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Evaluation of interradicular distance in class II malocclusion for mini-implant insertion: A CBCT study

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Abstract

Background: This study aimed to evaluate the buccal inter-radicular distance and middle inter-radicular distance of the Iraqi population for mini-implant insertion using cone-beam computed tomography (CBCT).

Methods: This cross-sectional study was conducted on maxillary and mandibular CBCT scans of 40 patients (14–25 years). Skeletal parameters were measured at 4, 6 and 8 mm apical to the cementoenamel junction (CEJ) by one examiner.

Results: The largest buccal inter-radicular distance in the maxilla was between canine and first premolar (4.8 mm for male, 4.5 mm for female) and in the mandible was between first and second molar (4.7 mm for male, 5.14 for female). The largest middle inter-radicular distance in the maxilla was between the second premolar and molar (3.75 mm for males, 3.41 mm for females) and in the mandible was between the first and second molar (4.71 mm for males, 4.74 mm for female).

Conclusions: The inter-radicular distance varies in different individuals. The buccal inter-radicular distances are wider than the middle inter-radicular distance in most sites. Within the limits of this study, the inter-radicular distances for both arches, as we move from coronal level to apical level, the inter-radicular distance increase gradually. The middle inter-radicular distance should be taken into consideration during mini-implant insertion because it is smaller than buccal inter-radicular distances and cannot evaluate clinically.

Keywords: CBCT, mini-implant, Orthodontic anchorage procedures, inter-radicular distance

Introduction

In orthodontic therapy, the anchorage is defined as resistance to undesirable tooth movement induced by the reacting force of orthodontic load [1]. Orthodontic mini-implants have gained popularity in recent years that are supported by the bones [2]. One of the continuing difficulties for orthodontists is the preservation of orthodontic anchoring. Intra-oral or extra-oral locations are used in traditional procedures. Extra oral methods are used to provide the best therapy results however extra oral Anchorage is difficult to use and usually requires the patient's compliance. When the word 'absolute anchoring' is used, it refers to a situation in which the anchorage unit is perfectly stable [3]. Mini-implants inserted into the jawbone for absolute anchoring support have been introduced into orthodontics [4].

The loss of anchoring during the therapy can lengthen the therapy time and cause poor results so mini-implants are widely being used in dentistry to resolve this problem. The mini-implant is made to give skeletal anchoring for non-cooperative patients, as well as aesthetics, ease of insertion and removal, and a low cost [5].

To maintain periodontal health, a minimum clearance of 1 mm of alveolar bone around the mini implant is advised. When considering the diameter of the mini implant and the minimal clearance of alveolar bone, more than 3 mm of inter-radicular space is required for safe mini-implant insertion. Many studies have been conducted to determine the safe locations for mini-implant installation in the inter-radicular spaces, referred to as "safe zones."[6]. Mini-implants can be inserted in a variety of intraoral positions. Interdentally, between the teeth roots, is the most usual placement. They can also be implanted at the maxillary tuberosity area, infrazygomatic crest area, retro-molar area, buccal shelf area and they can be inserted palatally (either interdentally or at the median or para-median sites) [7].

Because of the narrow inter-radicular spaces, it is safer to position the mini-implant directly in the middle of the interproximal site [8].

Furthermore, the proximity of the mini implant to the dental root increases the risk of root desorption. Many writers recommend a clearance of 1-1.5 mm between the mini-implant and the dental surface for these reasons. Because mini-implant migrates during orthodontic loading, it is recommended to make 2 mm of space surrounding the mini-implant [9]. The buccal sides are the primary choice for mini-implant placement because the inter-radicular space between the second premolars and first molars was widest in the maxilla, and the space between the first and second molars was widest in the mandible. The inter-radicular spaces increased from the cervical to apical levels except in the inter-radicular distance at the middle level between the maxillary first and second molars [10].

