Original Article

"Safe Zones": A Guide for Miniscrew Positioning in the Maxillary and Mandibular Arch

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ABSTRACT
The aim of this study was to provide an anatomical map to assist the clinician in miniscrew placement in a safe location between dental roots. Volumetric tomographic images of 25 maxillae and 25 mandibles taken with the NewTom System® were examined. For each interradicular space, the mesiodistal and the buccolingual distances were measured at two, five, eight, and 11 mm from the alveolar crest. In this article, measurements distal to the canines are presented. In the maxilla, the greatest amount of mesiodistal bone was on the palatal side between the second premolar and the first molar. The least amount of bone was in the tuberosity. The greatest thickness of bone in the buccopalatal dimension was between the first and second molars, whereas the least was found in the tuberosity. In the mandible, the greatest amount of mesiodistal dimension was between first and second premolar. The least amount of bone was between the first premolar and the canine. In the buccolingual dimension, the greatest thickness was between first and second molars. The least amount of bone was between first premolar and the canine. Clinical indications for a safe application of the miniscrews are provided, as well as the ideal miniscrew features. (*Angle Orthod* 2006;76:191–197.)

KEY WORDS: Miniscrew; Interradicular anatomy; Safe zones

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INTRODUCTION

Miniscrews, as an alternative method for absolute orthodontic anchorage, have been extensively used in the last few years.[1–4] The major advantages compared with dental implants or microplates are small size, allowing placement in many intraoral areas; low cost; and easy implantation and removal.

Numerous anatomical sites for miniscrew application have been presented.[5–7] Kanomi[8] and Costa et al[9] implanted microscrews (1.2 mm in diameter) and miniscrews (2.0 mm in diameter) into the basal bone below the roots of the teeth to prevent root damage. Because the implanted microscrews were positioned so high, the applied force for applying vertical vectors was limited. Park et al[10] and Park[11] implanted microscrews (1.2 mm in diameter) into the alveolar bone between the roots of the posterior teeth to increase the horizontal component of the applied force. Other critical issues in the evaluation of miniscrew application include anatomical guidelines for safe insertion, adequate mechanical properties of the screws, best material used, and type and length of active loading.

Despite the great interest in anchorage control with self-tapping screws, no studies have been performed for evaluating and measuring the anatomical sites for a safe implantation of the miniscrews in the interradicular spaces of the maxillary and mandibular arches.

A single study on images from 21 patients was performed to provide anatomic data to assist implantation of microimplants in the alveolar region.[12] A greater amount of bone tissue was observed in the interradicular spaces between the second premolar root and first molar root in the upper arch and between the first molar root and the second molar root in the lower arch.

The main aim of this study was to provide an anatomical map to be used as a guideline to assist the clinician in the determination of safe locations for miniscrew placement between the dental roots of the posterior teeth. A secondary objective was to identify the morphological features of the ideal miniscrew. The data were generated by a new type of digital volume

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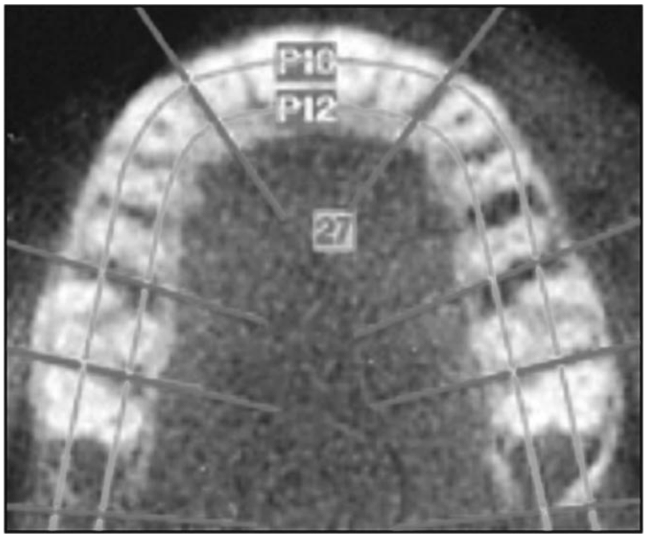

FIGURE 1. Maxillary posterior reference planes used for the mesiodistal measurements.

