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Original Article
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Evaluation of the Socket Morphology of Mandibular Molars for Immediate Implant Placement Using Cone-Beam Computed Tomography (CBCT) Imaging

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Objectives The aim of this retrospective study was to assess the dimensions of the mandibular molar socket for immediate implant placement, using cone-beam computed tomography (CBCT) imaging.
Methods The CBCT images of 81 patients were selected based on the inclusion and exclusion criteria. In the OnDemand software, measurements were assessed by virtually positioning a regular Straumann implant (4.8 mm) in the regions of the first and second mandibular molars. The socket morphology, the buccolingual width of cancellous bone, the gap between the implant and the socket wall, the length of the root, the cross-sectional morphology of the mandible, and the height and thickness of the inter-radicular septum were all determined. The variables were compared using either the Student's t-test or the Mann-Whitney U test.
Results Among the cross-sectional morphologies of the mandible, the undercut type (U) was found to be the most prevalent. The mean distance of the implant from the inferior alveolar nerve (IAN) was found to be 6.22 mm for the first molars and 5.17 mm for the second molars. Moreover, the mean horizontal distances from the implant to the mesial and distal socket walls were 2.01 and 2.30 mm for the first molars and 2.14 and 2.59 mm for the second molars, respectively. The width of the interradicular septum across various sections was found to have a significant correlation with the position of the tooth ($P<0.05$).
Conclusion The majority of the samples exhibited the undercut (U type) morphology of the mandible. The interradicular septum in the second molar tooth was found to be insufficient. Overall, the assessment of pre-extraction CBCT scans and the virtual positioning of implants can be beneficial for surgical treatment planning. This approach can also aid in minimizing potential complications.
Keywords Cone-Beam Computed Tomography; Dental Implants; Immediate Dental Implant Loading; Mandible; Molar

Introduction

Patients often experience the loss of a mandibular molar due to endodontic failure, severe caries, or vertical root fractures. [1] The failure to replace a missing posterior tooth can impact the alveolar bone surrounding the extraction socket. [2] This can lead to changes in bone formation and volumetric resorption, ultimately altering the dimensions and contours of the alveolar ridge. Immediate implant placement (IIP) in molar extraction sites has been associated with a high rate of clinical success, ranging from 97.8% to 100%. [3, 4] Some of the advantages of IIP include the lower number of surgical interventions, optimal positioning of the implant, and increased patient satisfaction. [5, 6] However, the posterior mandible presents a significant challenge for IIP due to the increased risk of injury to the inferior alveolar canal (IAC) and the presence of the concavity of the submandibular fossa. [7]

The likelihood of immediate molar implant failure may increase if factors, such as socket morphology, root length, thickness of the buccal cortical bone, and the gap defect between the implant and bone, as well as the interradicular septa, are not taken into consideration. Other factors, such as the quality and quantity of bone, the use of an atraumatic surgical technique, and the management of traumatic occlusal forces, also play a significant role in the success of an implant. [8-10]

Cone-beam computed tomography (CBCT) has revolutionized craniofacial imaging, as it provides clinicians with high-resolution images of anatomical structures. Additionally, it offers the advantage of producing small field-of-view images at a lower radiation dose. The generated CBCT DICOM data can be used to design a 3D surgical guide to facilitate implant placement. [11]

In the present study, implants were virtually positioned in the first and second mandibular molar regions, guided by prosthetic considerations, and the relationship between the virtually positioned implant and the associated anatomical structures was investigated. Factors, such as the socket morphology, the width of the interradicular bone, the length and morphology of the root, the thickness of the buccal cortical bone, and gap defects between the implant and bone were all measured and assessed.

