Effect of Cortical Bone Thickness and Implant Placement Torque on Stability of Orthodontic Mini-implants

Mitsuru Motoyoshi, DDS, PhD[1]/Tohru Yoshida, DDS, PhD[2]/Akiko Ono, DDS[3]/Noriyoshi Shimizu, DDS, PhD[4]

Purpose: *To examine the relationship between cortical bone thickness, inter-root distance (horizontal space), distance from alveolar crest to the bottom of maxillary sinus (vertical space) at the prepared site, and implant placement torque and the success rate of mini-implants placed for orthodontic anchorage.* ***Materials and Methods:*** *After computerized tomography examination, mini-implants 1.6 mm wide and 8 mm long were placed in the posterior alveolar bone. The mini-implant was judged a success when orthodontic force could be applied for at least 6 months without pain or clinically detectable mobility. The unpaired* t *test was performed to examine differences between the success and failure groups. The chi-square analysis or Fisher exact probability test was used to compare the implant success according to placement torque, location, and patient gender.* P *values less than .05 were considered significant.* ***Results:*** *The subjects included 4 males (11 implants) and 28 females (76 implants) who ranged in age from 14.6 to 42.8 years. The success rate of the 87 implants was 87.4%. Cortical bone thickness was significantly greater in the success group (1.42 ± 0.59 mm vs 0.97 ± 0.31 mm,* P *= .015). The success rate was significantly higher in the group with an implant placement torque of 8 to 10 Ncm (100%) as compared to implants with higher or lower placement torques. The odds ratio for failure of the mini-implant was 6.93 (*P *= .047) when the cortical bone thickness was less than 1.0 mm relative to 1.0 mm or more.* ***Conclusion:*** *A relationship between stability after implant placement and the width and height of the peri-implant bone was not demonstrated. The prepared site should have a cortical bone thickness of at least 1.0 mm, and the placement torque should be controlled up to 10 Ncm.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:779–784

Key words: *mini-implants, orthodontic, risk factor, survival, temporary anchorage devices*

Some clinicians use endosseous implants as immovable anchors for orthodontic tooth movement.[1–4] However, conventional dental implants can only be placed in limited areas, such as retromolar or edentulous areas.[5–7]

[1]Instructor and Lecturer, Department of Orthodontics, Nihon University School of Dentistry, Tokyo, Japan.
[2]Part-time Lecturer, Department of Orthodontics, Nihon University School of Dentistry, Tokyo, Japan.
[3]Researcher, Department of Orthodontics, Nihon University School of Dentistry, Tokyo, Japan.
[4]Professor and Chair, Department of Orthodontics, Nihon University School of Dentistry, Tokyo, Japan.

Correspondence to: Dr Mitsuru Motoyoshi, Department of Orthodontics, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan. E-mail: motoyoshi@dent.nihon-u.ac.jp

Recently, titanium mini-implants have been used as anchors during orthodontic treatment.[8–14] The screw-type mini-implants that have been designed for orthodontic anchorage can be placed in the small gap between roots. The small screw diameter and length reduce the invasiveness of these implants.[8] Mini-implants have been used to great advantage in the field of orthodontics[8,9]; however, they have a high failure rate.[15] Some clinicians experience a loosening of the mini-implants before or during orthodontic treatment,[15,16] despite the fact that animal experiments demonstrated high stability for these implants during experimental orthodontic loading.[7,17–21]

According to Miyawaki et al,[22] screws with a diameter of 1.5 mm should be used in patients with a low mandibular plane angle, and screws with a diameter of more than 2.3 mm should be used in patients with a high mandibular plane angle. Miyawaki et al[22] con-

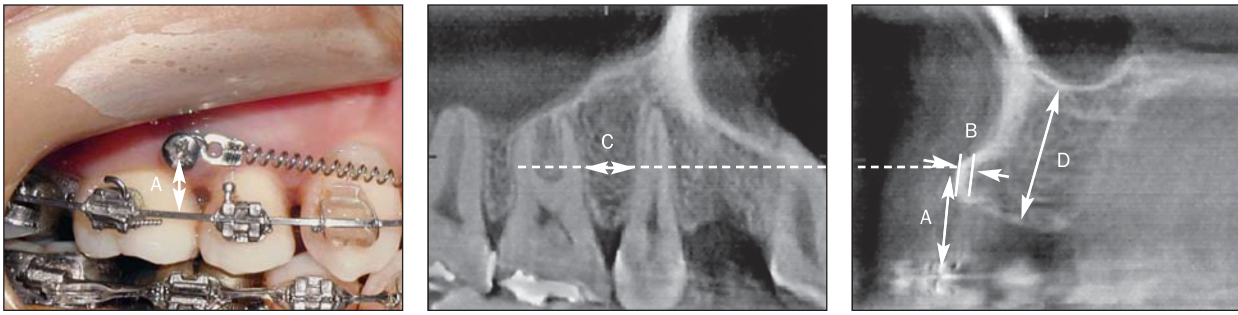
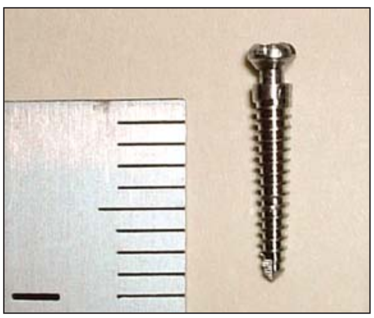


