

Evaluation of primary stability of inclined orthodontic mini-implants

Mizuki Inaba

Division of Applied Oral Sciences, Nihon University Graduate School of Dentistry, Tokyo, Japan

(Received 10 January and accepted 30 March 2009)

Abstract: The aim of this study was to investigate the initial stability of mini-implants when placed slanting or perpendicular to the bone surface, and to examine the effects of differences in tractional direction. Titanium mini-implants were inserted into rabbit nasal bones, slanting (60°, 120°) or perpendicular (90°) to the bone surface. These implants were then loaded with a force of approximately 2 N, using a NiTi coil spring. The mobilities on the traction and non-traction sides were assessed using the Periotest device immediately after placement and after traction for two weeks. Then, the tissues with the mini-implants were resected, and the contact between the bone and the implant was examined by electron microscopy. There was a tendency for the mobilities of the mini-implants at 60° and 120° to be smaller than those at 90° when measured before and after traction. The bone-implant contact lengths at 60° were significantly longer than those at 90°. There was no significant difference in the bone-implant contact ratio among the different angles. Correlations were evident between implant mobility and contact length or contact ratio. It is concluded that in clinical practice, implants inclined to the bone surface tend to have better primary stability. (*J Oral Sci* 51, 347-353, 2009)

Keywords: orthodontics; mini-implant; screw; primary stability; Periotest; bone-implant contact.

Correspondence to Dr. Mizuki Inaba, Department of Orthodontics, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan
Tel: +81-3-3219-8105
Fax: +81-3-3219-8312
E-mail: tsukada@dent.nihon-u.ac.jp

Introduction

In recent years, mini-implants have been used as stable orthodontic anchorages, allowing predictable tooth movement to be achieved successfully without patient cooperation (1-4). However, several researchers have reported loosening of mini-implants during orthodontic treatment (5,6). Therefore, a lot of research has been conducted on the success rate and loosening of mini-implants.

The stability of mini-implants is an important factor for improving the success rate of orthodontic treatment. Huja et al. (7) and Wilmes et al. (8) reported that cortical bone thickness was related to the stability of mini-implants. Motoyoshi et al. (9) investigated the relationship between cortical bone thickness and success rate, and concluded that the prepared site should be in an area with a cortical bone thickness of 1.0 mm or more to improve the success rate. Additionally, Miyawaki et al. (10) suggested that thin cortical bone was associated with greater mobility and failure of titanium screws. Cortical bone thickness may influence the primary stability of mini-implants. Moreover, Deguchi et al. (11) quantitatively analyzed the difference in cortical bone thickness in the maxilla and mandible using three-dimensional computed tomography (CT), and reported that the best available location for a miniscrew was mesial or distal to the first molar, and that the implantation should be slanting to the bone surface to minimize the chance of touching the adjacent root. Additionally, they stated that inclined miniscrews increased cortical bone contact. However, their study involved morphometric measurements using CT images, and did not investigate whether inclining the miniscrews actually increased their stability.

On the other hand, the Tweed-Merrifield technique has enhanced distal tipping of mandibular molars for

strengthening anchorage against Class II elastics (12). It was suggested that inclining in the direction opposite to the tractional force would provide a stronger anchorage.

In this study, we investigated the initial stability of mini-implants when placed slanting or perpendicular to the bone surface, and examined the difference in the stability of mini-implants according to differences in tractional direction, using Periotest and morphometric analysis.

Materials and Methods

Animals

Fifteen adult male Japanese white rabbits (12 weeks old, weighing 2.0-2.5 kg) were used in this study. Before the experiment, the health of the rabbits was monitored for two weeks. The rabbits were kept in a standard cage in an

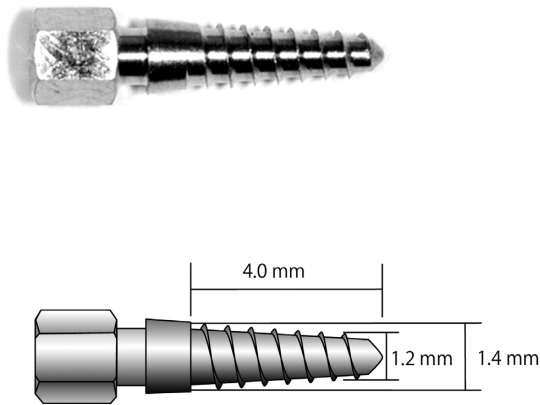


Fig. 1 Mini-implants used in this study.

