# Surgical positioning of orthodontic mini-implants with guides fabricated on models replicated with cone-beam computed tomography

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**Introduction:** This article illustrates a new surgical guide system that uses cone-beam computed tomography (CBCT) images to replicate dental models; surgical guides for the proper positioning of orthodontic mini-implants were fabricated on the replicas, and the guides were used for precise placement. The indications, efficacy, and possible complications of this method are discussed. **Methods:** Patients who were planning to have orthodontic mini-implant treatment were recruited for this study. A CBCT system (PSR 9000N, Asahi Roentgen, Kyoto, Japan ) was used to acquire virtual slices of the posterior maxilla that were 0.1 to 0.15 mm thick. Color 3-dimensional rapid prototyping was used to differentiate teeth, alveolus, and maxillary sinus wall. A surgical guide for the mini-implant was fabricated on the replica model. Proper positioning for mini-implants on the posterior maxilla was determined by viewing the CBCT images. **Results:** The surgical guide was placed on the clinical site, and it allowed precise pilot drilling and accurate placement of the mini-implant. **Conclusions:** CBCT imaging allows remarkably lower radiation doses and thinner acquisition slices compared with medical computed tomography. Virtually reproduced replica models enable precise planning for mini-implant positions in anatomically complex sites. (Am J Orthod Dentofacial Orthop 2007;131:00)

Titanium mini-implants have broadened the use of skeletal anchorage because they are easy to place, and there are many suitable intraoral sites.[1-7] Widespread use of mini-implants has led to a need for precise placement and better retention.

Most orthodontic mini-implants use mechanical retention as the main source of stability, and they can be placed in any site in the oral cavity with sufficient bone area to supplement conventional treatment.[1-7] Recently, osseointegrated mini-implants were introduced; they permit typical treatment mechanics, supported by 100% anchorage in several directions. Partial osseointegration reduces the risk of implant failure (Fig 1).[8-11]

It was reported that the volume of bone in the maxillary interradicular space between the second premolar and the first molar provides the optimal anatomic site for miniscrews.[4,7,12] Placement in this site permits a horizontal vector closer to the center of resistance of the teeth to be retracted. In addition, the position of the mini-implant is similar to that of a bracket and tube in the maxillary posterior teeth. Therefore, orthodontic mechanics can be applied effectively to the mini-implant instead of the bracket and tube. As a result, a single osseointegrated implant between the second premolar and the first molar can provide sufficient stability to reduce the number of mini-implants and the need for maxillary posterior bands and brackets.[10,11]

The advantages of accurate mini-implant positioning include improved retention during orthodontic loading and precise control of the force vector.

Placing a mini-implant without a surgical guide increases the risk of problems. Kanomi[1] implanted microscrews into the basal bone apical to the roots of the teeth to prevent root damage. Because the implanted microscrews were positioned too high, the applied

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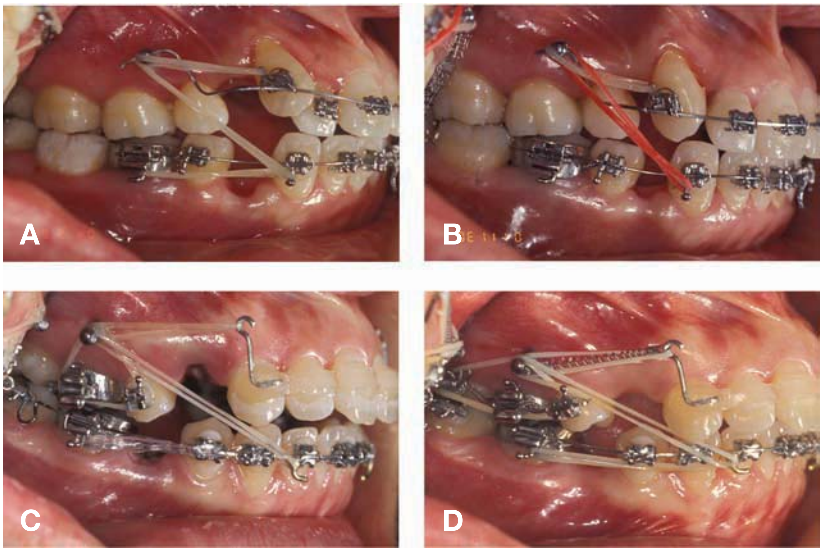