Methods and Materials

Patient selection

In this retrospective study, the CBCT scans of adult patients (age >18 years) were examined. The CBCT images used in this study were sourced from the archives of private dento-maxillofacial radiology clinics in Bandar-e Abbas, Iran, and were selected using a simple random sampling method. The criteria for inclusion in the study were CBCT images of the full mandible, featuring permanent dentition with healthy first and second mandibular molars, as well as a healthy periodontium. On the other hand, the exclusion criteria were partial or incomplete images and detection of any pathology in the mandible, such as caries, periapical pathologies, cysts, tumors, bone sclerosis, and impacted teeth. The sample size was calculated based on the following formula:

$$\frac{Z^2_{1-\frac{\alpha}{2}} \times s^2}{d^2}$$

Where $Z_{1-\frac{\alpha}{2}}$ denotes the standard normal variate; *SD* represents the standard deviation of the measured variable (i.e., root trunk length); and *d* denotes the absolute error or precision. The sample size for this study was determined based on an SD of 0.49, as reported in a previous study by Sayed AJ et al. [12]:

d = 0.14 SD = 0.49 $Z_{1-\frac{\alpha}{2}} = Z_{0.995} = 2.57$

$$n = \frac{(2.57)^2 \times 0.49^2}{0.14^{\ 2}} = 81$$

Radiographic measurements

A total of 81 CBCT scans were selected based on the inclusion and exclusion criteria. All scans were standardized using a CBCT machine (Carestream 9600). The scan parameters were set at 90 KvP, 21 mAs, and a scan time of 14 seconds. The field of view (FOV) was set at 15×15×15 cm³, with a voxel size of 0.3 mm³. The first and second mandibular molars were assessed using CBCT scans. Table 1 presents the alveolar bone parameters to be measured. These measurements were conducted in sagittal, axial, and cross-sectional views, as depicted in Figure 1. The OnDemand 3D software was used to evaluate all measurements separately.

Table 1 - Parameters Measured

- Socket Size Morphology (**Figure.2**)
1. Mesio-distal Width at the Crest
2. Bucco-lingual Width at the Crest
3. Mesio-distal Width at the Apex (Root tip Morphology – Convergence/Divergence)
- Vertical Root Length Parameters (**Figure.2**)
1. Length from the Crest of Interdental Bone to the Tangent from Furcation (Root trunk length)
2. Length from the Tangent of Furcation to the Tangent at Root Apex (Interradicular Septum Bone Length)
3. Total root Length

- Interradicular Septal Bone Morphology (**Figure.3**)
1. Mesio-distal Width at Apex
2. Mesio-distal Width at 3, 5, 7, 9, 11 mm apical to the alveolar crest
- Buccal Cortical Bone Thickness (**Figure.4**)
  Buccal Cortical Bone Thickness at the Crest

- Bucco-Lingual Width of Cancellous Bone (**Figure.4**)
1. Bucco-lingual Width of Cancellous Bone at the Apex
2. Bucco-lingual Width of Cancellous Bone Cervically 3 mm from the Apex
3. Bucco-lingual Width of Cancellous Bone Cervically 6 mm from the Apex

- Horizontal widths from the implant surface to the mesial and distal socket wall (**Figure.5**)
- The distances from implant surface to the buccal and lingual plates (**Figure.6)**
- The distance from implant to IAN (**Figure.6**)
- Cross-sectional morphology of the mandible (**Figure.7**)

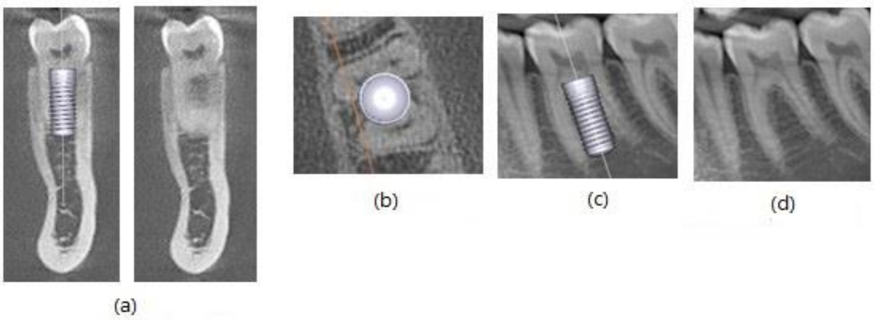


Figure 1: (a) Cross-sectional slice of mandibular ridge. (b) axial view. (c) sagittal view, virtual implant was placed parallel to the long axis of the tooth (Straumann, bone level regular, 4.8×12 mm) (d) sagittal view of the tooth.)

