

Bone density assessment for mini-implants position

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Abstract

Introduction: Cortical thickness, interradicular space width and bone density are key factors in the use of mini-implants as anchorage. **Objective:** This study assessed maxillary and mandibular alveolar and basal bone density in Hounsfield units (HU). **Method:** Eleven files with CT images of adults were used to obtain 660 measurements of bone density: alveolar (buccal and lingual cortical) bone, cancellous bone and basal bone (maxilla and mandible). The Mimics software 10.0 (Materialise, Belgium) was used to estimate values. **Results:** In the maxilla, the density of buccal cortical bone in the alveolar region ranged from 438 to 948 HU, and the lingual, from 680 to 950 HU; cancellous bone ranged from 207 to 488 HU. The buccal basal bone ranged from 672 to 1380 HU, and cancellous bone, from 186 to 402 HU. In the mandible, the buccal cortical bone ranged from 782 to 1610 HU, the lingual cortical alveolar bone, from 610 to 1301 HU, and the cancellous bone, from 224 to 538 HU. In the basal area, density was 1145 to 1363 HU in the buccal cortical bone and 184 to 485 HU in the cancellous bone. **Conclusions:** In the maxilla, the greatest bone density was found between the premolars in the buccal cortical bone of the alveolar region. The maxillary tuberosity was the region with the lowest bone density. Bone density in the mandible was higher than in the maxilla, and there was a progressive increase from anterior to posterior and from alveolar to basal bone.

Keywords: Bone density. Orthodontic anchorage procedures. Orthodontics.

INTRODUCTION

Mini-implants have been objects of study nowadays, and have achieved great popularity in the orthodontic community.^{1,2,6} The reasons are because these devices promote adequate anchorage in orthodontic mechanics.

All appliances or intraoral devices show some anchorage loss and headgear depend on the patient cooperation on the proper use of orthodontic appliances. When using an endo-

seous anchorage by means of temporary anchorage devices, as is the case for mini plates, mini-implants or dental implants, a satisfactory anchorage can be achieved without the need of cooperation from patients.

Comparing mini-implants with other anchoring devices, they have excelled in professional preference due to the ease of insertion and removal, the possibility of immediate loading, small size and low cost.^{8,11,16,20}

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Regarding the location for its placement, several sites have been proposed for the installation of mini-implants, which can be inserted in different regions of the basal and alveolar maxillary and mandibular bones. For anchorage in cases of retraction of anterior teeth after premolar extraction, mini-implant placement in the maxilla, between second premolar and first molar and in the mandible between the first and second molars are commonly used as a resource.^{7,12,19}

The choice of mini-implant insertion sites should be based on appropriate regions of soft tissues such as the presence of attached gingiva, adequate amounts of cortical bone, the angulation and the size of the mini-implant and foremost, the type of tooth movement that is desired, intrusion, extrusion, or space closure with both mesial or distal movement.^{10,17}

Consequently, so that mini-implants can be effective as anchorage, there must be adequate cortical bone thickness, enough spaces between the roots for their placement, without damaging the dental roots, and also the quality of this bone should be such that favors the mechanical retention of the device in a predetermined location. It is considered that bone density is a key factor for the efficiency of mini-implants as anchorage. This aspect of the assessment or mapping of characteristics related to bone density is still a subject little discussed and emphasized in the literature.

It was intended, therefore, with this study to evaluate the maxillary and mandibular bone density in various sites, both in the alveolar bone and basal bone by computed tomography (Cone-Beam), quantitatively in Hounsfield units (HU).

MATERIAL AND METHODS

The study sample consisted of 11 computerized tomography (CT) files in DICOM format (Digital Imaging and Communication in Medicine), obtained from two males and nine

females, Brazilians, aged between 20 and 30 years, presenting a Class I malocclusion with double protrusion and all permanent teeth present except third molars, from the database of tomographic images of the post graduate course in orthodontics, Fluminense Federal University-UFF (Niterói, RJ, Brazil).

The same measurements were performed for the left and right sides of the dental arches and since they did not present statistically significant differences between them, they were grouped, consisting the total sample of measurements of this study.

Six hundred and sixty measurements were performed, evaluating the alveolar bone region, the buccal and lingual cortical densities, cancellous bone and the basal bone region, as well as the densities of the buccal cortical and cancellous bone in both maxilla and mandible.

