Cone-beam computed tomography evaluation of mini-implants after placement: Is root proximity a major risk factor for failure?

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Introduction: The purposes of this study were to determine factors favoring successful mini-implant placement and to evaluate root proximity as a possible risk factor for failure of osseointegration-based mini-implants during orthodontic treatment. Methods: Three-dimensional cone-beam computed tomography images were used to examine 50 sandblasted, large-grit, and acid-etched surface-treated mini-implants (C-implant, Seoul, Korea) placed in 25 patients. The images were analyzed for 3-dimensional position of the mini-implant (placement angle and depth) and any contact with root surfaces or maxillary sinuses. Results: There were no remarkable differences in horizontal placement angles in the axial plane and placement depths of the mini-implants, but the vertical placement angle was significantly higher on the left side ($24.5^\circ \pm 11.0^\circ$) compared with the right side ($11.8^\circ \pm 11.6^\circ$). The horizontal mini-implant placement angle had a greater inclination tendency toward the maxillary first molar, and 11 mini-implants with root proximity showed mesiobuccal contact with the maxillary first molar root. Only 1 failure in 15 mini-implants with root proximity and 1 failure in 35 without root proximity were observed on the images. Conclusions: Root proximity alone was not considered a major risk factor for osseointegration-based mini-implant failure. (Am J Orthod Dentofacial Orthop 2010;138:264-76)

Achieving a high success rate for mini-implant placements is critical in the integration of temporary anchorage devices into clinical orthodontic treatment.1-3 Higher success rates improve the reliability of anchorage stability in planning orthodontic biomechanics, obtain better treatment results, prevent unexpected side effects that delay treatment, and avoid the use of complex appliances. For mini-implants, the usual placement site is the interradicular space between the maxillary second premolar and first molar, since it has the widest space between adjacent roots in the buccal maxillary area.2-6

Several authors have developed and suggested new surgical guide techniques for precise mini-implant placement in interradicular spaces.7-10 Choi et al7 suggested using a custom-made wire guide for preventing root damage. Estelita et al9 also developed a modified radiographic positioner for ensuring exact transfer between the periapical radiographic location and the intraoral drill trajectory position, thereby improving clinical outcomes. However, these surgical guides require additional steps involving x-rays of the patient taken at several times to check placement position. Also, at the present time, most surgical guide systems with 2-dimensional (2D) radiographs have technical limitations for reproducing the precise placement position in the 3 planes of space. If the mini-implant placement is technique sensitive because of complex anatomy, such as an expanded sinus or alveolar bone loss, a precise surgical guide fabricated by using cone-beam computed tomography (CBCT) data should be used.10 Despite its exceptional accuracy, a CBCT guide has some limitations: complex fabrication process, high cost, and higher radiation dose compared with 2D radiographs.11,12 Most clinicians generally place mini-implants without a surgical guide and use only panoramic radiographs or periapical films for presurgical treatment planning to estimate interradicular
In patients who have sufficient interradicular space and no visible complex anatomic structures, it is common for clinicians to carefully place mini-implants in the predicted position with a visual reference guide and only clinical judgment without surgical guides.

Many risk factors have been identified that can affect successful placement of conventional mini-implants in interradicular spaces. Of these adverse conditions, root proximity is a major factor for screw failure in orthodontic anchorage. Recently, some authors reported that the stability of mini-implants after placement can be affected by many factors, including location and timing of force application. Liou et al advocated that mini-implants should be placed in an edentulous area if the patient does not have enough interradicular space or there is less than a 1-mm gap between the mini-implant and the root.

In addition to conventional smooth-surface mini-implants, sandblasted, large-grit, and acid-etched (SLA) mini-implants have been introduced as firm anchorage systems that achieve partial osseointegration throughout the treatment period. This mini-implant system can work as an independent orthodontic appliance to implement anchorage without assistance from posterior anchorage teeth as set up in a conventional anchorage reinforcement system. With this partial osseointegration mini-implant system, research data by Kim et al showed that these devices resisted fracture during removal even after 6 months of nonloading and that the removal torque value (RTV) required to remove the SLA mini-implant was clinically acceptable. Although many mini-implant placements have been considered successful based on clinical stability, no studies have documented root proximity and stability of osseointegration-based mini-implants.

