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Review article

The influence of limbal and scleral shape on scleral lens design

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A R T I C L E I N F O

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Sagittal height

A B S T R A C T

Purpose: To summarize the research findings on the ocular surface profile, to provide a definition and a classification of the corneoscleral shape, and to offer guidelines in selecting scleral lens design.

Methods: The definition of rotational symmetry and rotational asymmetry was inquired and PubMed searches were conducted.

Results: The better understanding of the scleral contact lens comportment on the eye and the introduction of new diagnostic instruments to measure the anterior ocular surface have led to improve comprehension of corneoscleral contour formulating new scleral lens designs. The scleral lens landing zone is influenced by corneoscleral profile which may be rotationally symmetric and rotationally asymmetric. Corneal sagittal height, limbal shape, corneoscleral junction profile, corneal, limbal, and conjunctival angles, and scleral shape should be taken in consideration to prevent and manage fitting problems, such as air bubble formation, midday fogging, localized blanching, impingement, conjunctival prolapse, lens decentration, lens flexure, and to increase comfort, wearing time, overall satisfaction, and visual quality.

Conclusion: Corneoscleral shape may be considered rotationally symmetric including spherical, aspherical and toric profiles, and rotationally asymmetric including regular and irregular quadrants profiles. Each ocular surface contour requires a different landing zone design for an optimal fitting, vaulting properly over the cornea and limbus, and ideal alignment on the sclera. Further studies are still necessary to clarify many aspects of scleral lenses which are little known yet.

1. The background

Scleral shape has been widely described and measured for several years leading to clinical consequences on the fitting and design of scleral lenses in order to improve landing zone alignment with the sclera. In 1946, Feinbloom explained the first tangential fitting of Feincone Scleral contact lenses (ScCL) subdividing the lens into three sections: corneal, cone and temporal radius. The corneal section was to provide the refractive correction. The cone, or truncated conical section, available in 43, 46 and 49°, was to allow for lens bearing on the conjunctival tissue. The temporal radius was to reduce the interaction between the lens edge and the eyelid at the temporal side of the lens [1]. The purpose of such tangential fitting was to alleviate the pressure on the eye, to allow better tolerance and to increase wearing time [1,2]. In 1966, Marriott was the first to describe the ocular surface as asymmetrical. He found that the nasal sclera is flatter by using scleral shells taken from ocular impressions [3]. Later, in 1977, Bier and Lowther illustrated the issues that arise when fitting a spherical ScCL on toric scleras. The formation of air bubbles in the liquid reservoir behind the lens and the occurrence of sectorial blanching suggested the use of a spherical oval fitting or toroidal shell in eyes with high scleral toricity [4].

2. The technology

The introduction of new diagnostic instruments to measure the anterior surface shape, such as Scheimpflug Imaging, Projected Moiré Profilometry and Optical Coherence Tomography (OCT), confirmed the scleral shape intuited years ago. Several studies have reported the estimation and importance of the corneoscleral junction (CSJ) angle and profile [5–19]. Common findings were that the scleral toricity and asymmetry are more pronounced in the sclera than the limbus [5–19], and the limbal and scleral shape are more likely tangential rather than curved [5–11]. In radii, the nasal sclera was found to be flatter than the temporal [5–9,12,14,15–18] and in angles was smaller [5–10,13,16,19]. All of this data has led to the development of new ScCL designs with an improved fitting relationship.

3. Limbus and scleral shape affecting Sccl design

An optimal fitting consists of a proper vault over the cornea and limbus with a balanced distribution of lens pressure on the ocular

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Table 1
Classification of the ocular shape which automatically classify the scleral lens design, and more specifically the landing zone design. Each ocular profile requires a different landing zone design for a good fitting relationship and alignment with the sclera.

SCLERAL SHAPE		LANDING ZONE DESIGN
ROTATIONALLY SYMMETRIC	SPHERICAL	SPHERICAL
	ASPHERIC	ASPHERIC
	TORIC	TORIC
ROTATIONALLY ASYMMETRIC	REGULAR QUADRANTS	QUADRANT SPECIFIC DESIGN
	IRREGULAR	IMPRESSION TECHNIQUE/OR MORE THAN FOUR MERIDIANS

surface [20]. The only zone of a ScCL that should bear on the sclera is the landing zone (LZ). The scleral landing zone is where the name scleral lenses was derived. The LZ may be considered the most crucial parameter among all making it necessary to have a proper fitting relationship and alignment on the sclera in order to prevent and manage the most frequent fitting problems, such as air bubble formation, midday fogging, localized blanching, impingement, conjunctival prolapse, lens decentration, distortion and to increase comfort, increased wearing time, overall satisfaction and visual quality [21,22].