**Fig 1.** Osseointegrated mini-implant can endure heavy dynamic force, but its position is important. **A** and **B**, C-implant used for independent anchorage. **C** and **D**, C-implant as hook for elastics.

force seemed limited to vertical vectors. Furthermore, if the placement of the mini-implant relies on only the clinician's technique, skill, and experience, complications can occur—eg, root contact or damage, penetration of the maxillary sinus, and insufficient bone area for the mini-implant due to alveolar bone loss. Under these circumstances, the screw can become loose. In addition, replacement for similar treatment results can also lead to adverse effects. If roots are contacted, replacement in a new direction is recommended to avoid root damage.[5]

When it is necessary to place miniscrews near delicate anatomical structures such as the roots of teeth, the maxillary sinus, or the alveolar nerve, a surgical guide can be used to precisely locate the placement point and the vector to avoid damage to the adjacent structures.

### Methods for locating the proper position

There have been various efforts to standardize the proper positioning of mini-implants.[4,5 7,13] The placement site is critical to ensure a successful outcome, but the more important point is the implant guide itself. Bae et al[13] reported on a guide wire that provides a reference in the x-rays. However, wire guide systems require several x-rays for determining the proper position; this limits accuracy during drilling. The wires can be deformed or bent in the oral cavity during x-ray taking. Maino et al[5] used resin guides and several x-rays with the long-cone parallel method, but this approach is technique sensitive.

To overcome these drawbacks, another type of surgical guide was introduced for the orthodontic mini-implant, similar to a prosthetic implant guide.[14] A drawback is that accurate reproducibility of the alveolar bone cannot be obtained with the drilling position when arbitrarily estimating the midpoints of the 2 adjacent teeth on the plaster model. It means that accurate positioning of the drill direction (vector) is still difficult.

However, previous orthodontic guides are based on surface anatomy and compromised x-ray images that do not allow accurate analysis of bone volumes and vulnerable areas—eg, maxillary sinus, dilacereated roots, or altered bone surface topography due to alveolar bone loss. The sinus can be penetrated during mini-implant placement.[15] Also, the placement site decision is available mesiodistally, but the vertical positions of the crown-to-root areas are difficult to determine.

When the placement point of the mini-implant is known, the axial inclination of the pilot drill and then the implant are difficult to replicate. To consistently and accurately determine these relationships, we suggest 3-dimensional (3D) computed tomography (CT).

### Cone-beam computerized tomography and rapid 3D prototyping

Computer systems for image volume navigation enable the surgeon to locate the updated position of the implant.[16-18] Complex surgical procedures can be performed according to the preoperative plan based on CT

