A Clinical Method for Prediction of Alveolar Bone Mineral Density in the Area between the Second Premolar and First Molar in Iraqi Adults with Class I Occlusion

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ABSTRACT

Background: Orthodontic mini-implants are increasingly used in orthodontics and the bone density is a very important factor in stabilization and success of mini-implant. The aim of this study was to observe the relationship among maximum bite force (MBF); body mass index (BMI); face width, height and type; and bone density in an attempt to predict bone density from these variables to eliminate the need for CT scan which have a highly hazard on patient.

Materials and Methods: Computed tomographic (CT) images were obtained for 70 patients (24 males and 46 females) with age range 18-30 years. The maxillary and mandibular buccal cortical and cancellous bone densities were measured between 2nd premolar and 1st molar at two levels from the alveolar crest (3 and 6 mm). Face height and width were measured from CT. Clinically; Maximum bite force was measured on first molar region unilaterally by a digital device. The sample was divided into two groups according to the body mass index into; normal and overweight.

Results: The results obtained showed that there were no statistical significant differences in MBF or bone density in both genders. Only the cortical bone density in maxilla in overweight group tended to be higher than normal BMI group. The face width and height correlated significantly negatively with MBF which correlated significantly positively with cortical bone density.

Conclusions: It was concluded that a prediction of cortical bone density of preselected areas can be made from maximum bite force, body mass index and inter-zygomatic width.

Key words: Bone density, bite force, computerized tomography, orthodontic mini-implant. (J Bagh Coll Dentistry 2015; 27(4):161-167).

INTRODUCTION

Much of the success of orthodontic treatment depends upon careful anchorage preparation [(1)]. Concerning density of the alveolar bone are essential for selecting sites for mini-implant placement and predicting success [(2)].

The size of an individual (weight and height) may play an important role in the size, thickness and density of the bone [(3)]; on the other hand a positive correlation was found between bite force and body height and weight [(4)].

The growth facial pattern has an influence on the morphology of labial/buccal and lingual bone plates [(5,6)]. The subjects in the hyperdivergent group had significantly lower bone densities on the buccal side than hypodivergent subjects for both sex [(7)]. Bite force also varies with different facial profiles. It is greater in adults with a rectangular craniofacial morphology and skeletal deep bite than in those who have a long face and open bite [(8)].

Progressive bone loading changes the amount and density of bone, the bone is given time to respond to gradual increase in occlusal load. This increases the quantity of bone and improves bone density [(9)].

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Wherefore, the knowledge of how the body mass index, maximum bite force, and facial types, affecting on the bone mineral density (BMD) were considered in this study in an attempt to predict BMD from related variables.

MATERIALS AND METHODS

Sample:

The sample of the present study was selected from the patients who were attending the Computerized Tomography Department in Al Karkh General Hospital in Baghdad. Only 70 patients (24 males and 46 females with an age range from 18 to 30 years) who met following special criteria were selected.

1- No history of systemic disease and no previous chronic use of any medication that could affect bone density.
2- No history of previous orthodontic treatment and/or orthognathic surgery.
3- No regular smoking and/or alcohol consumption.
4- No clear facial asymmetry and no history of previous facial trauma assessed by visual examination.
5- No TMJ problem by clinical examination.
6- Skeletal and dental Class I.

The following criteria were considered in selected side:

a. No missing teeth excluded 3rd molar.
b. Well aligned teeth with no cross bite, rotation, spacing or crowding more than 2 mm [10].
c. No massive carious lesions and/or filling restorations and no teeth wearing.
d. No pathological lesion in the examined area which determined by clinical and radiographic examination (CT).
e. No pathological periodontal problem according to the gingival index and no alveolar bone loss from CT.

Method:

Patients were informed about the aims and objectives of the study. For each patient, the agreement to participate in this study was taken during his/her CT scan appointment.

BMI Measurement: It's measured by dividing weight (kg)/height^2 (m^2).

