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Root proximity and stability of orthodontic anchor screws

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Abstract: This study aimed to investigate a causal relationship between the stability of orthodontic anchor screws (screws) and the degree of their proximity to the root (root proximity) using mobility test device (Periotest) and cone-beam computed tomography (CBCT). In total, 165 (diameter 1.6 mm; length 8 mm) screws in 58 patients (average age, 24.4 ± 8.5 years) were evaluated. After screw placement, CBCT was used for diagnostic imaging of the area around the site. Root proximity was evaluated and categorized into three groups: A, no contact; B, single contact; and C, multi-contact. The Periotest value was used to assess screw stability. The screw failure rate according to root proximity significantly differed between categories A and C. In addition, failure rate significantly differed between mandibular screws with and without root contact. Periotest values in categories A and C were significantly higher in the mandible than in the maxilla. Mandibular screws had greater mobility than maxillar screws, even when the screw avoided root contact. The lower stability of mandibular screws with root contact might be related to their greater mobility. (J Oral Sci 56, 59-65, 2014)

Keywords: mini-implant; anchor screw; temporary anchorage device (TAD); root proximity; cone-beam computed tomography (CBCT).

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Introduction

Titanium anchor screws are used to strengthen orthodontic anchorage and ensure predictable tooth movement without reciprocal movement (1-7). To improve success rate, risk factors for screw failure have been investigated (8). Screw failure is thought to be related to inflammation near the placement site (9), overloading (8), cortical bone thickness (10), screw design (9), and proximity of the screw to the adjacent tooth root (11).

Because orthodontic anchor screws are frequently placed into small gaps between the roots of adjacent teeth, root proximity is often considered a clinical problem. Controversies can be found in the recent literature with regard to root proximity. Liou et al. (12) stated that when miniscrews were placed in an inter-root space, a clearance of 2.0 mm between the miniscrew and dental root is recommended for safety. Using two-dimensional dental radiographs, Kuroda et al. (11) measured the distance between screws and root and calculated correlations with screw success rates. They concluded that root proximity was a major risk factor for screw failure and that the association was highly significant in the mandible. However, the difference in the stability of screws placed in the maxilla and mandible is not well understood.

Information on the positions of adjacent tooth roots has been evaluated using two-dimensional images, including panoramic and dental radiographs (11,13,14). However, three-dimensional imaging using dental cone-beam computed tomography (CBCT) is recommended for accurate evaluation of small dental areas (15,16). CBCT is an X-ray CT imaging technique in which the X-rays diverge, forming a cone. CBCT gives an undistorted view of the dentition, which can be used to accurately visualize erupted and non-erupted teeth, orientation of the tooth root, and anomalous structures that cannot be satisfactorily visualized with conventional two-dimensional radiography (17). Recently, Watanabe et al. (18) used

CBCT to evaluate the relationship between root-screw distance and screw stability and found that CBCT was better than periapical dental radiographs for evaluating the proximity of miniscrews to the root.

To evaluate screw stability, Uemura et al. (19) used a Periotest device to measure screw mobility after placement. The Periotest was developed to measure periodontal integration in teeth and the stiffness of the bone-implant interface in oral implantology. Their study based on Inaba's study (20) which showed a strong correlation between the screw-bone contact state and the Periotest value (PTV), and concluded that the PTV was an appropriate index of the screw stability.

In the present study, CBCT was used to measure the root proximity of screws placed in the posterior buccal alveolar region. In addition, after placement the PTV for each screw was recorded to determine failure risk in relation to root proximity in the mandible.

Materials and Methods

A total of 165 screws from 58 patients (15 men, 43 women; average age, 24.4 ± 8.5 years) were evaluated. Screws were placed in the buccal posterior alveolar bone between the second premolar and first molar in all participants, as anchors for orthodontic treatment at Nihon University Dental Hospital.

Fig. 1 The commercially available orthodontic anchor screw used in this study (diameter 1.6 mm; length 8 mm).

Commercial orthodontic anchor screws (diameter 1.6 mm; length 8 mm; ISA Orthodontic Mini-implants; Biodent, Tokyo, Japan) were used (Fig. 1). After administering local anesthesia, a pilot hole was drilled with a bone drill under physiological saline flow into the buccal alveolar bone between the second premolar and first molar of the maxilla or mandible without a flap procedure. The drilling direction was fixed obliquely at 45° to 60° from the long axis of the neighboring tooth, to obtain a sufficient anchor in the thickness of cortical bone and decrease the probability of root contact. To improve the success rate, the author used bone drills with diameters of 1.0 mm in the maxilla and 1.3 mm in the mandible to maintain placement torque within the recommended range (5-10 N·cm), which was based on previously published results (10,21). Immediately after placement, the PTV was recorded using the Periotest device (Medizintechnik Gulden, Bensheim, Germany). A higher PTV indicates greater mobility and lower stability. Each measurement was repeated three times, and the average value was analyzed. An orthodontic force of approximately 2 N was then applied to the screw, and CBCT images were obtained for post-placement diagnosis of each participant. After screw placement, each patient was prescribed an antibiotic for 3 days to control infection.