The actual position of a mini-implant placed by a clinician using 2D radiographs without a surgical stent has not been evaluated, and there are no scientific analyses on the preferred area of root proximity for mini-implants. Therefore, the purposes of this study were to place SLA surface-treated mini-implants in the posterior maxilla by using panoramic radiographs only, to compare quantifiable parameters such as placement angles and placement depths for efficient and stable mini-implants, and to investigate correlations of root contact and maxillary sinus penetration to mini-implant failure by using a CBCT craniofacial imaging system. Additional information gained from the CBCT data will demonstrate its diagnostic usefulness in the placement of mini-implants.

### TABLE 1. Demographic distribution of the subjects

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F, Female; M, male.

*Treatment in progress; †head part and screw part of the C-implant were removed as 1 piece; RTV could not be measured.

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**Fig 1.** Schematic illustration of C-implant type of SLA mini-implant.

**Table 1.** Demographic distribution of the subjects

**MATERIAL AND METHODS**

We enrolled 25 patients (7 men, 18 women; average age, 26 years) seeking orthodontic treatment in the Department of Orthodontics, Uijeongbu St Mary’s Hospital, in Uijeongbu, Korea. They volunteered to receive...
orthodontic treatment with maxillary mini-implants and agreed to have a CBCT scan after mini-implant placement. They also consented to have the removal torque measured with a digital device after treatment. These patients all had mini-implants placed between the maxillary second premolar and first molar with a panoramic radiograph as the surgical planning tool and CBCT scans taken after the mini-implants were placed. There were 15 Class I malocclusion and 10 Class II malocclusion patients. No patient had severe periodontitis, severe crowding, missing teeth, or abnormality in the maxilla. One female patient (Table I, number 16) had an impacted maxillary canine. The mean treatment time was 15.3 months.

SLA mini-implants (diameter, 1.8 mm; length, 8.5 mm; C-implant, Cimplant Company, Seoul, Korea) were used for this study (Fig 1). These implants have a 2-component design consisting of an upper head part and a lower screw part.10,13-15 The threads have a smooth cutting edge like a conventional prosthodontic dental implant. The lower 6.5 mm is surface treated and embedded in the bone, whereas the upper 2 mm has a smooth surface in contact with the soft tissues. Since the main archwire can pass through the 0.8-mm diameter hole of the head part, this mini-implant can be used as an independent anchorage unit without fixed appliances on the posterior teeth (Fig 2).23,24 The retention portion of the SLA mini-implant has a higher osseointegration potential15,25-27 compared with smooth titanium mini-implants and therefore better resists the rotational tendency during heavy dynamic loads.28,29 Clinically, SLA mini-implants showing complete stability after 12 months of continuous load were considered successful. All SLA mini-implants used in this study functioned as independent appliances for 3-dimensional (3D) anterior retraction and involved no posterior teeth for anchorage.

The maximum interradicular distance was measured on the panoramic radiograph by using a dental explorer, and the attached gingiva on the placement site was perforated by a tissue punch under local anesthesia to anesthetize the gingiva (less than a quarter of a 1.8-mL volume). A pilot hole was created with a 1.5-mm diameter guide drill (Stryker Leibinger, Tuttingen, Germany). The surgical site was monitored for bleeding, and then the screw part of the mini-implant was placed. After a 4-week healing period, the head part was connected by tapping without a second surgical procedure. The detailed surgical procedure for the placement of C-implants has been given in previous articles.14,15
The postsurgical scans were taken with a CBCT device (PSR 9000N, Asahi Roentgen, Kyoto, Japan) with dosimetry parameters of 10 mA, 80 kV, and 30-second scan time. The panoramic computed tomography mode (0.15 mm³ voxel size) with a field of view encompassing the entire maxilla was selected. The patient was instructed to rest the chin on the machine’s chin-support cup, and the occlusal plane was aligned parallel with the positioning beam. The radiographic output was adjusted to 40-mm thickness and 36-mm width to accommodate the maxilla within the range of the positioning beam. A median beam line was used to center the face, and a head-holding rod was used to hold the head in a stationary position.

