Comparative Kitasato-type optical coherence tomography study of differences in scleral shapes between the superonasal and superotemporal quadrants

Masayuki Kasahara,1,3 Nobuyuki Shoji,1,2 Tetsuya Morita,3 Kimiya Shimizu1,3

1 Department of Ophthalmology, Graduate School of Medical Sciences, Kitasato University
2 Department of Rehabilitation, Orthoptics and Visual Science Course, School of Allied Health Sciences, Kitasato University
3 Department of Ophthalmology, Kitasato University School of Medicine

Objective: To determine differences in the scleral shape between the superonasal and superotemporal quadrants, which are the sites of scleral flap creation in trabeculectomy, using anterior-segment optical coherence tomography (OCT).

Methods: Thirty-eight eyes of 22 subjects without ocular diseases except for cataract or ametropia were enrolled. The mean patient age was 63.8 ± 15.7 years (range, 28−80 years). The same examiner captured all images using Kitasato-type anterior-segment swept-source OCT. The mean measurements were calculated from the three images captured 60 degrees from the horizontal line passing through the pupillary center in the superonasal and superotemporal sclera. The radius of the scleral surface curvature and the area of the convex part of the sclera were determined using image analysis software between the superonasal group (N group) and the superotemporal group (T group) using the Mann-Whitney U-test.

Results: The radius of the scleral curvature was 39.6 ± 10.9 mm in the N group and 19.2 ± 3.8 mm in the T group (P < 0.001). The area of the convex part of the sclera was 0.32 ± 0.1 mm² in the N group and 0.61 ± 0.1 mm² in the T group (P < 0.001).

Conclusions: Anterior-segment OCT analysis of the scleral shape showed a more gradual scleral gradient in the superonasal quadrant compared with the superotemporal quadrant. The current data suggested that creating a filtering bleb superonasally may lead to weaker adhesion between the conjunctiva and the sclera, thereby facilitating maintenance of the filtering bleb.

Key words: glaucoma, optical coherence tomography, scleral shape, radius of scleral curvature, trabeculectomy

Introduction

The superior quadrants are preferred over the inferior quadrants as the sites for a filtering bleb in trabeculectomy because the latter are associated with higher infection rates.1 However, no consensus has been reached on the superonasal quadrant and the superotemporal quadrant sites, because opinions vary on the maneuverability, extent of the operative field, and ease of expanding the filtering bleb.2-5 Some surgeons choose an operative field based on their own left or right handedness. Right-handed surgeons find the superotemporal quadrant of the right eye facilitates easier surgical maneuvers, while manipulating devices in the superonasal quadrant of the left eye tends to be more difficult due to the narrow operative field and interference from the bridge of the nose. Therefore, superotemporal filtering blebs are more often created during first surgeries. As a result (i.e., the majority of surgeons are right handed), studies rarely have compared superonasal and superotemporal filtering blebs. While some studies have reported no difference in the intraocular pressure (IOP)-lowering effect,2,3 others have indicated that superonasal filtering blebs are associated with a significantly greater decline in IOP, the difficulty in maneuverability notwithstanding.4,5 In those studies, however, the reason for the advantage of a superonasal filtering bleb was not explained. Although structural differences may have

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Correspondence to: Masayuki Kasahara, Department of Ophthalmology, Kitasato University School of Medicine
1-15-1 Kitasato, Minami-ku, Sagamihara, Kanagawa 252-0374, Japan
E-mail: m09078469240@hotmail.co.jp

134
contributed to the significant difference in IOP; the details remain unknown.

In the present study, we created the filtering blebs either in the superonasal or superotemporal sclera when we performed trabeculectomy. We focused on cases with scleral indentations, which are more common in the superonasal quadrant than in the superotemporal quadrant. When there is a protrusion on the scleral surface, the coated conjunctiva is in tight contact and tends to adhere; in contrast, when the surface is flat or indented, the adhesion to the scleral surface is weaker. Therefore, the shape of the scleral surface at the site of the filtering bleb may postoperatively affect the filtering bleb formation.

