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Relationship between Buccolingual First Mandibular Molar Inclination and Alveolar Bone Thickness by Cone-Beam Computed Tomography

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Keywords: Inclination; Cone-Beam Computed Tomography; Bone thickness; Length and width arch; Molar.

Abstract

Objective: The purpose of this study was to evaluate the relationship between different buccolingual molar inclination and cortical bone thickness of the first mandibular molar.

Materials and methods: The sample consisted of seventy-five cone-beam computed tomography. The inclination of the mandibular first molar, mandibular arch length, and width and the buccal and lingual bone thickness of the mandibular first molar in three different levels (crest, midroot, and apex) were measured by OnDemand3D application. To analyze the data spearman and Pearson correlation coefficient (depending on the type of variable distribution) were used. The significance of the outcomes was evaluated by considering the p-value less than 0/05. The ethical code was not necessary due to the fact that patients underwent CBCT imaging for various reasons such as implant treatment, etc., no additional dose or additional cost was imposed on the patient and also the results are mentioned in general and without mentioning the names of patients. There was no ethical consideration and no need for informed consent. All procedures were performed under the supervision of a radiologist and with his permission.

Results: In this study, we found out the positive relation between tooth inclination and bone thickness in MBA (Mesial Buccal Apex), DBA (Distal Buccal Apex), MLC (Mesial Lingual Crest) and DLC (Distal Lingual Crest) and negative relation in DBC (Distal Buccal Crest), DBM (Distal Buccal Midroot), DLM (Distal Lingual Midroot), DLA (Distal Lingual Apex) and MLM (Mesial Lingual Midroot) were a negative

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relationship. The result also showed that there was no significant relationship between molar inclination, mandibular arch length and width, and bone thickness in MBM (Mesial Buccal Midroot).

Conclusions: According to the result of this study, by increasing the tooth inclination, the bone thickness in MBA, DBA, MLC, and DLC increases and in DBC, DBM, DLM, DLA, and MLM decrease.

Introduction

The present paper seeks to investigate the relationship between the tooth inclination, the length and width of the mandibular arch, and the thickness (density) of the cortical bone in the buccal and lingual aspect of first mandibular molar using CBCT imaging.

Dehiscence is a defect in the alveolar plate, in which a large surface of the root has no bone cover.

Fenestration is a defect in the alveolar plate in which there is a part of the root without bone covering; however, there is a bone in the CEJ area of the tooth. Fenestration can gradually become dehiscence [1].

External root resorption is rooted in PDL, and it starts from the outer surface of the root, which, if not treated, results in loss of the tooth, and at times, no treatment can help [2].

In the study of Karine Evangelista et al. in 2010, the prevalence of dehiscence was observed to be 51.9% of teeth, and the prevalence of fenestration was 35.1% of teeth. These defects occur primarily (anatomical structure of the teeth and jaw) or secondary (due to orthodontic treatment, abrasion, etc.) [3]. Fenestration, Dehiscence, and Root resorption hold various risk factors such as insufficient maxilla width [4] and low alveolar bone thickness [1].

By becoming aware of these risk factors, during orthodontic treatment, we can perform treatments with minimal complications. CBCT imaging should be used in order to check such matters, in that it does not have panoramic radiography distortion and enlargement, it also does not have the high dose of exposure, and finally, it does not have the cost of CT imaging.

The benefits of CBCT include easy imaging, reduction of radiation area space, increased immunity, high image resolution, high spatial resolution, short scan time, and reduced metal artifact.

Some of the disadvantages of CBCT over CT can be reduced detail resolution, reduced contrast power, and reduced scan quality due to streaking artifact and beam hardening even on a small scale [5].

The CBCT reduces image artifacts compared to conventional CT; however, these artifacts continue to occur due to the presence of radiopaque materials such as metals, Gutta Percha, and sealer [6].