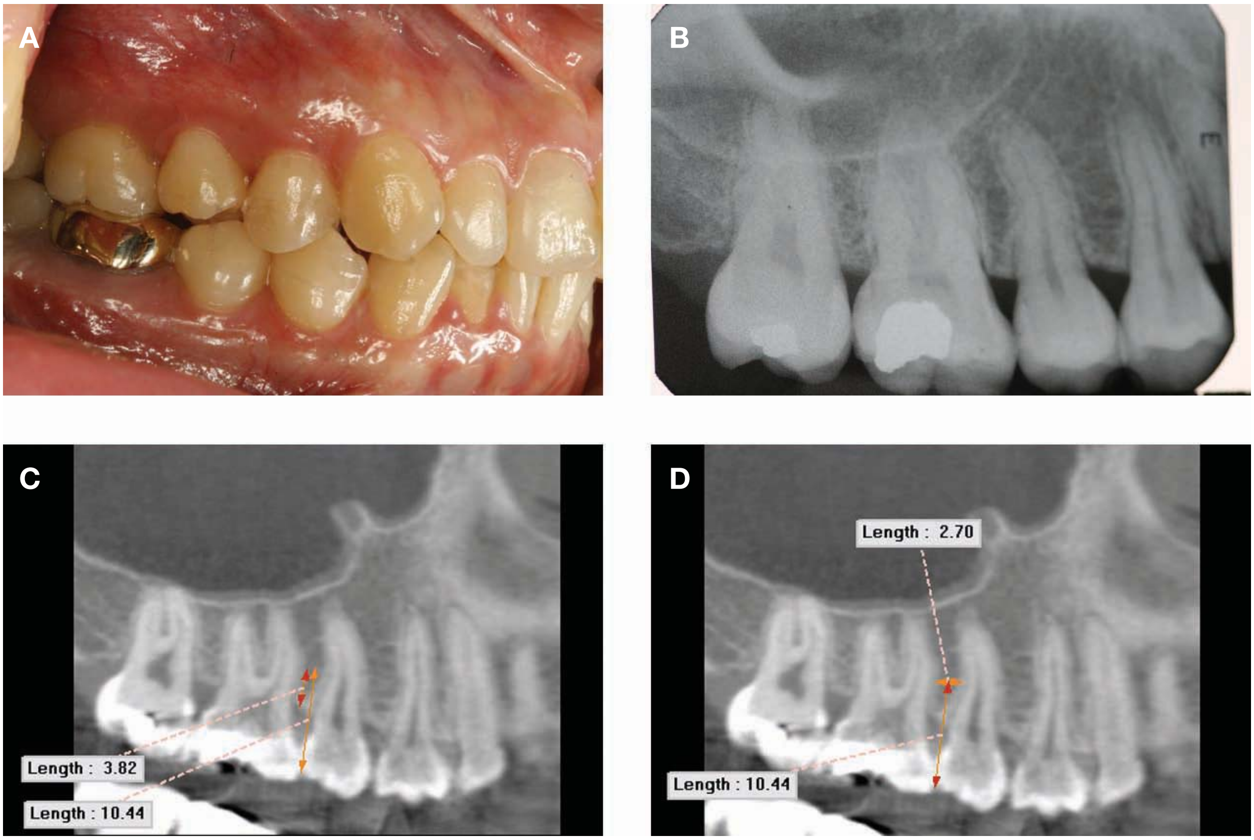


**Fig 2. A**, Pretreatment intraoral photograph of right posterior maxilla. **B**, Periapical view. **C**, CBCT view: planned implantation site is 3.82 mm from alveolar crest. **D**, CBCT view: interradicular space is 2.70 mm.

or magnetic resonance imaging data to minimize surgical risks and optimize clinical results.

Cone-beam CT (CBCT) can acquire more slices in a shorter time, covering large anatomic structures with thinner slices than spiral CT.[19-21] Three-dimensional reconstructed images acquired from the original slices (axial) of a CBCT could be used to obtain additional information about the anatomic structure of the posterior maxilla because pre-established parameters are used as thin interpolation slices. A safe, accurate, and simple system for locating mini-implants with CBCT data has been developed. A presurgical 3D model of the patient's teeth and underlying alveolar bone anatomy was created; this allowed the clinician to place the mini-implants in predetermined positions.

Data from the CT image are transformed by software for interactive segmentation of the images (Humobot, Seoul, Korea) into a format compatible with a stereolithography apparatus (SLA) (SLA5000, 3D Systems, Rock Hill, SC).[22] This apparatus uses different laser intensities for segmentation of the tooth and the alveolus in the resin model.