Primary stability is accomplished through mechanical attachment between the bone and the mini-implants, and secondary stability is produced by continued bone remodeling surrounding the implant [9]. The use of a mini-implant to treat Class II div.1 malocclusion can result in decreased anchoring loss, decrease mesial-in rotation of the maxillary posterior teeth, and less arch dimension alteration. Compared to traditional anchorage during en-masse maxillary anterior teeth retraction [10]. The majority of the mini-implant used in Class II correction procedures are recommended to begin after the permanent dentition has erupted, which included: En masse retraction, Fixed functional appliances, Molar distalization and Support for retraction after extraction. Mini implant anchorage has enhanced predictability for the correction of Class II malocclusions. Whether using direct anchorage retraction or indirect anchorage retraction [11].

Materials and Methods

The sample

The sample was obtained from records at al Noor specialized dental centre, in Mosul, Iraq. The study included participants who were referred for CBCT assessment in Radiology Unit for the different dental procedures. The records were collected between April and June 2022. All of these images were taken by using the same CBCT machine and the same technician. We informed the patient that CBCT information will include in my research. The study protocol was approved by the ethics committee of the college of dentistry, Mosul University and also by the ethics committee of Nineveh health directorate, Iraq. The study involved a total of 40 individuals (19males, 21 females) who met the following research requirements: males and females with ages ranging (from 14-25 years old), CBCT scans with all maxillary and mandibular teeth, CBCT images of good quality without artefacts that could interfere with the assessment of inter-radicular distance, Complete eruption of second permanent molars[12]. No missing, rotated, malformed teeth [12], no orthodontic treatment before[12], no periodontal disease and alveolar bone loss, absence of severe skeletal discrepancy, no congenital missing (except for third molars), absence of severe crowding, No dental spacing, absence of developmental anomalies such as cleft lip and palate, or syndrome [13], no rotations and developmental malformations [14]. Any patient who did not meet any of the aforementioned criteria was ruled out.

The cone beam computed tomography apparatus used was 8100carestream (Carestream Health, Inc.) the scanning was at dual jaw used for all patients at 90 kV, 2.5mA and exposure time 15 seconds and voxel size 150um and software used for taking image was Acquisition Interface that designed and developed specifically for the CS 8100. CS 3D Imaging v3.8.7 software was used to perform CBCT analyses. Using measuring software tools millimetric ruler was provided by software for measured buccal and middle inter-radicular distance in the maxilla and the mandible.

Image acquisition

Before radiation exposure, the patient was instructed to remove any metal object that could interfere with imaging like hairpins, jewelers, eyeglasses, etc. Ask the patient to wear a lead apron. The patient then stood inside the CBCT unit and bite on the bite block (supply with CBCT machine) with new cleared protective sheaths. The head position is adjusted from the positioning panel so that the area of interest is centred in the beam (patient midline will coincide with machine midline). The head was stabilized with a headrest and chin rest so that the Frankfort horizontal plane is parallel with the floor. The patient's head was located between the X-ray source and the late panel detector. Hand's patient Grip both the lower handles of the head and chin rest. The patient was instructed to avoid any head movement, don't open their mouth with mild breathing during the exposure time. Scanning is started with an X-ray tube-flat penal sensor rotation 360 degrees around the patient's head. We informed the patient that the machine will be rotated during the scan which is normal, and instructed the patient to remain stable

Image analysis

The CBCT images were evaluated by the CS 3D Imaging V3.8.7 software program. To reduce measurement errors caused by nonstandard head postures, all images were oriented according to a standardized procedure, the horizontal axis was parallel to the palatal plane. The nasal septum was aligned parallel to the vertical axis. The angle of slicing would be changed as a result.

Detection and measurement

CBCT images were analyzed on the axial, sagittal and coronal sections to described interradicular distance in anterior and posterior regions (from the second molar on one side to the second molar on the opposite side) for both maxillary and mandibular arches at 3 levels (4 mm, 6 mm, 8 mm respectively from CEJ).

At sagittal view: we determine the three levels for measurements for each tooth. The cementoenamel junction act as a referenced point because it is more reliable to detect in radiograph, so the levels were at 4 mm, 6 mm, and 8 mm from CEJ [12] as shown in figure 1.