CBCT (3D Accuitomo; J. Morita, Kyoto, Japan), with a voxel size of 0.125 × 0.125 × 0.125 mm in super-high-resolution mode, an X-ray tube voltage of 80 kV, and a current of 5.5 mA, was used for diagnostic imaging of the area around the site. Tomographic sections aligned to the long axis of the screw were observed simultaneously with the adjacent roots using three-dimensional viewing software (One Volume Viewer, version 1.6.1.13;

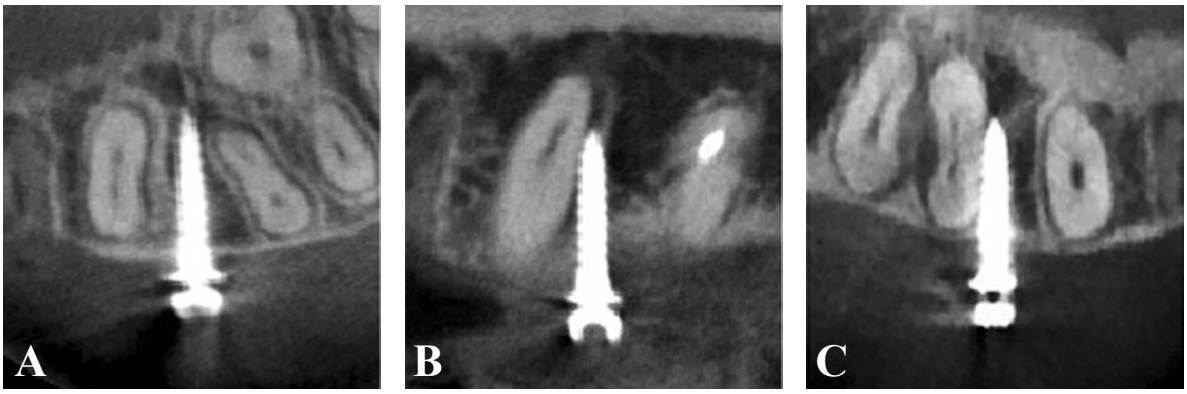

Fig. 2 Root proximity categories used in this study. **A** (no contact), no contact between the root and screw; **B** (single contact), one point of contact between the root and apex or body of the screw; **C** (multi-contact), two or more points of contact between the root and screw.

Table 1 Success rates of the studied screws

	n	No. of successful	Success rate %	*P*-value
Maxilla	79	76	96.2	0.722
Mandible	86	81	94.2	
Total	165	157	95.2	

Table 2 Root contact rate in the maxilla and mandible

	n	No. of root contact (†)	Rate of root contact %
Maxilla	79	19	24.1
Mandible	86	16	18.6
Total	165	35	21.2

†: Number of screws with root contact (B + C in Table 3).

Table 3 Screws categorized by root proximity

	A (no contact)		B (single contact)		C (multi-contact)	
	n	%	*n*	%	*n*	%
Maxilla	60	75.9	10	11.4	9	12.7
Mandible	70	81.4	10	11.6	6	7.0
Total	130	78.8	20	12.1	15	9.1

Table 4 Failure rate according to category of root proximity

Category	No. of failed screws	%
A (n = 130)	2	1.5 *
B (n = 20)	2	10.0 *
C (n = 15)	4	26.7

*: $P < 0.01$

Table 5 Comparison of failure rates in screws with and without root contact

	No contact		Contact	
	n	%	*n*	%
Maxilla	60	1.7	19	10.5
Mandible	70	1.4	16	25.0*
Total	130	1.5	35	17.1*

*: $P < 0.05$

Table 6 Mean Periotest values according to category of root proximity

	A (no contact)		B (single contact)		C (multi-contact)	
	Mean	SD	Mean	SD	Mean	SD
Maxilla	1.4	3.7	1.6	2.1	1.5	2.5
Mandible	2.9*	2.6	3.2	2.2	5.6*	3.8

*: $P < 0.05$ (maxilla vs mandible)

J. Morita, Kyoto, Japan). The author evaluated root proximity, which was categorized into three groups: A (no contact), no contact between the root and screw; B (single contact), one point of contact between the root and apex or screw body; and C (multi-contact), two or more points of contact between the root and screw (Fig. 2).

