathway A: Centered Ectasia

In patients with a centered cone, the fitting strategy is guided by disease severity (mild-moderate vs. advanced), peripheral clearance status, refractive error, and the presence or absence of scleral asymmetry.

For mild to moderate disease, peripheral clearance is typically adequate, allowing the practitioner to proceed directly to power management. Refractive error is usually low to moderate, and standard BOZR and BOZD selection is sufficient. However, as the disease progresses, scleral asymmetry may develop. In such cases, the practitioner should start with a spherical haptic and standard BOZR and BOZD but remain prepared to add quadrant-specific limbal and scleral adjustments as needed. Corneoscleral profilometry is recommended to rule out scleral asymmetry.

In advanced-centered ectasia, excessive peripheral clearance with good central vault is a common finding. The first-line strategy is to reduce the BOZD, which decreases peripheral clearance while maintaining the original lens power. If the BOZD modification is not available or the BOZD is already at its minimum safe limit, an alternative is to steepen the BOZR, which also reduces peripheral clearance but increases minus power and adds lens mass. Both strategies can be combined for a synergistic effect. Regardless of the approach, the practitioner must always verify that the BOZD remains larger than the scotopic pupil to avoid visual disturbances from the optic zone edge. The goals of this step are to optimize haptic alignment, prevent conjunctival compression, and reduce the risk of midday fogging. When significant scleral asymmetry is present in advanced disease, a customized or free-form lens design is recommended, guided by corneoscleral profilometry.

Pathway B: Decentered Ectasia

In patients with a decentered cone, the fitting strategy differs fundamentally from centered ectasia, as symmetric lens designs invariably lead to low or apical touch on the cone and excessive vault in the opposite quadrant. As with centered ectasia, the approach is guided by disease severity (mild-moderate versus advanced), distribution of clearance, refractive error, and the degree of scleral asymmetry.

Table 2: Scleral Lens Fitting Algorithm for Advanced Keratoconus

Step	Clinical Decision Point	Finding / Severity	Primary Strategy	Secondary Strategy	Contraindications / Clinical Pearls
STEP 1: INITIAL ASSESSMENT					
1.1	Anterior surface observation / Slit lamp examination	Inspect cornea, conjunctiva, limbus	Detect Fleischer's ring, Vogt's striae, corneal scarring, epithelial changes, scars, etc.	Document presence and location of clinical signs	Identifies factors influencing lens selection, clearance targets, and baseline pathology
1.2	Corneal topography / tomography	Map corneal elevation and curvature	Identify cone location (centered vs. decentered); measure Kmax and ry	Document cone location, Kmax (D), thinnest pachymetry (µm)	• Determines pathway selection (centered vs. decentered); • guides BOZR/BOZD selection
1.3	Disease progression status	Compare current Kmax and pachymetry with prior measurements (12–24 months)	Determine progressive vs. stable disease	Document rate of change (D/year or µm/year)	Progressive disease requires 100 µm additional safety margin (to add to initial target clearance 200–300 µm)
1.4	Corneoscleral profilometry	Map scleral elevation asymmetry	Identify steepest and flattest quadrants; detect regional variations	• Quantify asymmetry (µm) • Note which quadrants are steep or flat	• Guides quadrant-specific limbal adjustments • Significant asymmetry may require customized haptic
1.5	Scotopic pupil diameter	Measure under low light	Document value in millimeters	–	• Dictates minimum BOZD to avoid edge glare • Critical for all subsequent decisions
1.6	Refraction	Measure sphero-cylindrical refraction	Determine sphere, cylinder, axis; identify high myopia or high hyperopia	–	• Initial guide for oblate vs. steep BOZR strategy • Determines need for potential front surface toricity
STEP 2: FOUNDATIONAL FIT					
2.1	Central clearance target	Stable keratoconus	200-300 µm	–	Baseline target
		Progressive keratoconus	200–300 µm	Includes 100 µm safety margin	Prevents touch as cornea steepens
2.2	Over-refraction with a rigid lens on eye	Measure sphero-cylindrical refraction to determine lens power	High minus power: Implement oblate design; flatten BOZR	Reduce BOZD	• Large scotopic pupils (> 6.5 mm) may prohibit necessary BOZD reduction • Minimizes lens mass (power/thickness) • Reduces higher-order aberrations • Optimizes the fit
			High plus power: Steepen BOZR	Must be combined with Increase BOZD to counteract the reduced peripheral clearance caused by steepening the BOZR	• Prevent peripheral corneal touch • Minimizes lens mass (power/thickness) • Reduces higher-order aberrations • Optimizes the fit

