Lasik-Induced Posterior Corneal Changes Measured by Scheimpflug Imaging: Validation on Model Corneas and Measurements on Patients

Lucie Sawides[1], Jesús Merayo[2], Susana Marcos[1]

[1]Instituto de Optica, Consejo Superior de Investigaciones Científicas, madrid, Spain, [2]Instituto de OftalmoBiología Aplicada, Valladolid, Spain

lucie@io.cfmac.csic.es

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❶ Background & Purpose

Background:

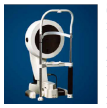
Although the contribution of the posterior corneal surface to ocular aberrations has often been neglected, there is evidence that it plays a role in normal eyes (i.e. compensatory role of astigmatism and other aberrations)[1,2], and many reports discuss changes of the posterior corneal shape following refractive surgery [3,4,5](with implications to understand biomechanical effects). Most of the literature regarding posterior corneal shape changes with refractive surgery referred to measurements obtained with scanning slit topography. Concerns of the reliability of this instrument have been raised [6], and some of the reported changes may be subject to artefacts. Scheimpflug imaging provides images of the anterior chamber of the eye with greater depth-of-focus, although these are also subject to distortions (geometrical, due to the geometric configuration of the camera and optical, due to the refraction from the preceding ocular surfaces). A validation of the correction of the images is needed before it can be reliable used to obtain posterior surface shapes and study changes with refractive surgery[7].

Purpose:

1. To check the reliability of the Pentacam (Oculus), to measure posterior corneal surface using corneal models on plastic material. We will assess whether the changes in the anterior surface (by laser ablation) affect measurements in the posterior surface.
2. To measure potential changes of the posterior corneal surface with LASIK in patient's eyes (before and after LASIK, as well as longitudinally after LASIK).

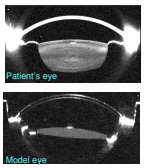
❷ Methods

Scheimpflug Imaging



Pentacam, Oculus

Scheimpflug cameras allow capture of cross-sectional images of the eye's anterior chamber, although these are subject to geometrical and optical distortions from the preceding ocular components[8]. We used a Pentacam system (Oculus), which nominally corrects for those distortions. 2-D elevation maps were reconstructed from 25 section images.



Custom algorithms were developed in Matlab to fit posterior corneal elevation maps with biconic functions.

$$Z_{BC}(x,\theta) = \frac{(R_y\cos^2(\theta-\theta_x) + R_x\sin^2(\theta-\theta_x))r^2}{R_xR_y + \sqrt{R_x^2R_y^2 - (p_xR_y^2\cos^2(\theta-\theta_x) + p_yR_x^2\sin^2(\theta-\theta_x))r^2}}$$

$r^2 = (X-Xo)^2 + (Y-Yo)^2$ and $\theta = \arctan\left(\frac{Y-Yo}{X-Xo}\right)$

Radius of curvature R = arithmetic average of Rx and Ry

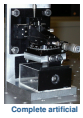
Shape factor p = arithmetic average of px and py

Z : Elevation (in a polar coordinate system (r, θ)),
Rx : Radius along the first meridian,
Ry : Radius along the perpendicular meridian,
px : Shape factor along the first meridian,
py : Shape factor along the perpendicular meridian,
θx : Angular offset of the biconic's principal meridians from the xy-coordinate axes

Radii of curvature and asphericity before and after ablation were compared with results from the commercial software
Paired t-tests were used to assess significant differences before and after ablation. Study was done to assess potential longitudinal changes and correlations with corrected spherical error. The level of significance was set at $p<0.05$

Corneal plastic models

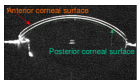
We checked that measurements of the posterior corneal surface were unaffected by anterior corneal refractive changes using spherical corneal models.



Complete artificial model eye [9]

Corneal models:

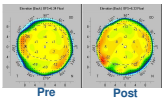
4 custom contact lenses of blue diffusing material (AR3 Vision)
Anterior radii of curvature : 7.95 ± 0.1mm



Posterior radii of curvature : 6.52 ± 0.05mm

Procedure:

The lenses were ablated [10] with a standard refractive surgery laser (Technolas 217-C LASIK),
Applied corrections : -12,-9,-5, +5 D,
Optical zone diameter : 5mm
8 or more measurements with the Pentacam were made pre- and post-ablation.



