Corneal Thickness Profiles in Rabbits Using an Ultrasonic Pachometer

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An ultrasonic pachometer was used to measure the central, mid-peripheral, and peripheral thickness in 17 locations across the corneas of 12 adult New Zealand Albino rabbit eyes. The mean thickness at each location was entered into a microcomputer to generate a three-dimensional plot of corneal thickness. The rabbit cornea was found to have uniform thickness, with an average thickness variation of only 7 μm across the cornea. The average central corneal thickness was 407 ± 20 μm. The three-dimensional representation of corneal thickness was useful in monitoring the surgical effects of cataract extraction and postoperative healing in rabbits. The ultrasonic pachometer was found to be well suited to animal studies. This study indicated that the velocity of sound in rabbit corneal tissue was approximately 1,580 m/sec. Invest Ophthalmol Vis Sci 24:1408-1410, 1983

The majority of clinical studies utilizing pachometry have been limited to the central cornea. This may be due to the assumption that central corneal thickness is representative of total corneal function, or because of the inconvenience of adapting current techniques to peripheral thickness measurement.

With the development of reliable ultrasonic pachometers, the measurement of peripheral corneal thickness has been made much easier. Since measurements can be made with a small hand-held probe, ultrasonic pachometers are also ideal for studies involving animals. However, ultrasonic pachometers require a knowledge of the velocity of sound in the tissue being measured. The velocity of sound in human corneal tissue, as quoted in the literature, varies between 1,502 and 1,610 m/sec. The velocity that gives absolute corneal thickness measurements is still subject to disagreement.

The purpose of this study was to determine the velocity of sound in rabbit corneal tissue, and to measure the central, mid-peripheral, and peripheral thickness of the cornea in healthy rabbit eyes to obtain an accurate in vivo corneal thickness profile.

A computer program was written to generate a three-dimensional representation of the thickness data. This technique was used to demonstrate the effects of cataract surgery on corneal thickness in rabbits.

Materials and Methods. Corneal thickness was measured using a VIDA-55 Ultrasonic Pachometer (Visual Instruments Distribution Associates, 229 Monarch Bay, South Laguna, CA.) with the hand-held transducer (No. 55-1). The pachometer was adjusted for a velocity of 1,550 m/sec, which the manufacturer stated would give absolute measurements of human corneal thickness. To test if this velocity was accurate for rabbit corneal tissue, the central corneal thicknesses of four Albino rabbit eyes were measured using the ultrasonic pachometer. The corneas then were excised and placed between two spherical PMMA surfaces—a dome of radius 7.0 mm and a “foot” of radius 8.5 mm attached to a digital length gauge (Heidenhain MT-10). The compression pressure on the corneal tissue was adjusted to 15 mmHg and the area of contact was approximately 4 mm in diameter. The digital gauge recorded the displacement of the foot to within 1 μm, thus giving an accurate measurement of corneal thickness.

Topographical corneal thickness was measured on the left eyes of 12 healthy New Zealand Albino rabbits (2.9 to 3.7 kg). The cornea was not anesthetized prior to application of the transducer. The probe was hand-held and maintained in an orientation normal to the cornea while measurements were taken. The rabbits were restrained and their eyelids retracted while the probe was touched gently onto the cornea for 1 to 2 seconds. The animals showed no sign of distress with this procedure.

Readings were taken at 17 locations covering the central, mid-peripheral, and peripheral cornea as shown in Figure 1. Placement of the probe was judged visually by the operator. Four readings were taken in each position and the mean thicknesses were entered into a microcomputer to generate a visual representation of the corneal thickness profile.

The method of least squares was used to fit a fourth-order polynomial surface to the 17 data points. The equation of the surface is of the form:

$$z = \sum_{i=0}^{4} \sum_{j=0}^{4} a_{ij} x^i y^j$$

The fourth-order surface with 15 coefficients pro-
provides a close fit to the 17 data points. The surface generated can be viewed on a visual display unit or plotted.

To monitor the effects of cataract surgery, corneal thickness was measured in 17 locations on a rabbit eye 9 months after it had undergone complicated cataract surgery (Rabbit Alpha). The corneal thickness data was used to generate a three-dimensional plot.

