Visual Benefit of Correcting Higher Order Aberrations in Keratoconus With Customized Scleral Lens

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Background

Irregular astigmatism (i.e., higher order aberrations) in eyes with keratoconus has much larger magnitude than normal eyes. As shown by previous studies, keratoconic eyes have an order of magnitude larger amount of higher order aberration than is present in normal eyes. The ability to effectively correct the aberrations will provide the patients with substantially improved visual performance. Unfortunately, there are limited and relatively ineffective correction options available especially for patients with advanced keratoconus.

Customized soft contact lenses have been developed and demonstrated their effectiveness in correcting the higher order aberrations and improving vision as shown below. However, the residual aberration with the customized soft contact lens is still larger than is observed in typical normal eyes, resulting in reducing the visual benefit significantly. This is due to unpredictable variability in position and rotational orientation of the lens.

To overcome this limitation of the customized soft contact lens, we propose customized scleral lens as another candidate for higher order aberration correction. The scleral lens is almost ideal lens, we propose customized scleral lens as another candidate for

Conventional scleral lens for keratoconus

The scleral lens (developed by Dr. Perry Rosenthal, Boston Foundation for Sight) has a large diameter (17-23 mm) that enables the lens to rest entirely on the relatively smooth sclera and rest above the cornea to create a fluid-free space between the back surface of the lens as shown above. The curvature of the central back surface of the lens was chosen to maintain a shallow tear film clearance of the cornea and limbus after the lens has settled. The posterior haptic surface of the lens was designed to create channels at its interface with the scleral surface to permit tear (not air) to be aspirated into the posterior fluid reservoir and prevent the development of fluid-ventilated lens suction.

Position and rotational stability of scleral lens over time

The goal of the study is to investigate the residual higher order aberrations that are present in keratoconic eyes with the conventional scleral lenses and to evaluate the potential to achieve additional visual benefit with customized scleral lenses correcting these aberrations.

Methods

• Eleven keratoconic (KC) patients (13 eyes) and one normal eye were recruited in this study.
• Conventional scleral lenses were fitted to individual eyes and aberration measurements were performed on each eye with the scleral lens on using a Shack-Hartmann wavefront sensor.
• The aberration was calculated for the subject's maximum natural pupil size under the mesopic illumination condition. From the measured aberration, the polychromatic modulation transfer function (MTFs) were calculated to estimate expected improvements in retinal image quality by customizing the scleral lens.
• Theoretical visual benefit was defined as the ratio of area under the MTFs with customized scleral lens to with the conventional scleral lens.

Residual aberrations in keratoconus and normal eyes with conventional scleral lens

Generating higher order aberrations of keratoconic eyes with scleral lens

Higher order Zernike mode

Conclusions

• Although the conventional scleral lens effectively neutralizes the higher order aberration induced by the anterior corneal surface, the residual aberration mainly from the posterior corneal surface were found to be significant.

• The feasibility of correcting higher order aberrations with the customized scleral lens was demonstrated and this success has the potential to provide substantial improvement in visual performance in keratoconic patients.

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