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Dentition, Bone Loss, and the Aging of the Mandible

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Abstract

Background: Facial aging is a dynamic process with impact on both the soft tissues and the bones. Despite a growing body of evidence, controversy still exists regarding absolute characteristics of the aging facial skeleton.

Objective: The purpose of this study was to investigate various mandibular measurements in different age groups and to delineate the relation of the dentition to these parameters.

Methods: Ninety Caucasian mandibles were assessed for the following distance landmarks: gonion-gonion, infradentale-gnathion, mental foramen–mandibular crest, mental foramen–inferior mandibular border, gnathion-gonion, condyle-gonion, and gonial angle. The measurements were compared according to age, sex, and dentition.

Results: The number of teeth decreased significantly with increasing age in males ($P = .002$) and females ($P < .001$). There were no other statistically significant differences between age groups for the rest of the parameters. The infradentale-gnathion distance ($P = .005$) and the mental foramen–mandibular crest distance ($P < .001$) was found to increase with total number of teeth. Other parameters did not show a significant relation to dentition. All parameters were significantly larger in the male subgroups with the exception of gnathion-gonion distance and gonial angle. Bilateral mandibular measurements were symmetric except for the gonial angle, which was more obtuse on the right side in males ($P = .007$) and females ($P = .018$).

Conclusions: Our findings support previous evidence that dentition is the main determinant of the morphology of the mandible. The skeletal characteristics are variable among individuals, and a longitudinal study is required to better understand age-related changes of the mandible.

Keywords

mandible, aging, age, bone, facial skeleton, dentition, morphology, facial surgery

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Mandibular contour in large part determines the shape and attractiveness of the lower face.[1-7] While the aging of soft tissue is affected predominantly by descent and perceived atrophy, aging of facial hard tissue results predominantly from bony resorption. The aging of both bone and soft tissue is affected to a variable degree by muscular function, environmental factors, and genetics.[8,9] In addition, bony changes are heavily dependent on tooth retention.[10-22] Together with soft tissue descent and atrophy, bony changes have a decided effect on facial shape, height, and the overall aging process.

Soft tissue changes in the aging face have been studied in significantly greater detail than hard tissue. Furthermore, some of the findings regarding bony changes are contradictory.[2,13,17,18,23-34] The purpose of this study is to investigate how aging affects various mandibular morphometric measurements, to relate our findings to inconsistencies in the existing literature, and to delineate the relation of dentition to these parameters.

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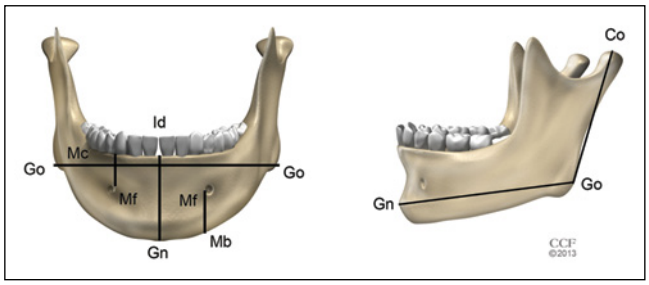


Figure 1. Measured anthropometric landmarks. Co, condyle; Co-Go-Gn, gonial angle; Gn, gnathion; Go, gonion; Id, infradentale; Mc, mandibular crest; Mf, mental foramen; Mb, mandibular border. Reprinted with permission from the Cleveland Clinic Center for Medical Art & Photography © 2013. All rights reserved.

METHODS

Ninety Caucasian mandibles of North American descent were used for morphometric analysis. The specimens were obtained from the preserved skull collection of Cleveland Natural History Museum, Cleveland, Ohio. Mandibles were divided into 3 age groups. Group 1 (young age) consisted of skulls of people between 20 and 40 years old, group II (middle age) between 41 and 64 years old, and group III (old age) older than 65 years. Those with obvious fractures or completely edentulous mandibles were excluded from analysis.