			Residual astigmatism: Rule out lens flexure and decentration	Correct residual astigmatism >0.75 D with front surface toric design	• Optimizes visual acuity • Compensates for lens-induced or residual refractive error
2.3	Minimum BOZD	Must exceed scotopic pupil	Increase BOZD > pupil diameter	Increase the BOZ only in the quadrant of the cone, if BOZD at minimum	Prevents edge glare and visual disturbance
STEP 3: CENTERED / DECENTERED ECTASIA PATHWAY Refer to Table 3, "Pathway 3A of the algorithm for Centered Ectasia" and Table 4, "Pathway 3B of the algorithm for Decentered Ectasia"					
STEP 4: TROUBLESHOOTING (SYMPTOM-BASED) Refer to Table 5, "Symptom-Based Troubleshooting Protocol"					
STEP 5: LONG-TERM MANAGEMENT					
5.1	1 week follow-up	All patients	Subjective assessment (vision, comfort, handling); Slit-lamp exam (lens fit, and ocular surface staining); OCT; corneal tomography without lens; pachymetry; assess disease progression; over-refraction	–	Confirm stability; detect early issues
5.2	1 month follow-up	All patients		–	Rule out delayed complications
5.3	6 months follow-up	Progressive KC or high risk		Refit in case of apex touch	• Document Kmax and pachymetry changes • Refit with increased clearance (add 100 μ safety margin)
5.4	12 months follow-up	All patients		–	Monitor annual changes
5.5	Annually thereafter	All patients		–	Long-term surveillance
WHEN TO REFIT					
5.6	Clearance loss	Clearance drops below 100μm over cone apex due to lens settling	OCT-confirmed	–	Refit immediately
5.7	New focal touch	Any new touch on cornea or limbus	OCT-confirmed	-	Refit immediately
5.8	Documented progression	Clearance drops below 100 μm over cone apex; Kmax increase	–	–	Refit with increased clearance (add 100 μ safety margin)
5.9	Persistent fogging	Persistent despite changing filling solutions	–	–	Refit with modified design
5.10	Any other fitting issues including lens decentration, blanching, indentation, limbal congestion, lens suction, edema, etc.	Any significant presence of issue	–	–	Refit immediately

Table 3: Pathway 3A of the algorithm for Centered Ectasia

STEP 3A: CENTERED ECTASIA PATHWAY					
Severity	**Clinical Decision Point**	**Finding**	**Primary Strategy**	**Secondary Strategy**	**Contraindications / Clinical Pearls**
Mild-moderate	Peripheral clearance status	Adequate	Proceed to power management	–	–
	Refractive error	Low to moderate	Standard BOZR/BOZD selection	–	Proceed to final verification
	Scleral asymmetry	More asymmetry possible as disease progresses	• Start with spherical haptic; add quadrant-specific adjustments if needed • Standard BOZR/BOZD	Be prepared to add quadrant-specific limbal and scleral adjustments as disease progresses	Profilometry recommended to assess scleral asymmetry
Advanced	Peripheral clearance status	Excessive with good central vault	• Reduce BOZD: - Reduces peripheral clearance - Maintains original lens power - Most effective strategy	• Steepen BOZR (if BOZD modification is not available or it is at minimum) - Reduces peripheral clearance - Increases minus power (adds mass)	• Always measure scotopic pupil size. BOZD must be larger than the pupil to avoid visual disturbances from the optic zone edge • Both strategies can be combined for a synergistic effect • Optimize haptic alignment • Prevent conjunctival compression and midday fogging
	Refractive error	High	Manipulate BOZR/BOZD	–	Check scotopic pupil size
	Scleral asymmetry	Asymmetric sclera	Customized/free form lens	–	Profilometry recommended to assess asymmetry and design a customized or free form lens
Final verification			Slit lamp and/or AS-OCT	Assess comfort and vision	• Confirm physiological safety before dispensing • If discomfort: check for limbal touch, blanching, indentation, suction, or excessive mass • If vision poor: check for edge glare and perform over-refraction and consider front surface toric design or oblate design for high myopia

