Original Article

Characterization of Mandibular First Molar Extraction Space for Dental Implant Placement Using CBCT Imaging – A Retrospective Analysis

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Abstract

Objective: The aim of this study was to evaluate the consequences of untreated mandibular first molar extraction space on alveolar bone and adjacent teeth to suggest appropriate implant size selection and direction of its placement to achieve a favorable relationship between the prosthetic part, the implant fixture, and the adjacent teeth.

Methods: This observational study evaluated 183 CBCT of mandibular first molar extraction spaces to measure adjacent teeth angulations, height, width, and length of interdental crestal bone. Besides interdental distance, unopposed teeth overeruption, and inferior alveolar nerve canal position were measured, and the continuous data have been subjected to the normality test to calculate the Mean and median of the variables.

Results: Mean molar-premolar, molar-bone crest, and premolar bone crest angles were 48.5±12.14◦, 46.4±11.9◦ , and 84.8±9.0◦ , respectively. Mean molar-premolar crestal bone lengths 11.66 ± 2.32 mm. The median bone width was 6.46 mm, and the median interdental distance was 7.54 mm. The mean alveolar crest to the roof of the inferior alveolar nerve canal was 16.42 ± 2.82 mm.

Conclusions: Untreated mandibular first molar extraction spaces significantly compromised interdental spaces and bone properties for proposing proper implant size, positions, and angulations.

Keywords: *CBCT, Mandibular first molar, Extraction space, Dental implant.*

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Introduction

Mandibular first molars (MFM) are first teeth to erupt in the mouth and are often the first teeth disposed to lose because of dental caries(1-4). The permanent first molars are located close to the middle of each side of the jaw. They are important to keep dental arch form and occlusal schemes. Their early missing adversely affects the arch continuity and the harmonious relationship between both arches(2,5). Untreated first molar extraction space (ES) results in drifting and tipping of the adjacent teeth, overeruption of unopposed teeth and, horizontal and vertical bone resorption(2,6-8). The tooth distal to the ES moves more into the ES compared to the tooth mesial to the ES(4,9). Therefore, restoration of prolonged untreated ES may be technically challenging, especially by dental implant restoration.

Tooth-implant parallelism is important to avoid damaging the adjacent teeth during bone preparation and implant placements(10,11). Free hand implant placement is usually associated with some deviation of the proposed position compared to a very slight deviation with guided implant surgery. When there is more than a 20-degree discrepancy present between residual bone and planned prosthetic angulation, restorative problems, and an unfavorable bending moment might be introduced(12). Therefore, conventional implant placement should be started only after appropriate clinical and radiological evaluations. Clinical and panoramic radiographical examinations may be sufficient for selecting proper implant width and length on one side, and the site and mesiodistal angulation of implant placement on the other side.

Nevertheless, depending on these diagnostic tools, entirely unintentional results may develop. Therefore, cross-sectional images are strongly recommended for potential implant sites to determine implant size, mesiodistal and buccolingual angulations, and depth of insertion(12-15). Cone-beam computed tomography (CBCT) has become the most reliable tool in both conventional and computer-guided implant treatment planning(16-18). Determination of the proper direction of drilling and implant placements is important to avoid damaging vital structures, create harmonic relations of the implant crown with occlusal forces from opposite teeth, and to establish peri-implant biologic stability(19,20). Since the evolution of osseointegration, dental implant placement became a substitute for fixed dental prosthesis for single molar tooth spaces, which uses the adjacent ES teeth as abutments(2,21-23). Studies on dental extraction consequences were properly documented for adjacent teeth drifting, tipping, and spatial bone resorption(4,7,24,25). For single ES implant placement, all these anatomical changes should be carefully evaluated and properly managed during implant surgery. For instance, surgical guide pins are frequently used to examine the mesial and distal angulations of the pilot drill and its proximity to the adjacent teeth and before starting subsequent drilling and implant placement(3,10). To the best of our knowledge, this retrospective, three-dimensional radiographic analysis represents the first available detailed information to characterize MFM-ES and adjacent teeth angulations for proper directing alveolar bone drilling and implant placement in favor of appropriate implant supra-crestal restorations in conventional and computer-guided implant surgeries.

