Acute Tissue Deformation of the Human Cornea After Radial Keratotomy

Jesper Ø. Hjortdal, MD, PhD; Niels Ehlers, MD, DrMedSci

ABSTRACT

PURPOSE: The regional deformation pattern of the cornea after radial keratotomy, which is essential for understanding the mode of action of the procedure, has not previously been studied in detail.

METHODS: Up to 90 tiny mercury droplets were placed from center to limbus on the epithelial and endothelial corneal surfaces of eight eviscerated human donor eyes with four radial keratotomies (depth 100% of central corneal thickness, 3.5-mm clear zone). From digital images obtained under pressure loads ranging from 2 to 100 mm Hg, the distances between the fixed droplets were measured with an accuracy of 1 μm. After transforming the data to polar coordinates, regional meridional and circumferential strain patterns were calculated. Regional meridional and circumferential radii of curvatures were calculated from corneal profile images obtained at different pressure loads before and after keratotomy.

RESULTS: Increasing the intraocular pressure from 2 to 100 mm Hg induced: an epithelial side wound gape of 44 μm; epithelial side circumferential tissue compression between incisions; considerable epithelial side meridional tissue elongation at and between incisions; little endothelial side circumferential strain across incisions; and little endothelial side meridional strain at and between incisions.

The radial keratotomy induced 2.30 diopters (D) of central corneal flattening at an intraocular pressure of 2 mm Hg. The degree of central flattening correlated linearly with the amount of wound gape. In the physiological pressure range of the central cornea flattened 0.05 D for each millimeter-of-mer-

cury increment in intraocular pressure. Pronounced meridional steepening was induced corresponding to the middle and peripheral parts of the keratotomy incisions.

CONCLUSIONS: Our study suggests that the peripheral “tissue addition” seen after radial keratotomy is a net result of wound gape and circumferential tissue compression. Local bending of intact stromal tissue below the incisions plays an important role for the generation of the wound gape at the corneal surface. These data may help verify finite-element computer models of the human cornea. [J Refract Surg. 1996;12:391-400.]

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ince its introduction in the 1970s, radial keratotomy has become a well-accepted procedure for correcting mild to moderate myopia. However, during recent years, excimer laser ablation has become increasingly popular, mainly due to a claimed superiority in precision and accuracy of the refractive change. Attempts to improve the refractive reproducibility of radial keratotomy have included various modifications of the surgical procedure1,2 and the use of empirically3 and theoretically4-based mathematical models.4-10 However, the precise regional deformation pattern of the cornea after radial keratotomy, which is essential for verification or falsification of the proposed theoretical mathematical models, has not previously been studied in detail.

The purpose of the present study was to determine the deformation pattern of the cornea after radial keratotomy. Using surface markers, we studied the regional deformation pattern of both sides of the incised human cornea and compared them with regional curvature measurements.

MATERIALS AND METHODS

Eight human eyes enucleated 24 to 96 hours postmortem from donors aged 64 to 88 years were used for the study. All of the eyes were frozen at
-25°C until use. On the day before each experiment, the eyes were thawed and the corneal epithelium was removed with a Beaver blade. A 9-mm trephine was used to create a circular hole, including the optic nerve, at the posterior pole of the eye. The eyes were eviscerated and thinned in 8% Dextran T500 (Pharmacia Biotech, Uppsala, Sweden) in 0.9% NaCl for 12 hours at 4°C. After markers for strain measurement had been positioned, the eyes were mounted in a chamber for in vitro biometry. A plastic tube was attached to the hole in the posterior pole of the eyes and connected to a reservoir filled with 8% Dextran T500 in 0.9% NaCl. The height of the reservoir could be adjusted to produce intraocular pressures ranging from 2 to 100 mm Hg. The applied intraocular pressure was controlled with a pressure transducer (Miller Type SPS-320, Houston, Tex). During measurement, the eyes were immersed in a solution of 8% Dextran T500 in 0.9% NaCl. Previous in vitro studies have shown that the colloid osmotic effect of this solution is a satisfactory substitute for the barrier and pumping functions of the limiting cell layers, at least with respect to preservation of normal corneal thickness. A small air-bubble at the site of the former anterior chamber was needed to secure attachment of the endothelial side markers.

**Surgical Procedures**

Four radial incisions were made in each of the eight eyes with a double-edged diamond knife. The incisor depth of the knife was set to 100% of the central corneal thickness as measured by a Haag-Streit pachymeter. A central optical “clear zone” of 3.5 mm was marked. Incisions were made from the center toward the periphery (1 mm from the limbus), with subsequent redeepening of the incision accomplished by following the track back to the 3.5-mm diameter.