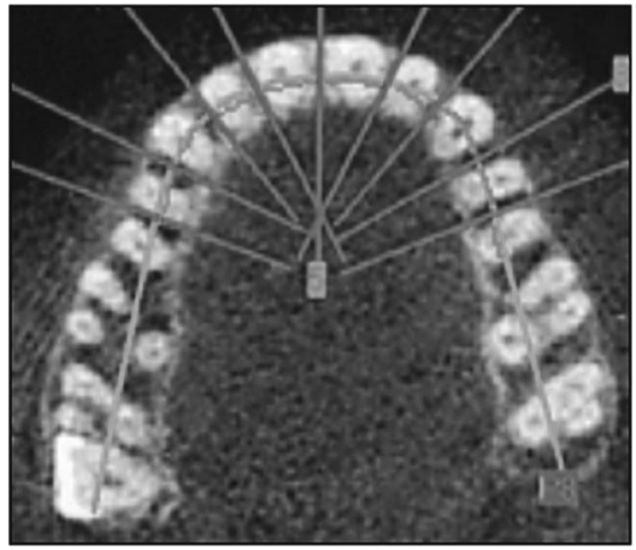

FIGURE 2. In the anterior maxillary arch, from right first premolar to left first premolar, the distance of adjacent roots were measured keeping a single reference plane.

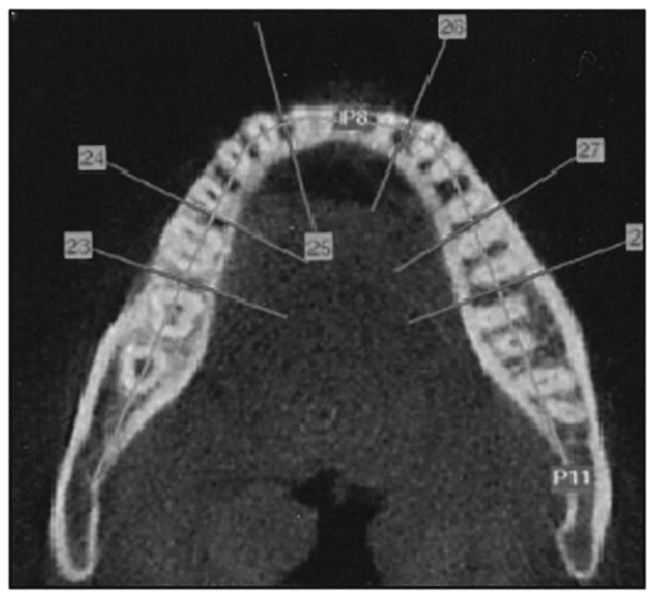

FIGURE 3. In the mandibular arch, the distance of adjacent roots were measured keeping a single reference plane.

tomography called NewTom® (DVT9000), based on a cone beam technique.[13,14]

MATERIALS AND METHODS

Data acquisition

Volumetric tomographic images of 25 maxillae and 25 mandibles were retrieved from the records of 2000 patients (age range: 20 to 40 years). Dental arches with severe crowding, missing teeth, or radiographic signs of periodontal disease were excluded.

The data were obtained using the NewTom® (DVT9000) Volume Scanner QRsr1 Verona for prosthetic implant investigation. The NewTom® 9000 scanner is based on a cone-shaped X-ray beam technique that uses the X-ray emissions very efficiently, thus reducing the absorbed dose to the patient. NewTom® 9000 provides one-to-one images.[13,14]

Measurements

For each interradicular space, the mesiodistal and the buccolingual distance was measured at four different depths from the alveolar crest, ie, at two, five, eight, and 11 mm.

Mesiodistal measurements. In the posterior region of the maxillary arch, the mesiodistal measurements were taken with two reference planes, one for the palatal side and one for the buccal side because of the anatomy of the molar roots (Figure 1).

In the anterior region of the maxillary arch, from right second premolar to left second premolar (Figure 2) and in the mandible arch (Figure 3), the distances of adjacent roots were measured keeping a single reference plane passing median to the teeth (Figure 4).

