

Do sand blasted with large grit and acid etched surface treated mini-implants remain stationary under orthodontic forces?

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ABSTRACT

Objectives: To determine the positional stability of sand blasted, large grit, and acid-etched (SLA) surface-treated mini-implants (C-implants) used as the exclusive source of anchorage during en masse retraction.

Materials and Methods: A retrospective clinical investigation was performed comparing pretreatment cone beam computed tomography (CBCT) images with those taken after en masse retraction of the six anterior teeth. Force was applied to 16 C-implants (1.8 mm in diameter, 8.5 mm in length) placed between the upper second premolars and first molars. Three-dimensional superimposition of CBCT data using mutual information was used to evaluate the positional difference of C-implants between preretracted and postretraction CBCT data.

Results: There was no significant difference in mini-implant position between the preretracted and postretraction CBCT evaluation.

Conclusions: The SLA-coated C-implant provides stationary anchorage as well as stable anchorage during orthodontic tooth movement. (*Angle Orthod.* 2012;82:304–312.)

KEY WORDS: Mini-implant; Stationary anchorage, CBCT; Superimposition; Root damage; Stability

INTRODUCTION

Orthodontic miniscrews provide stable anchorage, but opinion varies as to whether they remain absolutely stationary throughout orthodontic loading.^{1–6} Liou et al.² and Wang and Liou³ reported that machine surfaced miniscrews are not stationary and they might move when an orthodontic force is loaded. Clinicians are wary of potential problems arising from inappropriate placement of miniscrews, particularly relating to damage to such vital structures as the neighboring root, foramen,

blood vessel pathways, or major nerves.² It has been recommended that implants be placed either in a non-tooth-bearing area or in a tooth-bearing area, but that 2-mm of safety clearance between the miniscrew and dental root be provided.^{2,3} However, recently published studies^{7,8} have reported that in patients treated with acid-etched mini-implants that had been sandblasted with large grit, side effects and root damage were not found, despite the report of Liou et al.²

It is commonly thought that endosseous implants remain absolutely stationary under orthodontic loading due to osseointegration with the surrounding bone.^{6,9} Recent development of palatal orthodontic implants that osseointegrate have shown stationary anchorage.^{4–6} If mini-screws (typically with machined surfaces) were to be surface treated using a similar process as with a prosthetic implant, would this modified miniscrew be able to remain stationary if subjected to orthodontic forces? Would such a modified mini-screw overcome the limitations of the machined-surface miniscrew to endure the diverse loads and directions of sophisticated orthodontic forces?

The design of the orthodontic C-implant is similar to that of a prosthetic implant except for size and consists of two parts, the head and the screw part.^{10–12} It has a 1.8-mm screw diameter and sandblasted, large grit, and acid-etched (SLA) surface treated except for the

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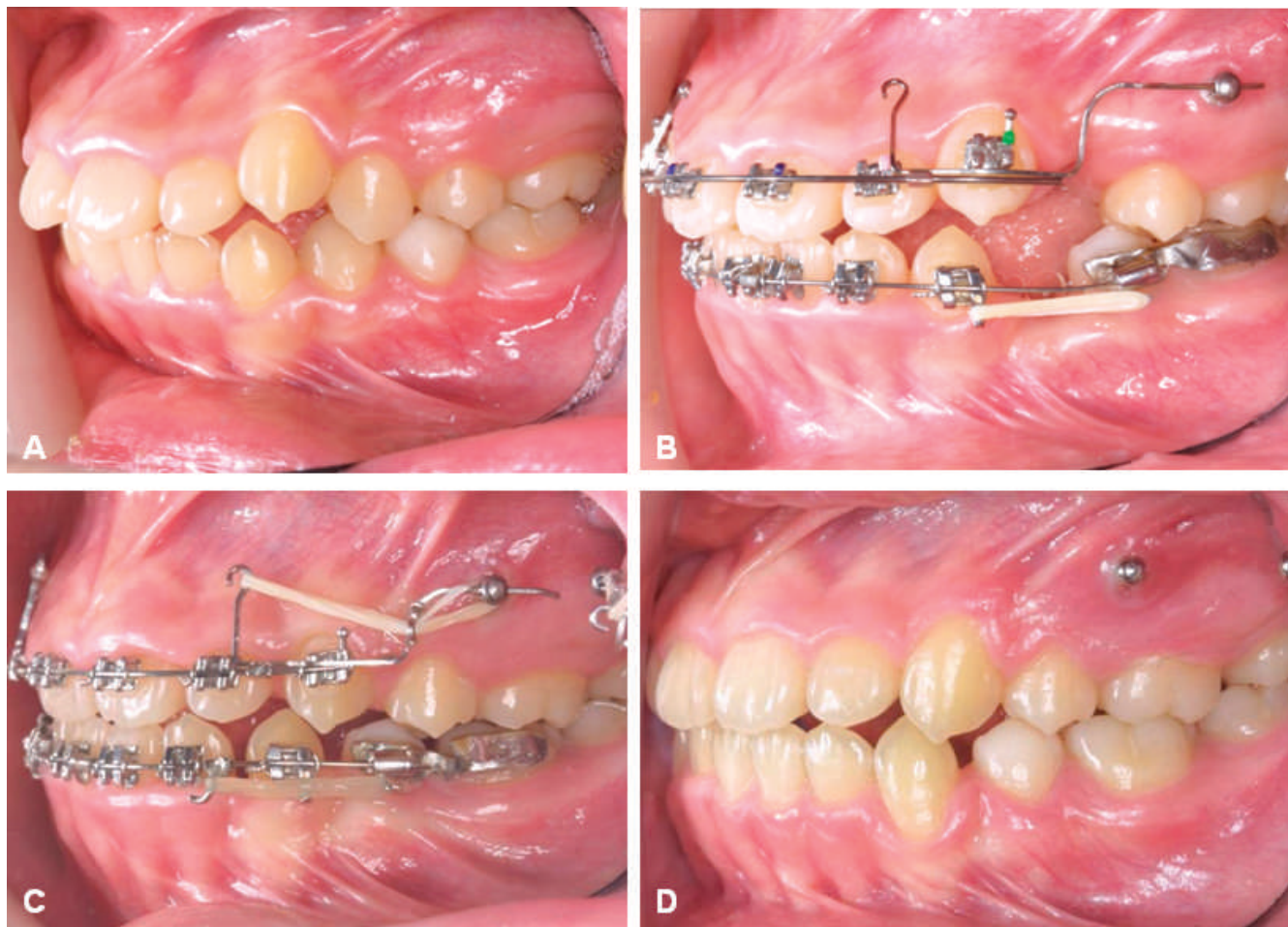