To our knowledge, there have not been any cases reported in the literature in which there were differences in the scleral shape between the superonasal and the superotemporal quadrants. Considering the potential impact on the outcome of trabeculectomy depending on the scleral shape, we report the results of a comparison of the scleral shapes between the superonasal and the superotemporal quadrants in normal eyes as a preliminary study using anterior-segment optical coherence tomography (OCT).

Methods

Subjects
Thirty-eight eyes of 22 subjects (22 eyes of 13 men; 16 eyes of 9 women) without ocular diseases except for cataract or ametropia were enrolled. The mean age of the subjects was 63.8 ± 15.7 years (range, 28−80 years). The mean ocular axial length was 23.3 ± 1.8 mm (range, 21.5−27.8 mm) (IOLMaster, Carl Zeiss Meditec, Tokyo). This study adhered to the Declaration of Helsinki, and the Kitasato University School of Medicine ethics committee approved the study.

Imaging method
Images were captured using the Kitasato-type anterior-segment OCT. This instrument is a swept-source (SS)-OCT system with a 1,310-nm SS laser wavelength. The axial resolution is 16 μm, the lateral resolution is 21 μm, and the scan speed is 3,125 A-scans/second. The performance is approximately more equivalent than existing anterior-segment SS-OCT. Anterior-segment SS-OCT uses a monochromatic, tunable, fast scanning laser source and a photodetector to find wavelength-resolved interference signals.6-9 The same examiner performed the imaging examinations without mydriasis using distance vision. The mean measurements were calculated from the three images captured 60 degrees from the horizontal line passing through the pupillary center in the superonasal and superotemporal sclera. The images covered an area from the scleral spur to 5 mm from the fornix. When obtaining the images, the examiner used the monitor to ensure that the aiming beam entered

Figure 1. Images of the right eye
Images are captured 60 degrees from the horizontal line passing through the pupillary center in the superonasal and superotemporal sclera. The images cover an area from the scleral spur to 5 mm from the fornix. When obtaining images, the examiner used the monitor to ensure that the aiming beam entered the limbus perpendicularly.
S, superior; I, inferior; N, nasal; T, temporal
the limbus perpendicularly (Figure 1).

*Image analysis*

The same reader reviewed the captured images to identify the scleral spur. Point A was defined as the location where the line from the scleral spur that was drawn using image analysis software (Image J, National Institutes of Health; Bethesda, MD, USA) perpendicularly intersected the scleral surface (Figure 2A). A 5-mm line was drawn from point A toward the fornix, with point B defined as the location where the line intersected the scleral surface (Figure 2B). A curve was then manually drawn along the top of the scleral surface between points A and B, with the radius of the scleral surface curvature determined

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**Figure 2.** Analytic procedure of the sclera shape

A. To identify the scleral spur, the same reader reviewed all images. Point A is defined as the location where the line from the scleral spur that was drawn using image analysis software (Image J) perpendicularly intersects the scleral surface. B. Point B is defined as the position where a 5-mm line drawn from point A toward the fornix intersects the scleral surface. C. A curve is drawn manually along the top of the scleral surface between points A and B, with the radius of the scleral surface curvature determined using the analysis software Image J. D. The area of the convex part of the sclera (the area of the part bounded by the line between points A and B and the line drawn along the scleral surface between points A and B) is determined using the analysis software Image J.

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**Figure 3.** Comparison of scleral curvature radii

The radius is 38.3 ± 11.4 mm in the N group and 19.6 ± 3.7 mm in the T group (**P < 0.001, Mann-Whitney U test**).

**Figure 4.** Comparison of areas of the convex part of the sclera

The area is 0.34 ± 0.1 mm² in the N group and 0.58 ± 0.1 mm² in the T group (**P < 0.001, Mann-Whitney U test**).
Differences in scleral shapes using the same analysis software (Figure 2C). The area of the convex part of the sclera also was determined using the same analysis software (Figure 2D). The radius of the scleral curvature and the area of the convex part of the sclera were compared between the superonasal group (N group) and the superotemporal group (T group). Statistical analysis was performed using PASW Statistics software (version 17.0, SPSS, Hong Kong) using the Mann-Whitney U test. P < 0.05 considered statistically significant.