Buccolingual measurements. The buccolingual bone thickness of interradicular maxillary and mandible bone was measured two, five, eight, and 11 mm from the alveolar crest (Figure 5).

A total of 144 measurements were recorded in each of the 25 maxillae, and a total of 104 measurements were recorded in each of the 25 mandibles. Each measurement was taken on the computer display monitor with the NewTom® measure software. The mean and the standard deviation of the measurements were calculated.

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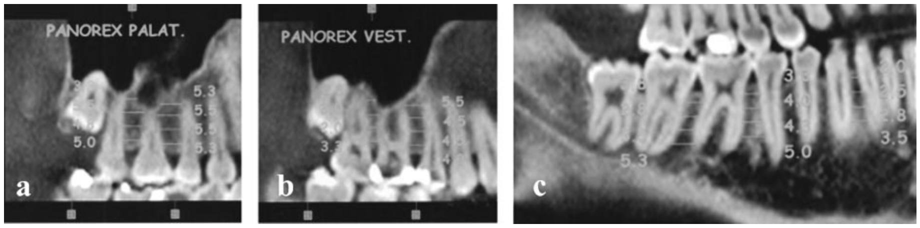

FIGURE 4. Mesiodistal measurements in the maxilla, (a) palatal and (b) buccal side and (c) in the mandible.

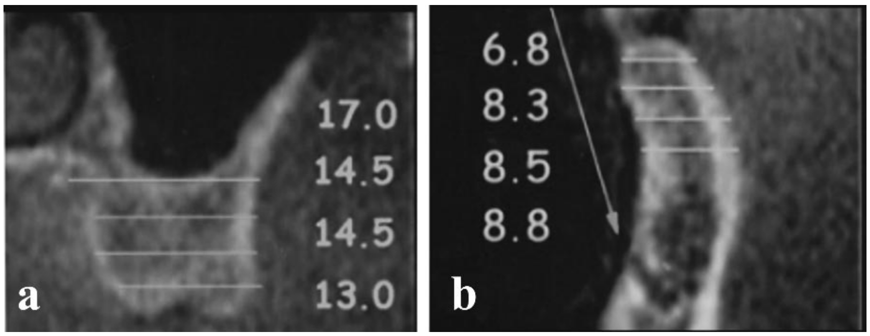

FIGURE 5. Buccolingual measurements (a) in the maxilla and (b) in the mandible.

Reliability of the measurements

The Method Error (ME) was calculated for the mesiodistal measurements and for the buccolingual measurements both in the maxilla and mandible. The volumetric tomographic images of 10 maxillary and 10 mandibular arches were selected and measured by the same observer after a two week interval. The ME calculations were performed using the Dahlberg formula, $ME = \sqrt{\Sigma d/2n}$, where d is the difference between two measurements of a pair and n is the number of paired double measurements.[15]

In the maxilla, the ME of the mesiodistal measurements and the buccopalatal measurements was 0.21 ($n = 617$) and 0.41 ($n = 179$), respectively. In the mandible, the ME of the mesiodistal measurements and the buccolingual measurements was 0.31 ($n = 427$) and 0.35 ($n = 372$), respectively. These differences were not statistically significant ($P > .05$).

RESULTS

The measurements of the interradicular spaces of the maxillary and mandibular posterior regions are reported in Table 1a,b and in Table 2a,b, respectively.

In the maxilla, the greatest amount of mesiodistal bone was on the palatal side between the first molar and the second premolar (5.5 mm SD 1.3, at five-mm depth); the least amount of bone was at the tuberosity (0.2 mm SD 1.2, at 11-mm depth). In 70% of the measured maxillae, the sinus or impacted wisdom teeth were present in the tuberosity, thus explaining the limited amount of bone found in this area.