Figure 1. (A) Intraoral photographs of C-implant dependent en masse retraction (16 years, female). (B) Pretreatment cone beam computed tomography scans were taken before en masse retraction and (C) after retraction. (D) Posttreatment.

upper 2-mm collar.^{11,13} This type of mini-implant uses the osseointegration potential as a retention source to resist both rotational force (lever arms) and heavy or dynamic loads (intermaxillary force application).^{14,15} C-implants in the posterior maxilla are typically used as the exclusive source of anchorage during en masse retraction without assistance of upper posterior bonded or banded appliances. This type of biomechanical system is called biocreative therapy.^{14,15}

The behavior of surface-treated C-implants during orthodontic loading and the suitability of the maxillary tooth-bearing zone to bear these implants have not been reported. One barrier to such a study has been that periapical radiographs or lateral and posterior-anterior cephalograms do not provide the spatial detail necessary to accurately assess the precise stability of a mini-implant, especially one that has an insertion angle of 10° to 30°.³

Our aim in this preliminary study was to accurately measure the positional stability of SLA surface-treated C-implants used as the exclusive source of anchorage

for en masse retraction periods. Our method includes the use of a newly developed three-dimensional (3D) superimposition method using cone beam computed tomography (CBCT).

MATERIALS AND METHODS

Eight patients (mean age 25.1 years; range 17–46 years; 7 female, 1 male) were enrolled in the study. They volunteered to receive orthodontic treatment with maxillary mini-implants and agreed to have CBCT scans after mini-implant placement and after anterior retraction. Sixteen SLA C-implants (1.8 mm in diameter, 8.5 mm in length, Cimplant Co, Seoul, Korea) were placed between the upper second premolars and first molars as a direct anchorage for en masse anterior retraction. These implants have a two-component design consisting of an upper head part and a lower screw part. The lower 6.5 mm was surface treated, to be embedded in the bone, whereas the upper 2 mm had a smooth surface intended to be in contact with the soft tissues. Since the main archwire

