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 devise (Periotest) and cone-beam computed tomography (CBCT). In total, 58 patients (average age, 24.4 ± 8.5 years) with 165 screws of 1.6-mm diameter and 8-mm length were evaluated. CBCT was used for diagnostic imaging of the area around the site after screw placement. Root proximity was evaluated, and then categorized into one of three groups: A, no contact; B, single contact; and C, multi-contact. Periotest value (PTV) was recorded to assess the stability of the screws. The failure rate of the screws according to root proximity revealed a significant difference between categories A and C. There was a significant difference in the failure rate between mandibular screws with and without root contact. PTV in categories A and C was significantly greater in mandible than in maxilla. The screw in the mandible showed higher mobility than in the maxilla even though the screw avoided root contact. The lower stability of the mandibular screws with root contact might be related to the higher mobility of the screws in the mandible.

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

Introduction

Orthodontic titanium anchor screws have been utilized to strengthen orthodontic anchorage and ensure predictable tooth movement without reciprocal movement (1-7). The risk factors for screw failure were investigated in an attempt to improve the success rate (8). Screw failure is thought to be related to inflammation surrounding 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 are placed in an inter-root space, a clearance of 2.0 mm between the miniscrew and the dental root is recommended for safety. Kuroda et al. (11) evaluated the distance between the screws and the root using two-dimensional dental X-rays and calculated correlations with the success rates of the screws. They concluded that root proximity is a major risk factor for failure of the screw. They also stated that especially highly significant relation was found in mandible, however the difference of the screw stability between maxilla and mandible is not well understood.

Information about the positions of adjacent tooth roots have been evaluated using two-dimensional images such as panoramic radiographs and dental X-rays (11, 13, 14). For accurate evaluation of small dental areas, three-dimensional imaging using dental cone-beam computed tomography (CBCT) should be performed (15, 16). CBCT is a medical imaging technique comprising X-ray CT in which the X-rays are divergent, forming a cone. CBCT offers an undistorted view of the dentition that can be used to accurately visualize both erupted and non-erupted teeth, tooth root orientation, and anomalous structures that conventional two-dimensional radiography cannot (17). Recently, Watanabe et al. (18) evaluated relationship between the root-screw distance and stability of the screw using CBCT and they stated that CBCT was superior to periapical dental X-rays for evaluating the proximity of miniscrews to the root.

To determine the stability of the screws, Uemura et al. (19) measured mobility of the screws after placement using Periotest device. The Periotest was developed to measure the degree of periodontal integration of 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 this study, the root proximity of the screws that were placed in the posterior buccal alveolar region was measured using CBCT, and PTV of each screw after placement was recorded to elucidate the higher risk for failure of the root proximity in the mandible.

Materials and methods

The study group comprised 58 patients (15 males, 43 females; average age, 24.4 ± 8.5 years) with 165 screws. Screws were placed in the buccal posterior alveolar bone between the second premolar and first molar in all subjects as anchors for orthodontic treatment at Nihon University Dental Hospital.

Commercial orthodontic anchor screws with a 1.6-mm diameter and 8-mm length (ISA Orthodontic Mini-implants; Biodent, Tokyo, Japan) were used (Fig. 1). After administration of 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 operation. The drilling direction was fixed obliquely at 45 to 60 degrees 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, we used bone drills with diameters of 1.0 mm in the maxilla and 1.3 mm in the mandible to control the placement torque within the recommended range (5-10 N□cm), based on previously published results (10, 21). Immediately after placement, we recorded a PTV using the Periotest device (Medizintechnik Gulden, Bensheim, Germany). Greater PTV indicates higher mobility and lower stability. Each measurement was repeated three times and an average value was calculated. An orthodontic force of approximately 2 N was then applied to the screw, and CBCT imaging was then performed for post-placement diagnosis for each subject. Each patient was prescribed an antibiotic for 3 days after screw placement to control infection.

