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Opinion

Corneal Correction Supported by Intraocular Pressure

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Abstract

Until now, it was impossible to correct corneal distortion using the current technology of laser vision correction. As a solution, we would like to present the method that removes the characteristics of a distorted cornea in order to correct corneal distortion. The distorted cornea has a thickness deviation in central symmetry and an eccentric cone shape at the posterior surface due to intraocular pressure. Therefore, we present a novel method where the laser eliminates the thickness deviation in central symmetry and as a result, the posterior corneal curvature is improved because intraocular pressure helps to place and maintain the posterior cone at the center.

In addition, if the laser eliminates the thickness deviation in central symmetry, the effect of preoperative pressure that was applied only on the posterior cone gets dispersed and weakens. In this point of view, this novel method can be applied to treat Keratoconus. The advantage of this method is that the surgical process is simple and it creates a clear vision by correcting corneal distortions after surgery.

Keywords: *Corneal Correction; Thickness Deviation in Central Symmetry; Eccentric Posterior Corneal Cone; Intraocular Pressure; Keratoconus*

Introduction

In laser vision correction, it is impossible to control the shape of the cornea. Thus, there has not been any effective method that can accomplish corneal correction despite the visual loss occurring from corneal distortion [1]. Corneal shape is maintained by intraocular pressure and the direction of the pressure is always heading towards the outside from the inside of the cornea. Thus, corneal distortion by intraocular pressure starts from the inside and proceeds outward. Similarly, corneal correction also starts from the inside and proceed outwards. The magnitude of the pressure applied to the cornea is inversely proportional to the thickness. Therefore, when corneal thickness becomes thinner by laser ablation, the corneal shape is changed by intraocular pressure.

In accordance with the above concept, finding a way to eliminate the features of corneal distortion is a shortcut for correcting distorted cornea. In our research, we found that the shape of the posterior cornea is distorted by intraocular pressure, distorted cornea shows the shape of an eccentric cone and it has thickness deviation in central symmetry, as shown in figure 1a. Accordingly, we suggest a corneal correction method, where the laser eliminates thickness deviation in central symmetry so that the thickness becomes central symmetric. This method enables intraocular pressure to trigger the posterior corneal cone to be placed in the center, as shown in figure 1b. The advantage of this method is that posterior corneal curvature can be improved by having posterior cone placed at the central cornea.

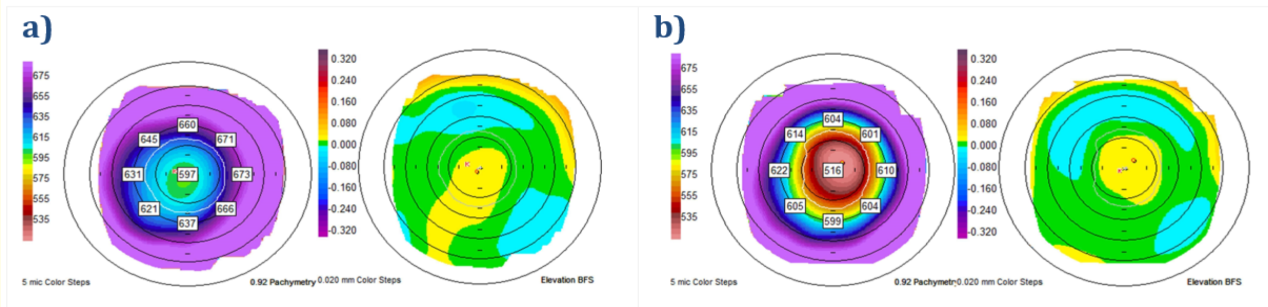

Figure 1: A patient's pre and postoperative changes in the corneal map by combined correction, corneal correction, and refractive correction. (a) shows preoperative maps, corneal thickness distribution (left) and eccentric posterior corneal cone (right). (b) shows postoperative maps, reduced corneal thickness deviation (left) and centered posterior corneal cone (right)..

Figure 2a is a laser ablation pattern to correct the corneal shape and refraction for the patient's cornea shown in figure 1a. Figure 2a is created by coupling corneal ablation patterns depicted in figure 2b and figure 2c. Figure 2b shows the asymmetric ablation pattern to remove the thickness deviation in central symmetry, without any changes of refraction. Figure 2c is the symmetric ablation pattern to correct a refractive power, -3.25D spherical, -0.25D cylindrical with axis 180°. The map in figure 1b is the outcome after the simulation of laser corneal ablation depicted in figure 2a.

