ORIGINAL ARTICLE

Frequency of Ankylosis, Loss of Pulp Vitality and External Root Resorption after Root Contact with Mini-screw

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Background and aims: To evaluate the frequency of ankylosis, loss of pulp vitality and external root resorption after intentional root contact with mini-screw.

Methods: Sixty maxillary and mandibular second, third, and fourth premolars teeth of five mature beagle dogs were randomly assigned into three experimental groups. Premolars teeth at group I, received a mini-screw (6-mm length, 1.5-mm diameter, self drilling) which was removed immediately after contact with the root. Group II consisted of teeth that received mini-screw and the screw left in situ for 15 weeks. In group III once contact was made with mini-screw, the teeth were shifted away from the screw with brackets and Titanium closed coil spring tightened to another bonded orthodontic brackets on the neighbor teeth. Group IV was the control group. The specimens were decalcified, stained and evaluated histologically to determine the presence/absence of root resorption, ankylosis and tooth vitality.

Results: There were no signs of ankylosis, root resorption, moderate to severe inflammation or necrosis within the pulp in any experimental group.

Conclusions: Ankylosis, pulp necrosis and sever root resorption are not common clinical outcomes when mini-screw contacts the root. Repair after contact with mini-screw depends on the severity of invasion. More severe invasion needs further time necessary for repair.

Keywords: Ankylosis, Dental Pulp Necrosis, Mini-screw, Root Resorption

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Introduction

In the past decades, Temporary Anchorage Devices (TADs) have been widely used for fascinating different orthodontic treatment procedures including corrections of open bites by molar intrusion,[1-5] deep bites by incisor intrusion,[6] Angle's Class II and Class III correction by distalizing molars[7-9] and many other though orthodontic tooth movements like posterior protraction and molar uprighting.[1]

There is an array of TADs choices for the clinician among the various types of devices;[11-15] However, mini-screws are the most frequently used due to low cost, simplicity of insertion and removal, immediate loading, positive reaction of patients as well as their small size. Mini-screws can also be inserted in both intra-alveolar and extra-alveolar sites. However, placement of mini-screws in non-keratinized tissues can cause inflammation and hypertrophy of the mucosa which increases the risk of failure. In contrast, placement of mini-screws in keratinized gingiva and inter-radicular spaces between two adjacent teeth increases the risk of damage to root surfaces and periodontium[11-15].

The most serious problems reported when the mini-screws contact root surfaces of the teeth are ankylosis, loss of tooth vitality and also permanent damage to root surfaces or periodontal ligament. [16] To prevent root damage during interradicular screw placement, safest sides for mini-screw placement have been determined, using clinical positioning guides and radiographic navigation.[17-26] Most investigators concluded that root contacts are likely to not affect the tooth's maintenance prognosis [27-30] although, ankylosis as well as root and bone resorption have been reported by others. [31-33] The purpose of this study was to evaluate the hypothesis that mini-screw contact with root during its insertion would increase the risks of pulp necrosis, root ankylosis and external root resorption.

Material &Methods

Maxillary and mandibular second, third, and fourth premolars of five mature beagle dogs, weighting 20-25 kg with the age range of 18-24 months were used in this study. Animals were caged individually supervised in the veterinary hospital for small animals for one week prior to the study. Their health status was evaluated by an experienced veterinary surgeon according to the animal welfare regulations. The study design was approved by the Ethics Committee of Dental Research Center. Animals were surgically pre-anesthetized with Ketamine (10 mg/kg) and 2% Xylazine (5 mg/kg) and 5% Thiopental Natrium. While anesthetized, vital signs of the animals were monitored and recorded by trained observers.

Twelve mini-screws were inserted in each sample (three in each quadrant) so that the screws touched the root surfaces. The root surface contact was verified and confirmed based on two periapical x-ray with different angulations and alteration in tactile sensation of clinicians while placing the miniscrews (Figure 1). To emulate clinical condition, drilling was discontinued after resistance was felt.

