The Cone Location and Magnitude Index (CLMI)

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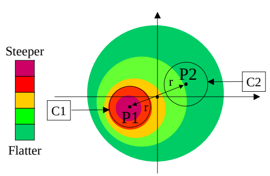
Purpose

Keratoconus is a non-inflammatory ectasia of the cornea of unknown etiology, characterized by progressive thinning and cone formation. These changes lead to acquired irregular myopic astigmatism. Due to its progressive nature, refractive surgery is not recommended to correct decreased vision associated with the disease. Therefore, it is important to accurately screen candidates when considering a refractive laser procedure. Because of the unpredictable nature of its clinical course, tracking progression is also vital. Presently, slit lamp biomicroscopy, retinoscopy, keratometry and corneal topography are all used for detection. While all of these examinations are useful in diagnosing Keratoconus, accurately detecting early signs are problematic. Currently, there are a number of topographic indices available but they only indicate whether or not a keratoconic pattern is detected and not the relative size or location of the cone on the cornea. The purpose of this project is to develop an index that can detect the presence or absence of keratoconic patterns in corneal topography maps and determine the location and magnitude of the cone.

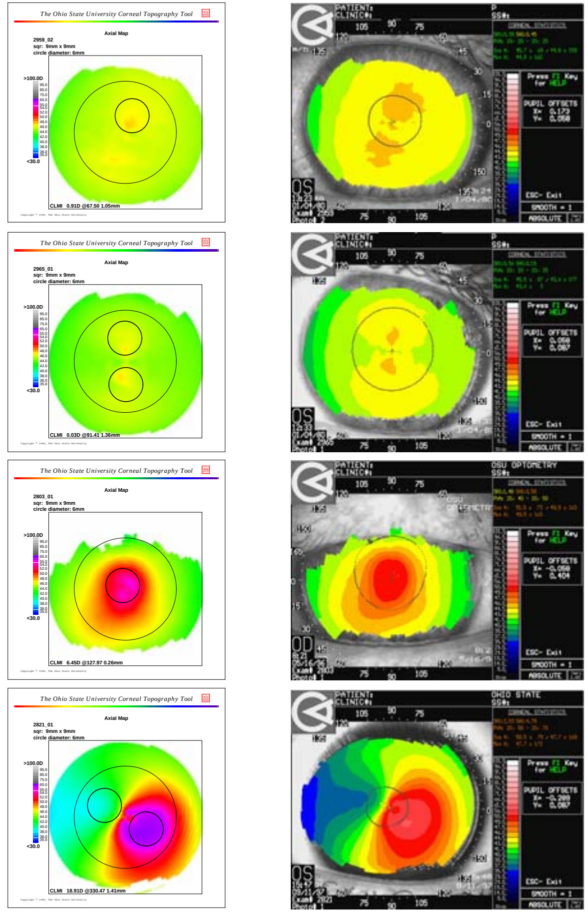
Methods

A software routine was written to extend the capabilities of The Ohio State University Corneal Topography Tool (OSUCTT)[2], which is a software tool for processing topographic data from any topographic machine. The routine finds the area-corrected average[3] steepest 2mm diameter circle (C1) present on the axial map, with the center P1(r,Θ) of the circle being within the central 6mm (see the figure below) of the the map. Then, the area-corrected average of all points outside of C1 is subtracted from the area-corrected average of all points inside of C1, resulting in magnitude M1. Next, the 2mm diameter circle (C2) centered at P2(r, Θ+180°) is analyzed. The area-corrected average of all points outside of C2 is subtracted from the area-corrected average of all points inside of C2, resulting in magnitude M2. If P1 is outside of the central 2.5mm of the map then CLMI = M1–M2, otherwise CLMI = M1. In simple terms, find the steepest area on the map. Then, compare that area to the rest of the map and determine whether or not the steepest area represents a cone. The radial and angular position and the magnitude of the cone are reported.

Depiction of CLMI – Axial Map



C1: 2mm diameter circle encompassing the steepest region on the map
P1: center of circle C1
r: radial distance of P1 from the center of the map
P2: the point 180° from P1
C2: 2mm diameter circle centered at P2



For the figures above, the images on the left are the output display from the OSUCTT with CLMI indicated. The images on the right are the corresponding output from the TMS-1. The top most pair of images shows a mild astigmatic cornea. Only the steepest area, C1, is analyzed because its center is within the 1.25mm threshold. The next pair down shows another astigmatic map but the center of the steepest area is outside of the 1.25mm threshold. Therefore, two areas, C1 and C2, are analyzed to calculate CLMI. The last two sets of images show keratoconic corneas with the cone located centrally and peripherally, respectively.

Methods (continued)

For validation, 2 scans from 30 eyes of 15 normal subjects and 4 scans from 21 eyes of 14 subjects with clinically diagnosed Keratoconus were obtained on a TMS-1. The Keratoconus Prediction Index (KPI)[3] was recorded for each map from the TMS-1. All maps that could not be processed by the TMS-1 were excluded. In addition, 2 maps were excluded due to an error by the TMS-1 which reported -35% and -50% as the value for KPI for a diagnosed keratoconic. The range for KPI is from 0% to 100% . Data generated by the TMS-1 were exported and processed through the OSUCTT to generate CLMI.

Results

A sensitivity/specificity analysis was performed on the data comparing KPI (30% threshold for disease[3]) and CLMI to the presence or absence of Keratoconus. KPI had 100% specificity and 86.54% sensitivity, while CLMI produced a complete separation of data, 100% sensitivity and specificity. The maximum CLMI for normals was 2.67D while the minimum CLMI for keratoconics was 4.40D. Normals had a mean and standard deviation CLMI of 1.16D ±0.69D and KPI of 0.93 ±4.09. Diagnosed keratoconics had a mean and standard deviation CLMI of 10.22D ±4.14D and KPI of 74.29 ±31.43.

Conclusions

CLMI provides a robust index that can detect the presence or absence of a keratoconic pattern in corneal topography maps. In addition, CLMI finds the location and magnitude of the cone present in corneal topographic maps in patients with Keratoconus. Currently, this algorithm is being applied to axial data. However, CLMI is amenable to any topographic map type.

References

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Acknowledgements

The authors would like to acknowledge the Ohio Lions Eye Research Foundation (OLERF) for their support. They would also like to thank Vladimir Marukhlenko for his design input.