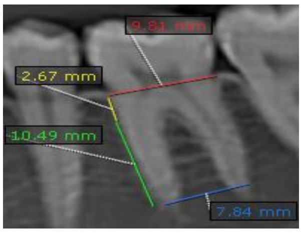


Figure 2: Socket size and Root length

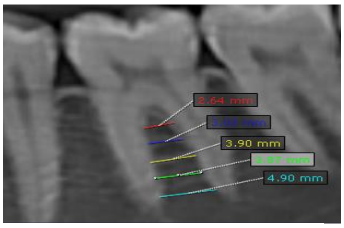


Figure 3: Interradicular width

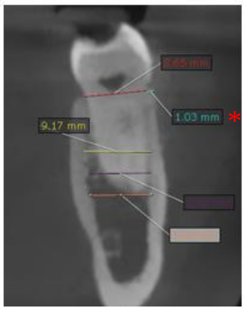


Figure 4: Buccolingual width of cancellous bone
***: Buccal cortical bone thickness**

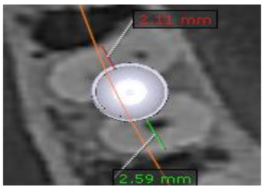


Figure 5: Implant distance to Mesial and Distal walls

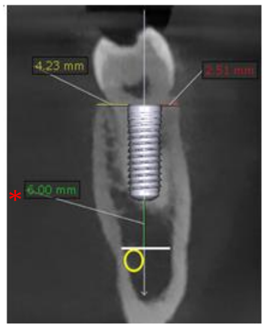
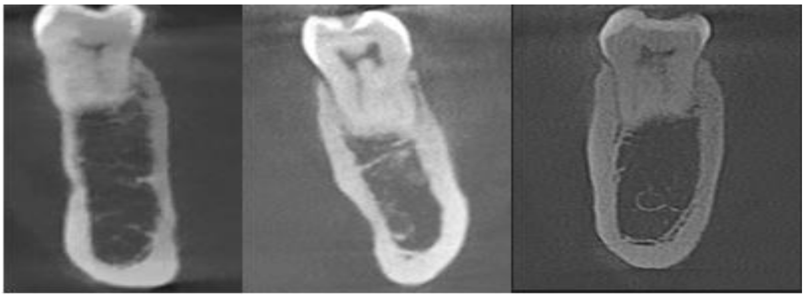


Figure 6: Implant distance to Buccal and Lingual wall
***: distance from implant to IAN**



Type P Type U Type C

Figure 7: Classification of cross-sectional morphology of mandible. Type P (Parallel): when the cross-sectional morphology showed a form of mandible with more or less parallel ridge, Type U (Undercut): when the ridge was narrower than its crest, and a lingual undercut on the lingual plate was observed, Type C (convergent): When the base of the mandibular ridge was wider than its crestal part.

A virtual implant (Straumann® Regular Bone Level Implant, 4.8×12 mm) was positioned in the first and second mandibular molars, aligned along the long axis of the crown. The implant's coronal platform was positioned 1mm below the crestal level. In the buccolingual direction, the implant was aligned with an imaginary line that passed through the central fossae of the neighboring teeth. The angulation of the implant in the mesiodistal and buccolingual directions was determined by the long axis of the opposing maxillary tooth and the curvature of the mandibular occlusal plane.

Statistical analysis

The mean, standard deviation (SD), minimum, and maximum values were calculated for each of the measurements. Differences were evaluated according to the tooth (first and second molars). The collected data was entered into SPSS Version 20. To determine the normal distribution of the measurements, a Kolmogorov-Smirnov test was performed. The Student's t-test or the Mann-Whitney U test was utilized for independent groups, depending on the normal distribution of data. The level of statistical significance was set at $P<0.05$.

