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Accurate pre-surgical determination for self-drilling miniscrew implant placement using surgical guides and cone-beam computed tomography

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SUMMARY Miniscrew implants have proven to be effective in providing absolute orthodontic anchorage. However, as self-drilling miniscrew implants have become more popular, a problem has emerged, i.e. root contact, which can lead to perforation and other root injuries. To avoid possible root damage, a surgical guide was fabricated and cone-beam computed tomography (CBCT) was used to incorporate guide tubes drilled in accordance with the planned direction of the implants.

Eighteen patients (5 males and 13 females; mean age 23.8 years; minimum 10.7, maximum 45.5) were included in the study. Forty-four self-drilling miniscrew implants (diameter 1.6, and length 8 mm) were placed in interradicular bone using a surgical guide procedure, the majority in the maxillary molar area. To determine the success rates, statistical analysis was undertaken using Fisher's exact probability test.

CBCT images of post-surgical self-drilling miniscrew implant placement showed no root contact (0/44). However, based on CBCT evaluation, it was necessary to change the location or angle of 52.3 per cent (23/44) of the guide tubes prior to surgery in order to obtain optimal placement. If orthodontic force could be applied to the screw until completion of orthodontic treatment, screw anchorage was recorded as successful. The total success rate of all miniscrews was 90.9 per cent (40/44).

Orthodontic self-drilling miniscrew implants must be inserted carefully, particularly in the case of blind placement, since even guide tubes made on casts frequently require repositioning to avoid the roots of the teeth. The use of surgical guides, fabricated using CBCT images, appears to be a promising technique for placement of orthodontic self-drilling miniscrew implants adjacent to the dental roots and maxillary sinuses.

Introduction

The use of skeletal anchorage, such as self-drilling miniscrews or microscrew implants, is growing in popularity because of its ability to provide absolute anchorage (Chae, 2006; Park *et al.*, 2006). Correct placement of implants is a basic requirement (Freudenthaler *et al.*, 2001; Cousley and Parberry, 2006). For example, one potential insertion site is between the roots in the alveolar process; however, this carries some risk of damaging the roots of neighbouring teeth and of causing loss of dentoalveolar bone (Figure 1; Coburn *et al.*, 2002; Fabbroni *et al.*, 2004).

Insertion of miniscrew implants in the alveolar process between the roots of the teeth is a critical procedure. Major complications can include damage to adjacent tooth roots. Fabbroni *et al.* (2004) reported that the incidence of screw/tooth contact in the placement of transalveolar screws was 63/232 (27.1 per cent). Although there has been little direct research on this topic, it has been noted that minor root damage during surgery usually heals without major complication (Andreasen and Kristerson, 1981; Asscherickx *et al.*, 2005). However, the same authors also noted that although the teeth were not moved subsequent to root damage, additional movement could exacerbate the situation. Thus, it is prudent to minimize the risk of such iatrogenic damage.

Placement of self-drilling miniscrew implants must be carefully monitored because the implants are often situated between tooth roots and occasionally close to the maxillary sinuses. Deguchi *et al.* (2006), in a study of cortical bone thickness using computed tomographic (CT) scanning, reported that the reason for implant failure was unclear but that it might have been associated with factors other than the amount of cortical bone surrounding the implant. In addition, Kuroda *et al.* (2007b) reported that the root contact of miniscrews, either before or during orthodontic treatment, could also have an impact on stability. To increase the predictability of success, it is essential that implants are correctly placed (Miyawaki *et al.*, 2003; Cheng *et al.*, 2004; Kuroda *et al.*, 2007a). Careful clinical and radiographic assessment before miniscrew implant placement is therefore a necessity.