Linear measurements were done using MicroScribe (Revware Systems, Raleigh, North Carolina) portable measurement system. MicroScribe has an articulated arm unit with a stylus tip that employs digital tracking technology. A series of optical encoders inside each of the MicroScribe joints work with electronics in the base to calculate the position of the stylus tip in 3-dimensional space. These data are then submitted to a host computer and exported as numerical output. The shortest distance between 2 points in space can be calculated with accuracy of up to 0.009 inches. A protractor was used for measuring angles.

The measurements were based on standard anthropometric landmarks, as follows: gonion to gonion (mandibular width), infradentale to gnathion (mandibular height in midline), mental foramen to mandibular crest, mental foramen to inferior mandibular border, gnathion to gonion (corpus length), condyle to gonion (ramus length), and gonial angle. A diagram of the measured landmarks and gonial angle is shown in Figure 1. Status of dentition was recorded for each mandible, including number and presence of teeth in the midline and along the mental foramen.

Analysis of data was done by pairwise comparison of measurements among 3 age groups using a repeated-measures generalized linear model test and among males and females using similar methods. For pairwise differences in 3 group comparisons, significance was $P < .0167$ based on Bonferroni correction for 3 possible pairs. For 2 group comparisons, significance was set at $P < .05$. Symmetry between left and right across all age groups was analyzed using correlation analyses, as was the relation of number of teeth with mandibular parameters. Bilateral parameters were pooled to yield a single mean for each skull.

RESULTS

The study population consisted of 15 male and 15 female specimens in each age group (ages 20-40, 41-64, and older than 65 years; total n = 90). Mean ages of the male specimens were 30.87, 53.73, and 69.20 years in young, middle, and old age groups, respectively. Mean ages of the female specimens were 33.13, 49.07, and 72.27 years in young, middle, and old age groups respectively.

Craniometric Analysis in Young, Middle, and Old Age Groups

Males and females were analyzed separately in each of the 3 age groups. There was progressive tooth loss with age for both males ($P = .002$) and females ($P < .001$). There were no statistically significant differences in any of the other comparisons. The results of analysis across 3 age groups, divided by sex, are summarized in Table 1.

Analysis of Mandibular Parameters and Teeth Relations

The effect of dentition on mandibular measurements was analyzed across all age and sex groups combined (Table 2). The infradentale to gnathion distance (mandibular height in midline) increased with total number of mandibular teeth ($P = .005$) (Figure 2). This distance also had a tendency to increase with presence of teeth in the midline but did not reach statistical significance ($P = .075$). The mental foramen to mandibular crest distance increased with both total number of mandibular teeth ($P < .001$) (Figure 3) and presence of teeth at the foramen level (left, $P < .001$; right, $P = .001$). The rest of the distances—including mental foramen to lower mandibular border, gnathion to gonion (corpus length), condyle to gonion (ramus length), and gonial angle—did not show any relation to number of teeth ($P > .05$) (Table 2).

Craniometric Analysis in Males vs Females

The distances described above were compared between male and female specimens, across all age groups. All parameters were significantly larger in the male subgroups, with exception of gnathion-gonion distance (corpus length) and gonial angle. The mean corpus length was longer in males and mean gonial angle was more obtuse in females; however, these values did not reach statistical significance. The mean number of mandibular teeth was

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Table 1. Analysis of Mandibular Parameters Across 3 Age Groups