Patients and methods

This retrospective study examined 827 CBCT files stored in B&R Dental Centre in Sulaymaniyah city, Kurdistan Region of Iraq, after attaining a written consent from the managing office of the dental center. The patient's age, sex, and date of CBCT imaging were verified by comparing patient demographic data in the CBCT files with the patients' registration information of B&R Dental Center - Patient Management Software. The patient's identities were kept confidential and not recorded during data collection.

A single examiner assessed all the CBCT files with the assistance of the dental radiologist at B&R Dental Center. Data collection and analysis performed between May 6th, 2019, and ended November 3rd, 2019. All the CBCT images were acquired using a single scanner, a GALILEOS Sirona comfort PLUS unit (Sirona Dental Systems GmbH, Bensheim, Germany). Performance features are 15.4cm spherical imaging volume, 0.25/0.125mm isotropic voxel size, 98 kVp, 3-5mA, and exposure time of 14s. GALILEOS Implant software was used to analyze CBCT images.

The inclusion criterium based on the presence of both mandibular second Premolar (MSP) and mandibular second molar (MSM) to MFM-ES in either or both right and left sides of the mandible. The exclusion criteria were spaces of extracted MFM root sockets appeared clearly in the CBCT images that indicated recent tooth extraction at the time of CBCT taking, one or both of MFM and MSP were missing, over-contouring restoration of adjacent MSP and MSM teeth, edentulous posterior segment, an implant placed in the MFM-ES, remaining retained roots, more than 2/3rd of the bone of the MSP and MSM loss, presence of orthodontic braces on the teeth and sites were unmeasurable owing to poor image quality. The proposal of the study was submitted to and approved by the Ethics and Scientific Committees of the University of Sulaimani before the commencement of data collection.

The extraction spaces of MFM in the CBCT images were examined, and the following measurements recorded:

1. The angle between MSP and MSM (Interdental angle): This was an angle that formed by the intersection of two lines that drawing from crestal-root junction points (CRJP) of MSP and MSM to the crest of curvatures (CC) s of both teeth until they matched coronally (Figure 1a).

2. The angle between MSP and MSM and alveolar bone crest (Molar-crest angle, Premolar-crest angle): Each angle was drawn from CRJP to the CC of the tooth and the CRJP of the corresponding tooth (Figure 1a).

3. Distance between MSM and MSP closest points (Interdental distance): These were CC of both teeth or CC and tip of the cusp of a severely tipped tooth (Figures 1b and 1c).

4. The bone length between MSM and MSP (crestal ridge distance): This was measured from the CRJP of MSP to MSM (Figure 1b and 1c).

5. Mid-crestal bone resorption: Measured from a point on crestal ridge distance line to the deepest point of crestal bone (Figure 1b).

6. Overeruption distance. This was measured from the line drawn from the most two coronal points of the mesial and distal adjacent teeth to the most coronal point of opposing tooth to MFM-ES (Figure 1d).

7. Crest to inferior alveolar nerve canal (IANC) distance (Crest-IANC distance): measured from the crest of alveolar bone to the uppermost point of IANC (Figure 2a).

8. IANC-lingual wall distance. It is measured from the most lingual point of the IANC to the lingual wall of the mandible (Figure 2a).

9. IANC-buccal wall distance. It is measured from the most buccal point of the IANC to the buccal wall of the mandible (Figure 2b).

10. Alveolar bone height: Measured from the crest of the alveolar bone to the base of the mandible (Figure 2b.

11. Width of the bone crest (Crestal bone width): measured from buccal to lingual walls of the mandible 2mm apical from bone crest (Figure 2c).

Statistical analysis

The continuous data have been subjected to the normality test (Shapiro-Wilk test) and, after that, subject to appropriate statistical tests. For parametric variables, mean and standard deviation have been calculated, and for nonparametric variables, median and inter-quartile range haven calculated. All calculations were performed using the SPSS software package (Version 21; SPSS INC., Chicago, IL, USA). GraphPad Prism software (version 8) has been used to make the graphs.