**Regional Corneal Strain**

In each eye, up to 50 small (50 µm in diameter) mercury droplets were placed on the epithelial side, and up to 40 droplets were placed on the endothelial side of the cornea over an area corresponding to one quadrant (Fig 1). To improve the attachment of the mercury droplets, each droplet was placed in a small spot of mineral grease. The epithelial side droplets were positioned from the corneal apex and to just across the corneal sulcus. Endothelial side droplets were placed in a similar pattern, the most peripher-
al droplets being located in clear cornea, approximately 1 mm central to the corneal sulcus. Sixteen corneal sectors were defined from their relation to the incision (Fig 1).

After mounting, the eyes were left for approximately 1 hour at an intraocular pressure of 25 mm Hg. Subsequently, five measuring series were completed. In each series, two digital images of the mercury droplets were obtained at successive pressure levels of 2, 10, 25, 100, 25, 10, and 2 mm Hg. One image was focused on the epithelial-side droplets, and in the other image, the endothelial-side droplets were brought into best focus. The images were taken from 5 to 10 minutes after the pressure had been changed. During strain measurements, the corneal apex was tilted approximately 25° to obtain the best focus for all the mercury droplets. The digital images of the corneal surfaces with mercury droplets were captured by a Zeiss OPMI-7 operating microscope equipped with a video camera (Dage MTI CC 72E, Michigan City, Ind) and a combined frame grabber and image processing board (512 × 512 pixels, 16 bits deep, Matrox MVP-AT, Dorval, Quebec, Canada) implemented in an IBM-AT-compatible microcomputer. For identification of the corneal apex, images covering the whole cornea also were acquired.

Strain Analysis

The light of the operating microscope was reflected from the surface of the mercury droplets, and the light intensity pattern of this small reflex was used for determining the position of each mercury droplet on each of the digital images (dedicated software based on subpixel resolution). The standard deviation for measuring a distance of approximately 3 mm with this method is approximately 1 μm.20 From low-magnification images of the whole cornea, the position of the corneal apex was determined subjectively, and the coordinates for the center-most and a peripheral mercury droplet were recorded. The position of the center-most droplet and the orientation of the line between the center-most and the peripheral droplet were used for alignment of all images.

The position of each droplet was converted into a set of polar coordinates with the origin at the corneal apex. Each mercury droplet was then allocated to one of the 16 corneal sectors (Fig 1). After allocation of the droplets, each sector contained up to eight mercury droplets. The precise polar location of the sector (r,θ) at a certain intraocular pressure was then found by averaging the polar positions of all the droplets within each sector. From the polar coordinates of each sector, the meridional distances (Δr) and circumferential angles (Δθ) between neighboring sectors were computed for each pressure level. Regional tangential corneal meridional strain (ε_m) was then calculated as (Fig 1):

$$\epsilon_m(IOP) = \frac{\Delta r_{IOP}}{\Delta r_{2mmHg}} - 1$$ (1)

Circumferential strain (ε_c) between neighboring sectors was calculated as:

$$\epsilon_c(IOP) = \frac{\Delta \theta_{IOP} \times r_{IOP}}{\Delta \theta_{2mmHg} \times r_{2mmHg}} - 1$$ (2)

Corneal epithelial surface wound gape was in addition calculated in absolute units as:

$$r_{IOP} = \Delta \theta_{IOP} \times r_{IOP} - \Delta \theta_{2mmHg} \times r_{2mmHg}$$ (3)

The strain components were computed from images with a sagittal view. Due to the sphericity of the cornea, the arc distances on the corneal surface are therefore underestimated. Profile images of the cornea, obtained through a 90° prism at each pressure level, were used to evaluate the angles between the sagittal viewing direction and the corneal surface.20-22 The angle between the corneal surface and the observation microscope was, at most, 14°, which resulted in less than a 0.05% underestimation of the actual tangential corneal strain. Thus, the discrepancy between the strain in the corneal arc and the strain in the measured chord was negligible. Pressure-induced changes in the angle between the sagittal viewing direction and the chord between the droplets would also affect the estimate of the arc strain. The maximum change in angle, approximately 1°, occurred at the center of the incisions. With the eye tilted, this change could result in an underestimation of corneal strain of approximately 0.5%. Accordingly, meridional strain measurements central to the incision and at the incision were corrected for these projected errors.