TABLE 1. (a) The Mean and the Standard Deviation of Mesiodistal Measurements and (b) Buccopalatal Measurements in the Maxillae

	Maxillae			
Cut level	2 mm	5 mm	8 mm	11 mm
a. Mesiodistal Measurements				
Tuber	1.3	1.0	0.4	0.2
SD	2.7	2.6	1.9	1.2
7-6 Buccal side	2.5	2.3	2.5	0.8
SD	0.7	0.8	1.5	1.5
6-5 Buccal side	2.7	2.9	3.0	1.6
SD	0.6	0.9	1.5	2.0
7-6 Palatal side	3.4	3.9	3.1	1.0
SD	0.8	1.1	2.4	2.0
6-5 Palatal side	4.5	5.5	4.6	1.9
SD	1.1	1.3	3.2	3.2
5-4	2.9	3.2	3.5	3.3
SD	0.6	0.8	1.1	1.6
4-3	3.0	3.4	3.9	4.3
SD	0.7	0.7	1.1	1.1
b. Buccopalatal Measurements				
Tuber	4.1	3.0	0.9	0.6
SD	5.0	5.0	3.2	2.7
7-6	13.2	14.3	12.0	3.7
SD	1.0	1.1	5.6	7.1
6-5	10.8	11.4	10.2	5.4
SD	1.2	1.2	4.5	6.8
5-4	9.3	9.9	10.0	8.2
SD	1.1	1.2	1.4	5.1
4-3	8.2	9.2	9.6	10.6
SD	1.2	1.1	1.3	4.6

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TABLE 2. (a) The Mean and the Standard Deviation of Mesio Distal Measurements and (b) Buccolingual Measurements in the Mandibles

Mandibles				
Cut level	2 mm	5 mm	8 mm	11 mm
a. Mesiodistal Measurements				
7-6	3.2	3.0	3.5	4.7
SD	0.7	0.9	1.3	1.9
6-5	3.0	2.9	3.1	3.9
SD	0.8	0.8	0.9	1.3
5-4	3.2	3.7	4.3	4.9
SD	0.6	0.8	0.9	1.0
4-3	2.7	2.8	3.0	3.5
SD	0.7	0.9	1.0	1.2
b. Buccolingual Measurements				
7-6	10.4	12.5	13.4	13.4
SD	1.0	1.2	1.5	2.0
6-5	8.9	9.7	10.4	10.6
SD	0.8	0.9	1.0	1.3
5-4	7.2	8.2	8.8	9.3
SD	0.8	1.0	1.2	1.4
4-3	6.8	8.1	8.3	8.4
SD	1.0	1.0	1.3	1.9

On the buccal side, the greatest amount of mesiodistal bone was between the first and second premolars (3.5 mm SD 1.1) and between the canine and first premolar (4.3 mm SD 1.1). In the interradicular space between the first maxillary molar and the second premolar, the greatest amount of mesiodistal bone was between the five-mm and the eight-mm cut from the alveolar crest (2.9–3 mm SD 1.5). The mesiodistal space between the first and the second maxillary molars on the buccal side is the narrowest of the arch (2.3–2.5 mm).

Less mesiodistal space is available on the buccal side than on the palatal side. This indicates that more sites for a safe screw insertion are available on the palatal side than on the buccal side. In the buccopalatal dimension, the greatest amount of space is between the first and second molars (14.3 mm SD 1.1, at five mm from the alveolar crest).

In the maxilla at 11-mm depth, both the buccopalatal and the mesiodistal values are low because of the frequent presence of the maxillary sinus. Once again, this result has a fundamental clinical application, showing that areas between the maxillary posterior teeth more than eight mm above the alveolar crest are off limits for any kind of implantation.

In the mandible, the greatest amount of bone in the mesiodistal dimension was between first and second premolars (4.9 mm SD 1.0, at 11-mm depth); the least amount of bone was between the first premolar and the canine (2.7 mm SD 0.7, at two-mm depth).

In the buccolingual dimension, the greatest amount of bone was between the first and second molars (13.4 mm SD 1.5, at eight- and 11-mm depth), and the least between the first premolar and canine (6.8 mm SD 1.0, at two-mm depth). Both in the maxilla and in the mandible, the mesiodistal interradicular measurements are less than the buccolingual ones and, therefore, they represent the key parameter to define an interradicular space suitable for miniscrew insertion.

DISCUSSION

This study analyzes the interradicular spaces in the maxillary and mandibular posterior region for safe miniscrew insertion. For a clinical evaluation of the data, it is important to combine the interradicular space measurements with the miniscrews' diameters and the bone clearance needed for both periodontal health and miniscrew stability.