Fig 1 Height from arch wire to the position of the implant placement (A) was identified to measure cortical bone thickness (B) and inter-root distance (C). Height from alveolar crest to the bottom of maxillary sinus (D) was measured parallel to the tooth axis.



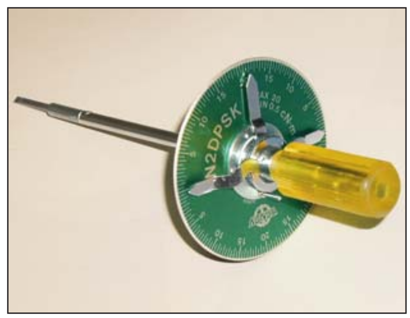


Fig 2 *(left)* The commercially available mini-implant used in this study.

Fig 3 *(right)* The torque screwdriver, which had a round dial gauge with a pointer to record the peak value of implant placement torque. According to the manufacturer, the device was accurate to ± 3%.

cluded that a high mandibular plane angle, which often exists with thin cortical bone, was associated with the failure of titanium screws. It is thought that the bone thickness and screw diameter are related to the stability and the loosening of mini-implants.

The purpose of this study was to investigate the relationship between cortical bone thickness and the success rate of the mini-implants placed in the buccal alveolar bone of the posterior regions of the dental arch. Furthermore, the relationship between inter-root distance (horizontal space) in maxilla and mandible, height from the alveolar crest to the bottom of maxillary sinus (vertical space), and implant placement torque and the success rate was investigated.

MATERIALS AND METHODS

The subjects were 32 patients who had mini-implants placed in the posterior alveolar bone as anchors for orthodontic treatment at Nihon University Dental Hospital. The usefulness of the mini-implants for orthodontic anchorage and the risk of loosening of the mini-implants during treatment were explained to the subjects or the subjects' parents. This study used only the diagnostic materials of patients who consented to the placement of mini-implants in cooperation with this study.

Before placement of the mini-implant, computerized tomographic images (3D Accuitomo; J. Morita, Kyoto, Japan) of the maxilla or mandible were obtained for diagnostic imaging of the planned implant location. The cortical bone thickness and the inter-root distance were then measured at the prepared site, and the height from alveolar crest to the bottom of maxillary sinus was measured in maxilla. The location of implant placement was identified by measuring from the height from arch wire to the position of the implant placement on the tomogram at the prepared site located in the inter-root gap between the either the second premolar and first molar or the first and second molars (Fig 1).

A taper-shaped titanium mini-implant with a diameter of 1.6 mm (spearhead diameter 1.3 mm) and a length of 8 mm (ISA system orthodontic implants; Biodent, Tokyo, Japan) was placed into the buccal alveolar bone at the prepared site of the maxilla and/or the mandible without raising a flap (Fig 2). After local anesthesia had been induced, a pilot hole with a diameter of 1.3 mm and a length of 8 mm was prepared using a bone drill. The mini-implant was then placed into the pilot hole, and the peak value of implant placement torque was recorded simultaneously during screwing-in of the mini-implant in the bone using a torque screwdriver (Fig 3; N2DPSK; Nakamura, Tokyo, Japan). An antibiotic (100 mg Flomox tablets; Shionogi, Osaka, Japan) was prescribed to each patient for 3 days after placement to prevent an infection. All the mini-implants were utilized as anchors for anterior teeth retraction after premolar extraction, and orthodontic force was applied immediately after the placement. The mini-implant was judged a success if orthodontic force could be applied for at least 6 months without pain or clinically detectable mobility. Cortical bone thickness, horizontal and vertical space for the implant placement (inter-root distance and space below the maxillary sinus), and implant placement torque were examined in relation to the success rate of the mini-implant for orthodontic anchorage.

