Orthodontics & Craniofacial Research

ORIGINAL ARTICLE

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# Orthodontic miniscrew failure rate and root proximity, insertion angle, bone contact length, and bone density

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Watanabe H., Deguchi T., Hasegawa M., Ito M., Kim S., Takano-Yamamoto T. Orthodontic miniscrew failure rate and root proximity, insertion angle, bone contact length, and bone density
*Orthod Craniofac Res* 2013; **16**:44–55. © 2012 John Wiley & Sons A/S

**Structured Abstract**
***Objectives –*** To test the hypothesis that there is no significant correlation between miniscrew failure rate and root proximity, insertion angle, bone contact length, and bone density.
***Setting and Sample Population –*** This study included 107 patients in whom 190 miniscrews had been placed from April 2008 to October 2009 in Tohoku University Hospital (Sendai, Japan).
***Materials and Methods –*** Cone beam computed tomography scans (CBCT) and periapical radiographs were taken before and after miniscrew placement. Differences in root proximity, screw insertion angle, bone contact length, and bone density were statistically compared; comparisons were also made between the CBCT images and periapical radiographs.
***Results –*** A significantly higher success rate was observed in the maxilla than in the mandible. The distance between the miniscrew and the root surface was significantly smaller in the failure group. There were no significant differences in the insertion angle, bone contact length, or bone density between the success group and the failure group. The concordance rate between the periapical dental radiographs and CBCT images was 46.5%.
***Conclusion –*** While bone contact length, miniscrew angle, and bone density did not exert major effects on miniscrew failure, root proximity was the factor that most affected miniscrew failure, especially for miniscrews placed in the mandible. CBCT was superior to periapical dental X-rays for evaluating the proximity of miniscrews to the root. Correction of the X-ray attenuation coefficient value was necessary for measuring bone density using CBCT.

**Key words:** cone beam computed tomography; failure analysis; miniscrew; orthodontic anchorage procedures; orthodontics

**Date:**
Accepted 9 August 2012

DOI: 10.1111/ocr.12003

## Introduction

Although miniscrews have been routinely used for orthodontic anchorage in the past few years (1–3), problems remain associated with their use, with miniscrew failure the most common problem (4). Several reports have analysed the main factors affecting miniscrew failure, such as inflammation of the surrounding bone, the location of the miniscrew, the thickness of cortical bone, skeletal characteristics, and age (1, 4–6). Recently, we used periapical radiograph evaluations to determine that root proximity is the major factor affecting miniscrew failure (7). In that report, we divided the failures into three types according to the proximity of the miniscrew and the neighboring root, and we concluded that a high failure rate occurred when the miniscrew was closer to the root. However, it was impossible to assess the distance between the miniscrew and the root in three dimensions via periapical radiography and/or panoramic radiography. This situation occurred because it was difficult to locate the actual position of the miniscrew in the mesial-distal and labial-lingual directions, and overlapping images of the miniscrew and root often occurred, depending on the angle of periapical radiography.

Cone beam computed tomography (CBCT) allows evaluation of the location of prosthetic implants, and recently, it has been used for orthodontic treatments involving miniscrews. CBCT has also been used to measure the space between roots (8–10) and the thickness of cortical bone to assess the optimal location for miniscrew placement (11, 12). Recently, Kim et al. (13) used CBCT to investigate whether root proximity is the major factor affecting mini-implant failure. However, their preliminary report included only a small sample, and none of their patients had brackets fitted to their posterior teeth.

In the present study, we used CBCT before and after miniscrew placement and performed a three-dimensional quantitative analysis of the relationships between miniscrew failure and root proximity, miniscrew insertion angle, bone contact length, and bone density. Furthermore, we assessed the differences between CBCT images and periapical radiographs taken at the same time.

## Materials and methods

### Subjects

A total of 190 miniscrews (132 in the maxilla, 58 in the mandible) had been installed between the maxillary and/or mandibular second pre-molar and the first molar for anchorage at our university hospital from April 2008 to October 2009 in 107 patients (30 males, 77 females; mean age, 21.0 years; range, 13.1–52.4 years). For these 107 patients, the ANB values were distributed as follows: 29 patients were skeletal I, 56 patients were skeletal II, and 22 patients were skeletal III. Miniscrews that showed mobility or failed within 1 year of placement were defined as having failed.

All of the patients consented to participate in the study before the start of their orthodontic treatment. The study protocol was reviewed and approved by the Institutional Board of Tohoku University, Sendai, Japan.

## Clinical procedure

The miniscrews (Absoanchor Dentos Inc., Taegu, Korea; diameter 1.4 mm, length 5 mm (n = 42), 6 mm (n = 145), or 8 mm (n = 3)) were installed under local anesthesia by two orthodontists (T.D. and T.H.). A screw hole was made in the bone with a 1.0-mm round bur and a drill (ø 1.1 mm) at 500 rpm, and the miniscrew was placed via the self-tapping method.