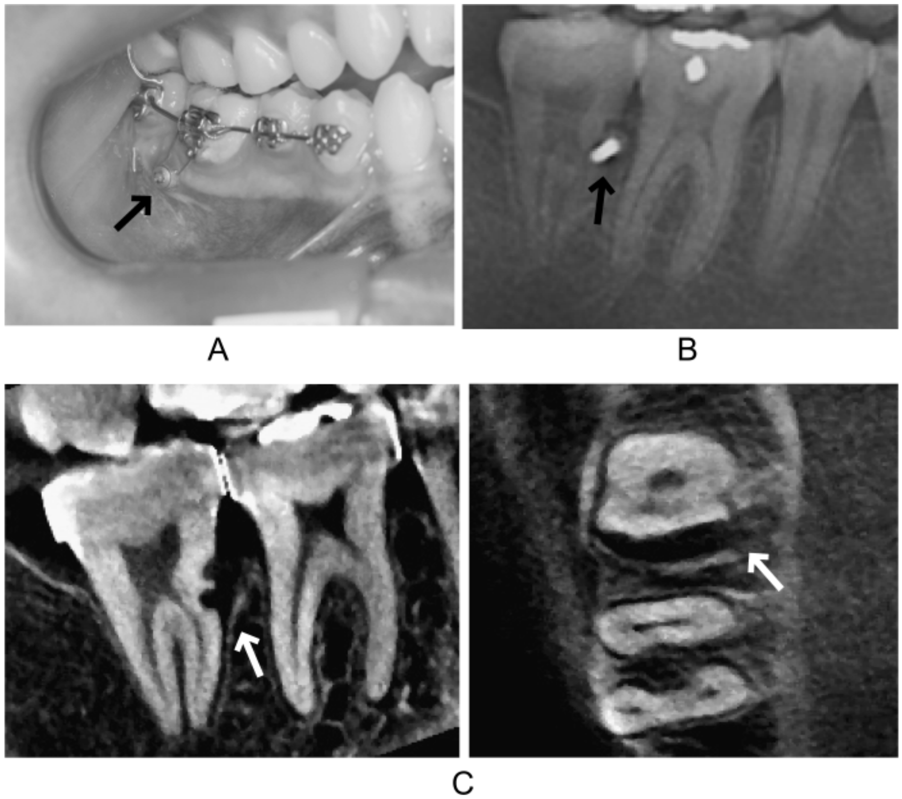


Figure 1 (A) Initial intraoral photograph of a 21-year-old male patient. A sectional multibracket appliance and miniscrew implant were placed between the first and second molar in the gingival region. There was no spontaneous pain, but slight miniscrew implant mobility was found. (B) Radiographic observation of the miniscrew implant and adjacent roots. (C) Computed tomographic images after removal of the miniscrew implant. Trauma was observed at the mesial root of the second molar. Furthermore, serious vertical resorption of adjacent dentoalveolar bone was found.

This research investigated the use of cone-beam computed tomography (CBCT) and precise surgical guides, an approach that provides three-dimensional (3D) control for accurate placement of self-drilling miniscrew implants at the desired location and angle.

Subjects and methods

The study protocol was reviewed and approved by the Institutional Board of Aichi-Gakuin University and informed consent was obtained from all patients.

Eighteen patients (5 males and 13 females; mean age 23.8; minimum 10.7 and maximum 45.5 years) who required skeletal anchorage for orthodontic therapy were included in this prospective study. Forty-four self-drilling miniscrew implants (34 in the maxilla and 10 in the mandible; Jeil Medical Corporation, Seoul, Korea) were placed into interradicular bone using a surgical guide procedure. The screws were 1.6 mm in diameter and 8 mm in length. The CBCT used in this study was a 3DX (Morita Co., Ltd, Tokyo, Japan). The small conical beam of the CBCT provides a limited exposure field yet produces computer-generated 3D reconstructions. The image reconstruction area was 29 mm (240 voxels) in height and 38 mm (320 voxels) in diameter, with a voxel comprising a square of sides, each of which was 0.119 mm long. If the orthodontic force could be applied to the screw until completion of treatment, screw anchorage was recorded as successful.

Fabrication of a surgical guide for self-drilling miniscrew implants

Dental casts were prepared and the planned insertion site was marked on the casts (Figure 2A). Using a light-curing splint resin (Splint-Resin LC; GC Corporation Ltd, Tokyo, Japan), the material was adapted over the occlusal and insertion area of the cast. Once the material was of the desired shape, the cast with the splint resin was cured using a plasma arc light curing unit (Flipo; GC Corporation Ltd). A hole was then made at the insertion site and the stainless steel guide tube (SUS-304; The Nilaco Co., Ltd, Tokyo, Japan) was set. Stainless steel guide tubes, 0.2 mm wider than the diameter and one-third of the length of the self-drilling miniscrews, were selected. Using self-curing resin (Ortho Crystal; Rocky Mountain Morita Co., Ltd, Tokyo, Japan), the stainless steel guide and light-curing splint resin material were fixed. A surgical guide was fabricated to incorporate a guide tube in accordance with the planned position and angles of the miniscrew implant (Figure 2B; Freudenthaler *et al.*, 2001; Morea *et al.*, 2005). It was designed to determine not only the best insertion site but also accurate placement of the head of the screw. In order to examine the prospective screw position and the optimal angle of insertion (Figure 3), CBCT was carried out with the surgical guide *in situ* prior to surgery. The guide tube position was adjusted as necessary before surgery according to the radiographic information in order to guide the self-drilling miniscrew implant to the correct site.