CBCT (3D Accuitomo; J. Morita, Kyoto, Japan), with voxel size of 0.125 × 0.125 × 0.125 mm in super-high-resolution mode, X-ray tube voltage of 80 kV, and 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 simultaneously observed with adjacent roots using a three-dimensional viewer program (One Volume Viewer, version 1.6.1.13; J. Morita, Kyoto, Japan). An examiner (T.S.) evaluated the root proximity, and then categorized into three groups: A (no contact), contact was not seen between the root and the screw; B (single contact), a point of contact between the root and the apex or body of the screw was seen; and C (multi-contact), two or more points of contact between the root and the screw were seen (Fig. 2).

When a screw endured an orthodontic force applied for 6 months or more without any mobility, it was considered a success. To verify the hypothesis that root proximity is a risk factor for screw failure, a 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 maxilla and mandible were 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, in randomly selected CBCT images of 10 subjects, their root proximity was re-evaluated, and categorized into three groups 1 month after the initial evaluation. A chi-square test or Fisher's 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. Sheffe's test and unpaired *t* test were used to compare PTVs in each category and in the jaws. These analyses were performed with the SPSS statistical program (version 16.0; SPSS Japan, Tokyo, Japan). A *P* value of <0.05 was considered to indicate statistical significance.

Results

Calculation of the intra-examination error showed no difference between the two judgments in all 10 selected subjects. The success rate of the screws used in this study was 95% (Table 1). There was no significant difference between the maxilla and mandible. The rate of contact of the screws with the adjacent root was approximately 20%, and there was also no significant difference between the maxilla and mandible (Table 2). In terms of categories, the rates of no contact (A), single contact (B), and multi-contact (C) were approximately 79%, 12%, and 9%, respectively (Table 3), without a significant difference between the maxilla and mandible. No subjects had root contact to both teeth (premolar and molar). The failure rate according to root proximity showed a significant difference between categories A and C (Table 4). Table 5 shows a significant difference in the failure rate between mandibular screws with and without root contact. PTVs of no contact (A), single contact (B), and multi-contact (C) in maxilla indicated a constant value approximately 1.5, and those in mandible ranged from 2.9 to 5.6 (Table 6). PTV in categories A and C were significantly larger in mandible than in maxilla.

Eight screws failed in this study, 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 categorized into 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 controlling the placement torque within the recommended range (5-10 N·cm), the success rate of the screws was increased to 95% in this study (21). The previously reported lower success rate in the mandible (11, 22) was also improved, which was associated with the recommended placement method (10, 21).

The rate of root contact was approximately 20% in the current study, whereas Kuroda et al. (11) reported that approximately 50% of subjects showed root contact. This difference was likely because of the two- *versus* three-dimensional evaluations. 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 the dental radiograph. Kim et al. (13) reported that 15 of 50 screws (30%) appeared to have root contact. Their screws exhibited a higher rate of root contact than shown in this study. This was likely related to the larger screw diameter (1.8 mm) than that in the current study (1.6 mm).

Min et al. (23) investigated the effects of root proximity on the success rate of a slender screw with a 1.2-1.3 mm diameter, and they reported that failure rate of the root-contacting screw was ~70%. In contrast, of the 35 screws with root contact, 29 (~83%) survived in the current study. The low failure rate of the root-contacting screw might be related to screws with larger diameters. The majority of the screws with a 1.6 mm diameter that contacted the root endured force application during orthodontic treatment. However, screws with multi-contact should be observed thoroughly and carefully because the multi-contact category had a significant higher failure rate 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 observation might also be important to avoid worsening of the lesion 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 following root contact. Kim and Kim (24) used minipigs and concluded that when the screw was placed <1 mm from the periodontal ligament, external root resorption occurred despite no direct contact. Brisceno et al. (25) used beagles and reported that healing can occur when root damage caused by screws is limited to the cementum or dentin. Asscherickx et al. (26) created root-proximity models using beagles and reported that histological examination of contacted roots demonstrated almost-complete repair of the periodontal structure (cementum, periodontal ligament, and bone) in a 12-week period following removal of the screws. Chen et al. (27) performed an animal study and described that after removal of the screw, 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, and was filled mainly with alveolar bone with preservation of the periodontal ligament space. Kadioglu et al. (28) performed a clinical study showing that root surfaces in contact with screws showed swift repair and almost complete healing within a few weeks of removal of the screw or the orthodontic force. Repair of root damage might be expected when the adjacent teeth move to the opposite direction from the screw, although this is only conjecture. Clinical circumspection is required when screws contact adjacent roots, and post-placement evaluation is required to evaluate the clinical course of root damage. At any rate, the root contact should be avoided when placing the screws, and the use of CBCT for diagnosis and evaluation of screw placement is strongly recommended.

