A Density Comparison of Human Alveolar and Retromolar Bone

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The term density has been used in a variety of different meanings by various skeletal tissue investigators. To some, density is the quality of radiopaqueness of roentgenograms. A weight-per-volume concept is implied as the x-ray absorption is proportional to the mass of calcium in that unit of bone volume.[1] Others have used density to be the weight of bone per unit volume as reflected by the external envelope of the organ bone.[2] Density has been used as an expression of the specific gravity of bone tissue.[3] Lastly, density has been used to describe the relative amount of marrow spaces present in a unit of bone tissue.[4]

Interest in skeletal tissue biology has greatly increased in recent years and the resulting research has altered older concepts of bone remodeling. An understanding of these processes may be useful in the clinical practice of orthodontics where the tooth movement reaction is dependent on the concomitant resorption and deposition of alveolar bone. Our knowledge of the relationship between force and rate of tooth movement is fragmentary. The oft-repeated histologic descriptions of the tooth movement reaction do not fully correlate with clinical observations and much work remains to be done in experimental tooth movement. It would seem more likely that differences in root surface area, or the total mass of bone that must be remodeled in the tooth movement reaction may yield information relative to the rates of tooth movement rather than bone density. The dental literature frequently speculates on the correlation of clinical phenomena with possible biologic explanations. An example is the observation of poor orthodontic distal root movement of lower molars attributed to possible differences of retromolar bone in the mandible.[5]

It has been shown that different bones as well as different regions of the same bone show variations in composition. Furthermore, variations also occur with age, sex and race. However, data describing these differences are not in agreement.[2] Very little data are available on the physical properties of human dental bone.

The purpose of this study was twofold:

1. To examine human mandibular bone for possible density differences between alveolar and retromolar areas.

2. To compare the different gravimetric techniques in present use and determine the interrelationships between them.

Materials and Methods

In general, we have followed the gravimetric method of water displacement to determine bone volume in a mass per unit volume relationship as used by Robinson and Elliott[3] and Gong et al.[6] The specific gravity of the bone sample is calculated according to the ratio of its mass and loss of mass in water. Since density and specific gravity are equivalent in the metric system at 4° centigrade, one gram of water equals one cubic centimeter at that temperature. Therefore, we are expressing the mass per unit volume as density with

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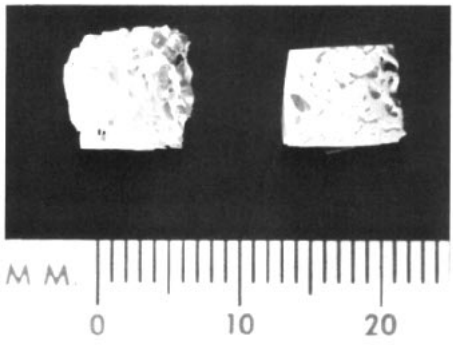

Fig. 1 Sample of human mandibular retromolar bone on the left and alveolar bone on the right showing gross architectural differences.

the appropriate temperature conversion factor.

The relationships utilized were:

(a) Hydrated weight in air minus hydrated weight in water equals hydrated volume.

$$\frac{\text{Hydrated weight in air}}{\text{Hydrated volume}} = \text{Hydrated density}$$

(b) Hydrated volume minus mass of water lost in drying equals dehydrated volume.

$$\frac{\text{Dehydrated weight in air}}{\text{Dehydrated volume}} = \text{Dehydrated density}$$

The human samples were obtained from the mandibles of ten adult white male cadavera. Samples were cut from each of the mandibles in the right and left cuspid areas and the right and left third molar areas. Periosteum and buccal and lingual cortical bone were removed from all samples. The alveolar samples included alveolar bone proper and supporting alveolus from the cuspid area. The retromolar samples included supporting alveolus from the third molar areas (Fig. 1).

Lipid material was extracted from the samples in a Soxhlet extractor using petroleum ether. Each extraction consisted of 150 cycles followed by a distilled water rinse of 150 cycles.

After a run of alveolar bone samples was calculated, it was decided to utilize an inorganic density determination to determine if any measurable differences existed. Therefore, protein material was extracted in a Soxhlet apparatus with an 80% aqueous solution of ethylene diamine. The extraction sequence consisted of two 150 cycle extractions separated by one and followed by two distilled water rinses of 150 cycles each.[6]

Dehydration of the samples was carried out in a 100° C. oven until the samples reached a constant weight after two weighings agreeing within ±1 milligram.