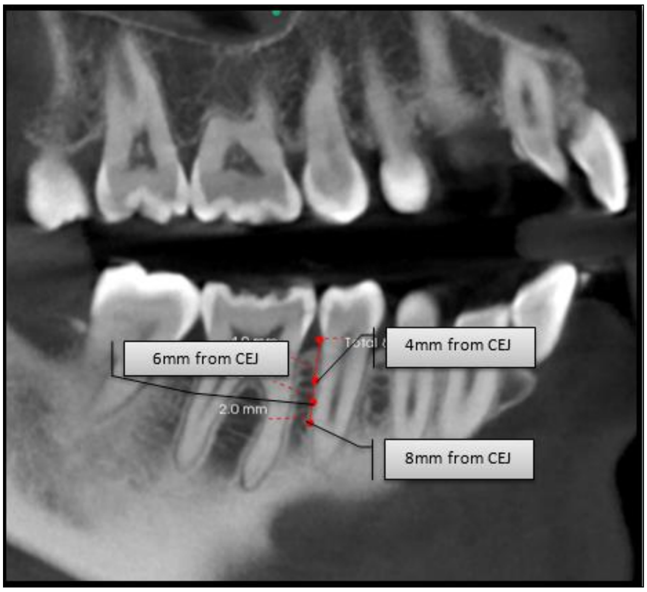

Fig 1: Measurement levels from CEJ.

After we decided on the levels we go to the axial view and we measured the buccal inter-radicular distance and the middle inter-radicular distance for each level.
Buccal inter-radicular distance: we measured the distance from the distobuccal point of the mesial tooth root to the mesiobuccal point of the distal tooth root which is the widest distance between the roots of adjacent teeth on the buccal aspect [12] (Figure 2).

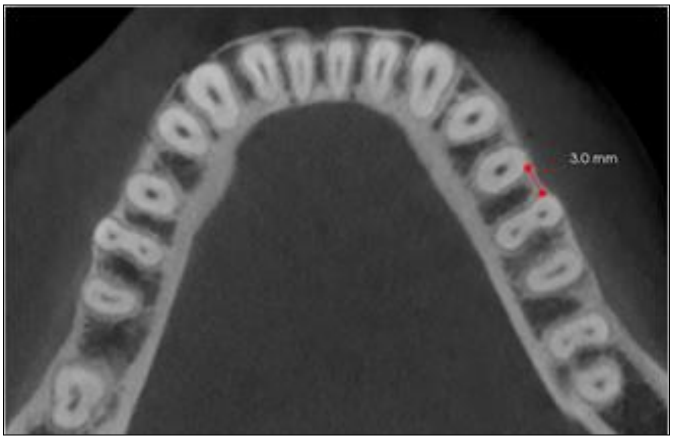

Fig 2: Radiophotograph show the buccal inter-radicular distance between lower premolar and molar.

Middle inter-radicular distance: This measurement is taken from the middle point of the distal side of the mesial tooth root to the middle point of the mesial side of the distal tooth root. In the case of non-parallel roots, the shortest distance in the mid-area between adjacent roots was chosen as the middle inter-radicular distance [12] (Figure 3).

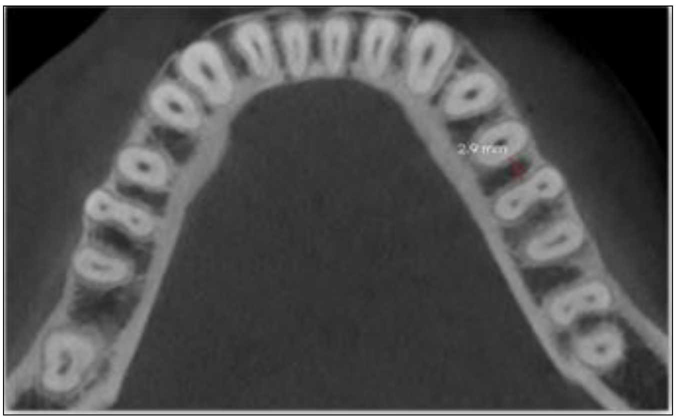

Fig 3: Radiograph shows middle inter-radicular distance between lower premolar and molar

Reliability of measurement

To assess measurement reliability, 10 randomly selected cases were used to measure all the variables at randomly selected sides and levels. Intra-examiner reliability was tested by repeating the measurements after 2 weeks intervals. Statistical comparison of the measurements obtained in these 2 periods using paired t-test showed no significance.