Results

We identified 183 single MFM-ES (97 right side + 86 left side) among CBCT images meeting inclusion criterium. Thirty extraction sites were completely closed and not accounted for in the analysis. The demographic percentages in the analysis were 41.2% male and 58.8% female. The mean age was 42.86 ± 11.075.

Teeth angulation characteristic of the ES

The premolar-molar, premolar, and molar to crestal bone angles had been measured to determine the tooth that most probably affected the direction of the drilling for the proper implant and prosthetic crown insertions. Mean molar-premolar, molar-crestal bone, and premolar-crestal bone angles were 48.5±12.14◦ (range: 15.45◦ - 85.00◦), 46.4±11.9◦ (range: 54.40◦-114.00◦) and 84.8±9.0◦ (range: 15.50◦-85.60◦) respectively. Although the normal distribution of the variables is approximate, the former two had shown more acute angles between long axes of the molar-premolar and long axis of the molar-alveolar bone crest, and the latter had a closer angle to 90◦ (Figure 3).

Mesiodistal and buccolingual characteristic of the ES

Proper bone quantity mesiodistally and buccolingually is important for proper implant fixture diameter and length selection. The mean molar-premolar crestal bone length was 11.66 ± 2.32 mm (range: 4.56 - 17.98). The minimum mesiodistal crestal bone length was 4.5 mm, and 99.5% were more than ≥ 6 mm. The median interdental distance was 7.54 mm (interquartile range: 11.38 - 2.25 mm). Of 182 interdental spaces measured, 42.3% were more than 8 mm, 25.8% were between 6-8 mm, and 31.8% less than 6 mm long. The width of the alveolar bone measured at 2 mm apical to the crestal bone; this was to reflect crestal bone osteotomy, more often doing for preparation of implant placement. The median bone width was 6.46 mm (interquartile range: 0.88-1.7 mm). Only one ES was 2 mm wide buccolingually, 36.2% were between 3.5-6 mm, and 63.8% were more than 6 mm long (Figures 4 and 5).

Mid-crest bone resorption and opposite teeth overeruption

To evaluate mid-crestal bone resorption and its effects on implant depth as dental implant places in the middle of the alveolar bone crest to minimize cantilevering. Unopposed teeth usually move toward ES of the opposite jaw; this will later compromise the crown-implant ratio. Median mid-crestal bone resorption was 1.51 mm (interquartile range: 1 - 2 mm). The median opposite teeth to ES overeruption was 1.29 mm (interquartile range: 5.33 - 9.1 mm) (Figure 6). The average of readable teeth overeruption was 75.4%, of which 76.8% was < 2 mm, 11.6% > 2 mm, and 11.6% showed no overeruption.

IANC distances to the buccal and lingual plate of the body of the mandible

These anatomic structures play major roles in buccolingual angulation of severely atrophic alveolar bone to place proper implant length without making trauma to the IANC. The mean distance of lateral IANC to the buccal surface of the body of the mandible is 4.11 ± 1.33 mm (range: 0.00-7.58 mm), and median distance of IANC to the lingual surface of the body of the mandible is 2.79 (interquartile range: 5.47 - 7.49 mm) (Figure 4 and 5). The average distances of IANC to buccal and lingual surfaces of the mandible were 4.1 mm and 3 mm, respectively.

Crest of the alveolar bone to the IANC distance and alveolar bone height

To determine implant depth, the alveolar bone height of the mandible was measured at ES. The length was taken from the crest to IANC for the implant depth, and the height of the ES bone for the possibility of the implant could bypass the canal. The mean alveolar crest to the roof of IANC and the lower border of the mandible were 16.42 ± 2.82 mm (range: 7.58 - 25.90 mm) and 26.48 ± 3.19 mm (range: 18.15 - 36.77 mm) respectively (Figure 7). The average of 16.42 mm was the distance from alveolar bone crest to the upper end of IANC.

