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Original Article

Age-Related Changes of the Orbit and Midcheek and the Implications for Facial Rejuvenation

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Abstract.
Background: Aging of the midface is complex and poorly understood. Changes occur not only in the facial soft tissues, but also in the underlying bony structure. Computed tomography (CT) imaging was used for investigating characteristics of the bony orbit and the anterior wall of the maxilla in patients of different ages and genders.
Methods: Facial CT scans were performed for 62 patients ranging in age from 21 to 70 years, who were divided into three age groups: 21–30 years, 41–50 years, and 61–70 years. Patients also were grouped by gender. The lengths of the orbital roof and floor and the angle of the anterior wall of the maxilla were recorded on parasagittal images through the midline of the orbit for each patient.
Results: The lengths of the orbital roof and floor at their midpoints showed no significant differences between the age groups. When grouped by gender, the lengths were found to be statistically longer for males than for females. The angle between the anterior maxillary wall and the orbital floor was found to have a statistically significant decrease with advancing age among both sexes.
Conclusion: Bony changes occur in the skeleton of the midcheek with advancing age for both males and females.
3 The anterior maxillary wall retrudes in relation to the bony orbit, which maintains a fixed anteroposterior dimension at its midpoint. These changes should be considered in addressing the aging midface.

Key words: Bony change—Facial remodeling—Maxilla—Maxillary angle—Midface aging—Orbit

Facial aging is a complex and incompletely under- 4
stood process. In the past, most authors focused on changes in the facial soft tissues and skin to explain the process of facial aging. However, it has been shown that changes in the bony facial skeleton also contribute significantly to the alterations in facial appearance that occur with increasing age. As first proposed by Enlow [2], these bony changes occur differently in different parts of the face [1,3,6–10,14].

The inferior orbital rim and the anterior maxilla serve as a key foundation for the soft tissues of the inferior orbit and midface. Changes in these structures individually and in their relationship with each other significantly affect the overlying tissues and, ultimately, facial appearance.

Previous work by Pessa et al. [8] has suggested that the orbital rim and the anterior maxilla both retrude with advancing age. Consequences include increased surgical risk during surgery on the lower lids and the inferior orbit in the presence of a so-called negative vector relationship [5]. It also implies that correction of the underlying bony changes would include augmentation of both the anterior maxilla and the inferior orbital rim [13].

This study investigated aging changes in the bony orbit and midface. We investigated the hypothesis that the previously described retrusion of the orbital rim and maxilla is attributable to shortening of the orbital floor. To demonstrate this, a study was designed to compare the length of the orbital floor with the length
of the orbital roof at different ages. The same images 5
would be used to measure the changes in the angles of the midface skeleton relative to the orbital floor.

Materials and Methods

The spiral computed tomography (CT) scans of 62 patients undergoing radiographic investigations for

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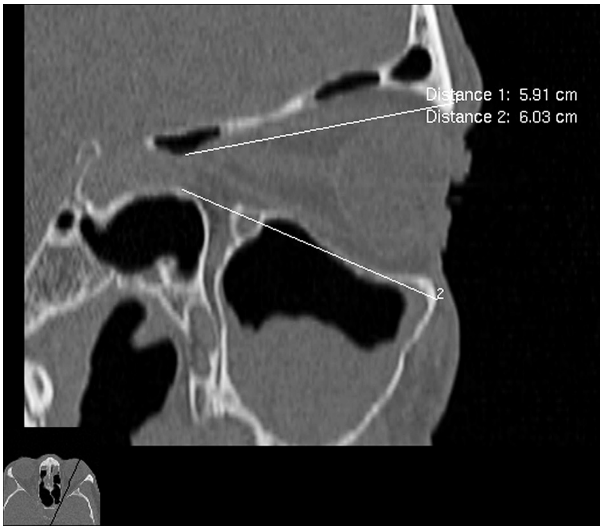

Fig. 1. Measurements of the superior and inferior orbital lengths.