The bone densities were calculated using the Mimics software version 10.01 (Materialise, Belgium) from images obtained from CT scans. The densities were measured in Hounsfield units (HU). With help of the software Mimics 10.01, CT cuts were made in the alveolar bone height in the range of 3 to 5 mm from the bone crest and to the basal bone height in the range of 5 to 7 mm from the apex of the teeth, as illustrated in Figure 1.

In certain areas of alveolar bone and basal bone, sites evaluated between teeth were between the central and lateral incisors (1 and 2); between cuspids and first premolars (3 and 4); between the first and second premolars (4 and 5); between the second premolar and first molar (5 and 6); between first and second molars (6 and 7); and the region distal to second molars (7D) for both the jaws (Fig 2).

In areas between the teeth the alveolar bone densities for the buccal cortical, lingual cortical and cancellous bone were measured. In the basal bone section the density of the buccal cortical and the cancellous bone was measured.

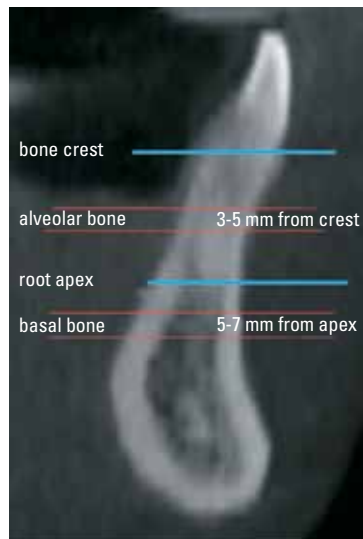


FIGURE 1 - Cross-sectional CT image shows site of crest and root apices, as well as measured areas, corresponding to alveolar bone (3 to 5 mm of bone crest) and basal bone (5 to 7 mm of root apices).



FIGURE 3 - Magnified view of CT section in the region between 1 and 2 in the mandible with the illustration of the measurement of bone density in the section of basal bone, for both buccal cortical and cancellous bone area. The area of alveolar bone is defined by the upper red lines.

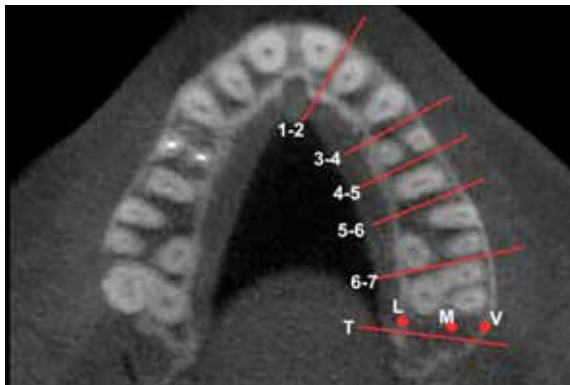


FIGURE 2 - Analyzed sites: 1 and 2, between the central incisor and lateral incisor; 3 and 4, between canine and first premolar; 4 and 5, between first and second premolar; 5 and 6, between the second premolar and first molar; 6 and 7, between first and second molar; T = tuberosity; V = buccal cortical; M = cancellous bone; L = lingual cortical.

Measurements of the cortical bone thickness met the limits of the buccal and lingual cortices and cancellous bone was measured in the section between cortices, corresponding to the cancellous bone with trabecular aspect (Fig 3). Data were organized in tables and proceeded to obtain measures of central tendency and statistical tests.

Statistical analysis

Mean and standard deviations were calculated for all data, for each analyzed region. The analysis of differences between the sites was evaluated by the analysis of variance (ANOVA), complemented with a post-hoc analysis (Tukey test) for multiple comparisons of differences between sample means.

For the purpose of multiple comparisons, the BioStat 5.0 software was used, which is a freeware and downloadable at the following site: www.mamiraua.org.br.

RESULTS

The means, standard deviations and statistical significance between the assessed areas for maxillary basal and alveolar bone density values are shown in Table 1.

The values obtained for the averages, standard deviations and statistical significance between the assessed areas, for mandibular basal and alveolar bone density are shown in Table 2.

The maxillary alveolar bone density, measured

from the buccal aspect showed a variation ranging between 438 and 948 HU, the lingual side between 680 and 950 HU, and cancellous bone in this region between 207 and 488 HU.