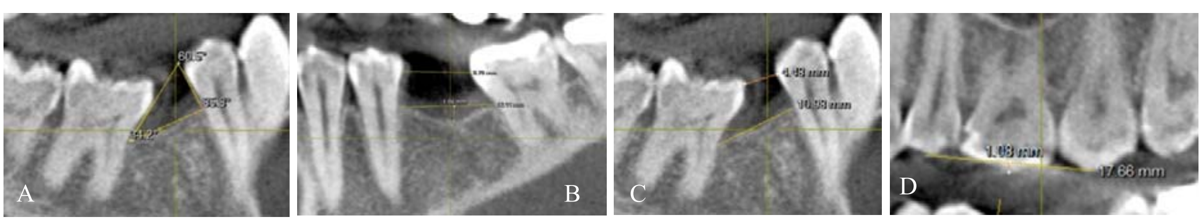

Figure 1: Measurements of teeth angulations, interdental distance and depth of bone resorption and tooth overeruption: **(a)** Measurement of the angles between teeth, and between teeth and crestal bone. **(b)** distance between CC of MSP and MSM, crestal bone length and depth of bone resorption; **(c)** between CC of MSP and distal cusp tip of MSM, and 0 bone resorption measured; (**d**) Measurement of the unopposed tooth overeruption.

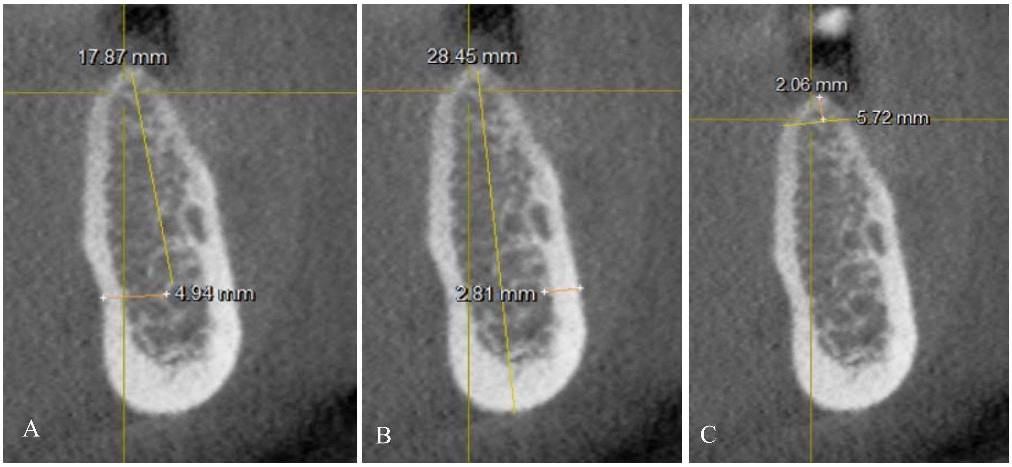

Figure 2: Measurements of alveolar bone heights and width: **(a)** crest to IANC and IANC to lingual surface of mandible **(b)** crest to the base of mandible and IANC to buccal surface of mandible; **(c)** crestal bone width 2 mm below alveolar bone crest.

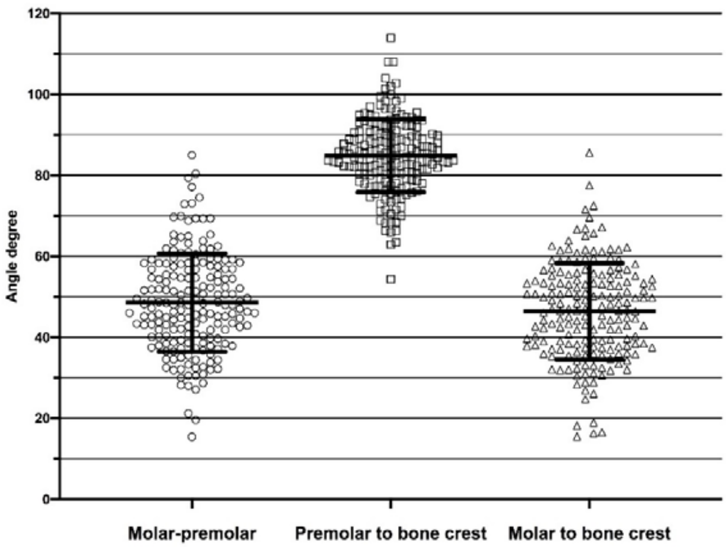

Figure 3: Mean and SD of Interdental angle, molar-crest angle and premolar-crest angle.