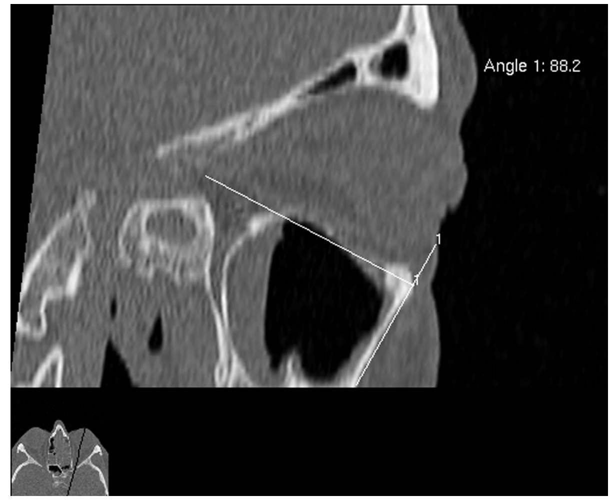

Fig. 2. Measurement of the angle between the orbital floor and the anterior wall of the maxilla.

unrelated reasons (e.g., sinus evaluations, negative studies) were reviewed. The scans were negative for pathology, and no patient had a history of facial malformation, trauma, or prior surgery. Parasagittal images through the midaxis of each right orbit in the plane of the optic nerve were reconstructed from existing data.

The patients were divided into three age groups: 21–30 years (21 patients), 41–50 years (20 patients), and 61–70 years (21 patients). The patients also were grouped by gender (31 males and 31 females).

The length of the orbital roof (superior orbit) was measured as the distance from the orbital apex to the most anterior projection of the superior orbital rim. The length of the orbital floor (inferior orbit) was measured as the distance from the orbital apex to the most anterior projection of the inferior orbital rim (Fig. 1). The angle formed between the line of the orbital floor and a line drawn parallel to the anterior wall of the maxilla, the "maxillary angle," was recorded (Fig. 2). The data were compiled, and a univariate regression analysis of association was performed for the different data sets.

Results

There was no statistically significant difference between the age groups in either the length of the orbital roof ($p = 0.2$) or the length of the orbital floor ($p = 0.3$). However, statistical significance was present in the analysis of association between patient gender and both the length of the orbital roof and the length of the orbital floor. The length of the orbital roof was, on the average, 3.1 mm longer for males than for females ($p = 0.004$), and the length of the orbital floor was 2.4 mm longer for males than for females ($p = 0.03$) (Tables 1–3).

Univariate regression analysis of association between the maxillary angle and age was found to be statistically significant between the different age groups. The mean angle decreased 3.5° from the youngest group to the middle-age group ($p = 0.002$), and 6° from the youngest group to the oldest group ($p < 0.001$). No statistically significant difference 6
between males and females was found for this angle ($p = 0.79$) (Table 4).

Univariate regression analysis showed a significant difference in the mean angle between the youngest male cohort and the middle-age and oldest male cohorts ($p = 0.01$ and $p < 0.001$, respectively). A similar trend was observed for females, although it reached statistical significance only between the youngest and oldest groups ($p = 0.10$ and $p = 0.004$, respectively). The difference in the angle change (youngest to oldest) between males and fe- 7
males, although considerable (7.6% for males and 4.4% for females), was not statistically significant (Table 5).

Discussion

Previous work has described a relative retrusion of the bony maxilla and the lateral aspect of the piriform aperture [6]. The hypothesis has been put forth that bony changes occur in the skull that are differentially additive and resorptive and can be described as a relative clockwise rotation of the facial bony features around a central point [8].

The results of this study confirmed that retrusion of the midface does occur, as compared with the upper third of the facial skeleton. However, our results also show that the lengths of the superior and inferior orbits remain constant with increasing age. This indicates that the significant changes in the bony skeleton occur below the inferior orbital rim, whose

Table 1. Summary statistics by each group and gender

	Male (mean ± SD)	Female (mean ± SD)	Male and female combined (mean ± SD)	
Superior orbit (cm)				9
21–30 years	5.45 ± 0.44	5.17 ± 0.44	5.32 ± 0.45	
41–50 years	5.41 ± 0.31	4.90 ± 0.38	5.16 ± 0.43	
61–70 years	5.48 ± 0.47	5.32 ± 0.34	5.40 ± 0.40	
All ages combined	5.45 ± 0.40	5.14 ± 0.41	5.29 ± 0.43	
Inferior orbit (cm)				
21–30 years	5.37 ± 0.46	5.21 ± 0.55	5.30 ± 0.50	
41–50 years	5.36 ± 0.43	4.96 ± 0.27	5.16 ± 0.41	
61–70 years	5.46 ± 0.48	5.30 ± 0.32	5.37 ± 0.40	
All ages combined	5.40 ± 0.44	5.16 ± 0.41	5.28 ± 0.44	
Angle (°)				
21–30 years	90.9 ± 3.6	89.7 ± 2.6	90.3 ± 3.1	
41–50 years	86.4 ± 4.3	87.3 ± 3.8	86.8 ± 4.0	
61–70 years	83.3 ± 3.8	85.3 ± 3.0	84.4 ± 3.4	
All ages combined	87.0 ± 4.9	87.3 ± 3.6	87.2 ± 4.3	