Currently, most miniscrews have diameters ranging from 1.2 to two mm. Conic miniscrews have an initial diameter of 1.5 mm with the diameter decreasing at the tip to 1.2–1.1 mm. The differences between the initial diameter and the tip is approximately 0.3–0.4 mm.[16]

No data are available on how much bone is necessary between the miniscrews and the dental roots for both periodontal health and miniscrew stability. Considering that the width of periodontal ligament is approximately 0.25 mm,[17] we assume that a minimum clearance of one mm of alveolar bone around the screw could be sufficient for periodontal health: combining this value with our data and the screw diameter, the safer zones for screw insertion in the interradicular spaces can be identified.

In Table 3a,b, maxillary and mandibular mesiodistal and buccolingual measurements of the interradicular spaces distal to the canines are matched to give a map of the safe interradicular spaces.

The green values (mesiodistal measure $>$3.1) are safe zones for placement of miniscrew with a maximum diameter of 1.2–1.3 mm. Screws with a 1.5-mm diameter could be considered safe if at least 3.5 mm of space are available in the interradicular space (between 7 and 6 palatal side at five-mm cut; between 6 and 5 on the palatal side at two-, five-, and eight-mm cut; between 5 and 4 at eight-mm cut; between 4 and 3 at eight- and 11-mm cut). Screws with a diameter of two mm cannot be considered safe for implantation in the posterior interradicular spaces of the maxilla except for between the first molar and the second premolar on the palatal side (above an eight-mm cut) and between first premolar and canine (at 11-mm cut).

The black values are intermediate zones where only 1.2- to 1.3-diameter screws might be safely placed after accurate radiographic control and with optimal sur-

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TABLE 3. (a) Maxillary Mesiodistal and Buccopalatal Measurements and (b) Mandibular Mesiodistal and Buccolingual Measurements are Matched to Give a Map of Safe Interradicular Spaces

Cut level	2 mm	5 mm	8 mm	11 mm
a				
Tuber palatal side				
Buccopalatal	4.1	3.0	0.9	0.6
Mesiodistal	1.9	1.8	0.6	0.3
Tuber buccal side				
Buccopalatal	4.1	3.0	0.9	0.6
Mesiodistal	1.3	1.0	0.4	0.2
7-6 palatal side				
Buccopalatal	13.2	14.3	12.0	3.7
Mesiodistal	3.4	3.9	3.1	1.0
7-6 Buccal side				
Buccopalatal	13.2	14.3	12.0	3.7
Mesiodistal	2.5	2.3	2.5	0.8
6-5 Palatal side				
Buccopalatal	10.8	11.4	10.2	5.4
Mesiodistal	4.5	5.5	4.6	1.9
6-5 Buccal side				
Buccopalatal	10.8	11.4	10.2	5.4
Mesiodistal	2.7	2.9	3.0	1.6
5-4				
Buccopalatal	9.3	9.9	10.0	3.3
Mesiodistal	2.9	3.2	3.5	3.3
4-3				
Buccopalatal	8.2	9.2	9.6	10.6
Mesiodistal	3.0	3.4	3.9	4.3
b				
7-6				
Buccolingual	10.4	12.5	13.4	13.4
Mesiodistal	3.2	3.8	3.5	4.7
6-5				
Buccolingual	8.9	9.7	10.4	10.6
Mesiodistal	3.0	2.9	3.1	3.6
5-4				
Buccolingual	7.2	8.2	8.8	9.3
Mesiodistal	3.2	3.7	4.3	4.9
4-3				
Buccolingual	6.8	8.1	8.3	8.4
Mesiodistal	2.7	2.8	3.0	3.5

gical skills. The red sites are not suitable for screw positioning.

The insertion of screws in the maxillary molar region above 8–11 mm from the bone crest has to be avoided with any type of screw because of the presence of the sinus (Figure 6). Some of the clinical reports present in the literature seem to overlook this anatomical observation.