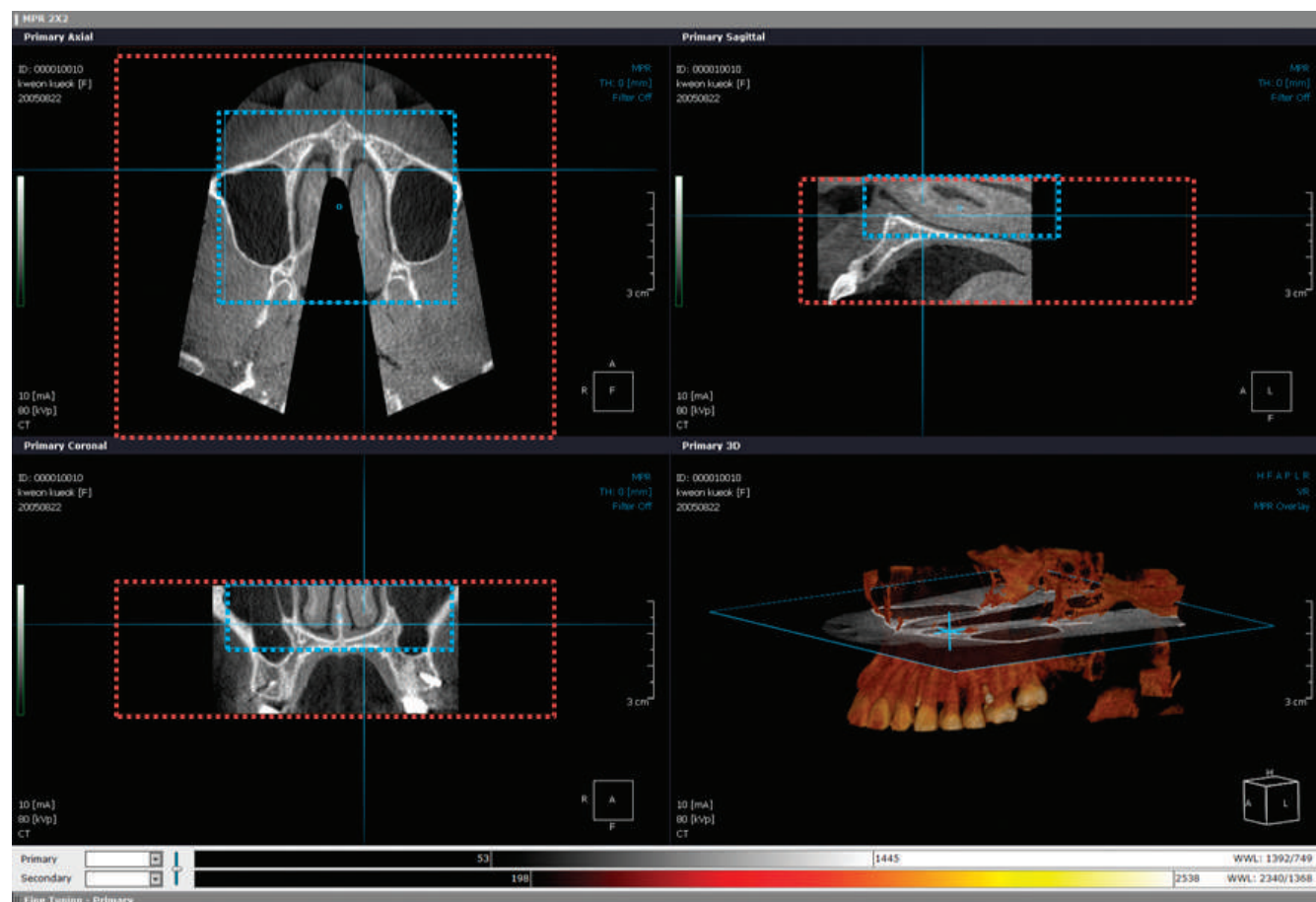


Figure 2. Cone beam computed tomography images of registration area for the automated voxel superimposition method. The blue dotted area is the registration area and the brown color box designates the field of view.

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. After a 4-week healing period, the friction-retained head part was tapped into place without the need for a second surgical procedure (Figure 1).¹⁶ The detailed surgical procedure for the placement of C-implants has been reported in previous articles.^{8,10}

The approximate retraction force was 450 g during en masse retraction. Immediately after placement of the C-implant, scans were taken with a CBCT device (PSR 9000N, Asahi Roentgen Ind, Kyoto, Japan) with dosimetry parameters of 10 mA, 80 kV, and a 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.¹⁶ 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. For one patient, a CBCT scan was taken with Alphard

Vega (Asahi Roentgen Ind) using the manufacturer's recommended parameters of 200 × 179 mm field of view, 80 Kvp, 10 mA, 17 second scan time, and 0.3 mm³ voxel size. 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. This preliminary report and associated data were reviewed by the Institutional Review Board at Kyung Hee University Dental Hospital (KHDIRB-005-1).

Automated Voxel Superimposition Method of CBCT

The 3D superimposition technique used in this study allows for subvoxel accuracy and highly robust registration. This method also works to superimpose two datasets with different protocols, voxel sizes, gray scales, and from different CBCT or CT devices.^{17–19} The OnDemand 3D software program (CyberMed Inc, Seoul, Korea) was used for superimposition of the DICOM data and to generate quantitative measurements.