Posterior corneal elevation maps* were obtained and processed as explained above

* Referred to best fitting sphere

Patient's eyes before and after LASIK

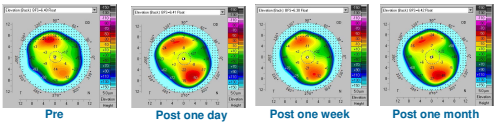
Subjects:

40 eyes of 21 patients who underwent myopic LASIK at the Institute of Applied Ophtalmobiology (IOBA, university of Valladolid, Spain)
Ages: between 20 and 54 years old (34±8 yrs)
Spherical correction : from -1.25 to -7.25 D
Cylindrical correction : from 0 to -2.5 D
Optical zone diameter : from 5.2 to 7 mm

Procedures:

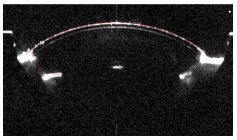
5 or more measurements were done pre-op and 1-day, 1-week and 1-month postoperatively.
Pre and one-day post ablation : 29 eyes; Pre and one-week post ablation: 15 eyes;
Pre and one-month post ablation: 23 eyes
Protocols had been approved by Institutional Review Boards and met the tenets of the declaration of Helsinki. Patients signed informed consents

Posterior corneal elevation* in a patient before and after LASIK (Ablation : spherical -5.5D, cylindrical -1.5D)

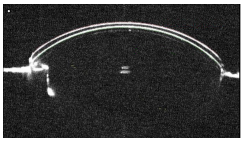


❸ Results

Corneal models



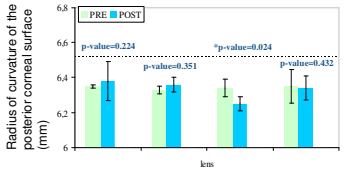
PMMA model: Software Reconstruction only possible for the anterior surface!!

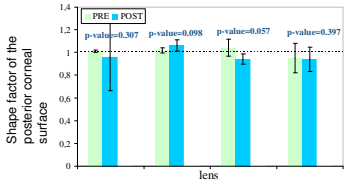


Blue Diffusing Material model: Software Reconstruction possible for both the anterior and posterior surfaces

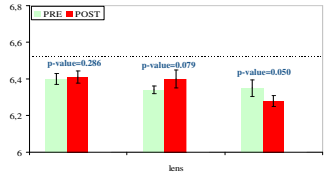
We found an adequate material to measure both the anterior and posterior corneal surfaces with the Pentacam.

CUSTOM ROUTINES





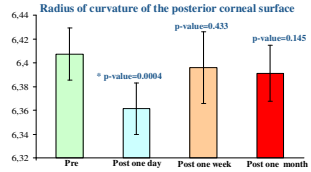
PENTACAM

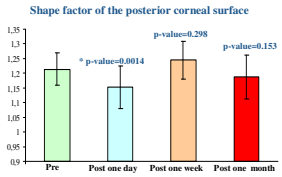


No significant changes in the posterior corneal surface shape on plastic model corneas before and after ablation : Optical distortions from the anterior cornea appear to be properly corrected by the Pentacam.

LASIK patients

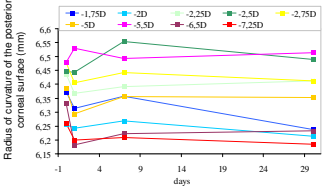
Average data across all eyes

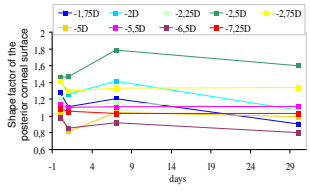




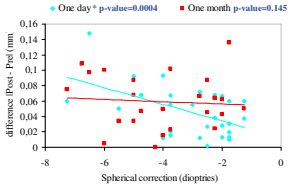
Changes in the posterior corneal surface : radius and asphericity are only significant immediately following the refractive surgery.

Individual longitudinal data





All eyes but one experience a decrease in posterior corneal radius (increased curvature), and all eyes experience a decrease in asphericity one day after surgery. The largest increase in corneal radius (from pre to one-day-post) occur for eyes with largest corrections (-6.5, -7.25D)



Largest changes occur with largest spherical correction one day after surgery, there is a significant correlation between decrease in posterior corneal radius and myopic spherical correction. Thos effect disappeared one month after surgery.

❹ Conclusions

1) We developed a corneal model for validations of the Pentacam posterior corneal shape
2) We did not find statistical significant changes in the posterior corneal surface on plastic model corneas before and after ablation. This means that posterior corneal radius of curvature is unaffected by changes in the anterior cornea, i.e. that optical distortion from the anterior cornea is properly corrected in the system
3) We only found statistical significant changes (decrease) in radius of curvature and asphericity in patients one-day-post-surgery. Differences tended to be higher for the highest corrections. Differences one week and one month post surgery are not significant
4) Using a calibrated Scheimpflug system (which did not introduce distortions) we found smaller changes in posterior corneal surface than previously reported with others system (Orbscan). These results have implications to understand optical and corneal biomechanical changes following refractive surgery.

❺ References

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