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Original Article

Densitometric Study of Dry Human Mandible

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Abstract

The purpose of this study was to evaluate the variability of bone density among three zones of adult human dry mandible and its relationship to age, gender, and dental status. Thirty-one dried mandibles (16 female ranging between 23 and 82 yr and 15 male ranging between 34 and 85 yr; 6 samples completely edentulous and 6 edentulous only in the molar-premolar zone) were analyzed by a Hologic QDR 1000 X-ray densitometer according to three zones: the ramus, the molar-premolar zone, and the incisor-canine zone. We found a significant inverse correlation between bone density of the ramus and age ($r = -0.41$, $p = 0.02$). The bone density of the incisor-canine zone was higher than the density of the other zones; males had a higher bone density than females in all zones analyzed. Our data suggest that mandibular bone density is influenced by age and gender in different ways according to the specific mandibular portion considered, whereas the dental status does not seem to influence mandibular bone density.

Key Words: Human mandible; densitometry; dual X-ray absorptiometry; bone density.

Introduction

Several researchers have examined the relationship between mandibular bone density and density of other skeletal regions *(1–6);* the data obtained, however, are contradictory, because of in vivo studies of the mandible have to be restricted to limited zones of the bone. Furthermore, different studies applied a wide range of techniques, such as radiographs.

Concerning the zonal variability of mandibular bone mineral density (BMD), in vitro studies demonstrate that different parts of the same bone differ in bone density *(7–10).* In particular, previous studies indicate that the anterior zone of the mandible has the highest bone density. However, no studies by dual X-ray absorptiometry (DXA) were performed in vitro; some studies on bone density of human mandible by DXA were performed in vivo in both dentulous *(11–12)* and edentulous subjects *(13),* but in those cases, the study design did not permit evaluation of different mandibular zones.

The aim of the present study was to evaluate the use of the DXA technique in detecting the bone density of different parts of the mandible (ramus, molar-premolar, and incisor-canine zones) and its relationship to age, gender, and dental status through an in vitro approach.

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Materials and Methods

Thirty-one dry mandibles (16 female ranging between 23 and 82 yr and 15 male ranging between

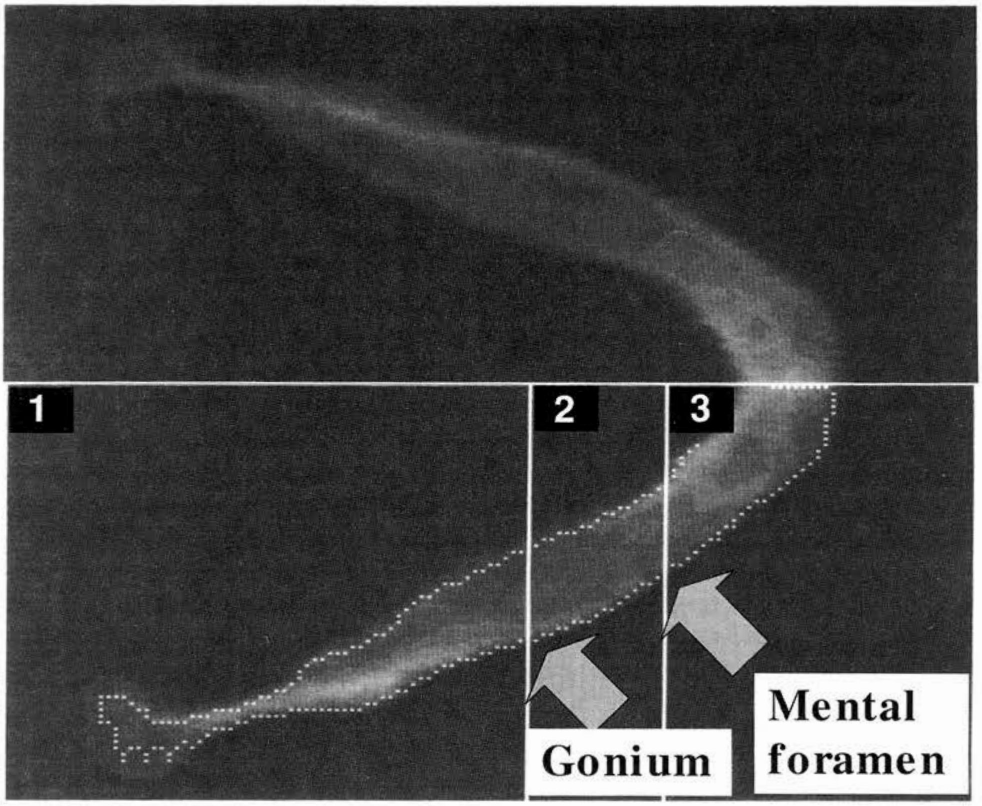

Fig. 1. Densitometric image of adult human mandible (male, age 72 yr) with the area of analysis. The mandible is divided into two halves and each half is divided into three zones: section 1 corresponds to the ramus, section 2 to the molar-premolar zone, and section 3 to the incisor-canine zone; analysis of the mandible right half is shown. BMD was calculated on each section. Arrows indicate the mental foramen and the gonium.

