8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

COMPUTATIONAL SIMULATION OF LASIK SURGERY

*** Alejandro Arciniegas[1], Fernando Ramirez[2], Luis E. Amaya[2] and Andres Guzman[3]**

[1] Escuela Superior de Oftalmoingenieria
I. Barraquer de America
Bogota, Colombia
aarciniegas@tutopia.com

[2]Universidad de los Andes
Civil and Env. Engineering
Bogota, Colombia
framirez@uniandes.edu.co
www.uniandes.edu.co

[3]Universidad de los Andes
Civil and Env. Engineering
Bogota, Colombia
fe-guzma@uniandes.edu.co
www.uniandes.edu.co

Key Words: *LASIK Surgery, Cornea, Stresses, Computing Methods.*

ABSTRACT

Today, Laser In Situ Keratomileusis (LASIK) is the most commonly used surgical procedure to correct ametropias. An increasing amount of available medical literature reports non-desirable long-term results such as undercorrection, overcorrection, induced astigmatism, ectasia1-4. The corneal tissue is normally subjected to internal forces that oppose the Intraocular Pressure (IOP) and maintain the cornea in equilibrium. During the LASIK refractive surgery the central corneal tissue is removed resulting in a redistribution of stresses to maintain the equilibrium. This redistribution depends on the changes produced upon the cornea by the surgery. In this study a finite element computational simulation is used to analyze the distribution and concentration of stresses on the cornea and thus obtain a better comprehension of the structural changes produced by LASIK surgery.

The geometric and functional parameters required to develop the finite element model of the cornea were obtained from a series of 148 patient records (265 myopic eyes) from the Barraquer Institute of America. The geometric parameters include the central and limbus corneal thickness, corneal height, interior and exterior corneal radius, microkeratome curvature radius and cut diameter and depth, ablation depth, optic zone diameter, diameter of constant ablation depth on the anterior corneal surface, and laser cut radius among others. The corneal tissue was assumed to behave as an isotropic material5-6 with modulus of elasticity E=20.0 MPa and Poissons ratio ?=0.37. The functional parameters are the IOP - measured with Goldmann's Tonometer - and the boundary conditions of the corneal base, which was assumed to be fully constrained. To validate this approach, another model of the whole eye with the boundary conditions provided by the attached muscles was developed. Analyzing the two models (cornea vs. whole eye) the difference in stresses was only about 2.0%, as a result and taking into account the geometric and material symmetry, only one quarter of the cornea was considered for the finite element analyses.

In order to study the changes in the state of stresses in the cornea due to the LASIK surgery three stages were considered: before surgery, after flap cut and elevation, and after ablation cut. Once the models were complete, an analysis of the propose model was run to obtain the different states of stresses for each surgical stage (Fig. 1).

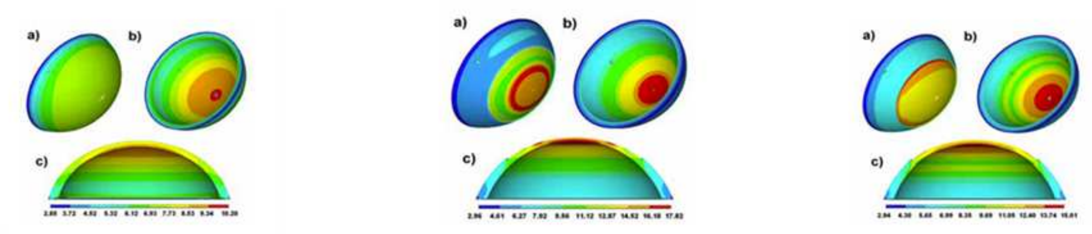

Figure 1: Corneal stress distribution before, during, and after LASIK surgery.

The highest preoperative stresses occur on the posterior corneal layers, and the highest stresses in the anterior and posterior layers of the cornea are not of equal magnitude, which indicates the presence of a mild flexion effect. In Stage 2, the corneal thickness decreases because of the flap, producing an increase in the stresses when compared to the previous step of about 50%. The highest value is observed in the center of the posterior corneal layers. A stress concentration is present in the flap contour, produced by the abrupt change of thickness in this location. The highest stress of this concentration occurs on the anterior layers of the residual stromal bed. Stage 3 presents a behavior similar to stage 2, the ablation produces an increase of the stresses, which have a highest value in the center of the posterior corneal layers, and is 80% higher than those calculated for the preoperative stage.

Using the proposed model it was also found that when the amount of ablation is increased, the stresses increase significantly in all corneal zones. The highest stresses of the anterior and posterior corneal layers on the residual stromal corneal bed for ablations below 30% are located on the posterior corneal layers, while for ablations above 30% the highest stress shifts to the anterior corneal layers. These shifts in the position of the highest stresses induce a bending effect that might result in the reported post-surgery ametropias.

REFERENCES

[1] I.F. Comaish, and M.A. Lawless. "Progressive post-LASIK keratectasia: biomechanical instability or chronic disease process." *J. Cataract Refract Surg.* Vol. **28**, 2206-2213, 2002.

[2] S. Esquenazi, and A. Mendoza. "Two year follow-up of LASIK for Hyperopia.". *J Refract Surg.* Vol. **15**, 648-652, 1999.

[3] R.T. Lin, and R.K. Maloney. "Flap complications Associated with Lamellar Refractive Surgery.". *Am J Ophthalmol.* Vol. **127**, 129-136, 1999.

[4] R. Ufret-Vicenty, R. Jiunn-Liang R, and D. Azar. "Corneal Flap Displacement and Drift in LASIK: Comparison of Hansatome and Automated Corneal Shaper Microkeratomes.". *Am J Ophthalmol.* Vol. **134**, 702-706, 2002.

[5] A. Arciniegas, L.E. Amaya, and E. Otero. "Factors Affecting the Stability of Lamellar Refractive Surgery: Biomechanical Approach.". *Ann Ophthalmol.* Vol. **31**, 216-221, 1999.

[5] A. Arciniegas, and L.E. Amaya. "Physical Factors that Influence the measurement of the IOP with Goldmann's Tonometer.". *New Trends Ophthalmol.* Vol. **1**, 170-200, 1986.