A screw was considered successful when it withstood an orthodontic force applied for 6 months or longer without mobility. To verify the hypothesis that root proximity is a risk factor for screw failure, the causal relationship between the stability of anchor screws and root proximity was investigated in relation to screw failure. The frequency of root contact and PTVs in the maxilla and mandible was also examined. This study was approved by the Ethics Committee of Nihon University School of Dentistry (2012-2), and all patients consented to participate in this study.

To evaluate examination error, root proximity was re-evaluated in randomly selected CBCT images of 10 participants and categorized into the three groups described above 1 month after the initial evaluation. The chi-square test or Fisher exact test was used to evaluate variability of the failure rate according to root contact, the contact ratio according to location, and the failure rate in the three categories. The Sheffe test and unpaired *t*-test were used to compare PTVs in each category and between the maxilla and mandible. All analyses were performed with SPSS statistical software (version 16.0; SPSS Japan, Tokyo, Japan). A *P* value of <0.05 was considered to indicate statistical significance.

Results

Calculations of intra-examination error showed no difference between the two judgments in any of the 10 selected participants. The success rate for screws used in this study was 95% (Table 1), and the rate did not significantly differ between the maxilla and mandible. The rate of screw contact with the adjacent root was approximately 20%, with no significant difference between the maxilla and mandible (Table 2). By category, the rates of no contact (A), single contact (B), and multi-contact (C) were approximately 79%, 12%, and 9%, respectively (Table 3), with no significant difference between the maxilla and mandible. No participant had root contact with both teeth (premolar and molar). The failure rate, by root proximity, significantly differed between categories A and C (Table 4). Table 5 shows the significant difference in failure rate between mandibular screws with and without root contact. PTVs for the no contact (A), single contact (B), and multi-contact (C) groups in the maxilla indicated a constant value of approximately 1.5, while those in mandible ranged from 2.9 to 5.6 (Table 6). PTVs in categories A and C were significantly larger in the

Table 7 Placement sites and failure categories of failed screws

Screw	Category				Site of failure (†)			Mesial / Distal (‡)	
	A	B	C	UR	UL	LR	LL	Premolar	Molar
1	*				*				
2	*						*		
3		*				*			*
4		*				*			*
5			*		*				*
6			*				*		*
7			*			*		*	
8			*	*					*
Total	2	2	4	1	2	3	2	1	5
P-value		0.642			0.941			0.119	

†: Screw placement site (UR: upper right, UL: upper left, LR: lower right, LL: lower left).
‡: Contacted teeth

mandible than in the maxilla.

Eight screws failed in this study, the details of which are shown in Table 7. Root contact was identified in six of the eight screws. Four of the six screws with root contact were included in group C; five contacted the root of the first molar, and one contacted the premolar. Details of the 35 screws with root contact are shown in Table 8. Six of the 35 screws failed; thus, more than 80% of screws with root contact survived ($P < 0.05$). Root contact was evident in approximately 10 screws each in the right and left maxilla and right mandible and in 5 in the left mandible. Twenty-two screws contacted the molar, and 13 contacted the premolar.

Discussion

By maintaining placement torque within the recommended range (5-10 N·cm), the success rate of screws used in this study was increased to 95% (21). The previously reported lower success rate in the mandible (11,22) was improved by using the recommended placement method (10,21).

The rate of root contact was approximately 20% in the current study. In contrast, Kuroda et al. (11) reported that approximately 50% of subjects showed root contact. This difference was likely due to the use of two- versus three-dimensional evaluation. As Kuroda et al. (11) reported, some screws were not actually in contact with the root despite the fact that proximity of the screw to the root was observed on a dental radiograph. Kim et al. (16) reported that 15 of 50 screws (30%) appeared to have root contact. That rate of screw contact with roots was higher than in this study, most likely because of the larger diameter of screws used in the previous study (1.8 mm vs 1.6 mm in the present study).

Min et al. (23) investigated the effects of root proximity on the success rate of a narrow screw (diameter 1.2-1.3 mm) and reported that the failure rate of the root-contacting screw was about 70%. In contrast, of the 35 screws with root contact in the current study, 29 (about 83%) survived. The low failure rate of root-contacting screws might be related to screws with larger diameters. Most screws with a diameter of 1.6 mm that contacted the root withstood force application during orthodontic treatment. However, multi-contact screws should be carefully observed, because screws in that category had a significantly higher failure rate as compared with the no-contact category. Two of 20 screws (10%) in the single-contact category failed, whereas 4 of 15 screws (27%) in the multi-contact category failed. This finding might also be important in avoiding worsening of lesions on the root surface.