34 and 85 yr) were analyzed by a Hologic QDR 1000 X-ray densitometer. The mandibles, obtained from fresh cadavers, belong to the osteologic collection of the Department of Anatomy, Pharmacology and Forensic Medicine, Faculty of Medicine, University of Turin. Six samples were completely edentulous and six were edentulous in one side of the mandible, in the molar-premolar zones, the remaining specimens were completely dentate. The mandibles were dissected, the remaining soft tissues were removed, and the bones were air-dried without prefixation by any fixatives (formaldehyde or others). To avoid superposition of the teeth, they were all extracted before the scans were perfomed.

Inferosuperior scans were executed by means of a Hologic QDR 1000 X-ray densitometer. The scans were carried out directly on the dry bones without interposition of water or other media simulating soft tissue; each mandible was positioned so that the X-ray beam was perpendicular to its horizontal plane. The results were expressed as BMD (g/cm^2). To estimate precision in measuring BMD, five scans were repeated on one 75-yr-old specimen, and the mandible was repositioned with each measurement. The accuracy of the densitometer was evaluated by repositioning a phantom with a known BMD.

On the densitometric image the mandibles were cut into two halves and each hemimandible was then divided into three zones: section 1 corresponding to the ramus, section 2 corresponding to the molar-premolar zone, and section 3 corresponding to the incisor-canine zone (Fig. 1). The BMD was calculated as partial BMD (i.e., the BMD of each section analyzed) and total BMD (i.e., the BMD of the overall mandible). The boundaries of the three zones considered in the edentulous samples were determined by using the mental foramina as reference points for the incisor-canine zone, and the gonium as a reference point for the posterior boundary of the molar-premolar zone.

BMD values obtained were correlated with age by using the Pearson coefficient and were then compared using analysis of variance (ANOVA). The p values obtained were considered significant when ≤ 0.05. BMD values of edentulous and dentate zones within the same mandible (left vs right side) were compared using the paired t-test. To evaluate the influence of age, gender, and dental status (partial or total edentula and complete dentition) on BMD of each mandibular section, we applied a multiple linear regression model.

Results

The coefficient of variation (CV) for the precision in measuring BMD was 0.43%, while the CV for the accuracy in measuring BMD was 1%. Females were, on average, 6.8 yr younger than males, but this difference was not statistically significant. There were no differences between the BMD values of the two hemimandibles; we used an average of the values obtained in each half in the statistical analyses. The BMD of mandibular zones significantly differed. The incisor-canine zone was significantly more dense than the other mandibular zones ($p = 0.002$; Table 1). The BMD of all zones considered was significantly higher in males than females ($p < 0.0001$); the result of unpaired t-test with Bonferroni correction between BMDs of the same region showed that the zone significantly more dense in male than in female specimens was the incisor-canine zone ($p = 0.003$). Of all the zones examined, only the BMD of the ramus showed an inverse correlation with age ($r = -0.41$, $p = 0.02$).

Nine male mandibles were dentate (60%), 2 were completely edentulous (14%), and 4 were partially dentate (26%), while in female specimens 10 were dentate (62.5%), 4 were completely edentulous (25%), and 2 were partially dentate (12.5%). In the six samples containing both dentulous and edentulous regions, the BMD of dentate molar-premolar zones was generally higher than edentulous molar-premolar zones. This difference was not statistically significant (BMD of edentulous zone = 1.086 ± 0.23 g/cm^2, BMD of dentate zone = 1.119 ± 0.22 g/cm^2).

The results of the multiple linear regression model between BMD of sections 1, 2, 3, and age,

Table 1
Mean of BMD Values of Three Sections Analyzed in Whole Sample[a]

	Whole sample (no. 31)	
	Mean (g/cm^2)	SD
BMD 1	1.05	0.21
BMD 2	1.02	0.24
BMD 3	1.21	0.20
Total BMD	1.08	0.19

[a] Section 1 corresponds to the ramus, section 2 to the molar-premolar zone, and section 3 to the incisor-canine zone. ANOVA: $p = 0.002$.

Table 2
Multiple Linear Regression Model Between BMD Values and Age, Gender, and Dental Status of Entire Mandible[a]

	Coefficient	SE	p
BMD of ramus ($r^2 = 0.18$)			
Age	–0.004	0.002	0.04
Gender	0.114	0.007	NS
Dental status	–0.048	0.047	NS
BMD of molar-premolar zone ($r^2 = 0.13$)			
Age	–0.003	0.002	NS
Gender	0.149	0.087	NS
Dental status	0.002	0.055	NS
BMD of incisor-canine zone ($r^2 = 0.29$)			
Age	–0.001	0.002	NS
Gender	0.212	0.064	0.003
Dental status	–0.002	0.041	NS
Total BMD ($r^2 = 0.22$)			
Age	–0.003	0.002	NS
Gender	0.158	0.065	0.02
Dental status	–0.030	0.041	NS

gender, and dental status of the entire mandible showed that age influenced the BMD of the ramus (Table 2). Conversely, its influence was not evident in the BMD of molar-premolar and incisor-canine sections and total BMD. Gender seems to influence the BMD of the incisor-canine sections and total BMD, but not the BMD of the molar-premolar region and the ramus. Dental status did not influence any of the zones examined (Table 2).