When values were observed without the data obtained for the maxillary tuberosity, the cortical alveolar bone density of the maxilla, both in the buccal and lingual evaluation ranged between 802 and 950 HU. The maxillary tuberosity shows, therefore, poor bone density when compared to other sites analyzed in this study. The mean for maxillary tuberosity bone density was 438 HU for the buccal cortical and 680 HU for the lingual cortical.

The area with greater bone density in the maxillary buccal cortical was found in the region between the premolars, with 948 HU (± 220), as shown in Table 1.

The maxillary basal bone showed a variation in the buccal cortical of 672-1380 HU, and cancellous bone of 186-402 HU. The standard deviations were also high for all areas assessed. In the basal bone, again, the exception was the maxillary tuberosity, which presented the lowest bone density averages, with 672 HU for buccal cortical and 186 HU for the cancellous bone region, indicating statistically significant low bone density.

According to the analysis of Table 1 and Fig-

TABLE 1 - Means, Standard Deviations and Statistical Significance of maxillary bone densities in Hounsfield units (HU) in regions evaluated between lateral incisor and central incisor (1 and 2), between canine and first premolar (3 and 4), first and second premolars (4 and 5), second premolar and first molar (5 and 6), first and second molars (6 and 7), and the maxillary tuberosity (7D).

		Region (between teeth)												P Value
		1 and 2		3 and 4		4 and 5		5 and 6		6 and 7		7D		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Alveolar Bone	Buccal cortical	802.67 ^A	170.95	876.67 ^B	190.15	948.40 ^B	220.42	840.33 ^C	100.54	886.00 ^C	185.14	438.76 ^F	211.08	<.0001
	Cancellous bone	488.30 ^A	168.54	365.82 ^C	190.15	281.67 ^A	167.94	207.51 ^B	159.03	230.93 ^F	212.92	207.89 ^E	158.04	<.0001
	Lingual cortical	802.46 ^A	130.45	912.88 ^A	196.61	930.18 ^A	175.35	873.35 ^C	177.33	950.24 ^A	210.05	680.05 ^D	281.10	<.0001
Basal bone	Buccal cortical	832.44 ^A	230.79	1043.68 ^D	211.78	1181.45 ^D	256.90	951.00 ^A	168.01	1380.90 ^E	236.32	672.20 ^F	208.65	<.0001
	Cancellous bone	370.84 ^A	170.60	290.80 ^C	121.08	301.16 ^A	174.42	247.76 ^E	68.94	402.79 ^A	244.61	186.42 ^D	168.09	.0005

Means followed by the same letter shows no statistically significant difference ($P > 0.05$) by Tukey test.

ure 4, it can be seen in the maxilla, the buccal cortical was more dense in the section of basal bone than in the section of alveolar bone in all regions analyzed.

In the evaluation of mandibular bone density, there was a variation of the alveolar bone in the buccal cortical (782-1610 HU), and lingual cortical (610-1301 HU), and in the alveolar cancellous bone area was 224-538 HU. The density in the basal area of the buccal cortical ranged from 1145 to 1363 HU and 184-485 in cancellous bone.

In general, a progressive increase in bone density from the anterior region of the mandible

(lower density) to the posterior region (higher density) was observed. In the mandible the buccal basal cortical compared to the buccal alveolar cortical, showed statistically significant higher density for the evaluated areas, except in the retromolar region (Table 2 and Fig 5).

The alveolar bone density of the buccal cortical region of the mandible was statistically higher than in the maxilla, except between central and lateral incisors (1 and 2) and between second premolar and first molar (5 and 6) as illustrated in Figure 6.

Comparing the cancellous bone of the alveolar region, the locations between canines and

TABLE 2 - Means, Standard Deviations and Statistical Significance of mandibular bone densities in Hounsfield units (HU) in regions evaluated between lateral incisor and central incisor (1 and 2), between canine and first premolar (3 and 4), first and second premolars (4 and 5), second premolar and first molar (5 and 6), first and second molars (6 and 7), and mandibular retromolar area (7D).