Cone beam computed tomography scans (3D-Accuitomo; J. Morita Co., Kyoto, Japan) was performed (80–90 mVp, 3.5–5 mA, scanning time 17.5 s, field of view 60 × 60 mm, voxel size 0.125 mm) both before and after miniscrew implantation. A stent made from paraffin wax and gutta-percha point (Fig. 1) was used during the pre-implantation CBCT, and periapical radiographs were also taken after miniscrew implantation.

### Measurements

Factors such as gender, age, malocclusion type, mandibular plane angle, and loading time were compared in groups of patients with failed or successful use of miniscrew. In addition, the total

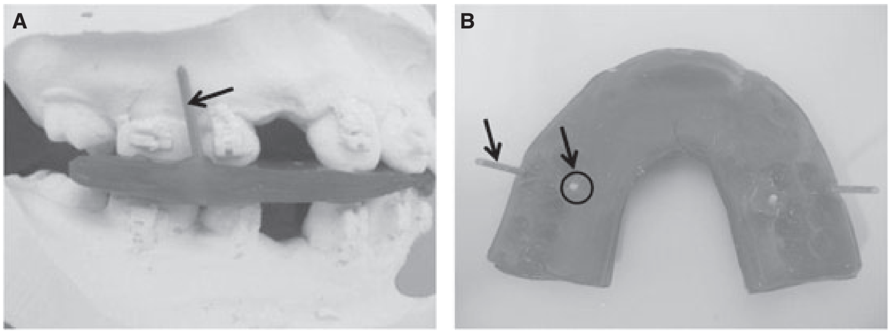


*Fig. 1.* Photographs of a stent (arrow). Buccal view (A) and occlusal view (B).

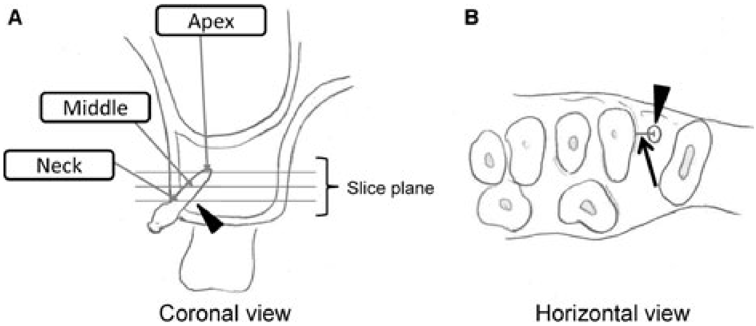


*Fig. 2.* Scheme of the measurement of root proximity. Three points (Apex, Middle, Neck: neck at alveolar bone level) on the miniscrew (arrowhead) were determined on the coronal view of the MPR image (A). The distances (arrow) were measured on the horizontal view (B).

success rate was calculated before (from June 2006 to March of 2008, n = 96) and after the use of CBCT.

Root proximity was measured using the One Data Viewer software (version 1.50, J. Morita Co.). Multiplanar reformatted (MPR) post-implantation CBCT images were made by slicing in the coronal direction, passing through the long axis of the miniscrew (slice interval, 0.25 mm; slice thickness, 0.5 mm). The measurement was taken from the root nearest the miniscrew. We measured the distance from three points (apex, middle, and neck at alveolar bone level; Fig. 2A) to the root surface on the horizontal plane (Fig. 2B).

For measurement of the miniscrew insertion angle, we checked the angulation value of the first molar by postero-anterior cephalogram tracing prior to placement of the miniscrew. Angulation was assessed between the line made from the buccal cusp to the lingual cusp of the first molar and facial midline (perpendicular to lateral-orbital line), with average values of 80.4° ± 1.9° (range, 76.4–84.3°) in maxillary molars and 77.2° ± 2.7° (range, 72.2–82.7°) in mandibular molars. After confirming that the molars were in good alignment in the CBCT images used in the measurement of root proximity, we selected two coronal plane images in which the buccolingual cusp and root of the first molar could be identified (Fig. 3A) and one frontal image of the long axis of the miniscrew (Fig. 3B). We then measured the line perpendicular to the line connecting the two buccal and lingual cusps, and the miniscrew insertion angle was defined as the mean angle between the long axis of the teeth and the miniscrew.

For measurements of bone contact length and bone density, the CBCT data were converted into a DICOM file and analysed using the OnDemand3D software (version 1.0; CyberMed, Seoul, Korea). CBCT images that could not be converted to DICOM files and images with artifacts were excluded from the bone contact length analysis (122 files from the maxilla and 52 from the mandible). Bone contact length was measured at two points (the upper and lower points) on the sagittal and coronal planes of the three-dimensional images, which ran parallel to the long axis of the miniscrew (Fig. 4).