For mild to moderate disease, a clearance distribution is more likely to be acceptable, but the patient should be monitored as the disease progresses. The primary strategy is to use an optic zone that is either acceptable as is or with mild decentration toward the cone. If decentration is not available, a mild increase of limbal clearance in the quadrant where the cone is located can be effective. Additionally, increasing the BOZD may provide more peripheral clearance if needed, and decreasing limbal clearance in the opposite quadrant can uniform the vault. The practitioner must ensure that the decentered OZ still fully covers the scotopic pupil. It is crucial to avoid over-increasing limbal clearance, which may cause decentration and fogging. For patients with low to moderate refractive error, standard BOZR and BOZD selection is appropriate. When mild to moderate scleral asymmetry is present, the practitioner should start with a spherical haptic and standard BOZR and BOZD, but remain prepared to add quadrant-specific limbal and scleral adjustments as the disease progresses. Corneoscleral profilometry is recommended to rule out subclinical asymmetry.

In advanced decentered ectasia, clearance distribution is characterized by low apical clearance or apical touch with excessive clearance in the opposite quadrant. The primary strategy is to decenter the back optic zone, shifting the entire optic zone toward the cone, which increases clearance over the apex and decreases clearance in the opposite quadrant. If the lens design does not support optic zone decentration, alternative strategies include quadrant-specific BOZ modification (increasing the BOZD only in the quadrant of the cone) or quadrant-specific limbal clearance adjustments (increasing limbal clearance in the cone quadrant and decreasing it in the opposite quadrant). The practitioner may increase the overall BOZD as needed and avoid simply increasing the overall sagittal height, as this will exacerbate the vault opposite the cone. Pupil size is critical; the decentered or manipulated optic must still fully cover the pupil under scotopic conditions, which may require increasing the overall BOZD. Quadrant-specific limbal clearance is particularly useful when the lens design does not allow for optic zone manipulation. When significant scleral asymmetry is present in advanced disease, a customized or free-form lens designed with corneoscleral profilometry is recommended. In summary, advanced strategies for managing decentered ectasia include optic zone decentration, quadrant-specific optic zone expansion, quadrant-specific limbal curve adjustments, and the oblate design combined with decentration, each with specific advantages and limitations as summarized in the corresponding table.

Final Verification (Common to Both Pathways)

Regardless of whether the ectasia pattern is centered or decentered, final verification follows the same principles. Slit lamp examination and anterior segment OCT are performed to confirm physiological safety before dispensing. The clinician must verify that central clearance is within the target range, that no focal touch is present, that peripheral clearance is uniform, and that the lens is more likely well-centered. If the patient reports discomfort, the clinician should check for limbal touch, conjunctival blanching, indentation, suction, or excessive lens mass. If vision is poor, the clinician should evaluate for edge glare, perform an over-refraction, and consider a front-surface toric design for residual astigmatism exceeding 0.75 D, or manipulate BOZR/BOZD for high-powered lenses. This systematic verification ensures that both centered and decentered ectasia cases achieve optimal visual function and long-term ocular health before the lens is dispensed.

