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Aging and Sexual Differences of the Human Skull

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Background: The aging process of the face comprises all layers: skin, subcutaneous fat, muscles, and skeleton, and the signs of aging depend mainly on which layer is mostly affected.
Objective: To evaluate the aging facial skeleton, as well as establish the sexual differences, areas with a strong predisposition to resorption, and aesthetic repercussion for better treatment approach.
Methods: Skulls from the Forensic Anthropology Department of the Institute of Forensic Medicine of Belo Horizonte, Brazil, were classified according to gender and age group (i.e., <20 years, 20–50 years, >50 years). Structural changes were classified according to gender and age group.
Results: Of the 241 skulls included, 192 were male skulls and 49 female. Sexual dimorphism and age-related peculiarities are described herein.
Conclusions: The knowledge of the anatomy of the aging face, taking into consideration all the layers (skin, fat pads, muscles, and bones), as a whole, for the treatment of folds and shadows is vital for a better and more natural final aesthetic outcome. (Plast Reconstr Surg Glob Open 2017;5:e1297; doi: 10.1097/GOX.0000000000001297; Published online 27 April 2017.)

Despite being more remarkable at adult age, the aging process begins since birth, and continues throughout the whole life, due to genetic and external factors, such as UV exposure and smoking. The face, in most cultures, is one of the most exposed areas of our bodies, so that the aging process is not only earlier, but more easily recognizable. The aging process comprises all layers of the face: skin, subcutaneous fat, muscles, and skeleton, and the signs of aging depend mainly on which layer is mostly affected. Aging may affect the skin in terms of quantity (skin sagging) and/or quality (changes in skin hydration, appearance of spots and wrinkles). There is a reduction of the collagen content of the skin, not only due to decrease in synthesis, as a process of intrinsic aging, but also due to extrinsic factors, such as UV radiation, which may generate reactive oxygen species (ROS), leading to an increment in collagen breakdown by upregulating enzymes called matrix metalloproteinases.[1] The decrease of collagen content may also affect deeper layers of the face. The loss of the subcutaneous facial fat compartments with age leads to the appearance of increased skin laxity or prominent folds around the nasolabial region, periorbital region, and jowl.[2] The muscles may present hypo- or hypertonicity (i.e., glabella, masseter) depending upon the use and area of the face. The bone is a dynamic, sensitive, ever-changing tissue. Bone growth takes place from birth until the hormonal stimulus ceases, with long bone epiphysis consolidation usually around 15–18 years of age. On the other hand, bone remodeling continues throughout life, determined not by intrinsic factors, but mainly by regional changes in the soft tissues related to each bone, such as muscles, tongue, lips, skin, brain, among others.[3,4] Bone remodeling serves to adjust bone architecture to meet changing mechanical needs, repair microdamages, and guarantee calcium homeostasis.[5] Therefore, it is transitory and does not involve the totality of the bone. The process of bone remodeling involves the removal of mineralized bone by osteoclasts and the formation of bone matrix through the osteoblasts. Both processes of bone remodeling occur throughout life, although the balance between them changes according to the period of life. Bone formation is more prominent in childhood; the processes

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Fig. 1. Anthropometric lines: OM, orbital medial (red line); MM, maxillary medial (green line). The MM/OM ratio depicts the increase in orbit and pyriform aperture size, due to maxillary resorption during aging.

are balanced in adults, although bone resorption is more prominent in the elderly. Among the theories of bone remodeling, the Functional Theory correlates bone remodeling to response to demand. When the bone is submitted to traction by a hypertrophic muscle or subcutaneous fat distension, a local demand is generated and bone is produced in that area. On the other hand, continuous pressure on the bone (e.g., silicon chin prosthesis) or intense muscle, ligament or skin laxity, may lead to bone resorption.[3,4] The objective of this study is to evaluate the aging facial skeleton, and establish the sexual differences, areas with a strong predisposition to resorption and aesthetic repercussion for a better treatment approach.

METHODS

The study was approved by the national research ethic committee (number CAAE: 55561816.5.0000.5119).

Between 2010 and 2015, skulls from the Forensic Anthropology Department of the Institute of Forensic Medicine of Belo Horizonte, Brazil, were evaluated and only intact skulls, with available clinical data, were included in the study. The skulls were further classified according to gender and age group (i.e., <20 years, 20–50 years, >50 years). Structural changes were then evaluated according to gender and age group.