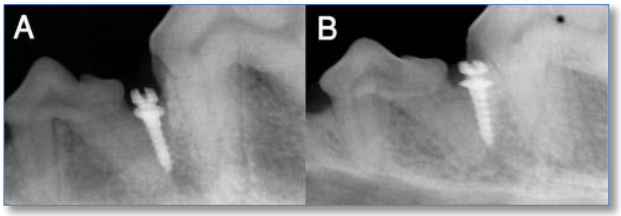

Figure 1. The proximity of mini-screw and root surface was confirmed by combination of two periapical x-ray with different angulations (A & B) and alteration of resistance during miniscrew insertion.

Each premolar tooth was assigned randomly to one of the experimental groups as follows:

- Group I: Mini-screws were placed in contact with root surfaces and removed immediately (Jeil Medical Corporation, Korea. 6 mm length, 1.5 mm diameter, self drilling) (Figure 2)

- Group II: Mini-screws were placed in contact with root surfaces and remained unloaded during the course of study (15 weeks).

- Group III: Teeth received mini-screw and when contact was made the teeth were shifted away from the screw with brackets. Orthodontic brackets (Roth, 0.022 inch) were bonded on buccal surfaces of premolar teeth as well as one adjacent cuspid or molar teeth in the same quadrant. The selection of cuspid or molar teeth was based on the distance of the teeth to the selected experimental premolar teeth. Brackets (Standard Edgewise, 3M Unitek Corporation, Monrovia, CA, USA) were bonded to

these teeth with No mix adhesive (3M Unitek Corporation, Monrovia, CA, USA) and NiTi closed coil spring (Ortho Technology Corporation, Florida, USA) were attached with a 0.254 mm (0.010 inch) diameter steel ligature wire (3M Unitek Corporation, Monrovia, CA, USA); subsequently the premolar teeth were pulled away from the adjacent mini-screws using 60 gr force. Titanium closed coil spring tightened to bonded orthodontic brackets were used. Simultaneously, the enamel surface was cleaned and etched for 30 seconds and these teeth were slid apart from each other by an active NiTi-based push coil spring (Ormco, Orange, California, USA) on 0.018 stainless steel segmental arch wires, providing a force of 60 g at both sites.

- Group IV: Control group. Premolar teeth that did not received mini-screw. Each premolar in each quadrant has the same chance to be in each experimental group (Figure 3).

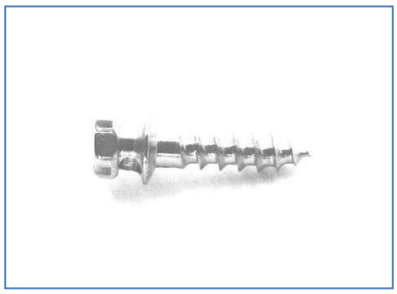

Figure 2. Self drilling mini-screw, (1.6 mm diameter, 6 mm length, Jeil Medical Corporation, Korea).

Figure 3. Clinical photograph indicating randomly assigned experimental groups. In this case upper left first premolar was assigned to group I, second premolar to group II, third premolar to group III and forth premolar to group IV while in lower left quadrant first premolar was assigned to group I, second premolar to group III, third premolar to group IV and forth premolar to group II.

Figure 4. Maxillary and mandibular jaws before decalcification procedure.

The mini-screws in group II and III were kept in site for 15 weeks.

After completion of the experiment, post-operative antibiotics (Penicillin 633, OD) and analgesics (Mefenamic Acid 250mg, BD) and Tramadol tablet 100 mg BD were administered for five days.

At the end of 15 week, the animals were euthanized and perfused with 4% Paraformaldehyde and 2% glutaraldehyde in 0.05 mol phosphate buffer (PH=7.4) for further histological evaluations.

