Bone density determination for the maxilla and the mandible in different age groups by using computerized tomography (Part I)

Sarah M. Tewfiq, B.D.S. [(1)]
Hadeel A. Al- Hashimi, B.D.S., M.Sc. [(2)]

ABSTRACT

Background: Mini implant stability is primarily related to local bone density; no studies have evaluated bone density related to mini implant placement for orthodontic anchorage between different age groups in the maxilla and the mandible. The present research aims to evaluate side, gender, age, and regional differences in bone density of the alveolar bone at various orthodontic implant sites.
Materials and method: Fifty three individuals who were divided into two groups according to their age into: group I (ages 16-20 years) and group II (ages 21-29 years) had subjected to clinical examination, then 64-multislice computed tomography scan data were evaluated and bone density was measured in Hounsfield unit at 102 points (51 in the maxilla and 51 in the mandible), and mean alveolar bone density was calculated at each site in the CT axial plane.
Results: No significant differences in bone density between the sides and gender were found. Generally, the bone density measurements of group I and II were not statistically different at almost most sites. The mean bone density of the alveolar cortical bone was greater in the mandible than in the maxilla and showed a progressive increase from the anterior to the posterior area, while in the maxilla the highest bone density was at the premolars region. The maxillary tuberosity was the region with lowest bone density. Cancellous bone had almost comparable densities between the mandible and the maxilla and its density was less than those of cortical sites.
Conclusion: When mini implants are indicated, no gender and side differences affect the success rate regarding bone density; while age and area should be considered when selecting and placing mini implants for orthodontic anchorage.
Keywords: Bone density, orthodontic mini implant, computerized tomography. (J Bagh Coll Dentistry 2013; 25(1):164-170).

INTRODUCTION

Goal of any orthodontic treatment is to achieve desired tooth movement with a minimum number of undesirable side effects. Anchorage control is an important factor directly affecting the results of orthodontic treatment, mainly when maximum anchorage is necessary [1, 2]. Strategies have been made to develop suitable anchorage for successful orthodontic treatment. Mini implants are clinical extra-dental intraoral anchorage systems that provide enhanced anchorage [3,4]. Regarding the failure rate of dental implants, which seems to be highly dependent on bone density as it was shown by Jaffin and Berman [5] who reported that it was 3% for types 1, 2, and 3 bone, but 35% for type 4 bone, according to bone quality as defined by *Lekholm and Zarb*. It was concluded that Q1 bone experienced a failure rate greater than the Q2 and Q3 bones[6]. Friberg et al reported that jaws with high bone density can experience overheating of the surgical sites during preparation without proper irrigation causing extensive bone necrosis which can result in subsequent implant failure during healing. This suggests that excessive bone density also might because of miniscrew loosening, whereas poor bone quality is certainly a risk factor for instability.

(1) Master student, Department of Orthodontics, College of Dentistry, University of Baghdad.
(2) Assistant professor, Department of Orthodontics, College of Dentistry, University of Baghdad.

Therefore, data concerning density of the alveolar bone are essential for selecting sites for mini implant placement and predicting success[7]. However, there are not enough data, especially dealing with density of the alveolar bone in the dentulous areas in patients. Generally, bone density is higher in the dentulous than edentulous bone and increases with decreasing inter-radicular distance. Furthermore, bone density tends to decrease with increasing depth, particularly in the posterior area [8]. Factors affecting the success of dental and mini implants might be multifactorial. In the clinic, mini implants can loosen during orthodontic treatment, often in teenagers [9, 10] which suggest that age may be a primary risk factor associated with such failure. Density of bone is a host factor that is known to play a crucial role in mini implant stability [11, 12]. One method for measuring bone density appropriately and more precisely is computerized tomography (CT) [13,14].

Tomography is a generic term formed from the Greek words tomo (slice) and graph (picture) that was adapted in by the international commission of radiological units and measurements in 1977 to describe all forms of body section radiography. CT has expediency and nondestructive nature and its images in DICOM format contain data of bone density so that the software program can measure it [14].