The aim of the present study is to determine the relationship between the tooth inclination of the first mandibular molar and the length and width of the mandibular arch with the thickness of the cortical buccal and lingual bone of first mandibular molar. Various studies have been conducted on this subject:

Tulstunov L. et al., in 2016, investigated the relationship between the mandible angulation of the third mandibular molar and lingual bone thickness by CBCT, he also examined bone thickness in three areas. The thickness mean of the bone in the region was equivalent to the height of the CEJ of the second molar, and it was 1.4 mm in the mid-root, and the apex was 1.07 mm. The thickness of the bone in the mid-root of the horizontal and mesioangular teeth (angle of fewer than 85 degrees) was significantly higher than the disto-angular teeth (angle of more than 85 degrees). Correlation between bone thickness and buccolingual direction was clearly associated with bone perforation in mid-root and apex [7].

In the study of Nuengrutai Yodthony et al. in 2013, he showed that changes in alveolar bone thickness

depended on the speed of tooth movement, rates of tooth inclination and intrusion change, and did not relate to the initial thickness of the bone [8].

In a study by Hyo-won Ahn et al. in 2013, according to CBCT images, the changes in the anterior maxillary teeth retractions were investigated, and it was found that, after closing the space on the palatal and labial surfaces of the teeth, the thickness of the bone decreased significantly, which reduced the thickness of the bone On the palatal side, more than labial. The dehiscence rate in the cervical plane on the palatal side was also more than the labial side [10].

In the Yo-Lou Tian et al. study in 2015, the central maxillary teeth with a lingual inclination had lower bone thickness in the apex area and the alveolar bone defects, such as its fenestration, were higher in the labial than in comparison to the normal inclination and labial dentinal group [11].

In a study by Ahmet Yagci et al. in 2012, the prevalence of dehiscence and fenestration in individuals with Cl. 1 jaw structure was shown identical in both jaws; however, it was shown more in the mandible in Cl. 2 and Cl. 3 [12].

In the study by W. Shewinvanakitkul et al., in 2011, the mandibular inclination means of the first molar tooth was 74.6 ± 4.7, and the mandibular width means was 40.9 ± 2.7. Also, the inclination of the first mandibular molar in Cl. 1 subjects was lower than that of Cl. 2 [2].

The study of Akira Horiuchi et al. (1998) stated that root resorption is one of the most common iatrogenic incidents during orthodontic treatment [4].

A study by Birgit Thilander et al. (1983) on six dogs illustrated that after the maintenance of the teeth in their original position, after moving them, the resorbed bone was healed during this period and also the bone defects were resolved [14].

Methods and materials

In this study, we measured the buccolingual inclination of the first mandibular molar, mandibular arch length and width, and cortical buccal bone thickness of first mandibular molar lingual in three areas of crust, mid-root, and apex, using the CBCT of eligible patients who were admitted to a private radiology clinic in Tehran during the years 2016 and 2017.

Our study population had the following characteristics:

1) Ages of 18 to 35 (the age of 18 due to the complete development of the teeth and the development of the vertical dimension, the age of 35 due to the bone density has not changed much and usually does not have advanced periodontitis/ Periodontal diseases).

2) The presence of all permanent teeth to the first mandibular molar.

3) Lack of cleft palate and skeletal malformation.

4) The absence of pathologic lesions in the mandible.

5) No history of trauma in the mandible.

6) No history of orthodontic treatment, also no ongoing orthodontic treatment [2].

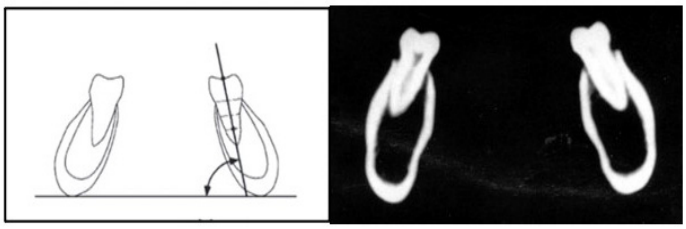
The aim of our study was to calculate the correlation coefficient between the inclination of first mandibular molar and cortical bone thickness in the first mandibular molar, mandibular length, and width, and mandibular arch. With 95% confidence coefficient and the confidence interval of 0.35 with a default value of R = 0.5, the number of the required samples was calculated 75. Sample size calculations were conducted in the PASS (Power and Sample Size Calculator) software.

