Relationship between Topographic Patterns and Corneal Astigmatism in Korean Adults

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The anterior corneal surface is one of the most important elements determining the optical performance of the eye. Corneal topography provides quantitative data about the anterior corneal surface. We studied the corneal topography of 200 normal corneas in 110 adult subjects. All of the eyes were examined using the Corneal Analysis System® (EyeSys 2000, Houston, Texas). The topographic maps were grouped into the following patterns: round, oval, symmetric bow tie, asymmetric bow tie, and irregular. The symmetric and asymmetric bow tie patterns were the most common topographic pattern (33.0%, and 32.5%, respectively) in our study population, followed by oval (14.5%), irregular (12.5%), and round (7.5%) patterns. The mean corneal astigmatism calculated from videokeratographic data was 0.32 D for round, 0.63 D for oval, 1.16 D for symmetric bow tie, 1.21 D for asymmetric bow tie, and 0.43 D for irregular patterns. There were significant differences among the corneal astigmatic values in the topographic patterns (p < 0.01, Gabriel post hoc test). The distributions of symmetric and asymmetric bow tie patterns were skewed toward greater amounts of corneal astigmatism. In conclusion, the results of this study demonstrate the relationship between topographic patterns and corneal astigmatism and should provide one possible normal standard for corneal topography in Korean adults.

Key words: bow tie, corneal astigmatism, topography, videokeratography

INTRODUCTION

Measurements of the shape and refractive power of the cornea are very important for diagnosing corneal diseases and designing vision correction surgeries. The majority of the commercial computerized videokeratographic instruments measure the topography of the anterior corneal surface, which accounts for the majority of the refractive power of the cornea. These instruments have the potential to greatly increase our knowledge about corneal shape and function in normal and abnormal corneas.

The quality of computer-assisted corneal videokeratography has greatly improved during the past decade and it now provides useful clinical information about corneal shape.1,2 Most importantly, it has been used to evaluate the surgical effects or complications of refractive surgery.3,4 With the accelerated interest in refractive corneal surgery and the enhanced refinement of intraocular surgery, there has been a widening realization that quantitative
measurements of corneal contour have significance in evaluating the effects of these procedures.

The goal of this study is to compare each corneal astigmatic value in the topographic patterns in Korean adults by surveying the range of variation of shape found in normal corneas. Therefore, these results may be used in further quantitative studies of the relationship of corneal shape to visual acuity.

**MATERIALS AND METHODS**

We studied the corneal topography of 200 normal corneas in 110 subjects. All of the eyes were examined using the Corneal Analysis System® (EyeSys 2000, Houston, Texas). The subjects consisted of 75 women and 35 men whose ages ranged from 18 to 55 (mean, 29, standard deviation, 12.1) years and whose spherical equivalent ranged from -16.13 D to +2.0 D (mean, -4.77 D, standard deviation, 3.48) with most commonly the corneas of myopic eyes. The distribution of the subjects’ age and sex was not even because we attempted to examine patients from all age groups. We did not attempt to prepare a true demographic cross-section of the population or a distribution of normal corneal topographic patterns of Korean adults. Normal subjects were defined as those who had (1) no history of ocular surgery, (2) no slit lamp microscopic evidence of trauma or corneal disease, (3) best corrected visual acuity of 20/100 or better to allow adequate fixation, (4) regular keratometer mires, and (5) no history of rigid gas permeable contact lens wearing. All patients with poor repeatability of the maps displayed by EyeSys 2000 were excluded from the study. With these criteria, 20 eyes were excluded.

The topography examination was performed by one of the authors (HC Kim) with the following procedure. The subject’s chin was placed on the chin rest and the forehead rested against the forehead strap. The subject was instructed to look at a green fixation light. Using the joystick, the examiner adjusted the image so that the pupil was centered in the centering box and focused until the blue line was centered horizontally within the green box, and then pressed the acquisition button on top of the joystick. In this manner the eye image was captured and color-coded maps were recorded at least twice for each eye.

A qualitative classification system for corneal topography was derived based on the patterns visible on the color-coded topographic maps. We used the criteria described by Bogan to define the categories for classification of corneal topographic patterns. According to Bogan’s classification, the pattern of the red color zone and colors peripheral to the yellow zone were not used for classification.

1. Round: the ratio of the shortest to the longest diameter at the color zone chosen for pattern reading was 2/3 or more (Fig. 1).

2. Oval: the ratio of the shortest to the longest diameter at the color zone chosen for pattern reading was less than 2/3 (Fig. 2).
3. Symmetric bow tie: (a) there was a central constriction in the outline of the color zone identified for pattern reading; (b) the ratio of the distance across the central constriction to the longest distance across each half of the bow tie pattern measured perpendicular to the long axis of the bow tie was 1/3 or less; (c) the ratio of the longest distance across each half of the bow tie pattern measured perpendicular to the long axis of the pattern or the ratio of the radius of the longest distance measured from the central constriction to either edge of the bow tie was 2/3 or more (Fig. 3).