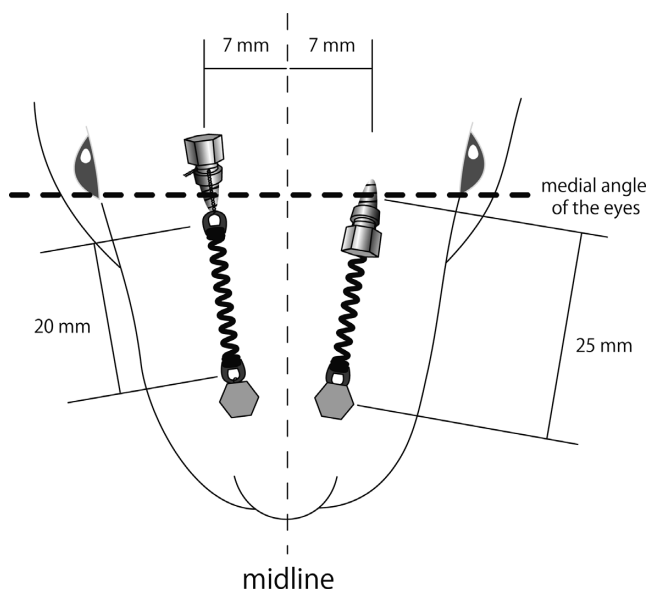


Fig. 2 Inserted position of mini-implants and methods of loading.

experimental animal room at 24°C, 55% humidity, 1 atm, 12/12 hour light/dark cycle and were fed a standard laboratory diet and water. This study plan was approved by the Animal Experimentation Committee of Nihon University School of Dentistry.

Titanium mini-implants

The experimental device was a custom-made titanium mini-implant. Each titanium mini-implant had a diameter of 1.4 mm (spearhead = 1.2 mm) and a length of 4.0 mm (Fig. 1). The implants were placed into rabbit nasal bones.

Surgical procedure

All operations were conducted under sterile conditions. General anesthesia was induced by injection of pentobarbital sodium via an ear vein, and was maintained by inhalation of halothane (1.5-2.0 vol%). The root of the nose of each rabbit was shaved and disinfected with 70% ethanol. Under local anesthesia with lidocaine HCl containing epinephrine (1:80,000, Xylocaine, Dentsply-Sankin, Tokyo, Japan), a cutaneous flap was created by making a linear minimum incision to expose laterally the bone surface. Pilot holes were then created at a position of the medial angle of the eyes and 7 mm lateral from the midline (Fig. 2), where there was a flat bone area and 1/4 inside the eye width, using a bone drill, with a diameter of 1.0 mm and length of 4.0 mm (Dentsply-Sankin), with varying angles to the bone surface under sterile saline flow (Fig. 2). The angles were arbitrarily fixed using an angled board: mini-implants were oriented at an angle of 60° to the bone surface, directed anteriorly (Fig. 3, 60°) or posteriorly (Fig. 3, 120°), and the other mini-implants were placed perpendicular to the bone surface (Fig. 3, 90°). A titanium mini-implant was then inserted into the hole using a hand driver, and the mobility of the implants was then measured. Another mini-implant was inserted perpendicularly, and placed at a distance of 25 mm anterior to the test implant. To prevent infection after surgery, tetracycline CMC paste (tetracycline hydrochloride paste; Showa Yakuhin Kako Co., Ltd., Tokyo, Japan) was applied to the surgical site.

Force application

A NiTi closed coil spring (Tomy International Co. Ltd., Tokyo, Japan), 20 mm in length when open, was attached to the implant inserted at designated angles and to the anterior implant (Fig. 2). A traction force of approximately 2 N was then imposed for two weeks immediately after placement, using the NiTi coil spring.

Assessment of implant stability using a Periotest device

Immediately after placement, and after traction for two weeks, the mobility of all mini-implants was measured using a Periotest device (Siemens AG, Bensheim, Germany). Measurements for each implant were performed by holding the tip of the instrument's handpiece as horizontal as possible to the bone surface. The rabbit's head was fixed, and the mobility of the mini-implants was measured from the traction side and the non-traction side (Fig. 4).

