The Relation Between Eyelid Tension, Corneal Toricity, and Age

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It has been demonstrated that corneal toricity can be altered by lifting the lids from the surface of the eye. Thus, corneal curvature is modified by the position or tension of the lids. Does it follow that differences in lid tension between individuals are related to variations in corneal toricity? A lid tensiometer was designed that measured the force exerted by a lid as it was pulled away from its resting place on the eye. When this force was plotted as a function of the displacement of the lid, an elastic coefficient of the lid was obtained. This elastic coefficient was used to denote lid tension. In a sample of 195 eyes, the elastic coefficient of the lid had a mean of 3.22 g/mm (SD ± 1.12), with a range from 1.16 to 6.78 g/mm. The results showed no correlation between the elastic coefficient and corneal toricity. Both the elastic coefficient and with-the-rule corneal toricity showed a statistically significant decrease with age. However, there was no significant relation between the elastic coefficient and corneal toricity when the effect of age was ruled out. From this experiment, and a reading of the literature, we conclude that there is no experimental evidence to show that lid tension determines corneal toricity.


The idea that the pressure of the lids on the eye influences corneal astigmatism was discussed by Gullstrand, but the topic probably was originated in the literature by Snellen. The theory has achieved wide acceptance and there is now a general belief that the lids influence the shape of the cornea.

Masci found that regardless of ocular rigidity, the effect of retracting the lids was an increase in against-the-rule astigmatism. This was shown to occur in both with-the-rule and against-the-rule astigmatic eyes, with a mean shift of 0.69 and 0.32 diopters, respectively. It was not recorded if the vertical meridian became flatter, the horizontal meridian became more curved or if both meridians changed. In a repeat of Masci's experiment, Wilson et al found that lifting the lids did cause a change in corneal toricity in the direction of more against-the-rule astigmatism. This change in toricity was caused by a steepening of the horizontal meridian of the cornea, and not a flattening of the vertical meridian.

In a clinical paper by Nisted and Hofstetter, it was noted that in a patient with chalazia on both the upper and lower lids, there was a significant shift in corneal and total astigmatism of the eye. Knoll noticed bilateral monocular diplopia after doing near work, and deduced that the lids were altering the shape of his cornea. A progressive ptosis while reading was linked to this phenomenon and suggested that the upper lids were the cause.

In a detailed study of senile changes in the palpebral fissure, Hill found that there is a medial drift of the lateral canthus and a shortening of the horizontal length of the palpebral aperture. As a result, it can be deduced that the force exerted on the eye by the lids decreases with age.

If, based on the literature cited, it is accepted that the eyelids are involved in the shaping of the cornea and that lid tension decreases with age, then it might be concluded that lid tension is a factor in the changes in corneal curvature with age. Furthermore, it might be concluded that differences in lid tension are also responsible for differences in corneal toricity between individuals.

This paper describes a lid tensiometer used to measure lid tension in a sample of 100 subjects with ages ranging from 20 to 80 years. Corneal toricity was measured with a keratometer. From the data collected, conclusions are drawn on the relation between lid tension and age, and the relation between lid tension and corneal toricity.

Materials and Methods

A lid tensiometer measured the force exerted by the lid as it was pulled away from its resting place on the eye. When this force was plotted as a function of the
displacement of the lid, an elastic coefficient of the lid was obtained. It is this elastic coefficient that is used to denote lid tension in this study.

Figure 1 is a photograph of the lid tensiometer. The central structure of the instrument is a Carl Zeiss® (Jena, East Germany) X-Y displacement stand mounted on an instrument table. A Grass® FT036 (Quincy, MA) force transducer is secured to the movable arm of the stand, such that as the arm is moved horizontally away from the subject’s eye, a positive force is registered by the transducer. Two rectangular surfaces 1.0 cm X 0.5 cm are attached to the upper and lower jaws of a clip such that they oppose one another to form a clamp for securing the lashes of the upper lid. The plunger of a displacement transducer is attached to the moveable portion of the stand. This transducer is situated so that the movement of the moveable arm away from the subject’s eye is registered as a positive distance. A head rest with an adjustable chin rest is mounted on the edge of the table to immobilize the subject’s head while lid tension measurements are being made. A Hewlett-Packard® 7035B (San Diego, CA) X-Y Recorder is coupled to the two transducers, and additional electronics to the force transducer gives a digital readout of force in grams. To aid in pulling the lid at a constant speed, a 45-cm long aluminum rod is attached to a knob which, by means of a rack and pinion, pulls the moveable arm of the stand away from the eye.

