Error in the Estimation of Ablation Centration Using Pachymetric Difference Maps

In the article “Topographic Analysis of the Centration of the Treatment Zone After SMILE for Myopia and Comparison to FS-LASIK: Subjective Versus Objective Alignment” by Lazaridis et al., a corneal thickness difference map was used to determine centration. The authors concluded that “the corneal thickness differential map in Scheimpflug-based systems is a useful tool to display the treatment zone and to estimate the centration after refractive surgery.” However, unlike curvature or elevation, corneal thickness is calculated normal to the anterior surface for most tomographic systems, including the Pentacam (Oculus Optikgeräte, Wetzlar, Germany), and then reflected to a two-dimensional display. This leads to two main problems. The anterior surface has been substantially altered and thus the normal-to-the-surface calculation and the direction in which corneal thickness is calculated are not comparable between preoperative and postoperative displays. Also, when potential misalignment exists between the preoperative and postoperative corneas relative to the reference axis (due to a change in the line of sight or other cause), the difference display can be adversely affected. This is illustrated in Figure 1A with a patient who underwent LASIK. The calculated point of maximum corneal thickness difference is far decentered from the thinnest points in both the preoperative and postoperative maps.

A mathematical simulation was performed to investigate misalignment when calculating a corneal thickness difference map. The preoperative cornea was modeled as two aspheric ellipsoids, one representing the anterior surface with central radius of curvature (Ro = 7.8 mm, eccentricity = 0.5) and one representing the posterior surface (Ro = 6.4 mm, eccentricity = 0.45). Central corneal thickness was set to 500 µm. A 6-mm ablation zone was simulated with the Munnerlyn approach and central ablation depth of 50 µm, leading to a postoperative Ro value of 8.55 mm. Figure 1B shows the simulated corneal thickness difference map for a translation of 0.4 mm and a rotation of 5° of the specified postoperative cornea relative to the preoperative cornea. Note that the apparent point of maximum ablation depth is decentered, despite the simulation of perfectly centered treatment. Also note the pattern of tilt in the difference map, similar to the corneal thickness difference map in Figure 1A.

A corneal thickness difference map is not an appropriate method to determine treatment centration. Although the case in Figure 1A is extreme because the locations of thinnest spots preoperatively and postoperatively are clearly displaced, it nevertheless illustrates the fundamental problem in using a corneal thickness difference map to determine treatment centration. In fact, this may explain the outliers Lazaridis et al. noted in their discussion. It is far more likely that artifact in the way the corneal thickness difference map is calculated would be the source for the outliers, rather than extreme decentration during the treatment itself. The many different ways in which corneal thickness can be interpreted are highlighted in a recent editorial due to the multiple possible algorithms that exist for defining the distance between two surfaces. This problem is not apparent in either the curvature or elevation difference maps because the direction of the subtraction is parallel to the reference axis rather than normal to the surface.

REFERENCES

Figure 1. (A) Orbscan (TECHNOLAS Perfect Vision, Inc., St. Louis, MO) corneal thickness difference map from a patient who underwent LASIK with postoperative minus preoperative difference displayed. Note that the maximum decrease in corneal thickness is displaced from the thinnest point in both the preoperative and postoperative maps. (B) A simulated corneal thickness difference map is shown from a perfectly centered treatment with a translation of 0.4 mm and a rotation of 5° of the postoperative map relative to the preoperative map. Note that the point of maximum difference is decentered with tilt present in the difference, similar to the Orbscan map from an actual patient.


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The author has no financial or proprietary interest in the materials presented herein.

Reply:

We would like to thank Dr. Roberts for the interesting remarks on our article.1 We evaluated the eccentricity of the treatment zone on the differential corneal thickness maps. Standard corneal thickness with Pentacam (Oculus Optikgeräte, Wetzlar, Germany) measures the distance between the anterior and posterior cornea normal to the anterior surface. This approach is characterized by repetitability and accuracy,2 and the differential corneal thickness maps are commonly used for assessing the spatial distribution of the extracted lenticule or photoablated tissue in the corneal stroma after corneal refractive surgery.

It is true that corneal thickness measured normal to the surface tangent3 might present value deviations compared to minimal distance measurements, especially when performed on an ectatic cornea. Our examined groups included myopic, non-ectatic eyes that did not develop any iatrogenic ectasia (at least until the 3-month examination). Regarding our measurements, both the preoperative and postoperative measurements were performed with the same measurement principles and, despite the central corneal flattening after the surgery, they can be compared and subtracted. According to optical engineers at Oculus Optikgeräte, corneal thickness maps generate reliable subtraction maps, provided that each measurement is well aligned to the reference axis. In that case, the corneal thickness progression from the periphery to the thickest point demonstrates the volume of extracted lenticule or the photoablated tissue and its center. Therefore, they provide sufficient three-dimensional data (corneal thickness corresponds to the z-axis), despite being projected on a two-dimensional display.

We knew that corneal refractive surgery would cause a change of the corneal optics and the eye’s visual optics, especially by decentered treatment zones. This is the reason we did not assess the predictability of the intraoperative alignment (coordinated in relation to the preoperative corneal parameters) on the postoperative maps. Regarding the potential misalignment between preoperative and postoperative measurements, we could only rely on the quality specification data supplied by the instrument regarding the x, y, and z alignments. Unfortunately, we do not know if the algorithms used by the Pentacam to create subtraction maps compensate for changes of the visual axis, the line of sight, or both, which are difficult (if not impossible) to determine accurately.

Regarding the thinnest point on the preoperative maps, it is considered to be of great importance to determine the thickness of the lenticule, the depth of the ablation, and the thickness of the flap. Moreover, its displacement could indicate a subclinical keratoconus. However, its location on the preoperative maps is irrelevant to the attempted or achieved centration. The location of the point of maximum corneal thickness difference, as identified by our method, should not necessarily coincide with the thinnest points in preoperative or postoperative maps.

The predictability and accuracy of mathematical simulation that Dr. Roberts presents, although interesting, should be correlated to actual clinical and visual results. Unfortunately, we could not find the manuscript of the dissertation from Yih-Tyng Wu Y-T, “Change of Line of Sight After LASIK,” to further evaluate the methods and results.

We believe that our study achieved the purpose of assessing and comparing the predictability of the intraoperative alignment between small incision lenticule extraction and femtosecond laser-assisted LASIK. We believe that differential corneal thickness maps could be useful to assess the centration of the treatment zone. However, possible changes of the eye’s optics should be taken into consideration.

REFERENCES


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