Effect of Microkeratome Suction Duration on Corneal Flap Thickness and Incision Angle

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ABSTRACT

PURPOSE: To determine the effect of suction duration on corneal flap thickness and incision angle of the cut margin created by a microkeratome in a porcine eye.

METHODS: Thirty porcine eyes were randomly assigned to three groups according to different suction duration: group 1 (10 sec), group 2 (35 sec), and group 3 (60 sec). The Hansatome microkeratome with a #160 plate and 8.5-mm-diameter suction ring was used to create a corneal flap with a diameter of 8.5 millimeters. Corneal flap thickness was measured by automated ultrasonic pachymetry, and the incision angle was assessed by measuring the angle of a sagittal section of the cornea using image analysis software.

RESULTS: Mean corneal flap thickness in groups 1 (10 sec), 2 (35 sec), and 3 (60 sec) was 87.8 ± 22.0 μm, 116.0 ± 7.0 μm, and 127.2 ± 16.8 μm, respectively. There was a statistically significant difference between groups 1 (10 sec) and 2 (35 sec) (P<.005) and groups 1 and 3 (P=.004). The mean incision angle in groups 1, 2, and 3 was 34.8 ± 9.0°, 44.4 ± 16.1°, and 48.24 ± 15.3°, respectively. A statistically significant difference was found between groups 1 (10 sec) and 2 (35 sec) (P=.044) and groups 1 (10 sec) and 3 (60 sec) (P<.001).

CONCLUSION: In laser in situ keratomileusis in porcine eyes, an increase in suction duration resulted in a thicker flap and greater incision angle. [J Refract Surg 2002;18:715-719]

Atrogenic keratectasia is a serious complication that can occur after laser in situ keratomileusis (LASIK). To prevent ectasia, the cornea must be rigid enough to withstand the outward forces of intraocular pressure (IOP). During LASIK, a corneal flap is made in order to ablate the underlying stromal tissue, but does not contribute to the biomechanical stability of the cornea. Therefore, creating a flap with a predictable thickness is essential to maintaining the strength of the residual posterior stroma and preserving the shape of the cornea. During the flap cut, the distance between the fixed microkeratome plate and the edge of the metal blade determines the thickness of the flap. This thickness is known to vary within a certain range for any given microkeratome because of several factors, such as corneal thickness and curvature, and turbine and translational velocities of the microkeratome. The Hansatome unit, despite having fixed turbine and translational velocities, also shows a large flap thickness variability ranging from 64 to 190 μm. This large variability with the Hansatome cannot be fully accounted for by the corneal thickness and curvature alone, which suggests that other factors may contribute to flap thickness variability.

Because the eyeball is relatively malleable, continuous suction delivered by a suction ring can change the shape of the cornea, causing it to bulge above the cutting plane, resulting in inconsistent flap shapes and thickness. The usual suction duration used for the Hansatome before cutting the cornea without intentional delay is between 8 to 15 seconds (unpublished data). Our study explored the effects of different suction durations on the...
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corneal shape, flap thickness, and the angle of incision made during keratomileusis.

**MATERIALS AND METHODS**

Porcine eyes were obtained from a local abattoir. The eyes were kept at 4°C in moist chambers and were used for experiments within 12 hours of enucleation. The status of the epithelium in each eye was inspected, and eyes with epithelial defects were excluded to avoid any bias in corneal thickness and incision angle measurements. The intraocular pressures (IOP) of each porcine eye were measured four times (and then averaged) with a Tono-Pen (Mentor Ophthalmics, Norwell, MA). The IOP was controlled by the injection of normal saline through the optic nerve and maintained within 20 to 25 mmHg.

**Measurement of Flap Thickness With Different Suction Duration**

Porcine eyes were randomly assigned to three groups, which were exposed to different suction duration: group 1 (10 seconds, n=10 eyes), group 2 (35 seconds, n=10 eyes), and group 3 (60 seconds, n=10 eyes). Measurements of central corneal thickness and keratometry were performed prior to the procedure using an automated ultrasonic pachymeter (DGH technology, Inc., Exton, PA) and an automatic keratometer (Auto Ref-keratometer RK-3, Canon Inc., Tokyo, Japan). There were no differences in corneal thickness and keratometric values among the three groups. The porcine eyes were secured to a plastic holder on a modified operating table. Simulating LASIK surgery of the right eye, corneal flaps were made by using an 8.5-mm-diameter suction ring and the #160 plate of the Hansatome microkeratome (Bausch & Lomb Surgical, Irvine, CA). A drop of normal saline was used to moisten and lubricate the cornea to facilitate resection. The incision using the microkeratome was made from the midpoint of the temporal and inferior side to the nasal side (superior hinge). After resection, the remaining corneal stromal thickness was measured centrally three times by the automated pachymeter. The difference in the corneal thickness and the remaining stromal thickness was defined as the flap thickness. The flap was repositioned on the stroma, and the eyeball was fixed with 10% buffered formalin for 24 hours.