The Evolving Role of Piggyback Systems

A piggyback system in the context of scleral lenses refers to the use of a soft contact lens placed either under the scleral lens (between the scleral lens and the cornea/sclera) or over the scleral lens (on its front surface). While traditionally associated with corneal lenses, piggyback configurations have specific, evidence-based applications in scleral lens wearers with complex ocular surface conditions.[29,34,41,42,43,44]

In progressive keratoconus, the cornea may continue to steepen over time. A scleral lens that provides adequate clearance at the initial fitting may develop apical touch within 6 to 12 months. If the lens warranty has expired and the patient cannot afford a replacement, placing a soft contact lens beneath the scleral lens will act as a cushion, preventing touch and mechanical stress on the cone.[29,34] This approach is especially useful in pediatric or rapidly progressive keratoconus, where frequent lens replacements are burdensome. However, it is only a temporary solution intended to bridge the gap until a new lens can be obtained, typically within two years, although replacement intervals may vary depending on several factors, including but not limited to lens condition and clinical needs.[45]

A limitation of the piggyback system is the potential for reduced oxygen supply to the cornea; however, a short-term study in healthy young adults found that a reverse piggyback scleral lens did not induce clinically or statistically greater central corneal edema compared to standard scleral lens wear.[46]

Troubleshooting Common Complications

Despite careful initial fitting, patients with advanced keratoconus may present with specific symptoms or clinical signs that indicate underlying lens design or fit issues. Rather than resorting to trial-and-error adjustments, a systematic approach guided by clinical observation allows the practitioner to identify the root cause and implement targeted parameter modifications. Table 5 summarizes the most common complications encountered in scleral lens wearers with keratoconus, their potential causes, recommended investigative actions, and the corresponding parameter adjustments to resolve each issue.

Table 4: Pathway 3B of the algorithm for Centered Ectasia

STEP 3B: DECENTERED ECTASIA PATHWAY					
Severity	**Clinical Decision Point**	**Finding**	**Primary Strategy**	**Secondary Strategy**	**Contraindications / Clinical Pearls**
Mild-moderate	Clerance distribution	Clearance more likely acceptable. To monitor as disease progresses	OZ acceptable or mild decentration toward the cone	• If decentration not available: mild increase of limbal clearance in the quadrant where the cone is located • Increase BOZD for more peripheral clearance if needed • Consider decreasing limbal clearance in the opposite quadrant by 20–30 µ to improve balance	• Ensure decentered OZ still covers scotopic pupil • Increase overall BOZD if needed • Avoid over-increasing limbal clearance, which may cause decentration and fogging
	Refractive error	Low to moderate	Standard BOZR/BOZD selection	–	Proceed to final verification
	Scleral asymmetry	Mild to moderate asymmetry possible as disease progresses	Start with spherical haptic; add quadrant-specific adjustments if needed; standard BOZR/BOZD	Be prepared to add quadrant-specific limbal and scleral adjustments as disease progresses	Profilometry recommended to assess scleral asymmetry
Advanced	Clerance distribution	Apical touch with excessive clearance in the opposite quadrant	• Decenter BOZ - Shift the entire optic zone toward the cone - This will increase clearance over apex and decrease clearance in opposite quadrant	• Quadrant-specific BOZ - Increase the BOZ only in the quadrant of the cone • Quadrant-specific limbal clearance - Increase limbal clearance in the quadrant where the cone is located - Decrease limbal clearance in the opposite quadrant	• Increase BOZD • Avoid simply increasing overall sagittal height • Pupil size is critical. Ensure the decentered or manipulated optic still fully covers the pupil in scotopic conditions. You may need to increase the overall BOZD to achieve this • Quadrant specific limbal clearance is useful when the lens design does not allow for optic zone manipulation
	Refractive error	High	Manipulate BOZR/BOZD	–	Check scotopic pupil size
	Scleral asymmetry	Significant asymmetry (see table 2)	Customized/free form lens	–	Profilometry recommended to assess asymmetry and design a customized or free form lens

Final verification	Slit lamp and/or AS-OCT	Assess comfort and vision	• Confirm physiological safety before dispensing • If discomfort: check for limbal touch, blanching, indentation, suction, or excessive mass • If vision poor: check for edge glare and perform over-refraction. Consider front surface toricity or BOZR/BOZD manipulation for high powered lens