Result

We calculated the means and standard deviations of the buccal inter-radicular distance, and middle inter-radicular distance. Shapiro Wilk's test revealed a normal distribution of the data. We used Paired Samples Test to compare between right and left sides and also between buccal inter-radicular distance and middle inter-radicular distance. All statistical analyses were carried out by the SPSS software program (version 20; SPSS Inc., Chicago, IL, USA). The Comparison between the right and the left side was no significant differences either in maxilla and mandible, so we deal with it as one side in statistic and display the date, one for maxilla and one for mandible

Maxilla

Comparison between buccal inter-radicular distance and middle inter-radicular distance in 6 sites at three levels for males are displayed in the table (3.1) and for females in the table 2.

At all sites and levels, the buccal inter-radicular distance was wider than the middle inter-radicular distance in males and females. The differences in all sites were significant at P value< 0.05except in males between (5-6) sites at levels 6 mm and 8 mm from CEJ.

Table 1: Comparison between buccal and middle interradicular distance in maxilla for male

Level	variables	Maxilla measurement for male								
		1-2			2-3			3-4		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	2.76	9.98	.000	3.69	7.33	.000	4.16	6.31	.000
	MID	1.90			2.79			2.77		
6 mm from CEJ	BID	3.02	11.0	.000	4.12	9.25	.000	4.57	5.97	.000
	MID	2.07			3.10			3.03		
8 mm from CEJ	BID	3.17	14.0	.000	4.60	12.1	.000	4.81	5.03	.000
	MID	2.26			3.40			3.30		
Level	variables	4-5			5-6			6-7		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	3.74	5.66	.000	3.42	4.01	.001	3.12	3.106	.005
	MID	2.91			2.98			2.44		
6 mm from CEJ	BID	4.09	6.05	.000	3.68	1.64	.114	3.32	3.34	.003
	MID	3.25			3.40			2.55		
8 mm from CEJ	BID	4.27	5.57	.000	4.00	1.987	.059	3.32	3.44	.002
	MID	3.45			3.75			2.48		

BID: Buccal Interradicular distance, MID: Middle Interradicular distance, CEJ: Cementoenamel junction

Table 2: Comparison between buccal and middle inter-radicular distance in the mandible for females.

Level	variables	Maxilla measurements for female								
		1-2			2-3			3-4		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	2.73	19.249	.00	3.59	8.535	.00	3.63	9.736	.00
	MID	1.72			2.85			2.74		
6 mm from CEJ	BID	2.95	15.955	.00	4.09	12.837	.00	4.26	12.131	.00
	MID	1.93			3.13			3.14		
8 mm from CEJ	BID	3.20	12.330	.00	4.45	13.652	.00	4.57	10.568	.00
	MID	2.36			3.40			3.39		
Level	variables	4-5			5-6			6-7		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	3.26	8.577	.00	3.53	7.740	.00	2.69	6.536	.00
	MID	2.46			2.75			1.91		
6 mm from CEJ	BID	3.41	8.009	.00	3.59	6.907	.00	2.42	6.118	.00
	MID	2.67			2.87			1.81		
8 mm from CEJ	BID	3.44	7.555	.00	3.79	8.413	.00	2.40	5.713	.00
	MID	2.78			3.41			1.86		

BID: Buccal Interradicular distance, MID: Middle Interradicular distance, CEJ: Cementoenamel junction

Mandible: Comparison between buccal inter-radicular distance and middle inter-radicular distance in 6 sites at three levels for males are displayed in the table 3 and for females in the table 4.