	Age Group, y, LS Mean (95% CI)				
Characteristic	20-40	41-64	65+	*P* Value	Pairwise Differences[a]
Males					
Bigonial distance	87.29 (83.9-90.7)	90.67 (87.3-94.1)	92.48 (89.1-95.9)	.100	
Anterior height (Id – Gn)	24.85 (22.6-27.1)	27.26 (25.0-29.5)	24.81 (22.6-27.1)	.22	
Mf – Mc	12.78 (11.1-14.4)	13.07 (11.4-14.7)	11.96 (10.3-13.6)	.62	
Mf – Mb	11.77 (10.9-12.7)	12.12 (11.2-13.0)	12.16 (11.3-13.1)	.80	
Corpus length (Gn – Go)	71.42 (67.9-75.0)	75.08 (71.5-78.6)	75.45 (71.9-79.0)	.21	
Ramus height (Co – Go)	62.30 (59.2-65.4)	60.97 (57.8-64.1)	63.60 (60.5-66.7)	.49	
Gonial angle	115.47 (111.2-119.7)	116.30 (112.1-120.5)	115.27 (111.0-119.5)	.93	
Number of teeth	13.27 (11.4-15.1)	11.60 (9.7-13.5)	8.33 (6.5-10.2)	**.002**	1 vs 3, 2 vs 3
Females					
Bigonial distance	80.98 (77.6-84.4)	81.77 (78.4-85.1)	82.00 (78.6-85.4)	.90	
Anterior height (Id – Gn)	23.28 (21.7-24.9)	24.96 (23.4-26.6)	22.23 (20.6-23.8)	.060	
Mf – Mc	10.89 (9.5-12.3)	10.35 (9.0-11.7)	9.30 (7.9-10.7)	.25	
Mf – Mb	10.58 (9.7-11.4)	11.63 (10.8-12.5)	10.91 (10.1-11.8)	.21	
Corpus length (Gn – Go)	70.95 (67.7-74.2)	72.81 (69.6-76.1)	71.02 (67.8-74.3)	.65	
Ramus height (Co – Go)	54.80 (52.1-57.5)	57.23 (54.6-59.9)	57.13 (54.5-59.8)	.35	
Gonial angle	117.67 (113.5-121.8)	118.17 (114.0-122.3)	116.67 (112.5-120.8)	.87	
Number of teeth	12.40 (11.0-13.8)	8.07 (6.6-9.5)	3.80 (2.4-5.2)	**<.001**	1 vs 2, 1 vs 3, 2 vs 3

The bilateral parameters have been pooled to yield a single mean value. CI, confidence interval; Co, condyle; Gn, gnation; Go, gonion; Id, infradentale; LS, least squares; Mb, mandibular border; Mc, mandibular crest; Mf, mental foramen. Bold *P* values indicate statistical significance.
[a]Pairwise differences are significant at $P < .0167$, based on Bonferroni correction for 3 possible pairs.

11.07 in males and 8.09 in females, which was also significantly different overall ($P = .001$). The difference between absolute values of measurements was largest for bigonial distance and ramus length. Table 3 demonstrates the differences between male and female mandibles.

Analysis of Symmetry of the Mandible

All bilateral mandibular measurements, with the exception of the gonial angle, were symmetric for left and right sides. The gonial angle was more obtuse on the right side in males ($P = .007$) and females ($P = .018$) (data not shown because of lack of statistical significance).

DISCUSSION

Facial growth processes have been studied in great detail.[8,9] The current understanding of these mechanisms has in large part been fueled by both longitudinal growth studies and by experimental surgical modifications in animal models.[2,24,29,30,33,35,36] Significantly less information is currently available with regard to the effect of facial aging on the bony skeleton.[2,23,31,32,37,38] We suggest that the physiologic processes of bony deposition and resorption described in detail and so important in facial bone growth and development also have a decided effect on facial aging.[8-11,22,39,40]

The stigmata of the aging face consist of soft tissue descent and an apparent loss of soft-tissue volume, as well as loss of support of the bony foundation.[3,5,7,31] Controversy still exists regarding the process and characteristics of the aging skeleton and its implications on overall facial aging.[2,13,17,18,23-34] This includes changes in bigonial distance, mandibular ramus height, alveolar height, and mandibular body length. The differences in the various studies on the topic may be attributed to a number of factors, including differing age ranges of patients studied, variations in methodology (radiography vs direct skull measurements), different sampling methods, and differences

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Table 2. Relationship of Mandibular Parameters With Number and Presence of Teeth Across All Age and Sex Groups