ADVANCED STRATEGIES FOR DECENTERED ECTASIA – MECHANISMS, EXECUTION, ADVANTAGES, AND LIMITATIONS

Strategy	How It Works	Technical Execution	Advantages	Disadvantages & Considerations
Optic zone decentration	• Shifts maximum clearance zone toward ectasia • Reduces clearance opposite quadrant	Move OZ toward cone	• Most direct method • Creates uniform fluid reservoir thickness • Improves stability	**Critical:** Ensure decentered OZ fully covers scotopic pupil; often requires larger overall BOZD
Quadrant-specific OZ	• Expands OZ only over cone quadrant; • Creates „custom vault"	Manipulate OZ diameter in one quadrant only (e.g., increase inferior OZ to 10.0 mm while keeping superior at 8.5 mm)	• Precise clearance control without affecting normal cornea optics • Bypasses pupil limitations of full decentration	Not all lens designs support this feature; requires advanced expertise
Quadrant-specific limbal zones	„Rocks" lens into alignment via asymmetric limbal clearance	• Over cone: Increase limbal clearance • Opposite quadrant: Decrease limbal clearance	• Does not alter optic zone (no visual disturbance) • Excellent for fine-tuning haptic alignment	Cannot fix severe apical touch alone; best for refinement
Oblate design in decentered ectasia	• Provides relative clearance over cone • Steepens periphery and aids mid-peripheral alignment	• Flatten BOZR, then reduce BOZD • May be combined with decentering OZ	Effective at reducing high minus power while managing clearance	May still cause excessive clearance opposite cone, requiring additional correction

Table 5: Symptom-Based Troubleshooting Protocol

STEP 4: TROUBLESHOOTING (SYMPTOM-BASED)				
Symptom / Clinical Sign	**Potential Cause**	**Investigative Action**	**Primary Strategy**	**Secondary Strategy**
Midday fogging	Excessive clearance	Measure clearance, especially peripheral and limbal clearance	• Reduce central, peripheral and/or limbal clearance • If uniform, reduce overall sagittal height • If asymmetric, apply decentered ectasia strategies	If mild-moderate ectasia, reduce lens diameter
	Non-optimal haptic alignment	Customized lens to achieve a good alignment on the conjunctiva.	Reduce peripheral and limbal clearance in a quadrant specific mode if necessary	Customize haptic
Persistent fogging after uniform clearance reduction	Multifactorial (ocular surface disease, allergy, and blepharitis)	Differential diagnosis	• Treat ocular surface disease, allergy, and blepharitis • Change filling solution - With electrolytes - More viscous solution • Add fenestrations	Consider piggyback system (soft lens under scleral lens). Temporary solution; monitor for hypoxia
Lens decentration	Excessive clearance	Reduce central, peripheral and/or limbal clearance	• Reduce central, peripheral and/or limbal clearance • If uniform, reduce overall sagittal height • If asymmetric, apply decentered ectasia strategies	If mild-moderate ectasia, reduce lens diameter
	Excessive lens mass	Implement oblate design if high minus, or steepen BOZR if high plus (reduce mass)	Manipulate BOZD accordingly	Reduce lens diameter
	Non-optimal haptic alignment	Optimize lens fit to achieve a good alignment on the conjunctiva	Reduce peripheral and limbal clearance in a quadrant specific mode if necessary	Customize haptic
Blurry, distorted vision	Decentration-induced coma	Improve centration	• Check centration, pupil size, and lens power • Increase BOZD if OZ edge in pupil	See above: "Lens Decentration"
	Spherical aberrations	Manipulate BOZR to reduce lens power	–	Check lens power