## SURGICAL GUIDE FABRICATION AND IMPLANTATION PROCEDURE

Three-dimensional CBCT images were taken of the posterior maxilla by using a new type of CBCT system (PSR 9000N, Asahi Roentgen, Kyoto, Japan) that delivers 0.1 mm in voxel size. An advantage of this model was improved reproducibility of anatomical structures with acquisition of a 0.15-mm slice. A CBCT record that was transformed into DICOM format was changed into 3D images (Figs 2 and 3 ). A replica model of the right posterior maxilla was fabricated by using the SLA method (Fig 4).

A 2-component sand-blasted, large-grit, and acid-etched SLA mini-implant (C-implant, C-implant Co, Seoul, Korea) was placed in this area. The C-implant is a unique titanium device that provides stability primarily through osseointegration and secondarily by mechanical retention (Fig 5).[7-11] It has 2 components, a head part and a screw part. The screw part is 1.8 mm in diameter at the SLA surface treated area, 2.0 mm in height at the smooth surface area, and 8.5 mm in length.[7]


**Fig 3. A**, Axial CBCT view for implantation. **B**, 3D reconstruction imaging for implantation site.


**Fig 4. A** and **B**, 3D imaging for replica model construction. **C**, Replica model using SLA method.

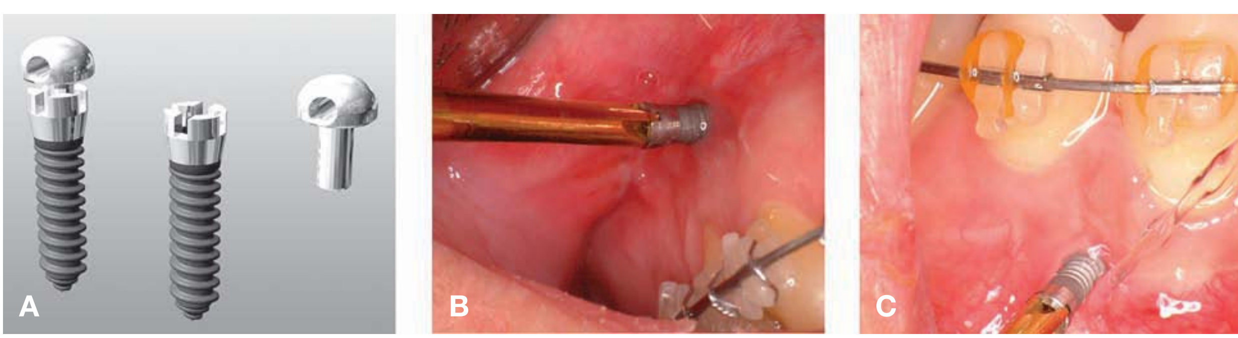


**Fig 5. A**, C-implant orthodontic mini-implant is SLA surface treated. **B** and **C**, screw part adaptation to driver tip.

The surgical guide was made by using the patient's plaster model without guide hole preparation (Fig 6, *A*). The surgical guide without a hole was adapted to the replica model (Fig 6, *B*). This replica model does not include the soft-tissue anatomy, but the surgical guide can be registered on the dentition, which is accurately reproduced in the replica model. One can easily see the ideal position and vector to drill a pilot hole at the implant site in the replica model, with a 1.5-mm guide drill (Stryker Leibinger, Freiburg, Germany ) (Fig 6, *C*). The surgical guide with hole was adapted to the replica model, and the accuracy of the surgical guide hole was confirmed (Fig 6, *D*). The surgical guide has 2 holes: one a convertible cap for pilot drilling (1.6 mm diameter), and the other for C-implant placement (2.7 mm diameter).