Results

In this study, out of 81 participants, 31 were female (38.3%), and 50 (61.7%) were male. The mean age of the participants was 30.1±7.9 years. Based on the results, the mean mesiodistal width at the crest was 9.1±0.5 mm, the mean buccolingual width at the crest was 8.1±1.4 mm, and the mean mesiodistal width of the roots at the apex was 7.3±1.7 mm in the first molar teeth. In the second molars, the mean mesiodistal width at the crest was 9.4±0.7 mm, the mean buccolingual width at the crest was 8.3±0.7 mm, and the mean mesiodistal width of the roots at the apex was 6.2±1.6 mm.

According to the results, the mean distance from the crest of the bone to the tangent of furcation was 2.8±0.7 mm, the mean distance from the tangent of furcation to the root apex was 10.8±1.6 mm, and the total mean length of the root was 13.7±1.4 mm in the first molar teeth. In the second molars, the mean distance from the crest of the bone to the tangent of furcation was 2.9±0.6 mm, the mean distance from the tangent of furcation to the root apex was 9.7±1.6 mm, and the total mean length of the bone root was 12.6±1.5 mm.

The mean buccal cortical bone thickness at the crest was 0.8±0.3 mm in the first molars and 0.8±0.3 mm in the second molars(mentioned in table 2). The width of the inter-radicular septum is presented in Table 3. The results demonstrated that the differences between the first and second molars were not significant. In the first molars, the buccolingual width of the cancellous bone at the apex was measured to be 6.9±1.6 mm. The width of the cancellous bone, moving cervically towards the trunk, was 3 mm from the apex, with a mean width of 8.1±1.4 mm. Also, the buccolingual width of the cancellous bone, moving cervically from the apex, was 6 mm, with a mean width of 8.9±1.1 mm (table 2). The differences between the first and second molars were statistically significant.

Table 2 – Socket morphology

	Mandibular 1st molar with n = 81				Mandibular 2nd molar with n = 81				P-Value*
	Max	Min	St.Deviation	Mean	Max	Min	St.Deviation	Mean	
Mesiodistal width at the crest	10	8	0.51	9.14	11	8	0.65	9.36	0.11
Buccolingual width at the crest	10	7	0.63	8.12	10	7	0.71	8.27	0.38
Mesiodistal width of the roots at the apex	10	3	1.72	7.29	9	2	1.60	6.24	0.01
Distance from the crest of the bone to the tangent of furcation	5	2	0.65	2.80	4	2	0.64	2.94	0.41
Distance from the tangent of furcation to the root apex	15	7	1.58	10.83	13	7	1.56	9.67	0.004
Length of the root	18	11	1.40	13.69	16	9	1.51	12.60	0.003
Buccal cortical bone thickness at the crest	2	0	0.33	0.84	2	0	0.31	0.77	0.38
Buccolingual width of the cancellous bone at the apex	11	3	1.59	6.97	13	5	2.03	8.19	0.005
Buccolingual Width of Cancellous Bone Cervically 3 mm from the Apex	12	6	1.36	8.11	11	6	1.52	8.97	0.01
Buccolingual Width of Cancellous Bone Cervically 6 mm from the Apex	12	7	1.14	8.85	13	7	1.40	9.37	0.09

* Independent samples t-test

Table 3 - The widths of inter-radicular septum

Distance to alveolar crest (mm)	Mandibular 1st molar with n = 81				Mandibular 2nd molar with n = 81				P-Value*
	Max	Min	St.Deviation	Mean	Max	Min	St.Deviation	Mean	
3	3	0	0.89	1.09	1	0	0.54	0.45	<0.001
5	4	1	0.63	2.42	3	1	0.55	1.66	<0.001
7	5	1	0.75	2.73	3	1	0.77	1.84	<0.001
9	5	1	0.96	2.81	4	1	0.89	1.81	<0.001
11	5	0	1.14	2.86	3	0	0.82	1.30	<0.001
apex	7	1	1.38	3.59	5	0	1.33	2.05	<0.001

