OVERVIEW

Anatomical Guidelines for Miniscrew Insertion: Vestibular Interradicular Sites

BJÖRN LUDWIG, DMD, MSD
BETTINA GLASL, DMD, MSD
GERO S.M. KINZINGER, DMD, MSD, PHD
THOMAS LIETZ, DDS
JÖRG A. LISSON, DDS, PHD

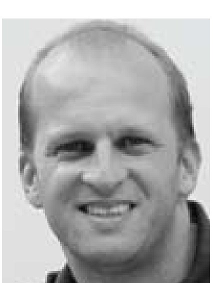
(Editor's Note: In this quarterly column, JCO provides an overview of a clinical topic of interest to orthodontists. Contributions and suggestions for future subjects are welcome.)

Studies and case reports featuring the use of mini-implants for temporary orthodontic anchorage indicate a preference for interradicular screw insertion on the vestibular side. This positioning does have a number of drawbacks, including:

- A loss rate as high as 25%.[1]
- Difficulties in determining the availability and quality of local bone.
- Risk of damage to the root or periodontium.
- Risk of intraoperative screw fracture.

In the maxilla, such problems may be avoided by placing the mini-implant in the anterior palate, which involves comparatively simple insertion with few complications. Considering that a treatment plan or appliance may require vestibular placement in either arch, however, reliable and suitable locations are needed in both jaws.

The selection of an interradicular insertion site is determined by three factors: the biomechanics of the chosen appliance, the patient's anatomy, and the dimensions of the mini-implant. Only a narrow corridor of bone is suitable for interradicu-


Dr. Ludwig


Dr. Glasl


Dr. Kinzinger


Dr. Lietz


Dr. Lisson

Drs. Ludwig and Glasl are Instructors, Dr. Kinzinger is a Professor, and Dr. Lisson is Professor and Head, Department of Orthodontics, University of Homburg, Saar, Germany. Drs. Ludwig and Glasl are also in the private practice of orthodontics at Am Bahnhof 54, 56841 Traben-Trarbach, Germany. Dr. Lietz is in the private practice of orthodontics in Neulingen, Germany. Dr. Ludwig is a Contributing Editor of the *Journal of Clinical Orthodontics*; e-mail him at bludwig@kieferorthopaedie-mosel.de.

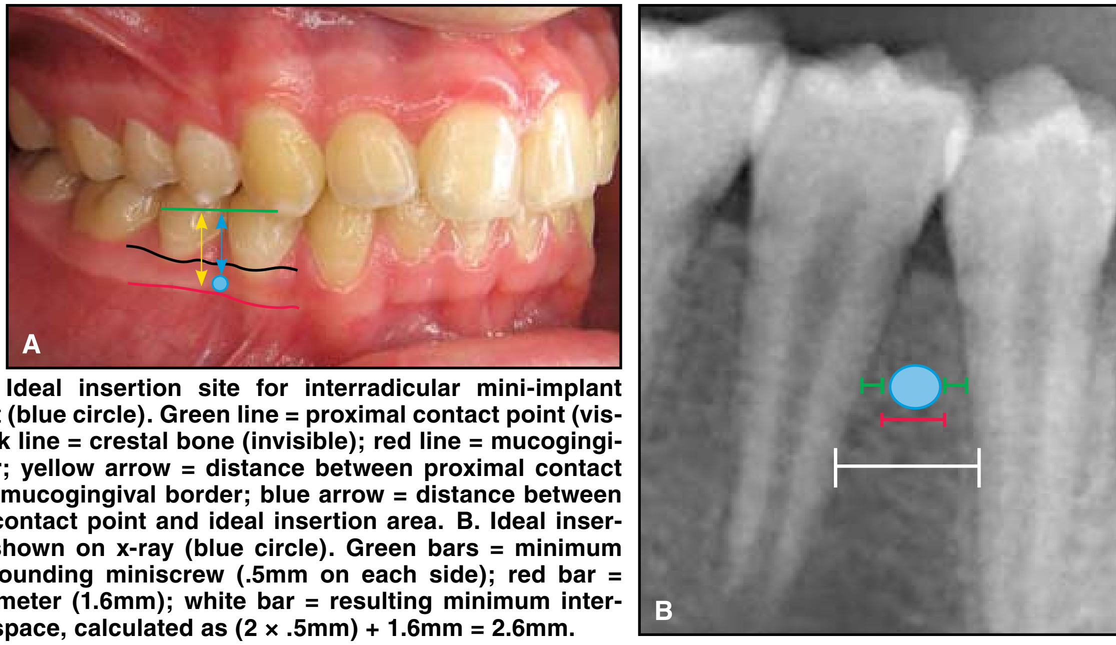


Fig. 1 A. Ideal insertion site for interradicular mini-implant placement (blue circle). Green line = proximal contact point (visible); black line = crestal bone (invisible); red line = mucogingival border; yellow arrow = distance between proximal contact point and mucogingival border; blue arrow = distance between proximal contact point and ideal insertion area. B. Ideal insertion site shown on x-ray (blue circle). Green bars = minimum bone surrounding miniscrew (.5mm on each side); red bar = screw diameter (1.6mm); white bar = resulting minimum interradicular space, calculated as (2 × .5mm) + 1.6mm = 2.6mm.