The X-Y recorder is set up so that the ordinate and abscissa represent the force and displacement, respectively. A calibration of 1 g equal to 2 cm, and 1 mm equal to 4 cm on the graph was found to be suitable for the forces and displacements occurring in this study.

The force transducer was calibrated with a 5-g weight at the beginning and at the completion of each measuring session. The displacement transducer was calibrated at the same time with a 5-mm measured movement. The linearity of both of the transducers was checked at intervals and found to be within 1%.

Subjects for this study were obtained from clinic waiting rooms. None of the subjects wore contact lenses. The age range of the 100 subjects was from 20 to 80 years. Eighty-six subjects wore an ophthalmic prescription and 18 subjects were having a vision examination on the day they participated in the study. Fifty-six of the subjects were women.*

Each subject’s head was placed comfortably in the chin rest and head rest. Directions were given to look straight ahead at a fixation mark on a wall 150 cm directly in front of and at eye level to the subject. Blinking was not prohibited and subjects were encouraged to keep their eyes as comfortable as possible. The eyelash clamp then was positioned at the level of the lash insertion into the upper lid and attached firmly to at least 10 lashes in the approximate center of the right lid. Two unrecorded pulls on the lid were per-

* Human informed consents were received prior to undertaking this study.
formed to demonstrate the sensation to be expected. When the subject was relaxed and comfortable, a series of from four to eight pulls were executed with each pull exerting a force of up to 6 g or traversing a distance of up to 5 mm, whichever came first. Each pull was begun at or within the point where force was first exerted by the lid on the transducer. The lid was pulled at a rate of approximately 1 mm per second and released back to the zero force point at the same rate.

After the completion of the procedure on the right lid, it was repeated on the left. Keratometry readings were then taken of both eyes with a Bausch and Lomb® (Rochester, NY) keratometer.

A straight line was fitted visually to each force-displacement plot and the slope of the line was expressed in g/mm. This was rounded off to the nearest 0.1 g/mm and recorded as a measurement of lid tension. Any single force-displacement plot was rejected if there

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**Fig. 2.** Examples of acceptable force-displacement plots. The best fit straight line is shown with the slope (lid tension) indicated.

**Fig. 3.** Examples of unacceptable force-displacement plots. Excessive lid, eye, or head movements have contaminated the plot so that an accurate assessment of lid tension is not possible.
was excessive head or lid movement that contaminated the plot. Unsteady eye fixation also was cause for rejection. There were between four and eight usable measurements for each eyelid and these measurements were averaged. Figures 2 and 3 are examples of the types of plot that were obtained.

The amount and type of corneal toricity was determined from the keratometry readings for each eye with the lid in the normal position. If the minus cylinder axis was 180 degrees ± 30 degrees, it was designated with-the-rule. If the minus cylinder astigmatism was 90 degrees ± 30 degrees, it was designated against-the-rule. Any other minus cylinder axis was designated "oblique" and rejected from this study.

**Results**

The data show a range of lid tensions from a low of 1.16 g/mm to a high of 6.78 g/mm; the mean (n = 195) was 3.22 g/mm (standard deviation ± 1.12).
Figures 4 and 5 are plots of corneal toricity against lid tension for the right and left eyes, respectively. The correlation coefficient for the corneal toricity and lid tension of the right eyes was found to be 0.070 (n = 98). The same correlations for the left eyes showed a coefficient of 0.033 (n = 97). These correlations were not significant at the 5% level.

An additional correlation was calculated between the difference in toricity between the right and left eyes of each subject and the difference in tension between the two eyes. This calculation revealed a correlation coefficient of −0.096 (n = 97) which was not significant at the 5% level.

The average lid tension of each subject was correlated with age and a coefficient of −0.244 was obtained with n = 97. This correlation coefficient was significant at the 5% level. From the slope of the linear regression through the data points the decrease in lid tension was 0.015 g/mm/yr for this subject population. The change in lid tension with age is illustrated in Figure 6.