	Region (between teeth)												P Value	
	1 and 2		3 and 4		4 and 5		5 and 6		6 and 7		7D			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Alveolar Bone	Buccal cortical	782.75 ^A	172.73	1010.34 ^D	105.98	1098.33 ^E	164.39	801.76 ^A	221.60	1320.08 ^E	139.17	1610.42 ^B	145.25	<.0001
	Cancellous bone	505.70 ^A	210.80	538.63 ^F	178.87	474.58 ^A	124.51	224.31 ^F	220.38	358.00 ^B	130.54	324.78 ^F	81.81	<.0001
	Lingual cortical	707.18 ^A	198.00	1108.55 ^D	135.14	1250.20 ^D	188.95	610.27 ^F	109.72	1290.71 ^E	139.11	1301.20 ^B	203.68	<.0001
Basal bone	Buccal cortical	1285.12 ^A	230.50	1145.57 ^D	312.99	1339.06 ^B	80.99	1363.44 ^B	244.14	1299.70 ^E	108.94	1166.70 ^B	149.06	<.0001
	Cancellous bone	435.50 ^B	262.40	485.78 ^A	320.24	274.97 ^F	201.48	413.38 ^C	305.16	223.76 ^B	180.04	184.52 ^E	105.74	<.0001

Means followed by the same letter shows no statistically significant difference ($P > 0.05$) by Tukey test.

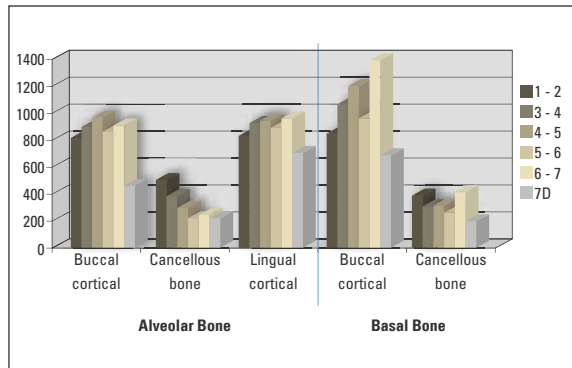


FIGURE 4 - Averages of the maxillary bone densities in Hounsfield units (HU) between the regions: central incisor and lateral incisor (1 and 2), canine and first premolar (3 and 4), first and second premolars (4 and 5), second premolar and first molar (5 and 6), first and second molars (6 and 7), and the region of the maxillary tuberosity (7D).

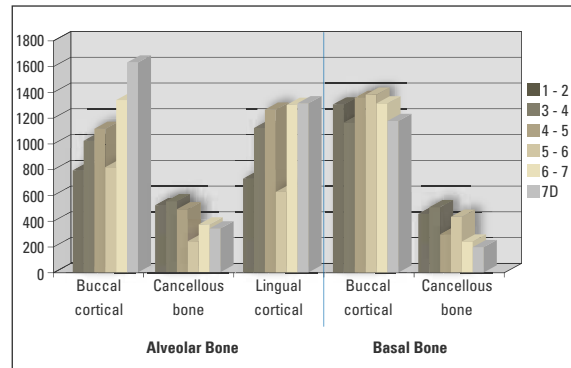


FIGURE 5 - Averages of mandibular bone densities in Hounsfield units (HU) between regions: central incisor and lateral incisor (1 and 2), canine and first premolar (3 and 4), first and second premolars (4 and 5), second premolar and first molar (5 and 6), first and second molars (6 and 7), and retromolar mandibular area (7D).

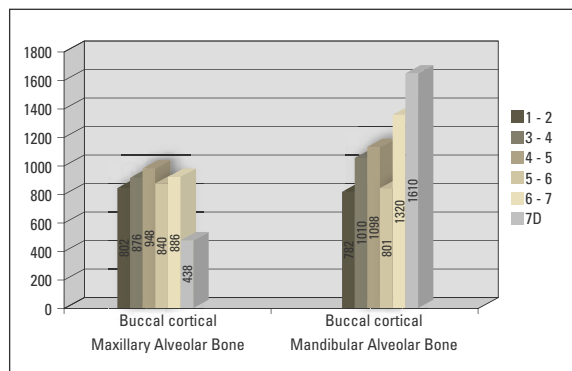


FIGURE 6 - Comparison between the mean bone density measurements (HU) areas of alveolar bone, in the maxillary and mandibular buccal cortical.

first premolar (3 and 4) and between first and second premolars (4 and 5) were denser in the mandible compared to the maxilla, which is statistically significant.

In the alveolar bone, the values obtained for the lingual cortex were very similar with the average values for the buccal cortex, both for the maxilla and the mandible.

DISCUSSION

The study of bone density in the maxilla and mandible, using images obtained from CT (Cone-Beam), and using the software Mimics to read images in DICOM format, allowing slices in the regions between the teeth, and evaluating the sections on both alveolar and basal bone in certain areas defined at 3-5 mm from the bone crest and 5-7 mm from the root apices, as possible locations for the installation of mini-implants, was very appropriate for this study.