Morphometry

After experimental traction for two weeks and Periotest measurements, the animals were euthanatized with an overdose of pentobarbital. Tissues with the mini-implants were excised and fixed with 10% formalin for 48 h. Following dehydration and delipidation in a graded ethanol series and acetone, the tissues were embedded in Rigolac 2004 (Showa Highpolymer Co. Ltd., Tokyo, Japan) and polymerized at 60°C for 8 h. Resin blocks (10 × 10 × 6 mm) were cut with a crystal cutter (Maruto Instrument Co. Ltd., Tokyo, Japan) and the surface was polished by grinding successively with waterproof grinding paper (#800, #1200 and #2000) and a hard grinding cloth with the aid of a liquid paste containing diamond particles. The polished surface coated with osmium (HPC-1S type osmium coater; Shinku Device Co. Ltd., Ibaraki, Japan)

was examined closely with a field-emission scanning electron microscope (FE-SEM; S-4300, Hitachi Science Systems Ltd., Ibaraki, Japan), and its backscattered electron (BSE) images were recorded digitally at ×35 magnification.

The bone-implant contact was evaluated in BSE images. After tracing the images, the actual bone-implant contact length (BIL; gray line in Fig. 5) was measured, and the

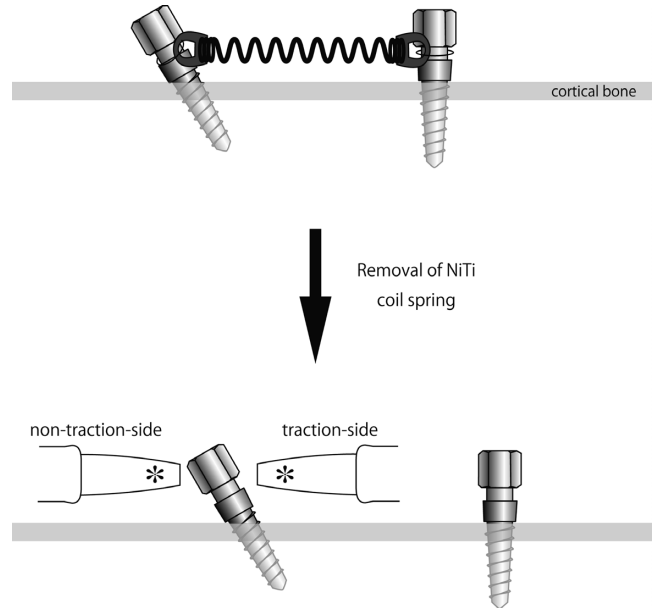


Fig. 4 Method of mobility measurement using Periotest. * The tip of the Periotest handpiece.

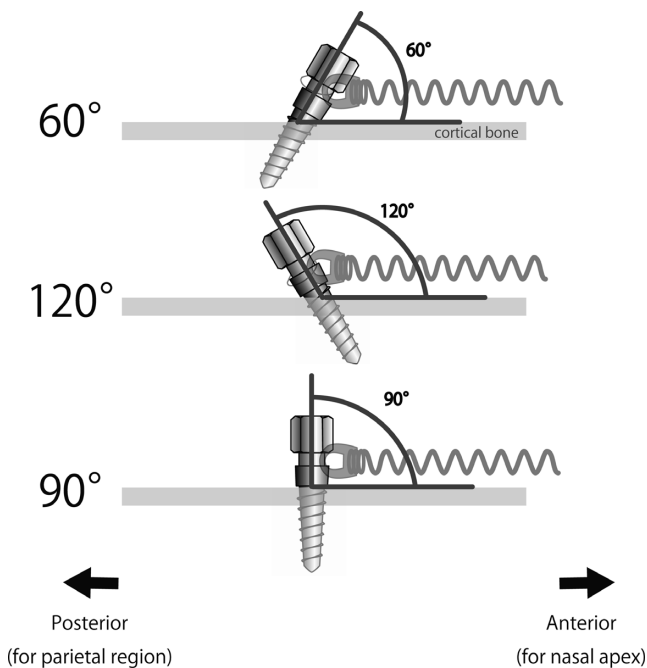


Fig. 3 Insertion angle of mini-implants.