Prior to the measurement of bone density, we calibrated the X-ray attenuation coefficients. We excluded images with significant artifacts or teeth that had been treated with metal crowns or in which root canal treatment had been performed on the neighboring molar root. Hounsfield units (HU) were the units of the X-ray attenuation

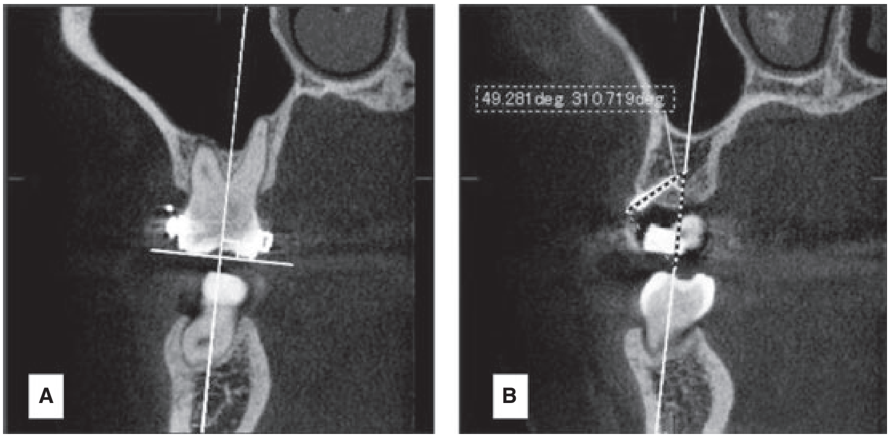


*Fig. 3.* Measurement of the miniscrew insertion angle. The long axis of the teeth (A), and the angle between the long axis of the teeth and the miniscrew was measured (B).

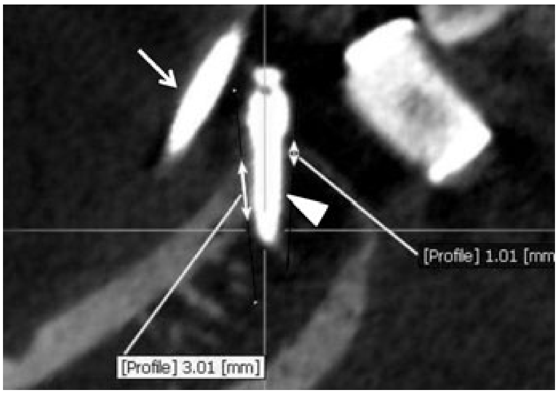


*Fig. 4.* Measurement of the bone contact length. The thickness of the bone contact zone was measured at two points (double-headed arrow) along the miniscrew (arrowhead). The gutta-percha point is indicated by an arrow.

coefficients in OnDemand 3D. The X-ray attenuation coefficients of air, gutta-percha point, and dentin were used as calibration indices. The DICOM files of the CBCT data from 10 patients were randomly selected and loaded in OnDemand3D. The calibrated value of dentin was presented as a percentage when air was taken as 0, and gutta-percha point was set at 100. We calculated the correlation between the HU value and the calibrated X-ray attenuation coefficient of dentin at both the pre- and post-implantation stages in the same patient at the same location.

The X-ray attenuation coefficient (bone density) was obtained by measuring the angle and location of the implanted miniscrew (Fig. 5A) and was projected onto the pre-implantation MPR image (Fig. 5B). Measurements were taken by reconstructing the horizontal plane perpendicular to the long axis of the miniscrew in the center of the cortical bone (Fig. 5C). We also used the implant simulation function for these measurements. Using the post-implantation MPR images, the sagittal (Fig. 6A), coronal (Fig. 6B) and horizontal (Fig. 6C) planes were determined at the apex of the miniscrew. On the sagittal and horizontal views, the angle between the line perpendicular to the miniscrew and the dental arch (the line

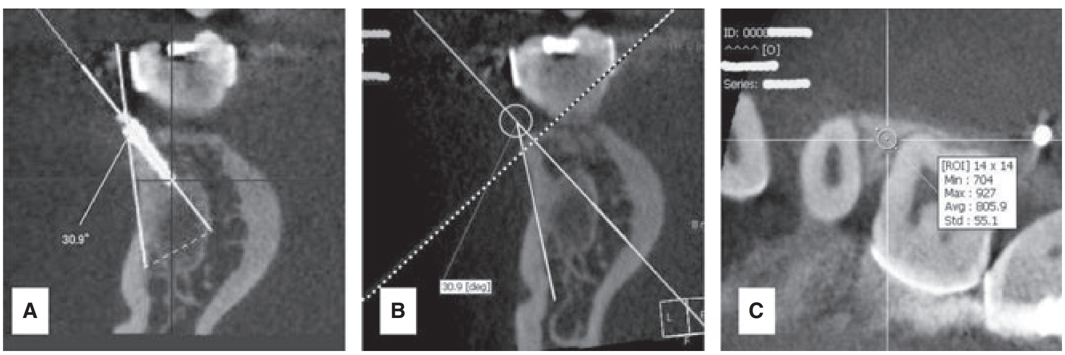


*Fig. 5.* Measurement of bone density on post-implantation images. Location of the implanted miniscrew on post-implantation images was measured from the pre-implantation image (A). The exact location of the miniscrew was projected onto the pre-implantation image (B). Bone density was measured in a cross-sectional plane (B; dot-line) on the line perpendicular to the long axis of the miniscrew (C).