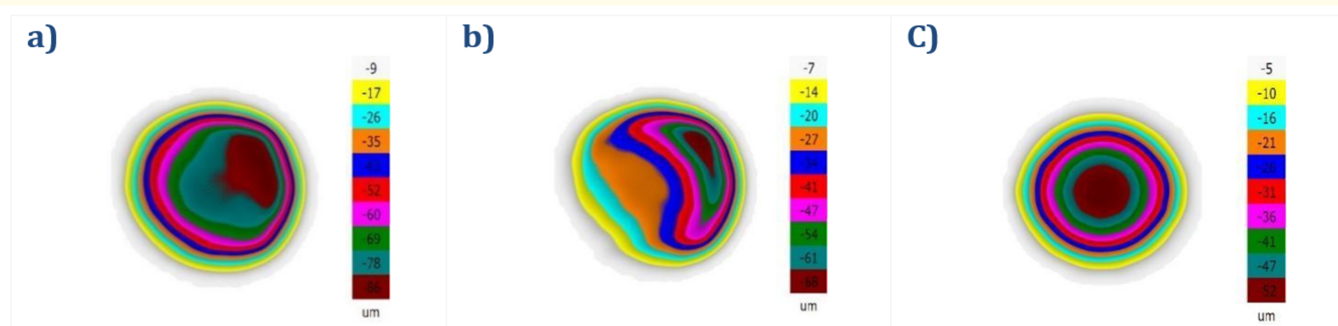

Figure 2: Simulations to explain the configuration of the combined corneal ablation pattern depicted in (a). (a) shows customized ablation pattern created by combining (b) and (c). (b) shows asymmetric ablation pattern for correcting corneal distortion without the change of refraction. (c) shows symmetric ablation pattern for refractive correction of -3.25D spherical, -0.25D cylindrical with axis 180°.

Figure 3a is the same as figure 2b. In figure 3a, corneal correction pattern is produced by a combination of figures 3b and 3c. Figure 3b shows corneal ablation for correcting thickness deviation in central symmetry. The ablation pattern of corneal thickness deviation in central symmetry is produced by the C-shaped combination of semi-cylindrical ablation patterns, as depicted in figure 3b. When performing the C-shaped ablation shown in figure 3b, it should be considered that a refractive change (Δ) occurs and results in a myopic shift. Therefore, laser ablation for myopia correction shown in figure 3c is necessary in order to cancel out the generated refractive change [Δ]. Indeed, up to now, the semi-cylindrical removal pattern has been used for cylinder correction by axisymmetric coupling in laser refraction correction. From this point of view, the change in refraction (Δ) shown in figure 3b can be calculated using the spherical equivalent refraction formula. Therefore, -2D spherical refractive correction as shown in figure 3c is required.

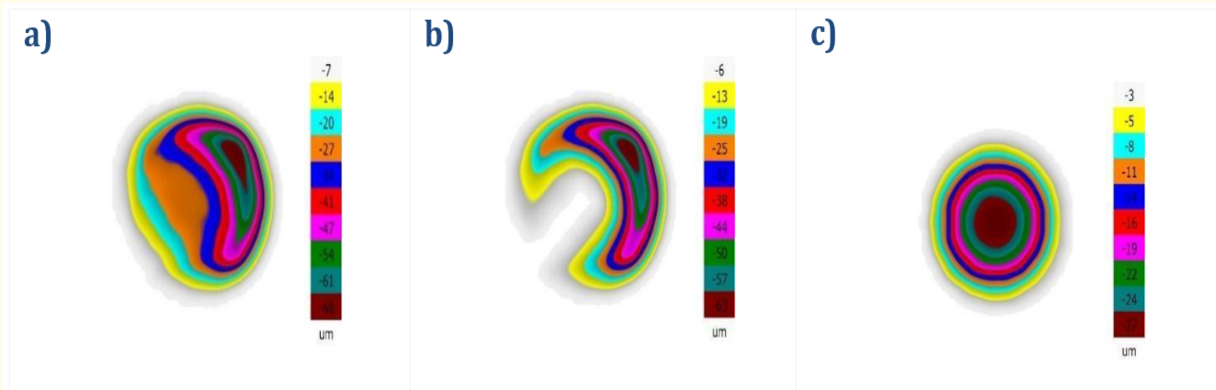

Figure 3: *Simulations to explain the configuration of the laser ablation pattern depicted in Figure 2 (b). (a) is the same as corneal ablation pattern depicted in Figure 2 (b). (b) shows C-shaped corneal ablation pattern to remove thickness deviation in central symmetry. (c) shows corneal ablation to correct -2D spherical created by executing a C-shaped corneal ablation depicted in (b).*

C-shaped corneal ablation pattern as shown in figure 3b can be applied to the treatment of keratoconus [2]. It has the ability to correct corneal shape by ablating the thicker zone, as depicted in figure 4. The relative concentration of intraocular pressure at the cone is reduced by ablating the thickness deviation.

