A NOVEL METHOD OF MEASURING THE SAGITTAL DEPTH OF SCLERAL CONTACT LENSES USING ANTERIOR SEGMENT OPTICAL COHERENCE TOMOGRAPHY

By

Kevin Bos

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APPENDIX D

ABSTRACT

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Scleral contact lenses (SCLs) are rigid gas-permeable contact lenses rest on the sclera and vault the cornea. Because of this SCLs are able to mask surface irregularities by creating a new refractive surface, which also makes sagittal depth arguably the most important parameter used in the process of fitting SCLs. Regrettably, not all manufactures of SCLs make this parameter available for practitioners for reference, necessitating an efficient and accurate method for the measurement this parameter. In this study, a device was created to hold a scleral contact lens so it could be easily scanned by anterior segment optical coherence tomography (AS-OCT). A method was devised to ensure accurate measurements could be obtained and the SCL was imaged. Using digital calipers in the AS-OCT software, 3 measurements were obtained. The averages of 30 SCLs were then compared to the reported values from the contact lens manufacturer. Using basic statistical analysis, it was determined that the average difference between the reported sagittal depth and the measured sagittal depth was 7.33 μm with an average standard deviation of 18.08 μm and a 95% confidence interval of 0.58 to 14.08 μm. The maximum difference between the reported sagittal depth and the measured sagittal depth was 53.33 μm and the min with a minimum difference of -23.33 μm. The data demonstrates the viability of AS-OCT in the measurement of SCLs.

APPENDIX E

TABLE OF CONTENTS

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INTRODUCTION

Scleral contact lenses (SCLs) are rigid gas-permeable contact lenses rest on the sclera and vault the cornea. Because of this SCLs are able to mask surface irregularities by creating a new refractive surface, which also makes sagittal depth arguably the most important parameter used in the process of fitting SCLs. Regrettably, not all manufactures of SCLs make this parameter available for practitioners for reference, necessitating an efficient and accurate method for the measurement this parameter.

In order to make fitting the fitting process of these lenses more efficient many practitioners have devised ways of estimating this important parameter. At least one author has noted success by measuring corneal sagittal depth using a chord the length of the diameter of the SCL via anterior segment optical coherence tomography (AS-OCT). The sagittal depth obtained was used to mathematically find a starting base curve for the SCL fit (1). However novel this approach is, it is limited by the fact that modern SCLs do not have a uniform base curve. SCLs are designed with differing transitional zone curves that change the sagittal depth of the lens, independent of base curve (2). For this reason the fitting process still relies heavily on trial and error.

There have been numerous studies using AS-OCT technology to perform a variety of clinical and research functions. AS-OCT technology has been used intraoperatively in trabeculotomy surgeries, for the design of SCLs, in the management of glaucoma with pachymetry and iridocorneal angle imaging, laser corneal surgery, cataract surgeries, and the fitting of SCLs as mentioned above (1–6). The AS-OCT (Visante AS-OCT, Carl Zeiss) uses scanning laser interferometry to take multiple A-scans to construct B-scan images (1,2). The manufacturer reports the Visante's optical axial resolution as 18 μm, which somewhat limits the quality of the images and the measurements that are obtained. There are at least 3 other AS-OCT systems with higher axial resolution than that of the Visante, but axial resolution does not necessarily affect the repeatability of measurements (5).

METHODS

Measurements were obtained by imaging an entire set of 30 scleral lenses of known sagittal depth (Blanchard Mini Scleral Design lenses) using the Visante AS-OCT. To achieve this a device was made to hold the contact lenses so the lenses could be measured quickly and accurately (Figure 1, Appendix F).