Misch[15] mentioned that the bone density measurements using CT provide more accurate results than radiographic assessment. Misch and Kircos[16] expressed numerically the subjective bone density obtained mainly from experience and tactile sensation, and classified the bones into 5 categories according to density: D1>1250 HU; D2, 850-1250 HU; D3, 350-850 HU; D4, 150-350 HU; and D5<150 HU.

The purpose of this study was to determine the bone density of the maxilla and the mandible for patients in different age groups with normal occlusion and compare the data according to the side, gender and site to supply a guideline for bone density when CT imaging is not possible so that orthodontic clinicians would not overlook some potentially important information.

MATERIALS AND METHOD

Sample

The total sample consisted of 53 Iraqi subjects, 28 males and 25 females, with age range of 16-29 years old, collected from Al-Shaheed Ghazi Al-Hariri Hospital.Subject selection criteria included:

1. They have full set of permanent teeth in both jaws “excluding the 3rd molar”
2. Clinically skeletal class I, bilateral class I molar and canine relationships, with normal over jet and overbite and well-aligned arches.
3. Subjects should have no large metal restorations (including crowns and fillings) that produce ‘‘scatter’’ and cause streak artifacts and affect the density of the adjacent bone tissue.
4. No history of general diseases, chronic regular use of medication that affect the bone density.
5. No previous or present regular tobacco smoking or alcohol drinking.
6. No history of dentofacial deformities, pathologic lesions in the jaws or facial trauma.
7. None of the subjects had received previous orthodontic and orthopedic treatment.

Materials and equipment

A. Disposable dental mirrors and probes and sliding caliper
B. 64-multi-detector CT scanner (SOMATOM Definition AS, Siemens AG, Germany, z-UHR (Ultra High Resolution).
C. Siemens Work station computer.
D. *SyngoVX*2009B, image fusion(Siemens AG imaging software multimodality reading, Germany).

Method

To measure the bone density of the alveolar bone, the axial plane was selected. The measurements were performed by the "Three-Dimension View" to indicate the planned point in three planes of space at the same time, given that the location of any point in any plane will be changed at the same time in the three planes, consequently the appropriate slice in the wanted section can be matched by the slice serial number to be opened on the "viewing" mode, then all the desired points would be measured. For the alveolar bone 51 points for each jaw was measured, 24 points for each side and 3 points between the right and left central incisors, the buccal cortical bone, cancellous bone and palatal/lingual cortical bone between each two teeth (central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar areas and tuberosity area in the maxilla and the retromolar pad area in the mandible) for both the left and right side in the male and female subjects were the bony sites of interest to perform the measurements. For the cortical bone, the center point of its thickness distal to the distal most surface of the tooth of interest was chosen 5 to 7 mm apical to the alveolar crest, the density of the cancellous bone was measured at the trabeculae, located halfway bucco-lingually between the buccal and palatal/lingual cortical plates of each tooth[17]. For the cortical bone distal to the second molar, 1 to 2 mm distal to the distal most surface of the distal root of the second molar, 5 to 7 mm from the alveolar crest ridge was the point of choice. For the cancellous bone, its density was measured at the trabeculae, located halfway buccolingually between the buccal and palatal/lingual cortical plate. Forthe cortical bone of the maxillary tuberosity and mandibular retromolar pad areas, its center point was chosen 3 to 4 mm away from the distal most surface of the last molar root, 5 to 7 mm from the alveolar crest. For the cancellous bone, the density was measured at the trabeculae, located halfway bucco-lingually (Figure 1).