The unpaired *t* test was performed to examine the differences in the variables such as the bone morphologic features derived from computerized tomography and implant placement torque between the success and the failure groups. The chi-square analysis or Fisher exact probability test was used to compare the success rate of the mini-implant according to implant placement torque, location of placement, and gender. Pearson's correlation coefficient of implant placement torque and cortical bone thickness was then calculated to examine the relationship of the bone thickness to the implant placement resistance. The Breslow-Day test was performed to estimate the common odds ratio. The Mantel-Haenszel test was then used to calculate the odds ratio (risk ratio) for failure of the mini-implant according to the cortical bone thickness. These analyses were carried out using SPSS for Windows (SPSS Japan, Tokyo, Japan). A *P* value of less than .05 was established as the threshold of statistically significance.

RESULTS

The sample comprised 32 patients, including 4 male patients (11 implants) and 28 female patients (76 implants) with ages ranging from 14.6 to 42.8 years (average age 24.4 years, SD 6.5 years).

The success rates ranged from 85.7% to 90.9% when calculated according to the placement location or patient gender; the success rate for the entire sample was 87.4% (Table 1). No significant differences in success rates were found with respect to placement location or gender.

The bone morphological features and implant placement torque for success and failure groups are shown in Table 2. Cortical bone thickness was significantly greater in the success group than in the failure group (1.42 ± 0.59 mm versus 0.97 ± 0.31 mm, *P* = .015). Table 3 shows the success rate where the subjects were divided into 3 groups (approximately 30 subjects per group) according to implant placement torque. The success rate was significantly higher in the group with an implant placement torque of 8 to 10 Ncm (100%) as compared with the < 8 Ncm group (83.9%, *P* = .034) or the > 10 Ncm group (78.6%, *P* = .012).

Table 1 Success Rate and No. of Implants

	Success rate (%)	n	*P*
Jaw			.601
Maxilla	87.5	56	
Mandible	87.1	31	
Side			.656
Right	85.7	42	
Left	88.9	45	
Gender			.579
Male	90.9	11	
Female	86.8	76	
Total	87.4	87	

Table 4 shows cortical bone thickness, inter-root distance, and implant placement torque in the maxilla and mandible. The cortical bone thickness and implant placement torque were significantly greater in the mandible than in the maxilla. The correlation coefficient between cortical bone thickness and implant placement torque was .32 (*P* = .002, Table 5). According to the Breslow-Day test (*P* = .38), the common odds ratio could be estimated (Tables 6a and 6b). The odds ratio for failure of the mini-implant anchor was 6.93 (*P* = .047) when the cortical bone thickness was less than 1.0 mm relative to 1.0 mm or more.

DISCUSSION

In a preliminary report, Costa et al[15] reported that 2 of 16 miniscrews 2 mm in diameter and 9 mm in length loosened before completion of an orthodontic treatment (success rate: 87.5%). Miyawaki et al[22] used 3 kinds of titanium screws with different diameters and lengths as orthodontic anchors and reported success rates of 0.0% for a screw with a diameter of 1.0 mm, 83.9% for a screw with a diameter of 1.5 mm, and 85.0% for a screw with a diameter of 2.3 mm. The success rate is therefore likely to be approximately 85% when using a titanium screw with a diameter of 1.5 to 2.3 mm. The success rate was 87.4% in the present study. This study confirmed the success rate for orthodontic mini-implants reported previously.

Miyawaki et al[22] found no correlation between mini-implant success rate and clinical parameters such as gender and implant location. The present study also revealed no significant difference in mini-implant success rate with respect to placement location or gender. Furthermore, there was no significant

Table 2 Bone Morphologic Features and Implant Placement Torque: Success Implants Versus Failures

	Success		Failure			
	Mean	SD	Mean	SD	n	*P*
Cortical bone thickness (mm)	1.42	0.59	0.97	0.31	87	0.015*
Inter-root distance (mm)	3.79	1.69	3.51	0.79	87	0.598
Height from alveolar crest to maxillary sinus (mm)	9.28	2.84	7.42	3.20	56	0.116
Implant placement torque (Ncm)	8.83	2.83	9.64	6.62	87	0.476

*$P < .05$.

Table 3 Success Rate According to Implant Placement Torque

Implant placement torque (Ncm)	Success	Failure	n	Success rate (%)	*P*
< 8	26	5	31	83.9	0.034* (< 8 vs 8 to 10); 0.601 (< 8 vs > 10)
8 to 10	28	0	28	100.0	
> 10	22	6	28	78.6	0.012* (8 to 10 vs > 10)

Table 4 Bone Morphologic Features and Implant Placement Torque According to Implant Location

	Maxilla		Mandible		
	Mean	SD	Mean	SD	*P*
Cortical bone thickness (mm)	1.16	0.45	1.72	0.62	< .001**
Inter-root distance (mm)	3.55	0.97	4.11	2.33	.209
Implant placement torque (Ncm)	8.28	3.65	10.11	2.86	.018*

*$P < .05$; **$P < .01$.