The CBCT data were saved as a digital imaging and communications in medicine (DICOM) file by using the Picture Archiving Communication System (Infinit, Seoul, Korea) at Kyung Hee University Dental Hospital. The V-works software program (version 5.0, CyberMed, Seoul, Korea) was used for analyzing the DICOM data to generate quantitative measurements.

For the frontal CBCT plane, an axial plane that passed through the mini-implant was constructed. After comparison with the facial planes that passed through the maxillary second premolar and the mini-implant, the vertical placement angles of the left and right sides (Fig 3, A) were measured. The absence or presence of maxillary sinus penetration was also noted.

To measure the plane parallel to the long axis of the mini-implant, after orientation of the axial plane intersecting the frontal plane, the depth of cortical bone penetration was measured (Fig 3, B). The horizontal mini-implant placement angle between the maxillary second premolar and first molar was measured on both sides.

To evaluate root proximity and maxillary sinus penetration with the axial and sagittal planes of the CBCT images, the proximity of the root structure to the mini-implant was checked. Sagittal and frontal plane images were used to identify any maxillary sinus penetration of the mini-implant. Root proximity was defined as contact of the mini-implant surface with the neighboring root or overlay to the periodontal ligament of the root in the CBCT images. The mini-implants in this study were divided into 4 groups according to root proximity or sinus penetration: group 1, the screw showed root proximity only on 1 side; group 2, the screw showed root proximity on both sides; group 3, the screw had no root contact but penetrated the sinus; and group 4, the screw had both root proximity and sinus penetration (Fig 4).

When the mini-implants were removed after treatment, RTV was measured by 2 experienced clinicians (K.S.H. and C.K.R) using an established protocol with a digital torque sensor accurate to ±0.01 Ncm (STS-31, Lorenz Messtechnik, Alfdorf, Germany; D-1700, Emobile Tech, Seoul, Korea). The peak maximum torque value was recorded as the RTV. When there was sufficient friction to inhibit separation of the upper head part, RTV was not measured. Torque values of 20 implants from 10 patients were obtained.

![Fig 4. Schematic illustrations of 3D root proximity group classifications: A, screw shows 1-side root proximity; B, screw shows 2-side root proximity; C, screw is separate from root but penetrates the sinus; D, screw shows both root proximity and sinus penetration.](image-url)
Statistical analysis

To test for intraoperator variability, CBCT data sets from 8 patients were randomly selected and remeasured by using the same defined parameters 2 weeks after the initial data analysis. Measurement errors were calculated with the Pearson correlation coefficient test.

Contact with root surface, placement depth of the mini-implant, and horizontal mini-implant placement angle between the maxillary second premolar and first molar in the axial CBCT plane parallel to the mini-implant’s long axis, vertical placement angles of the mini-implant in the frontal CBCT plane, and RTV after treatment were recorded and compared by using paired t tests between the left and right sides.

With the CBCT images, the relationship of root contact or maxillary sinus invasion with clinically observed mini-implant failure was compared and calculated with respect to the mean success rate.

Since there were more women in this study, no sex comparison was performed. Statistical analyses were done with SAS software (version 8.0, SAS Korea, Seoul, Korea).

RESULTS

The raw data of age, sex, total treatment time, and RTV are presented in Table I. Mean RTV after treatment showed 19.9 Ncm with a noticeable statistically significant difference between the right and left sides (6.38 ± 7.23 Ncm on the right side vs 23.47 ± 9.74 Ncm on the left; P = 0.0812).