The next step was to drill the pilot hole in the alveolus. A 2.5-mm diameter hole is appropriate for a mini-implant that has a 1.8-mm diameter SLA portion and 2.0-mm diameter upper portion of the screw part. To guide the drill, we used a removable resin tube 1.6 mm in diameter (Fig 7, *A*). The pilot drilling fits into the resin tube and turns at a low speed of 800 rpm with a supply of water to perforate only the cortical bone (Fig 7, *B*). After the convertible cap was removed from the guide

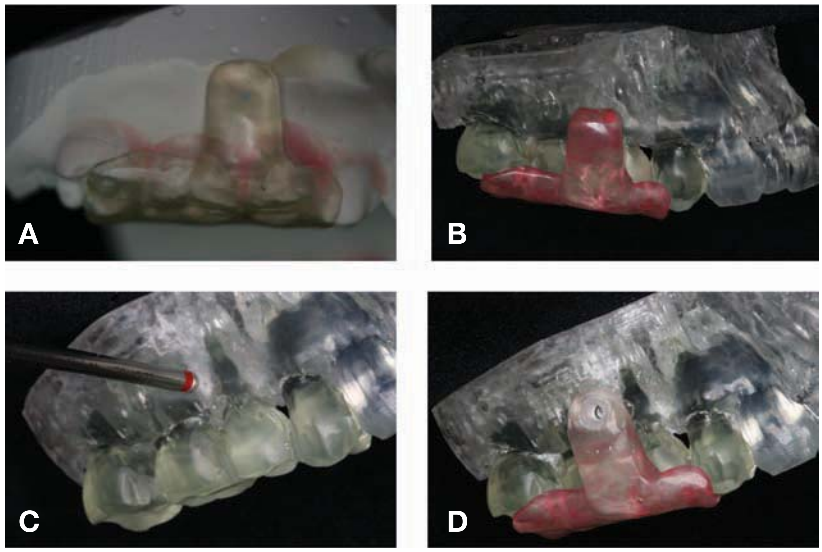

**Fig 6.** Surgical guide fabrication procedure. **A**, Surgical guide without hole fabricated from dental cast. **B**, Surgical guide without hole adapted to replica model. **C**, Drilling in replica model: interradicular space can be determined. **D**, Surgical guide with hole adapted to replica model.