Results. Measurements of the four excised corneas using the ultrasonic pachometer and the digital length gauge indicated that the velocity of sound in rabbit corneal tissue was 1,580 ± 60 m/sec (Table 1). As this value is not significantly different from the manufacturer's recommended setting, subsequent corneal thickness measurements were made with the velocity set at 1,550 m/sec.

We found that the average central corneal thickness in 12 eyes of rabbits weighing 2.9 to 3.7 Kg to be 407 ± 20 μm. Figure 2A shows the average corneal thickness and standard deviation in each of the 17 locations measured. This data was used to generate a three-dimensional representation of corneal thickness in the rabbit (Fig. 2B), which shows that the normal rabbit cornea has nearly uniform thickness. Individual rabbit corneas showed an average standard deviation from uniform thickness of 7 μm.

As a result of the intracapsular lens extraction, Rabbit Alpha's corneal thickness was found to lose its uniformity. Surgical complications included vitreous prolapse, leading to vitreous touch syndrome, and anterior synechiae. A large opacity was visible near the center of the cornea. Figure 3 shows the corneal thickness and the 3-D profile of the operated eye. A marked central thickening is apparent, which coincides with the visibly opaque area. There is also a marked increase in corneal thickness along the incision line.

Discussion. The finding of 407 ± 20 μm for the rabbit central corneal thickness is within the range of published values which vary between 370 μm³ and 430 μm³.

### Table 1. Comparison of in vivo ultrasonic pachometry with digital thickness gauge measurements of excised corneas

<table>
<thead>
<tr>
<th>Ultrasonic pachometer readout (Velocity set at 1550 m/sec)</th>
<th>Thickness of excised cornea (Measured with digital gauge)</th>
<th>Calculated velocity to match ultrasonic readout to excised thickness (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>406 ± 3</td>
<td>420 ± 4</td>
<td>1,600</td>
</tr>
<tr>
<td>402 ± 3</td>
<td>424 ± 1</td>
<td>1,640</td>
</tr>
<tr>
<td>397 ± 3</td>
<td>382 ± 1</td>
<td>1,490</td>
</tr>
<tr>
<td>378 ± 4</td>
<td>393 ± 2</td>
<td>1,610</td>
</tr>
</tbody>
</table>

The finding of a nearly parallel profile of the average rabbit corneal thickness compares favorably with Beran's finding of 372 μm in the center and 377 μm in the periphery of trephinated rabbit corneal discs when measured with a microscopic screw. The slightly lower value for central corneal thickness determined by Beran (372 μm vs. 407 μm) could be a result of compression.
Fig. 3. Corneal thickness profile of Rabbit Alpha's operated eye. Corneal thickness in the control eye is shown by a dashed line. Note the marked thickening in the center and along the incision line, as a result of complicated cataract surgery.

of the corneal tissue by the microscopic screw, or because of differences between species or animal size.

The uniform thickness of the rabbit cornea contrasts with the human cornea which is 520 µm thick in the central 3 mm and about 630 µm to 660 µm towards the periphery. The rabbit cornea is also markedly thinner than the human cornea.

The ultrasonic pachometer was particularly useful for monitoring the effects of surgery on corneal thickness in the case of Rabbit Alpha. However, there was a large variability in the thickness readings in both the central corneal area and the region of the incision, as indicated by the large standard deviation at points 1, 7, 8, and 17. Kirsch, Levine, and Singer have described edematous thickening and posterior protuberance in the region of the internal lips of the cataract incision, making the thickness very irregular. It appears that the probe used in this study does not have sufficient resolution to investigate such irregularities in detail.

The use of topographical ultrasonic pachometry on human corneas has yet to be validated, especially for the peripheral cornea. Possible difficulties include locating the area of the cornea being measured by the probe, and ensuring the probe is normal to the corneal surface. For rabbit corneas where the thickness is fairly uniform, a hand-held probe is quite adequate and the repeatability (± 4 µm) is very good.

Key words: rabbit, corneal thickness, topographical ultrasonic pachometer, computer plotting

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References