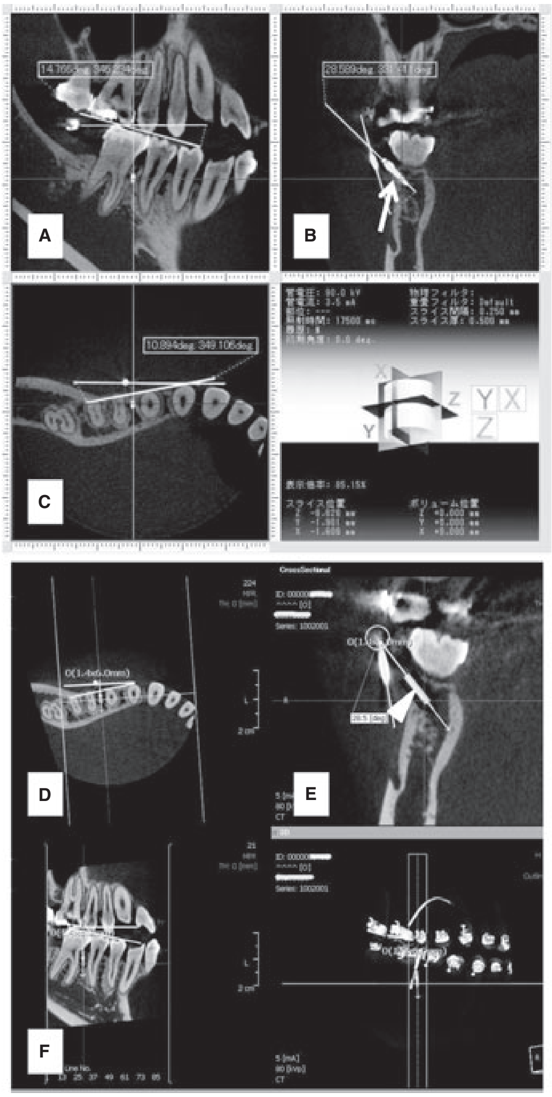


*Fig. 6.* Bone density measurement using the implant simulation function. Using the post-implantation MPR images, the apex of the miniscrew (arrow) was determined on the sagittal (A), coronal (B), and horizontal (C) planes. The location of the miniscrew was estimated on the pre-implantation images onto the horizontal (D), coronal (E), and sagittal (F) views. The simulated miniscrew is indicated by an arrowhead.

passing the buccal cusp tips) was measured. From these post-implantation measurements, the location of the miniscrew was estimated on the pre-implantation image by projecting the corresponding image onto the horizontal (Fig. 6D), coronal (Fig. 6E), and sagittal (Fig. 6F) views. The X-ray attenuation coefficient was measured on the surface and in the inner region of the simulated miniscrew using OnDemand3D.

A total of 127 cases (93 maxilla, 34 mandibles) with available CBCT and periapical radiographs were used for comparison of the CBCT images and periapical radiographs. The periapical radiographs were classified from A to D according to the proximity of the miniscrew and the root (Fig. 7). The CBCT images were classified into four types according to the proximity of the three points (apex, middle, and neck at alveolar bone level) to the root (A: all three points $>0.7$ mm from the root surface; B: only the apex point $\leq 0.7$ mm from the root surface; C: only the middle point $\leq 0.7$ mm from the root surface; D: two points $\leq 0.7$ mm from the root surface). It was difficult to differentiate the root surface from the miniscrew when the distance was $<0.7$ mm (Fig. 8).

#### Statistical analysis

For statistical analysis, the Mann–Whitney *U*-test was carried out to examine the differences between root proximity, screw insertion angle, bone contact length, and bone density, as well as for comparisons of CBCT images and periapical radiographs. Fisher's exact test was used to examine the statistical significance of differences between factors such as gender, age, location, malocclusion type, mandibular plane angle, skeletal type, and the timing of loading. Bone density calibration was assessed with Pearson's product-moment correlation coefficient. *p*-values $<0.05$ were considered significant. These analyses were carried out using the statistical analysis software Statview (SPSS, Chicago, IL, USA).