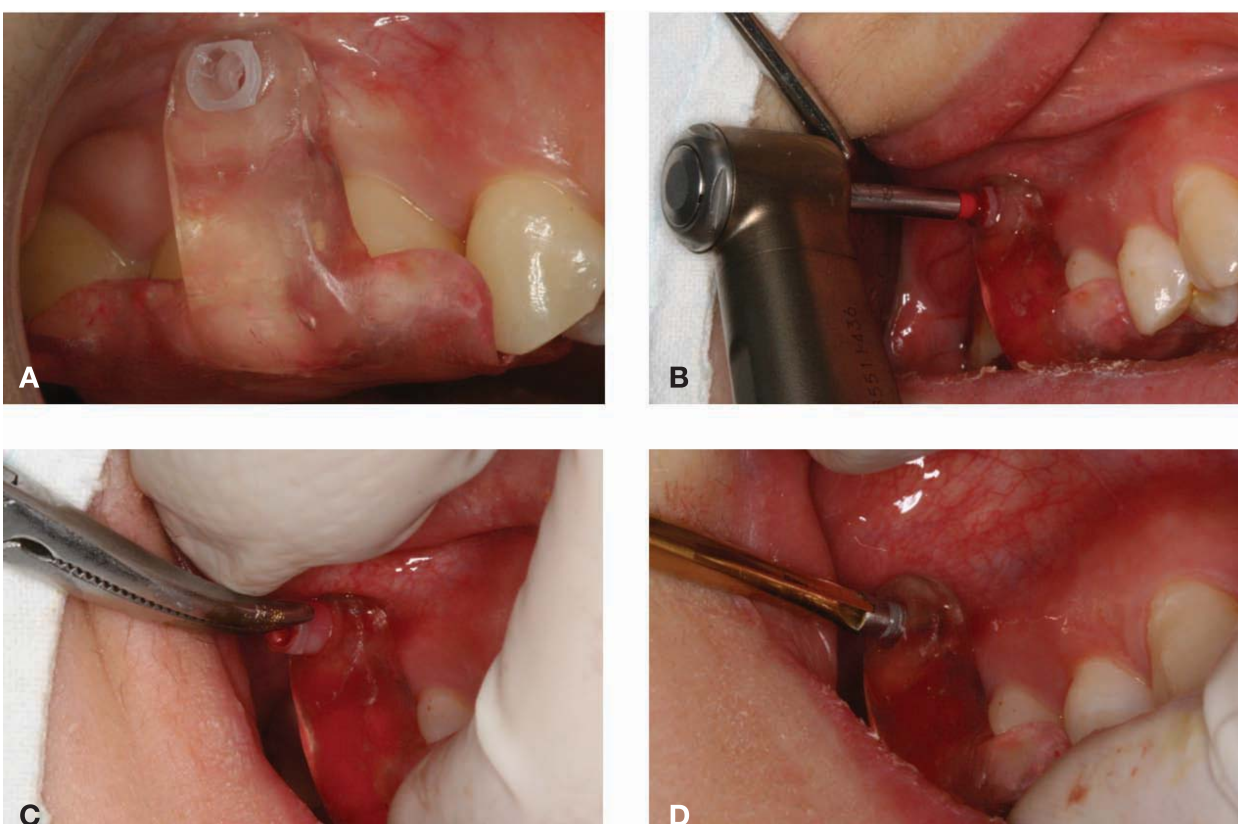

**Fig 7.** Surgical procedure for C-implant placement with guide. **A**, Surgical guide adapted to clinical site. **B**, Drilling through surgical guide. **C**, Drill cap is removed. **D**, Screw part of C-implant placed through surgical guide.

(Fig 7, *C*), the screw part of the C-implant was carefully inserted (Fig 7, *C*). After placement, the guide was removed, and the head of the C-implant fixture was inserted into the screw part of the fixture. A detailed method for the C-implant procedure was previously reported.[9,10] An orthodontic force of 100 g was applied immediately.