Measurement of the distance from the superior orbital rim to the inferior orbital rim (OM) (Fig. 1)[6] and from the inferior orbital rim to the lateral inferior portion of the pyriform aperture was performed (MM). The MM/OM ratio was calculated.

RESULTS

Overall, 241 skulls were included, being 192 male and 49 female (Fig. 2). The distribution among age groups and gender is described in Table 1.

Sexual Dimorphism

Among women, the forehead is straighter (Fig. 2, Table 2), the glabella is more curved and less pronounced, and the supraorbital rim is less noticeable than in men.

The midface in women presents more subtle angles, whereas the midface in men presents more pronounced zygomatic bones (Fig. 3). In men the mandible is larger, stronger, and more faceted and has more clear-cut angles

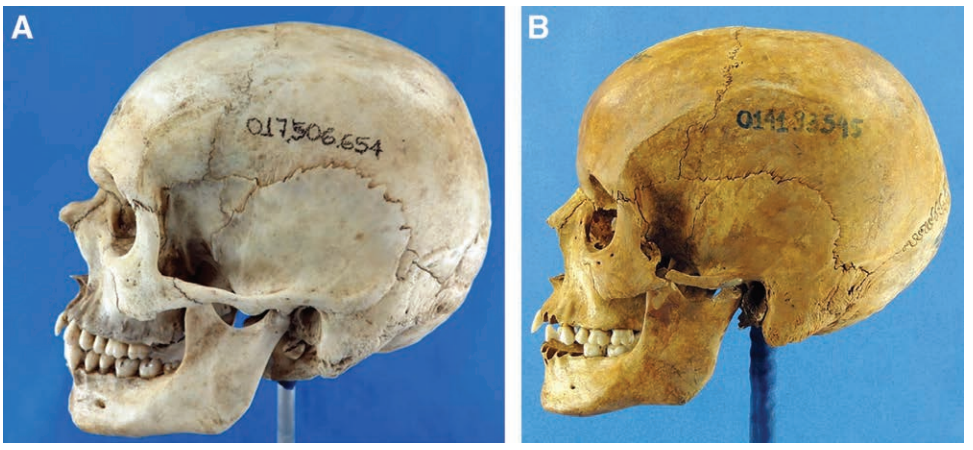

Fig. 2. Male (A) and female (B) skulls, from the same age group. In men the forehead is oblique, the glabella and frontonasal suture are more pronounced, and the supraorbital rim is prominent. In women, on the other hand, the forehead is straight, the glabella is delicate, and the supraorbital rim is subtle or even absent.

Table 1. Distribution of Skulls According to Gender and Age Group

Age Group	Male	Female
<20 y	23	08
20–50 y	120	28
>50 y	49	13
Total	192	49

than in women. Also, the chin is larger, giving men a square-shaped face, whereas women tend to have a triangular or heart-shaped face.

Aging Skull

The pyriform aperture becomes larger with aging, experiencing remodeling of lateral and inferior walls, whereas the upper and olfactory cavities remain intact, so that the nasal cavity presents a lateral and anterior expansion and the palatus is reallocated inferiorly. The maximum nasal aperture (the length of the base of the pyriform aperture) increases with age (Fig. 4).

With the process of aging, the floor of the orbit expands inferiorly and laterally, losing the round shape observed in younger skulls (Fig. 4). The lacrimal bone works as a pivot: its inferior portion rotates laterally, leading to an inferior slide of the maxilla. The maxilla is more anterior and more prominent in younger skulls, whereas in older skulls an anterior and inferior bone resorption takes place, giving the appearance of a retrusion of the face (Fig. 5). The zygoma presents an anterior resorption (Fig. 6), whereas the zygomatic arch suffers a posterior and anterior remodeling, increasing the temporal fossa. The MM/OM ratio increases from <20 years to 20–50 years and decreases in >50 years group (Table 3).

The mandible undergoes a posterior and superior bone formation, although it suffers an anterior and inferior resorption (Fig. 5). Without the presence of teeth, the mandible experiences further atrophy. The angle of the mandible increases with age (97 degrees in younger skulls to 135 degrees in older skulls), mainly due to resorption of the inferior border of the angle, next to body–ramus junction (Fig. 7). Also, the chin becomes more anterior, oblique, and shorter with age (Fig. 7).

