A Comparison of CustomCornea Myopia Algorithms for Wavefront-Guided Laser In Situ Keratomileusis

Colin C. K. Chan, MD, FRANZCO; Brian S. Boxer Wachler, MD

Objective: To determine whether the new CustomCornea M3 (myopic astigmatism) algorithm places additional pulses in the periphery to counter excimer laser peripheral ablation inefficiency.

Methods: Analysis of 25 myopic eyes of 18 patients that were within the approved indications for both the myopic astigmatism (M3) and myopic sphere (A7) algorithms. We analyzed ablation depth at peak and 4-mm, 6-mm, and 7-mm zone diameters for both the A7 and M3 algorithms.

Results: The M3 algorithm programmed for more of an ablation at the peak and peripheral zones than the A7 algorithm (P < .001). Even accounting for the additional peak ablation, there was significantly greater ablation in the periphery with the M3 algorithm compared with the A7 algorithm (P < .001). The mean (SD) manifest sphere was −4.09 (1.90) diopters (D), the mean (SD) manifest cylinder was −0.60 (0.52) D, and the mean (SD) manifest spherical equivalent was −4.39 (1.92) D. The manifest sphere ranged from −1.00 to −7.50 D, the manifest cylinder from 0.00 to −1.25 D, and the manifest spherical equivalent from −1.50 to −8.25 D.

Conclusion: The new CustomCornea M3 algorithm is programmed to perform additional ablation in the periphery to counter decreased pulse efficacy and the potential for induced spherical aberration.

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Increased spherical aberration after myopic laser in situ keratomileusis (LASIK) can lead to symptoms of halos and glare as well as patient dissatisfaction despite excellent uncorrected visual acuity. The change in corneal shape from prolate to oblate is one of the main causes of spherical aberration. This may be due to the decreased effectiveness of laser pulses in the periphery as the angle of incidence of the laser to the cornea increases toward the periphery. It has also been found through mathematical modeling that a greater depth of central ablation than predicted by the Munnerlyn formula is required to maintain the prolate shape. The first-generation CustomCornea algorithm, known as myopic sphere or A7 (Alcon Laboratories, Inc, Fort Worth, Texas), was the initial software used for CustomCornea LASIK. The second-generation CustomCornea myopic astigmatism algorithm, or M3 (Alcon Laboratories, Inc), is meant to minimize induction of spherical aberration by placing greater pulses in the periphery of the ablation profile. The aim of our study was to evaluate the ablation profile of the M3 algorithm to determine whether additional pulses are placed in the periphery as compared with the A7 algorithm.

METHODS

We conducted a technical analysis of 25 myopic consecutive eyes of 18 patients. Wavefront data were captured on the CustomCornea LADARWave (Alcon Laboratories, Inc). Inclusion criteria were no previous ocular surgery, phoropter spherical refraction of up to −7.90 diopters (D), and phoropter cylinder refraction of up to −1.49 D. We chose these criteria to remain within the allowable limits of both the A7 and M3 algorithms. This makes the data applicable to current US approved ranges for both algorithms. The M3 approved indications for use are phoropter refractions of up to −8.00 D sphere, −0.50 D to −4.00 D cylinder, and up to −8.00 D spherical equivalent. This is an expanded range compared with the original CustomCornea A7 algorithm (up to −7.00 D sphere and −0.50 D cylinder with an allowable difference of 1.00 D between the phoropter and wavefront refractions).