In a comparison of the failure rate of screws with no contact and those with contact (both single and multi-contact), a highly significant difference was found in the mandible. This supports the findings of Kuroda et al. (11) who showed that root proximity is a major risk factor and that this tendency is more obvious in the mandible. In mobility measurement of the current study, PTV showed significantly higher mobility in mandible than in maxilla for the screws categorized in no contact and multi-contact (categories A and C). This suggests that the screw showed higher mobility in the mandible than in the maxilla regardless of the 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. PTV approximately 3 in the mandible may be an acceptable mobility to endure an orthodontic force because there is no significant difference between the success rate in the maxilla and in the mandible in this study. Threshold of PTV approximately 3 might be an index for estimating prognosis of the screw. However delicate and dubious stability of the mandibular screws might easily collapse in association with an external factor such as the root proximity and this might induce the failure of the screws in the mandible. Micro crack occurred in hard cortical bone might be related to the strong relation between root contact and screw failure in the mandible.

Category, site of failure, and position of contact of each failed screw were noted. Six screws contacting the adjacent root failed, and 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 failure rate according to root proximity results shown in Table 4. Five of the six screws contacted the root of the first molar, while only one contacted the premolar. Higher rate of root contact might be observed in posterior teeth, however a future study should be designed to verify this.

In conclusion, the screw in the mandible showed higher mobility than in the maxilla even though the screw avoided root contact. The lower stability of the mandibular screws with root contact might be related to the higher mobility of the screws in the mandible.

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Tables

Table 1 Success rate of the screws used in this study

	n	*Number of success*	*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 maxilla and mandible

	n	*Number of root contact* (†)	*Rate of root contact %*
Maxilla	79	19	24.1
Mandible	86	16	18.6
Total	165	35	21.2

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

Table 3 Rate of categories of 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 categories of root proximity

Category	*Number of failure*	*%*	
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 between contacted and no-contacted screws

	No-contacted screws		*Contacted screws*	
	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 PTVs according to categories of root proximity

	A (no contact)		*B (single contact)*		*C (multi-contact)*	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
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)

Table 7 Placement sites and categories of failure 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*	

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

‡: Contacted teeth.

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

Screw	*Category*		*Success / Failure*		*Site of root contact* (†)				*Mesial / Distal* (‡)	
	B	*C*	*Success*	*Failure*	*UR n=38*	*UL n=41*	*LR n=44*	*LL n=42*	*Premolar*	*Molar*
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.

Figures

Fig. 1

The commercial orthodontic anchor screw of 1.6 mm diameter and 8 mm length used in this study.

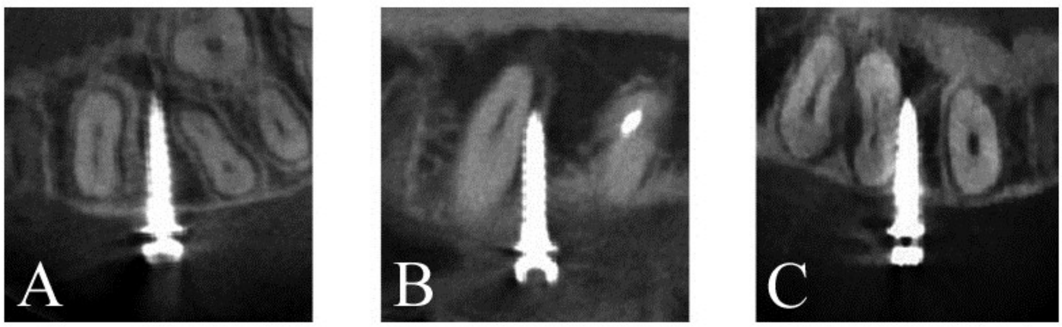

Fig. 2

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