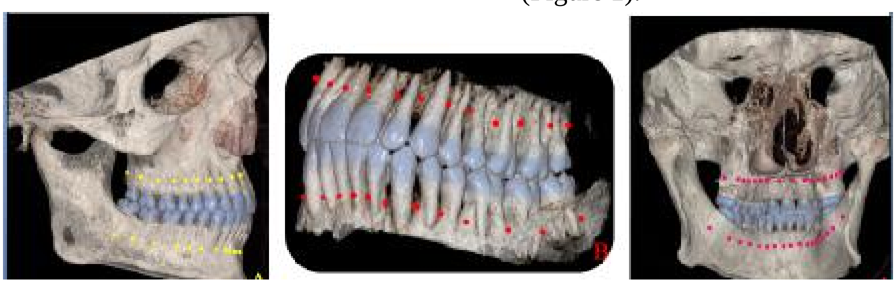

Figure 1: Measurement points on the alveolar bone of the maxilla and the mandible (A) on the buccal cortical bone (B) on the cancellous bone (C) on the palatal/lingual cortical bone

RESULTS

Bone density measurements are given according to Misch's[16] classification (Table 1). With this classification, the alveolar cortical bone in the maxilla was type 2 or 3 and for the mandible, the alveolar cortical bone was type 1and 2; whereas the density of the cancellous bone was type 3 and 4 in the maxilla and type 3 in the mandible in both groups. Table 2 showed that although there were significant differences between the two age groups for the maxilla and the mandible in some points, there were no significant differences in the others. For the buccal cortical bone in the maxilla, the differences were present anteriorly; while for the mandible, the differences occurred posteriorly. Regarding the alveolar cancellous bone, the differences occurred posteriorly in both the maxilla and the mandible.

For the maxillary palatal cortical bone, there were no significant differences between both groups; yet there were significant differences between the groups in the mandible except the point between the central incisors and the point distal to the canine. When comparing the buccal cortical bone in the maxilla and the mandible, the mandible was denser than the maxilla in both groups except the point distal to the maxillary central incisor at which there was statistically no significant difference.

For the cancellous bone, the mandible tended to be denser than the maxilla but statistically there was no significant difference anteriorly in both groups.

For palatal/lingual cortical bone there were significant differences between the maxilla and the mandible except the points between two centrals and central/lateral in group I and the points between two centrals and first/second premolars in group II which show no significant difference (Table 3).

DISCUSSION

In the present study the interradicular spaces were the areas of interest since they are generally the site of choice for mini implant placement for their ease of access, simplicity of procedure, and less traumatic placement [18].The results of the present study indicate that there were no significant differences between the right and left sides for all measured variables for both genders and in both groups. Therefore, all comparisons were performed with combined data. This could be supported by the observations of bilateral symmetry in bone density in the same anatomic sites that was reported for animal studies of rhesus monkey[19]. This investigation found no significant gender differences in the bone density which is in agreement with others [8,17,20]. This result can be explained by the presence of estrogen hormone in higher levels in the female subjects compared to the male subjects which is compensated by the exercises exerted by the males and the different chewing patterns. However other studies [21,22] showed that adult females had significantly greater cortical bone density than adult males did, this is in conflict with the finding of the present study suggesting that the presence of gender difference may be dependent on the different specific sites being examined in the bone or due the CT scanning machine setting being used. This study showed that the differences in bone density between group I and II were not statistically different at almost most sites. The age range for successful implantation is a matter of controversy. This study covered a broad age range, from 16 to 29 years since orthodontic treatment is mostly applied in that age. During childhood and adolescence, a bone mass increase till a plateau is reached between 18 and 23 years [23].

Also, in both gender, a large variance in bone density is observed among healthy individuals at the beginning of the third decade [24].The age differences can be attributed to the normal bone physiology and histology [25] and by changes in functional capacity, because maximum bite forces, masticatory muscle size, and muscle activity all tend to increase with age considering that muscle conditioning has a positive effect on bone density [26]. It was found that the maxillary buccal cortical alveolar bone at the canine and the premolars area has the highest bone density and the maxillary tuberosity area was found to have lowest bone density, these variations may be partly explained by the different anatomic characteristics in these areas [27]. In the present study, the bone density showed increase from the anterior to the posterior area in the mandible, this pattern might be explained by the higher functional demands placed on the posterior teeth since they receive two thirds of the occlusal loads [28] and by the increase in the longitudinal elastic modulus between the molar region and the symphysis [29].