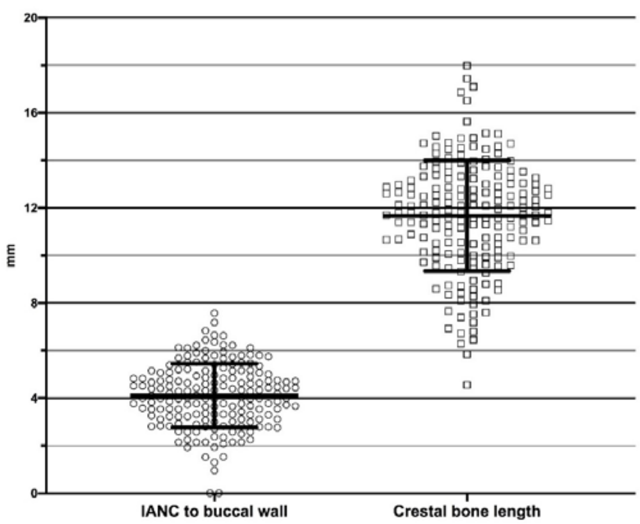

Figure 4: Mean and SD of IANC distance to mandibular buccal wall and crestal ridge distance.

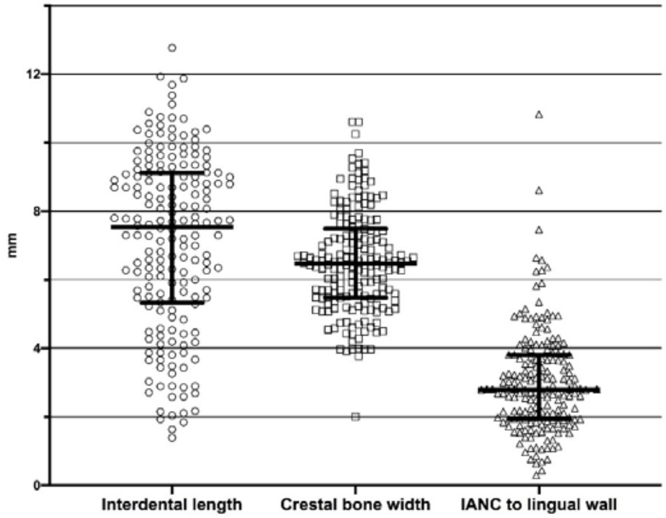

Figure 5: Median and interquartile range of interdental length, crestal bone width and IANC to mandibular lingual wall.

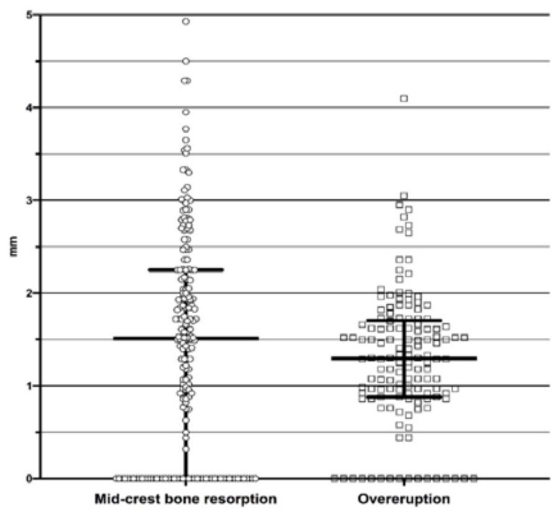

Figure 6: Median and interquartile range mid-crestal bone resorption and unopposed teeth overeruption.