The ocular surface may be symmetric and asymmetric; each type of eye profile requires a different ScCL design [23] (Table 1). Factors conditioning ScCL alignment with the ocular surface start peripherally from the limbal area. These consist of the shape of the limbus, CSJ, corneal, limbal and scleral angles and sclera. The aim of this paper is to define and classify the ocular surface profile, to collect and summarize the research findings on the anterior corneoscleral contour, and to provide guidelines in choosing the right ScCL design for each profile.

3.1. Terminology in consideration

As stated before, the ocular surface may be roughly rotationally symmetric and asymmetric. By definition, a rotationally symmetric surface is a shape which still looks the same after a rotation. The number of times it matches when going once around is called order (Fig. 1). When rotating a spherical surface, its shape remains symmetric with respect to any angle. A toroidal surface is characterized by a rotationally symmetric surface, where the axis of symmetry meets the axis of revolution through the vertex of the surface [24]. Toric surfaces, with perpendicular principal meridians, still look the same after being rotated 180°. Therefore, it presents a rotational symmetry of order 2. Similar to the cornea, the sclera presumably exhibits an aspheric shape with a constant variation of eccentricity along the meridians which maintain the same profile after a rotation of 180°. Along with this, spherical, toric and aspheric surfaces may be considered rotational symmetric surfaces (Fig. 2).

Asymmetric surfaces have a shape of order 1, with no symmetry since all shapes look alike after a rotation of 360° spherical. A rotationally asymmetric sclera may be defined as having a different height in different quadrants. A sclera may exhibit a rotational regular asymmetry and rotational irregular asymmetry. The sclera has rotational regular asymmetry when it shows a constant change in its shape, even relevant, between the different quadrants. In contrast, the sclera may be considered rotationally asymmetric irregular when there is no geometric similarity in the different quadrants, such as the presence of a relevant change in its shape within the same quadrant (conjunctival elevation: pinguecula, pterygium, blebs, ecc.).

Similar to the asymmetry found elsewhere throughout the human body, the ocular surface is also characterized by small amounts of asymmetry. A study demonstrated that the sclera shows roughly 105 µm of toricity at 15.0 mm chord [25]. This suggests that small diameter scleral lenses, less than 15.0 mm, may be fit rotationally spherical with no need of toric or quadrant specific designs [19,25]. In accordance with these findings, the sclera may be considered clinically spherical and rotationally symmetric when it respectively presents a toricity or an asymmetry up to approximately 100 µm [25].

3.2. Symmetric ocular shape

3.2.1. Spherical

a- Limbus

- Limbal diameter

The limbus forms a border between the transparent cornea and opaque sclera, making it very difficult to determine its exact dimension. Recently, a study illustrated a novel method to accurately demarcate the corneoscleral limbus using profilometry [13]. However, the most

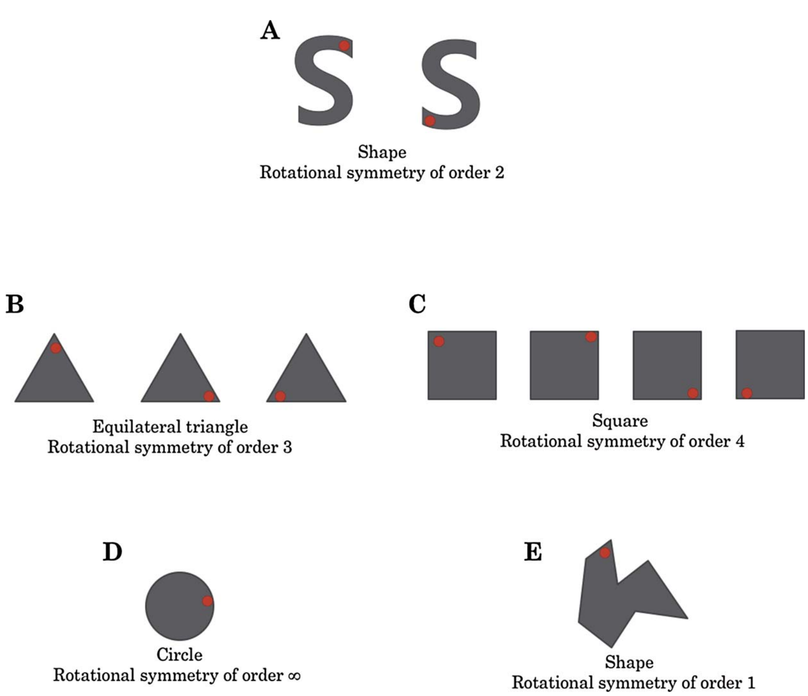

Fig. 1. Shapes with rotational symmetry of different orders and rotational asymmetry. A: Shape with rotational symmetry of order 2. B: Equilateral triangle with rotational symmetry of order 3. C: Square with rotational symmetry of order 4. D: Circle with rotational symmetry of order infinity. E: Shape which matches itself only one time. There is no rotational symmetry when the order is less than 2. The red dot is to indicate the rotation of the surface. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)