## Results

#### Factors associated with miniscrew failure

The total success rate of the miniscrews inserted between the second pre-molar and first molar was increased by approximately 15% by performing a CBCT evaluation before miniscrew placement. Table 1 contains comparisons of miniscrew success rate and possible failure factors. There were no significant differences according to age, gender, mandibular plane angle classification, or loading pattern. There were also no significant differences between the right and left side in the

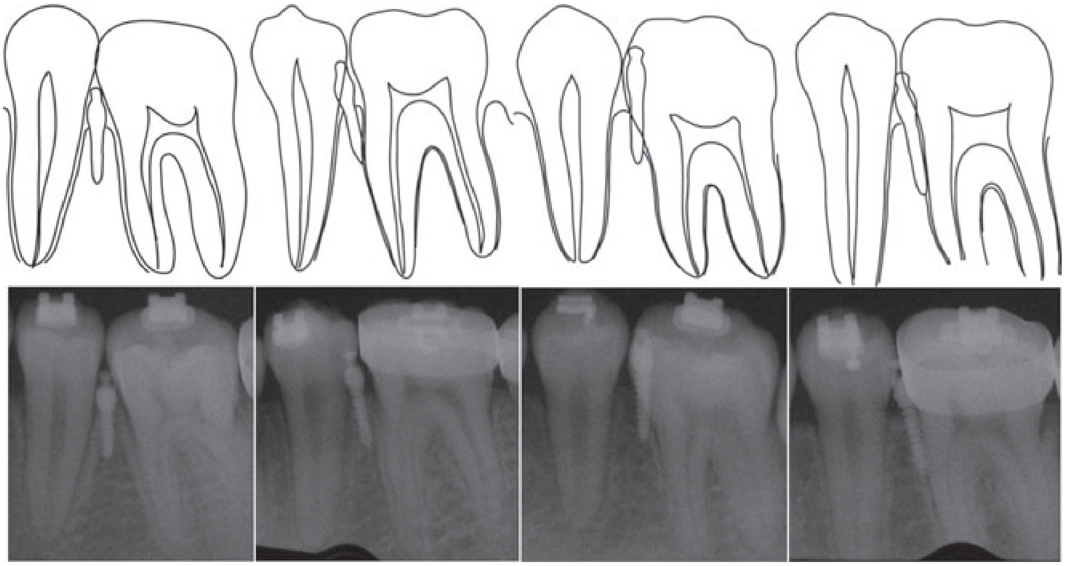


*Fig. 7.* Classification of the periapical radiographs from A to D according to the proximity of the miniscrew and the root. (A) The miniscrew was completely separated from the root surface. (B) Only apex of the miniscrew was in contact with the root surface. (C) The neck at alveolar bone level or middle part of the miniscrew was in contact, and the apex was separated from the root surface. (D) The entire body of the miniscrew was in contact with the root surface.

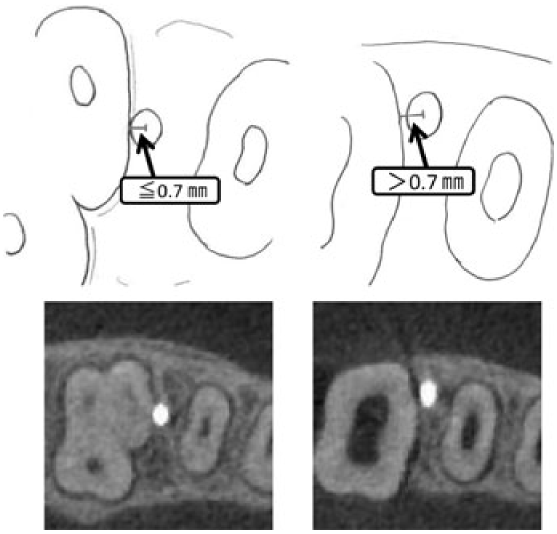


*Fig. 8.* Scheme and cone beam computed tomography scans image of the line between the root surface and the miniscrew.

maxilla or mandible. A significantly higher success rate was observed in the maxilla than in the mandible. In addition, the mandibular protrusion cases were associated with a lower success rate than the maxillary protrusion cases.

#### Root proximity, insertion angle, and bone contact length

The distance between the miniscrew and the surface of the root was significantly shorter in the failure group than in the success group at all three points in both the maxilla and mandible (Table 2). The angle between the miniscrew and the tooth axis was approximately 42–43° in the maxilla and 45–47° in the mandible. There was no significant difference in the insertion angle between the success group and the failure group in either jawbone (Table 3). The bone contact length surrounding the miniscrew was approximately 1.5–1.6 mm in the maxilla and 2.2–2.3 mm at the mandible, with no significant difference between the success and failure groups (Table 4).

#### Bone density

The regression line of the corrected HU value changed from $y = 0.6729x + 355.6$ to $y = 0.8864x + 6.1$, making it significantly closer line to the $y = x$ line (Fig. 9). The correlation coefficient also increased after correction, from 0.565 ($p < 0.01$) to 0.801 ($p < 0.001$). Table 5 contains a comparison of the corrected bone density values in the failure and success groups; there was no between-group significant difference in the CBCT HU value in the estimated region of miniscrew placement (Table 5).

