Location of Steepest Corneal Area of Cone in Keratoconus Using Pentacam Stratified by Age

Aylin Ertan, MD; Günhal Kamburoğlu, MD; Joseph Colin, MD

ABSTRACT

PURPOSE: To evaluate topographic patterns in keratoconic cases and to classify those topographic patterns according to different age groups.

METHODS: Four hundred eighty-two eyes of 251 patients with keratoconus were separated into 3 groups based on age. The age range of group 1 (younger) was <21 years (83 eyes), group 2 (middle) was 21 to 40 years (362 eyes), and group 3 (older) was >40 years (37 eyes). All patients underwent full ocular examination and Pentacam (Oculus Optikgeräte GmbH) measurement. Topographic patterns were analyzed by comparing the results according to age groups.

RESULTS: Distribution ratios of keratoconic eyes in the three age groups were 17.2% younger, 75.3% middle, and 7.5% older. The most frequent topographic patterns for those patients were vertical bowtie pattern (28.4%) in the younger group, inferior global cone pattern (23.7%) in the middle group, and inferotemporal global cone pattern (16.4%) in the older group. Temporal global cone pattern was more frequently seen among younger keratoconus patients—22% for the eyes in the younger group, 6.9% for the eyes in the middle group, and 11.1% for the eyes in the older group.

CONCLUSIONS: In keratoconus, the steepest part of the cone can be located temporally, especially in younger patients, which is unusual. Younger candidates for refractive surgery should be screened for temporal forme fruste. [J Refract Surg. 2008;xx:xxx-xxx.]

Keratoconus, classically, has its onset at puberty and progresses until the third to fourth decade of life, when it usually arrests. Keratoconus is a noninflammatory corneal ectasia with an incidence of approximately 1 per 2000 in the general population.¹ Prevalence falls between 50 and 230 per 100,000. The differences in frequency partly reflect differences in the diagnostic criteria. The natural course of the disorder is difficult to determine because the corneal changes usually begin before the first examination of the patient. Typically at the age of puberty, the presumably normal cornea of the patient begins to thin out and protrude, resulting in irregular astigmatism. The severity of the disorder at the time when progression stops may range from very mild irregular astigmatism to severe thinning.²

Recently, biomechanical properties of the cornea in different age groups are the focus of intense research.³ The progressive alteration of the keratoconic corneal shape may be caused from elastic deformation. Corneal hysteresis is a measurement that purportedly reflects the viscoelastic properties of the cornea. Experimental ex vivo studies have shown an age-related change in corneal collagen fibril properties, which may contribute to an increased stiffness of the cornea with age.⁴⁵ Progressive alteration of the keratoconic corneal shape may be caused from elastic deformation. Theoretically, increased intraocular pressure, decreased corneal tissue strength, decreased corneal tissue mass, or a combination of these, may be the pathogenic factors. In the literature, topics concerning tissue mass and strength have attracted the most attention.²

In the present study, Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) topographic patterns of 482 keratoconic
Temporal Cone Frequency in Keratoconus/Ertan et al

patients and methods

PATIENT POPULATION AND EVALUATION

A total of 482 keratoconic eyes of 251 patients were evaluated according to the topographic pattern with the Pentacam Scheimpflug photographic camera.

The Pentacam system uses a rotating Scheimpflug camera and a monochromatic slit light source (blue light emitting diode at 475 nm) that rotate together with the camera around the optical axis of the eye. Within 2 seconds, the system rotates 180° and obtains 25 images that contain 500 measurement points on the front and back corneal surfaces to construct a true elevation map. The software supplies the images as volume data, thus multi-planar re-projections allow the creation of axial and tangential maps. The rotating camera takes multiple (25 or 50, depending on the user settings) slit images of the anterior eye segments in approximately 2 seconds with 500 true elevation points included in each slit image. For this study, the “50 images per scan” settings option was chosen. By capturing images at a steady speed, it eliminates vibrations and image artifact that might occur during acceleration or deceleration. After completing a scan, the software creates a three-dimensional image of the anterior segment, including anterior and posterior corneal surface and lens surface as well as lens opacities. Mean central corneal curvature was calculated automatically by the device as the mean value of horizontal and vertical central radial curvatures in the 3-mm zone.

Eyes were divided into groups with respect to the patients’ ages and topographic patterns.

CLASSIFICATION OF TOPOGRAPHIC PATTERNS

Sagittal topography was used as a baseline for the database of videokeratography patterns to classify keratoconic eyes in two major groups: global cone pattern and bowtie pattern. The following Pentacam parameters were used for analysis of cone locations: 1) location of the thinnest point, and 2) location of the maximum height of anterior and posterior elevations (Fig 1).