Using the LADARWave platform, we collected data on the proposed ablation profile for each eye using both the M3 and A7 algorithms. Measurements of the peak ablation along with the ablation depth at optical zones of 4-, 6-, and 7-mm diameters were taken. The LADARWave platform allows the user to move a cursor over various points of the proposed ablation profile to determine the ablation depth at that point. The position of the cursor is displayed as x and y Cartesian coordinates so that any spot of the ablation profile can be pinpointed.
Wavefront and manifest refractions for the 25 eyes are outlined in Table 1. Table 2 shows that the mean (SD) peak ablation was 84.9 (33.5) µm in the M3 algorithm and 74.8 (29.9) µm in the A7 algorithm. This was a mean (SD) difference of 10.1 (3.7) µm, or 13.5% (74.8 (29.9) µm in the A7 algorithm. This was a mean (SD) difference of 10.1 (3.7) µm, or 13.5% (P < .001). Even accounting for the increased central ablation depth of the M3 algorithm, the peripheral zones had a greater percentage increase in ablation depth. The amount of additional ablation at the 4- and 6-mm zones with the M3 algorithm compared with its peak ablation correlated with attempted spherical equivalent correction (both P < .001). Even accounting for the increased peak ablation that occurs with the myopic astigmatism algorithm, significant additional ablation occurs in the peripheral zones. This is more evident at the 6- and 7-mm zones.

![Figure 1. Ablation profile display on LADARWave (Alcon Laboratories, Inc. Fort Worth, Texas). Cartesian coordinates are in the top left corner. The cursor is currently at the 90° meridian at the 6.0-mm zone diameter (Cartesian coordinates: 0.0, 3.0).](image)

Table 1. Wavefront and Manifest Refractions

<table>
<thead>
<tr>
<th>Refraction</th>
<th>Wavefront Refraction, Diopters</th>
<th>Manifest Refraction, Diopters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Sphere</td>
<td>-4.03 (1.90)</td>
<td>-1.23 to -7.13</td>
</tr>
<tr>
<td>Cylinder</td>
<td>-0.78 (0.42)</td>
<td>-0.08 to -1.49</td>
</tr>
<tr>
<td>Spherical equivalent</td>
<td>-4.42 (1.96)</td>
<td>-1.64 to -7.84</td>
</tr>
</tbody>
</table>

Induced spherical aberration after LASIK may occur owing to 3 primary interconnected factors: (1) pupil and optical zone mismatch; (2) lack of a transition zone or blend zone leading to an abrupt change in refractive power at the edge of the optical zone; and (3) change from a prolate corneal shape to an oblate shape. Periphereal rays undergo greater bending relative to the central rays in an oblate cornea. This results in symptoms including glare and halos, especially under scotopic conditions when the pupil dilates and encompasses these peripheral rays.

Most studies propose that the change in shape takes place because change in fluence or laser energy occurs when the laser beam strikes the cornea at an increasingly more oblique angle as it moves from the center to the periphery. This results in a decrease of the actual energy reaching the surface as well as increased reflectance of the incident beam. This has also been called the cosine effect because the perpendicular or effective component of the incident beam is given by \( \cos^2 \phi \). Other theories suggested to account for the corneal shape change after LASIK are either biological (wound healing or epithelial hyperplasia) or biomechanical (increased pull by peripheral corneal lamellae). It has been proposed that additional laser pulses in the periphery would help prevent spherical aberration. It is not known how much extra ablation should take place. Holladay et al. have stated that the laser's effective energy decreases by 16% at 1 mm, 20% at 2 mm, and...
Our findings confirm that the new CustomCornea M3 algorithm is designed to add pulses in the periphery to counter UV reflectance and minimize induction of spherical aberration. This technique can be a benefit to all laser platforms—although some manufacturers state that compensatory software is present. For example, the Wavelight platform (Wavelight Laser Technologie AG, Erlangen, Germany) has wavefront-optimized software that is meant to minimize induced spherical aberration based on higher-order aberration data derived from a normal population. The VISX laser software (VISX USA, Inc, Santa Clara, California) is also meant to have spherical aberration software compensation that uses K values to judge how to compensate for the cosine effect. We did not analyze our data to determine whether this is the case with the CustomCornea algorithms. However, owing to the proprietary nature of the software, no details on these other systems are available, nor are there any peer-reviewed articles to our knowledge that have analyzed these systems like we did in this study.