Finally, we considered that the curvature, thickness, and refractive index of the cornea could affect measurements of strain on the posterior side of the cornea. The effect of refraction was minimized by immersing the eyes during the measurements, ensuring that the change in magnification induced by corneal curvature changes would be less than 0.05%. Experimentally, it was verified that no measurable error in distance measurements was intro-
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Circumferential Strain

At incision

<table>
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<th>Strain (%)</th>
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<th>1.2</th>
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<td>IOP (mmHg)</td>
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<tr>
<td>IOP (mmHg)</td>
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20° from incision

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<td>IOP (mmHg)</td>
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<tr>
<td>IOP (mmHg)</td>
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35° from incision

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<td>IOP (mmHg)</td>
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<th>Wound Gap (µm)</th>
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Figure 2: Regional circumferential corneal strain in the human cornea after radial keratotomy at increasing intraocular pressure. Epithelial side (●) and endothelial (O) side of the cornea. Values are mean ± SEM (N=8).

duced by varying the amount of the covering immersing fluid.

In conclusion, by measuring and taking into account corneal shape changes, measurement of projected chord strain can give a reliable estimate of tangential in-plane corneal strain.

Regional Corneal Contour and Radius of Curvature

Before and after incising the cornea, corneal profile images were captured at each pressure level with the previously described digital image analysis system. Thus, the epithelial-side mercury droplets were placed after profile images of the incised cornea had been obtained. The profile images were captured through a 90° prism after the eye had been carefully positioned with the corneal apex pointing upward, with a meridian between the incisions forming the surface contour. The digital images of the corneal and limbal profile were edge-enhanced, and the coordinates describing the profile (x, z) were extracted by a subpixel-based automatic tracing algorithm.20 From each profile, the meridional corneal slope (α), the first derivative of the profile, (x'), and the second derivative of the profile (z'') were calculated numerically.22 Subsequently, the local regional radii of curvatures in the meridional direction (R_m) were calculated from:

\[ R_m = \frac{(1 + (z'')^2)^\frac{3}{2}}{z''} \]  

(4)

which is a general formula for computing the radius of curvature of a line. The regional radii of curvatures in the circumferential direction (R_c) were calculated from:
Meridional Strain

At incison

20° from incision

35° from incision

Figure 3: Regional meridional corneal strain in the human cornea after radial keratotomy at increasing intraocular pressure. Epithelial side (●) and endothelial (O) side of the cornea. Values are mean ± SEM (N=6).

\[ R_c = \frac{x}{\cos \alpha} \]  

(5)

which is valid for computing the circumferential radius of curvature for axis-symmetrical surfaces (surfaces of revolution). The average regional radii of curvatures were then computed from data values within (1) a 1-mm-diameter zone at the corneal apex, (2) a 1-mm range at the center of the incisions, (3) a 1-mm range at the middle of the incisions, (4) a 1-mm range at the periphery of the incisions, (5) a 1-mm range at the peripheral cornea outside the incisions, and (6) a 1-mm range at the limbus.

Wound Depth Measurements by Histology

After completion of the experiment, the central corneal thickness was measured with an optical Haag-Streit pachymeter. Finally, the eyes were processed for light microscopy. The tissue was fixed in 4% formaldehyde, embedded in paraffin, sectioned, and stained with hematoxylin and eosin. From perpendicular sections approximately 1 mm from the central end of the wound, the relative depth of the keratotomies was measured using a Zeiss-Winkel light microscope equipped with the previously described digital image analysis system.

Data Presentation

The average strain at each pressure level of measurements from the five cycles of increasing and decreasing pressures, and the average radii of curvatures at each pressure level of the two cycles of increasing and decreasing pressures, were calculated. The results from the sector-wise strain measurements were further averaged in order to obtain the best estimate of circumferential and meridional
strain. Thus, the final strain patterns comprised surface strain central to the incision, across or along the incision, and peripherally to the incision, and, for each radial position, the three meridians: at the incision, and 20° and 35° from the incision. However, values for the 20° meridian were not computed centrally, due to the small distance between the neighboring sectors.

RESULTS

The central corneal thickness was 0.46 ± 0.04 mm after completion of the experiments. All incisions penetrated to more than 90% of the corneal thickness as measured from the histologic sections.