Cone patterns were divided into five subgroups according to their locations—inferior, superior, inferotemporal, temporal, and nasal cones (Fig 2).

Bowtie patterns were classified according to axis of the steepest points—vertical, horizontal, and oblique bowtie patterns. Oblique bowtie patterns were confirmed with astigmatism axis, which was found in the topographic data.

RESULTS

DISTRIBUTION RATIOS IN DIFFERENT AGE GROUPS

Patients were divided into three groups according to age. The age intervals of the patients in group 1, 2, and 3, respectively, were <21 (younger), between 21 and 40 (middle), and >40 (older) years. Groups 1, 2, and 3

Figure 1. Analysis of cone location using elevation maps and pachymetry maps. The thinnest point moved towards temporal locations and was correlated with elevation and anterior curvature.
included 83 (17.2%), 362 (75.1%), and 37 (7.7%) eyes, respectively.

**DISTRIBUTION RATIOS OF TOPOGRAPHY PATTERNS IN DIFFERENT AGE GROUPS**

All topographic views were divided into two major groups according to the following patterns; global cone patterns in 298 (61.8%) eyes and bowtie patterns in 184 (38.2%) eyes. Six different cone locations as subgroups were observed among 298 eyes having cone pattern; the inferior cone in 114 (23.7%), central cone in 54 (11.2%), temporal cone in 47 (9.8%), inferotemporal cone in 79 (16.4%), nasal cone in 2 (0.4%), and superior cone in 3 (0.6%). Two different bowtie patterns as subgroups were observed as follows: vertical bowtie in 137 (28.4%) eyes and oblique bow tie in 46 (9.5%) eyes.

The most frequent between the two major keratoconus patterns was the global cone pattern which was determined in 298 (61.8%) of the 482 eyes, but when we analyzed all subgroups of these 482 eyes, we found that the most frequent subgroups were vertical bowtie cone pattern (28.4%), inferior cone pattern (23.7%) and inferotemporal cone pattern (16.4%) (Table 1). The least frequent patterns were nasal with the incidence ration of 0.4 % and superior cone with the incidence ration of 0.6 % among all the patients.

Figure 3 and Table 2 show keratoconus topography pattern distribution among each age group.

- **Temporal cone pattern** was more frequent among the younger keratoconus patients, with an incidence ratio of 22% among eyes in the young group, 6.9% among eyes in the middle group, and 11.1% among eyes in the older group.
- **Inferotemporal cones** were more frequently seen among the older group, with the incidence ratio of 22% among eyes in the young group, 6.9% among eyes in the middle group, and 11.1% among eyes in the older group.
- **Asymmetric vertical bowtie pattern** and inferior cone pattern were the most frequent patterns among all groups.

**DISCUSSION**

Comprehensive histopathologic analysis of corneal buttons undergoing penetrating keratoplasty in keratoconus have revealed the presence of two types of cone
morphologies: “nipple” type cones, located centrally, and “oval” (sagging) type cones, located inferiorly or inferotemporally. Maguire and Bourne \(^7\) published a study on patients with suspected keratoconus who had not shown any evidence of the disorder under the slit-lamp examination. They reported that computer-assisted topographic analysis was useful for detecting corneal irregularity in the early stages of the disease.

Several studies have characterized the topographic patterns of keratoconus.\(^8\)-\(^9\) In our study, a pattern was considered conic if the thinnest point and highest point, respectively, in anterior and posterior elevations were localized at the same spot, whereas this spot was also the steepest area on the anterior curvature map. In

**TABLE 1**

**Keratoconus Topography Pattern Distributions in 482 Eyes**

<table>
<thead>
<tr>
<th>Major Pattern</th>
<th>No. of Eyes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global cone</td>
<td>298 (61.8)</td>
</tr>
<tr>
<td>Inferior</td>
<td>114 (23.7)</td>
</tr>
<tr>
<td>Central</td>
<td>54 (11.2)</td>
</tr>
<tr>
<td>Temporal</td>
<td>47 (9.8)</td>
</tr>
<tr>
<td>Inferotemporal</td>
<td>79 (16.4)</td>
</tr>
<tr>
<td>Nasal</td>
<td>2 (0.4)</td>
</tr>
<tr>
<td>Superior</td>
<td>3 (0.6)</td>
</tr>
<tr>
<td>Major Pattern</td>
<td>184 (38.2)</td>
</tr>
<tr>
<td>Vertical</td>
<td>137 (28.4)</td>
</tr>
<tr>
<td>Oblique</td>
<td>46 (9.5)</td>
</tr>
</tbody>
</table>