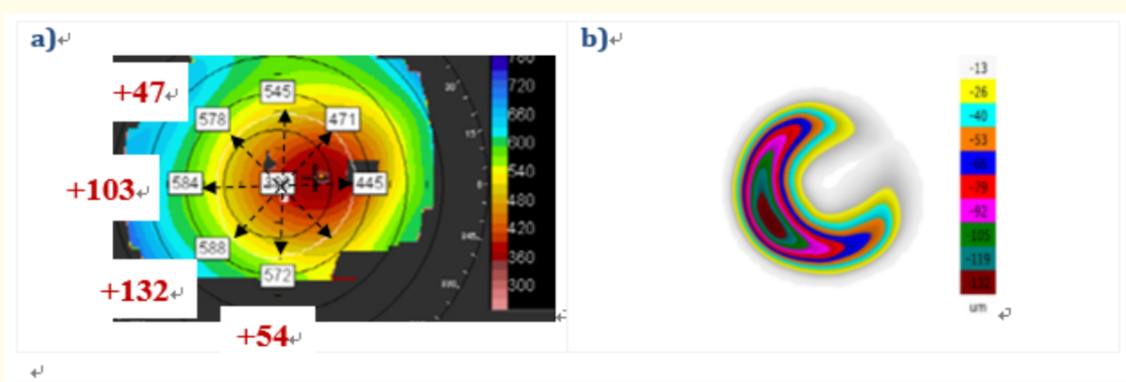

Figure 4: *An example map of keratoconus (a) and a simulation of customized corneal ablation pattern to correct keratoconus depicted in (a). In the map of (a), the black numbers inside the boxes represent the corneal thickness and the red numbers show thickness deviation in central symmetry. In the simulation of (b), the customized corneal ablation pattern for treating keratoconus is shown. The laser ablation plan depicted in (b) is obtained by Vision-Up software for corneal correction.*

Discussion

The cornea depicted in figure 4a shows keratoconus and the patient's visual acuity has trouble from severe glare symptoms. In laser corneal ablation for treating keratoconus, the original plan was to use the C-shaped ablation pattern that ablates 132 microns in the center as shown in figure 4b. However, during the actual operation, the laser eliminated only 88 microns of the thickness deviation, as can be shown in figure 5a. The reason for this is that it was the first attempt to treat keratoconus using this novel corneal correction method, and we needed to carefully approach it to confirm that the outcome would be the same as in our hypothesis, without any kind of side effects when thickness deviation is decreased in keratoconus.

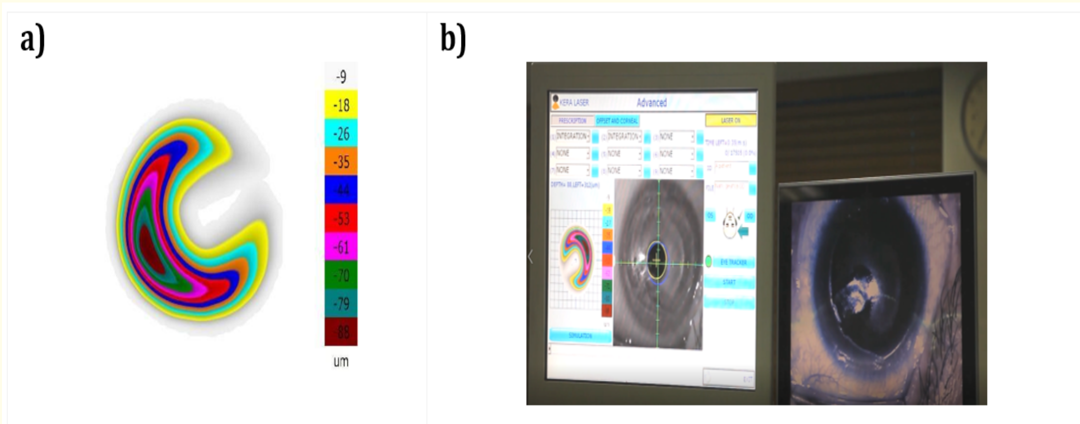

Figure 5: *The treatment of keratoconus by laser ablation for corneal correction method. (a) shows the simulation of the actual corneal ablation in the surgery. (b) shows the surgical scene of an actual corneal ablation. The laser executed C-shaped corneal ablation (right monitor) according to the plan (left monitor). The laser fluence, wavelength, energy per purse and effective repetition rate that were used 100 - 180 mJ/cm2, 193 nm, < 1mJ and 300 Hz respectively in the corneal ablation.*

After the surgery, the glare symptom was significantly reduced and there was no side effect except dry eye symptom. Our intentional surgical process mentioned above was explained to the patient and she consented to our surgical plan. The operation was performed at Lee Seongsu eye center in 2018. A second surgery will be executed to remove the remaining thickness deviation after a one-year follow-up.

Conclusion

We are convinced that the corneal shape can be corrected by the corneal ablation of thickness deviation in central symmetry. If the posterior cone locates in the corneal center, it helps corneal curvature to be contour type. In addition, this method can be applied to the treatment of Keratoconus. If laser ablates the cornea with the ablation of thickness deviation in central symmetry, the compressing effect in the cone-shaped zone by intraocular pressure is reduced and corneal curvature can change smooth round type. Treating keratoconus by the corneal correction method we present has the advantage that corneal distortion can be corrected by a simple process, and of obtaining clear vision than when keratoconus is treated with other methods developed so far [3-5].

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