Not all the bones in the skull suffer resorption. Although the midface recedes, the forehead suffers contin-

Table 2. Sexual Dimorphism Among Skulls

Area	Female	Male
Forehead	More straight	More oblique
Glabella	Curved and subtle	Frontal-nasal suture is more prominent
Supraorbital rim	Less conspicuous	More striking
Midface	Subtle angles	Irregular surface and little anterior projection
Zygoma	More prominent and curvilinear	Less prominent
Mandible	Lighter, with subtle angles	Larger, stronger, with clear-cut angles
Chin	Smaller and rounded shape	Larger and square-shaped

Fig. 3. Midface and mandible. In men, the midface presents more clear-cut angles, irregular surface, and little anterior projection, and the mandible is larger and more angled and has a square shape, whereas in women both the midface and mandible are more subtle, discrete, and rounded in shape.

Fig. 4. Orbit and piriform aperture. The rounded orbit shape initially increases its size, while maintaining the shape. Later the latero-inferior border presents a more pronounced resorption. The maximum measurement of piriform aperture increases with aging, being prominent in skulls >50 years.

Fig. 5. Maxilla and mandible. There is an increase in maxillary resorption with aging, which is associated with decrease in skin fat and collagen contents and leads to midface soft-tissue descent. Also, with increasing age, the mandible loses its vertical projection and is more fragile.

uous expansion, due to bone deposition in the external wall of the frontal bone, especially in the supraorbital rim (Fig. 8).

DISCUSSION

The sexual dimorphism among human skulls is a well-established subject in anthropology. These differences have aided in the distinction of male and female skulls (Fig. 2). Nevertheless, it is the array (Table 2), and not single characteristic that allows gender determination of skulls.[7,8]

The correct knowledge of gender differences of the human skull is vital in the aesthetic approach to aging, because exaggerated filling of particular areas may render a masculine appearance to women, for example. A prominent supraorbital region is characteristic of men (Fig. 2), so that filling these areas in women must be careful and subtle, only to restore the retro-orbicular fat loss. On the other hand, when treating the aging midface, it is imperative to remember that a more curvilinear prominent cheekbone is peculiar to women, whereas men present a more angled face, due to strong muscle insertions.

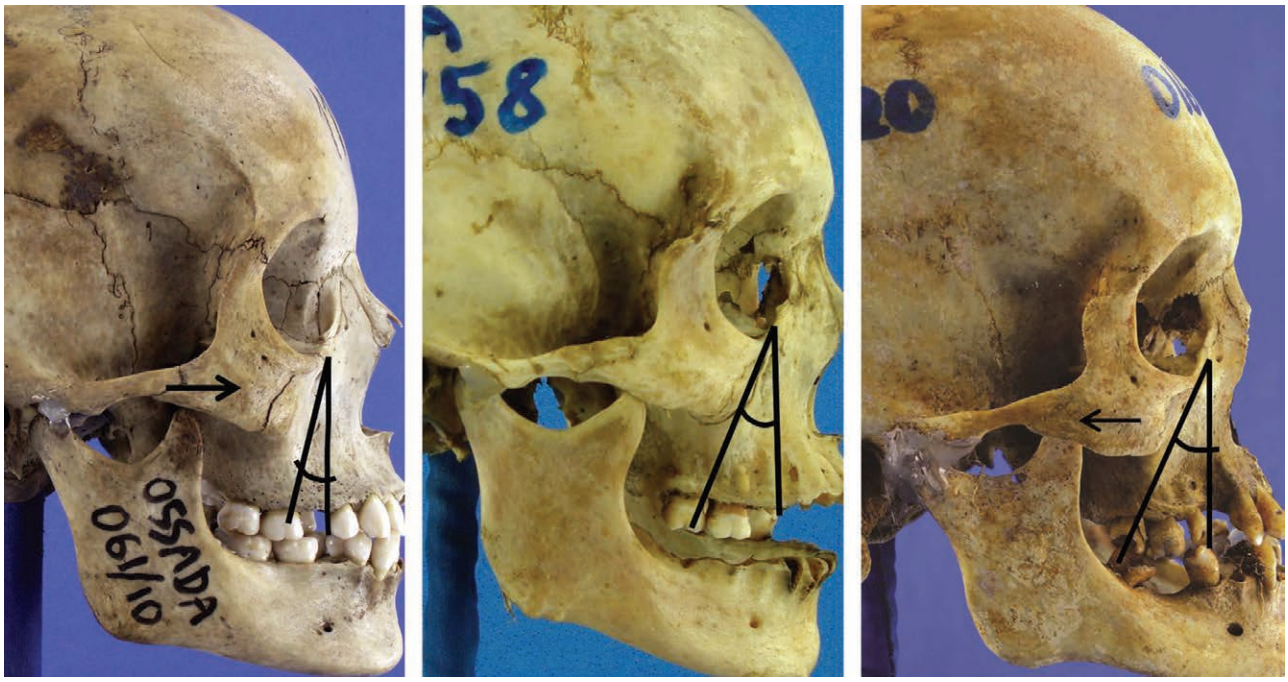

Fig. 6. Zygoma. Considering the skull in anatomic position, the zygoma becomes more retropositioned with aging, with an increasing angle between an imaginary vertical line and the anterior border of the zygoma.