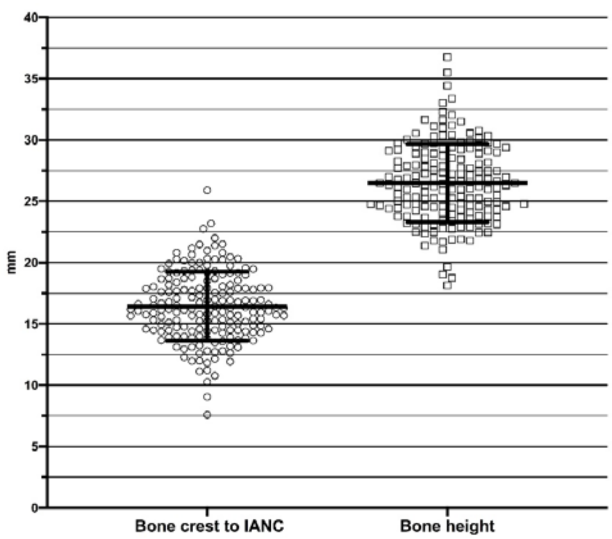

Figure 7: Mean and SD of alveolar bone crest to IANC and alveolar bone crest to the base of the mandible.

Discussion

Although computer-guided implant placement is more accurate than conventional implant placement even with experienced surgeons, still the latter is more commonly utilized[26,27]. Guided implant surgeries are technically expensive, require more equipment and facilities; this wouldn't be affordable for every dentist and patient[28]. Though the missing tooth sites are assessed clinically and radiographically, nevertheless, some complications could be encountered during dental implant placement[11]. This observational study examined CBCT images that had been taken for different dental procedures. However, the study utilized these CBCT for evaluation of MFM-ES for implant placement. The right and left were calculated together, either of the same patients or different patients, to evaluate all anatomical changes that happened around MFM-ES.

After tooth extraction, three-dimensional changes may occur adjacent to and opposite to ES. These changes are associated with the overeruption of unopposed teeth and the tilting of adjacent teeth toward space[4,29]. Therefore, proper mesiodistal and buccolingual site of placement of the implant in the ES is important to keep the implant in harmony with the occlusal forces of the opposing tooth, thus minimize the excessive occlusal force that is accounted for mechanical and biological failure[10,19,30].

Mal-positioned implant often complicates clinical and laboratory procedures of implant supra-structure fabrication and placement[31]. Tooth drifting and spatial bone resorption of the ES will further complicate proper implant site anatomy for restoration. Proper clinical and radiographical evaluation for single dental implant placement and prosthetic restoration should involve axial inclination of adjacent teeth, alveolar bone height and width, and the distance provided between two natural teeth for implant placement[32]. In the mandibular posterior teeth, the examination should involve IANC; perhaps this might be one of the most common limitations to dental implant placement, especially when there is severe alveolar bone resorption[2].

In the current study, interdental (molar-premolar) angles were more acute and very similar to molar-crest angles, which indicates that tilted MSM had a greater influence on the interdental angles than MSP. Consequently, MSM had greater effects on interdental and occlusal dimension than MSP following the extraction of MFM teeth. Therefore, it is recommended to use the MSP axis for conventional and computer-guided implant drilling direction because of minor distal inclination; on the contrary, MSM showed more mesial inclinations to ES. The advantages of this radiographic guide are to avoid technical errors that induce using angled implant abutments, prevent non-axial occlusal forces, minimize cantilever abutment crown, reproduce appropriate occlusal table, and easy path of abutment and crown insertion, and avoid biological complications like damaging adjacent roots and minimize bacterial plaque and food debris retentions between the implant and MSM crowns.

The crestal bone length and width showed fewer complicating factors in MFM-ES compared to the mesiodistal dimension of interdental distance. The current study revealed that the selection of proper implant diameter was not affected by the bone quantity as much as it was affected by teeth angulation and interdental space missing. The crestal bone length and width (99.5% and 63.8% respectively) were more than 6 mm, which indicates that 63% of ES had an available bone to place standard implant of 3.75 mm and keeping 1 mm cortical bone around implant crestal part. The rest should be restored with narrow implant diameters and bone augmentation. For selecting proper implant diameter, the interdental distances should be considered; the more tilting of the teeth, the narrower the interdental space is. Therefore, the interdental distance will mostly determine the size of the dental implants to be selected, not only the amount of bone itself. In some ES, sufficient length and width of crestal bone were available; however, the interdental distances were very narrow to fabricate appropriate implant supra-structures. In these instances, orthodontic intervention is recommended to create space for proper implant size selection and supra-crestal crown fabrication[33]. Other restorative procedures may be manipulated; it could be as small as enameloplasty or requires extensive tooth structure removal - odontoplasty that could endanger pulp vitality[34,35]. As this study has shown, proper mesiodistal bone quantity with improper interdental space and this happens because the teeth usually tilted rather than drifted, in these cases, implants with narrow diameter should be placed and some orthodontic-restorative space widening for implant crown fabrication. Therefore, the crown should be fabricated more premolar-like in shapes than a molar tooth with a smaller occlusal table. The more MSM tilting, the more undercut spaces left between the crown and the MSM crown, and more food trapped in.