* Independent samples t-test

The distance from the implant to the IAN was 6.2±2.7 mm in the first molar teeth and 5.2±3.2 mm in the second molars. The horizontal width from the implant surface to the mesial socket wall was 2.0±0.4 mm in the first molars and 2.1±0.6 mm in the second molars. Also, the horizontal distance from the implant surface to the distal socket wall was 2.3±0.5 mm in the first molars and 2.6±0.6 mm in the second molars. Moreover, the horizontal distance from the implant surface to the buccal plate was 2.9±0.7 mm in the first molars and 4.3±1.3 mm in the second molars. Additionally, the horizontal distance from the implant surface to the lingual plate was 4.4±1.3 mm in the first molars and 4.9±1.0 mm in the second molars. Table 4 demonstrates the distribution of different types of mandibular morphologies. The most prevalent mandibular morphology was the undercut type (U shaped) in both the first and second molar teeth.

Table 4 - Classification of the cross-sectional morphology of the mandible

	Morphology of the alveolar bone, n (%)		
Tooth	P (Parallel)	C (convergent)	U (undercut)
First molar	10.3%	5.2%	84.5%
Second molar	4.3%	0.35%	95.7%

Discussion

This study examined the dimensions of alveolar bone surrounding permanent mandibular molars to assess the support provided by the bone structure of tooth socket in achieving primary stability for immediate implants. The primary stability of an implant is a crucial factor that influences the successful osseointegration of dental implants. [13] It is often challenging to achieve sufficient primary stability in molar extraction sites. The use of ultra-wide or wide-diameter implants can enhance engagement and increase the contact area with the inter-radicular septum and socket walls. A recent study has shown that the use of these implants can be feasible depending on the size of the socket. However, the long-term prognosis of ultra-wide diameter implants remains a topic of debate. [14]
An alternative to using wide-diameter implants is to place the implants into the inter-radicular septum [15], which has been shown to yield favorable outcomes. [1, 15, 16] Reports indicate that a minimum width of 3 mm for the interradicular septum is necessary to ensure initial implant stability. [16-18] In the present study, it was found that implants should be placed 4-5 mm into the first molar site. However, in the second molars, the width of the inter-radicular septum should be less than 2 mm. This suggests a risk of inadequate initial stability when placing immediate implants in the second molar site.
In this study, it was observed that both the first and second molars exhibited a parallel or slightly convergent root morphology. In such instances, the primary stability is likely to be enhanced by the apical and interdental bones. In the present study, the horizontal distance of the surface of a regular diameter (4.8 mm) implant from the mesial and distal socket walls varied between 2 mm and 4 mm in both the first and second mandibular molars. The findings suggest that the placement of wider implants could result in a minimal gap defect. However, when placing regular diameter implants, it should be considered that augmentation procedures may be necessary. To minimize the risk of injury to the IAN, a safe distance of 1.5-2 mm is recommended between the implant and the IAN. [19] In the present study, the mean distance was 6.22 mm in the first molars and 5.17 in the second molars, which helped ensure the integrity of the IAN.
Generally, the mandibular morphology can be classified into three types: C (convergent), P (parallel), and U (undercut). Previous studies have predicted a higher risk of lingual perforation in U-type mandibles. In the present study, the most prevalent mandibular morphology was the U-shaped ridge. Therefore, conducting a cross-sectional evaluation can be advantageous in devising treatment plans and mitigating the potential risk of complications.
A limitation of this study was that it relied on evaluations based on pre-extraction CBCTs, without considering potential changes in the alveolar bone following extraction. Furthermore, the data was limited due to artifacts resulting from patient movement and the presence of metal artifacts.

Conclusion

This study underscored the significance of CBCT in planning immediate implant placement in the posterior region. The ability to anticipate primary implant stability can equip dentists with the necessary foresight to prevent potential complications. The interradicular septal bone and the walls of the molar socket are the primary contributors to implant stability. In the case of second molar teeth, the lack or absence of an interradicular septum should be taken into account. Also, there is definite need for a good selection of cases, atraumatic extraction with preservation of IRB(Interradicular septal bone) for higher success of immediate molar implants.

Conflict of Interest

No Conflict of Interest Declared ■

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