In this study there is a general observation that the density of the cancellous bone is less than that of cortical bone which may be attributed to the fact that the cancellous bone forms a trabecular network pierced by many small blood vessels, lymphatic vessels, and nerves. These elements will reduce the amount of the basic chemical in bone, calcium phosphate, which gives bone its hardness and strength [30]. The bone density of the present study was compared between the maxilla and the mandible on the buccal and lingual sides of cortical bone and for the cancellous bone.

However, the mandible tended to be denser than the maxilla on both groups and all the mandibular posterior sites showed statistically greater bone densities while the differences in the anterior areas mostly were not significant especially in the cancellous bone. These results agree with other previous studies[8,17,31]. Concerning bone density differences between the maxilla and the mandible, it might be associated with the different biomechanical functions: the mandible is a force absorption unit; while the maxilla is a force distribution unit hence the maxilla has a thin cortical palate and fine trabecular bone [14].

Moreover, the obtained data of the present study may serve as tips for selecting the most suitable areas during mini implants installation and give clinicians, for the first time, reference data for clinical assessments of bone density for Iraqi subjects, both within and between ages and both within and between regions in human maxilla and mandible. Finally, it remains pertinent to be aware of the attendant risk of computed tomography, which continues to impart a higher radiation dosage compared to conventional radiographs, but to weigh this against the power of the diagnostic information that it can provide.

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Table 1: Distribution of bone density according to Misch's classification in the maxilla and the mandible

Site	Bone	Group	1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-	Tuberosity/ Retromolar pad areas
MAXILLA	Buccal Cortical	Group I	3	2	2	2	2	2	2	2	3
		Group II	3	2	2	2	2	2	2	2	3
	Cancellous	Group I	3	3	3	4	4	4	3	3	4
		Group II	3	3	3	4	4	4	3	3	4
	Palatal Cortical	Group I	2	2	2	2	2	2	2	2	3
		Group II	2	2	2	2	2	2	2	2	3
MANDIBLE	Buccal Cortical	Group I	2	2	2	2	2	1	1	1	1
		Group II	2	2	2	2	1	1	1	1	1
	Cancellous	Group I	3	3	3	3	3	3	3	3	3
		Group II	3	3	3	3	3	3	3	3	3
	Lingual Cortical	Group I	2	2	2	2	1	1	1	1	1
		Group II	2	2	2	2	2	1	1	1	1

Table 2: Comparison between the groups in the alveolar buccal cortical, cancellous and palatal/lingual cortical bones of the maxilla and the mandible