Eight of the 25 patient data sets in this study were randomly selected and remeasured 2 weeks later. Remeasurement results showed highly reproducible data analysis with the Pearson correlation analysis (correlation coefficient, 0.86-0.99; P <0.01).

On the frontal CBCT images, the placement angulations of the left and right mini-implants were measured and compared by using t tests. There was a statistically significant difference between the right and left vertical placement angles (α angle) (P = 0.0002) (Table II). The mean vertical placement angles of the mini-implants on the frontal plane were 11.8° for the right side and 24.5° for the left side. A larger angle on the left side reflected a greater placement inclination of the mini-implant and therefore established more cortical bone contact.

Data of the axial CBCT plane running parallel to the long axis of the mini-implant were compared for the left and right sides with an independent t test. There was a tendency of inclination toward the maxillary first molar during mini-implant placement. A mean angle of 4.91° on the right side showed more inclination to the maxillary first molar than the mean angle of 4.36° on the left side (compared with the horizontal mini-implant placement β angle), although this difference was not statistically significant. There was no noticeable difference in placement depths of the mini-implants on either side. However, depths were 6.79 mm on the left and 6.76 mm on the right; this was longer than the bone contact screw length of the mini-implant (6.5 mm).

In this clinical study, 15 root contacts (8 left, 7 right) with neighboring roots were observed on the CBCT images (Figs 5-9). Most root contacts were in group 1, which included root proximity only on 1 side. Of these 13 root contacts, 4 mini-implants showed proximity to the maxillary second premolar (1 on the right, 3 on the left, Fig 5) and 9 mini-implants showed proximity to the first molar (5 on the right, 4 on the left; Figs 7 and 8, respectively). One mini-implant (in group 2) showed root contact with maxillary sinus invasion.
proximity to the 2 neighboring teeth simultaneously (Figs 8 and 9), and 1 mini-implant showed both sinus penetration and root proximity (Fig 10, group 4). Of these, only 1 implant (in group 2) was removed for complications.

Of the 35 mini-implants placed without root contact, only 1 failed (Fig 11, group 3). Three cases of maxillary sinus penetration on the left side caused no problems or failure, but 1 mini-implant placed in the right pneumatization area failed (Fig 11). All failed implants were removed within 1 month. After the failures, the mini-implants were replaced with an orthodontic miniplate with a tube (C-tube, Gebrüder Martin, Tuttlingen, Germany) supported by a self-tapping mini-screw (diameter, 1.5 mm; length, 4 mm) for use as skeletal anchorage (Fig 9). In the comparisons of root contact with the mini-implant, the horizontal placement angle on the axial plane had no significant difference between the left and right sides.

**Fig 6.** Axial CBCT view of group 1 mini-implants. Root proximity is observed at the mesiobuccal root of the maxillary right first molar. Arrows, root proximity areas.

**Fig 7.** Axial CBCT view of group 1 mini-implants. Root proximity is observed at the mesiobuccal root of the maxillary left first molar. Arrows, root proximity areas.
Fig 8. Group 2 mini-implant (subject 15): A, axial CBCT view; B and C, sagittal views; D, frontal view. Root proximity is observed on the mesiobuccal roots of the maxillary right first molar and second premolar simultaneously. Arrows, root proximity areas.

Fig 9. Group 2 mini-implant (subject 15): A, SLA mini-implant on the left posterior maxilla with root contact failed in the first month after placement; B, I-type C-tube with 2 self-drilling miniscrews (drill-free miniscrew, Gebrüder Martin KLS Martin, Tuttlingen, Germany) was used for narrow interradicular space to achieve the same results; C, 3D volumetric image.
DISCUSSION

With CBCT technology, which provides precise 0.15-mm³ voxel-size 3D images, the position of mini-implants placed in the interradicular spaces between the maxillary second premolar and first molar can be evaluated for bone contact, bone penetration, and iatrogenic consequences.¹,⁵,¹⁰-¹² The importance of this study is that it is the first to evaluate the actual final position of mini-implants and identify risk factors such as root proximity and sinus penetration by using 3D CBCT. This could not be evaluated previously with conventional 2D radiographs.