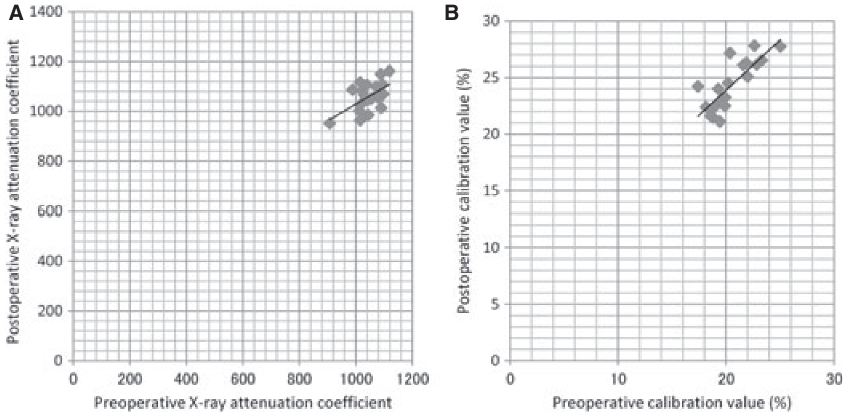


*Fig. 9.* Comparison of X-ray attenuation coefficient values before (A) and after (B) calibration.

#### Comparison with periapical radiographs

The success rates for the CBCT images and periapical dental images in each classification are shown in Table 6. The percentages of the class A, B, C, and D CBCT images (Fig. 7) were 86.6, 6.3, 1.6, and 5.5%, respectively. These percentages were 40.2, 9.4, 28.3, and 22.1%, respectively, for the periapical dental images. In the maxilla, almost all miniscrews that were classified (CBCT) as A, B, or C belonged to the success group, and the miniscrews classified as D had a low success rate. In the mandible, miniscrews classified as A were associated with a high success rate, but miniscrews classified from B to D had significantly low success rates. In contrast, miniscrews classified as A in the periapical dental radiograph classification displayed 100% success, and those classified from B to D also were associated with a high success rate. In the mandible, a high success rate occurred for the class A miniscrews, and those classified as B or D had a low success rate. Furthermore, all of the miniscrews classified as A or C on the periapical dental radiographs were classified as A in the CBCT classification in both jaws (Table 7). The concordance rate between the periapical dental radiographs and CBCT images was 46.5%.

## Discussion

Our results indicate that maxillary miniscrews are significantly more stable than mandibular miniscrews, a conclusion consistent with most previous studies (5, 6). The thicker and harder cortical bone in the mandible may underlie the higher failure rate, as overheating during drilling results in miniscrew failure (5). Moreover, we suggest that the high failure rate may be due to surgical difficulties caused by the anatomical structure of the posterior mandible, because it has a more loosely attached gingiva and a narrow oral vestibule.

In the past few years, several studies have analysed HU values from multi-slice computed tomography (MSCT) relative to orthodontic miniscrews (14, 15). There is a correlation between the HU values of MSCT and CBCT (16), but HU values from CBCT are known to have low repeatability and lower reliability for bone density measurement than values from MSCT (17, 18). In this study, we corrected the X-ray attenuation coefficient prior to measuring bone density. As a result, a significantly higher correlation ($r$ = 0.801) was calculated after the correction, implying that more reliable measurements of bone density were possible in this study. We suggest that correction of the X-ray attenuation coefficient is necessary when measuring bone density using CBCT. When we used the corrected X-ray attenuation coefficients, there were no significant differences in bone density between the failure and success groups, indicating that bone density may not be a major factor affecting miniscrew failure.

There was an approximately 10% increase in the success rate after the introduction of CBCT at our clinic. One of the reasons for this improvement is that we obtained more precise data about the

***Table 1.* Comparison between the miniscrew success rate and various suggested failure factors**

| | Success rate | n |
|---|---|---|
| Gender | | |
| Male | 80.77% | 52 |
| Female | 86.96% | 138 |
| Age | | |
| <20 | 84.07% | 113 |
| ≥20∼<30 | 86.67% | 60 |
| ≥30 | 88.24% | 17 |
| Jaw | | |
| Maxilla | 90.67% * | 132 |
| Mandible | 70.69% | 58 |
| Malocclusion type | | |
| Crowding | 84.21% | 38 |
| Maxillary protrusion | 91.55% * | 71 |
| Mandiblar protrusion | 72.97% | 37 |
| Bimaxillaryprotrusion | 92.31% | 13 |
| Open bite | 83.88% | 31 |
| Mp.angle | | |
| Low | 82.05% | 39 |
| Average | 84.89% | 79 |
| High | 81.58% | 72 |
| Skeletal pattern | | |
| I | 83.63% | 55 |
| II | 90.72% * | 97 |
| III | 73.68% | 38 |
| Immediate loading | | |
| Yes | 84.76% | 105 |
| No | 85.88% | 80 |

*$p < 0.05$.