			BUCCAL CORTICAL			CANCELLOUS			PALATAL/LINGUAL CORTICAL		
	Points	Groups	Descriptive statistics Mean	Descriptive statistics S.D	p-value	Descriptive statistics Mean	Descriptive statistics S.D	p-value	Descriptive statistics Mean	Descriptive statistics S.D	p-value
MAXILLA	1-1	I	829.10	98.47	0.59 (NS)	411.13	118.05	0.73 (NS)	755.96	74.54	0.75 (NS)
		II	840.35	75.85		399.90	138.55		878.11	74.86	
	1-2	I	1006.85	113.43	0.004 (HS)	420.12	121.17	0.76 (NS)	1119.62	124.32	0.79 (NS)
		II	1076.24	74.11		412.22	133.99		1126.25	72.12	
	2-3	I	885.05	95.65	0.006 (HS)	409.84	123.16	0.84 (NS)	1004.48	94.49	0.36 (NS)
		II	948.21	84.46		404.42	123.83		1029.43	108.66	
	3-4	I	1051.27	103.37	0.38 (NS)	330.10	98.63	0.84 (NS)	1168.01	120.77	0.39 (NS)
		II	1072.70	87.37		347.20	95.93		1138.16	120.25	
	4-5	I	1123.83	112.74	0.14 (NS)	300.35	93.45	0.08 (NS)	1217.47	112.06	0.96 (NS)
		II	1164.51	102.04		342.35	83.80		1218.71	83.59	
	5-6	I	1126.30	116.14	0.52 (NS)	319.81	95.48	0.70 (NS)	1218.95	112.97	0.72 (NS)
		II	1144.81	109.62		339.56	87.38		1209.02	90.55	
	6-7	I	976.24	81.15	0.06 (NS)	408.81	101.72	0.76 (NS)	1066.30	95.60	0.30 (NS)
		II	1016.35	79.38		401.37	84.67		1085.41	65.02	
	7-	I	961.21	87.10	0.06 (NS)	418.53	100.59	0.52 (NS)	1037.42	90.60	0.11 (NS)
		II	1002.54	83.55		401.61	97.08		1073.05	70.01	
	Tuberosity area.	I	500.64	85.48	0.11 (NS)	239.07	102.54	0.01 (S)	602.29	110.70	0.66 (NS)
		II	546.30	119.43		190.07	54.95		615.11	99.03	
MANDIBLE	1-1	I	895.88	89.96	0.98 (NS)	427.43	99.83	0.47 (NS)	904.62	98.01	0.72 (NS)
		II	895.31	98.84		405.14	122.94		894.95	92.57	
	1-2	I	1031.94	104.36	0.87 (NS)	437.18	101.61	0.52 (NS)	1134.61	93.92	0.001 (HS)
		II	1036.13	82.84		418.21	104.72		1028.90	91.98	
	2-3	I	1087.05	105.53	0.81 (NS)	465.12	100.55	0.14 (NS)	1187.38	92.54	0.001 (HS)
		II	1094.01	99.13		422.64	110.97		1080.91	108.49	
	3-4	I	1167.07	92.97	0.06 (NS)	480.34	92.73	0.06 (NS)	1240.18	91.06	0.38 (NS)
		II	1214.69	85.98		426.58	107.46		1216.07	105.86	
	4-5	I	1228.04	85.58	0.07 (NS)	486.35	109.85	0.054 (NS)	1295.89	90.43	0.048 (S)
		II	1277.19	94.31		428.00	122.88		1242.97	93.91	
	5-6	I	1298.57	82.66	0.68 (NS)	501.56	108.94	0.09 (NS)	1338.10	94.20	0.02 (S)
		II	1309.94	101.79		427.03	115.54		1272.85	86.32	
	6-7	I	1400.75	99.67	0.02 (S)	509.96	114.03	0.04 (S)	1424.83	99.37	0.024 (S)
		II	1475.58	105.37		436.73	112.64		1364.87	75.64	
	7-	I	1428.58	93.28	0.01 (S)	520.00	113.76	0.008 (HS)	1442.99	90.76	0.007 (HS)
		II	1505.88	109.79		428.56	129.94		1369.64	87.48	
	Retromolar pad area.	I	1467.37	103.70	0.009 (HS)	512.72	111.06	0.012 (S)	1435.77	76.67	0.001 (HS)
		II	1549.42	108.94		427.86	109.5		1344.92	100.15	

P > 0.05 NS Non-significant
P ≤0.05 S Significant
P ≤0.01 HS Highly significant

Table 3: Difference between the maxilla and mandible regarding the alveolar buccalcortical, cancellous and palatal/lingual cortical bone in both groups