In addition to gravimetric methods, an air pycnometer was used to obtain direct volume measurements which were repeatable within limits of ±0.05 cc.

Random samples were selected for multiple determinations of mass error determination (SD=.0001 gm. for repeated measurements). A hydrated bone sample was used for mass volume determination (SD=.001 cc. for repeated measurements). A standard steel reference ball reference unit was used for the air pycnometer error (SD=.03 cc. of repeated measurements). With this precision, density is reported to the second decimal place. All balance weighings were averaged double determination on a Mettler Balance type H6T. As the individual bone samples fell within the range of inherent error of the air pycnometer, the means reported are the result of the average of four runs of pooled samples.

Results

A statistical analysis using the "t" test at the P=.01 level was performed on the mean densities of the right and left alveolar and right and left retromolar samples determined by the water displacement method. No significant difference was found. A coefficient of variation was calculated for these samples and ranged between 4.7 and 8.7. The results of pooling the entire sample as mandibular inorganic bone are also

	Water Displacement						Air Pycnometer
	Hydrated			Dehydrated			Dehydrated
Sample	Mean	SD	CV	Mean	SD	CV	Mean
Left Alveolar	1.91	0.09	4.7	3.10	0.27	8.7	3.56
Right Alveolar	1.89	0.12	6.3	3.23	0.25	7.7	3.62
Left Retromolar	1.92	0.09	4.7	3.12	0.18	5.8	3.59
Right Retromolar	1.91	0.10	5.2	3.18	0.26	8.2	3.39
Pooled Sample	1.91	0.09	4.7	3.16	0.24	7.6	3.54

Table 1. Inorganic densities of right and left human alveolar and retromolar bone and pooled sample, N = 10.

reported (Table I). A scattergram of the pooled sample plotted with density determined by the dehydrated method on the Y axis and hydrated density on the X axis and a correlation coefficient was computed (r=0.3).

Discussion

The methods of sample preparation in this study closely approximated the techniques used by Robinson and Elliott. The caution that the data are only valid for a sample handled in a similar manner should be noted.

Preliminary experiments of whole cadavera bone yielded a hydrated density that approximated the data of others. However, the dehydrated density was lower than expected. It has been reported that the water compartment in adult dog bone is never less than 20% by volume or 10% by weight, and furthermore that this compartment never intrudes into the organic carbon dioxide space and inorganic ash compartment.[3] For this reason, the density of hydrated whole bone never reaches the density of dry bone. However, other investigators reported on fresh animal bone and our sample was from human cadavera material which would have the organic compartment fixed in the embalming process, plus possible alteration of other compartments. Therefore, it was decided to eliminate the organic compartment by the ethylene diamine treatment and test only the inorganic density.

The inorganic hydrated density of 1.91 is lower than that reported by other investigators while the dehydrated of 3.16 is in agreement. Gong et al. reported an average inorganic dehydrated density of 3.021 for beagle bone and our average was 3.16. This may be due to the altered water compartment, other postmortem changes, differences between this cancellous sample and other reported compact bone samples, storage in distilled water or human bone vs. other mammals, etc. However, a more likely possibility for our difference between hydrated and dehydrated density is measurement error in the techniques of volume determination.

Robinson and Elliott reported a trend toward correlation of hydrated and dry densities. They also, with caution, stated that such a correlation is not to be expected in all bone specimens. Our calculated correlation coefficient of 0.3 indicated a very low relationship exists

in our sample for measurements between hydrated and dry inorganic density.

The air pycnometer values are all higher than the rest of the reported values. To our knowledge this instrument has not been used in this manner and no comparisons are available. The air pycnometer is reported to be extremely efficient in determining porosity of dental plaster and other similar difficult volume determinations. A good probability exists that the air pycnometer may yield an improved estimate of absolute skeletal density.

Of major importance is the similarity in density of retromolar and alveolar bone. It does not explain reported clinical phenomena.

Conclusions

1. No significant difference in density exists between retromolar and alveolar inorganic bone when handled by these specialized techniques.

2. The interrelationship between density determination of inorganic samples by the hydrated and dehydrated technique is very low (r=0.3).

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