We selected 75 samples based on the available criteria from the 1600 available CBCTs in the clinic, after which a patient's demographic information was obtained, including age, gender, and case number. In the end, the length and width of the mandibular arch, the inclination of the mandibular molar, and the buccal and lingual cortical bone thickness of the first mandibular molar were calculated using the OnDemand 3D software on CBCT images. All measurements were performed by an observer (dental student). Each of the variables was measured as follows:

1) In order to determine the inclination of the first mandibular molar, at first, a line was drawn from the lower mandibular board (basal line). The longitudinal axis of the tooth was then drawn (as below). The formed angle between these two lines was considered equivalent to the buccolingual inclination of the tooth [2].

Table 1: Research variables, measurement type, and scale.

	Variable Title	Variable's Practical Definition	Measuring Method	Measuring Scale
1	Dental Inclination	The dental angle of with the plane is vertical, which can be mesial/distal/buccal (labial) / or lingual (palatal)	Buccolingual Angle of Longitudinal Axis with lower Mandibular Border in CBCT	Degree
2	Cortical Bone Thickness	The shortest distance from one point on the external cortical bone to the other point on the inner cortical bone	he shortest distance from one point on the external cortical bone to the other point in the inner cortical bone in the three areas of Crest, Mid-root and Apex in CBCT	Millimeter
3	Arch length	The distance between the most anterior connection point of the mandibular center, perpendicular to the line passing through the mesial of the first molars mandibular	The distance between the most anterior connection point of the mandibular center, perpendicular to the line passing through the mesial of the first molars mandibular	Millimeter
4	Arch Width	The distance between the central pit from the right mandibular molar to the central pit of the first mandibular molar on the left	The distance between the central pit from the first mandibular molar on the right to the central pit of the first mandibular molar on the left	Millimeter
5	Age			Year
6	Sex			Male/female



(b) (a)

Figure 1: **(a)** Image of the mandibular molar in CBCT images; **(b)** Measuring the angle of the dental inclination (degrees): The angle between the basal line (the line extending from the lower mandibular border in the right and left) and the longitudinal axis of the tooth.

Initially, each of the CEJ regions of roots to the apex was divided into three equal parts, including the upper, middle, and lower ones. In the middle of the lower third part, the mesial root was named as point A and the distal root as point B. A line connected point A to point B, and the centerline was named as point C. The longitudinal axis of the first mandibular molar was a connecting line from the central fossa to the C point.

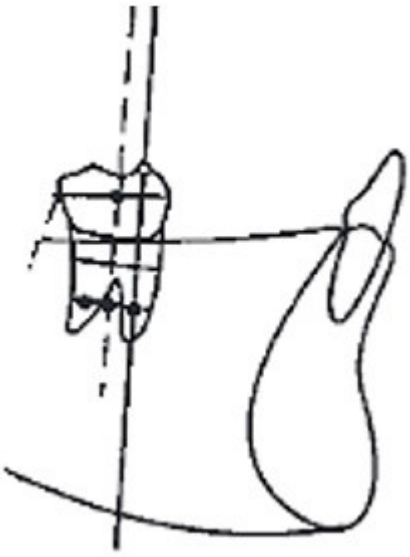


Figure 2: **(a)** Image of the mandibular molar in CBCT images; **(b)** Measuring the angle of the dental inclination (degrees): The angle between the basal line (the line extending from the lower mandibular border in the right and left) and the longitudinal axis of the tooth.

2) The in-between width of the molar is equal to the millimeter gap of the line drawn from the central pit of the left first mandibular molar to the central pit of the right first mandibular molar.