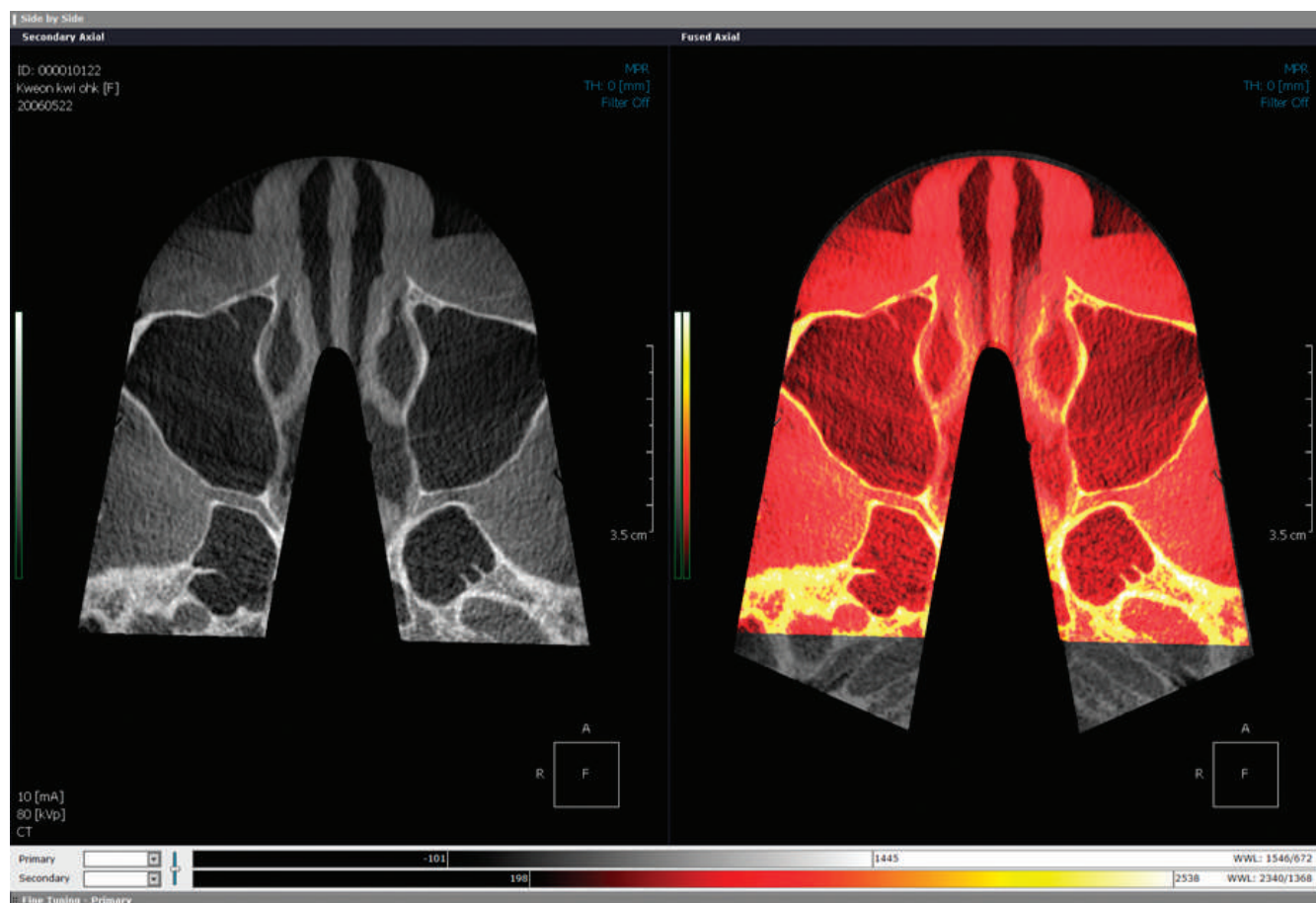


Figure 3. Superimposed axial slice images of the anterior cranial base before (gray) and after en masse retraction (red-yellow). The sinus wall and other fine anatomic structures are perfectly registered.

The maxillary sinus and palate was designated as the registration area because these anatomic structures do not change during orthodontic treatment (Figure 2). The software then automatically calculates the best agreement of this registration area and superimposes the two datasets (Figure 3). The tails and centers of the imaginary head of the C-implants were identified, and the 3D coordinate of each point was measured (Figures 4 and 5). In this study, the tail was determined to be the apex of the C-implant screw part, and imaginary head (lhead) as between the top of the screw and below 0.5 mm from the top. The XY plane is parallel to the upper occlusal plane, and the YZ plane is parallel to midsagittal plane (Figure 6). Only one of the authors superimposed CBCT datasets and measured the movement of C-implant to avoid interrater errors.

Statistical Analysis

The three dimensional changes of the C-implants before and after en masse retraction of the screw tail and screw head were analyzed by paired *t*-tests

($P < .05$). Half of the sample CBCT datasets (eight datasets) including 16 C-implants were randomly selected and measured again 1 month later for error analysis ($P < .05$). Error analysis was carried out according to the formula $\sqrt{(SD)^2/2}$.²⁰

RESULTS

The experimental group of patients experienced anterior dental retraction against C-implant anchors for an average of 9 months (Table 1). Mean removal torque value (RTV) of the mini-implant screw part was 23.69 Ncm; right 20.74 Ncm and left 26.64 Ncm. Two patients were excluded from the measurement of RTV since they kept the C-implant in the oral cavity beyond the assigned T2 time point (after en masse retraction). Relative location changes of the tail and lhead in X-axis, which would indicate a change in intrusion or extrusion are -0.04 ± 0.19 mm and 0.01 ± 0.18 mm, respectively (Table 2). Absolute value comparison to check displacement showed that changes in tail and lhead positions were 0.16 ± 0.11 mm and 0.14 ± 0.11 mm, respectively (Table 3). Relative location