Wound Gape and Surface Strain

In general, the relationship between regional strain and intraocular pressure was nonlinear, and large differences in surface strain were observed depending on the relation to the incision. The epithelial- and endothelial-side circumferential strains are illustrated in Figure 2. On the epithelial side, a pressure-induced gaping of the wound was evident (44 mm for the pressure increment from 2 to 100 mm Hg). Between the incisions, the tissue was compressed with increasing intraocular pressure, although the degree of compression decreased with increasing distance from the wound. In the area just central to the wound, the strain was positive, while further away from the wound, the central corneal surface was compressed with increasing pressure. Just peripherally to the wound, the epithelial-side strain increased to high values, while further away from the wound, the pressure-induced epithelial-side strain was smaller.

The mechanical response of the endothelial side was different. The endothelial side below the incision did not strain circumferentially with increasing pressure. Between the incisions, however, the endothelial side elongated with increasing pressure. Endothelial-side strain could not be determined centrally to the wound, because few eyes contained mercury droplets in these sectors. Peripherally to the wound, the endothelial-side strain increased to high values, while decreasing with increasing distance from the wound.

The corresponding meridional strains are illustrated in Figure 3. On the epithelial side, the pressure-induced strains were highest central to, and just along, the incision; further away, they decreased somewhat. Peripherally to the wound, epithelial-side strain was small, but it increased with increasing distance from the wound. The endothelial side did not stretch as much as the epithelial side along the incision, but the strain increased with increasing distance from the incision. Centrally and peripherally to the incision, endothelial-side meridional strain was high, but decreased with increasing distance from the incision.

Curvature

The meridional and circumferential corneal radii of curvatures before keratotomy did not change significantly with the intraocular pressure, although there was a tendency toward corneal flattening with increasing pressure at peripheral corneal positions (Fig 4). At the very periphery of the cornea and at the limbus, the meridional radius of curvature peaked to very high levels, and at the limbus, it even sometimes became negative. These findings correspond to extreme peripheral corneal straightening and the corneal sulcus, respectively.

Radial keratotomy induced significant flattening of the central cornea, and increasing the intraocular pressure exaggerated the typical features of the cornea after radial keratotomy (Fig 4). In units of power (n=1.3375), the curvature of the central intact cornea (mean ± SEM) at 2 mm Hg was 45.88 ± 0.59, and the curvature of the central cornea after radial keratotomy was 43.61 ± 0.88, 43.08 ± 1.09, 42.13 ± 1.15, and 40.66 ± 1.07 at 2, 10, 25, and 100 mm Hg, respectively. The dependency between radius of curvature and intraocular pressure was nonlinear: with increasing pressure, the change in curvature associated with a certain change in pressure was smaller.

The average meridional radius of curvature increased at the corneal center, but the flattening was even more pronounced around the central end of the incision (Fig 4). At the middle and periphery of the keratotomy incisions, the meridional radius of curvature decreased, corresponding to corneal steepening. The average circumferential radius of curvature generally was less influenced by the keratotomy (Fig 4). The flattening at the center of the incision was less prominent, and the steepening at the peripheral part of the incision was almost absent. At the corneal periphery, values for the circumferential radii of curvatures were similar to those of the intact cornea.

Correlations

The change in central corneal radius of curvature correlated linearly with the change in wound gape ($R^2 = 0.98, p < .01$) (Fig 5). The regression line describing the dependency was (Corneal radius [mm] = 7.74 + 0.013 × Wound Gape [µm]). In terms of power, this
corresponds to approximately 0.05 diopters (D) of central corneal flattening for each micron increase in each of the four wound gaps. If we assume that the radius of curvature of the cornea after radial keratotomy at zero intraocular pressure is equal to the radius of curvature of the intact cornea, we can estimate that the wound gape at 2 mm Hg was 30 μm (the solid square in Figure 5).

**DISCUSSION**

These experiments are, to our knowledge, the first to document that the mechanical behavior of the incised human cornea is a complex combination of tissue extension, tissue compression, and internal shear. Previous attempts to study the mechanics of the incised cornea include keratometry measurements,24,25 holography measurements,26,27 and intra-
corneal markers.28 By using markers attached to the corneal surfaces, we were able to measure pressure-induced regional surface deformations directly. The advantage of this approach is that multidirectional regional surface strains can be measured simultaneously, and, because the cornea is transparent, strains can be measured on both sides of the membrane. As the position of the eye was optimized for acquisition of images in the sagittal direction, and as meridional corneal shape changes were measured and taken into account, it was possible to estimate corneal arc strains from measurements of chord strain.