lar insertion of a mini-implant. From cervical to apical, appropriate sites fall between the clinically invisible crestal bone margin and the clinically visible mucogingival border (Fig. 1); we recommend placing the screw as apically as possible within the attached gingiva. From mesial to distal, the roots generally diverge apically, thus determining the available space.

Mini-implants are available with diameters between 1.2mm and 2.3mm.[2] If a larger screw diameter (≥1.8mm) is selected because of the need for good primary stability and high loading capacity, the interradicular space may be insufficient. Conversely, a smaller screw diameter (≤1.5mm) may resolve the space problem, but also reduce primary stability and loading capacity. Smaller-diameter screws are more likely to bend or fracture during insertion and extraction.[2-5] A diameter of 1.6mm or 1.7mm can be a reasonable compromise, providing sufficient mechanical properties[5] without requiring a wide insertion space.

Published opinions on the amount of surrounding bone needed to provide sufficient retention for the implant vary between .5mm and 1mm on either side.[6-8] To avoid root contact, periodontal width should be included in this calculation, adding .25mm per side. For a 1.6mm-diameter mini-implant, therefore, an adequate amount of mesiodistal bone width would be 2.6-3.1mm; more than 3.1mm would be an optimum width.

Clinical complications are minimized if the head of the mini-implant rests within the attached gingiva,[9] as can easily be confirmed visually. The marginal bone ridge and the bone volume below are more difficult to assess. To measure the amount of bony support for mini-implants in various interradicular spaces, we performed a prospective cone-beam computed tomography (CBCT) study. This article summarizes the results, describing ideal screw-insertion sites that can be identified by means of readily distinguishable anatomical structures.

Materials and Methods

We examined the records of 70 adolescent and adult orthodontic/orthognathic patients who were undergoing CBCT scans as part of their treatment. The scans were taken in a German radiology practice using a Veraviewepocs 3D scanner* with a pixel size of .125mm × .125mm, producing scans with slice thicknesses of .25mm each.

The patient's head was fixed to ensure opti-

*Registered trademark of J. Morita USA, 9 Mason, Irvine, CA 92618; www.morita.com.

mal three-dimensional orientation and to avoid movement artifacts. The sagittal-transverse plane was adjusted parallel to the occlusal plane of the patient. An additional jig ensured a secure occlusal position. The maxilla and mandible were imaged completely, with the images extending upward to the lower aspects of the maxillary sinuses, thus including complete root formations in each arch.

All patients were Caucasian; only the sex and age were indicated on our copy of each image. Scans were thoroughly inspected to verify the correct exposure and, especially, correct positioning in relation to the occlusal plane. Patients with obvious head malpositioning were excluded from the investigation. Although minor positional errors were impossible to identify, they were considered to have minimal influence on our findings. Extended prosthetic restorations, large numbers of missing teeth, and expressed skeletal dysgnathia were also excluding factors, since the anatomical relationships could not be regarded as representative in such cases. These exclusions left 36 maxillae and 38 mandibles of 39 patients in the study sample (Table 1).

TABLE 1
PATIENT DISTRIBUTION

Age	Male	Female	Total
12-20	8	6	14
21-40	7	6	13
41-60	4	8	12
Total	19	20	39

The open-source DICOM viewer OsiriX** was used to analyze the digitized data sets for every available interradicular space (Fig. 2). The