Corneal toricity was correlated with the age of each subject and a coefficient of −0.296 was obtained with n = 98. This correlation coefficient was significant at the 5% level. This shows a significant relationship between corneal toricity and age, i.e., corneal toricity shifts towards against-the-rule with age. A linear regression of this data showed the rate of shift to be 0.017 diopters/yr for this subject population. This shift in corneal toricity with age is illustrated in Figure 7.

From Figure 6 and Figure 7, it can be seen that both lid tension and corneal toricity change with age, but apparently only after 50 years of age. Because of the apparent parallel course of these changes, correlation coefficients were calculated for subjects 50 years old and older. The correlation coefficient for corneal toricity and lid tension of the right eyes of this age group was found to be 0.055 (n = 31), which was not significant at the 5% level. The same correlation for the left eyes showed a coefficient of 0.049 (n = 31), which was not significant at the 5% level. These correlations again do not indicate any significant statistical correlation between corneal toricity and lid tension.

The repeatability of the technique was measured with one subject. A session in which at least four usable measurements of lid tension were taken for each eye of the subject took place at different times of the day on six separate days. The measurements from each session were averaged and the averages from all six sessions were combined to give figures separately for the right and left eyes. The average lid tension of the right eye was 3.87 g/mm with a standard deviation of ±0.62. The average tension of the left eye was 3.22 g/mm with a standard deviation of ±0.27.

Lid tensions in the left and right eyes were related significantly at the 5% level. The correlation coefficient was 0.435 (n = 97).

Discussion

This study has shown that lid tension decreases with age. The decrease in lid tension fits well with the wide-
spread belief that lids are looser in old age. Data reported by Hill\(^7\) showed changes in the palpebral fissure with age from which it can be inferred that the lids rest more gently on the eye.

Our subjects also showed a shift in corneal toricity with age. The rate of shift was 0.017 diopter/yr compared with a rate of 0.025 diopter/yr for total astigmatism found by Hirsch.\(^8\) Changes in corneal toricity and total astigmatism were shown by Anstice\(^9\) to be correlated strongly. When the rate of change of corneal toricity is calculated for subjects 40 years of age and older, as was done by Hirsch,\(^8\) a rate of 0.036 diopter/yr is obtained for our subjects. Thus, our subjects and those of Hirsch showed a similar rate of change with age and both were towards against-the-rule corneal toricity.

The lack of correlation between corneal toricity and lid tension is the most important finding in this study. This appears to conflict with Mandell and St. Helen,\(^10\) Masci,\(^3\) Nisted and Hofstetter,\(^3\) and Knoll,\(^6\) where it clearly has been demonstrated that the lids can change the shape of the cornea. The influence of the lids is especially evident in the studies of Masci\(^3\) and Wilson et al,\(^4\) where the cornea tends to shift towards against-the-rule when the lids are lifted away from the eye.

Much of the value of lid tension is in the belief that it is an indication of the pressure exerted by the lids on the cornea, an assumption that has not been subjected to rigid scrutiny. An example that can be used to illustrate the contrary of this assumption would be to imagine a weak elastic band draped over a spherical surface and secured at both ends. There would be virtually no force exerted by the band on the surface, but if the band were to be pulled away from the surface, a small tension would be measured. The same example could be constructed with a strong elastic band that also would exert virtually no force on the surface but would exert a large tension when pulled away from the surface. Thus, a high lid tension and a low lid tension conceivably could exert the same pressure on the cornea, or pressures that could not be related in any way to lid tension measurements. Miller,\(^11\) from measurements of lid pressure using a contact lens, claimed that the lids exert little or no pressure on the eye.

The finding that there is no relation between corneal toricity and measured lid tension does not conflict with any experimental evidence. In the experiments of Mandell and St. Helen,\(^10\) Masci,\(^3\) Nisted and Hofstetter,\(^3\) Knoll,\(^6\) and Wilson et al,\(^4\) it has been shown that, in an individual eye, abnormal positions of the lids can change corneal curvature. There is no necessity
to conclude that unusual lid conditions causing a change in toricity in a single eye are the reason for differences in toricity between eyes under normal conditions.

Thus, there is no experimental evidence that differences in lid tension between individuals are responsible for differences in corneal toricity. The widespread belief in the influence of lid tension on corneal toricity can only be attributed to the feeling that it makes sense. It has little experimental basis.

**Key words:** astigmatism, corneal toricity, lid tension, eyelids, ametropia.

**References**