Tooth specimens which included the insertion sites of mini-screws were taken and fixed in 10% buffer formalin for two weeks. Mini-screws in group II and III were removed from the site and then specimens were soaked in 10% nitric acid at an adequate PH for one week and embedded in paraffin blocks. The specimens were sectioned mesiodistally (5 µm thickness) with a microtome (Letiz 1600 Saw microtome), and stained with Hematoxylin and Eosin method. Qualitative histomorphometric assessments of the coded specimens were made by the same examiner twice with a Nikon light microscope (E-400, Japan) and digital photographs were obtained and recorded. The PDL reorganization, the presence/absence of root resorption, ankylosis and tooth vitality was investigated.

Results

Of the sixty teeth examined histologically, twenty samples were excluded due to loosening of mini-screws or brackets during the 15-week period of the study or technical difficulties throughout histological processing (4 in group I – 3 in group II - 12 in group III and 1 in group IV). As the drilling was discontinued after felting

resistance at insertion, the range of induced damage did not vary considerably among groups. The extent of damage was limited mostly to the minor penetration of miniscrews into the dentin.

Ankylosis

As it is shown at table 1, no sign of ankylosis was seen in the experimental groups; however, in some cases, osteoid sequesters were observed in the periodontal ligament. As the PDL demonstrated normal widths on either side, these sequesters were not considered as an ankylosis.

Tooth vitality

In order to categorize the grade of pulpal tissue inflammation, the percentage of inflammation in whole pulpal tissue at different microscopic magnifications was considered as the inflammation index. (Category I: less than 25% of total pulpal tissue; category II: between 25%-50% of pulpal tissue; category III: between 50%-75% of pulpal tissue; and category IV: greater than 75% of total pulpal tissue).

There were no sign of inflammation more than 25% in any of the samples. Pulpal tissue of the tooth with loosened mini-screw also demonstrated healthy and normal status (Table 1).

Table 1. Distribution of Ankylosis, pulp vitality and complete repair by secondary cementum in experimental groups.

		Group I	Group II	Group III	Control
Ankylosis	**yes**	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	no	16 (100%)	17 (100%)	8 (100%)	19 (100%)
Pulp vitality	**yes**	16 (100%)	17 (100%)	8 (100%)	19 (100%)
	no	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Complete repair by secondary cementum	**yes**	10 (62.5%)	9 (52.9%)	1 (12.5%)	
	no	6 (37.5%)	8 (47.1%)	7 (87.5%)	

PDL reorganization

Reorganization was evident due to formation of new periodontal ligament fibers, presence of new fibroblasts and new PDL cells. In the sample with loosed mini-screw, inflammation was present in more than 50% of periradicular tissues with areas of inflamed granulation tissues were found.

Repair of mini-screw defects with secondary cementum

Non uniform formation of secondary cementum was found in 62.5% of group I samples, 52.9% of group II samples and 12.5% of group III samples; which demonstrated the reverse relationship to the depth of injury. The greater the depth of injury, the less degree of healing and apposition of secondary cementum was evident (Figure 4 & Figure 5).

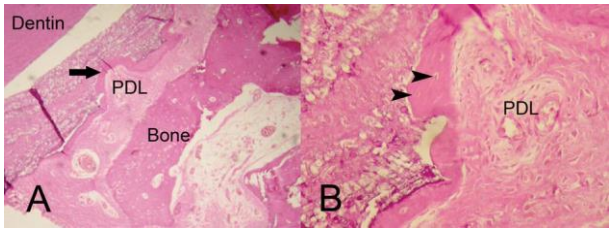

Figure 4. The defect is within the cementum and reorganized completely by secondary cementum.

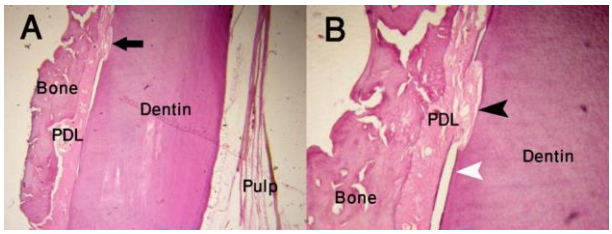

Figure 5. The defect has invaded dentin and has not covered completely by secondary cementum.