		BUCCAL CORTICAL						CANCELLOUS						PALATAL/LINGUAL CORTICAL					
		Group I			Group II			Group I			Group II			Group I			Group II		
Point	**Jaw**	**Mean**	**S.D**	**p-value**	**Mean**	**S.D**	**p-value**	**Mean**	**S.D**	**p-value**	**Mean**	**S.D**	**p-value**	**Mean**	**S.D**	**p-value**	**Mean**	**S.D**	**p-value**
1-1	**Max.**	829.10	98.47	0.03	840.35	75.85	0.02	411.13	118.05	0.63	399.90	138.55	0.87	870.92	104.54	0.29	878.11	74.86	0.43
	Man.	895.88	89.96	(S)	895.31	98.84	(S)	427.43	99.83	(NS)	405.14	122.94	(NS)	904.62	98.01	(NS)	894.95	92.57	(NS)
1-2	**Max.**	1006.85	113.43	0.46	1076.24	74.11	0.045	420.12	121.17	0.62	412.22	133.99	0.84	1119.62	124.32	0.66	1126.25	72.12	0.000
	Man.	1031.94	104.36	(NS)	1036.13	82.84	(S)	437.18	101.61	(NS)	418.21	104.72	(NS)	1134.61	93.92	(NS)	1028.90	91.98	(VHS)
2-3	**Max.**	885.05	95.65	0.000	948.21	84.46	0.000	409.84	123.16	0.12	404.42	123.83	0.54	1004.48	94.49	0.000	1029.43	108.66	0.05
	Man.	1087.05	105.53	(VHS)	1094.01	99.13	(VHS)	465.12	100.55	(NS)	422.64	110.97	(NS)	1187.38	92.54	(VHS)	1080.91	108.49	(S)
3-4	**Max.**	1051.27	103.37	0.000	1072.70	87.37	0.000	330.10	98.63	0.000	347.20	95.93	0.003	1168.01	120.77	0.04	1138.16	120.25	0.008
	Man.	1167.07	92.97	(VHS)	1214.69	85.98	(VHS)	480.34	92.73	(VHS)	426.58	107.46	(HS)	1240.18	91.06	(S)	1216.07	105.86	(HS)
4-5	**Max.**	1123.83	112.74	0.002	1164.51	102.04	0.000	300.35	93.45	0.000	342.35	83.80	0.002	1217.47	112.06	0.02	1218.71	83.59	0.28
	Man.	1228.04	85.58	(HS)	1277.19	94.31	(VHS)	486.35	109.85	(VHS)	428.00	122.88	(HS)	1295.89	90.43	(S)	1242.97	93.91	(NS)
5-6	**Max.**	1126.30	116.14	0.000	1144.81	109.62	0.000	319.81	95.48	0.000	339.56	87.38	0.000	1218.95	112.97	0.001	1209.02	90.55	0.005
	Man.	1298.57	82.66	(VHS)	1309.94	101.79	(VHS)	501.56	108.94	(VHS)	427.03	115.54	(VHS)	1338.10	94.20	(HS)	1272.85	86.32	(HS)
6-7	**Max.**	976.24	81.15	0.000	1016.35	79.38	0.000	408.81	101.72	0.004	401.37	84.67	0.16	1066.30	95.60	0.000	1085.41	65.02	0.000
	Man.	1400.75	99.67	(VHS)	1475.58	105.37	(VHS)	509.96	114.03	(HS)	436.73	112.64	(NS)	1424.83	99.37	(VHS)	1364.87	75.64	(VHS)
7-	**Max.**	961.21	87.10	0.000	1002.54	83.55	0.000	418.53	100.59	0.004	401.61	97.08	0.35	1037.42	90.60	0.000	1073.05	70.01	0.000
	Man.	1428.58	93.28	(VHS)	1505.88	109.79	(VHS)	520.00	113.76	(HS)	428.56	129.94	(NS)	1442.99	90.76	(VHS)	1369.64	87.48	(VHS)
Tuberosity/ Retromolar pad areas	**Max.**	500.64	85.48	0.000	546.30	119.43	0.000	239.07	102.54	0.000	190.07	54.95	0.000	602.29	110.70	0.000	615.11	99.03	0.000
	Man.	1467.37	103.70	(VHS)	1549.42	108.94	(VHS)	512.72	111.06	(VHS)	427.86	109.5	(VHS)	1435.77	76.67	(VHS)	1344.92	100.15	(VHS)