Surgical procedure for placement of self-drilling miniscrew implants

To avoid bacterial contamination, the surgical guide was submerged in 1 per cent chlorhexidine for 12 hours prior to miniscrew placement. Local anaesthesia was applied and the stent was placed in the mouth. Implant holes were drilled to two-thirds the depth of the screw at the implant site through the metal sleeve of the surgical guide, using the self-drilling implants and a screwdriver (Figure 4A). After stopping the self-drilling miniscrew insertion on the guide tube, the miniscrew was removed once by turning counterclockwise to allow for surgical guide removal. Once the guide was removed, the same miniscrew was again inserted and completely seated in the implant hole (Figure 4B and 4C). In all cases, the second insertion followed the same direction as the first, with sufficient stability and without significant destruction of the cortical and cancellous bone. Follow-up CBCT was performed after surgery to verify the implant position relative to the adjacent roots. Orthodontic force was loaded 2 weeks after implant placement. The self-drilling miniscrew implants were used for *en masse* retraction of the maxillary or mandibular six anterior teeth. For *en masse* retraction, sliding mechanics were used with an elastic chain or a closed coil spring from the self-drilling miniscrew implants to hooks between the lateral incisor and canine. The estimated force was between 150 and 250 g. If the orthodontic force could be applied to the screw until completion of orthodontic treatment, screw anchorage was recorded as successful.

Statistical analysis

Fisher's exact probability test was used to examine differences in the success rates between the maxilla and mandible using the Statistical Package for the Social Sciences, version 15.0 (SPSS Inc., Chicago, Illinois, USA).

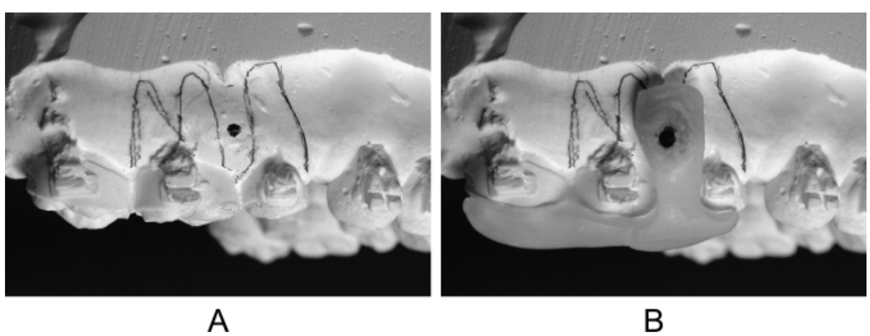
Results

The implant sites and the success rates for the 44 miniscrew implants are listed in Table 1. The mean orthodontic loading period was 20.4 months (minimum 7 months, maximum 45 months). No root contact was observed on the post-surgical CBCT images. While there were no concerns about the accuracy of the insertion site (Figure 5), 52.3 per cent (23/44) of the guide tubes required a change of location or angle before surgery, based on CBCT evaluation, in order to determine the optimal site. Although a few metal artefacts are apparent on Figure 3, these did not affect the image of the guide tubes or the screw, and the practitioner who fabricated the surgical guide could identify the direction of the guide tubes and the relationship between the roots and screw. The total success rate of miniscrew implants was 90.9 per cent (40/44). There was no significant difference in the success rates between the maxilla and mandible.

No miniscrew was found to be in contact with a root either at insertion or before removal, both in the upper and in the lower arch.

Discussion

Suzuki and Suzuki (2008) reported that the accuracy of miniscrew implant placement with a surgical guide was significantly improved with a 3D surgical guide compared with a wire guide or no guide. Cousley and Parberry (2006) reported an approach for miniscrew placement without



A B

Figure 2 Template with the stainless steel sleeve for determining the direction of insertion of the miniscrew. (A) The planned insertion site was marked on the casts. (B) A surgical guide was fabricated to incorporate a guide tube in accordance with the planned position and angles of the miniscrew implant.

removing the stent. An alternative guide for mini-implants, composed of a separate screw and head parts, was designed by Kim *et al.* (2007). Such screw placement methods have been reported, but these complicated the making of the surgical guide or required the use of separate screw and head parts. While the present method involved the manufacture of a surgical guide, it might be less expensive and produce satisfactory results if miniscrews, produced by other companies, were used.