Table 5 Correlation Coefficient Between Cortical Bone Thickness and Implant Placement Torque

	Mean	SD	n	Pearson correlation coefficient	*P*
Cortical bone thickness (mm)	1.36	0.58	87	0.320	.002*
Implant placement torque (Ncm)	8.93	3.49	87		

*$P < .01$.

Table 6a Odds Ratio for Mini-implant Failure According to Cortical Bone Thickness

	CBT > 1.0 mm		CBT < 1.0 mm	
	Successful implants	No. of failures	Successful implants	No. of failures
Maxilla				
Right	17	0	6	4
Left	15	1	11	2
Mandible				
Right	12	2	1	0
Left	14	2	0	0

CBT = cortical bone thickness.

Table 6b Breslow-Day and Mantel-Haenszel Tests

Breslow-Day test	
Chi square	3.09
Degrees of freedom	3
P	0.380
Mantel-Haenszel test	
Common odds ratio	6.93
Log odds ratio	1.94
Standard error	0.90
95% confidence interval	1.19 to 40.55
Chi square	3.96
P	.047

difference between the success and failure groups with respect to the width or height of bone material supporting the implant body.

Implant placement torque was measured using a torque screwdriver. The success rate was significantly higher in the group with an implant placement torque of 8 to 10 Ncm as compared with the group with an implant placement torque of less than 8 Ncm (P = .034) or the > 10 Ncm group (P = .012) when the subjects were divided into 3 roughly equal groups based on implant placement torque. Adequate placement torque was determined within a range from 5 to 10 Ncm when tightening a mini-implant with a diameter of 1.6 mm in a previous study.[23] The present study reaffirmed that the placement torque should be controlled up to 10 Ncm.

Cortical bone thickness (P < .001) and implant placement torque (P = .018) were significantly greater in the mandible than in the maxilla. Nkenke et al[24] measured the height of the crestal cortical bone of the implant sites in human cadavers and the peak insertion torque of dental implants and found that the height of the crestal cortical bone penetrated by the implants was 2.1 to 2.5 mm in the maxilla and 5.1 to 5.4 mm in the mandible on average and that the peak insertion torque values were 23.8 ± 2.2 Ncm in the maxilla and 45.0 ± 7.9 Ncm in the mandible. Although these values were higher than those in the present study because of differences in implant placement location and screw diameter, it is relevant that the peak insertion torque and the height of the cortical bone of the implant sites were greater in the mandible than in the maxilla in both studies. This is most likely because the bone is more compact in the mandible than in the maxilla.[25] Significant correlation was also observed between cortical bone thickness and implant placement torque (r = 0.320, P = .002). It is obvious that a thicker layer of compact bone would cause increased placement resistance when tightening mini-implants.

In the present study, cortical bone thickness of the mini-implant was significantly greater in the success group than in the failure group. The difference in cortical bone thickness between the success and failure groups was 0.45 mm, and the thickness of the failure group was less than 1.0 mm on average. Huja et al[26] investigated the pull-out strength of screws in bone as related to the placement location of the mini-implants using dogs and found a positive correlation between cortical bone thickness and pull-out strength. Initial stability after insertion of the mini-implant was facilitated by greater cortical bone thickness. In the present study, a cortical bone thickness of 1.0 mm or less was assumed to be a risk factor for mini-implant failure; therefore, the odds ratio (risk ratio) was estimated when the bone thickness was less than 1.0 mm. The Mantel-Haenszel test derived a large value, 6.93, as the estimated common odds ratio (P = .047). The success rate for the mini-implants placed into cortical bone thickness to more than 1.0 mm is therefore expected to be improved. However, the success rates were similar for the maxilla and the mandible, even though cortical bone thickness was significant larger in the mandible than in the maxilla. While the success rate seems obviously related to cortical bone thickness, cortical bone thickness greater than 1.0 mm does not necessarily improve the success rate.

CONCLUSION

In the present study, no relationship was found between mini-implant stability and the width and height of bone material supporting the implant body. However, the prepared site should be established in an area with a cortical bone thickness of more than 1.0 mm, and an adequate placement torque (8 to 10 Ncm) should be applied to raise the success rate. Computerized tomographic examination in dentofacial field and technical modifications in the implant placement would facilitate improvement of the success rate.

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