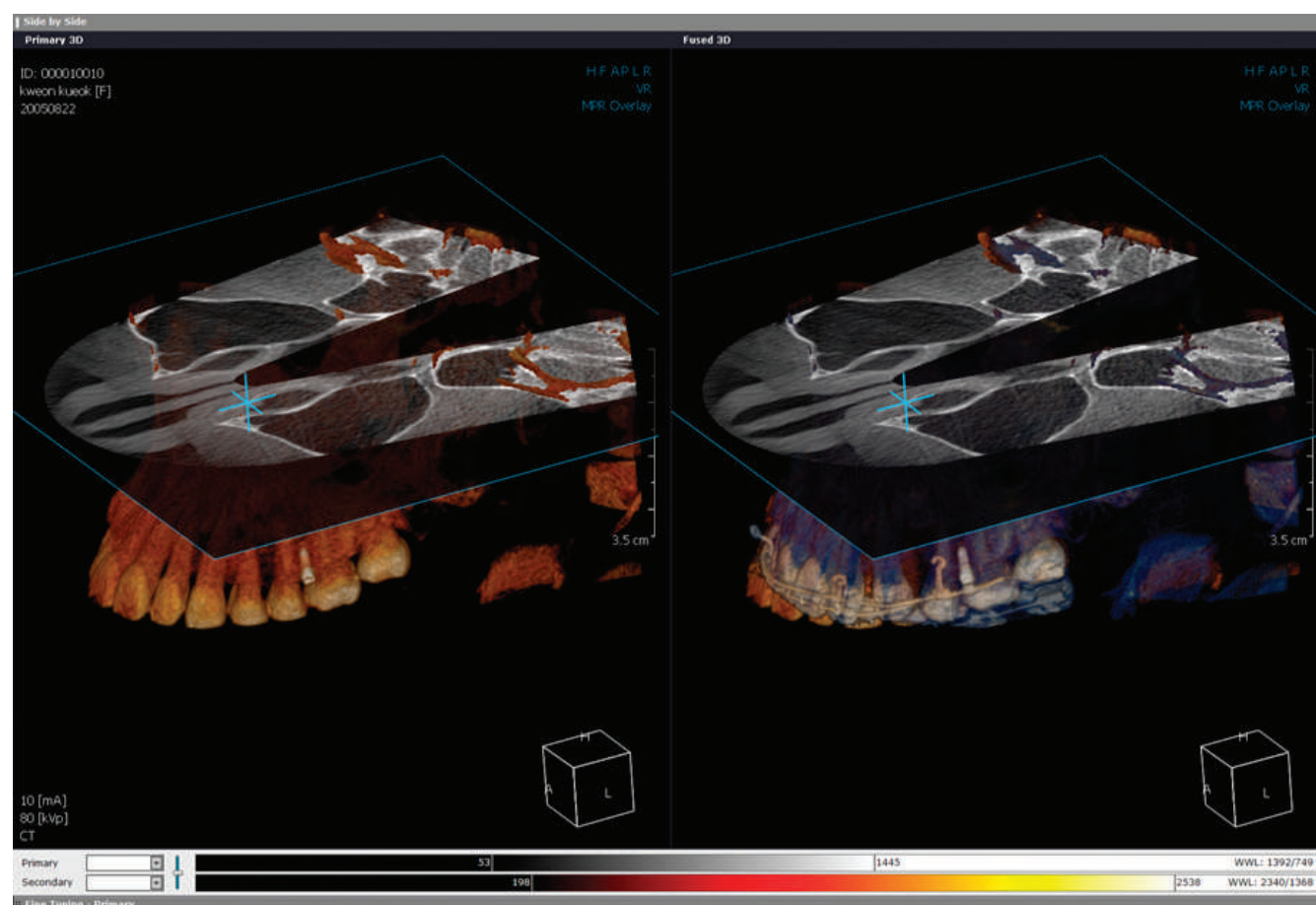


Figure 4. Three-dimensional volume rendering images with axial slice before en masse retraction (left side) and superimposition (right side).

changes in Y-axis (signifying mesiodistal movement) were 0.07 ± 0.14 and 0.05 ± 0.12 mm, respectively.

The absolute value comparison showed a change of 0.12 ± 0.10 mm and 0.14 ± 0.12 mm, respectively. Relative location changes in Z-axis were measured to indicate any vertical movement in reference to the occlusal plane. The tail part showed 0.03 ± 0.16 mm and the lhead showed -0.02 ± 0.20 mm. Also, tail and lhead showed 0.13 ± 0.10 mm and 0.13 ± 0.15 mm, respectively, in absolute value comparison. In summary, there was no significant difference between the preretracted and postretraction CBCT evaluation in the X, Y, and Z axis. The analysis of method errors is shown in Table 4.

Even though semi-osseointegrated C-implants are of a smaller diameter than the larger osseointegrated palatal implants, we speculate that the SLA surface treatment and a 4-week period to allow partial osseointegration may be the reason for dependable stability.

DISCUSSION

Recent software developments now allow both visualization and superimposition of volumes and

slices.^{18,19} Some of these methods require landmark registration, however, which can incorporate observer-dependent errors, but to a minor extent.¹⁸ Fine features of the cranial base are also difficult to visualize on CBCT volumes, further complicating landmark identification.