Each lens was placed on the device affixed to the AS-OCT and serially measured. First, the lens was placed in the contact lens holder, which held the lens flush against the glass slide of the device (Figure 1, Appendix F). The high-resolution cornea quad scan was selected (Figure 2, Appendix F). The video feedback monitor was used to visually align the approximate apex of the contact lens with the center of the scan marked by the intersection of the scanning laser lines. At this time the contact lens was adjusted about the z-axis to place the contact lens' anterior and posterior surfaces between the two horizontal lines shown on the live B-scans. Then using the x- and y-axis adjustments on the device the alignment was fine-tuned. While first adjusting the horizontal alignment, a solid white reflex can be visualized in the video feedback monitor when viewing the apex in the 90 degree meridian. After this is achieved, the vertical alignment is adjusted until the reflex in the 180-degree meridian was centered on the vertical yellow line. If performed properly, the reflex should be viewed in all four meridians, making fine tune x and y adjustments to center the lens better (Figure 2, Appendix F). The scanning mode was then switched to the high-resolution cornea single scan and the scan from which the measurement would be obtained was performed.

The AS-OCT software assumes that it is imaging a single surface refracting interface (SSRI), or the anterior chamber of the eye. Under this assumption the AS-OCT uses optical principles to adjust output making corrections for the refraction that occurs (2); however, using the method described, the contact lens is not an SSRI. To account for the refraction, the AS-OCT indicates where it assumes the anterior and posterior surfaces of the cornea are with lines (Figure 3, Appendix F), the position of which can manually be changed (Figure 4, Appendix F). Therefore, before each of the scans was measured the surface interface was manually changed for each scan setting both lines behind the plane of the glass slide. This was achieved by selecting "change surface" from the edit pull down menu and manually setting the position of the two surfaces. The resultant output is a scan that has not been warped under the assumption that the image was of the human eye.

The caliper was then selected, taking care to place the first point at an analogous point on each contact lens corresponding with the reflex on the scan and the posterior surface of the lens. Care was also taken with the second point, selecting an analogous point on the slide corresponding to the reflex and the anterior surface of the slide (Figure 5, Appendix F). The caliper measurement was hidden from the technician as to not introduce bias to the results. Three separate measurements were taken and the results underwent basic statistical analysis.

RESULTS

The average standard deviation of all 3 measurements made by the above method was 7.45 µm, with a maximum standard deviation of 17.32 µm and a minimum standard deviation of 0.00 µm. These statistics demonstrate the relative precision that was obtained by the above method.

Additionally, it was determined that the average difference between the reported sagittal depth and the measured sagittal depth was 7.33 µm with a standard deviation of 18.08 µm; however, it should be noted that the average of absolute value of the difference was higher at 15.56 µm. The maximum difference between the reported sagittal depth and the measured sagittal depth was 53.33 µm and the min with a minimum difference of -23.33 µm. This gives a range of 76.67 µm for the data. The 95% confidence interval was 0.58 to 14.08 µm.

DISCUSSION

Although this small study has demonstrated the validity of measurements of SCLs taken by AS-OCT when compared to data provided from contact lens manufacturers, it failed to compare data obtained objectively from another method of measurement. A caliper and slide method was attempted, but abandoned after the results were deemed too variable to be valid.

This study could also have been limited by the axial resolution of the Visante AS-OCT. Although there is not any direct evidence that this absolutely affects the measurements, it is intuitive that more accurate measurements could be obtained with higher resolution images.

As the usefulness of AS-OCT imaging in various modes of practice becomes more apparent, the software packages that manufacturers include with their machines will become more robust and applicable to new tasks. This author sees a future in which vector-graphic overlays, essentially a virtual lens, with the contact lens manufacturer's contact lens parameters will be included within the AS-OCT software package. This would give a clinician the ability to "fit" several lenses in a matter of minutes, without the patient having to try on the lens, or the clinician evaluate it.

