ANALYSIS OF ANTERIOR CORNEAL IRREGULARITY BY MEANS OF NEW PLACIDO-BASED INDICES IN KERATOCONUS AND SUBCLINICAL KERATOCONUS PATIENTS

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Introduction

Purpose: the assessment of previously built metrics of corneal irregularity based directly on the digitized images of the Placido disks1, bypassing the mathematical reconstruction of the corneal curvature or topographic maps.

Current stage: discrimination between “normal” and “irregular” corneas. Tested with three groups of patients, those classified as normal eyes, those with a clinically diagnosed keratoconus (KC) and those diagnosed as keratoconus suspect eyes (KS).

Clinical applications: to serve as a complement to popular and widely implemented corneal indices. Among them, some primary indices β-8, SimK1/SimK2, OSI, CSI, SAI or SRAQ, based essentially on curvature maps, and some compound or compilation indices (KSA% or KPI).

Placido disks images

The Placido disk images reflected on the cornea might permit to discriminate between normal and KC corneas, as one can see on the images below. For a normal eye, the mires are very close to a circle, whereas for a keratoconic eye the mires are distorted and displaced with respect to circles.

A set of indices measuring this deviation of the mires with respect to circles is proposed and their ability to discriminate between different types of eyes is assessed.

Irregularity Indices

Fit a circle to the n-th mire and read the coordinates of its center, $C_i$, and radius, $R_i$. Ideally, all centers coincide; asymmetric deformations yield dispersion in the location of these centers. So, we define the diameter and drift

$$P_1 = \frac{1}{N} \max \left\{ \|C_i - C\| \right\}$$

$$P_2 = \frac{1}{N} \sum \left\{ \|C_i - C\| \right\}$$

Fit an ellipse to the n-th mire, read the axis ratio $\alpha_i \geq 1$ , and define

$$P_3 = \frac{1}{N} \sum \left\{ \alpha_i - 1 \right\}^2 , \quad \text{where} \quad \gamma = \frac{1}{N} \sum \alpha_i$$

A regression line for the coordinates $x_i$ and $y_i$ of the centers $C_i = (x_i, y_i)$ is computed, yielding the expression $y = ax + b$ and then define

$$P_4 = a$$

Define also $AR(4) = R_i$ as the radius of the 4th mire.

A linear model combining some of the previous indices is defined by

$$GLPI = 400 \times \text{Probit}(\eta)$$

$$\eta = 10^{-0.1(15.7 + 1043.9 \times P_1 - 184.2 \times P_2 - 30.0 \times AR(4) + 0.5 \times P_4)}$$

Its value can be regarded as a percentage of irregularity of the cornea.

Results

The indices above have been tested with a database of 50 normal eyes (N), 50 keratoconic eyes (KC) and 24 keratoconus suspect eyes (KS).

The Mann-Witney-Wilcoxon test states that indices $P_1$, $P_2$ and $P_3$ are able to discriminate when classifying “N vs KC”, “N vs KS” and “KC vs KS”, and indices $P_4$ and $AR(4)$ are able to discriminate “N vs KC” and “KC vs KS”.

For the classification between N and KC, the areas under the ROC curve [AROC] for those indices have been computed, giving very good values (1 is perfect classification ability).

The following table shows the percentage of correctly classified eyes in the three groups for the proposed indices $P_1$, $P_2$ and $GLPI$ and the well-known index KPI

<table>
<thead>
<tr>
<th>Index</th>
<th>N</th>
<th>KC</th>
<th>KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$</td>
<td>100%</td>
<td>100%</td>
<td>21%</td>
</tr>
<tr>
<td>$P_2$</td>
<td>100%</td>
<td>100%</td>
<td>25%</td>
</tr>
<tr>
<td>$P_3$</td>
<td>87%</td>
<td>90%</td>
<td>79%</td>
</tr>
<tr>
<td>$AR(4)$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLPI</td>
<td></td>
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</tbody>
</table>

The index GLPI is a perfect classifier between KC and N eyes, and yielded results comparable to the KPI when discriminating between the normal and subclinical KC eyes. Furthermore, a combination of GLPI with $P_1$ allows achieving an excellent capability of detection of irregular corneas, considering as irregular both the keratoconic and the preclinical keratoconic ones.

Conclusion

Direct analysis of the digitized images of the Placido mires projected on the cornea is a valid and effective tool for detection of corneal irregularities. The new indices performed well applied to the keratoconus suspect eyes, with the advantage of simplicity of calculation combined with high sensitivity in corneal irregularity detection. Thus, they can be used as supplementary criteria for diagnosing and grading keratoconus that can be added to the current keratometric classifications.

References