Table 3. MM/OM Ratio

Age Group	Male (n = 192)	Female (n = 49)
<20 y	0.75	0.78
20–50 y	0.77	0.77
>50 y	0.68	0.71

N = 241.

Furthermore, deep knowledge of the anatomy of the aging face allows a better approach to the underlying cause of the fold, rendering better and more natural results than just simply filling up the fold. The maxillary retrusion, associated with the decrease in collagen content of the skin and loss of fat compartments, works as a true slide for soft-tissue descent (Figs. 5, 6).[9] Because the zygoma works as a support of the soft tissue of the midface, restoring the volume of the zygomatic prominence would not only improve the local area, giving a youthful and more natural appearance, but would also improve[10,11] and minimize the need to treat the nasolabial fold itself. The changes in MM/OM ratio observed in this study reflect the increase in orbit and pyriform aperture size, at the expense of the maxillary bone in the process of aging, corroborating the findings of previous authors.[6,12,13] High G prime hyaluronic acid or poly-L-lactic acid injections deep in the supraperiosteal area and in the pyriform fossa help soften the lengthening of the nose, drooping of the nose tip, and enlargement of the nostrils.

The orbit does not age homogeneously. The superior-medial and inferior-lateral aspects of the orbit have the greatest tendency to resorb, which is associated with soft-tissue laxity that occurs with aging, leading to an increased prominence of the medial fat pad and length-

Fig. 7. Mandible angle and chin. At younger age, the angle is acute (in males 97 degrees), becoming more obtuse with increasing age (135 degrees), and the chin, with bone remodeling, becomes more oblique and shorter, with increased anterior projection.

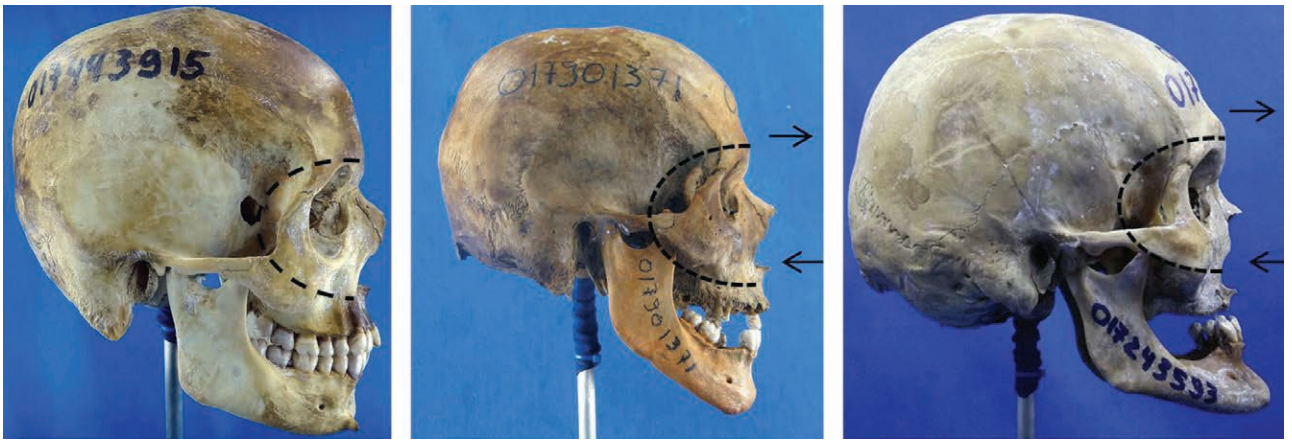

Fig. 8. Craniofacial bone remodeling. While the midface recedes, the forehead suffers continuous expansion, due to bone deposition in the external wall of the frontal bone, especially in the supraorbital rim.

ening of the lid–cheek junction, giving the patient a sad appearance.[13–16]

The facial remodeling depends entirely on growth, development, and overlying soft-tissue function. All bone volume or size changes throughout life occur in response to functional demand of the face.[17,18] Indeed, loss of teeth, due to infection, trauma, or aging, increases local bone resorption and is listed among the major bone factors that impact aesthetic outcome.[19,20] The decrease in mandible volume and shortening of the chin, due to decrease in bone support, lead to further soft-tissue excess and sagging (Fig. 7).[21,22]

CONCLUSIONS

The clinical approach to the aging face has changed in the past years.[2] The knowledge of the anatomy of the aging face, taking into consideration all the layers (skin, fat pads, muscles and bones), as a whole, for the treatment of folds and shadows, is vital for a better and more natural final aesthetic outcome.