**Pixmeo SARL, 266 Rue de Bernex, CH-1233 Bernex, Switzerland; www.osirix-viewer.com.

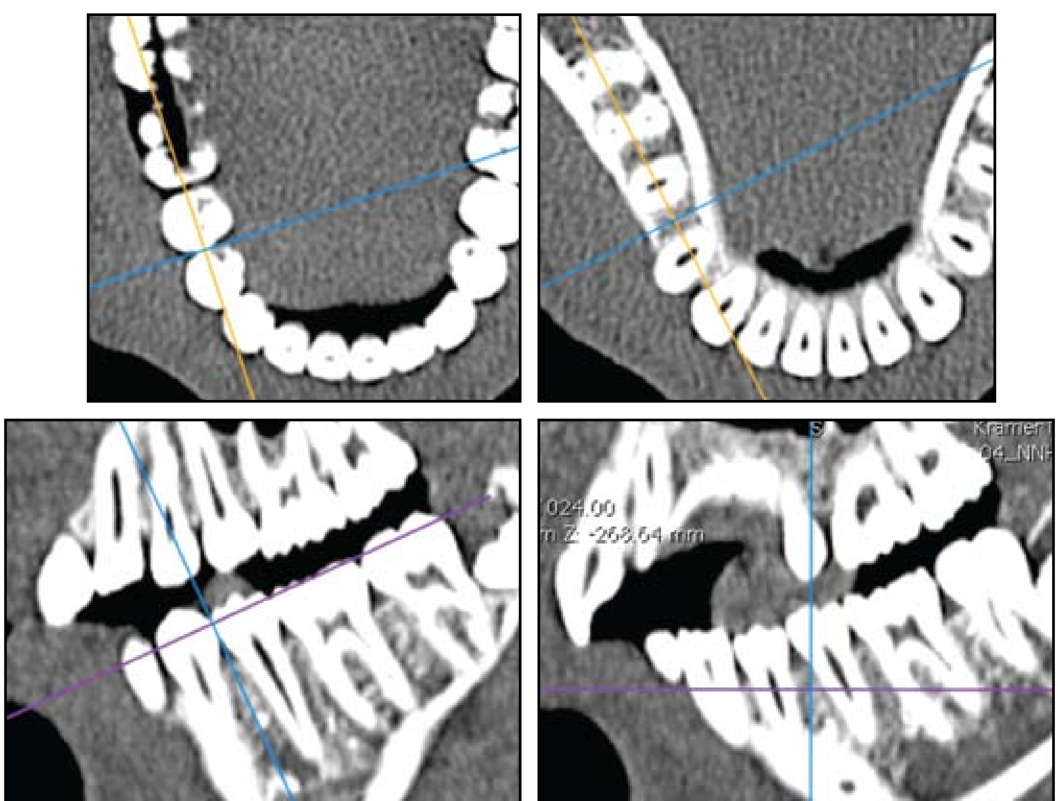


Fig. 2 Distance between teeth measured in .5mm intervals from proximal contact to apex, following line perpendicular to corticalis and insertion direction of mini-implant.

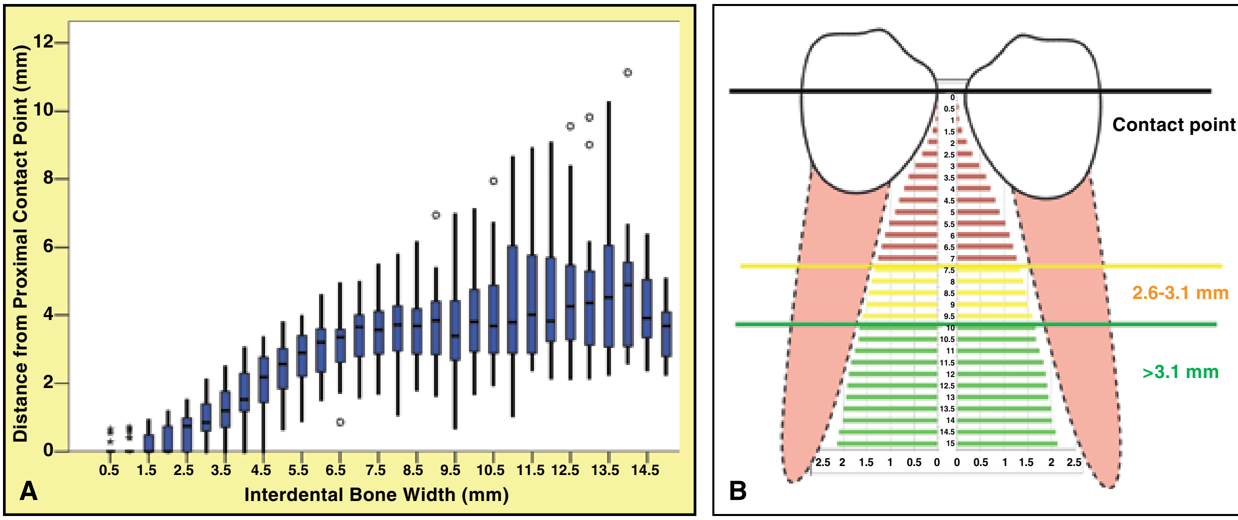


Fig. 3 Interdental bone space between lower first and second premolars. A. Individual interdental measurements taken at vertical heights from proximal contact point to root apex: mean, median, standard deviation, minimum, and maximum. B. Graphic representation of mean interdental widths according to suitability for mini-implant insertion: red = unsuitable (mesiodistal width <2.6mm), yellow = adequate (2.6-3.1mm); green = optimal (>3.1mm).

proximal contact of the dental crowns was chosen as the starting or reference point for measurement because it could easily be identified without additional clinical tools. From the reference point, 3D vertical slices were examined at .5mm intervals, ending 15mm apically. Following the insertion path of a mini-implant, the shortest distance between the lateral root surfaces of adjacent teeth was marked parallel to the cortical bone and then measured by the software. All measurements were performed by a single examiner and repeated five times, resulting in about 25,000 values.

