A New Method to Describe Cone Shape in Keratoconic Corneas

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1. Purpose

To introduce and validate a novel method to describe the cone features in keratoconic corneas.

2. Methods

Corneal anterior and posterior surfaces were described using a spherical coordinate system to generate a new spherical height map to allow the detection of the cone apex, Figure 1. Cone boundaries were objectively estimated using second derivatives of spherical height in an iterative process. Corneal topography exams of 309 keratoconic patients with different disease severities were evaluated with the new automated method as its first validation. In addition, 12 cornea specialists blindly evaluated the tangential and elevation maps relative to the best-fit sphere of 6 patients. Their estimations were cross-checked and compared with the results of the new automated method in order to evaluate the subjective variability and provide a second validation of the method.

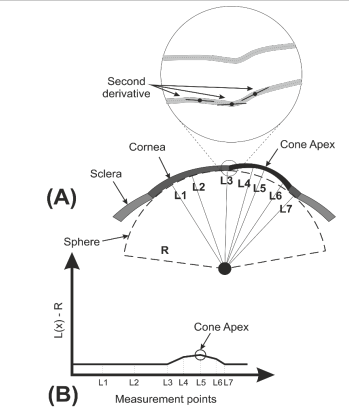

Figure 1 (A) Spherical height map and detection of cone boundaries. (B) Determination of cone apex.

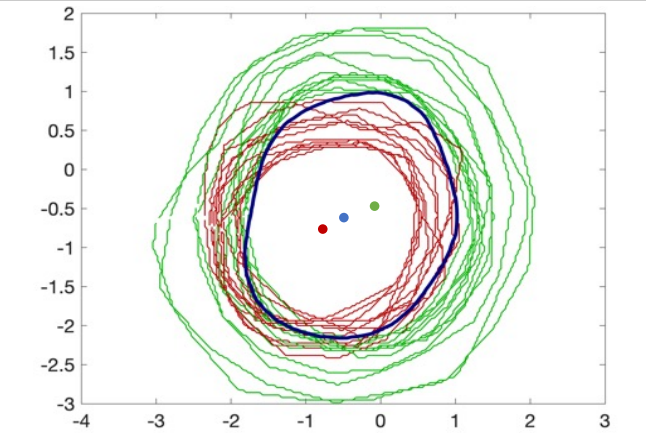

Figure 3 Case example of the cone apex and shape estimations by 12 corneal specialist in tangential map (green), relative elevation map (red) and the automated method (blue)

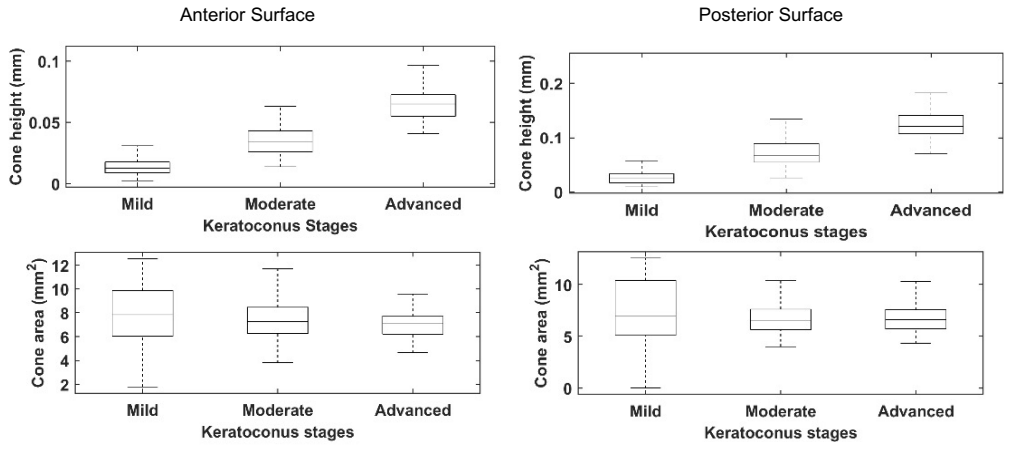

Figure 2. Relations between cone height and cone area with disease severity in both corneal surfaces.

3. Results

The main cone features in the anterior and posterior surfaces were evaluated in the large clinical dataset. There was strong correlation between the cone height and the disease severity in both surfaces ($R=0.71$, $p<0.01$), while the disease stage did not show significant correlation with cone area in any of the surfaces ($R=0.01$, $p=0.77$). The height of the posterior cone was, on average, larger than the corresponding anterior cone height by 37 ± 24 µm (0–158). In relation to the experts' assessment, there was high inter-subject variability, up to 55%, among experts' estimations of the cone area and low intra-subject agreement in cone apex location using different maps ($p<0.05$). However, there was no statistically significant difference between the automated estimation and the specialists' estimations in both maps ($p>0.05$). The cone boundaries estimated by the automated method were within the range of the specialists' estimations in all cases, Figure 3.

4. Conclusion

An objective automated method able to determine the cone's 3D features was developed and validated in a large clinical dataset and against corneal specialists' estimations. The method's results were in agreement with disease severity and independent of the subject variability observed among different experts. The objective method provided a reliable and unique evaluation of keratoconus features that is independent of maps' type or color-scale.

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