**Measurement of Cutting Angle at the Flap Edge**

The flap was peeled and removed from the stromal bed by cutting the hinge with a scissors. The remaining cornea and sclera were divided into four sagittal sections with a sharp blade. Stromal

![Blade Diagram](Image)

Figure 1. The Hansatome blade penetrates the cornea infero-temporally. The cornea was then sliced into quadrants, and pictures were taken on each opposing side of each quadrant, as marked by the arrows.

wounds at the temporal, inferior, and nasal stromal sites were photographed with a microscope under 40X magnification (Fig 1). The corneas were prepared for light microscopy with gentian violet stain at the site of the flap incision before photography. One examiner (XHW) performed all of the procedures. Slide images were scanned using Nikon software. Image color and contrast were adjusted using Adobe 5.0.2k software to obtain the delicate incision angle. Measurements of the incision angles were made by using Jandel Scientific, Mocha 1.2 software. Each incision angle was measured five times, and the values were averaged (Fig 2). To calculate the angle of the flap at one site, measurements of the angle from opposing sides of a single incision were averaged.

Statistical analysis was performed with one-way analysis of variance and Tukey's multiple comparison tests in order to evaluate the differences in corneal thickness and incision angle after varying the suction duration. A *P*-value less than or equal to .05 was considered statistically significant.

** Videokeratographic Changes With Suction Duration**

To evaluate the effects of suction on corneal shape, videokeratography (EyeSys Technologies, Houston, TX) was used on the pig eyes (n=10) before and after suction to determine the changes in corneal surface. The suction ring used in this experiment was the same as previously mentioned. Since the minimum time required to perform videokeratography was longer than the interval of 25 seconds, it was not possible to evaluate the corneal shape at 10, 35, and 60 second intervals on the same day.
eye. In this study, videokeratography was performed before suction and 10 and 75 seconds after suction.

RESULTS

Flap Thickness Changes According to Suction Duration

Values for the flap thickness varied with the suction duration and are as follows: 87.8 ± 22.0 μm (10 sec), 116.0 ± 7.0 μm (35 sec), and 127.2 ± 16.8 μm (60 sec). The flaps of group 1 (10 sec) were statistically thinner than that of group 2 (35 sec, P = .005) and group 3 (60 sec, P = .004). The flap became thicker with increased suction duration, even though there was no statistical significance between groups 2 and 3 (P = .095) (Table).

Incision Angle Changes According to Suction Duration

The average incision angles increased with elongation of suction duration. The average incision angle of group 1 (10 sec, 34.8 ± 9.0°) was significantly less than that of group 2 (35 sec, 44.4 ± 16.1°) (P = .044) and group 3 (60 sec, 48.24 ± 15.3°) (P = .000). There was, however, no statistically significant difference between group 2 and group 3 (P = .074).

Upon further analysis of the incision angles from the temporal, inferior, and nasal sites among the three groups, there were slightly steeper initial incision angles at the temporal site with prolonged suction duration. The differences among the groups at the temporal site, however, were not statistically significant. At the inferior site, there was a statistically significant difference in the incision angles between group 1 (10 sec) and group 3 (60 sec) (P = .039). At the nasal site, group 1 showed a statistically significant difference with both group 2 (35 sec) (P = .005) and also with group 3 (60 sec) (P = .001), but there were no significant differences between group 2 (35 sec) and group 3 (60 sec) (P = .862).

Videokeratography Changes by Suction Duration

Videokeratography revealed that the corneal shape above the suction ring changed according to suction duration. Before suction, the central corneal curvature was steeper than that of the peripheral cornea (Fig 3A). Ten seconds after suction, the peripheral cornea (Fig 3B) became steeper than the central cornea. As the suction duration increased, the curve of the peripheral cornea grew increasingly steeper (Fig 3C).