Our analysis of the spherical aberration outcomes as they were not clinically assessed. The purpose of this study was a technical assessment to verify how the manufacturer had incorporated spherical aberration compensation into the algorithm. This information is not released to the surgeon or technician and is proprietary. We also cannot comment on how or whether such software is incorporated into other laser platforms—although some manufacturers state that compensatory software is present. For example, the Wavelight platform (Wavelight Laser Technologie AG, Erlangen, Germany) has wavefront-optimized software that is meant to minimize induced spherical aberration based on higher-order aberration data derived from a normal population. The VISX laser software (VISX USA, Inc, Santa Clara, California) is also meant to have spherical aberration software compensation that uses K values to judge how to compensate for the cosine effect. We did not analyze our data to determine whether this is the case with the CustomCornea algorithms. However, owing to the proprietary nature of the software, no details on these other systems are available, nor are there any peer-reviewed articles to our knowledge that have analyzed these systems like we did in this study.

The new CustomCornea M3 algorithm is designed to add pulses in the periphery to counter UV reflectance and minimize induction of spherical aberration. This technique can be a benefit to all laser platforms by increasing ablation efficiency in the corneal periphery.

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Author Contributions: Dr Chan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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The Stiles-Crawford effect needs to be considered when formulating compensatory software. Photoreceptors are maximally stimulated by rays of light incident perpendicularly; as a result, peripheral rays do not contribute as much to the image perceived by the patient. This effect compensates for spherical aberration. A ray at the 6-mm margin has an effectivity of 35% to 40% of a central ray, and a ray at the 8-mm margin has a 20% effectivity. Gatinel et al have also shown through a mathematical model that the depth of the central ablation also must be greater to maintain a prolate shape. The more prolate the cornea is initially, the less ablation is required.

The new CustomCornea M3 algorithm does appear to incorporate these factors when creating an ablation profile. Our results show that the new CustomCornea M3 software does result in more pulses centrally and in the midperiphery compared with the A7 algorithm. It also places additional pulses at the +4- and 6-mm zones relative to the central ablation. Even though the peak ablation depth is slightly increased, the peripheral ablation depth is significantly greater to counteract the decreased peripheral ablation efficiency that occurs with the excimer laser. The additional ablation performed by the M3 algorithm correlated very strongly with the degree of attempted correction. The degree of additional peripheral pulses also correlated with the degree of attempted correction. The increased central ablation is a limiting factor for greater corrections to avoid an increase in the risk of ectasia.

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The more prolate the cornea is initially, the less ablation is required. Increasing attempted correction would necessitate an increasing amount of ablation to maintain a prolate shape as well as a large effective optical zone. The Stiles-Crawford effect needs to be considered when formulating compensatory software. Photoreceptors are maximally stimulated by rays of light incident perpendicularly; as a result, peripheral rays do not contribute as much to the image perceived by the patient. This effect compensates for spherical aberration. A ray at the 6-mm margin has an effectivity of 35% to 40% of a central ray, and a ray at the 8-mm margin has a 20% effectivity. Gatinel et al have also shown through a mathematical model that the depth of the central ablation also must be greater to maintain a prolate shape. The more prolate the cornea is initially, the less ablation is required.

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REFERENCES


Giuseppe Schiantarelli (circa 1750-1836) appears to have been an ophthalmologist working in Milan, Italy. The Norton collection at the library of the Bascom Palmer Eye Institute in Miami, Florida, contains a Schiantarelli publication entitled “Sull’ago da catterata e sul metodo di cura da usarla dopo l’operazione stessa... Brescia: Nellia tipografia Bendiscioli, 1819.”

In Italy in 1836, a commemorative medal for the death of Schiantarelli, by the artist Giuseppe Zapparelli, was struck in bronze, 45 mm in diameter. The obverse depicts his clothed bust to the left, with an inscription below: ZAPPARELLI; within the curve around: IOSEPHVS. SCHANTELLARIVS. MEDICVS. OCVLARIVS. EXPERENTISSIMVS.

The reverse depicts a mourning angel holding a snake-entwined staff in the right hand next to a gravestone, with an inscription at the base of the gravestone: ZAPPARELLI; within the curve around: EXIMIA. MORBIS. ARTE. DEPVLIS. MDCCCXXXVI.

Courtesy of: Jay M. Galst, MD, clinical associate professor, New York Medical College, and Peter van Alfen, PhD, associate curator, American Numismatic Society.
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