3) The arch length is equal to the linear distance of the most anterior region of the central touch to the line that is perpendicular to the right and left of the mesial of the first molars mandibular. (In millimeter)

4) The cortical bone thickness of the one mandibular molar in the mesial and distal roots was measured on the buccal and lingual side in the three regions of the crust, mid-root, and apex. Midroot was a point in the middle of the distance between the CEJ and the apex of the tooth. The lowest distance between the external cortical bone with the internal cortical bone was recorded as cortical bone thickness at the specified points [13].

The CBCT device used in this study was the 3D model of Soredex Scanora manufactured in Finland with a 5.5 × 10 cm field of view, a voxel size of 200 µm, an mA = 8, and a KVP of 90.

The intra-rater agreement method was used to reduce measurement error. The data was again measured within 48 hours. The result was that there was no significant difference between the two measurements (using paired t-test)

We used SPSS (Statistical Package for Social Science) version 21 to analyze the data. The central indexes and dispersion (mean and standard deviation), and the minimum and the maximum of each variable were measured and reported. In the present study, in order to investigate the relationship between variables, the Pearson Correlation Coefficient (for variables with normal distribution) and Spearman Correlation Coefficient (for variables without normal distribution) were used. The significance (understandability) of the outcomes was evaluated by considering the p-value less than 0.05.

Results

The study was conducted on 75 CBCT images -51% female, 49% male - with age mean of 25.79%. A total of 75 first mandibular molar were examined. The minimum, maximum, mean, and standard deviations of variables are shown in Tables 2 and 3.

Table 2: Bone thickness in different root regions.

Level	Buccal/ Lingual Side	Mesial/Distal Root	Mean	SD	Min	Max
Curst	Buccal	Mesial	84/0	87/0	0	40/3
		Distal	86/0	91/0	0	93/2
	Lingual	Mesial	22/1	94/0	0	20/3
		Distal	45/1	88/0	0	50/3
Mid-Root	Buccal	Mesial	47/1	13/1	0	90/3
		Distal	80/1	03/1	0	86/3
	Lingual	Mesial	27/2	6/0	41/0	90/3
		Distal	94/1	51/0	62/0	90/2
Apex	Buccal	Mesial	25/2	12/1	0	83/3
		Distal	59/2	9/0	3/0	96/3
	Lingual	Mesial	18/2	12/1	0	86/3
		Distal	14/2	88/0	0	85/3

Table 3: Molar inclination, mandible arch length, and width.

	Mean	SD	Min	Max
Inclination	Apr-76	7-Jun	26/59	36/99
Arch Length	32/21	1-Dec	20/16	91/27
Arch Width	73/42	Jun-00	31/38	71/50

The highest mean of the cortical bone thickness was observed at the apex level of the buccal surface of the distal root, which is equal to 2.99 mm. The lowest mean of the cortical bone thickness was found in the crust of the buccal surface of the mesial root and is equal to 0.84 mm. Also, the lowest cortical bone thickness was found to be zero in the samples, which was found in 12.22% of the samples, and the largest thickness of cortical bone was 3.96 mm, which was found at the apex level at the buccal level of the distal root with a dental inclination of 75.43°.

The type of association between the inclinations with other variables is shown in the table below. Positive association means that by increasing the dental inclination, the thickness of the cortical bone or the length and width of the arch also increased, and, with a decrease in the inclination, these results were the opposite. A negative correlation means that by increasing dental inclination, the thickness of the cortical bone, or the length and width of the arch decreased, and by reducing the dental inclination, these results were the opposite.