The reasons for the failure of four miniscrews were as follows: one miniscrew, between the lower buccal first and second premolar, was broken when the implant hole was drilled. The reason for the failure of the other three miniscrews, between the buccal upper second premolar and first molar, was unclear. However, there was a sense of looseness during insertion, which was different from the other miniscrews, and these three miniscrews failed less than 45 days after orthodotic loading.

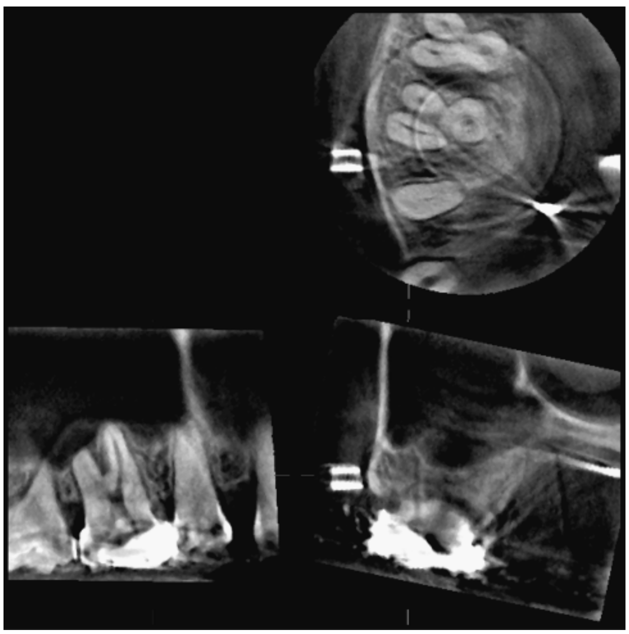


Figure 3 Computed tomographic images of the stainless steel sleeve for determining the correct position and angles for insertion.

The total success rate of the present method was similar to that of other studies (Miyawaki *et al.*, 2003; Kuroda *et al.*, 2007a, 2007b) with no significant difference between the maxilla and mandible. However, Cheng *et al.* (2004) and Deguchi *et al.* (2003) indicated a significantly lower success rate in the mandible.

A recent CT image study (Poggio *et al.*, 2006) provided an anatomical map, which can assist clinicians in safely placing miniscrews between dental roots. Those authors showed that there was less mesiodistal bone in the mandibular compared with the maxillary molar region. It was suggested that the incidence of screw/tooth contact in the placement of miniscrews was higher in the mandible. Kuroda *et al.* (2007b) reported that root contact of miniscrews could also have had an impact on stability. In the present study, no miniscrew was observed to be in contact with a root at either insertion or before removal. This may be one reason why no significant difference in the success rate was observed between the maxilla and mandible. Further studies are needed to evaluate the accuracy and success rate of the placement of miniscrew implants under controlled experimental conditions.

The key to whether the technique achieves general recognition and use will probably hinge on the relative risk of radiation and the benefit of accurate self-drilling miniscrew implant placement. Because of the advantages and possibilities of CBCT, orthodontists use this method for patient assessment (Silva *et al.*, 2008). Compared with multislice CT, the radiation dose to the patient with CBCT is markedly lower (Nakajima *et al.*, 2005; Swennen and Schutyser, 2006). Silva *et al.* (2008) reported that an effective dose of CBCT is approximately 15 per cent lower than of multislice CT.

