Tissue reaction surrounding miniscrews for orthodontic anchorage: An animal experiment

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Abstract  Background/purpose: Nowadays, mini-implant anchorage is incorporated for achieving a variety of orthodontic treatment goals. However, when a miniscrew is located in the interdental area, potential root contact may lead to miniscrew mobility or even failure. Therefore, miniscrew/root contact and possible tissue responses, including root repair, were histologically investigated in the current study.

Materials and methods: Eight miniscrews were surgically placed in a single dog mandible. Among these, four miniscrews (experimental group) were intentionally placed in contact with a root and then retained for different time durations, three (control group) were also intentionally placed in contact with a root but were immediately removed after insertion, and one was placed without root contact and was retained for 24 weeks. The animal was sacrificed after 24 weeks.

Results and conclusions: (1) Tissue surrounding roots damaged by a miniscrew showed a significant inflammatory response. (2) Root resorption was occasionally observed after 3 weeks following insertion of a miniscrew even if the miniscrew was not in direct contact with the root. (3) Root repair was noted with a cementoblast lining along the resorption surface at as early as 3 weeks after miniscrew insertion. Alveolar bone filled in the lesion when the root damage was large so that the contour of the alveolar bone followed that of the damaged root, with the width of the periodontal ligament space being maintained. (4) Stable miniscrews were mainly those which did not contact adjacent roots, and for which the surrounding tissue showed only a small inflammatory response with some extent of direct bone contact around.

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the miniscrew. On the contrary, most of the failed miniscrews were those which had direct contact with adjacent roots, and which exhibited severe tissue inflammation and were covered by thick layers of soft tissue. Failure was detected 3 weeks after insertion. Surprisingly, the epithelial lining surrounding the miniscrews might not have spontaneously resolved 6 weeks after screw removal. Persistent infection in the sinus tract was noted, and this would require attention.

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Introduction

Reliable and convenient anchorage is important for efficient and successful orthodontic treatment. Orthodontic implants, including miniscrews and miniplates, provide stable and reliable anchorage for orthodontists to produce various kinds of tooth movement, including anterior retraction, posterior protraction, whole-arch distalization, intrusion of the anterior or posterior teeth, and molar uprighting.1–6 Mini-implants also minimize a patient’s compliance, which used to be critical for attaining certain treatment goals with the long-term use of headgear or intraoral elastics. Furthermore, both insertion and removal of mini-implants are simple procedures, and mini-implants can be loaded with an orthodontic force after 2–3 weeks of healing following insertion instead of several months for conventional dental implants, which require osseointegration.7–11

However, despite the convenience and desirable treatment effects of mini-implants, they have certain inherent disadvantages as do all other treatment modalities. Surgical insertion of mini-implants is an invasive procedure compared to conventional anchorage devices. The potential risk of damaging adjacent roots when a mini-implant is inserted into interdental areas is a concern, especially if there is a narrow interdental area, or an atypical root morphology is noted.12,13 In addition, correct judgment of root angulation requires knowledge and experience. Most importantly, if a patient cannot maintain fair oral hygiene around the mini-implant area, inflammation of the surrounding soft tissue might result in mini-implant failure.14

In a previous animal study, we showed that miniscrews contacting a root were at greater risk of failure. Those screws exhibited a lower removal torque and higher mobility, and were surrounded by a greater volume of soft tissue. The purpose of this study was to comprehensively investigate the surrounding tissue response following miniscrew insertion with or without direct root contact at the histological level using an animal model.

Materials and methods

One mongrel dog was used in the study for a histological analysis. The housing, care, and experimental protocols were in accordance with guidelines of the Medical Institutional Animal Care and Use Committee of National Taiwan University (approval no. 20030017). All procedures were performed under general anesthesia. The miniscrews used in this study were pure titanium, 2.0 mm in diameter and 11 mm long (Leibinger, Muhlheim-Stelten, Germany). A pilot drill with a diameter of 1.5 mm was used before miniscrew insertion.

Eight miniscrews were surgically placed in the mandible. Among these, four miniscrews (the experimental group) were intentionally placed in contact with a root, and were retained for variable periods, became mobile, and were lost, and then were allowed to heal for 1, 3, 6, and 15 weeks (E1, E2, E3, and E4, respectively). Three miniscrews (root contact:RC) were also intentionally placed in contact with a root but were immediately removed after insertion, and the area was allowed to heal for 3, 12, and 24 weeks, while another one (no root contact:NRC) was placed without root contact and was retained for 24 weeks.

At the end of the 24-week experiment, the animal was sacrificed with a 4% paraformaldehyde perfusion under deep anesthesia. After the animal was sacrificed, the head was removed and sectioned along the midsagittal plane. Radiographs were taken to evaluate the positions of the miniscrews relative to adjacent roots and the associated damage. Mandible blocks were obtained, and tissue preparations were subsequently performed with decalcification, paraffin-wax embedment, block sectioning, and hematoxylin and eosin staining. Prepared tissue slides were examined under a light microscope.