Generally, at all sites and different levels, the buccal inter-radicular distance was wider than the middle inter-radicular distance in males and females. The differences in all sites were significant at a P value of < 0.05

Table 3: Comparison between buccal and middle inter-radicular distance in the mandible for male

Level	variables	mandible measurements for male								
		1-2			2-3			3-4		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	2.25	8.10	.00	2.67	5.97	00	3.67	8.77	.00
	MID	1.6			1.99			2.32		
6 mm from CEJ	BID	2.53	8.98	.00	3.10	5.83	00	4.02	6.94	.00
	MID	1.73			2.35			2.54		
8 mm from CEJ	BID	2.45	6.76	.00	3.44	6.14	00	4.37	7.54	.00
	MID	1.80			2.49			2.86		
Level	variables	4-5			5-6			6-7		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	4.10	6.12	.00	4.10	3.05	00	4.19	4.95	.00

	MID	3.00			3.67			3.59		
6 mm from CEJ	BID	4.69	6.36	.00	4.57	3.74	.001	4.70	4.95	.00
	MID	3.58			4.03			4.07		
8 mm from CEJ	BID	5.00	8.50	.00	4.99	4.11	.00	5.54	6.04	.00
	MID	3.69			4.38			4.71		

BID: Buccal inter-radicular distance, MID: middle inter-radicular distance, CEJ: Cementoenamel junction

Table 4: Comparison between buccal and middle inter-radicular distance in the mandible for female

Level	variables	Mandible measurements for female								
		1-2			2-3			3-4		
		mean	t-value	p-value	mean	t-value	p-value	mean	t-value	p-value
4 mm from CEJ	BID	2.17	12.436	.00	2.80	6.885	.00	3.38	11.800	.00
	MID	1.41			2.26			2.37		
6 mm from CEJ	BID	2.30	12.323	.00	3.22	8.433	.00	3.79	15.429	.00
	MID	1.50			2.58			2.58		
8 mm from CEJ	BID	2.27	11.949	.00	3.43	9.301	.00	3.90	12.161	.00
	MID	1.57								
Level	**variables**	**4-5**			**5-6**			**6-7**		
		mean	**t-value**	**p-value**	**mean**	**t-value**	**p-value**	**mean**	**t-value**	**p-value**
4 mm from CEJ	BID	4.33	10.610	.00	4.09	5.332	.00	4.23	6.304	.00
	MID	3.31			3.45			3.61		
6 mm from CEJ	BID	4.78	9.522	.00	4.35	6.143	.00	4.60	3.772	.001
	MID	3.88			3.80			4.14		
8 mm from CEJ	BID	5.04	8.623	.00	4.85	6.207	.00	5.14	2.971	.005
	MID	4.29			4.09			4.74		

BID: Buccal inter-radicular distance, MID: middle inter-radicular distance, CEJ: Cementoenamel junction

Discussion

In this study we used CBCT which give 3D image in contrast to Conventional X-ray which may have severe distortions and overlapping dental images, failing to obtain the distance between roots. 3D CBCT technology allows for better visualization of mini-implant placement. Both panoramic and periapical images are not accurate enough when assessing the location of mini-implants [15]. All variables were measured at 4 mm, 6 mm, and 8 mm, from CEJ. The CEJ is used as the reference point for measurement which is more reliable, easy to distinguish in CBCT, constant position, visibility and easy access by the examiner, contrasting with other studies [16,17] which used the alveolar bone crest, used the alveolar bone crest is not recommended because it affected by different factors such as periodontal diseases. The level of measurement was 4 mm, 6 mm, and 8 mm from CEJ it is at attached gingival tissue which gives a high success rate at these levels about 90% [18]. According to pan *et al*. mini implants placed in non-keratinized tissue have the highest rate of mobility [12]. The maximum level of measurement in the study was 8 mm from CEJ because more than 10 mm may be apical to roots and may be placed in moveable mucosa causing gingival tissue irritation and inflammation and failure rate increase [18]. If a mini-implant is inserted at more than 10 mm may cause dangerous sinus perforation [19]. The clearance area between the roots and orthodontic mini-implant is so important for success rate [20]**,** and the proximity of the mini-implant to the adjacent tooth root is an important risk factor for failure of screw anchorage [21].