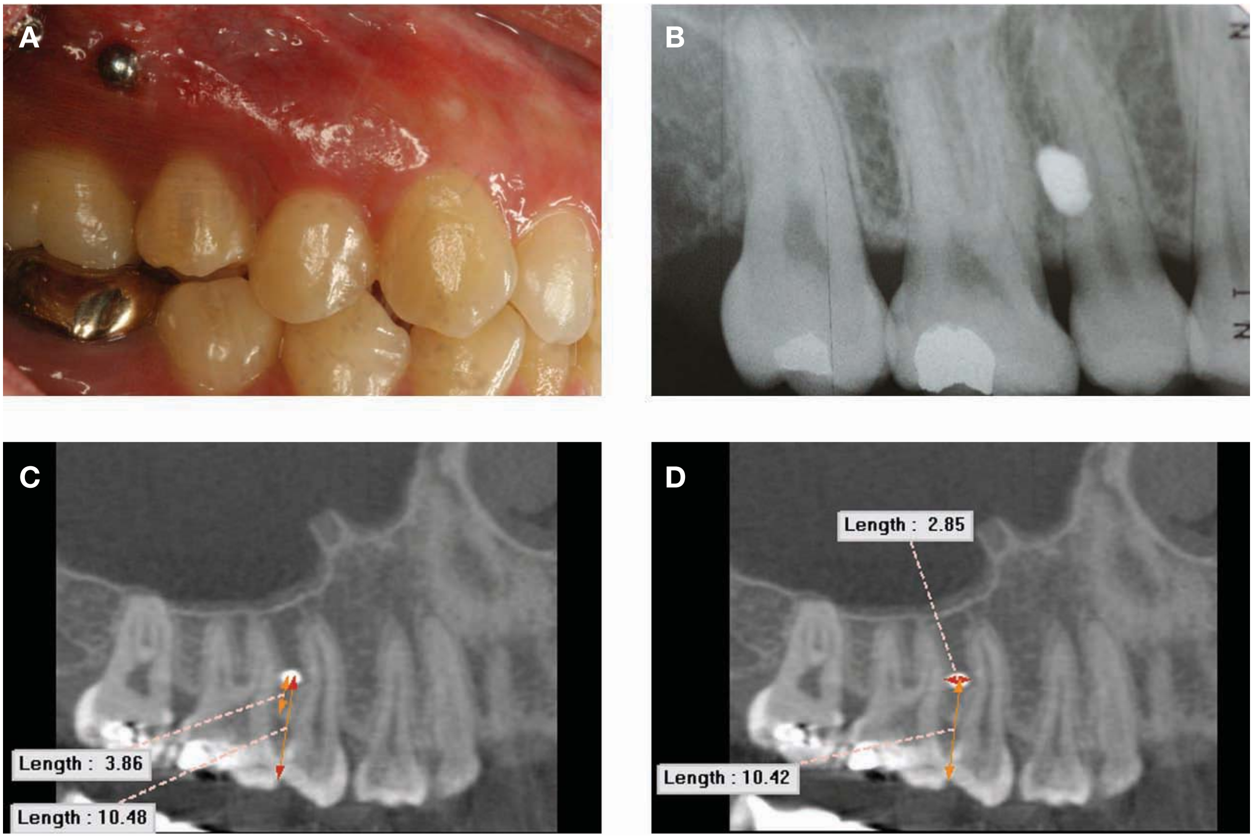


**Fig 8. A**, Posttreatment intraoral photograph. **B**, In periapical view, possiblility of root contact is not clear. **C** and **D**, CBCT view: C-implant placed in planned area without distortion.

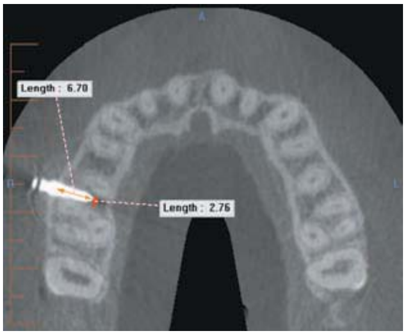


**Fig 9.** Axial CBCT view of C-implant, placed as planned by using surgical guide.

The precise position of the mini-implant could then be verified by taking a new CBCT. The position was not clear in the periapical view (Fig 8, *B*), but, with the CBCT images (V-Works, Cybermed Co, Seoul, Korea), it was possible to keep a safe interradicular distance from the screw (Fig 8, *C* and *D*; Figs 9 and 10).

## DISCUSSION

A CBCT guide is recommended for mini-implant placement for the following reasons.

### Position of the implant in the horizontal plane

The horizontal (interradicular) position of the implant can be determined more safely with a mechanical guide rather than by the clinician's skill and experience. Ideal placement at the first attempt is correlated with better stability. This system is useful to determine the best location for molar distalization. Mini-implant anchorage now has a much wider range of applications, and the initial position of the implant has become more clinically important. Although contact between dental roots and implants has been shown to produce no remarkable adverse effects, the risk of injuring critical anatomic structures and manual placement error can be minimized by precise positioning of the implant.[23] The patient in this study had delayed healing after flap surgery; therefore, we decided to use a 1.8-mm diameter C-implant as skeletal anchorage in spite of a narrow interradicular space (2.7 mm). However, if a slight space between the roots causes placement difficulty, a C-tube can be substituted for the C-implant to achieve the same results.[24]

### Vertical position of the implant

To determine the 3D vertical location, a virtual model constructed from a CBCT record that shows high