Statistical analysis

Considering no variation in measured principal dependent variables (no ankylosis, no pulp necrosis and root resorption), statistical analysis could not be performed

Discussion

As it is stated in the literature, when a miniscrew contact a tooth root structure, only minimal damage occurs.[32] The results of the present study demonstrated no sign of moderate to severe pulpitis, PDL and alveolar bone inflammation or necrosis after mini-screw contact with roots. However, varying degree of injuries and repair to periodontal tissues were observed.

An important factor in periodontal response to mini-screw contact is the actual distance between the mini-screw and dentin; the less distance between screw and dentin, the more the incidence and severity of root damage. Complete reorganization of periodontal ligament and cementum was observed when dentin was not invaded. As figure 5 shows, in this study varying degrees of repair by secondary cementum, (dentin damaged cases) can be attributed to the extent of the damage; the greater the extent of dentinal invasion the greater the probability of repair. Comparison of group I with group II, demonstrated that leaving the miniscrews in contact a root might have detrimental effect of healing process of cementum.

Previous clinical studies[28,34] and several animal studies.[27, 30] evaluated healing potential of periodontal tissues including cementum, PDL and alveolar bone after intentional injuries induced by mini-screws. In a clinical study premolar teeth were intentionally moved against the mini-screw. Resorptive root damage which was repaired by deposition of cellular cementum after discontinuation of the force was reported by Maino[34]. In another clinical study Kadioglu concluded that root surfaces that touch miniscrews show swift repair and almost complete healing within a few weeks after removal of the screw or the orthodontic force[28]. Asscherickx in a similar histologic examination reported complete repair of periodontal tissue in damaged roots by mini-screw invasion in a period of 12 weeks, following removal of the screws.[27] Renjen in another similar study reported no evidence of external root resorption and inflammatory infiltrate or necrosis in the pulp tissue; however only in cases of severe injury with displacement of root fragments ankylosis was noted.[29]

In addition, varying degrees of root damage depends on how mini-screw insertion was attempted. Compare to oblique angulation, severe root damage by self drilling mini-screws tip in a perpendicular direction is unlikely. Herman and cope demonstrated less than 0.25 mm surface indentation in this regard.[10] However, severe root damage with complete separation of root fragments was reported by Renjen et al, when root invaded by mini-screw in an oblique manner,.[29]

More severe root damages might be attributed to other etiologic factors accompanying mini-screw insertion. Furthermore, there is a body of evidence that shows that tooth pulp damage after dentinal injury is unlikely. Notching into the dentin caused new cementum formation without pulp damage[35] and even apical transection of one root of a multi rooted tooth in dogs did not cause pulp necrosis. [35] Yaghmaiee *et al.* [36] reported that the pulp of multi-rooted teeth remained vital after apical transection of the tooth roots in dogs. We discontinued drilling after resistance was felt and periapical x-ray confirmed close contact with the root to emulate clinical condition. Detection of alterations in placement resistance of self-drilling miniscrews with sharpened tips (which are designed to facilitate their placement) compared to self-tapping miniscrews seems to be more difficult. This early detection would avoid severe root damage that could occur during placement; however, if drilling is continued after contact with tooth root, the displacement of the root might cause PDL compression on the opposite aspect of the root which may increase the risk of ankylosis in the opposite side of PDL, consequently. Resistance increases gradually as the miniscrew is placed, but will be sharply differ when the miniscrew contact or penetrate into the root structure.[32] Applicaton of 2-dimensional radiographs is not considered appropriate since they overestimate the presence of contact with root surface. [10,32]