4. Asymmetric bow tie: both criteria a and b for symmetric bow tie were met; one or both of the ratios described in criteria c for symmetric bow tie was less than 2/3 (Fig. 4).

5. Irregular: no clear pattern could be identified according to the above criteria (Fig. 5).

According to this classification, the color-coded topographic maps were grouped into the following patterns: round, oval, symmetric bow tie, asymmetric bow tie, and irregular.

After calculating the mean corneal astigmatism from the simulated keratometric power (SimK), the distribution of topographic patterns was examined according to the corneal astigmatic values (Fig. 6).

We statistically evaluated the topographic patterns and corneal astigmatism by analysis of variance. The Gabriel post hoc test was used to determine the specific group differences when the analysis of variance showed a statistically significant difference.
Table 1. Distribution of qualitative topographic patterns in normal corneas

<table>
<thead>
<tr>
<th>Topographic pattern</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>15</td>
<td>7.5</td>
</tr>
<tr>
<td>Oval</td>
<td>29</td>
<td>14.5</td>
</tr>
<tr>
<td>Symmetric bow tie</td>
<td>66</td>
<td>33.0</td>
</tr>
<tr>
<td>Asymmetric bow tie</td>
<td>65</td>
<td>32.5</td>
</tr>
<tr>
<td>Irregular</td>
<td>25</td>
<td>12.5</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>100</td>
</tr>
</tbody>
</table>

RESULTS

There were no statistically significant differences among any of the patterns for age, sex, or left or right mean keratometric power. According to the qualitative classification system of normal corneal topography based on the patterns identified from the normalized color-coded topographic maps, there were 15 corneas (7.5%) with round pattern, 29 (14.5%) with oval pattern, 66 (33.0%) with symmetric bow tie pattern, 65 (32.5%) with asymmetric bow tie pattern, and 25 (12.5%) with irregular pattern (Table 1). The bow tie patterns were the most common in our study. All corneas were steeper centrally and flatter peripherally.

The mean SimK was 44.31 ± 1.19 diopter (D) in steep meridian and 43.37 ± 1.07 D in flat meridian. The mean corneal astigmatism of all cases was 0.94 ± 0.48 D. According to topographic pattern, it was 0.32 D for round, 0.63 D for oval, 1.16 D for symmetric bow tie, 1.21 D for asymmetric bow tie, and 0.43 D for irregular pattern (Table 2).

There were significant differences among the corneal astigmatic values in the topographic patterns (p < 0.01). The Gabriel post hoc test was used to determine the specific group differences and the two bow tie groups showed different amounts of corneal astigmatism than the other three groups. The corneal astigmatic values of round, oval, and irregular patterns were lower than 1 D. The distributions of symmetric and asymmetric patterns were skewed toward greater amounts of corneal astigmatism (Fig. 6).

DISCUSSION

It is recognized that the corneal surface and the precorneal tearfilm provide 75 to 80% of the refractive power of the normal eye. Therefore, many surgical techniques to correct refractive error by altering the corneal surface have been developed. With the evolution and widespread use of refractive surgical techniques, such as astigmatic keratotomy, photorefractive keratectomy, and photoanesthetic keratectomy, the need for more accurate and detailed analysis of the corneal surface has increased as the quality of instrumentation has improved. The ability to obtain detailed information about the normal corneal topography offers the promise of improved understanding of corneal surface abnormalities and their relation to visual function.

Clinicians have a number of methods for measuring corneal power and corneal shape including keratometry, keratography, photokeratography, interferometry, computer assisted videokeratography, and rasterstereography. The computer-assisted videokeratoscope uses a collimating cone to reflect 25-30 rings off the corneal surface, yielding as many as 8000 data points for computer analysis. This technique detects the curvature and refractive power of the anterior corneal surface. Further quantitative studies of corneal topography should pro-

Table 2. Simulated keratometric results and keratographic astigmatism according to topographic pattern

<table>
<thead>
<tr>
<th>Topographic pattern</th>
<th>Steep meridian* (D)</th>
<th>Flat meridian* (D)</th>
<th>Keratographic astigmatism* (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>43.47 ± 1.21</td>
<td>43.15 ± 1.18</td>
<td>0.32 ± 0.30</td>
</tr>
<tr>
<td>Oval</td>
<td>43.52 ± 1.92</td>
<td>42.89 ± 1.85</td>
<td>0.63 ± 0.54</td>
</tr>
<tr>
<td>Symmetric bow tie</td>
<td>44.06 ± 2.21</td>
<td>42.92 ± 2.06</td>
<td>1.16 ± 1.15</td>
</tr>
<tr>
<td>Asymmetric bow tie</td>
<td>45.12 ± 2.07</td>
<td>43.90 ± 1.94</td>
<td>1.21 ± 0.73</td>
</tr>
<tr>
<td>Irregular</td>
<td>44.28 ± 1.72</td>
<td>43.85 ± 1.83</td>
<td>0.43 ± 0.38</td>
</tr>
</tbody>
</table>

*: mean ± SD, D: diopter
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provide more detailed information defining the distinctions between normal and pathologic corneas, and the topographic characteristics of normal corneas in various refractive states.