		n	ρ (95% CI)	*P* Value
Anterior height (Id – Gn)	Number of teeth	90	0.30 (0.09 to 0.50)	**.005**
Mf – Mc	Number of teeth	90	0.56 (0.38 to 0.73)	**<.001**
Mf – Mb	Number of teeth	90	0.07 (–0.14 to 0.28)	.53
Corpus length (Gn – Go)	Number of teeth	90	–0.05 (–0.26 to 0.16)	.63
Ramus height (Co – Go)	Number of teeth	90	0.18 (–0.03 to 0.39)	.096
Gonial Angle	Number of teeth	90	–0.19 (–0.40 to 0.02)	.069
Anterior height (Id – Gn)	Presence of tooth	90	0.19 (–0.02 to 0.40)	.075
Mf – Mc (left)	Presence of tooth	90	0.41 (0.22 to 0.60)	**<.001**
Mf – Mc (right)	Presence of tooth	90	0.34 (0.14 to 0.54)	**.001**
Mf – Mb (left)	Presence of tooth	90	–0.15 (–0.36 to 0.06)	.16
Mf – Mb (right)	Presence of tooth	90	0.16 (–0.05 to 0.37)	.13

A positive value means that there is a positive relationship and a negative value means there is an inverse relationship. CI, confidence interval; Co, condyle; Gn, gnation; Go, gonion; Id, infradentale; Mb, mandibular border; Mc, mandibular crest; Mf, mental foramen. Bold *P* values indicate statistical significance.

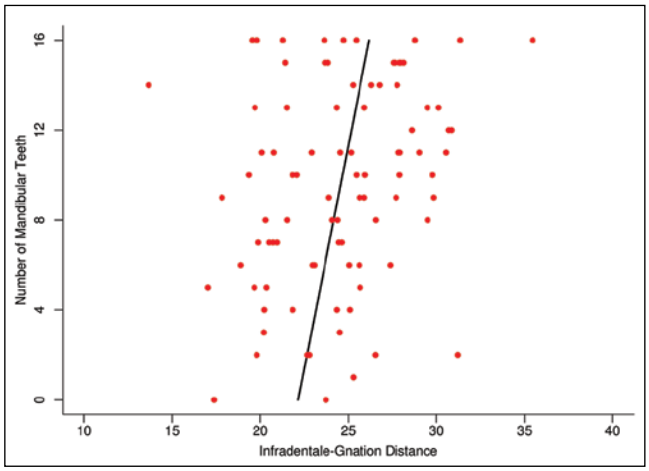


Figure 2. Direct relationship of infradentale-gnathion distance with total number of mandibular teeth (based on the analysis in Table 2).

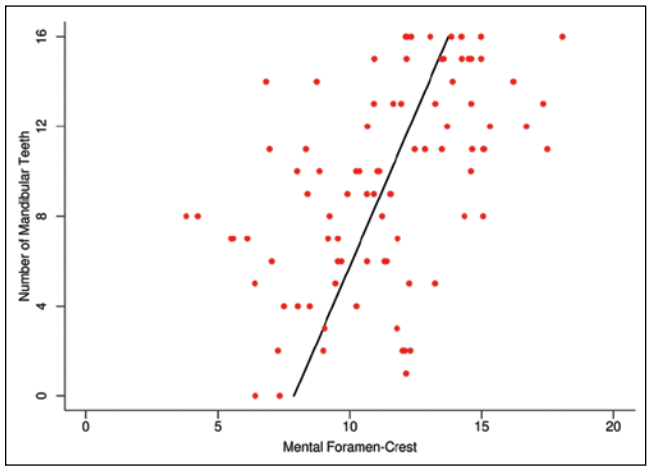


Figure 3. Direct relationship of mental foramen–mandibular crest distance with total number of mandibular teeth (based on the analysis in Table 2).

in each study population's ethnic backgrounds. Particularly lacking are longitudinal studies of adult bony facial changes. This is not surprising, since these are inherently difficult to conduct. Longitudinal cephalometric analysis in the aging face remains an area to be fully investigated.