SD, standard deviation

Table 2. Univariate regression analysis of association between superior orbit and age/gender

Predictor	Difference in mean superior orbit length	95% CI interval for the difference in means	*p* Value
Age			
21–30 years (reference)	0	—	—
41–50 years	−0.16	−0.43 to 0.11	0.24
61–70 years	0.08	−0.19 to 0.34	0.55
Gender			
Female (reference)	0	—	—
Male	0.31	0.10 to 0.52	0.004

CI, confidence interval

Table 3. Univariate regression analysis of association between inferior orbit and age/gender

Predictor	Difference in mean inferior orbit length	95% CI for the difference in means	*p* Value
Age			
21–30 years (reference)	0	—	—
41–50 years	−0.14	−0.41 to 0.14	0.33
61–70 years	0.08	−0.19 to 0.35	0.57
Gender			
Female (reference)	0	—	—
Male	0.24	0.02 to 0.45	0.03

CI, confidence interval

Table 4. Univariate regression analysis of association between angle and age/gender

Predictor	Difference in mean maxillary angle	95% CI for the difference in means	*p* Value
Age			
21–30 years (reference)	0	—	—
41–50 years	−3.49	−5.70 to −1.29	0.002
61–70 years	−5.99	−8.17 to −3.81	<0.001
Gender			
Female (reference)	0	—	—
Male	−0.29	−2.48 to 1.90	0.79

CI, confidence interval

anterior projection at the midpoint of the inferior orbital rim remains unchanged.

The absence of change in the anteroposterior dimension of the orbit confirms the work by Bartlett et al. [1], whose detailed study of the age-related changes in the craniofacial skeleton showed little to no overall age-related changes in the fixed bony skeleton in the anteroposterior direction.

However, the findings of this study do not support the suggestion that a posterior displacement of the inferior orbital rim occurs, as postulated by Pessa et al. [8]. This discrepancy may be attributable to the fact that the authors measured the inferior orbital rim in relation to the anterior projection of the cornea and inferior orbital fat and did not directly measure the length of the inferior orbit itself.

Our study does confirm that suborbital maxillary retrusion occurs with aging, as shown by the decrease in the angle formed between the maxilla and orbital floor, as previously predicted by Enlow [2], described by Pessa et al. [8,9], and recently confirmed by Shaw and Khan [11]. This study is more precise because it

Table 5. Univariate regression analysis of association between angle and age for males and females

	Male		Female	
Predictor	Difference in mean angle (95% CI)	p Value	Difference in mean angle (95% CI)	p Value
Age				
21–30 years (reference)	0	—	0	—
41–50 years	−4.52 (−8.00, − 1.04)	0.01	−2.41 (−5.31, 0.49)	0.10
61–70 years	−7.61 (−11.1, −4.13)	< 0.001	−4.40 (−7.23, −1.56)	0.004
Difference between change in angle (youngest to oldest) between males and females	3.21	0.30		

CI, confidence interval

uses measurements taken at the midaxial orbital rim for standardization based on axial CT scan rather than three-dimensional reformatted images. This relative posterior displacement of the anterior maxillary wall may contribute significantly to the descent of the soft tissues of the lower orbit and cheek with advancing age. The posteriorly displaced bone would provide less support for the overlying soft tissues, further accentuating the appearance of soft tissue atrophy and aging in the midface. Like Pessa et al.
8 [8,9], we found that males tended to have greater changes in the maxillary angle with age than females, although the difference did not reach statistical significance in our group.

Atrophy of the upper alveolus and loss of dentition have been described also as causing significant changes in the appearance of the midface. Aging changes are accentuated by a loss of alveolar bone stock and a decreased number of viable teeth [12]. The subjects of this study did not have significantly more tooth loss in the older groups than in the younger groups. Therefore, the skeletal changes found in our data were present even in the absence of tooth loss among the older patients.

The results of this study suggest that augmentation of the bony framework over the anterior maxillary wall should be included in the correction of this aspect of midfacial aging. Augmentation of the inferior orbital rim strictly to address skeletal aging changes does not appear to be necessary, although such augmentation may be required for other reasons for individual patients [13].