Human donor eyes not suitable for corneal transplantation were used in the present study. Corneal hydration significantly influences the shape of the cornea after radial keratotomy.24,25 To substitute for the active pumping and passive barrier functions of
the limiting cell layers, we used 8% Dextran to thin the corneas to a physiological level of hydration.21 Under such circumstances, the central corneal thickness decreases approximately 10 μm when the pressure is increased from 2 to 100 mm Hg.21 In a previous study, human corneas following radial keratotomy flattened 0.33 D for each 10-μm increase in corneal thickness.25 Thus, in the present experiments with normohydrated corneas, the observed changes in corneal shape with increasing pressure (3.00 D of central flattening) were mainly due to the direct effect of increasing corneal membrane stress, while pressure-induced changes in corneal hydration played a minor role. The donors were rather old, and clinical studies have shown that age affects the outcome of radial keratotomy.29 However, the fundamental forces exerted by radial keratotomy are probably independent of age.

The surface strain of the incised human cornea changed in a nonlinear way with the intraocular pressure, and was highly different in different locations, depending on position vis-à-vis the radial incisions. On the epithelial side, the tissue between the gaping incisions was increasingly negatively strained in the circumferential direction when the intraocular pressure was increased (on average, 0.4% to 0.5% for a pressure rise from 2 to 100 mm Hg). Consequently, the addition of tissue was less than what would be expected from wound-gape measurements alone. In the meridional direction, the epithelial side of the stroma strained approximately 1% when the pressure rose from 2 to 100 mm Hg. The mechanical behavior of a material in two orthogonal directions is represented by Poisson’s ratio.30 An incompressible tissue has a Poisson’s ratio of 0.5, and in such cases, the orthogonal strain will be negative, with half the strain in the loading direction. The present findings thus are consistent with a model with an in-plane Poisson’s ratio between 0.4 and 0.5 and very small circumferential stresses.

The surprising finding of little endothelial-side circumferential straining below the incision can be explained by a local outward bulging of the corneal tissue at this site. Bending will cause epithelial side straining—or wound gape—whereas the endothelial side will become relatively compressed (Fig 6). Similarly, the small meridional endothelial-side strain associated with high epithelial-side strain at the incision also can be explained by an outward bulging of the cornea at this location. At the corneal periphery, the endothelial side strained more than the epithelial side in the meridional direction, suggesting that internal shear movements occur at this location due to a straightening of the corneal periphery at the site of the incision. The circumferential epithelial- and endothelial-side strains were high at the corneal periphery, especially in the area next to the incision, suggesting an absence of corneal bending and the presence of high stresses in this region. Centrally to the incision, strain values were also higher than those measured in the intact cornea.21,22

The intraocular pressure did not affect the central radius of curvature of the intact cornea. After radial keratotomy, the cornea was more sensitive to
changes in the intraocular pressure. It has been shown that, at intraocular pressures below the physiological range, the curvature of the incised cornea changes dramatically with the intraocular pressure. This relationship was also found in the present study; namely, the central cornea flattened 2.30 D at 2 mm Hg following keratotomy. At higher pressures, the pressure-induced change in corneal curvature was much smaller: approximately 0.05 D per mm Hg within the physiological pressure range (10 to 25 mm Hg). Thus, the curvature-pressure relationship of the human cornea after radial keratotomy is highly non-linear. Comparative experimental studies of wound gape and corneal power have been performed by Petroll et al. They measured wound gape by confocal microscopy and found, as we did, that the surface gape distance was linearly correlated with changes in corneal power. These authors were unable to determine the interincisonal changes in strain, and, therefore, possibly overestimated the overall circumferential arc length in their model. Buzard et al measured post-keratotomy wound gape in vitro by using intracorneal sutures as markers. Quantitative comparisons, however, would be meaningless due to the many differences in the surgical procedures and experimental designs.

The complex mechanical performance of the cornea after radial keratotomy and the events that lead to central corneal flattening can be summarized as follows. When the human cornea is radially incised, the axial symmetry of the corneal membrane is broken. If all fibrils above the depth of the incision bore no effective load, the intact fibrils at the endothelial side would perform as an evenly stressed, continuous layer with axial symmetric properties. However, due to the possible combined effect of these factors, the cornea will deform non-axis-symmetrically, with a localized bending of the tissue below the incisions. This bending will, in combination with the Poisson coupling between interincisonal meridional strain resulting in interincisonal circumferential tissue compression, induce epithelial-side wound gape.

Most previous models have assumed that the incised cornea behaves like an axis-symmetric membrane, and that the increase in circumferential arc length can be predicted from calculations based on an increased stress level on remaining uncut fibrils near the endothelial side. The present study, however, suggests that the cornea bends at the incisions and that the endothelium actually is under very low net strain at this location.