No definitive view of repair of root resorption has been obtained, and controversy continues. Animal and clinical studies have examined root damage after root contact. In a study of minipigs Kim and Kim (24) concluded that when a screw was placed <1 mm from the periodontal ligament, external root resorption occurred despite no direct contact. In a study using beagles Brisceno et al. (25) reported that healing could occur when root damage caused by screws was limited to the cementum or dentin. Asscherickx et al. (26) used beagles in a root-proximity model and reported that histological examination of contacted roots showed almost complete repair of periodontal structure (cementum, periodontal ligament, and bone) during the 12-week period after screw removal. Chen et al. (27) performed an animal study and found that after screw removal the lesion associated with root contact was repaired, with a narrow zone of mineralized tissue deposited on the root surface (which was likely cellular cementum). The lesion was filled mainly with

Table 8 Placement sites and categories of screws contacted to the adjacent roots

	Category		Success / Failure		Site of root contact (†)				Mesial / Distal (‡)	
Screw	B	C	Success	Failure	UR	UL	LR	LL	Premolar	Molar
					n = 38	*n* = 41	*n* = 44	*n* = 42		
1	*		*				*			*
2	*		*					*	*	
3	*		*			*			*	
4	*		*				*		*	
5	*		*			*				*
6	*		*		*					*
7	*		*				*			*
8	*		*		*					*
9	*		*					*		*
10	*		*		*					*
11	*		*			*			*	
12	*		*		*					*
13	*		*		*				*	
14	*		*			*			*	
15	*		*				*			*
16	*		*				*			*
17	*		*					*		*
18	*		*			*				*
19	*			*			*			*
20	*			*			*			*
21		*	*		*					*
22		*	*				*		*	
23		*	*			*				*
24		*	*				*		*	
25		*	*					*		*
26		*	*			*			*	
27		*	*				*		*	
28		*	*			*			*	
29		*	*		*					*
30		*	*		*					*
31		*	*		*				*	
32		*		*		*				*
33		*		*				*		*
34		*		*			*		*	
35		*		*	*					*
Total	20	15	29	6	10	9	11	5	13	22
P-value	0.339					0.345			0.055	

†; Position of screw placement (UR: upper right, UL: upper left, LR: lower right, LL: lower left).
‡; Contacted teeth.

alveolar bone, and the periodontal ligament space was preserved. In a clinical study Kadioglu et al. (28) found that root surfaces in contact with screws exhibited swift repair and almost complete healing within a few weeks of screw removal or cessation of orthodontic force. Repair of root damage might be expected when adjacent teeth move in the opposite direction from the screw, although this is unproven. Patients should be carefully followed up when screws contact adjacent roots, and post-placement evaluation is required in order to evaluate the clinical course of root damage. In any case, root contact should be avoided when placing screws, and the use of CBCT for diagnosis and evaluation of screw placement is strongly recommended.

The failure rate of screws with contact (single or multi-contact) and without contact significantly differed in the mandible. This supports the findings of Kuroda et al., (11) who found that root proximity was a major

risk factor and that this tendency was more obvious in the mandible. In mobility measurements in the current study, PTVs showed significantly higher mobility in the mandible than in the maxilla for screws in the no-contact and multi-contact categories (categories A and C). This suggests that screws have greater mobility in the mandible than in the maxilla regardless of root proximity. Higher failure rate in the mandible in previous reports (18, 22), and higher risk for failure of the mandibular screws in this study might be related to the higher mobility (PTV: approximately 3 in category A) in the mandible. In the mandible, a PTV of approximately 3 may be acceptable mobility to withstand orthodontic force, because there was no significant difference between the success rates for the maxilla and mandible in this study. A PTV threshold of approximately 3 might thus be an index for estimating prognosis of the screw. However, delicate and dubious stability of mandibular screws could result in easy collapse due to external factors such as root proximity, which might induce screw failure in the mandible. Micro-cracks in hard cortical bone might be related to the strong association between root contact and screw failure in the mandible.

Category, site of failure, and the position of contact for each failed screw were noted. Six screws contacting the adjacent root failed, and the failure of two screws without root contact was caused by other, obscure factors. Four of the six screws with root contact were categorized into the multi-contact group. This supports the findings regarding failure rate in relation to root proximity, shown in Table 4. Five of the six screws contacted the root of the first molar, while only one contacted the premolar. The rate of root contact might be higher for posterior teeth; however, this needs to be verified in a future study.

In conclusion, even in the absence of root contact, mandibular screws had greater mobility than maxillar screws. The lower stability of mandibular screws with root contact might be related to their greater mobility.

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