Table 4

Independent Variable	Dependent Variable	Variable distribution	p-value	Pearson Coefficient	Spearman Coefficient	Result
Inclination	Mesial Root, Buccal Surface, Crust Level	Abnormal	04/0		12/0-	Negative Association
Inclination	Mesial Root, Buccal Surface, Mid-root Level	Abnormal	65/0		05/0-	No Association
Inclination	Mesial Root, Buccal Surface, Apex Level	Abnormal	04/0		23/0	Positive Association
Inclination	Mesial Root, Lingual Surface, Crust Level	Abnormal	001/0		37/0	Positive Association
Inclination	Mesial Root, Lingual Surface, Mid-root Level	Normal	06/0	21/0-		Negative Association
Inclination	Mesial Root, Lingual Surface, Apex Level	Abnormal	01/0		27/0-	Negative Association
Inclination	Distal Root, Buccal Surface, Crust Level	Abnormal	001/0		36/0-	Negative Association
Inclination	Distal Root, Buccal Surface, Mid-Root Level	Normal	0	39/0-		Negative Association

Inclination	Distal Root, Buccal Surface, Apex Level	Abnormal	008/0		3/0	Positive Association
Inclination	Distal Root, Lingual Surface, Crust Level	Abnormal	0		41/0	Positive Association
Inclination	Distal Root, Lingual Surface, Mid-root Level	Normal	02/0	26/0-		Negative Association
Inclination	Distal Root, Lingual Surface, Apex Level	Normal	0	39/0-		Negative Association
Inclination	Arch Length	Abnormal	17/0		16/0-	No Association
Inclination	Arch Width	Abnormal	09/0		19/0-	No Association

The results of this study showed that there is a significant relationship between the dental inclination and the cortical bone thickness in the buccal surface of the mesial root in the apex level, in the lingual of the mesial and buccal roots, and the lingual root of the distal, at all three levels of crust, mid-root, and apex - value <0/05.

This association in the apex area of the buccal surface of the mesial and distal root is positive (direct) in the lingual crust of the mesial and distal roots, and in the buccal crest and the distal mid-root of the distal root, in the lingual mid-root and apex of the distal root and lingual mid-root, the mesial root is negative - inverse relationship. The results also showed that there is no significant relationship between the inclination and length and width of the mandibular arch and bone thickness in the buccal mid-root of the mesial root.

Discussion

Fenestration, dehiscence, and external root resorption can be of iatrogenic complications of orthodontic treatment [1,2]. There are various dental movements in orthodontic treatment, one of which that can increase the complications probability is the tipping movement of the teeth, in which the crown moves to one side and the root, towards the opposite.

Dehiscence, fenestration, and root resorption have various risk factors such as inadequate arch width [4], low alveolar bone thickness [1], etc. According to Karine Evangelist and Robert D. Ruppercht, the existence of dehiscence and fenestration have a direct relationship with low alveolar bone thickness. By knowing these risk factors, we can prevent such problems from occurring [3].

Orthodontic devices often extend to the first molar teeth. Also, the first molar tooth is used as anchorage in the elastics, etc. Therefore, the cortical bone thickness during orthodontic treatment in this tooth is significant for us to know. Most of the studies have investigated the central and lateral teeth [8-11], that due to the lack of sufficient information on molar teeth in this study, the first mandibular molar was used as the information source.

Our aim was to investigate the correlation between cortical bone thickness and different dental buccolingual inclinations of the first mandibular molar by CBCT.

In the study by Adam M.Timock et al. (2011), the accuracy and ability of CBCT to determine the thickness of bone on a dry skull were investigated. The study found that CBCT imaging could provide an accurate and reliable assessment of alveolar bone dimensions. In recent years, CBCT technology has become available to dentists, which is known as a golden standard in this field due to its three-dimensional and highly detailed images. In this study, as in studies Cevidanes [15], De Oliveira [16], and Ganguly [17], CBCT imaging has also been used.

In this study, as in the study of Nuengrutai Yodthong et al. in 2013, the bone thickness was evaluated in three levels of curst, mid-root, and apex. The reason for studying the thickness of the bones in the three levels of curst, mid-root and apex were that in the tipping movements of the teeth, because the axis of rotation is in the 1/3 of the apical root, it is likely to move in the opposite direction of the dental root during orthodontic treatment, which requires the examination of the bone thickness at the beginning of the treatment [8].