Although previously assumed to be spherical, it is now known that the normal cornea has an asymmetrical shape along its meridians. Grossly, the cornea can be divided into two zones: spheric central and aspheric peripheral. As the visual axis passes through it, the apical zone is responsible for the quality of the visual image, whereas the peripheral zones do not directly affect the visual image. More peripheral rings were not included in the calculation because some of the peripheral data points are often absent in peripheral rings, especially in eyes with pathologic conditions. In practice, it is difficult to consider all parameters in individual eyes. Moreover, determination of the reference point of a videokeratography system itself depends on several topologic approximations, on accurate fixation by the patient, and on proper alignment of the instrument. Given these limitations, the calculation methods used in the present study appear to fulfill the reasonable requirements of a clinically convenient evaluation method for the anterior corneal surface. In a regular spherocylinder, the two flattest semimeridians and the two steepest semimeridians have the same curvature and refractive power, and form a 180 degree angle. Whereas SimK allows regular astigmatism (total cylinder and location of the steepest meridian) to be quantitatively measured, astigmatism irregularity is another limitation to use topographic data. Theoretically, the amount of irregular astigmatism is inversely correlated with spectacle-corrected visual acuity, but such an association has not been examined. Oshika and his coworkers reported that Fourier analysis of topographic data can be used to separate the irregular astigmatism component from the spherical and cylindrical components, and that visual acuity can be predicted from the irregular astigmatism components. To solve this problem, the corneal topographic indices obtained from videokeratoscopes may be useful for quantifying the extent of the irregular astigmatism and for estimating the effects of irregular astigmatism on visual acuity in subjects with normal-shaped corneas to moderately irregular corneas. Despite the numerous advances in the field of corneal topography recently, however, topographic measures that serve as direct correlates of ocular visual performance still remain elusive. In our study, we analyzed the relationship between the topographic patterns and corneal astigmatism correlated with visual acuity in Korean adults using the Corneal Analysis System® (EyeSys 2000, Houston, Texas) and Bogan's classification.

Bogan and coworkers examined both ametropic and emmetropic eyes by videokeratography. They derived a qualitative system for classifying normal corneal topography based on patterns identified on color coded topographic maps. In their study, asymmetric bow tie pattern was the leading topographic form found in 32% of normal corneas, followed by round (22%), oval (21%), symmetric bow tie (18%), and irregular (7%) patterns. In addition, Kim et al6 reported that 99 eyes (42.7%) had asymmetric bow tie, 44 (19.0%) irregular, 42 (18.1%) symmetric bow tie, 31 (13.4%) oval and 16 (6.9%) round patterns in Korean adults.

However, in our study, the symmetric and asymmetric bow tie patterns were the most common topographic pattern (33.0%, 32.5%), followed by oval, irregular, and round (Table 1). These different results may have originated from the different topography system, maps, scale and selection bias. In Bogan’s study with the Corneal Modeling System, all 11 available colors were used in each keratograph and there were 0.2 to 0.3 D steps between adjacent colors. All keratographs were classified based on the configuration of the predominant pattern of one of the middle 4 of the 11 colors depicted (brown, tan, gold, and yellow) and they analyzed both emmetropic and ametropic eyes with a wide range of corneal astigmatism. However, we used EyeSys 2000 which had all 15 colors with 0.5 D steps and classified the topographic map patterns with central colors rather than middle colors and evaluated mainly the corneas of myopic eyes. In 1995, Alvi and coworkers17 also used the EyeSys corneal analyzing system and classified the normal corneal topography into six groups. Their topographic classification differs from Bogan’s with the addition of teardrop and kidney patterns. Alvi proposed that the reason for variation in classification models was based on the different analyzing systems used. In our study, the teardrop pattern was
classified as asymmetric bow tie and the kidney pattern was classified as either oval or irregular patterns.

The groups of topographic patterns showed different amounts of corneal astigmatism. The mean corneal astigmatism of round, oval, and irregular patterns was lower than 1 D. The symmetric and asymmetric bow tie patterns were distributed toward greater amounts of corneal astigmatism. These results indicate that the topographic patterns are largely determined by the corneal astigmatic values. A topography examiner might predict that an eye with greater amounts of corneal astigmatism more than 1 D would probably show symmetric or asymmetric bow tie patterns. However, the topographic maps may not be accurate enough to determine the true shape of the corneal surface for interpretation, as Kanpolat and coworkers have suggested. Therefore they postulated that the topographic configuration may not be a good predictor of visual function, and they proposed using more sophisticated analyzers, such as videokeratographs which calculated the local radius of curvature or projection-based methods.

In conclusion, the results of this study demonstrate the relationship between topographic patterns and corneal astigmatism and will provide one possible normal standard for corneal topography in Korean adults.

REFERENCES