In some cases, the ESs were very narrow, and implant placement seems to be impossible. These cases are better to be fixed with orthodontic or restorative procedures to close the spaces. Similar to mesiodistal crestal length, bone width is important not only to select proper implant size but also to buccolingual angulation of the implant to obtain a proper emergence profile. The wider the alveolar bone, the more freedom for buccolingual manipulation for correct axial implant placement and proper prosthetic procedures.

The occlusal over eruption of unopposed teeth may affect implant crown height and changes occlusal scheme, this subject implant to overloads and complicate excursive occlusal relationship(29,36). The current radiological study had shown overeruption of the teeth opposing ES occurred in the majority of readable CBCT radiographs. These results are comparable to the previous studies(35,37). The inter-occlusal distances should be evaluated clinically and on the patient's dental casts for proper dimension reading to select appropriate implant abutment.

Sufficient bone volume is important for implant success predictability as studies had shown implants shorter than 10 mm associated with a higher rate of failure(38). The current study recorded almost all MFM-ES had sufficient bone volume to place 10 mm and longer dental implants. The extraction of MFM seems to have a lesser impact on the vertical dimension of the ES. An average of 16.42 mm distance from alveolar bone crest to the roof of the IANC was obtained, which is very close to the previous study by Oliveira et al., the average was 14.7 mm long(2). Therefore MFM-ES could be successfully used for implantation due to sufficient vertical height of bone. This study has also found some bone depressions or resorption, especially in the middle of the alveolar bone crest. However, these resorptions did not show great impacts on the implant length as the average of resorption was 1.47 mm.

In severely resorbed mandibular ridge and to avoid damage to IANC, the implant could be placed either buccal or lingual to IANC, which subsequently may end up with facial or lingual inclination of the implant. In this case and to avoid bone augmentation procedure on the buccal or the lingual aspect, the problem could be solved using standard, narrow-diameter, or tapered dental implants with or without an angled implant.

The current study showed averages of 3 mm and 4.1 mm distances from the medial and lateral sides of IANC to the lingual and facial mandibular cortexes, respectively. Similar results have been obtained by Gowgiel in which the IANC located about a half-centimeter from the buccal plate in the lower premolar and molar regions(39).

The ideal position of the dental implant is better to be surrounded by at least 2 mm of bone thickness buccolingually and 1.5 mm with adjacent teeth mesiodistally(40). After tooth extraction, the proper bone volume and interdental space for this purpose will be compromised. Different ES volume requires different implant sizes. In these situations, two treatment options should be considered, bone augmentation or placement of smaller implant size because the alveolar bone width is greater in dentate site than edentulous space after extraction(16). The mesiodistal dimensions will be further compromised by teeth drifting/tipping too. Based on our study analysis, we suggest socket preservation and immediate implant placement after extraction of MFM as a first treatment approach. For untreated ES, it is recommended to be maintained by a space maintainer to prevent drifting and tilting immediately after extraction. The final suggestion for narrower ES is to apply orthodontic-restorative procedures either to close the ES or redistalization of MSM for widening ES.

Conclusions

The extraction space volume of MFM was compromised mainly by mesial tilting and drifting of MSM. Narrower interdental spaces may also compromise proper dental implant diameter placement. According to this radiographic analysis, the MSP axis can facilitate proper implant site drilling directions and implant placement with lesser prosthetic complications. The next most complicating factor is the alveolar bone width for selecting implant size. The extraction of MFM showed almost no effects on alveolar bone height for placing long dental implants.

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