distance between the roots and about the anatomical structure of the implantation site by performing a three-dimensional quantitative evaluation before miniscrew placement. Moreover, we used a stent of simple paraffin wax and gutta-percha point that was attached not only on the buccal side between the two teeth but also on the lingual side, producing a guideline for easier miniscrew placement. Producing this stent does not require complex or time-consuming laboratory work; it can be easily made at chair side. Using the stent as a guide in combination with CBCT was very useful for determining the location and angle of the miniscrew during its placement. Although stents have previously been used in combination with panoramic or periapical radiographs (19, 20), two-dimensional evaluation with these radiographic techniques prevented determination of the insertion angle of the miniscrew in the mesial-distal and labial-lingual directions. Another investigation reported the use of a stent in combination with CBCT imaging, but only a single case was involved and a replica of the patient's mouth and complex laboratory work were required (21). Therefore, we conclude that our use of a simple stent and CBCT improved the miniscrew success rate.

The distance between the miniscrew and the root was most significantly correlated with miniscrew failure in this study. When we previously classified root proximity into three groups by periapical dental X-rays, we found that the closer the miniscrew was to the root, the higher the failure rate (7); however, no quantitative analysis was performed. In this study, we detected a significant correlation between root proximity and the mandibular failure rate, which was consistent with our previous investigation. In the present study, our cases were further classified into four types according to the distance between the miniscrew and the root. Category B was defined as the situation in which the apex was in contact with the root, and category C consisted of samples in which the neck part of the miniscrew overlaid the lamina dura. On periapical dental X-ray, these type C miniscrews tended to be more stable than the type B miniscrews. When the teeth are retracted during treatment, the root moves toward the miniscrew, resulting in increased mechanical stress where the miniscrew touches the root. Moreover, when the miniscrew contacts the root, occlusal force may be transmitted through the teeth to the miniscrew, causing its mobilization.

We detected no significant correlation between root proximity and miniscrew failure in the maxilla, possibly because only a small number of subjects suffered maxillary miniscrew failure. A recent study that used CBCT to evaluate the relationship between root proximity and miniscrew failure concluded that root proximity did not have a major influence on miniscrew failure (13). However, as only two failed miniscrews were

***Table 2.*** **The measurement of the distance between the miniscrew and the surface of the root**

| | n | Apex (mm) | SD | Middle (mm) | SD | Neck (mm)† | SD | Mean (mm) | SD |
|---|---|---|---|---|---|---|---|---|---|
| Maxilla | | | | | | | | | |
| Success | 121 | 1.37 | 0.51 | 1.64 | 0.48 | 2.22 | 0.57 | 1.74 | 0.45 |
| Failure | 11 | 0.95* | 0.54 | 1.18* | 0.46 | 1.66* | 0.34 | 1.27* | 0.38 |
| Mandible | | | | | | | | | |
| Success | 41 | 1.45 | 0.41 | 1.47 | 0.31 | 1.82 | 0.32 | 1.58 | 0.29 |
| Failure | 17 | 0.81* | 0.44 | 0.90* | 0.37 | 1.27* | 0.39 | 0.99* | 0.34 |

*$p < 0.05$ vs. success.
†Neck at a alveolar bone level.

***Table 3.*** **The angle between the miniscrew and the tooth axis**

| | n | Mean (degree) | SD |
|---|---|---|---|
| Maxilla | | | |
| Success | 121 | 43.44 | 9.97 |
| Failure | 11 | 42.27 | 9.47 |
| Mandible | | | |
| Success | 41 | 47.64 | 12.45 |
| Failure | 17 | 45.16 | 9.88 |

***Table 4.*** **The thickness of the cortical bone surrounding the miniscrew**

| | n | Mean (mm) | SD |
|---|---|---|---|
| Maxilla | | | |
| Success | 112 | 1.63 | 0.26 |
| Failure | 10 | 1.53 | 0.2 |
| Mandible | | | |
| Success | 38 | 2.34 | 0.57 |
| Failure | 14 | 2.19 | 0.47 |

included in that study, it may be difficult to draw a reliable conclusion with regard to the relationship between root proximity and miniscrew failure. In addition, our study substantially differed from this previous one in terms of the size of the miniscrews (diameter, 1.8 mm; length, 8.5 mm), the implantation angle (perpendicular in their study), the location analysed (only the maxilla), and the treatment method (they did not place any brackets on the posterior teeth). Kim et al. also reported that the miniscrews in contact with both the second pre-molar and first molar had failed. Our animal study revealed that 5.2% of the 96 miniscrews placed in dogs were in contact with or had damaged the root and that the bone volume surrounding the miniscrew may be reduced (data not shown). From these findings, we suggest that the normal process of bone remodeling is inhibited when the miniscrew is contact with the adjacent tooth, resulting in less bone mass than when the miniscrew is placed in an adequate alveolar area. We conclude that root proximity is the major factor affecting miniscrew failure, especially for miniscrews placed in the mandible.