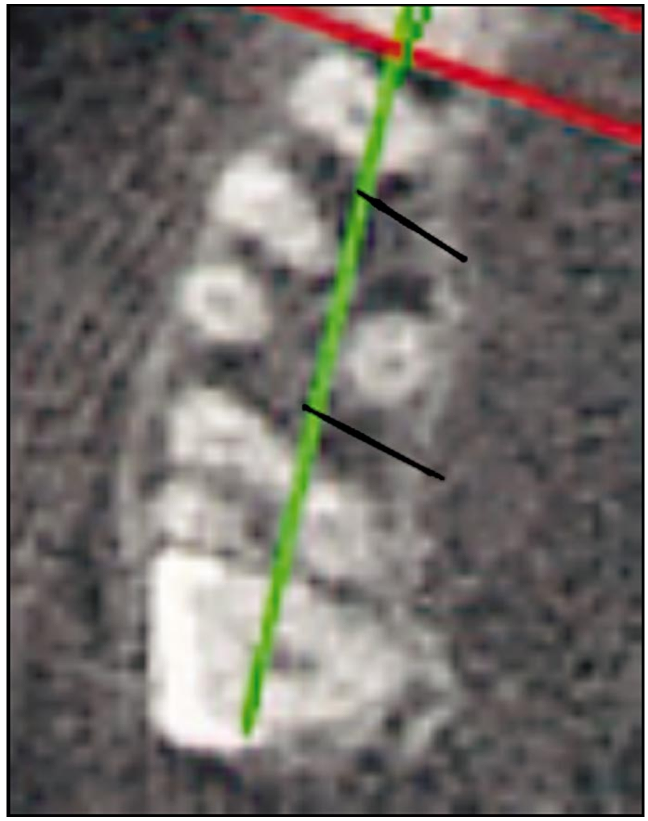

FIGURE 7. On the palatal side, the miniscrew should be embedded for no more than 6–8 mm bone depth, to avoid damaging the facial roots.

Another area that is generally not suitable for screw implantation is the tuberosity, where the amount of bone is very limited by the presence of wisdom teeth. Of course, in cases where the wisdom teeth are extracted, the tuberosity might become eligible for screw application if the quantity of bone reflects the minimum clearance.

More sites for a safe screw insertion are available on the palatal side than on the buccal side, but the palatal insertion must be carefully evaluated. The mesiodistal spaces between the palatal roots are in general sufficient, but embedding the screw into the bone toward the buccal side, the available space decreases because of the presence of the buccal molar roots (Figure 7). For a safe miniscrew insertion in this area, the insertion axis and the screw shape become critical.

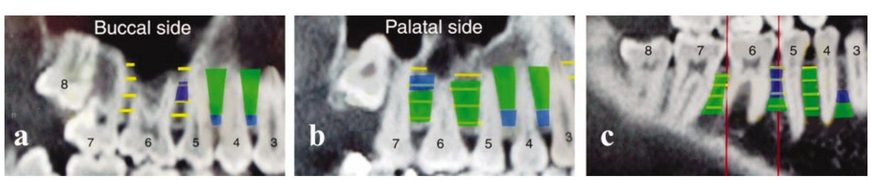

FIGURE 6. (a) Maxillary buccal and (b) palatal side, and (c) mandible images. In green are the zones with a mesiodistal measure over 3.1 mm. In blue are the zones with a mesiodistal measure between 2.9 and 3.1 mm.

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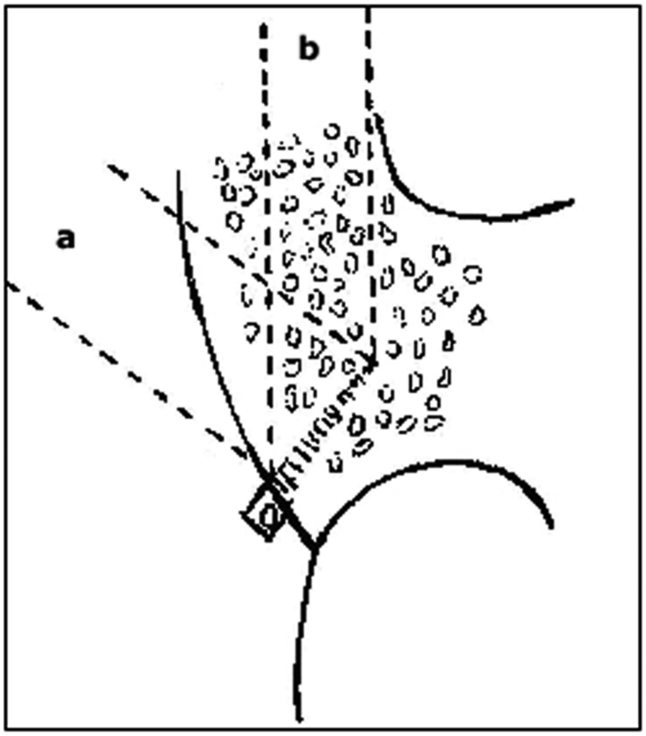