**TABLE 2**

**Keratoconus Topography Pattern Distribution Within Each Age Group**

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Group 1 (Young) (&lt;20 y)</th>
<th>Group 2 (Middle) (21 to 40 y)</th>
<th>Group 3 (Older) (&gt;40 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inferior cone</td>
<td>24.4</td>
<td>22.8</td>
<td>27.8</td>
</tr>
<tr>
<td>Asymmetric bowtie</td>
<td>31.7</td>
<td>27.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Central cone</td>
<td>9.8</td>
<td>11.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Temporal cone</td>
<td>22.0</td>
<td>6.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Oblique bowtie</td>
<td>7.3</td>
<td>10.0</td>
<td>11.1</td>
</tr>
<tr>
<td>Inferotemporal cone</td>
<td>4.9</td>
<td>19.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Nasal cone</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Superior cone</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 3.** Keratoconus topography pattern distributions within each age group.
this study, Scheimpflug camera imaging was used. The advantage of using Scheimpflug images was to obtain detailed elevation and pachymetry maps all at once.

This is a large case series and all keratoconus patterns were classified according to the results obtained from Pentacam data, which provided us the advantage of obtaining Scheimpflug-generated elevation maps. In previous studies, only the highest points were used to detect cone location on color-coded maps. In Placido systems, which are reflective, one would not record data from the posterior surface and therefore would be incapable of generating a pachymetry map.

At first, all topographic patterns were classified in two major groups for the sake of simplicity. Previous studies were different from our classification in which peripheral steepening and central steepening were different from our classification in two major groups for the sake of simplicity. Previous studies, only the highest points were used to detect cone location on color-coded maps. In Placido systems, which are reflective, one would not record data from the posterior surface and therefore would be incapable of generating a pachymetry map.

The bowtie pattern group was divided into subgroups according to axis as vertical bowtie pattern, horizontal bowtie pattern, and oblique bowtie pattern. Previously, bowtie pattern was classified according to skewed radial axis and inferior and superior steepening. Vertical asymmetric bowtie pattern (28.4%) was the most frequent among the bowtie patterns and cone patterns. Oblique bowtie pattern (9.5%) was rare among all other patterns and was also the least frequent in the younger age group.

From this study it can be concluded that keratoconus can be observed in different topographic patterns, and inferosuperior asymmetry on anterior curvature maps does not give adequate information without detailed evaluation of elevation and pachymetry maps for refractive surgery. Elevation maps are important to detect cone location in keratoconic eyes. In young patients, the cone can be localized temporally, which is an unusual location for keratoconus. Young candidates for refractive surgery should be screened for temporal forme fruste.

REFERENCES
AUTHOR QUERIES

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The title has been changed per Dr Waring. Okay as edited?

Abstract, Conclusions: Rewritten per Dr Waring. Okay as edited?

Page 2: The following statements seem repetitive. Please advise as to which can be omitted.

Within 2 seconds, the system rotates 180° and obtains 25 images that contain 500 measurement points on the front and back corneal surfaces to construct a true elevation map. The software supplies the images as volume data, thus multi-planar re-projections allow the creation of axial and tangential maps. The rotating camera takes multiple (25 or 50, depending on the user settings) slit images of the anterior eye segments in approximately 2 seconds with 500 true elevation points included in each slit image.

Page 3, left column: The following is confusing, as the percentages are based on the total number of eyes (482). Shouldn’t the percentages be based on the number of eyes included in the subgroup? Also, 114+54+47+79+2+3 = 299, not 298. Please advise. Also, 137+46 = 183, not 184. Please advise.

All topographic views were divided into two major groups according to the following patterns; global cone patterns in 298 (61.8%) eyes and bowtie patterns in 184 (38.2%) eyes. Six different cone locations as subgroups were observed among 298 eyes having cone pattern; the inferior cone in 114 (23.7%), central cone in 54 (11.2%), temporal cone in 47 (9.8%), inferotemporal cone in 79 (16.4%), nasal cone in 2 (0.4%), and superior cone in 3 (0.6%). Two different bowtie patterns as subgroups were observed as follows: vertical bow tie in 137 (28.4%) eyes and oblique bow tie in 46 (9.5%) eyes.

Page 3, right column: Please clarify the following. What is meant by ration? Should it be ratio?

The least frequent patterns were nasal with the incidence ration of 0.4 % and superior cone with the incidence ration of 0.6 % among all the patients.

Page 5, left column: Please clarify the following. What is meant by “away from”? Perhaps “different” is a better word choice.

These locations were away from traditional keratoconus description criteria including inferior steepening.8

Page 5, left column: Please clarify the following. Does “this study” refer to the current study or Perry et al?

In this study, cone patterns were divided into sub-classes according to their locations as inferior, temporal, inferotemporal, nasal, and superior. In the majority of cases, inferior (23.7%) and inferotemporal cone locations (16.4%) of the cornea were observed.