Quantitative 3D Geometry of the Aging Eyelid
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INTRODUCTION
While facial aging is a well known phenomenon, it has not been quantitatively characterized. Current methods for measuring and assessing eyelid dimensions, which rely almost exclusively on two-dimensional imaging techniques, are limited. Current three-dimensional (3D) imaging allows for quantitative and rigorous analysis of eyelid shape, and how it may change over time.

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OBJECTIVE
This study introduces a novel technique for capturing perilibral structures using 3D imaging and point cloud data collection. Analyses are performed to assess changes in normal eyelids with age.

METHODS
Under IRB approval forty-six white, female subjects were included and divided into three age groups: 20 to 39 years (16 subjects), 40 to 59 years (15 subjects), and 60 years and older (15 subjects). Patients were scanned with the Canfield\textsuperscript{R} 3D photogrammetry imaging system, and the resulting data files were exported to the 3D point cloud processing software CloudCompare\textsuperscript{R}. Points were manually selected to define five key features for each patient’s right and left eye: the medial canthus (MC), lateral canthus (LC), inferior margin midpoint (IM), superior margin midpoint (SM), and superior crease midpoint (SC). Superior creases were also delineated, as seen in Figure 1.

The manually selected points provided the basis for a fitted model, as shown in Figure 2. These points also define the feature space for characterizing the effect of age on eyelid geometry through principal component analysis (PCA). In this analysis, the projection of the principal axis onto each of the original dimensions indicates the sensitivity of a given property with respect to the observed principal measurement.

RESULTS
A comparison of contours across age groups suggests the youngest and oldest eyes demonstrate the most visually notable differences, as seen in Figure 3.

The plot of Figure 4 indicates that subjects in the 60+ group (green) tend to have positive PCA values, while the 20-30 group (blue) tends to have negative values. The 40-50 group (red) values are roughly evenly spread between the two domains.

These analyses performed across the age groups suggests the width and height of the palpebral fissure decreases, with the width decreasing more rapidly. The superior lid crease height diminishes with age, and the crease impingement on the superior margin. The depth of the lateral canthus relative to the medial canthus decreases with age.

CONCLUSIONS
This technique enables rigorous and reliable evaluation of the eyelid shape, and how it may change over time. This series suggests age-induced changes to eyelid margin, crease, and lateral canthus positions, which have been noted anecdotally, but poorly quantified until now.

REFERENCES

Figure 1. A typical set of manually selected points. In this example the superior crease is being delineated.

Figure 2. Views of the 3D eye model contours. a) The manually selected key features are: the medial canthus (MC), lateral canthus (LC), inferior margin midpoint (IM), superior margin midpoint (SM) and superior crease midpoint (SC). The superior crease (cyan), superior margin (red), and inferior margin (yellow) contours are defined by 3D polynomial curves. b) A sagittal view of the contours.

Figure 3. Composite overlays of the 3D contours. Results for the youngest age group (20-30 years) are in the top panel, and those for the oldest age group (60+ years) are in the bottom panel. The composites consist of the superior crease (cyan), superior margin (red), and inferior margin (yellow). The medial canthus is registered to the 3D origin (0, 0, 0).

Figure 4. The value of the principal component analysis (PCA) measure for each subject, by age category. The 60+ group (green) tends to have positive PCA values, while the 20-30 group (blue) tends to have negative values. The 40-50 group (red) values are roughly evenly spread between the two domains.