Surprisingly, the dexterous preference of the practitioner (left- or right-handedness) did not have a significant effect on the horizontal placement angles of the mini-implants. The horizontal placement angle averaged 4.91° on the right side; this was slightly inclined to the maxillary first molar compared with 4.36° on the left side, but this difference was not statistically significant. In examining the specific cases of root contact, the horizontal placement angles of both sides were not significantly different. This angulation consistency might be because of the clinician’s tendency for placing mini-implants in the direction that resists more of the orthodontic load. The depths of cortical bone penetration were 6.79 mm on the left and 6.76 mm on the right; this was longer than the expected length of 6.5 mm, but statistically these value differences were not significant ($P = 0.86$). Kim et al⁵ determined that the average length of the cortical bone surface to the narrowest interradicular space was approximately 5 mm. Therefore, it can be extrapolated that the closer the apex of the mini-implant to the teeth, the narrower the maxillary interradicular space. Thus, more attention is needed to avoid placing the screw part into inner soft tissue.

However, a dramatic difference was noted on the vertical placement plane that tended to be inclined toward the long axis of teeth on the frontal CBCT plane. The vertical placement angle of the right side (mean, 11.2°) was much more vertical to the surface of bone compared with the left side (mean, 24.5°), with a statistical value of $P = 0.0002$. This is most likely the result of greater right-handed prevalence of clinicians placing mini-implants more inclined toward the patient’s left side. The perforation of the maxillary sinus is probably a result of this placement angulation deviation. Three maxillary sinus perforations occurred on the left side. This should serve as a caution for right-handed clinicians to be more careful in the placement of mini-implants on the left side (and vice versa). Also, by attempting to place the SLA mini-implant in the middle of the surgical site and avoiding root contact, the clinician might become so focused on the horizontal vector and compromise the vertical angulation during
min-implant placement without realizing the potential risks of maxillary sinus perforation.

According to the studies of Park and Park et al., issues that affected the success rates of mini-implant placement were mobility and inflammation around the mini-implants. Among these factors, the most significant was mobility that could be caused by the root contact. In a study by Kuroda et al., root proximity was identified as another major risk factor. However, that study had some limitations—i.e., a different mini-implant design, different screw lengths, and the use of 2D periapical radiographs. Poggio et al. studied the safe zone for mini-implants and concluded that the diameter of mini-implants should not exceed 1.5 mm. A 3.5-mm interradicular space is required for safe placement, but the buccal area between the maxillary second premolar and first molar is limited when viewed at the 2-, 5-, 8-, and 11-mm axial slice distances from the alveolar crest.

In this study, the overall success rate for mini-implant placement was 96%. The sample size and the number of mini-implants placed were sufficient to validate this success rate. In addition, the heavy and dynamic biomechanical load to the SLA mini-implants during orthodontic treatment with multiple intermaxillary elastics, rotation force for torque control, and archwire housing reflected the successful implementation of the mini-implants. It was assumed that partial osseointegration of the mini-implant combined with the SLA mini-implant’s treated surface and blunt end made it possible to achieve such a high success rate. The animal study of Oh et al. showed that SLA mini-implants had a higher mean RTV (8.29 Ncm) than did the smooth-surface group (3.34 Ncm) after 6 weeks of loading. Also, published research showed significantly higher RTV in the SLA group than in the machined group, even though the implants were removed and re-implanted. Mean RTV after treatment in this study was 19.9 Ncm, which was sufficient to resist heavy and dynamic orthodontic loads and statistically significant differences between the right and left sides. The counterclockwise rotation moment to the right side during anterior retraction might have resulted in a lower value of the right RTV. The well-established biomechanics for anterior torque control by using osseointegration-based mini-implants have been elucidated previously. These observations were consistent with the findings of this study.