Results

In the current study, the longest period a miniscrew was retained in the oral cavity was 24 weeks without root contact. All miniscrews intentionally placed in direct contact with a root became mobile and were lost before the end of the intended experimental period. A significant inflammatory response of the surrounding tissue was commonly found when a miniscrew was placed in contact with a root.

According to histological observations, tissues surrounding a screw retained without contacting a root were relatively healthy except for mild inflammation with some lymphocyte infiltration at the more-coronal mini-implant/tissue interface (Fig. 1, screw no root contact). Layers of connective tissue surrounded by small dilated blood vessels were also noted in the soft tissues. In more-apical portions of the interface, greater direct bony contact was noted.

For those miniscrews with direct root contact, acute inflammation with active root resorption was a common
finding after a healing time of 1 or 3 weeks. Severe inflammation with bacterial clusters, polymorphonuclear neutrophil leukocyte infiltration, and active root resorption at adjacent sites were obvious findings. Although some amorphous woven bone was seen around the screw, most of the interface was filled with inflammatory tissues. Histological findings of screws retained for more than 8 weeks and then lost due to excessive mobility revealed root resorption of the second premolar was observed on the surface close to the screw hole with cementoblast lining (arrowheads in the enlarged view) along the resorption lacunae, indicating ongoing cementum repair. (G) On the other side of the screw hole, a major root concavity was noted which indicated resorption at the distal surface of the first premolar, even though no direct root contact of the miniscrew was observed. The adjacent alveolar bone filled in the concavity along the root surface with the width of the periodontal ligament space remaining constant. No evidence of ankylosis was found. (H) In a more-lingual section, the screw hole was entirely surrounded by alveolar bone with little evidence of inflammation, which is in contrast with (A) and (E) at more-coronal portions of the implant tissue interface. In (A), the screw hole was surrounded by soft tissue layers. In (E), it was partly surrounded by alveolar bone and partly by soft tissue. The direct bony contact of the miniscrew at a more-apical level of the interface and the minimal inflammation of surrounding tissue assured its stability throughout the entire experimental period. Scale = 100μm.

Figure 1  Histological findings of a successful miniscrew which was inserted mesially to the second premolar for 24 weeks. This miniscrew remained stable and was immediately removed before the animal was sacrificed. (A) The screw hole was close to the mesial side of the second premolar without direct contact with the root. (B) The screw hole was surrounded by thick layers of soft tissue with only mild infiltration of lymphocytes. (C), (D) Where the screw emerged into the oral cavity, the epithelial lining which circled the screw head portion was thin and non-keratinized. Chronic inflammation was more obvious at the conjunction zone of the non-keratinized epithelium with the normal keratinized oral epithelium. (E), (F) In a more-lingual section, the screw was in close proximity with both the first and second premolars without obvious evidence of root contact. However, root resorption of the second premolar was observed on the surface close to the screw hole with cementoblast lining (arrowheads in the enlarged view) along the resorption lacunae, indicating ongoing cementum repair. (G) On the other side of the screw hole, a major root concavity was noted which indicated resorption at the distal surface of the first premolar, even though no direct root contact of the miniscrew was observed. The adjacent alveolar bone filled in the concavity along the root surface with the width of the periodontal ligament space remaining constant. No evidence of ankylosis was found. (H) In a more-lingual section, the screw hole was entirely surrounded by alveolar bone with little evidence of inflammation, which is in contrast with (A) and (E) at more-coronal portions of the implant tissue interface. In (A), the screw hole was surrounded by soft tissue layers. In (E), it was partly surrounded by alveolar bone and partly by soft tissue. The direct bony contact of the miniscrew at a more-apical level of the interface and the minimal inflammation of surrounding tissue assured its stability throughout the entire experimental period. Scale = 100μm.
damage with severe inflammatory reactions and active bone remodeling, and woven bonelike tissues close to the screw hole was still present after 3 weeks of healing (Fig. 2, screw E2).

If the healing period was increased to 6 weeks, the inflammation became chronic in nature with masses of lymphocyte infiltration and large amounts of dilated blood vessels. Surprisingly, a sinus tract with an epithelial lining

Figure 1 (continued).

Figure 2  Histological findings of a failed miniscrew, E2, which was inserted mesially to the third premolar for 9 weeks. Afterwards, the screw was lost, and healing took place for 3 weeks before the animal was sacrificed. Acute inflammation in the surrounding tissue was noted with bacterial clusters (asterisk), polymorphonuclear neutrophil leukocyte infiltration, and a large amount of dilated blood vessels (A). Root resorption at an adjacent site was obvious. An irregular cementum outline (B) and dense connective tissue around the root apex (C) seem to indicate ongoing repair. Amorphous woven bone (D) around the screw (arrows: osteoclasts; arrowheads: osteoblasts), and the interface was filled with inflammatory tissues after 3 weeks of healing. Scale in (A) = 100μm; same magnification for (B), (C) and (D).
was found along the screw hole with acute inflammatory signs which would likely allow constant bacterial infections (Fig. 3, screw E3). When more healing time was allowed (up to 15 weeks), only residual chronic inflammation remained. Nevertheless, only soft tissues had undergone repair (Fig. 4A, B; screw E4).

