

BACKGROUND

Aging of the face and neck is driven by changes in the underlying skeletal structures and the soft tissue envelope [1]. Much emphasis has been placed on bony resorption as a contributor to facial aging [1, 2]. But does the bony facial skeleton resorb significantly with aging? This study employs advanced 3D analysis to comprehensively assess age-related bony changes in the midface and the mandible.

OBJECTIVES

- To comprehensively analyze age-related bony changes in the midface and mandible using 3D statistical shape modeling (SSM) and average predicted models [3].
- To visualize gender- and population-specific facial bone remodeling patterns across different age groups.

Validation Study

To assess the accuracy and reliability of the SSM in capturing age-related skeletal changes, a longitudinal study was conducted. A total of 27 patients with at least two CT scans taken 10 years apart were analyzed retrospectively.

METHODS

This retrospective study was approved by our institutional review board (IRB: 18-009730). Facial CT scans from 2011 to 2023 were extracted from our database, including individuals above 5 feet 5 inches of white ethnicity (non-Hispanic or Latino) to ensure dataset uniformity. Edentulous individuals or any suspected abnormalities were excluded. The final sample included 564 individuals: 280 White subjects and 284 Black subjects. They were divided into three age groups—young (20–39 years), middle-aged (40–59 years), and older adults (60–79 years)—as detailed in **Table 1**.

TABLE 1

Characteristics	Young group 20-39 yrs		Middle group 40-59 yrs		Old group 60-79 yrs	
Gender	F (n=98)	M (n=105)	F (n=93)	M (n=67)	F (n=84)	M (n=117)
Mean Age, yr & SD	31.8 (±4.8)	30.8 (±5)	50.2 (±5.3)	51.2 (±6.4)	66.5 (±6.2)	68.3 (±5.94)
Mean BMI, kg/m ² & SD	30.5 (±9.8)	30.3 (±6.7)	30.2 (±7)	29.7 (±6.4)	29.2 (±5.9)	30.5 (±7)

Each age group (20-39, 40-59, and 60-79 years) was represented by an averaged predicted SSM model (**Figure 1**), which was utilized for pairwise heatmap comparisons to illustrate age-related bone remodeling patterns.

FIGURE 1

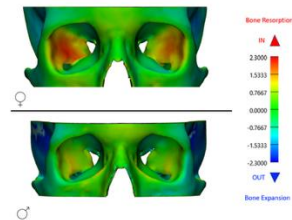
Gender-Specific 3D Statistical Shape Models for Each Age Group



- The anthropometric measurements detailed in **Table 2** demonstrate significant gender-specific and age-related variations in key craniofacial dimensions, with notable changes in angular, linear, and width measurements across the midface and mandible, confirming progressive skeletal remodeling over time.
- The heatmap analyses (**Figures 2, 3, and 4**) visually illustrate these age-related skeletal changes. Key areas of bone resorption and expansion are highlighted in red and blue, respectively.
- Both populations showed significant age-related increase in the distances between orbital foramen, with Black/African females displaying the largest increase (9 mm, $p < 0.001$).
- Pyramidal and maxillary angles contracted in both groups ($p < 0.005$), while mandibular angles increased ($p = 0.00$).
- Heatmaps volume analyses confirmed lateral orbital walls resorption and slight midface profile flattening.

FIGURE 2

Midface Heatmap Analyses



RESULTS

TABLE 2

White Population			
Measurement	Female Δ Diff (mm)	Male Δ Diff (mm)	P
Midface			
Nasofrontal Angle	6.2°	7.1°	< 0.01
Glabellar Angle	4.5°	5.2°	< 0.01
Pyramidal Angle	4.2°	4.2°	< 0.01
Maxilla Width	1.7	1.7	< 0.04
Superior Orbital Foramen Inter-distance	4.6	6	< 0.01
Midfacial Width	8.5	4.3	< 0.01
Midfacial Height	3.1	2.1	< 0.01
Mandible			
Mandibular Ramus Height	5.3	4.2	< 0.01
Inter Condylar Width	4.4	6.5	< 0.01
Bigonial Width	4.3	7.3	< 0.01
Mandibular Angle	3.9°	0.8	< 0.01
Alveolar Angle	2.2°	5.7°	< 0.01
Black Population			
Measurement	Female Δ Diff (mm)	Male Δ Diff (mm)	P
Midface			
Nasofrontal Angle	6.3°	3.1°	< 0.01
Glabellar Angle	0.5°	6.9	< 0.01
Pyramidal Angle	4.5°	7.1°	< 0.01
Maxilla Width	1.8	3.8	> 0.05
Superior Orbital Foramen Inter-distance	9.8	2.3	< 0.01
Midfacial Width	2.6	0.2	> 0.05
Midfacial Height	1.5	6.6	> 0.05
Mandible			
Mandibular Ramus Height	5.1	1.5	< 0.01
Inter Condylar Width	3.3	0.5	> 0.05
Bigonial Width	0.7	2.5	< 0.01
Mandibular Angle	3.5°	1°	< 0.01
Alveolar Angle	1.5°	8.4°	< 0.01

- Bigonial widths expanded by 5-7 mm with age in the White population ($p < 0.001$) but remained stable in the Black population.
- Mandibular rami heights decreased by 4-5 mm in males and females ($p = 0.00$), respectively.
- Female SSMs exhibited greater bone resorption than their male counterparts in both populations, highlighting distinct gender-aging differences. Additionally, This study suggests a potentially more stable lower facial skeleton with aging in the Black cohort.
- Lastly, a 10-year longitudinal analysis of 27 patients (54 scans) validated the reliability of SSM in capturing age-related craniofacial changes.

FIGURE 3

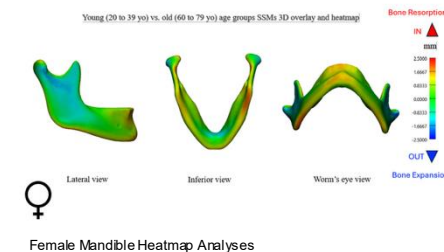
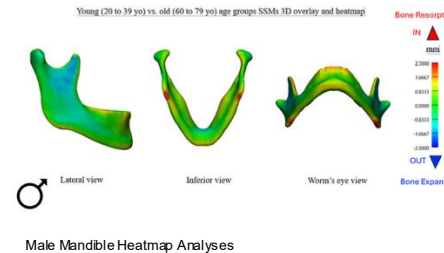


FIGURE 4



DISCUSSION

- While earlier research attributed facial flattening changes to exaggerated bone resorption [1,2], our study shows that such changes may result from a combination of resorption and structural remodeling.
- Our validation using anthropometric analysis [3], and the longitudinal sample confirmed the accuracy of SSM in detecting subtle bony changes over time.
- This understanding advocates targeted interventions that align with the underlying facial bony aging [4], moving beyond exaggerated volumetric filling techniques that may contribute to unnatural or overfilled appearances.

CONCLUSIONS

- Both women and men exhibit significant age-related changes in midfacial and mandibular structures that occur independently of tooth loss. However, the nature and magnitude of these changes differ between genders, which carries important implications for gender-specific aesthetic and reconstructive approaches.
- The overall modest skeletal changes, approximately 5 mm, suggest that soft tissue changes play a more prominent role in facial aging.

ACKNOWLEDGEMENTS

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