APPENDIX F

TABLES AND FIGURES

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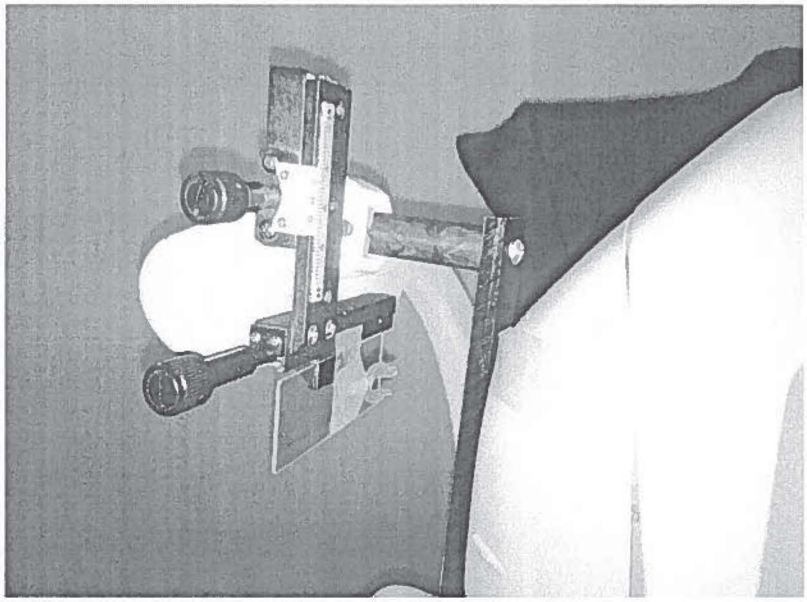

Figure 1. Custom device coupled with Visante AS-OCT

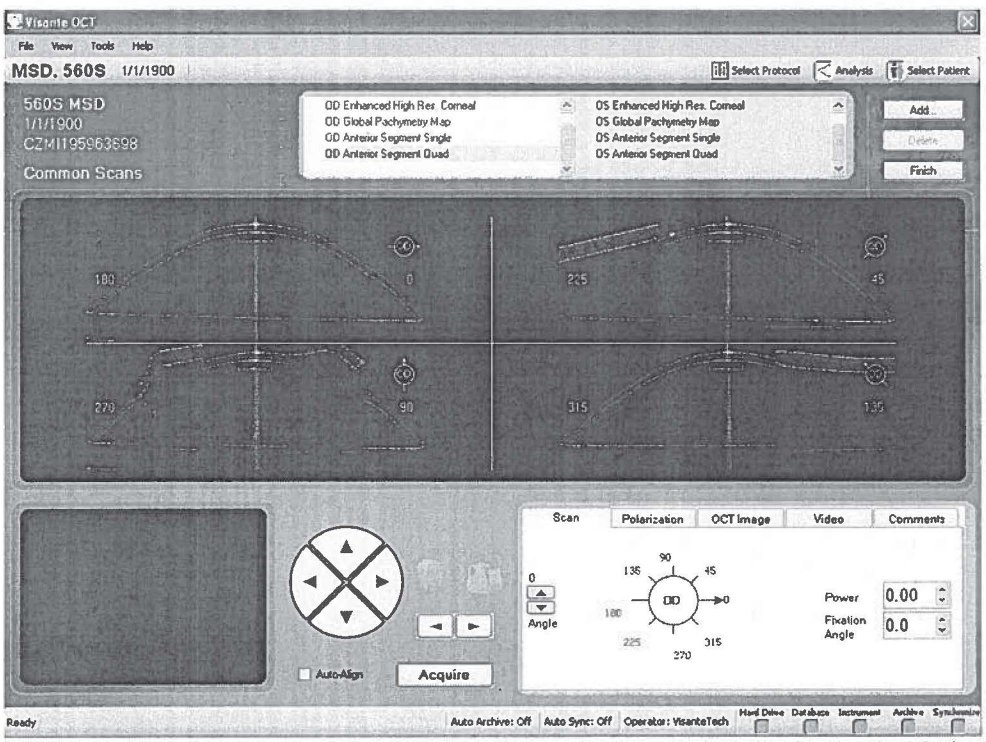

Figure 2. Anterior Segment Quad scan showing light reflexes in all quadrants, indicating that the SCL is properly aligned. The next step is to switch to Anterior Segment Single to capture the image.