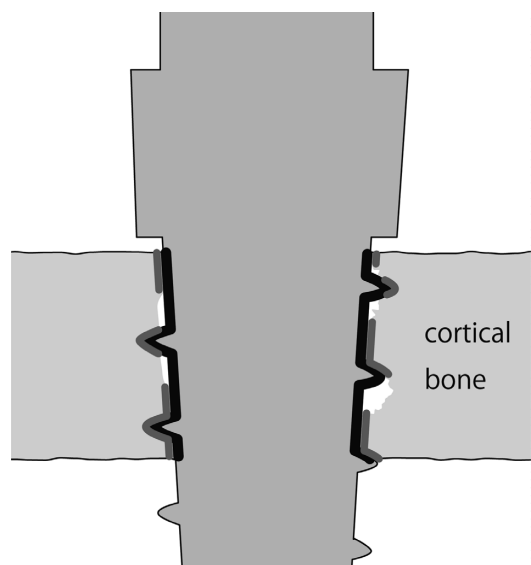


Fig. 5 Bone-implant contact. The length of the implant surface on the cortical bone is shown in black, and BIL in gray.

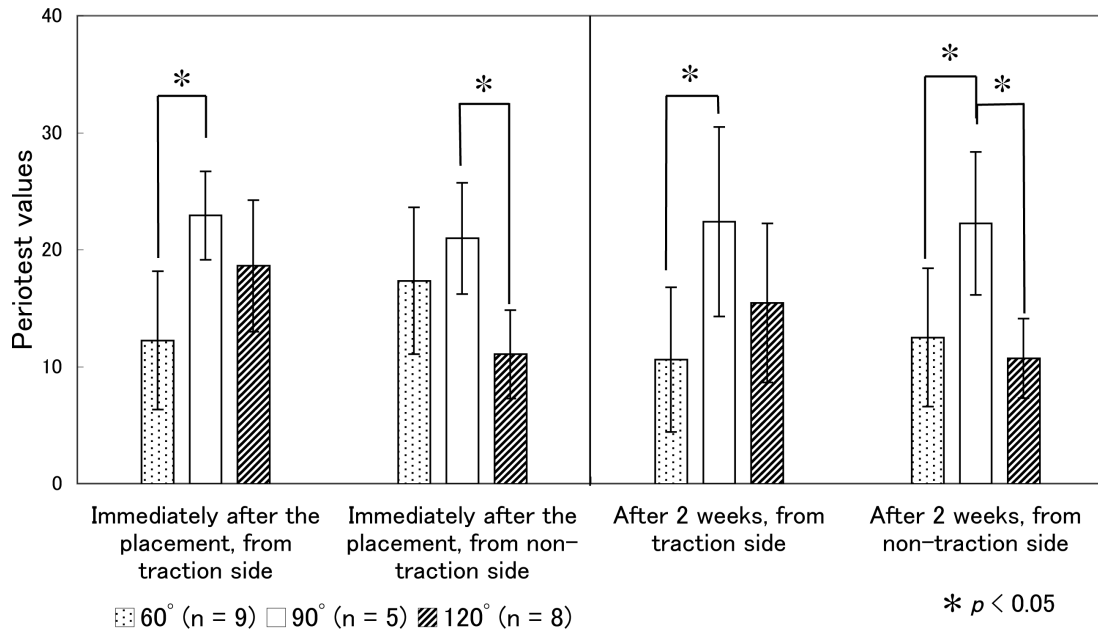
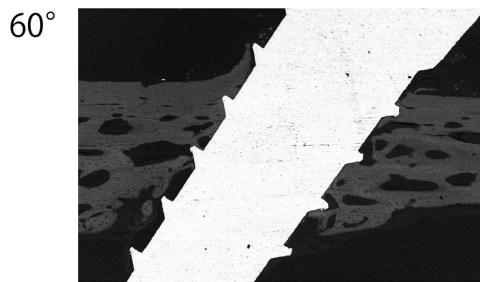


Fig. 6 Mobility of implants at each insertion angle.



Posterior Anterior

Fig. 7 Backscattered electron images of mini-implants at each insertion angle.

bone-implant contact ratio (BIR) was calculated, using the following equation (13):

$$BIR = (BIL / \text{length of implant surface in cortical bone}) \times 100$$

Statistical analysis

One examiner measured the mobility of the mini-implant and traced all photographs to eliminate inter-examiner error. Each mobility measurement was repeated five times, and the average was taken. Again, the same examiner carried out all measurements of BIL and BIR. All tracings and measurements were performed at least twice to reduce intra-examiner error, and the mean values were used. When there was a difference of more than 5% between the BIL values of a trace, they were remeasured, and the mean value of the three measurements was used. Scheffe's test was used to compare the mobility of the implant with BIL or BIR in each group, using the SPSS software package (Version 8.0 for Windows, SPSS Inc., Chicago, Illinois, USA).