In the present study, before insertion and just after surgery for miniscrew placement, CBCT was performed to verify root contact in all patients, and affirmation by a CBCT scan after surgical guide revision was not carried out. No root contact was seen for any of the self-drilling miniscrew implants, suggesting that the technique could allow for accurate surgery using just one CBCT image with surgical guides before insertion. However, orthodontic assessment

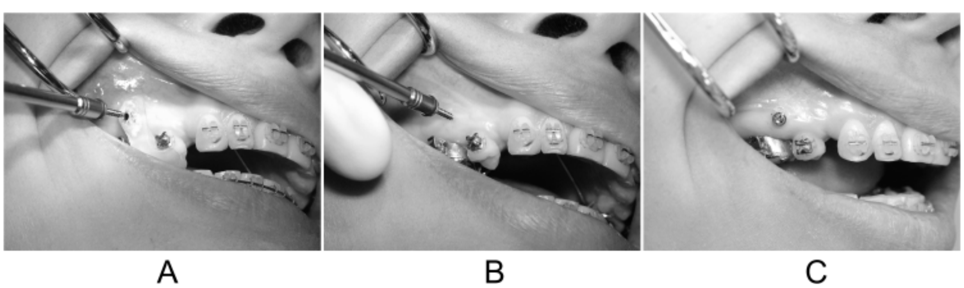


Figure 4 (A) The implant hole was drilled once with a self-drilling miniscrew implant using the stainless steel sleeve as a guide to make a tap in the bone. (B) The self-drilling miniscrew implant surgical guide was then removed. The same self-drilling miniscrew implant was then reinserted into the bone. (C) The self-drilling miniscrew implant was completely seated in the implant hole.

Table 1 Implant site and various rates of success for self-drilling miniscrew implants. L, lower; U, upper.

Implant site	Between the second premolars and first molars				Between the first and second premolars				Total n (%)
	Buccal		Lingual		Buccal		Lingual		
	U	L	U	L	U	L	U	L	
Implanted miniscrews	23	2	4	0	5	8	2	0	44 (100)
Corrected guide tubes and rates before implantation	15	0	2	0	4	2	0	0	23 (52.3)
Root contact miniscrews and rates after implantation	0	0	0	0	0	0	0	0	0 (0)
Success numbers and rates after orthodontic treatment	20	2	4	0	5	7	2	0	40 (90.9)

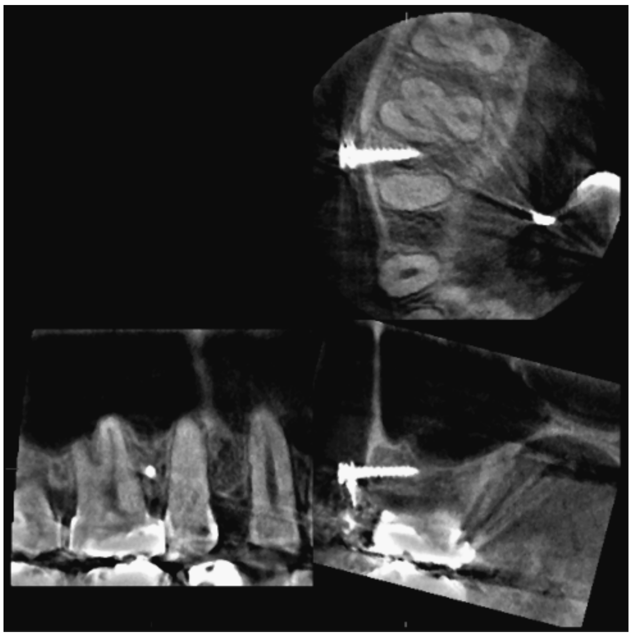


Figure 5 Post-surgical follow-up computed tomographic image of a 33-year-old female patient. The screw was separated from the root.

with CBCT should follow the 'as low as reasonably achievable' (ALARA) principle.

Recent improvements in CBCT could allow for wide-range imaging, thereby the total effective dose received by the patient could be greatly reduced if stents were attached to all regions with an insertion plan, and images were taken singularly when a CBCT scan of each patient was performed.

The present method not only allowed easy access and easy placement for surgery, but did not result in any root proximity of the screw in either the maxilla or the mandible. Surgical and radiographic guides (Freudenthaler *et al.*, 2001; Kitai *et al.*, 2002; Cousley, 2005) permit implants to be placed in preselected positions and at correct angulations. The system presented is a safe means of ensuring accurate implant placement.

These results suggest that a more accurate direction and sufficient stability are obtained using this surgical guide.

Conclusion

Surgical guides can indicate implant inclination and facilitate precise location through the use of CBCT. In blind placement, self-drilling miniscrew implants must be carefully monitored because even guide tubes made on casts often need repositioning between the tooth roots. It is believed that the template used in this study for pre-surgical diagnosis, together with the surgical guide, provides the safest means of ensuring accurate implant placement. This approach is particularly valuable when a self-drilling miniscrew implant is inserted by an orthodontist not highly experienced in implant techniques.

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