The results may be used as additional information when selecting and electing the most suitable places to receive the anchorage devices, such as mini-implants.

The sample consisted of digital images obtained from adults, generating a total of 330 measurements on each side of the dental arches, and since sides did not present statistically significant differences data was grouped, resulting on 22 representative measurements of each area evaluated, in a grand total of 660 measurements. The sampling strategy adopted, with various measurements and in several sites, generating results as averages in millimeters of cortical thickness, can be considered a point of emphasis of this work in comparison with other studies.^{4,9,10,16,17,18}

It was found that specific areas of the maxilla, such as the buccal cortical alveolar bone between the premolars, is one of the sites with greater bone density and the maxillary tuberosity area was found to have lower bone density.

There are many reasons for the failure of mini-implants as anchorage, and among these the loss or unscrewing may be cited. This fact is due not only to bone density, but the knowledge of bone density values of both alveolar and basal bones constitutes yet another important factor for the selection of suitable sites for mini-implant placement.

The uppermost areas in the maxilla, the basal bone in this study represented by the regions located 5 to 7 mm from the root apices showed higher density in comparison with those located in the alveolar bone. The application of forces supported by mini-implants should be based on the type of tooth movement desired,^{7,14,20} but when intrusion movements are expected and there is no impairment of mechanical efficacy with the placement of mini-implants more superiorly, together with little interradicular space, uppermost areas can be considered, since they have greater bone density.^{16,18}

Another factor that provides the stability of mini-implants is cortical bone thickness.^{9,10,16} This study verified that the bone density values of cortical areas are larger, generally in the same region, and can double or be to 3-4 times greater than the density of the cancellous bone in the same area. This observation reinforces the need to insert mini-implants at an angle of 10-20 degrees to the long axis of the teeth, to make the most of the small thickness and higher density of cortical bone, either per buccal or lingual.¹⁰

With the aesthetic concerns of the appliances, and for greater control mechanical, anchorage devices can be installed by the lingual side.^{9,10} This study demonstrated that bone density in maxillary alveolar region is similar to the density on

the buccal side, with even slightly higher values.

The placement of mini-implants in the mandible, considering only the highest bone density as a factor for success, would be more interesting in the more posterior and inferior regions. But this fact does not always occur, because other factors may contribute to loss or unscrewing of the mini-implants. In some situations, in areas of basal bone, and without attached gingiva, alveolar mucosa may be one of the causes of failures, together with hygiene difficulty in this area.^{3,11}

However, despite the greater mandibular bone density, the heating caused by the drilling process of the thick cortical bone with drills, could cause bone necrosis at temperatures above 47°C, causing the loss of the anchoring device.¹¹

The most interesting places of election to receive the mini-implants, in clinical cases of retraction of anterior teeth for space closure after extraction of premolars, are the region between second premolar and first molar in the maxilla and between first and second molars in the mandible. These sites appear to be interesting, because together with the good quality of bone density, there is a safe space for mini-implants between the roots of the teeth.^{12,15}

In the basal bone range, the density of lingual cortical bone was not analyzed, because of difficulty and even impossibility of clinical application of mini-implants in this anatomical region. Bone density in this region was also not evaluated since it is extremely thin and usually there is not enough space for its placement.

The obtained data will serve as guides for choosing procedures of the most suitable areas for the placement of mini implants. It should be emphasized that in all measurements, the standard deviations found were very high, representing a wide variation of behavior of bone densities, requiring special consideration by the clinician for each case specifically.

More specific studies with larger samples and, involving digital images, must be per-

formed to qualify and quantify the characteristics of the most suitable sites for installation of mini-implants.

CONCLUSIONS

In the buccal cortical of the maxillary alveolar bone, the greater bone density was observed in the area between the premolars.

For the basal maxillary bone, higher density was observed in the buccal cortical between the premolars and molars.

The density of the maxillary lingual alveolar

cortex showed slightly higher density than in the buccal cortex.

The maxillary tuberosity was the region with lower bone density.

Bone density in the mandible was higher than in the maxilla in practically all assessed areas.

A gradual trend of increase in bone density from anterior to posterior and superior to inferior was observed in the mandible.

The mandibular alveolar cortical density was higher in the retromolar region, both buccally and lingually.

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