Bite Force Registration: Maximum bite force was measured using bite force measuring device (GM10; Nagano KeiKi Company, LTD Tokyo, Japan) (Figure 1); the device consisted of hydraulic pressure gauge and a biting element made of a vinyl material encased in a plastic tube called disposable occlusal cap that will be replaced for each subject; by putting the device between upper and lower first permanent molars unilaterally in the left side or right side (the side fulfill the inclusion criteria) and the subject was asked to bite firmly for a few seconds as much as he/she can until the maximum bite force was obtained then the bite force was calculated in Newton and displayed digitally. This bite measurement was repeated three times with 2-3 minutes interval between records, and the highest value was registered.

Figure (1): Occlusal Force-Meter GM10.

Computerize Tomography (CT) Scan Measurements were taken as following:

- Measurement of ANB Angle**:** For further assurance that the selected subject was skeletal Class I, ANB angle was measured according to Steiner [11] by using the cephalometric option.
- Measurement of Bone Loss**:** Alveolar bone crest level was measured in 3 dimensions facial bone (skull).The alveolar crest should be slightly apical to the cementoenamel junction (CEJ) by approximately 1.5 to 2 mm [12].
- Measurement of Bone Density: Bone density was measured in the axial view in mid-way between 2nd premolar and 1st molar in the selected side (left or right). Bone density of the alveolar bone was measured at two levels from the alveolar crest (3 and 6 mm) for the buccal cortical and cancellous bones in both jaws. The measurement of buccal cortical bone density was made in the center point of its thickness. The measurement of cancellous bone density was made at the trabeculae, located halfway buccolingually between the buccal and palatal/lingual cortical plates [13]. Densities of the bone were measured in Hounsfield units (HU).
- Measurement of Facial Type: Facial types were measured in 3dimensions facial bone (skull) by measuring facial height(distance between the point nasion and menton in bone) and facial width (inter-zygomatic distance) (Figure 2).The facial typeswere determined according to the facial index which was calculated by dividing facial height *100/ facial width [14].

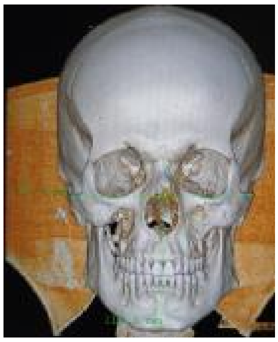

Figure (2): Measurement of Facial Height and Width.

RESULTS

The measurements of bone density were considered the principle outcome variable in the current study, other variables being used to predict this outcome. The face dimensions which include face height and width were considered instead of face type since the entire sample has normal face.

The bone density at two preselected points (3 and 6 mm) in each jaw was combined and the average of them was used,

Table 1 showed that there were no statistically significant gender differences in bite force and bone density. Based on this result, both gender groups were combined.

The samples of present study were including normal and overweight categories of the international classification of BMI[15]. Table 2 showed that there were no statistically significant BMI differences in bite force. Regarding to bone density, only the cortical bone density in maxilla shows a statistical significant difference.

Table 3 showed that the relationship of face width and height with MBF was negatively significant.

Table 4 showed that the relationship of the bone density of cortical bone in the maxilla and mandible had a statistically significant relation with MBF while the cancellous bone had not. The bone density (cortical and cancellous) in the maxilla and mandible with face dimensions (height and width) was statistically non-significant.

To study the net and independent effect of gender, BMI, MBF, face length and width on cortical bone density in maxilla and mandible, a multiple linear regression model was used. A forward step inclusion algorithm was used to select among the suggested explanatory variables only those that significantly affect cortical bone density in maxilla and mandible.

Maxilla (Table 5)

The final prediction model was based on a combination of MBF, BMI and face width.

This model explains 21.9% of observed variation in the outcome variable (bone density).

MBF, BMI and face width had a statistically significant direct linear association with cortical bone density. Cortical bone density is expected to increase for each variable after adjusting (controlling for the confounding effect of other explanatory variable included in model).

For each 1(N) increase in MBF, the cortical bone density in maxilla is expected to increase by 0.5 (HU).

For each 1(Kg/m^2) increase in BMI, the cortical bone density in maxilla is expected to increase by 14.3 (HU).

For each 1(mm) increase in face width, the cortical bone density in maxilla is expected to increase by 4.2 (HU).