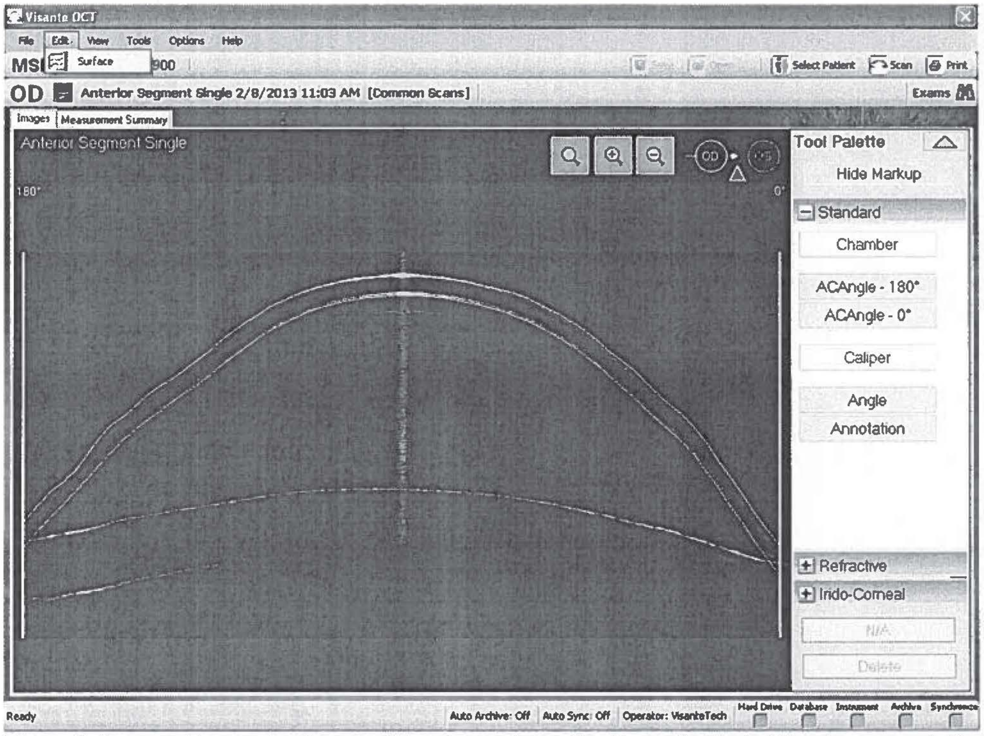

Figure 3. Processed image showing anterior and posterior surface lines of what the Visante assumes is the cornea and the "correction" it makes to the flat glass slide.