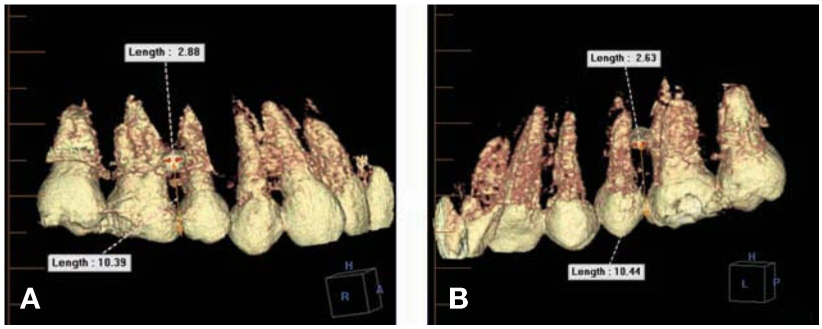


**Fig 10.** 3D reconstruction imaging of C-implant and maxillary posterior teeth. **A**, Buccal view. **B**, Palatal view: screw part of C-implant did not show root contact.

reproducibility is valuable.[18] A study on the perforation of the maxillary sinus by titanium implants showed that perforation did not have adverse effects on the maxillary sinus.[15] However, perforation might result in a poor and inadequate bone base for the implant screw and compromise its stability. For orthodontic mini-implants, it is important to obtain initial mechanical retention because immediate loading is always preferred.[7]

The conventional surgical guide for mini-implant placement (wire and resin guides) does not have the benefits of precise location of the maxillary sinus and accurate rendering of the alveolar bone anatomy.

### Less radiation and more cost efficient

The CBCT is superior to conventional CT for these purposes. CBCT images are produced with lower radiation doses, similar to full-mouth periapical views. Compared with spiral CT, they provide higher resolutions in every axis.[19-21] Under optimum exposure conditions, the radiation dose of dental CBCT is less than one fifteenth that of spiral CT, has a remarkable reproducibility of 0.1 mm voxel size, and is more cost efficient.[19] The main advantage of CBCT is a high-resolution image in 3 dimensions of an area as small as 2 or 3 teeth. Especially beneficial for both patients and clinicians are its significantly lower cost and radiation exposure.[21]

### Improved design of the surgical guide

We designed a dual surgical guide that can be used for both drilling and placement as is done with a prosthetic implant. Conventional surgical guides for orthodontic mini-implants have limitations. They are used as a guide for only pilot drilling, not for placement. When placing the implant, the clinician must remove the guide. The guide also requires a hole large enough to allow the bulky driver tip to pass through it. A conventional mini-implant is a 1-component system with a complicated head design and a bulky driver tip because of its hexagonal head design. Compared with the conventional mini-implant system, the C-implant has 2 separate components that allow the screw part to be inserted just like a prosthetic implant.[9-11] Therefore, a small-diameter guide hole is advantageous and allows the clinician to place the implant in the same vector as the drilling axis .

### Improvement of the replica model

In this study, the SLA method with an atypical intensifying laser application was used to provide a replica model that showed the borders between the teeth and the interradicular space. The SLA method can obtain high reproducibility compared with the powder-added method[22]; the resolution for 3D reconstruction was 0.5 mm. By using different colors on the teeth and adjacent bone, precise drilling can be easily visualized through a tooth-borne surgical guide placed directly on an SLA replica model.

However, the relatively low reproducibility of the occlusal shape of tooth structures, the depth of soft tissue interfaced between bone surface and guide, and the high cost of the SLA replica model are factors that might limit the broad use of this surgical guide system for mini-implants. The direct surgical guide system construction for orthodontic mini-implants can also be considered similar to that of prosthetic implant guides made with computer software.[19]

## CONCLUSIONS

The benefits of CBCT include its low radiation dose and higher resolution in 3 dimensions, and it has been gaining popularity for diagnosis and treatment. Placement of mini-implants is easier and safer with a CBCT guide.

Further study is needed to construct the guide directly without the additional process of making a cast, just as the prosthetic implant guides were made with computed analysis.

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