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A quantitative analysis of periorbital aging with three-dimensional surface imaging[☆]

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Summary *Background:* Studies of facial aging up to the present have largely been observational and subjective. This study applies state-of-the-art facial imaging and three-dimensional computer modelling to measure changes in the aging female face. The markers of facial aging discussed here go beyond descriptive accounts by individual practitioners and are presented as quantitative measurements of the volume change in the aging periorbital region.

Methods: Three-dimensional image data sets were acquired of 42 mother–daughter matched pairs (83 individuals). Overall similarity of the faces of the mother–daughter pair were confirmed using best fit analyses prior to further processing of the data. The changes in facial structure secondary to aging were measured using volumetric comparisons of periorbital tissues in the daughter and mother. The age range of the individuals imaged range from 15 to 91 years.

Results: A consistent pattern of volume difference and regression of soft tissues associated with the medial canthus nasojugal groove was demonstrated in the aged individual of each pair. The volume difference associated with the tear trough ranged from 0.02 cc to 1.27 cc with median values of 0.38 cc and 0.42 cc. Volume differences in the adjacent periorbital tissues are also measured.

Conclusions: Imaging clearly shows a consistent pattern of atrophy and regression of soft tissues associated with the medial canthus and nasojugal groove. Histogram depth analysis of the soft tissue shows greatest atrophy in the medial canthal region and soft tissues caudal to the lower lid. Volumetric analysis of the atrophy of these tissues is a useful adjunct in the accurate rejuvenation of the periorbital region.

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Over the past 20 years there has been an increasing appreciation of the three-dimensional changes that occur in the aging face. Considerable focus has been directed onto the aging of the periorbital region with the increasing popularity of new modalities for facial rejuvenation. Characteristics frequently observed and studied are the development of nasojugal groove deformity, infraorbital festoons, increasing eyelid skin laxity, and deepened appearance of the orbital hollows.¹ Multiple authors now incorporate an element of volume restoration as a component of facial rejuvenation.^{2–5} Subtle changes in skin colour and consistency, subcutaneous fat atrophy, and changes in the underlying bony substructures are responsible for the appearance of the aged individual, although the relative importance of each of these is still incompletely understood.

Studies of the face have historically relied on two-dimensional standard photography, and the surgeon's clinical gestalt. In recent years three-dimensional evaluations of the face have been performed with MRI, as well as by cephalometric studies of the skulls of individuals of different ages.^{6,7} Recent studies have more clearly elucidated the landmarks of age, including the nasojugal groove. This 2 or 3 cm depression extending from the medial canthal region inferolaterally has several names; Duke-Elder and Wybar named it the nasojugal groove,^{8,9} Flowers termed it the tear trough,¹⁰ and others have described it as the lid-cheek junction. This region of depression often extends superiorly from the medial canthal region, becoming confluent with atrophic infraorbital tissues superior to the globe. Although descent of the cheek in relation to the lower eyelid has been described,¹⁰ dissection studies demonstrate that the tear trough and lid-cheek junction extend below the orbital rim, and are fixed to relatively immobile substructures that preclude significant ptosis.¹¹ This correlates well with Lambros' observations that there is no significant movement of facial landmarks with age, and that the phenomenon of descent is illusory.³ The tear trough and lid-cheek junction overlie the junction of the palpebral and orbital portions of the orbicularis oculi muscle and the cephalic border of the malar fat pad. Along the tear trough, the orbicularis muscle is attached directly to the bone. Along the lid-cheek junction, the attachment is ligamentous by means of the orbicularis retaining ligament. Descent of the soft tissue of the infraorbital tissues with age is unlikely due to the close association of these structures to the underlying bone.¹¹ Treatments for correction of the nasojugal groove include injection of fillers, redraping, alloplastic implants, release of periorbital muscles, transposition of orbital fat, and fat grafting.¹² Although there is no contention that there are changes in facial volumes that are reflected in the tear trough, the exact amount of change has yet to be quantified.

There has been no longitudinal study of the aging face using modern imaging techniques. In the absence of this ideal, we have developed a model comparing mothers and daughters who share striking facial similarities (Figure 1). Taking advantage of the conventional wisdom that girls grow to look like their mothers, three-dimensional imaging data sets were acquired, and the computer-generated models of the subject's faces were analysed for



Figure 1 A representative of mother–daughter pair with similar facial morphology.

reproducible patterns of change related to age. Information generated in this study gives the first quantitative measure of volume loss in the soft tissues medial to and inferior to the globe, and may improve pre-operative planning for volume restoration.⁴

Subjects and methods

Subjects

The data was acquired in a prospective fashion in accordance with a protocol approved by the Institutional review board. The subjects are unpaid volunteers, none of whom had undergone any facial rejuvenation within the previous 12 months. Participants including mothers (aged from 32 to 91, average 56.6) and corresponding daughters (aged from 15 to 62, average 27.8) from Loma Linda, California were enrolled in this study as 42 sets of mother–daughter matched controls. In total, there were 33 Caucasian, three Filipino, two Chinese, two Korean, one Hawaiian, and one Vietnamese mother–daughter pairs enrolled in this study. A three-dimensional image of each participant's face in repose was captured with 12 lenses at various angles and sent to the 3dMD software desktop for data processing. Two-dimensional photos of the mother taken at the time of the daughter's current age were used to verify and confirm the similarity of the mother to the daughter at the same age (Figure 2). The individuals imaged were all in good health, with no underlying chronic medical conditions. All subjects have their native dentition. A history of facial rejuvenation in the mothers did not exclude them from the study, as it was felt that no current aesthetic technique fully reverses the signs of age in the face. Three of the mothers had undergone facial rejuvenation with Obagi, and out of these three, two had undergone rhytidectomy.

Imaging system

The 3dMD digital camera system and the accompanying patient software (3Q Corporation) are comprised of twelve cameras arranged in a circumferential array centred on the patient to be imaged. The cameras fire simultaneously,

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