Results
The radii of the scleral curvature were 39.6 ± 11.4 mm in the N group and 19.6 ± 3.7 mm in the T group (P < 0.001) (Figure 3). The areas of the convex part of the sclera were 0.34 ± 0.1 mm² in the N group and 0.58 ± 0.1 mm² in the T group (P < 0.001) (Figure 4).

Discussion
We conducted the present study after observing that mild scleral indentations were more commonly observed superonasally than superotemporally in patients who underwent trabeculectomy. While some studies have evaluated the scleral thickness¹⁰,¹¹ and the shape of the posterior sclera,¹² no details about the shape of the anterior scleral surface have been reported. Asejczyk-Widlicka et al.¹⁰ reported that the scleral thickness in fresh porcine eye was 0.53 mm near the corneal limbus and 0.39 mm (the thinnest), near the equator (13 mm from the limbus). Ohno-Matsui et al.¹² studied the shape of the posterior sclera in highly myopic eyes and reported that all eyes in which the scleral curvature sloped toward the optic nerve had a nasally distorted shape in the three-dimensional magnetic resonance images, although the authors provided no information on the radii of the scleral curvature. In addition, Rauber and Kopsch¹³ reported that the radius of the scleral curvature was 12.7 mm and the scleral shape resembled a slightly flattened vertical ellipsoid. However, no any details were provided, including any nasotemporal or anteroposterior differences in the radius of the scleral curvature. Hogan¹⁴ also described a differential distribution of type-1 collagen in the sclera at different sites, including a nasotemporal difference, although there was no mention of whether or

A. Representative case 1. The figure shows the right eye of a 28-year-old woman. The axial length in the right eye is 24.6 mm, and the superonasal sclera has a flatter surface compared with the superotemporal sclera.

B. Representative case 2. The figure shows the left eye of a 65-year-old man. The axial length in the left eye is 23.5 mm, and the superonasal sclera has a flatter surface compared with the superotemporal sclera.

Figure 5.
not such a differential distribution affected the scleral shape. In the present study, the images of two representative cases showed a flatter surface on the superonasal sclera than on the superotemporal sclera (Figure 5A, B). Analysis of the images of all subjects also showed that the superonasal scleral surface was flatter than the superotemporal scleral surface. Although one study reported no differences in the IOP-lowering effect after creation of the superonasal, superior, or superotemporal filtering blebs, other reports found a significant decrease in IOP associated with superonasal filtering blebs.\(^2,3\) However, those reports did not provide details on why the superonasally created filtering blebs were associated with a greater drop in IOP. The current data suggested that the superonasal sclera was flatter than the superotemporal sclera and that creating a filtering bleb superonasally may lead to weaker adhesion between the conjunctiva and the sclera, thereby facilitating maintenance of the filtering bleb. Furthermore, the anatomic distance between the limbus and fornix is shorter in the superonasal quadrant than in the superotemporal quadrant, which potentially gives the conjunctiva and Tenon’s capsule greater ability to stretch. However, further anterior-segment OCT studies of the thickness of the conjunctiva and Tenon’s capsule are needed.

A limitation of the current study was that it was based on a cross-sectional image analysis of normal eyes. Therefore, it was impossible to investigate post trabeculectomy changes in the scleral shape or to determine if the reservoir created was sufficiently large for aqueous humor retention that would actually contribute to IOP lowering. Because no previous studies have compared the scleral shapes between the superonasal and the superotemporal quadrants, the differences in the shapes found in the current study are new findings. In the future, the presence of a correlation between the scleral gradient and the postoperative IOP decrease should be investigated by obtaining preoperative measurements of the scleral gradient in patients with glaucoma who undergo trabeculectomy.

References