Results

To allow us to present the results in a clear and structured manner, the corresponding interradicular spaces of two quadrants in the same jaw were combined; for example, the interdental spaces between both right and left upper first and second molars were identified as "upper 6-7".

PASW Statistics*** software was used to calculate the mean, median, standard deviation, and minimum and maximum distances for each .5mm interval (Fig. 3A). We then constructed a virtual set of teeth representing the mean interradicular distances of all 39 patients (Fig. 3B).

Unfortunately, a simple mean measurement of a particular space is not an indication of its suitability for mini-implant insertion. A further step was needed to determine the likelihood of finding at least adequate bone width at each interradicular site among our study patients (Fig. 4). When an interradicular distance of at least 2.6-3.1mm was present in 61-70% of the patients, the space was categorized as "acceptable". "Good" indicated adequate space in 71-80% of the patients, "very good" in 81-90%, and "excellent" in 91-100%. Values below 60% were considered "poor", and values below 50% "unacceptable" for insertion purposes.

Maxilla

Preferable spaces: In the maxilla, only the interdental space between the central incisors offered the best conditions. Adequate bone width of 2.6-3.1mm was found between the central incisors in 100% of the patients, and optimal width of greater than 3.1mm in 94.9%. On average, the adequate width was reached at 11.5mm apically, and the optimal width above 13.5mm.

***Registered trademark of IBM, 233 S. Wacker Drive, Chicago, IL 60606; www.spss.com.

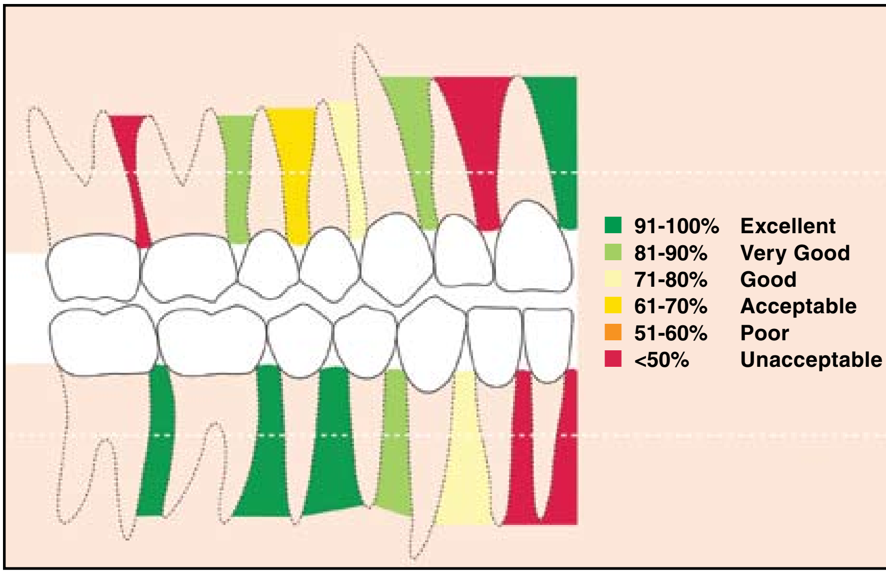


Fig. 4 Breakdown of patients showing minimal desirable bone width of 2.6-3.1mm and resulting classification of interdental spaces. Percentage indicates likelihood that adequate bone may be available in specific interdental space.

"Very good", "good" and "acceptable" spaces: The spaces between the lateral incisor and canine and between the second premolar and first molar offer very good insertion conditions. Both showed a high probability for the required minimal width, with adequate bone width found 10.5mm and 8.5mm apical to the contact points, respectively. Nearly 90% of the subjects showed at least an adequate insertion area between the second premolar and first molar, and 85% showed optimal space. Good conditions were noted between the canine and first premolar in only 72% of the patients; the mean vertical location was about 14mm apical to the contact point. Between the first and second premolars, acceptable bone width was found in 68% of patients, 9.5mm above the contact point.