The most commonly reported complications of clinical mini-screw application are screw loosening (76%), soft-tissue overgrowth/irritation (69%), and irritation caused by auxiliary springs (67%).[37] There were no reported cases of tooth ankylosis or pulp necrosis. Unusual response to mini-screw invasion (ankylosis, pulp necrosis) can be attributed to other possible contributors of tissue damage during mini-screw placement *e.g.* insertion torque (the greater the torque, the greater the possibility of injury or mini-screw fracture), microbial contamination of mini-screw surface, tooth movement against the screw, diameter of the screw (the greater the diameter, the greater the risk of injury), duration of mini-screw contact with tooth root, and the variable healing potential of host periodontal tissues. [28,30,33]

Sufficient sample size and randomization technique so that each premolar tooth in each quadrant has the same chance to be in each experimental group was attempted to strengthening the power of the study. The most important limitation in our study was unavailability of 3D radiography. We inserted mini-screws in an angle to

hit the root; tactile sensation and two dimensional x-ray was used to confirm mini-screw-root contact, but sever root damage was detected in few samples. In the clinical situation, if screw-root contact was suspected, redirection of the screw or assistance of a more accurate technique (3D imaging) helps avoiding tissue damage.

Conclusion

- Ankylosis, pulp necrosis and severe root resorption are not common clinical outcomes when mini-screw contacts the root.
- Repair after contact with mini-screw depends on the severity of invasion; the greater the depth of the invasion, the greater the probability of repair.

References

1. Umemori M, Sugawara J, Mitani H, Nagasaka H, Kawamura H. Skeletal anchorage system for open-bite correction. Am J Orthod Dentofacial Orthop 1999; 115:166-74.

2. Sherwood K, Burch J, Thompson W. Closing anterior open bites by intruding molars with titanium miniplate anchorage. Am J Orthod Dentofacial Orthop 2002; 122:593-600.

3. Erverdi N, Keles A, Nanda R. The use of skeletal anchorage in open bite treatment: a cephalometric evaluation. Angle Orthod 2004; 74:381-90.

4. Kuroda S, Katayama A, Takano-Yamamoto T. Severe anterior open-bite case treated using titanium screw anchorage. Angle Orthod 2004; 74:558-67.

5. Kravitz ND, Kusnoto B, Tsay TP, Hohlt WF. The use of temporary anchorage devices for molar intrusion. J Am Dent Assoc 2007; 138:56-64.

6. Kang YG, Nam JH, Park YG. Use of rhythmic wire system with miniscrews to correct occlusal-plane canting. Am J Orthod Dentofacial Orthop 2010 ; 137:540-7.

7. Lim SM, Hong RK. Distal movement of maxillary molars using a lever-arm and mini-implant system. Angle Orthod 2008; 78:167-75.

8. Oberti G, Villegas C, Ealo M, Palacio JC, Baccetti T. Maxillary molar distalization with the dual-force distalizer supported by mini-implants: a clinical study. Am J Orthod Dentofacial Orthop 2009; 135:282-3.

9. Chung KR, Kim SH, Choo H, Kook YA, Cope JB. Distalization of the mandibular dentition with mini-implants to correct a Class III malocclusion with a midline deviation. Am J Orthod Dentofacial Orthop 2010; 137:135-46.

10. Herman R, Cope JB. Miniscrew implants: IMTEC mini ortho implants. Semin Orthod 2005; 11:32-9.

11. Wehrbein H, Feifel H., Diedrich P. Palatal implant anchorage reinforcement of posterior teeth: A prospective study. Am J Orthod Dentofacial Orthop 1999: 116:678-86.

12. De Clerck H, Geerinckx V, Siciliano S. The Zygoma Anchorage System. J Clin Orthod 2002; 36:455-9.

13. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. J Clin Orthod 1983 ;17:266-9.

14. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg 1998; 13:201-9.

15. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH. Clinical application of micro-implant anchorage. J Clin Orthod 2002; 36:298-302.

16. Kravitz ND, Kusnoto B. Risks and complications of orthodontic miniscrews. Am J Orthod Dentofacial Orthop 2007; 131:S43-51.