DISCUSSION

According to our data, flap thickness can be controlled by suction duration. Control of flap thickness can be useful in several clinical aspects. One can minimize the risk of cutting an overly thick flap by maintaining optimal suction duration, which helps maintain a residual stromal bed thicker than the 250 μm. Very flat corneas with average keratometric power of less than 41 diopters (D) are at a greater risk for cutting a free flap. Sufficient suction duration that thickens the flap would include the hinge area and result in decreasing the probability of creating a free flap.

| Table |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Suction Duration Group (n=10 eyes in each group) | Mean Flap Thickness (μm) | Mean Incision Angles (°) of Cut Margin | Average |
| Temporal | Inferior | Nasal |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Group 1 (10 sec) | 87.75 ± 22.00 | 26.7 ± 6.0 | 35.5 ± 7.2 | 42.3 ± 6.3 | 34.8 ± 9.0 |
| Group 2 (35 sec) | 116.00 ± 7.03 | 31.0 ± 7.1 | 42.6 ± 12.5 | 59.6 ± 12.6 | 44.4 ± 16.1 |
| Group 3 (60 sec) | 127.17 ± 16.78 | 34.7 ± 8.9 | 47.8 ± 10.1 | 62.2 ± 12.2 | 48.24 ± 15.3 |

Flap thickness: P = .005 between Groups 1 and 2; P = .095 between Groups 2 and 3
Incision angle average: P = .044 between Groups 1 and 2; P = .074 between Groups 2 and 3
**Figure 3.** Videokeratography (EyeSys) revealed that a suction-induced high IOP changed the corneal shape. **A)** Before suction, the central cornea was steeper than the peripheral cornea. **B)** Ten seconds after suction, the central cornea was flattened, while the peripheral cornea where the blade would pass (8.5-mm zone, arrows) was steepened. **C)** As suction duration continued, the peripheral cornea steepened in this zone. The left-side topographic defect on each image was caused by artifacts produced by the shadow of the Hansatome handle.
Yildirim and colleagues studied the reproducibility of corneal flap thickness using the Hansatome and evaluated the effect of preoperative central corneal thickness and corneal keratometric power on flap thickness. They reported that the correlation between the baseline central corneal thickness and flap thickness had a low level of statistical significance. Our data showed a significant correlation of flap thickness with suction duration when baseline central corneal thickness and keratometric values among groups were held constant.

Kim and colleagues showed that lower surgeon translational velocity and high turbine velocity resulted in a significantly thicker flap. As the surgeon velocity increased, the final cutting angle that represents the diagonal vector decreased, which resulted in a functionally sharper blade with smoother tissue resection and a relatively thin flap. In comparison, an increase in oscillating frequency resulted in a relatively dull blade with more tissue loss and a thicker flap. They used an SCMD manual microkeratome (New United Development Corp.); oscillation of the blade and translational velocity was controlled by the surgeon. The Hansatome used in this study is an automated microkeratome designed to produce a surface parallel keratectomy of a preset flap diameter and a uniform flap thickness, and has fixed turbine and translational velocities. The data in this study showed that suction duration was related to differences in the incision angle and flap thickness.

Videokeratographic data in this study showed that suction of more than 64 mmHg applied to an eyeball with the use of a suction ring altered the shape of the cornea. With the continuous vacuum power of the suction ring, the IOP increased, and the cornea, because of its intrinsic elasticity, was molded until the elastic forces reached equilibrium with the IOP force. The peripheral cornea, where the blade would pass (Fig 3, 8.5-mm zone, arrow) became steeper with increased suction duration. With prolongation of suction duration, the angle with which the blade approaches the tangential plane of the cornea becomes more acute, thereby resulting in an incision angle that tends to be greater. In addition, the initial incision bite made by the blade would be greater and promote a thicker flap. The significance of making an incision angle closer to a right angle may have significance for postoperative epithelial ingrowth, a well-known complication following LASIK along the interface. Incisions that are perpendicular to the corneal surface will more likely inhibit epithelial ingrowth—the “manhole effect.” The clinical utility of incision angle data and relevance to epithelial ingrowth inhibition requires further investigation.

In addition to suction duration and incision site, there are other variables that may affect corneal thickness and incision angle, such as corneal curvature, corneal diameter, and corneal elasticity. We focused only on suction duration and tried to control the other factors as precisely as possible.

We observed that the corneal thickness and incision angles of corneal flaps increased with suction duration. We hope these data will be useful in decreasing the incidence of iatrogenic keratectasia and free flap complications after LASIK.

REFERENCES