Unacceptable spaces: The interdental spaces between the central and lateral incisors and the first and second molars were rarely adequate. Between the central and lateral incisors, only patients age 41-60 had optimal bone width, and then in only 60% of the cases. The space between the first and second molars was appropriate for use only in subjects without third molars or in patients age 21-40. Younger patients or patients with third molars had optimal insertion spaces in only 15.3% of the cases.

Mandible

The mandible appears to have more ideal insertion sites that may be used without consideration of age, sex, or dentition status. Suitable interradicular spaces included almost all of those distal to the canines.

Preferable spaces: The spaces between the premolars, between the second premolar and first molar, and between the first and second molars showed excellent probability for the minimal width of 2.6-3.1mm: 99%, 97%, and 94%, respectively, with areas of adequate bone located 7.5mm, 6mm, and 5.5mm apical to the contact points.

"Very good" and "good" spaces: The space between the canine and first premolar was a very good insertion site in terms of adequate bone availability and also a good insertion site for optimal insertion probability—optimal bone width was seen in 74% of the patients—but this area was found nearly 15mm apical to the contact point. Between the lateral incisor and canine, 71% of the subjects showed adequate space and 57.5% showed optimal space; adequate bone width was found a mean 13.5mm apical to the contact point.

Unacceptable spaces: Spaces between the lower central incisors and the central and lateral incisors were inadequate.

Age, Sex, and Third Molars

Patient age, sex, and presence or absence of third molars were evaluated separately for their relationships to adequate and optimal bone width.

Age: Statistically significant differences in bone width of two maxillary interdental spaces were found among the different age groups. Between the central and lateral incisors, the 41-60 age group showed greater incidence of adequate bone width than both patients age 12-20 ($p < .05$) and age 21-40 ($p < .05$). For the space between the maxillary first and second molars, the percentage of patients age 21-40 showing optimal bone width was significantly higher than both the 12-20 ($p < .001$) and 41-60 ($p < .005$) groups. Other interradicular areas in the maxilla showed no significant age-related differences.

In the mandible, patients age 12-20 were significantly more likely to have adequate bone width between the second premolar and first molar compared to the 41-60 group ($p < .05$), which was more likely to show optimal bone width. Further analysis of the optimal insertion sites revealed significant differences in patients age 12-20 vs. those age 21-40 for the space between the first and second molars, with the middle age group showing optimal root distances more frequently than the younger group ($p < .05$). None of the other interradicular spaces in the mandible exhibited any significant age-related differences.

Sex: Only a few gender-specific differences were noted in the study. Two maxillary locations showed statistically significant differences between male and female patients: in the space between the upper lateral incisor and canine, males were more likely to have adequate bone width ($p < .05$); in the space between the second premolar and first molar, males were more likely to have both adequate ($p < .05$) and optimal ($p < .05$) bone width.

In the mandible, females showed a significantly higher likelihood of optimal bone width in the interdental spaces between the first and second premolars ($p < .05$) and the first and second molars ($p < .05$).

Third molars: The absence of maxillary third molars always corresponded with a highly significant bone-width surplus between the first and second molars in our study ($p < .001$). All patients without third molars showed increased interradicular bone width in the maxillary molar region, indicating a potentially higher success rate for implant insertion. In the mandible, on the other hand, the presence or absence of third molars had no apparent influence on interradicular bone width between the first and second molars or in any of the other interdental spaces.

Bone Width and the Mucogingival Border

Although the color-coded graphic representation of the adequacy of various interdental spaces provides a quick overview for treatment planning (Fig. 4), it does not indicate the vertical location of the suitable bone width or its relationship to the mucogingival border. According to our CBCT measurements, the required bone width is often found apical to the attached gingiva.

This finding led us to measure the distance from the proximal contact points to the mucogingival border (Fig. 5) in 58 subjects (25 male, 33 female, mean age 35.7). In this separate (unpublished) study, we examined radiological findings and clinical reports of the height of the attached gingiva and compared the results, again using the

Fig. 5 Measurement of distance between proximal contact point and mucogingival border with dental floss and periodontal probe.