Fig 11. Group 3 mini-implant (subject 10) with SLA mini-implant that penetrated the maxillary sinus without root proximity: A, CBCT axial view; B, CBCT sagittal view. This SLA mini-implant showed no root contact but still failed in the first month after placement.

Fig 12. Schematic illustration shows differences between complications in CBCT and actual implant failure. M1, Maxillary first molar; PM2, maxillary second premolar; Mx., maxillary; black numbers, total number of mini-implants; red numbers, failed mini-implants.

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with the RTV research of Kim et al.\textsuperscript{15} A previous study on 64 C-implants placed in 37 patients showed a significant difference in removable torque ratios between the right ($15.28 \pm 7.76$ Ncm) and left ($17.79 \pm 7.35$ Ncm) sides.\textsuperscript{15} The inclination of the mini-implant results in a greater surface area of cortical bone contact and ultimately leads to improved bone adhesion.

Of the 15 SLA mini-implants with root proximity seen on CBCT, there was a 92.9\% clinical success rate (1 mini-implant loosened). All mini-implants with root proximity of this study were in category II or III of the study of Kuroda et al.\textsuperscript{19} Thirty-five SLA mini-implants without root contact on CBCT had a higher success rate of 97.2\% (1 mini-implant loosened). Compared with the study of Kuroda et al.\textsuperscript{19} our different results demonstrate whether root contact of the mini-implant is a major risk factor for its subsequent failure.

In a clinical environment, a patient under minimum infiltration anesthesia for the gingiva can still feel discomfort when a mini-implant contacts a root surface, and the practitioner can easily change the placement direction to minimize root contact. However, in our study, no patients had any pain or discomfort during placement of the mini-implants, and therefore tooth root penetration by the mini-implant and related pulpal damage were not considered.

From our data, it can be assumed that root proximity itself is not a major risk factor for SLA mini-implant failure. Several reasons might account for this low failure rate. First, the additional SLA properties of the mini-implants used in this study could have reduced any likelihood of failure even with a small amount of root contact, because the osseointegration potential of the SLA mini-implant is much higher than other mini-implants with only mechanical retention.\textsuperscript{15,27} Also, a 4-week healing period after placement improves the osseointegration potential of the mini-implant.\textsuperscript{30} In early loading, the most important factor for success is preventing micromobility, which would affect initial stability.\textsuperscript{30} Therefore, the healing period and the initial load should be considered.\textsuperscript{31,32} Second, a guide drill was used to penetrate the cortical bone, and the self-tapping screw with blunt pitch and apex prevents any harmful effects on the adjacent periodontal ligament or root. Even though there might be contact with the periodontal ligament or cementum, Andreasen and Kristerson\textsuperscript{31} suggested that periodontal ligament deficits on the root surface up to 2 mm can be repaired by a new attachment without ankylosis. Third, the successful implants were in group 1, which had 1 side contacting the root. It appears that a threshold bone contact is sufficient to withstand the micromotion generated from occlusal forces. Fourth, every patient in this study was treated by a systemized orthodontic treatment technique in which the archwire was engaged in the hole of the mini-implant without fixed appliances on the posterior dentition. Therefore, it was believed that the root contact area is stable during orthodontic treatment. It is the same effect as if no anterior appliances were used during the forced eruption of a canine.