Finally, depending on the equation below we can predict the cortical bone density in maxilla.

y = -33.1+(0.5*MBF)+(14.3*BMI)+(4.2*face width)

Mandible (Table 6)

The final prediction model was based on MBF only.

This model explains 9.6% of observed variation in the outcome variable (bone density).

MBF had a statistically significant direct linear association with cortical bone density.

For each 1(N) increase in MBF, the cortical bone density in mandible is expected to increase by 0.51 (HU),

So depending on the equation below, we can predict the cortical bone density in mandible.

y=1069.6+ (0.51*MBF)

- y = cortical bone density.

Table (1): Gender Differences of Bite Force (N) and Bone Density (HU) (Cortical and Cancellous) in Maxilla and Mandible.

Variables			Total Samples (N=70)					
			N	**Range**	**Mean**	**SD**	**SE**	**P-value**
MBF		♂	24	182-587	326.7	111.6	22.8	0.92 [NS]
		♀	46	122-513	324.0	112.3	16.6	
Maxilla	**Cortical BMD**	♂	24	823-1327 D_3-D_1	1030.7 D_2	116.0	23.7	0.26 [NS]
		♀	46	570-1347 D_3-D_1	985.8 D_2	175.5	25.9	
	Cancellous BMD	♂	24	142-408 D_5-D_3	283.2 D_4	83.9	17.1	0.13 [NS]
		♀	46	119-458 D_5-D_3	251.4 D_4	82.2	12.1	
Mandible	**Cortical BMD**	♂	24	1039-1513 D_2-D_1	1283.0 D_1	156.3	31.9	0.11 [NS]
		♀	46	784-1614 D_3-D_1	1209.7 D_2	191.5	28.2	
	Cancellous BMD	♂	24	157-449 D_4-D_3	290.8 D_4	92.6	18.9	0.25 [NS]
		♀	46	149-458 D_5-D_3	265.2 D_4	84.8	12.5	

Table (2): BMI Differences of Bite Force (N) and Bone Density (HU) (Cortical and Cancellous) in Maxilla and Mandible.

Variables		BMI	Total Samples (*N*=70)					
			N	Range	Mean	SD	SE	P-value
MBF		Normal	43	140-587	329.6	114.5	17.5	0.66 [NS]
		Overweight	27	122-490	317.4	107.6	20.7	
Maxilla	Cortical BMD	Normal	43	570-1241 D_3-D_2	971.5 D_2	147.0	22.4	0.046 [S]
		Overweight	27	727-1347 D_3-D_1	1048.6 D_2	166.5	32.0	
	Cancellous BMD	Normal	43	121-419 D_5-D_3	261.2 D_4	79.7	12.2	0.89 [NS]
		Overweight	27	119-458 D_5-D_3	264.1 D_4	91.0	17.5	
Mandible	Cortical BMD	Normal	43	784-1513 D_3-D_1	1209.3 D_2	168.5	25.7	0.14 [NS]
		Overweight	27	880-1614 D_2-D_1	1275.5 D_1	199.1	38.3	
	Cancellous BMD	Normal	43	154-449 D_4-D_3	271.3 D_4	74.8	11.4	0.75 [NS]
		Overweight	27	149-458 D_5-D_3	278.3 D_4	106.5	20.5	

Table (3): Relationship of MBF (N) with Face Dimensions (mm).

Variables		MBF Total Samples (*N*=70)					ANOVA trend
		N	Range	Mean	SD	SE	P-value
Face Height	Lowest quartile≤100.9	18	218-499	374.7	88.0	20.7	0.011 [S]
	Interquartile range 101.0 - 111.5	36	122-587	321.0	118.1	19.7	
	Highest quartile≥111.6	16	171-490	277.6	101.0	25.3	
Face Width	Lowest quartile ≤116.2	18	146-499	365.0	100.9	23.8	0.044 [S]
	Interquartile range 116.3 - 126.7	35	129-587	321.7	109.6	18.5	
	Highest quartile≥126.8	17	122-513	288.9	117.6	28.5	

DISCUSSION

MBF was measured in the 1st molar region since it is typically obtained in the 1st molar area [16] as the 1st permanent molar is the largest tooth in maxillary and mandibular arch [17], and its position is considered as a key and fulcrum of functional occlusion [18].