It is known that, with aging, the face becomes more square.[41] By measuring bigonial width, we sought to determine if the width of the mandible changed with aging. Our results did not reflect any significant bigonial widening in the middle and older age groups compared with the younger age group (Table 1). This finding is in accordance with those of Shaw et al.[31,32] Several contradicting results, however, have been reported.[2,23,24] Pessa et al[2] found in their longitudinal analysis of 16 cephalograms that bigonial distance increased with age. The patients in their sample had measurements at 2 time/age points, the first being in the range of 5 to 17 years and the second being in the range of 46 to 60 years. This discrepancy in findings may be explained by the fact that the baseline starting point in their study occurred before skeletal maturity was achieved. Therefore, their result is better interpreted as documentation of mandibular growth from adolescence to adulthood rather than that of facial aging. Bartlett et al[23] measured several craniometric parameters utilizing a

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Table 3. Comparison of Mandibular Parameters Between Males and Females

	Males		Females		
	n	LS Mean (95% CI)	n	LS Mean (95% CI)	*P* Value
Bigonial distance	45	90.15 (88.2-92.1)	45	81.59 (79.6-83.5)	**<.001**
Anterior height (Id – Gn)	45	25.64 (24.5-26.8)	45	23.49 (22.4-24.6)	**.009**
Mf – Mc	45	12.60 (11.7-13.5)	45	10.18 (9.3-11.0)	**<.001**
Mf – Mb	45	12.02 (11.5-12.5)	45	11.04 (10.5-11.5)	**.007**
Corpus length (Gn – Go)	45	73.98 (72.1-75.9)	45	71.59 (69.7-73.5)	.085
Ramus height (Co – Go)	45	62.29 (60.6-63.9)	45	56.39 (54.7-58.0)	**<.001**
Gonial angle	45	115.68 (113.3-118.0)	45	117.50 (115.2-119.8)	.28
Number of mandibular teeth	45	11.07 (9.8-12.3)	45	8.09 (6.8-9.3)	**.001**

The bilateral parameters have been pooled to yield a single mean value. CI, confidence interval; Co, condyle; Gn, gnation; Go, gonion; Id, infradentale; LS, least squares; Mb, mandibular border; Mc, mandibular crest; Mf, mental foramen. Bold *P* values indicate statistical significance.

human skull collection and also found that bigonial distance was larger in an older age group. However, this difference was observed only in female subjects, and the mandibles were compared only in 2 age groups: younger than 45 years and older than 70 years.

The height of the lower face is dictated by the height of the mandible, the maxilla, and the occlusal relationships. Previously, a decrease in mandibular corpus height was reported to correlate with age[23,31,32] and with status of dentition.[10,13,15,17,22,40,42,43] It is well known that atrophy of the alveolar ridge is responsible for this reduction.[3,16] This was corroborated in our study. The anterior mandibular height both in the midline and at the mental foramen was directly related to the total number of teeth in the mandible (Figures 2, 3 and Table 2). Furthermore, mandibular height was increased in those locations of the mandibular corpus where teeth were present (Figure 4 and Table 2). Thus, our findings support the previous evidence that the presence or absence of teeth is the primary determinant of mandibular morphology.

In the literature, both an increase and decrease have been described in ramus height with advanced age.[24,31-33] Chrcanovic et al[13] reported a lower ramus height in edentulous female mandibles, commenting that in male subjects, ramus length is maintained due to greater masticatory strength and higher amount of testosterone. We have found no difference in the height of the ramus between age groups (Table 1). The ramus height did not appear to be affected by the presence of dentition either (Table 2).

Previous publications have reported varying results with regard to mandibular length, with some studies noting a decrease[24,29,31] and others an increase with age.[28,33] In our study, the measurement of mandibular corpus from gnathion to gonion showed that the length of the mandible changes neither with age nor with status of dentition (Tables 1 and 2).

Our evaluation of the gonial angle failed to document any significant changes with age or tooth number (Tables 1 and 2). This finding is consistent with many other reports.[18,23,25-27,30] However, there are also publications documenting a more obtuse angle with age or edentulousness.[13,17,18,31,34] In the latter studies, longstanding tooth loss leading to bone resorption was proposed as the mechanism of an increase in the gonial angle. We suggest that the resorption occurs along the inferior border of the body and posterior border of the ramus if the gonial angle is to increase. It therefore seems more likely that this bony resorption is due to loss of masticatory forces rather than as a direct loss of teeth per se. Stated another way, the bone resorption at the gonial angle leading to a more obtuse angle with age may be due to tooth loss, which then results in loss of masticatory forces. The aging mandible conforms to Wolff's law: form follows function.[39] The bone and its muscle envelope function as an integrated



Figure 4. The mandible of a 68-year-old man shows signs of atrophy along regions of tooth loss (red arrow) whereas the anterior mandible height (white arrow) has been maintained due to presence of teeth.