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REFERENCES

1. Helfrich YR, Sachs DL, Voorhees JJ. Overview of skin aging and photoaging. *Dermatol Nurs.* 2008;20:177–183; quiz 184.
2. Farkas JP, Pessa JE, Hubbard B, et al. The science and theory behind facial aging. *Plast Reconstr Surg Glob Open* 2013;1:e8–e15.
3. Enlow DH. *The Human Face.* New York: Harper and Row; 1968.
4. Enlow DH, Hans MG. *Noções Básicas de Crescimento Facial.* 1st ed. São Paulo: Santos;1998.
5. Rucci N. Molecular biology of bone remodelling. *Clin Cases Miner Bone Metab.* 2008;5:49–56.
6. Pessa JE, Zadoo VP, Yuan C, et al. Concertina effect and facial aging: nonlinear aspects of youthfulness and skeletal remodeling, and why, perhaps, infants have jowls. *Plast Reconstr Surg.* 1999;103:635–644.
7. Rosas A, Bastir M, Martínez-Maza C, et al. Sexual dimorphism in the Atapuerca-SH hominids: the evidence from the mandibles. *J Hum Evol.* 2002;42:451–474.
8. Bartlett SP, Grossman R, Whitaker LA. Age-related changes of the craniofacial skeleton: an anthropometric and histologic analysis. *Plast Reconstr Surg.* 1992;90:592–600.
9. Pessa JE, Zadoo VP, Mutimer KL, et al. 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.* 1998;102:205–212.
10. Shaw RB Jr, Kahn DM. Aging of the midface bony elements: a three-dimensional computed tomographic study. *Plast Reconstr Surg.* 2007;119:675–681; discussion 682.
11. Gosain AK, Amarante MT, Hyde JS, et al. A dynamic analysis of changes in the nasolabial fold using magnetic resonance imaging: implications for facial rejuvenation and facial animation surgery. *Plast Reconstr Surg.* 1996;98:622–636.
12. Fitzgerald R, Vleggaar D. Facial volume restoration of the aging face with poly-l-lactic acid. *Dermatol Ther.* 2011;24:2–27.
13. Mendelson B, Wong CH. Changes in the facial skeleton with aging: implications and clinical applications in facial rejuvenation. *Aesthetic Plast Surg.* 2012;36:753–760.
14. Mendelson BC, Hartley W, Scott M, et al. Age-related changes of the orbit and midcheek and the implications for facial rejuvenation. *Aesthetic Plast Surg.* 2007;31:419–423.
15. Lambros, V. Observations on periorbital and midface aging. *Plastic Reconstr Surg.* 2007;120:1367–1376; discussion 1377.
16. McCord CD, Boswell CB, Hester TR. Lateral canthal anchoring. *Plast Reconstr Surg.* 2003;112:222–237; discussion 238.
17. 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.* 2000;106:479–488; discussion 489.
18. Pessa JE, Desvigne LD, Lambros VS, et al. Changes in ocular globe-to-orbital rim position with age: implications for aesthetic blepharoplasty of the lower eyelids. *Aesthetic Plast Surg.* 1999;23:337–342.
19. Sutton DN, Lewis BR, Patel M, et al. Changes in facial form relative to progressive atrophy of the edentulous jaws. *Int J Oral Maxillofac Surg.* 2004;33:676–682.
20. Wong CH, Mendelson B. Newer understanding of specific anatomic targets in the aging face as applied to injectables: aging changes in the craniofacial skeleton and facial ligaments. *Plast Reconstr Surg.* 2015;136(5 Suppl):44S–48S.
21. Coleman SR, Grover R. The anatomy of the aging face: volume loss and changes in 3-dimensional topography. *Aesthet Surg J.* 2006;26(1S):S4–S9.
22. Pessa JE, Slice DE, Hanz KR, et al. Aging and the shape of the mandible. *Plast Reconstr Surg.* 2008;121:196–200.