The measured points were preselected to be at 3 and 6 mm from alveolar crest in order to be in the alveolar bone since it was more favorable for mini-implant success than free mucosa [19].

The area of the alveolar bone between 2nd premolars and 1st molars in maxilla was preselected to measure the bone density since it is the most proper area for insertion of mini-implant [20]. The same area was preselected in the mandible for standardization.

Attention was not paid to the side because previous studies demonstrated no significant side differences regarding bite force [21,22], and the bone density [13,23,24].

In the present study there were no statistically significant gender differences in bite force and bone density. This result can be attributed to the occlusal force gauge used in this study and since males and females eat essentially the same types of food, the strain produced during mastication might be expected to be similar, as would bone density. This result is in agreement with Chun and Lim [25] and Palinkas et,al.,[26] and in disagreement with others [21,27,28] who found males were present higher maximum bite force than females. Furthermore, this result regarding bone density comes in accordance with others [13,24]. It can be reflected clinically by previous studies that found no differences in the success rate and stability of mini implants between male and female subjects[29,30].

Table (4): Relationship of Bone Density in Maxilla and Mandible (HU) with MBF (N) and Face Dimensions (mm).

Variables			*N*	Cortical Bone Density				p-value	Cancellous Bone Density				p-value
				Range	Mean	SD	SE		Range	Mean	SD	SE	
Maxilla	MBF	lowest quartile ≤213	18	708-1327 D_3-D_1	909.1 D_2	155.3	36.6	0.02 [S]	119-368 D_5-D_3	241.3 D_4	77.4	18.2	0.57 [NS]
		Interquartile range 232-413	36	570-1301 D_3-D_1	1031.4 D_2	157.8	26.3		148-458 D_5-D_3	274.9 D_4	83.3	13.9	
		Highest quartile ≥ 414	16	828-1347 D_3-D_1	1036.9 D_2	126.4	31.6		121-383 D_5-D_3	257.6 D_4	90.7	22.7	
	Face Height	Lowest quartile≤100.9	18	635-1301 D_3-D_1	995.1 D_2	170.5	40.2	0.76 [NS]	142-458 D_5-D_3	264.7 D_4	84.0	19.8	0.85 [NS]
		Interquartile range 101.0 - 111.5	35	570-1327 D_3-D_1	999.4 D_2	157.0	26.2		119-419 D_5-D_3	257.6 D_4	91.8	15.3	
		Highest quartile ≥111.6	17	770-1347 D_3-D_1	1012.2 D_2	156.7	39.2		168-408D_4-D_3	270.2 D_4	66.0	16.5	
	Face Width	Lowest quartile ≤116.2	18	635-1301 D_3- D_1	985.2 D_2	179.4	42.3	0.78 [NS]	142-458 D_5-D_3	267.6 D_4	80.9	19.1	0.78 [NS]
		Interquartile range 116.3 - 126.7	35	570-1347 D_3 – D_1	1009.7 D_2	162.6	27.5		119-419 D_5-D_3	261.1 D_4	92.8	15.7	
		Highest quartile ≥126.8	17	770-1168D_3-D_2	1000.6 D_2	131.0	31.8		121-408 D_5-D_3	259.2 D_4	69.6	16.9	
Mandible	MBF	lowest quartile ≤213	18	784-1487 D_3-D_1	1128.3 D_2	198.7	46.8	0.009 [HS]	149 - 439 D_5-D_3	267.9 D_4	94.9	22.4	0.25 [NS]
		Interquartile range 232-413	36	880-1614 D_3-D_1	1263.9 D_1	153.8	25.6		157 - 449 D_4-D_3	264.3 D_4	75.0	12.5	
		Highest quartile ≥ 414	16	1039-1609 D_2-D_1	1289.2 D_1	185.3	46.3		154 - 458 D_4-D_3	302.5 D_4	104.6	26.2	
	Face Height	lowest quartile≤100.9	18	863-1614 D_2-D_1	1229.4 D_2	165.7	39.0	0.71 [NS]	154 - 430 D_4-D_3	291.8 D_4	92.9	21.9	0.92 [NS]
		Interquartile range 101.0 - 111.5	35	880-1513 D_2-D_1	1229.2 D_2	178.4	29.7		159- 449 D_4-D_3	258.4 D_4	75.5	12.6	
		Highest quartile≥111.6	17	784-1609 D_3-D_1	1253.5 D_1	217.3	54.3		149 - 458 D_5-D_3	288.9 D_4	105.5	26.4	
	Face Width	Lowest quartile ≤116.2	18	863-1614 D_2-D_1	1205.0 D_2	172.4	40.6	0.99 [NS]	154 - 430 D_4-D_3	298.3 D_4	86.8	20.5	0.99 [NS]
		Interquartile range 116.3 - 126.7	35	880-1609 D_2-D_1	1264.1 D_1	182.4	30.8		157 - 449 D_4-D_3	257.2 D_4	79.6	13.5	
		Highest quartile ≥126.8	17	784-1527 D_3-D_1	1206.1 D_2	193.6	47.0		149 - 458 D_5-D_3	282.6 D_4	101.8	24.7	