The healing process was also observed 24 weeks after a root had intentionally been damaged by inserting a screw which was immediately removed (Fig. 4C, D, screw RC). Alveolar bone filled in the concavity of the damaged root, while a sound periodontal ligament space was maintained. There were no active resorptive cells on the root or bone, but some residual lymphocyte infiltration was noted.

Discussion

Factors related to the success of miniscrews were widely investigated and revealed the importance of a proper location of the miniscrew, the quantity and quality of the alveolar bone, the condition of the surrounding soft tissue, and the miniscrew dimensions. In our previous and current studies, emphasis was put on the miniscrew/root contact and its relationship with miniscrew success. Our results suggest that successful miniscrews are usually those with no direct contact with the root, showing a small inflammatory response, and with some direct bony contact around the miniscrews. On the contrary, failed miniscrews were mostly

![Figure 3](image_url)

Figure 3  Histological findings of a failed miniscrew being inserted in the furcation area of the lower right third premolar which was prematurely lost 6 weeks after insertion; the wound was allowed to heal for another 6 weeks before the animal was sacrificed. (A) Chronic inflammation in the surrounding tissue was noted with masses of lymphocyte infiltration and a large amount of dilated blood vessels. Acute inflammation with clusters of neutrophils (arrow in B) can also be seen. The neutrophils indicated an ongoing bacterial infection (asterisk in B), which was assumed to have been carried along the miniscrew via the sinus tract with its epithelial lining (arrows in C and D). Scale in (A) and (B) = 100μm; (B) is with the same magnification for (C) and (D).
those with direct root contact, which caused severe tissue inflammation, and which were surrounded by a thick layer of soft tissue. The mobility of such miniscrews often increased with time, and loss of miniscrews could be seen at as early as 3 weeks.

Our results suggest that when a miniscrew hits an adjacent root, various extents of root damage and inflammatory responses around the miniscrew subsequently occur. Most of the inflammation was chronic, but in the presence of bacteria, acute inflammation was often seen as well. Sinus tracts were occasionally noted along the miniscrew, through which bacteria could migrate in from the oral cavity. Therefore, if a miniscrew fails, curettage and debridement of the surrounding soft tissue are recommended during the removal procedure to eliminate any possible existing sinus tracts for better tissue healing. Indeed, a dimple of a soft-tissue defect was sometimes found in the patient after screw removal (Fig. 5).

Miniscrew/root contact often results in direct or indirect root external surface resorption. If there was significant inflammation around the miniscrew and the miniscrew was in close proximity but without contacting the root, there may have been some irregular resorption lacunae along the adjacent root surface. This kind of indirect root resorption

Figure 4  (A, B) Histological findings of a failed miniscrew (E4) being inserted in the furcation area of the lower right second premolar and prematurely lost 9 weeks after insertion; the wound was allowed to heal for another 15 weeks before the animal was sacrificed. There was still some residual chronic inflammation remaining around the previous insertion site. Only the soft tissues exhibited repair. (C, D) Histological findings of an insertion site of a miniscrew (RC) after it was inserted and immediately removed. This wound was allowed to heal for 24 weeks before the animal was sacrificed. Ingrowth of the alveolar bone into the root’s concave defect was obvious. However, a well-preserved periodontal ligament space was maintained. Some residual chronic inflammatory cells were still present more coronally (arrow in D). Scale in (B), (C) and (D) =100μm.
Miniscrews without direct root contact usually exhibited better stability. A certain extent of direct alveolar bone/screw contact was found in sections from successful miniscrews. Root resorption was occasionally observed even if the miniscrew did not directly contact a root. This kind of root resorption could be seen 3 weeks following miniscrew insertion. Types of tissue in direct contact with stable miniscrews varied. Some areas of the screw were surrounded by almost-complete layers of soft tissue, some were partly covered by soft tissue and partly by hard tissue, and some were mostly enclosed by alveolar bone. It is possible for a miniscrew to be surrounded by different types of tissue at different levels relative to the insertion depth. The osseointegration of mini-implants is not as necessary as with conventional dental implants, which makes their removal relatively easier after orthodontic treatment, and a certain extent of bony contact was found to be beneficial to miniscrew stability.

In conclusion, although some studies advocated that there might not be many complications of clinical significance when a root is damaged by a miniscrew, root contact should still be avoided during miniscrew insertion, especially when the dentition is crowded and the inter-dental space is limited, to prevent root damage and consequent tissue inflammation and miniscrew failure. If miniscrew/root contact is noted, the miniscrew should immediately be removed to avoid further resorption of the cementum or alveolar bone. Curettage of the inflamed tissue when a screw is lost or removed is highly recommended to eliminate formation of a residual epithelial lining trapped inside the healing wound.

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