Discussion

The technique used for the preparation of the specimens did not modify their weight and shape *(11)* and hence their BMD. However, there were limitations of the samples. It was not possible to control for the following variables, which are important in the genesis of systemic osteoporosis:

1. Cause of death.
2. Menstrual status of the females.
3. Time and cause of edentulism.
4. Presence of risk factors for systemic osteoporosis.
5. Anthropometric traits such as height and weight.

Therefore, such limitations could influence our results. However, our data, according to previous literature *(5–7),* show that the incisor-canine zone had a bone density significantly higher than the other mandibular zones.

The BMD was higher in males than females in all the mandibular zones. There was a significant, inverse correlation between age and BMD only at the level of the ramus. The multiple linear regression model states that age influences the BMD of the ramus. These data suggest that bone density of the mandible is related to age at the level of the ramus. The ramus is the mandibular portion in which the masticatory forces are affected only by muscular movements and condylar reaction forces. This might influence the relation between the BMD of the ramus and age. In contrast to previous results *(12–14),* our data show that dental status (partial or total edentulism vs complete dentition) did not influence mandibular BMD in any of the zones considered. On the contrary, age clearly influenced the BMD of the ramus, and gender influenced only the BMD of the anterior part of the mandible and the total BMD. Our previous data on bone density of developing human mandibles *(15)* showed that the dental status (from decidual to mixed dentition) strongly influences the mandibular pattern of ossification, in contrast with our present data, which demonstrate that the adult dental status has no bearing on BMD.

In conclusion, our results demonstrate that mandibular bone density is influenced by age and gender according to the specific mandibular portion considered, while the dental status does not affect total mandibular bone density as well as zonal BMDs. Further studies with a larger sample will be useful in confirming our results.

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References

1. Bassi F, Procchio M, Fava C, Schierano G, Preti G. 1999 Bone density of human dentate and edentulous mandible using computer tomography. Clin Oral Implant Res 10:356–361.
2. Jonasson G, Bankvall G, Kiliaridis S. 2001 Estimation of skeletal bone mineral density by means of the trabecular pattern of the alveolar bone, its interdental thickness, and the bone mass of the mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontics 92(3):346–352.
3. Horner K, Devlin H, Alsop CW, Hodgkinson IM, Adams JE. 1997 Mandibular bone mineral density as a predictor of skeletal osteoporosis. Br J Radiol 69:1019–1025.
4. Bollen AM, Taguchi A, Hujoel PP, Hollender LG. 2000 Case-control study on self-reported osteoporotic fractures and mandibular cortical bone. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontics 90(4):518–524.
5. Klemetti E, Vainio P, Lassila V, Alhava E. 1993 Trabecular bone mineral density of mandible and alveolar height in postmenopausal women. Scand J Dent Res 101:166–170.
6. Kingsmill VJ, Boyde A. 1998 Variation in the apparent density of human mandibular bone with age and dental status. J Anat 192:233–244.
7. Takaoka S. 1998 Bone mineral density (BMD) distribution in edentulous mandible—a measuring system for bone mineral content with computed radiography. Kokubyo Gakkai Zasshi 65:112–124.
8. Horner K, Devlin H. 1998 The relationship between mandibular bone mineral density and panoramic radiographic measurements. J Dent 26(4):337–343.
9. Horner K, Devlin H. 1998 The relationships between two indices of mandibular bone quality and bone mineral density measured by dual energy X-ray absorptiometry. Dentomaxillofac Radiol 27(1):17–21.

10. Turner AS, Maillet JM, Mallinckrodt C, Cordain L. 1997 Bone mineral density of the skull in premenopausal women. Calcif Tissue Int 61(2):110–113.
11. Krahl VE, Mueller CW. 1947 Permanent dry preparations of cartilage and bone: a method especially applicable to fetal material. Anat Rec 97:41–45.
12. Branemark PI. 1987 Introduction to Osseointegration. In: Tissue Integrated Prostheses Osseointegration in Clinical Dentistry. Branemark PI, ed. Zarb, G. & Albrektsson, T: Quintessenz Verlags-GmbH, Berlin, Chapter 15, pp. 16–25.
13. Erhardson S, Sheikholeslam A, Forsberg CM, Lockowandt P. 1993 Vertical forces developed by the jaw elevator muscles during unilateral maximal clenching and their distribution on teeth and condyles. Swed Dent J 17:23–34.
14. Hart RT, Hennebel VV, Thongpreda N, Van Buskirk WC, Anderson RC. 1992 Modeling the biomechanics of the mandible: a three-dimensional finite element study. J Biomech 25:261–286.
15. D'Amelio P, Panattoni GL, Di Stefano M, Isaia GC. 2000 Bone mineral density in the growing human mandible. J Cran Genet Dev Biol 20(4):201–205.