The accuracy of the superimposed CBCT data can be improved beyond the computer estimation by operator adjustment of the superimposition via minute translation and rotation of the images. Cevdanes et al.¹⁹ used this method to obtain geometric information from one software program and then applied it to another when comparing presegmented surface models. We expanded the procedure to include volume and slice imaging and also refined the algorithm and user interfaces. In addition, a new automated method enables us to accurately measure 3D positional change of objects using mutual information. In this study, a custom program was modified to digitalize both the amount and the angles of 3D displacements. In this study, a 0.15 mm^3 voxel sized CBCT apparatus was used in seven of eight patients, and a 0.3 mm^3 voxel was used for the one remaining patient. Any change in screw part position was between 0.12 and

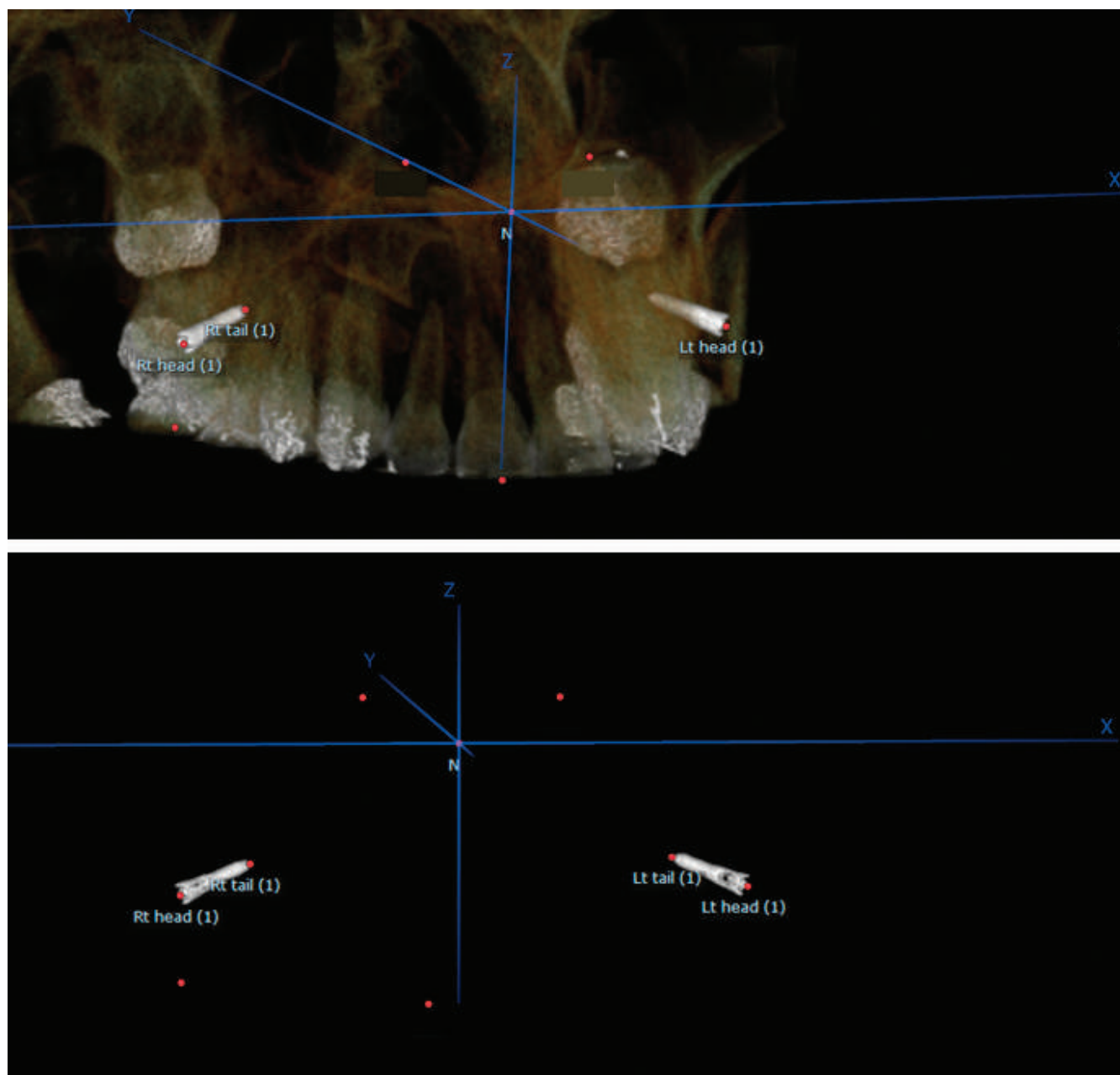


Figure 5. Measuring points of C-implants in the 3D volume rendering images (A) with anatomic structure and (B) without anatomic structure. The tail was determined to be the apex of the C-implant screw part, and imaginary head (lhead) as between the top of the screw and below 0.5 mm from the top. The XY plane is parallel to the upper occlusal plane, and the YZ plane is parallel to the midsagittal plane.

0.16 mm, so these were within the 0.15–0.3 mm³ voxel range. Another major advantage of this method is that even though the CBCT and CT datasets were generated by different devices, protocols, voxel sizes, and grayscales, they still can be superimposed.¹⁸

Any minor differences in the mini-implant positions in this study seem to be more from inevitable error sources such as observer-dependent landmark identification, artifacts in CBCT imaging due to partial volume averaging effect and metallic implants, than actual displacements of C-implants.^{21,22} In any case,

the minor changes in position of the mini-implant were not statistically significant.