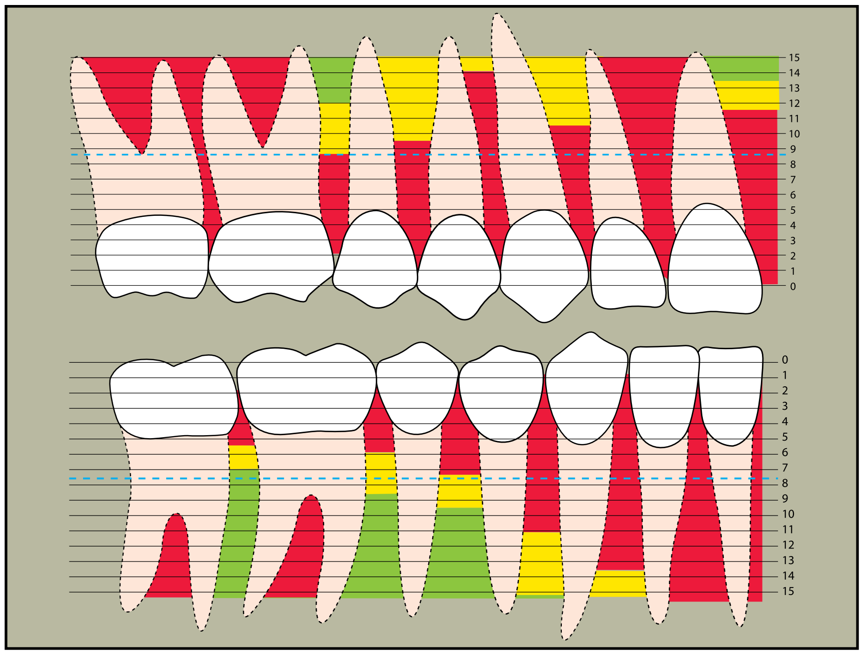


Fig. 6 Graphic representation of probability of adequate (2.6-3.1mm, yellow) or optimal (>3.1mm, green) mesiodistal bone width for each interdental space. Dashed line = mean level of mucogingival border.

proximal contact as a reference point.

Figure 6 illustrates the relationship between the mucogingival border and the vertical heights of adequate and optimal bone width, with distances measured from the proximal contact points. For example, in the space between the maxillary second premolar and first molar, adequate space of 2.6-3.1mm can be found 8.5mm apical to the contact point. The mini-implant must therefore be placed close to the mucogingival border, which is about 8.1mm apical to the proximal contact point. The equivalent interdental area in the mandible provides adequate bone width at a distance of only 6mm from the contact point, with the mucogingival border another 1.5mm away.

It is apparent that only a few interradicular spaces can be considered ideal, with at least adequate interdental bone width *and* attached gingiva:

• Between the upper and lower second premolars and first molars.

• Between the upper and lower premolars (with caution).

• Between the lower first and second molars.

Other spaces can reliably supply sufficient bone width only in areas without attached gingiva.

Discussion

Insufficient bone width can result in contact between a mini-implant and the root. Even though root contact is usually considered harmless due to post-traumatic regenerative capability,[10-12] root proximity or contact still results in less-stable anchorage and higher rates of implant failure.[13] The results of our study clearly delineate the locations of adequate and optimal insertion space.

Other studies have also found that interradicular bone width increases apically and distally in the maxilla, with the exception of the space between the first and second molars,[14,15] and that the spaces between the upper central incisors and the upper second premolars and first molars are preferable for mini-implant insertion.[16] Studies by Hu and colleagues[17] and Lee and colleagues[18] did not show inadequate space between the upper first and second molars, but this may be due to the dif-

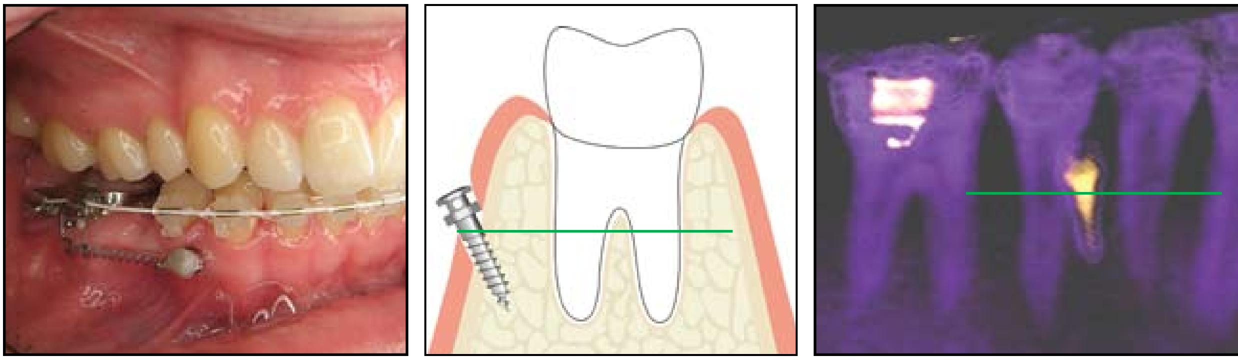


Fig. 7 Insertion site between lower canine and first premolar has insufficient available bone; mini-implant is therefore placed at oblique angle, keeping head of screw in attached gingiva (above green line), with threads inserted more apically into adequate bone.

fering ages of the study subjects. While our data were taken mainly from juvenile and adolescent patients, Lee and colleagues investigated groups age 19 and older,[18] and Hu and colleagues' study patients[17] were older than 29—well beyond the pubertal growth spurt.