The implication is that more advanced models are needed to accurately model the mechanical performance of the human cornea. Unfortunately, authors presenting advanced mathematical computer models of the incised cornea rarely have reported the predicted local stresses and strains. The one report that does provide such information actually predicts that the anterior corneal tissue is negatively stressed in the circumferential direction between the incisions. Dedicated finite-element analyses that concentrate on surface strain rather than stresses are needed to make full use of the data presented in this study. However, the presence of tissue compression between the four radial incisions can explain why additional incisions do not induce much additional corneal flattening. Somewhere between the epithelial and endothelial side, the tissue compression is, however, changed to tissue tension, and if the incision exceeds this depth of neutral tension, additional load-bearing fibrils are cut, and additional corneal flattening can be expected.

Refractive keratotomy for myopia is a fast and safe procedure. However, it still lacks the accuracy and precision obtainable with conservative refractive corrections. Greater accuracy and precision await the development of physiologically plausible computer models of the cornea, which will allow the surgeon to specifically plan the procedure in each patient based on measurements of corneal shape and a thorough understanding of corneal material properties. Although such models preferably would also be sufficiently detailed to allow representation of the complex influence of corneal hydration and wound healing, more limited experiments such as those presented in this paper are essential for initial verification of preliminary but essential mechanical models.

REFERENCES


Marco Teórico: Este abordaje de lente en pinza con soporte al iris permite la corrección reversible de un amplio rango de ametropía y anisocoria, proporcionando una excelente predictibilidad y estabilidad. Sin embargo, la preocupación acerca del daño potencial al endotelio ha frenado el amplio uso de esta abordaje.

Nuestra experiencia con la técnica quirúrgica del sistema cerrado y con el dispositivo deslizador empleado en 180 casos entre 1987 y 1993 nos permite atribuirle a la técnica de la implantación del lente potenciales complicaciones más que a las propiedades del lente por sí mismo.

Métodos: Realizamos un estudio prospectivo de 35 casos consecutivos operados entre Agosto/1993 y Agosto/1994. La edad promedio fue de 38 años (rango: 21 a 55 años). La refracción por equivalente esférico preoperatoria fluctuó desde -6.00 a -21.25 D.

Propósito: Evaluar el efecto de los cambios de presión intraocular sobre patrones de tensión superficial regional corneal en ojos humanos con queratotomía radial.

Métodos: Se colocaron más de 90 pequeños frascos de vidrio con mercurio sobre las superficies corneales epitelial y endotelial de ocho ojos humanos donantes eviscerados con cuatro queratotomías radiales (100% de profundidad del grecer central corneal, zona óptica de 3.5 mm), de centro a limbo.

Resultados: El aumento de la presión intraocular desde dos hasta 100 mmHg indujo 1) una amplia apertura de 44 μm en el lado epitelial d la herida 2) una compresión circunferencial de tejido en el lado epitelial entre incisiones 3) considerable elongación meridional de tejido en el lado epitelial y entre incisiones 4) pequeña banda circunferencial en el lado endotelial atraves de incisiones y 5) pequeña banda meridional en el lado endotelial dentro y entre las incisiones. La queratotomía radial indujo 2.3 dioptrías de aplanamiento central corneal a una presión intraocular de 2 mmHg. El grado de aplanamiento central corelacionado linealmente con la extensión de la apertura de la herida, y en el rango de presión fisiológica la cornea central se aplanó 0.05 dioptrías por cada mmHg de presión intraocular. El aplanamiento meridional pronunciado fue inducido de acuerdo con las partes mediales y periféricas de las incisiones de la queratotomía.

Conclusiones: Los patrones de tensión inducidos por cargas de presión de la cornea humana luego de queratotomía radial son complejos, con grandes diferencias regionales. El estudio sugiere que la “adición tisular” periocular observada luego de queratotomía radial es un resultado neto de la apertura de la herida y la compresión tisular circunferencial. El encurvamiento local del tejido estromal intacto debajo de las incisiones juega un importante papel en la formación de la apertura de la herida en la superficie corneana. La relación entre los patrones radial y meridional sugiere que el radio de Poisson en pleno para el estroma corneal es de 0.4-0.5. Los datos suministrados por este estudio deberían ser útiles en la verificación o falsificación de modelos en computador finite-element de la cornea humana. (Translated by Juliana Tirado-Angel, MD, Bogota, Colombia.)