Limitations of this study would include a small sample size ($n = 8$). All patients had upper first premolar and lower premolar extractions and were treated with biocrete therapy, which allows retraction with no appliances on the upper posterior teeth. Since the C-implant has dynamic stability, active intramaxillary and intermaxillary elastics could be applied to the device to provide anchorage to both the maxillary and mandibular dentition.

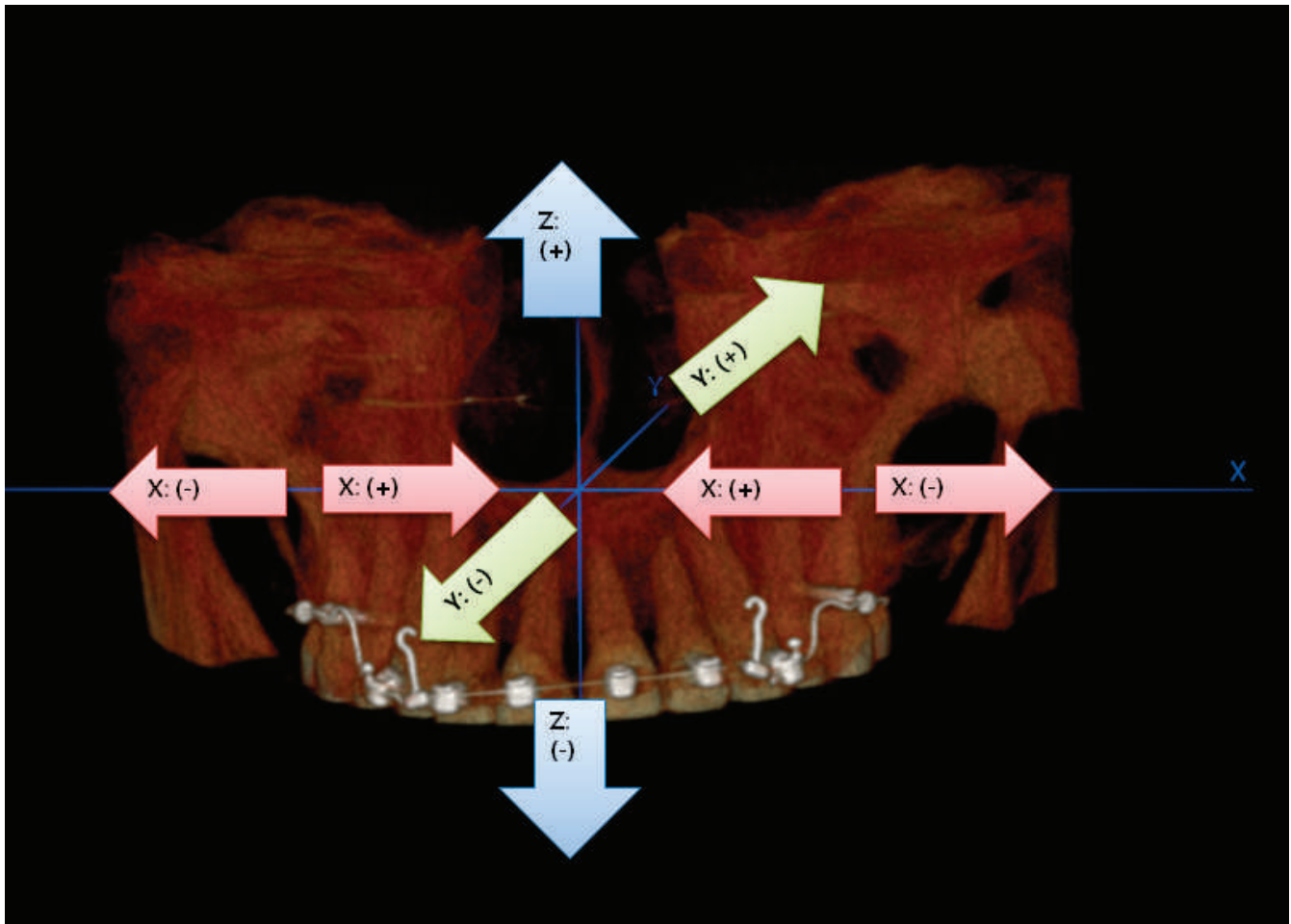


Figure 6. Variables of 3D superimposition of C-implants between preretraction and postretraction periods. Measurement of C-implant on the X-axis: (+) indicates intrusion and (–) indicates extrusion. Measurements on the Y-axis: (–) indicates mesial and (+) indicates distal movement, and on the Z-axis (–) indicates occlusal and (+) indicates cervical movement.