As CBCT is not commonly used as a diagnostic tool in private practice, it is extremely important to know the limitations of periapical dental X-rays, motivating our comparison of identical areas using periapical dental X-rays and CBCT. In the CBCT evaluation, 86.6% of the samples were classified as group A (no contact with the root), while only 40.2% of the same samples were classified as group A in the apical dental evaluation, possibly because eccentric projection during the periapical dental x-ray resulted in overlapping images of the miniscrew and root. Overlapping images on periapical dental x-rays were often observed for the maxillary miniscrews. As the concordance rate between CBCT and periapical dental images was 46.5%, the utility of periapical dental x-rays is limited, and CBCT is recommended for evaluating the proximity of the root to the miniscrews.

The insertion angle is known to have a significant effect on the stress distribution produced by mechanical stress (22), and it may significantly affect failure rate. Furthermore, by placing the

*Table 5.* **Comparison of the corrected bone density values of the failure group and the success group**

| | n | Bone surface (%) | SD | Outside (%) | SD | Inside (%) | SD |
|---|---|---|---|---|---|---|---|
| Maxilla | | | | | | | |
| Success | 24 | 15.51 | 1.32 | 12.39 | 1.42 | 10.86 | 1.5 |
| Failure | 5 | 14.43 | 3.04 | 13.39 | 1.25 | 11.36 | 1.23 |
| Mandible | | | | | | | |
| Success | 21 | 14.68 | 1.65 | 12.22 | 1.36 | 10.13 | 1.32 |
| Failure | 13 | 14.92 | 1.43 | 12.08 | 1.4 | 10.29 | 1.78 |

*Table 6.* **The success rates of cone beam computed tomography scans images and periapical dental images in each classification**

| | A | | B | | C | | D | |
|---|---|---|---|---|---|---|---|---|
| | Success rate (%) | n | Success rate (%) | n | Success rate (%) | n | Success rate (%) | n |
| CT | | | | | | | | |
| Maxilla | 95.00 | 85 | 80.00 | 5 | 100.00 | 1 | 50.00* | 2 |
| Mandible | 92.00 | 25 | 33.33* | 3 | 0* | 1 | 0* | 5 |
| Total | 94.50 | 111 | 62.50* | 8 | 50.00* | 2 | 14.29* | 7 |
| Dental | | | | | | | | |
| Maxilla | 100.00 | 37 | 85.71* | 7 | 88.89* | 27 | 90.91 | 22 |
| Mandible | 85.71 | 14 | 40.00 | 5 | 88.89 | 9 | 33.33*,† | 6 |
| Total | 96.08 | 51 | 66.67* | 12 | 88.89 | 36 | 78.57* | 28 |

*$p < 0.05$ vs. A.
†$p < 0.05$ vs. C.

*Table 7.* **Correspondence table of classification at 'cone beam computed tomography scans image' and 'periapical dental image'**

| Dental\CT | A | B | C | D |
|---|---|---|---|---|
| Maxilla | | | | |
| A | 37 | | | |
| B | 3 | 2 | | 2 |
| C | 27 | | | |
| D | 18 | 3 | 1 | |
| Mandible | | | | |
| A | 13 | | 1 | |
| B | 1 | 3 | | 1 |
| C | 9 | | | |
| D | 2 | | | 4 |

miniscrew at a different angulation, the change in the amount of bone contact length may affect the failure rate (23). In this study, there was no significant difference in miniscrew angle between the success and failure groups. The angle of the miniscrew to the long axis of the teeth was generally 43–47°, which resulted in the miniscrew being relatively far from the neighboring roots; this angle range was considered to be ideal in previous studies (9, 23). Nor did we detect a significant difference in bone contact length between the success and failure groups, although it has been suggested that the miniscrew failure rate increases if the cortical bone thickness is <1.0 mm (11). Here, the mean bone contact length was 1.6 mm in the maxilla and 2.2 mm in the mandible and was not a major factor affecting miniscrew failure.

## Conclusion

This investigation has revealed that combining a simple stent with CBCT is useful for determining the location and angle of miniscrews during their placement. A higher failure rate occurred for the miniscrews placed in the mandible than for those placed in the maxilla. Our major finding was that root proximity is the factor that most affected miniscrew failure, especially for miniscrews placed in the mandible. Bone density was not a major determinant of miniscrew failure, and neither bone contact length nor miniscrew angle had a major effect on miniscrew failure. In addition, correction of the X-ray attenuation coefficient is necessary for measuring bone density using CBCT. We suggest that there are limitations on the use of periapical dental x-rays, and we recommend CBCT for evaluating the root proximity of miniscrews.

## Clinical Relevance

In recent years, miniscrews have become a much-used device for orthodontic anchorage. However, the use of miniscrews is known to have a high failure rate, motivating us to use CBCT to analyse various factors that may have a major effect on miniscrew failure. We discovered that root proximity is the major factor for miniscrew failure, and we recommend the use of CBCT over conventional periapical dental radiographs for diagnosis and evaluation of miniscrew placement.

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