A minimum of 1 mm clearance from the alveolar bone around the mini implant has been suggested for periodontal health. Thus, the inter-radicular distance should be more than 3 mm for mini-implant placement [22]. The current study showed buccal inter-radicular distance wider than the middle inter-radicular distance in most sites in the upper and lower jaw and the differences were significant at P-value<0.05 this may be attributed to root anatomy, root angulation, and tooth position. it is very important to evaluate the middle inter-radicular distance on a CBCT because it differs from the buccal inter-radicular distance, and the tip of the mini-implant reaches the middle inter-radicular area and should be wide enough to avoid any periodontal ligament or root damage [12]., the inter-radicular distance values were greater in males than in females in most sites, suggesting a larger inter-radicular space leading to a safer mini-implant insertion in males. And this is consistent with the pan *et al*. study [12]. The results in the maxilla showed that buccal inter-radicular distance in different sites is more than 2.5 mm and will increase as we move apically. The maximum buccal inter-radicular distance was between canine and premolar at an 8 mm level from CEJ (4.81 in the male) and (4.57in females). this may be due to the canine having conical straight single root anatomy and premolar has straight slender root Buccally, This finding with the agreement with the results published by Bittencourt *et al*. 2011 [23].

The largest distance in middle inter-radicular space in the maxilla was (3.75 mm in males, and 3.41 in females) between the second premolar and molar at an 8 mm level from CEJ.

The buccal inter-radicular distance increase when we go from level 4 mm to level 8 mm from CEJ, this may be due to teeth roots anatomy and root shape this finding agrees with Sawada *et al*. who proposed that inter-radicular distances increase in the direction of the root apex, so adequate root proximity can be assured at a site close to the root apex [24].

The largest measured in the mandible in the buccal inter-radicular distance was (4.7 mm in males) (5.14 mm in females) between the first and second molar at an 8 mm level from CEJ.

The largest measured in middle inter-radicular distance in the mandible was (4.71 mm in males) (4.74 mm in females) between the first and second molar at an 8 mm level from CEJ.

Generally, the most site at level 6 mm from CEJ and at level 8 mm from CEJ is suitable for mini-implant insertion except between central and lateral. The safer area between (6-7) gives a large buccal and middle inter-radicular distance Similar findings were reported by [22] and also by [19] and [14], and in contrasting Poggio *et al*., 2006 [16] who reported that the site of (6-7) and (4-5) is safer.

The minimum inter-radicular spaces were observed on the buccal aspect of both jaws between the central and lateral incisors and this finding agrees with a study by Seyed Hossein Moslemzadeh *et al*. [14].

According to the results, the mandible has a wider inter-radicular distance than the maxilla, so the mandible is safer than the maxilla, this finding agree with Silvestrini Biavati *et al*. who measured the inter-radicular distance distal to canine, reported that the maxilla has only 13% of measured sites were suitable (3.3 mm) for mini-implant insertion, vs. 63% in the mandible.

The variations in the results between this result and other results can be attributed to different methodologies used, such as, used the alveolar crest as the reference point, which is not reliable and can be affected by periodontal disease, some studies used CT and did not CBCT scans for such measurement, used different sections and levels, Different races and ethnicities included in the study and measurement. Sample selection, the age included in the study.

Conclusion

Buccal inter-radicular distances are wider than the middle inter-radicular distance in most sites. Generally buccal inter-radicular distances in the mandible are wider than buccal inter-radicular distances in the maxilla. Within the limits of this study, the inter-radicular distances for both arches, as we move from coronal level to apical level, inter-radicular distance increase gradually. There are significant between the buccal and middle inter-radicular distances. Middle inter-radicular distance should be taken into consideration during mini-implant insertion because it is smaller than buccal inter-radicular distances and cannot evaluate clinically.

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