	High minification	Flatten BOZR (oblate design)	–	Check lens power
	OZ edge in pupil	Increase BOZD	–	Measure pupil in scotopic conditions
Sectorial conjunctival blanching	Excessive asymmetric peripheral and limbal clearance	Optimize lens fit to achieve a good alignment on the conjunctiva	Decenter OZ	Reduce peripheral and limbal clearance in a quadrant specific mode if necessary
	Non-optimal haptic alignment	Optimize lens fit to achieve a good alignment on the conjunctiva	Reduce peripheral and limbal clearance in a quadrant specific mode if necessary	Customize haptic
Circumferential blanching	• Small lens diameter • Excessive peripheral and limbal clearance	Switch to a looser lens	• Increase lens diameter • Reduce peripheral and limbal clearance	• Lift edge in at least one quadrant • Add fenestrations
Apical touch	Insufficient clearance over cone	Clear the cone	• Decenter OZ • Increase limbal clearance in the ectasia quadrant	Increase overall sag only if combined with a reduction of clearance in the opposite quadrant
Conjunctival prolapse (Benign as long as tissue retrocedes)	Excessive peripheral and limbal clearance	Reduce peripheral clearance	• Decrease BOZD • Reduce peripheral and limbal clearance in a quadrant specific mode if necessary	Reduce lens diameter
Limbal congestion	Excessive limbal clearance	Reduce clearance in affected quadrant	• Decrease BOZD • Reduce peripheral and limbal clearance in a quadrant specific mode if necessary	Increase lens diameter for a looser lens

Table 6: Summary of Key Clinical Pearls

Principle	Clinical Application
100 µm Safety Margin for Progressive KC	Target 200–300 µm central clearance. Add 100 µm for documented progressive disease
Power Management	• Use oblate designs (flatten BOZR + reduce BOZD) as primary strategy to combat excessive minus power and its associated problems (minification, thickness, mass) • Steepen BOZR and increase BOZD to reduce lens plus power
BOZR vs. BOZD	BOZR controls central clearance and lens power; BOZD controls peripheral clearance without altering power
Pupil Size is Paramount	Every decision regarding BOZD and optic zone decentration must be checked against scotopic pupil measurement
Asymmetry Requires Asymmetric Solutions	• For decentered cones, avoid simply increasing overall sagittal height • Use OZ decentration, quadrant-specific changes, or combination to achieve balanced position
Imaging is Essential	• Corneoscleral profilometry is essential for mapping scleral elevation asymmetry across all quadrants and guiding quadrant-specific adjustments to achieve balanced haptic alignment • AS-OCT is indispensable for objectively measuring clearance across different corneal and limbal quadrants, lens alignment, and validating parameter changes
Piggyback as Temporary Rescue	Soft lens under scleral lens can act as a cushion and protect the cornea from touch and mechanical stress in progressive KC when lens replacement is not immediately possible

Integration of All Three Pillars

The three pillars described in this article – the 100-micron progression safety margin, the manipulation of BOZR and BOZD, and the scleral asymmetry, alongside the comprehensive algorithm for centered versus decentered ectasia and the piggyback system – are not independent options but rather integrated components of a single, unified fitting strategy. For any given patient, the practitioner begins with the pre fitting data collection, then selects the appropriate ectasia pathway (centered or decentered), applies the progression safety margin, addresses high-power lenses if indicated, and reserves piggyback configurations. Clinical observations serve as the common thread, validating each step and guiding iterative adjustments. By following this structured, evidence based approach, even the most challenging advanced keratoconus cases can be successfully rehabilitated with scleral lenses, achieving the dual goals of optimal visual function and long term ocular health. This algorithm assumes the availability of fully customizable scleral lens designs. Economic and access disparities may limit implementation. Table 6 summarizes the key clinical pearls.

Conclusion

Advanced keratoconus management with scleral lenses requires a systematic, parameter-driven approach. By understanding the distinct effects of BOZR and BOZD manipulations and by applying targeted strategies based on ectasia pattern and scleral asymmetry, practitioners can achieve successful, reproducible outcomes. The presented algorithm offers a structured clinical pathway that integrates current evidence with practical fitting principles, advancing the standard of care for this complex patient population.

Conflict of interest

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