Our results showed that the most suitable mandibular interdental spaces for mini-implant insertion are between the second premolars and first molars and the first and second molars. Other authors have also reached this conclusion,[7,17,18] although it is difficult to compare the findings since different reference points were used in each study. Our reference was the proximal contact point, Poggio and colleagues used the crestal bone margin,[7] Lee and colleagues used the enamel-dental border,[18] and Hu and colleagues used the dental cervix.[17]

The noted gender-specific differences in our sample may reasonably be ignored, because the groups were relatively small and the range of interdental distances relatively large. Poggio and colleagues[7] found no gender-specific effects in their results, while Lee and colleagues[18] and Kim and colleagues[16] did not consider sex differences.

The influence of race on interradicular space is as yet unknown. Our population was Caucasian, as was probably true of the study by Poggio and colleagues.[7] Data evaluated in the studies by Lee and colleagues[18] and Kim and colleagues[16] were most likely drawn from Asian populations. In addition, tooth size and shape have yet to be investigated in relation to interdental space.

When CBCT records are available, the ideal insertion site may be easily determined by measuring the distance to the proximal contact. Ordering a CBCT scan merely to identify a mini-implant placement site is not justifiable, however. The vertical distance from the proximal contact to an area with sufficient bone width can be measured from a panoramic or periapical x-ray if the magnification factor is known.[17]

Although this area will ideally be located in the attached gingiva, other possibilities should be considered if adequate bone is found only in areas of unattached gingiva. If the mucogingival border is close to the ideal position, the mini-implant may be inserted in the attached gingiva and angulated toward an area of suitable bone width (Fig. 7). If the distance to the ideal bone area is too great, another insertion location should be considered. Alternative strategies can include laser preparation of the unattached gingiva to create a "punched" area for mini-implant insertion (Fig. 8A) and the use of miniplate anchorage (Fig. 8B). The central palatal bone is always a suitable alternative in the maxilla; we will discuss the preferred locations and procedures for palatal insertion in a subsequent article.

Conclusion

This is the first study to investigate interdental bone width in relation to the mucogingival border and the proximal contact point, thus producing reliable data for identifying suitable mini-implant insertion sites in the maxilla and mandible. Of course, since these data were taken from a cross-sectional study, individual clinical and radiological findings must always be respected. The amount of bone width necessary for successful implantation can be calculated in any patient by

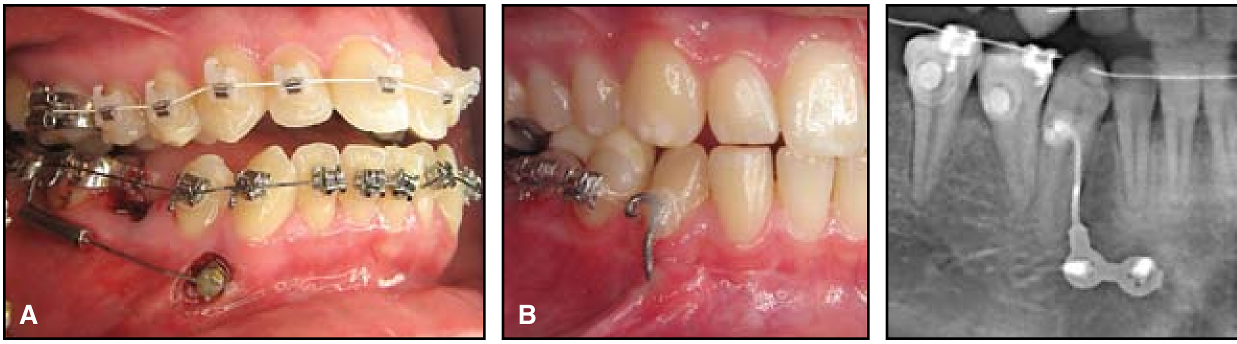


Fig. 8 A. Laser used to create "punched" area for mini-implant insertion in area of unattached gingiva, preventing soft-tissue coverage of mini-implant head. B. Miniplate providing indirect anchorage to lower canine.

adding the screw diameter plus two times a width of .5mm for bone on either side and an additional two times .25mm to respect the periodontium. This information can reduce the risk of loss or failure in mini-implant anchorage treatment.

In our opinion, only the interdental spaces considered "very good" or "excellent" in this study should be chosen for miniscrew placement, because sufficient bone width is to be expected only in those locations, and is even rarer in combination with attached gingiva (Fig. 6). Of course, any insertion site with less than 100% optimal bone width carries some incremental risk of failure.