FIGURE 8. The screw should be implanted 30–40° to the dental axis that would allow the insertion of longer screw in the available bone depth. (a > b).

If the screw is inserted perpendicular to the dental axis, it might reach the narrowest interradicular space earlier than when inserted at an oblique angle and, according to our findings, it should be embedded for no more than 6–8 mm of bone depth, ie, the 50% of the buccolingual average measure between first and second molars. A miniscrew insertion at 30–40° to the dental axis allows the insertion of a longer screw in the available bone depth. Because of the reduced tip diameter, a conic screw insertion has a lower risk of damaging roots (Figure 8).

In the mandible, the safest sites are between the first and second molars and between the first and second premolars, at all depths investigated. Between the first and second molars, and because of the shape of the first molar's mesial root, there is a safe zone for the insertion of 1.2- to 1.5-mm diameter screws only at an 11-mm depth. Between the first premolar and canine, because of the root proximity, the values are suitable for miniscrew safest insertion over eight mm from the alveolar crest (Figure 6). Because of the limited amount of interradicular space, miniscrew stability under mechanical loading such as an orthodontic force is an important clinical issue.

A retrospective clinical study[18] showed that factors such as the diameter, inflammation of the peri-implant tissue, and thin cortical bone could be associated with the mobility (ie, failure) of a titanium screw placed in the facial alveolar bone of the posterior region. No significant correlation was observed with the screw length, kind of placement surgery, immediate loading, age, sex, crowding, anteroposterior jaw base relationship, controlled periodontitis, and temporomandibular disorder symptoms. However, in this retrospective study, different types of miniscrews and mini-implants are compared erefore, it is extremely difficult to draw conclusive statements.

A recent study showed that miniscrews are not absolutely stable,[19] with a range of movement on average less than 0.5 mm. Nevertheless, if the bone clearance and the location are safe, it is possible to tolerate their possible movement. Many factors could play a key role, such as the type and direction of the applied force, the loading period, bone quality, and quantity of the insertion site. These questions should be opened to future research.

CONCLUSIONS

The order of the safer sites available in the interradicular spaces of the posterior maxilla is as follows:

- On the palatal side, the interradicular space between the maxillary first molar and second premolar, from two to eight mm from the alveolar crest.
- On the palatal side, the interradicular space between the maxillary second and first molars, from two to five mm from the alveolar crest.
- Both on buccal or palatal side between the second and first premolar, between five and 11 mm from the alveolar crest.
- Both on buccal or palatal side between the first premolar and canine, between five and 11 mm from the alveolar crest.
- On the buccal side, in the interradicular space between the first molar and second premolar, from five to eight mm from the alveolar crest.
- In the maxilla, the more anterior and the more apical, the safer the location becomes.

The following is the order of the safer sites available in the interradicular spaces of the posterior mandible:

- Interradicular spaces between the second and first molar.
- Interradicular spaces between the second and first premolar.
- Interradicular spaces between the first molar and second premolar at 11 mm from alveolar crest.
- Interradicular spaces between the first premolar and canine at 11 mm from the alveolar crest.
- These findings are statistical evaluations of data coming from a group of nontreated patients. They represent a guide for the clinicians but do not elim-

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inate the need for a radiographic evaluation in each individual case before miniscrew insertion.

- The features of the ideal titanium miniscrew for orthodontic skeletal anchorage in the interradicular spaces should be 1.2- to 1.5-mm maximum diameter, with 6–8 mm cutting thread and a conic shape.

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