Huja and Roberts\textsuperscript{32} suggested that an elevated rate of continuous remodeling within 1 mm of the loaded mini-implant is not a major risk factor for SLA mini-implant failure. Several reasons might account for this low failure rate. First, the additional SLA properties of the mini-implants used in this study could have reduced any likelihood of failure even with a small amount of root contact, because the osseointegration potential of the mini-implant is much higher than other mini-implants with only mechanical retention.\textsuperscript{15,27} Also, a 4-week healing period after placement improves the osseointegration potential of the mini-implant.\textsuperscript{30} In early loading, the most important factor for success is preventing micromobility, which would affect initial stability.\textsuperscript{30} Therefore, the healing period and the initial load should be considered.\textsuperscript{31,32} Second, a guide drill was used to penetrate the cortical bone, and the self-tapping screw with blunt pitch and apex prevents any harmful effects on the adjacent periodontal ligament or root. Even though there might be contact with the periodontal ligament or cementum, Andreasen and Kristerson\textsuperscript{31} suggested that periodontal ligament deficits on the root surface up to 2 mm can be repaired by a new attachment without ankylosis. Third, the successful implants were in group 1, which had 1 side contacting the root. It appears that a threshold bone contact is sufficient to withstand the micromotion generated from occlusal forces. Fourth, every patient in this study was treated by a systemized orthodontic treatment technique in which the archwire was engaged in the hole of the mini-implant without fixed appliances on the posterior dentition. Therefore, it was believed that the root contact area is stable during orthodontic treatment. It is the same effect as if no anterior appliances were used during the forced eruption of a canine.

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Fig 13. Group 1 mini-implant (14-year-old girl): A, periapical view; B, sagittal view; C, axial CBCT view. Surface root contact of the mini-implant is observed at the mesiobuccal root of the maxillary right first molar (version 3.1, InVivo Dental software, Anatomage, San Jose, Calif).
implant makes it possible to resist bone fatigue and maintain integration in less-mineralized bone. Serra et al33 showed that immediate loading with low and unidirectional force resulted in a lower RTV than in unloaded mini-implants. This could explain the difference between the loaded and unloaded groups, where a less mineralized bone produced in the loaded group provided a lower RTV. If orthodontic tooth movement occurred in this study, the stability and retention of mini-implants with root proximity might decrease. From an orthodontic perspective, the lower RTV can be beneficial because of the eventual necessity to remove the temporary mini-implant after treatment.

However, a mini-implant with more than 1 side contacting the adjacent roots (group 2) failed within a month (Fig 12). The problem seemed to be caused by the lower initial stability because of the decreased bone-to-implant contact caused by several contacts and the different micromotions between the premolar and the molar. Therefore, root proximity to the 2 tooth roots is a major risk factor for failure of a mini-implant. The 4 patients with maxillary sinus penetration in this study are too few to assess risk factors in mini-implant failures, especially since 3 patients (except for the patient with pneumatization) were considered successful. Maxillary sinus penetration, however, should still be considered a potential risk factor in mini-implant retention.1 Of the 4 implants with maxillary sinus penetration, it was the right mini-implant that failed. The reason for this failure was most likely due to an absolute shortage of bone-to-implant contact when the pneumatization of the maxillary sinus invaded the interradicular space. These factors depend on the relationship between the quality and quantity of host bone in the placement site and the implant form.33 When interradicular space is too narrow, teeth have dilacerated roots, the maxillary sinus is expanded, or there is severe alveolar bone loss, these might prohibit the placement of mini-implant screws. Then other types of skeletal anchorage should be considered, such as cross type C-tube or C-palatal plate.34,35

All samples in group A of this study had success, even though they had root-implant contact on 1 side. It appears that the threshold of bone contact is sufficient to withstand micromotion generated from occlusal forces. However, a 14-year-old girl in group A had loosening of the mini-implant, since there was also surface contact to the neighboring root (Fig 13). In this patient, we changed the skeletal anchorage from an SLA mini-implant to a miniplate immediately (Fig 14). This was a condition analogous to category III of Kuroda et al.19
CONCLUSIONS

From this study, it is apparent that the vertical angulation of mini-implant placement has a significantly greater variability than the horizontal angulation. One-side root proximity in the osseointegration-based mini-implant and sinus perforations with initial stability might not be major risk factors for mini-implant failure. Several roots in proximity to the mini-implant combined with sinus perforation without initial stability was defined as the major risk factor for screw failure. The amount of root contact area of a mini-implant is more important for its stability. Additional clinical research with 3D CBCT technology is needed to determine the actual stability of mini-implants after root contact.

REFERENCES