Table (5): Prediction of Cortical Bone Density of Maxilla.

Variables	Partial regression coefficient	p-value
Constant	-33.1	0.91 [NS]
MBF(N)	0.5	0.002 [HS]
BMI(Kg/m^2)	14.3	0.015 [S]
Face width (mm)	4.2	0.32[S]

Table (6): Prediction of Cortical Bone Density of Mandible.

Variables	Partial regression coefficient	p-value
Constant	1069.6	0.001[HS]
MBF(N)	0.51	0.009 [HS]

It was found that there were no statistically significant BMI differences in bite force and this result agree with others [8,22,31-33]. The relationship of the cortical bone density of maxilla with BMI was statistically significant, while of mandible was not. This may be explained as the masseter muscle thickness was found to be positively correlated to BMI [34]. Furthermore, muscle weight is an important determinant of bone mass because the weight of a muscle reflects the forces that it exerts on bones to which it is attached [35] and since the maxilla is the fixed bone, so the cortical bone of maxilla is logically more affected than the mandibular one.

For the relationship of face width and height with MBF it was negatively significant. This may be explained as any increase in the width and height of face may be associated with an increase in surface area to which that force is distributed, but not necessarily associated with an increase in the occlusal contact area which is considered as the key determinant affecting bite force. Furthermore, the masticatory muscles of subjects with increase height of face were less efficient in generating bite force at a particular point on the lever arm[36], and the size of masseter muscle also decreased, and since bite force magnitude depends on the size of the masseter muscle, the lever arm lengths of bite force and muscle forces [37].

For the relationship of bone density (cortical and cancellous) in the maxilla and mandible with face dimensions (height and width) was statistically non-significant. Since the sample of the present study included normal face only, so this may explain these results.

On the other hand, the density of cortical bone in the maxilla and mandible had a statistically significant relation with MBF, as with increasing MBF, the cortical bone density increase, while cancellous bone density in maxilla and mandible had a statistically non-significant relationship with MBF.

The demonstration of bone density by means of CT scanning directly depends on the quantity of inorganic crystals contained in the bone tissue. The cancellous bone forms a trabecular network, surrounds marrow spaces that may contain either fatty or hematopoietic tissue, lies subjacent to the cortical bone, and makes up the main portion of a bone [38]. Most of mastication forces are directed to the cortical bone due to the teeth root inclination toward the cortical bone [39]. Force applied to teeth act as mechanical stimulus to the underlying cortical bone and when they reach certain thresholds they influence bone remodeling [40]. All the above may explain why the cortical bone density was correlated to the MBF while cancellous bone was not.

Finally since the bone density is a critical variable in determining the success of orthodontic mini-implant and because it remains pertinent to be aware of the attendant risk of computed tomography, which continues to impart a high radiation dosage, the obtained data of this study will serve as a preliminary preparation clarified the possibility of prediction of bone density from novel, easy, and non-invasive method which depends on simple things (MBF, BMI and width of face) which all can obtained clinically without needing the patient to expose to the hazards of CT scan.

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