Results

Mini-implant mobility

No loosening of any implants was observed, but 8 implants out of the total of 30 were found to be in contact with intranasal bone when segments around the mini-implants were resected. As this study was intended to evaluate the effects of monocortical anchorage, the 8 implants that had bicortical anchorages were excluded. The

Table 1 Bone-implant contact length at each angle

Inserted angle	Contact length (mm)
60°	3.58 ± 0.91
120°	2.76 ± 0.51
90°	2.27 ± 0.42

* $P < 0.05$

Table 2 Bone-implant contact ratio at each angle

Inserted angle	Contact ratio (%)
60°	64.23 ± 11.93
120°	56.30 ± 9.81
90°	54.48 ± 11.74

* $P < 0.05$

Periotest values for each implant inserted at different angles are shown in Fig. 6. In the measurements immediately after placement, the Periotest value for 90° implants was significantly higher than that for 60° implants measured from the traction side and that of 120° implants from the non-traction side ($P < 0.05$). In the measurements after two weeks of traction, the Periotest value for 60° implants was significantly lower than that for 90° implants measured from the traction side, and the values for both 60° and 120° implants were significantly lower than that for 90° from the non-traction side ($P < 0.05$).

Bone-implant contact

Figure 7 shows representative BSE images for the implant inserted into bone at an angle. Six cases were excluded from measurement because of considerable damage during tissue preparation. Thus, the remaining 16 cases were measured. The angle between the 60° mini-implant and the bone surface was $56.8 \pm 2.69^\circ$ (mean \pm SD; $n = 6$), the angle for the 120° mini-implant was $127.0 \pm 5.44^\circ$ ($n = 5$), and the angle for the 90° mini-implant was

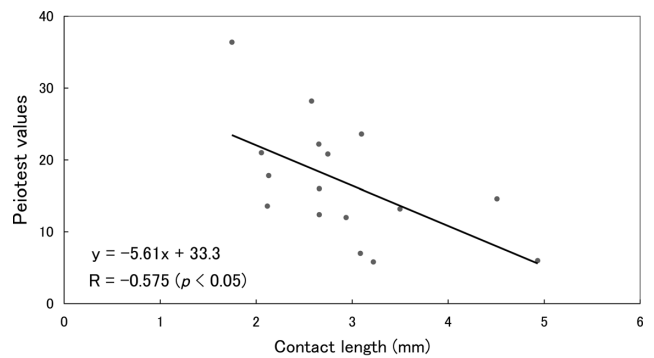


Fig. 8 Relationship between traction side mobility and BIL.

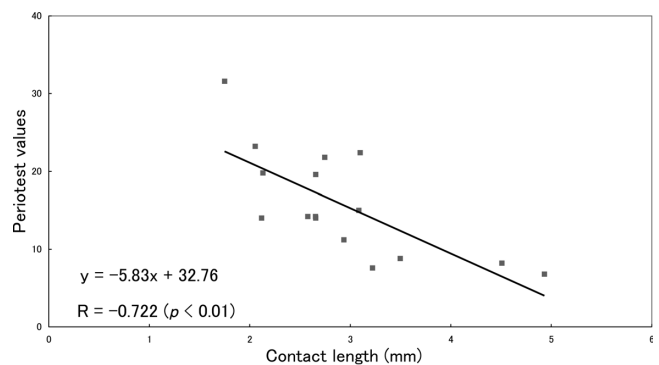


Fig. 9 Relationship between non-traction side mobility and BIL.

$88.7 \pm 2.77^\circ$ ($n = 5$).

There was no significant difference in cortical bone thickness among the 60°, 120° and 90° groups, and the average thickness was 1.00 ± 0.23 mm.

BIL of each angled implant is shown in Table 1. Those inclined at 60° showed significantly longer contact lengths than those inclined at 90°. BIR for each angle is shown in Table 2. There was no significant difference in the ratio according to the inserted angle. Figures 8 and 9 show the relationship of the mobility to BIL and BIR, respectively. The correlation coefficient was -0.575 between BIL and traction side mobility ($P < 0.05$, Fig. 8), -0.722 between BIL and non-traction side mobility ($P < 0.01$, Fig. 9), -0.590 between BIR and traction side mobility ($P < 0.05$, Fig. 10), and -0.550 between BIR and non-traction side mobility ($P < 0.05$, Fig. 11).