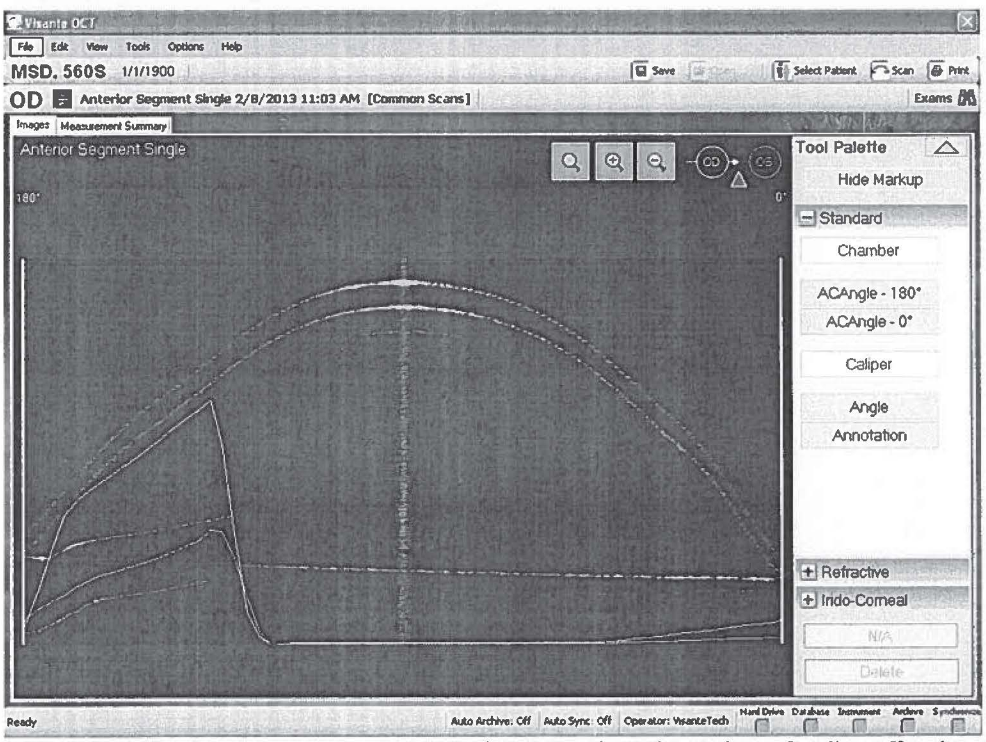

Figure 4. Screenshot illustrating how manually setting the anterior and posterior surface lines affect the output.

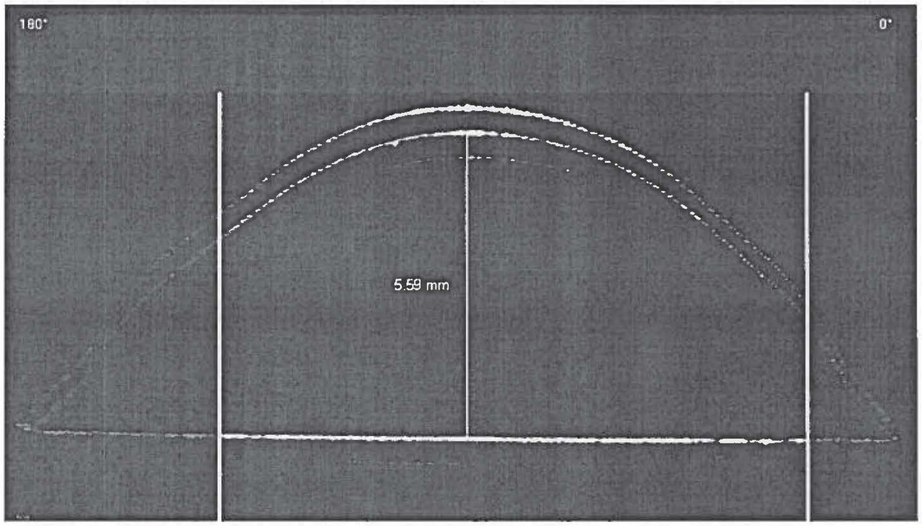

Figure 5. Screenshot showing the caliper measurement from the 560s MSD lens.

AStdDevM	M	StdDev	CI	Max	Min	Range
7.45 μm	7.33 μm	18.08 μm	0.58 to 14.08 μm	53.33 μm	-23.33 μm	76.67 μm

Table 1. Basic Statistical Analysis of Data
AStdDevM, Average Standard Deviation of All Measurements; M, Mean for Difference Between Reported and Measured Sagittal Depths; StdDev, Standard Deviation for Difference Between Reported and Measured Sagittal Depths; CI, 95% for Difference Between Reported and Measured Sagittal Depths; Max, Maximum Value for Difference Between Reported and Measured Sagittal Depths; Min, Minimum Value for Difference Between Reported and Measured Sagittal Depths; Range, Range for Difference Between Reported and Measured Sagittal Depths

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