In a study by W Shewinvanakitkul et al. In 2011, the inclination of the first mandibular molar tooth and mandibular arch width were evaluated. The results represented that the mandibular molar inclination mean was 74.6 ± 7.4, and the mandibular arch width mean was 40.9 ± 2.7. The first mandibular molar inclination in CL I was less than CL II. There was little correlation between the arch width and the buccolingual inclination [14,15].

This low correlation between the dental buccolingual inclination and the arch width is consistent with the present study. The difference between that study and the study in hand was in measuring alveolar bone thickness, which plays a significant role in people's medical decision-making [2].

The purpose of the Nuengrutai Yodthong et al. study in 2013 was to evaluate factors associated with changes in alveolar bone thickness during the retraction of upper incisors. Labial bone thickness, palatal bone thickness, and total bone thickness were investigated in three levels of curst, mid-root, and apex. When maxillary incisors are retracted, there is a significant increase in the labial bone thickness and the total thickness of the bone in the apical balance. Changes in the alveolar bone thickness depend on the dental movement speed, the change in the teeth inclination, and the rate of teeth intrusion; however, it is not related to the initial bone thickness. This lack of relationship is contradictory to the present study, which is due to the direction of dental movement, in that in the anterior teeth the movement is often perpendicular to the bone surface, while in the posterior teeth - except for expansion cases – the movements are often parallel to the bone surface, which can justify the difference between the study Nuengrutai Yodthong and the present study. On the other hand, changes during orthodontic treatment are investigated in that study, while in our study, the examination was performed on normal people without a history of orthodontics [8].

Limitations of the study

Our study limitations include

1) Due to ethical issues related to providing CBCT without reason, there is no access to those who have a completely healthy and intact oral and dental system. In the case of providing CBCT from these people, they receive unnecessary radiation, which is against ethical rules.

2) Another limitation was the error in the measurements of the under investigation variables, which was reduced to a minimum by constant measurements within 48 hours, selection of

one device, software selection, and the supervision of radiology specialists.

3) Sample selection from one center.

4) Sample collection.

Which increases the need for further studies with more samples.

Conclusion

According to the results of this study, by increasing teeth inclination (further dental buccalization):

1) Increase of cortical bone thickness in the lingual side of the curst and the buccal side of the apex region in both the mesial and distal roots.

2) Reduction of cortical bone thickness in the buccal side of the curst region and the lingual side of the apex region of both the mesial and distal roots, the mid-root region of the lingual side of the mesial root the mesial and distal root and the mid-root region of the buccal side of the distal root.

3) Lack of correlation between the cortical bone thickness in the mid-root region of the buccal side of the mesial root, length, and width of the mandibular arch.

Therefore, the more buccalized the tooth is, the higher the possibility of buccal dehiscence and fenestration prevalence in the crust and in the lingual in the apex. These results are reversed by reducing dental inclination.

Ethical considerations

Due to the fact that patients were subjected to CBCT imaging for various reasons, such as implant therapy, etc., no additional dose or additional cost was imposed on the patient, and the results are mentioned in an objective manner without mentioning patients' names. Ethical considerations and the need for informed consent were not needed also. All procedures were carried out under the supervision of an expert on radiology and by his direct permission and the ethical code Number of : IR.SBMU.RIDS,REC,1395,308

Main points

According to the results of this study, by increasing teeth inclination in further dental buccalization:

1) Increase of cortical bone thickness in the lingual side of the curst and the buccal side of the apex region in both the mesial and distal roots.

2) Reduction of cortical bone thickness in the buccal side of the curst region and the lingual side of the apex region of both the mesial and distal roots, the mid-root region of the lingual side of the mesial root the mesial and distal root and the mid-root region of the buccal side of the distal root.

3) Lack of correlation between the cortical bone thickness in the mid-root region of the buccal side of the mesial root, length, and width of the mandibular arch.

Therefore, the more buccalized the tooth is, the higher the possibility of buccal dehiscence and fenestration prevalence in the crust and in the lingual in the apex. These results are reversed by reducing dental inclination.

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