A limitation of this study is that the measurement for the length of the orbital floor and the angle of the midcheek skeleton were taken at only one point, in the line of the midaxis of the orbit. Two bones contribute to the inferior orbital rim and the anterior face of the midcheek skeleton, and these bones vary in their contribution to the different parts. The maxilla forms the medial third of the midcheek and orbital rim. The body of the zygoma forms the lateral third of the midcheek and orbital rim. The middle third of the orbital rim proper is formed by the zygoma, specifically by the maxillary (also called the orbital) process of the zygoma. This is the most forward-projecting part of the inferior orbital rim. This part was shown not to change with aging in this study.

Immediately inferior to the more projecting orbital process of the zygoma, the midcheek skeleton is formed by the maxilla. This is the part of the skeleton clearly shown to undergo retrusion by this and other studies. It would not be completely unexpected to find that the resorptive characteristics of the maxilla are not isolated to this one part of the bone, but extend to the medial orbital rim component. The maxilla has a completely different origin from the other bones of the orbital rim. The maxilla is a bone of dental origin and originally was not involved in the formation of the orbital rim. Only higher in the evolution of the vertebrate facial skeleton does the maxilla extend between the zygoma and the lacrimal bone into the orbit, and then to a progressive degree [4].

The results of this project, based on the midaxial orbital rim, are definitive and significant. Further study is now required to complete our understanding of the inferior orbital rim by comparing the aging changes in the medial and lateral ends of the rim.

Conclusions

Age-related changes do occur in the facial bony skeleton. These skeletal changes are not uniform, and different portions of the facial skeleton change differently with age. The length of the midpoint of the bony orbit remains constant with increasing age. Males have slightly longer orbits than females, probably because of the overall larger average size bone structure of males. The angle between the orbital floor and the anterior maxillary wall decreases with increasing patient age. These results indicate that with aging, the infraorbital midfacial skeleton retrudes or decreases in prominence relative to the middle of the bony orbit, which retains its constant anteroposterior dimensions.

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paring the aging changes in the orbital floor with those in the orbital roof.

References

1. Bartlett SP, Grossman RG, Whitaker LA: Age-related changes of the craniofacial skeletal: An Anthropomorphic and histologic analysis. *Plast Reconstr Surg* **90:**592, 1992
2. Enlow DH: *The human face* Harper and Row, New York, 1968
3. Flowers RS: Tear trough implants for correction of tear trough deformity. *Clin Plast Surg* **20:**403, 1993
4. Gregory WK: *Our face from fish to man* Putnam, New York, 1929
5. Jelks GW, Jelks EB: Preoperative evaluation of the blepharoplasty patient: Bypassing the pitfalls. *Clin Plast Surg* **20:**213, 1993
6. Pessa JE: An algorithm of facial aging: Verification of Lambros's theory by three-dimensional stereolithography, with reference to the pathogenesis of midfacial aging, scleral show, and the lateral suborbital trough deformity. *Plast Reconstr Surg* **106:**479–488discussion 489–490, 2000
7. Pessa JE, Chen Y: Curve analysis of the aging orbital aperture. *Plast Reconstr Surg* **109:**751–755discussion 756–760, 2002
8. Pessa JE, Desvigne LD, Lambros VS, Nimerick J, Sugunan B, Zadoo VP: Changes in ocular globe-to-orbital rim position with age: Implications for aesthetic blepharoplasty of the lower eyelids. *Aesth Plast Surg* **23:**337–342, 1999
9. Pessa JE, Zadoo VP, Mutimer KL, Haffner C, Yuan C, DeWitt AL, Garza JR: Relative maxillary retrusion as a natural consequence of aging: Combining skeletal and soft tissue changes into an integrated model of midfacial aging. *Plast Reconstr Surg* **102:**205–212, 1998
10. Pessa JE, Zadoo VP, Yuan C, Ayedelotte JD, Cuellar FJ, Cochran CS, Mutimer KL, Garza JR: Concertina effect and facial aging: Nonlinear aspects of youthfulness and skeletal remodeling, and why, perhaps, infants have jowls. *Plast Reconstr Surg* **103:**635–644, 1999
11. Shaw RB, Kahn DM: Aging of the midface bony elements: A three-dimensional CT study. *Plast Reconstr Surg* **116**(Suppl)**:**12–14, 2005
12. Sutton DN, Lewis BRK, Patel M, Cawood JI: Changes in facial form relative to progressive atrophy of the edentulous patients. *Int J Oral Maxillofac Surg* **33:**676–682, 2004
13. Yaremchuk MJ: Infraorbital rim augmentation. *Plast Reconstr Surg* **107:**1585, 2001
14. Zadoo VP, Pessa JE: Biological arches and changes to the curvilinear form of the aging maxilla. *Plast Reconstr Surg* **106:**460–466, discussion 467–468, 2000

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