Discussion

The Periotest instrument was developed to measure the degree of periodontal integration of teeth and the stiffness of the bone/implant interface in oral implantology (14-16).

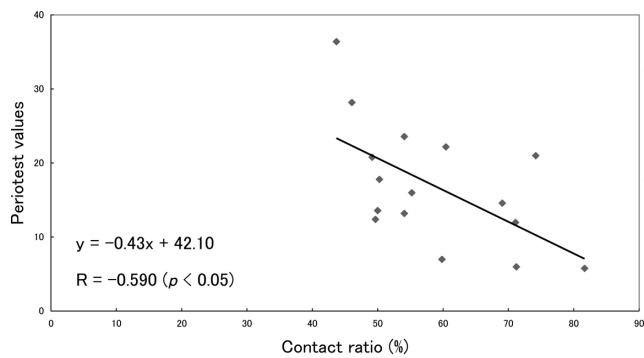


Fig. 10 Relationship between traction side mobility and BIR.

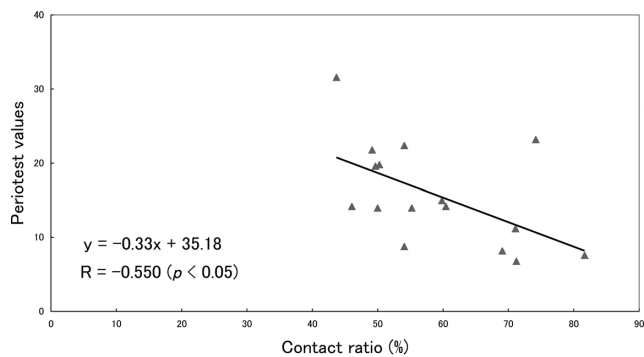


Fig. 11 Relationship between non-traction side mobility and BIR.

Some researchers have evaluated the reliability of the Periotest device for assessing implant stability, and reported that it can significantly evaluate variations in bone composition, differences in inter-implant stability of adjacent implants, and peri-implant bone reduction (17-19). Additionally, Lioubavina-Hack et al. (20) reported that bone-to-implant contact was not observed when initial stability could not be acquired. Thus, it is considered that as the implants were fixed rigidly to the bone, initial stability could be acquired. In the present study, the initial stability of mini-implants was investigated using the Periotest and morphometric analysis.

Olivé and Aparicio (21) reported that values above 10 Periotest units for dental implants in humans were associated with osseointegration failure. All measurements in this study showed larger values than this reported threshold (Fig. 6), perhaps due to differences in cortical bone thickness, implant size, and implant length.

Although inclination in the direction opposite to the tractional force was thought to facilitate anchorage, there was no significant difference between implants inclined

in the direction opposite the tractional force (120°) and implants inclined on the other side (60°). Thus, an inclined implant could be stable, regardless of the tractional direction. However, consistent with the statement by Deguchi et al. (11) that slanting a mini-implant increases the apparent cortical bone thickness, and might enhance stability, the data from this study showed that inclined mini-implants did have enhanced stability.

BIL at 60° was longer than implants inclined at 90° to the bone surface (Table 1). However, there was no significant difference between 120° and 90° , although this may have been due to the small number of samples. There was no significant difference in BIR between angles (Table 2). Since the bone remodeling response may differ among the groups, a longer-term experiment over several months might change BIR.

In the present study, the relationships between mobility, BIL and BIR were examined to evaluate the stability of the mini-implants. There were correlations between implant mobility and BIL or BIR. The larger BIL and BIR became, the lower the implant mobility (Figs. 8-11). This means that implant-bone cohesion is closely related to the stability of the mini-implant. Consequently, mobility measurements with the Periotest device can effectively assess the contact condition of a bone-implant interface.

In conclusion, the mobility of a mini-implant inclined to the bone surface was significantly less than that of a mini-implant inserted perpendicularly. However, there was no significant difference in mobility between implants inclined and oppositely inclined to the direction of tractional force. Thus, in clinical practice, implants that are inclined to the bone surface would have increased primary stability, providing better anchorage for orthodontic treatment.

Acknowledgments

I wish to thank Hideo Nagai (Department of Anatomy, Nihon University School of Dentistry, Tokyo, Japan) for technical assistance with electron microscopy. This study was supported by grants from the Promotion and Mutual Aid Corporation for Private Schools in Japan for 2008.

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