17. Choi HJ, Kim TW, Kim HW. A precise wire guide for positioning interradicular miniscrews. J Clin Orthod 2007; 41:258-61.

18. Suzuki EY, Suzuki B. Accuracy of miniscrew implant placement with a 3-dimensional surgical guide. J Oral Maxillofac Surg 2008; 66:1245-52.

19. Kim SH, Choi YS, Hwang EH, Chung KR, Kook YA, Nelson G. Surgical positioning of orthodontic mini-implants with guides fabricated on models replicated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2007; 131:S82-9.

20. Kravitz ND, Kusnoto B, Hohlt WF. A simplified stent for anterior miniscrew insertion. J Clin Orthod 2007; 41:224-6.

21. Ludwig B, Glasl B, Lietz T, Kopp S. Radiological location monitoring in skeletal anchorage: introduction of a positioning guide. J Orofac Orthop 2008; 69:59-65.

22. Suzuki EY, Buranastidporn B. An adjustable surgical guide for miniscrew placement. J Clin Orthod 2005; 39:588-90.

23. Reddy KB, Kumar MP, Kumar MN. A grid for guiding miniscrew placement. J Clin Orthod 2008; 42:531-2.

24. Cousley RR, Parberry DJ. Surgical stents for accurate miniscrew insertion. J Clin Orthod 2006; 40:412-7.

25. Schnelle MA, Beck FM, Jaynes RM, Huja SS. A radiographic evaluation of the availability of bone for placement of miniscrews. Angle Orthod 2004; 74:832-7.

26. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop 2006; 129:721.e7-12.

27. Asscherickx K, Vannet BV, Wehrbein H, Sabzevar MM. Root repair after injury from mini-screw. Clin Oral Implants Res 2005; 16:575-8.

28. Kadioglu O, Büyükyilmaz T, Zachrisson BU, Maino BG. Contact damage to root surfaces of premolars touching miniscrews during orthodontic treatment. Am J Orthod Dentofacial Orthop 2008; 134:353-60.

29. Renjen R, Maganzini AL, Rohrer MD, Prasad HS, Kraut RA. Root and pulp response after intentional injury from miniscrew placement. Am J Orthod Dentofacial Orthop 2009; 136:708-14.

30. Rinaldi JC, Arana-Chavez VE. Ultrastructure of the interface between periodontal tissues and titanium mini-implants. Angle Orthod 2010; 80:459-65.

31. Brisceno CE, Rossouw PE, Carrillo R, Spears R, Buschang PH. Healing of the roots and surrounding structures after intentional damage with miniscrew implants. Am J Orthod Dentofacial Orthop 2009; 135:292-301.

32. Hembree M, Buschang PH, Carrillo R, Spears R, Rossouw PE. Effects of intentional damage of the roots and surrounding structures with miniscrew implants. Am J Orthod Dentofacial Orthop 2009; 135:280-1.

33. Lee YK, Kim JW, Baek SH, Kim TW, Chang YI. Root and bone response to the proximity of a mini-implant under orthodontic loading. Angle Orthod 2010; 80:452-8.

34. Maino BG, Weiland F, Attanasi A, Zachrisson BU, Buyukyilmaz T. Root damage and repair after contact with miniscrews. J Clin Orthod 2007 ;41:762-6.

35. Garrett S, Bogle G, Adams D, Egelberg J. The effect of notching into dentin on new cementum formation during periodontal wound healing. J Periodontal Res 1981; 16:358-61.

36. Yaghmaiee M, Yavari AS, Mashhadiabbas F, Bahrami A, Farnia P, Sharifi D, et al. Histological assessment of pulp condition after apical vital root transection in one root of multirooted teeth in dogs: a preliminary study. J Endod 2007; 33:1061-5.

37. Hyde JD, King GJ, Greenlee GM, Spiekerman C, Huang GJ. Survey of orthodontists' attitudes and experiences regarding miniscrew implants. J Clin Orthod 2010; 44:481-6.