ACKNOWLEDGMENT: The authors wish to thank Drs. Marc Schieren and Seong-Hun Kim for their assistance and support with this study.

REFERENCES

1. Chen, Y.J.; Chang, H.H.; Lin, H.Y.; Lai, E.H.; Hung, H.C.; and Yao, C.C.: Stability of miniplates and miniscrews used for orthodontic anchorage: Experience with 492 temporary anchorage devices, Clin. Oral Impl. Res. 19:1188-1196, 2008.
2. Lietz, T.: Mini-screws: Aspects of assessment and selection among different systems, in *Mini-Implants in Orthodontics: Innovative Anchorage Concepts*, ed. B. Ludwig, S. Baumgaertel, and S.J. Bowman, Quintessence Publishing Co., London, 2008, pp. 11-72.
3. Büchter, A.; Wiechmann, D.; Gaertner, C.; Hendrik, M.; Vogeler, M.; Wiesmann, H.P.; Piffko, J.; and Meyer, U.: Load-related bone modelling at the interface of orthodontic micro-implants, Clin. Oral Impl. Res. 17:714-722, 2006.
4. Park, H.S.; Jeong, S.H.; and Kwon, O.W.: Factors affecting the clinical success of screw implants used as orthodontic anchorage, Am. J. Orthod. 130:18-25, 2006.
5. Sung, J.H.; Kyung, H.M.; Bae, S.M.; Park, H.S.; Kwon, O.W.; and McNamara, J.A. Jr.: *Microimplants in Orthodontics*, Dentos, Daegu, 2006.
6. Liou, E.J.; Pai, B.C.; and Lin, J.C.: Do miniscrews remain stationary under orthodontic forces? Am. J. Orthod. 126:42-47, 2004.
7. Poggio, P.M.; Incorvati, C.; Velo, S.; and Carano, A.: "Safe zones": A guide for miniscrew positioning in the maxillary and mandibular arch, Angle Orthod. 76:191-197, 2006.
8. Schnelle, M.A.; Beck, F.M.; Jaynes, R.M.; and Huja, S.S.: A radiographic evaluation of the availability of bone for placement of miniscrews, Angle Orthod. 74:832-837, 2004.
9. Wu, T.Y.; Kuang, S.H.; and Wu, C.H.: Factors associated with the stability of mini-implants for orthodontic anchorage: A study of 414 samples in Taiwan, J. Oral Maxillofac. Surg. 67:1595-1599, 2009.
10. Brisceno, C.E.; Rossouw, P.E.; Carrillo, R.; Spears, R.; and Buschang, P.H.: Healing of the roots and surrounding structures after intentional damage with miniscrew implants, Am. J. Orthod. 135:292-301, 2009.
11. Hembree, M.; Buschang, P.H.; Carrillo, R.; Spears, R.; and Rossouw, P.E.: Effects of intentional damage of the roots and surrounding structures with miniscrew implants, Am. J. Orthod. 135:280.e1-9, 2009.
12. Kadioglu, O.; Buyukyilmaz, T.; Zachrisson, B.U.; and Maino, B.G.: Contact damage to root surfaces of premolars touching miniscrews during orthodontic treatment, Am. J. Orthod. 134:353-360, 2008.
13. Kuroda, S.; Yamada, K.; Deguchi, T.; Hashimoto, T.; Kyung, H.M.; and Takano-Yamamoto, T.: Root proximity is a major factor for screw failure in orthodontic anchorage, Am. J. Orthod. 131(4 suppl):s68-73, 2007.
14. Monnerat, C.; Restle, L.; and Mucha, J.N.: Tomographic mapping of mandibular interradicular spaces for placement of orthodontic mini-implants, Am. J. Orthod. 135:428.e1-9, 2009.
15. Deguchi, T.; Nasu, M.; Murakami, K.; Yabuuchi, T.; Kamioka, H.; and Takano-Yamamoto, T.: Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants, Am. J. Orthod. 129:721.e7-12, 2006.
16. Kim, S.H.; Yoon, H.G.; Choi, Y.S.; Hwang, E.H.; Kook, Y.A.; and Nelson, G.: Evaluation of interdental space of the maxillary posterior area for orthodontic mini-implants with cone-beam computed tomography, Am. J. Orthod. 135:635-641, 2009.
17. Hu, K.S.; Kang, M.K.; Kim, T.W.; Kim, K.H.; and Kim, H.J.: Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation, Angle Orthod. 79:37-45, 2009.
18. Lee, K.J.; Joo, E.; Kim, K.D.; Lee, J.S.; Park, Y.C.; and Yu, H.S.: Computed tomographic analysis of tooth-bearing alveolar bone for orthodontic miniscrew placement, Am. J. Orthod. 135:486-494, 2009.