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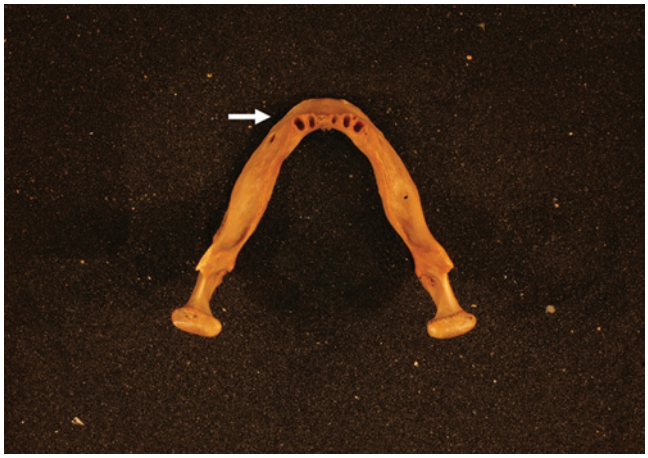


Figure 5. The bird's-eye view of an 82-year-old female mandible with prejowl atrophy that is more prominent on the left side (arrow).

unit in which the bony architecture dynamically responds to physical stresses.[44-46] Typically, bone is deposited in sites subject to mechanical load and resorbed in its absence. With loss of dentition, the mandible is altered both directly at locations where the tooth is missing and also at locations where muscles insert. The latter is due to lack of functional stimulation, such as seen in the gonial angle. In our study, we have excluded totally edentulous mandibles in an effort to concentrate on changes relevant to age. It is suggested that the gonial angle changes are due to tooth loss and the resultant loss of masticatory forces. This may be the reason for not finding an increase in the gonial angle in our specimen population.

The 2-dimensional measurements we used do not detect topographic changes that are visible by observation of the bone surfaces. After analyzing various mandibles in different age groups, our subjective impression was that bony ridges occur in areas of muscular insertion independent of age. This also is consistent with Moss and Salentijn's functional matrix concept,[8] which states that the soft tissue environment shapes its morphology. We have also noted a bony atrophy in the prejowl region, which has previously been reported by other authors[2-5,47] (Figure 5).

Although not investigated in our study, changes in the bone density of the maxillofacial skeleton have been proposed as another contributor to age-related changes.[48] Bone density alteration has been attributed to age, nutrition, hormonal changes, comorbidities, and tooth loss.[48-52] The loss of density in turn may result in a decreased facial volume and diminished skeletal support for soft tissues.

In summary, we found surprisingly few differences in direct morphologic measurements when male and female skulls were compared in differing age groups. Furthermore, as demonstrated previously, the changes were related to tooth loss in areas of the mandibular body. When we compared and contrasted our results to previous work, we conclude that the resorptive changes seen in the aging mandible are due to 2 related factors only: tooth loss and the resultant loss of masticatory function that follows.

There are several strengths and weaknesses in our study. Strengths include the sample composed of mature skulls older than 21 years, obviating any changes attributable to facial growth rather than facial aging.[53,54] Furthermore, the human mandibles were compared in evenly distributed age and sex groups, and status of dentition was included in our analyses. Weaknesses include the fact that skeletal characteristics are greatly variable among individuals and pooling these data in age groups is not an ideal way of assessing age-related changes. Although the presence and the number of teeth were recorded in an effort to correlate measurements with dentition, the mandibles were not classified strictly according to tooth number, and specimens in the older age groups inevitably had fewer teeth than the younger groups. An ideal methodology would be to use each individual as his or her own control in a longitudinal study.

CONCLUSIONS

Few morphologic changes were found when mature mandibles of increasing age were compared. Furthermore, as previously shown, these changes were found to correlate entirely with tooth loss. These changes and those seen in other studies on the aging mandible appear to be due to tooth loss and the loss of masticatory function that follows. Age, per se, plays little role in these changes.

Disclosures

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