The changes of shape of the human cornea with age

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ABSTRACT

Purpose: To assess the changes of shape and alignment of the anterior and posterior surfaces of the mean cornea with age, as they can help to explain the optical quality of the aging eye. Methods: A group of 407 normal corneas of 211 subjects with ages ranging from 4 to 79 years old was analyzed by fitting their elevation topographies to a general biconic plus a Zernike expansion of the residual. Results: The anterior apex curvature increases with age, and becomes more prolate along the meridian of maximum curvature. The curvatures and conic constants of the posterior surface remain constant, which causes a peripheral thinning [2]. Zernike coefficients \( \tilde{Z}_4 \) \& \( \tilde{Z}_6 \) show big changes in both surfaces. In addition the cornea rotates as a solid body by 2 minutes of arc per year, thus increasing its misalignment with the keratometric axis with age. Conclusion: The mean cornea shows highly significant changes with age, which might cause an important increase of corneal HOA.

METHODS

Setting: Antwerp University Hospital [5]
Instrument: Pentacam Scheimpflug camera (Oculus Optikgeräte, Wetzlar, Germany)
Subjects: 211 healthy subjects (62 male, 149 female; 204 Caucasian, 7 non-Caucasian)
Ages: Range 4-79 years old, mean 41.6 ± 14.5 years
Valid samples: 407 elevation topographies (anterior & posterior) + pachymetry

The surface model

Canonic form:

\[
z = c_x x^2 + c_y y^2 + z_0 + \sum z_i Z_i + \text{HOR}
\]

Biconic

Zernike polynomial

General form:

\[
x = R(s - x_0), \quad y = R(s - y_0), \quad \alpha = \beta = \gamma = 0
\]

3D Rotation

Translation: \( s \rightarrow (x, y, z) \rightarrow (x, y, z) \)

Parameters

Biconic: \( R_{\text{max}}, R_{\text{min}}, Q_{\text{min}}, Q_{\text{max}} \)
Position/orientation: \( \alpha, \beta, \gamma, x_0, y_0, z_0 \)

Zernike coefficients: \( [a_i] \)

Corneal thickness: \( T_{\text{min}} - T_{\text{peripheral}} = \langle T \rangle \text{ring}(6-9 \text{ mm}) \)

RESULTS 1: THE MEAN CORNEA

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Anterior</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{\text{max}} )</td>
<td>5.76 ± 0.38</td>
<td>5.72 ± 0.35</td>
</tr>
<tr>
<td>( R_{\text{min}} )</td>
<td>5.12 ± 0.29</td>
<td>4.98 ± 0.27</td>
</tr>
<tr>
<td>( Q_{\min} )</td>
<td>0.19 ± 0.12</td>
<td>0.22 ± 0.13</td>
</tr>
<tr>
<td>( Q_{\max} )</td>
<td>0.32 ± 0.14</td>
<td>0.30 ± 0.13</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>4.25 ± 1.10</td>
<td>3.85 ± 1.00</td>
</tr>
<tr>
<td>( \beta )</td>
<td>2.02 ± 1.09</td>
<td>1.83 ± 0.95</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>7.50 ± 1.10</td>
<td>8.10 ± 1.05</td>
</tr>
</tbody>
</table>

QUALITY OF FIT:

- RMS = 1.36 µm
- RMS = 0.85 µm

RESULTS 2: CHANGES WITH AGE (examples)

SUMMARY & CONCLUSIONS

1.- Previous findings confirmed:

- Both surfaces: prolate biconic (or ellipsoid) [Refs. 2, 3]
- Corneal misalignment (tip & tilt) [Ref. 4]
- “Aspherical” \( Z_4 \) \& \( Z_6 \) coeff. are significative [Ref. 4]
- Anterior surface: more prolate & curvative with age [Ref. 2] ⇒ Peripheral thinning
- Balance external/internal changes with age [Ref. 1]

2.- New findings:

- \( Q_{\text{min}} \) changes but \( R_{\text{min}} \) remains constant with age
- Corneal tip & tilt increase with age
- Anterior/posterior misalignment is constant ⇒ Solid body rotation
- \( Z_4 \) \& \( Z_6 \) changes dramatically in both surfaces
- Changes in tip, tilt, \( Z_4 \) \& \( Z_6 \) suggest strong impact on optical quality (sph. aberration & coma.)

REFERENCES