Osseointegration improves the mini-implant stability and provides anchorage to support lever-arm mechanics and to resist the perturbations of intermaxillary elastics.^{8,10} The C-implants used in this study are diameter reduced temporary skeletal anchorage devices, and as is true with dental implants, we assume

that a 4-week waiting period establishes adequate osseointegration.¹⁶

Liou et al.² reported that the main cause of mini-screw (machined-surface) displacement after orthodontic loading was allowing a waiting period before loading. It could also be that, if the implant is not

Table 1. The Demographic Distribution of the Subjects^a

No.	Sex	Age, y	Malocclusion	Retraction Period, mo	Treatment Period, mo	RTV (Ncm)	
						Rt	Lt
A.Y.S	F	17	I	11	17	26.11	29.44
H.K.I	F	22	II	11	16	25	33
K.A.J	F	46	I	9	16	27.51	30.41
Y.R	F	27	II	7	16	^c	^c
K.K.O	F	23	I	9	15	9.41	16.55
S.E.S	F	25	I	8	14	19.86	32.94
C.A.R	F	24	I	8	18	16.56	17.48
O.J.T	M	17	II	9	17 ^b	^c	^c

^a F, indicates female; M, male; RTV, removal torque value; Rt, right side; and Lt, left side.

^b Treatment is under progress.

^c C-implant was not removed yet. RTV could not be measured from these cases.

Table 2. Average Movement (mm) of C-implants at Preretraction (T1) and Postretraction Periods (T2) (Relative Value)^a

Variables	Tail X	Tail Y	Tail Z	Ihead X	Ihead Y	Ihead Z
Mean	-0.04 (NS)	0.07 (NS)	0.03 (NS)	0.01 (NS)	0.05 (NS)	-0.02 (NS)
SD	0.19	0.14	0.16	0.18	0.17	0.20
Max	0.38	0.31	0.45	0.35	0.46	0.45
Min	-0.31	-0.23	-0.24	-0.32	-0.23	-0.48

^a SD indicates standard deviation; Max, maximum; Min, minimum; Tail, apex of screw part of C-implant; Ihead, imaginary head as between the top of the screw and below 0.5 mm from the top; and NS, not significant.

Table 3. Average Movement (mm) of C-implants at T1–T2 (Absolute Value)^a

Variables	Tail X	Tail Y	Tail Z	Ihead X	Ihead Y	Ihead Z
Mean	0.16	0.12	0.13	0.14	0.14	0.13
SD	0.11	0.10	0.10	0.11	0.12	0.15
Max	0.38	0.31	0.45	0.35	0.46	0.48
Min	0.01	0.00	0.01	0.01	0.01	0.00

^a SD indicates standard deviation; Max, maximum; Min, minimum; Tail, apex of screw part of C-implant; and Ihead, imaginary head as between the top of the screw and below 0.5 mm from the top.

loaded immediately, jiggling from mastication contributes to failure. A study reported that the quality of osseointegration might be enhanced by the cellular activity of the bone tissue around the implant when static light orthodontic force was immediately loaded.²³ In our study, orthodontic force was not loaded until 4 weeks after placement. During this waiting period, orthodontic appliances were placed and extractions performed. Jeon et al.¹³ and Mo et al.²⁴ showed statistically significant high RTV of 150 g with the SLA mini-implant which was compared to machined-surface mini-screws in beagle dogs.²⁴ Rabbit research with lateral force applications also showed high stability. RTV studies and histomorphometric studies of the SLA C-implant reported that both surface treatment and early loading have a positive effect on osseointegration of mini-implants. Using only two mini-implants, orthodontic forces can be applied that will enable intrusion, retraction, or protraction. Usually, the C-implant is placed in the alveolar bone between the maxillary second premolar and the first molar at the

Table 4. Analysis of Method Error (Repeated Measurements in Eight Cone Beam Computed Tomography Datasets Including 16 C-implants)^a

	Mean	SD	t value	Random Error
Tail X	0.02	0.10	0.666 (NS)	0.07
Tail Y	0.00	0.12	0.040 (NS)	0.09
Tail Z	0.03	0.06	1.880 (NS)	0.04
Ihead X	0.05	0.22	0.856 (NS)	0.16
Ihead Y	0.01	0.06	0.380 (NS)	0.04
Ihead Z	0.11	0.40	1.072 (NS)	0.28

^a SD indicates standard deviation; Tail, apex of screw part of C-implant; Ihead, imaginary head as between the top of the screw and below 0.5 mm from the top; and NS, not significant.

mucogingival junction. The advantage of this site is that the mini-implant can be used to retract and intrude anterior teeth with no orthodontic appliances on the posterior teeth.²⁶ The stability gained by the osseointegration potential allows the head to be large enough to accept archwires. Therefore, they can serve not only as the posterior anchorage, but also as hooks for intermaxillary elastics. This location is also good in terms of vector and moment. In contrast, placement of devices at the infrazygomatic region may not enable some of these biomechanical options. Usually they are limited to retraction or indirect anchorage.

Rather than avoiding the interradicular space of the upper posterior maxilla, our study found it to be a suitable site for implantation, since the osseointegration potential appears to limit any movement of the device. This concept is very important for obtaining a simple and efficient treatment result. Further studies are needed about immediately loaded C-implants using larger samples, orthodontic miniplates, or skeletally anchored expansion appliances. The use of CBCT scans will provide accurate and objective assessment of such protocols.

CONCLUSION

- Stability of the C-implant during active force application was established.

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