Root and Bone Response to the Proximity of a Mini-Implant under Orthodontic Loading

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ABSTRACT

Objective: To determine the histological reaction of the root and bone as a mini-implant approaches the root.

Materials and Methods: Two kinds of mini-implants were inserted into the buccal alveolar bone of 4 beagles (2 males and 2 females). The specimens were classified as the near-root group, the PDL contact group, the root contact group, and the root perforation group. Cementum resorption, dentin resorption, cementum repair, cementum growth, ankylosis, root cracking, and root fracture were assessed as the implant neared the root.

Results: The incidence of root resorption increased when the mini-implant was less than 0.6 mm from the root in the near-root group and PDL contact group. Root cracking and root fracture occurred in the root contact group and root perforation group. Bone resorption and ankylosis were observed in some specimens. However, some specimens of the PDL contact group and root contact group had cementum growth or little root resorption despite proximity to the root. In the root perforation group, root resorption and ankylosis occurred on the side opposite the insertion.

Conclusions: There is a risk of root contact and severe tissue damage from a thick mini-implant and the drilling procedure, either of which can induce root resorption or ankylosis. Use of smaller mini-implants may reduce root contact and tissue damage. However, the small mini-implant may need enhancement of its stability. (*Angle Orthod.* 2010;80:452–458.)

KEY WORDS: Mini-implant; Proximity; Root; PDL; Root resorption; Ankylosis

INTRODUCTION

The orthodontic mini-implant has some advantages for orthodontic anchorage,[1] providing application to various sites because of its small size[2] and simple operative procedure.[3] However, there are some risks such as implant fracture and loosening, and injury to the surrounding tissue.[4] Root contact may occur if the mini-implant is placed between the roots. This is one of the reasons that clinicians hesitate to use this device.[5]

The interdental space can be evaluated using a CT to provide safe insertion of the mini-implant.[6] The orthodontic mini-implant is usually inserted from the buccal side between the second premolar and first molar for maximum anchorage. The interdental space between these teeth at 5 mm from the alveolar crest is usually about 3.0 mm. This space might be insufficient for a mini-implant having a diameter of 1.2 mm to 2.0 mm. Although root contact can be prevented by operating carefully and using a radiograph, CT, or surgical stent, the mini-implant may be close enough to the root to histologically affect the root and surrounding tissue. Another study using 236 screws for intermaxillary fixation showed that root contact occurred 27.1% of the time.[7]

With prosthodontic implants, surgical stents have been used to avoid damage to adjacent structures and to guide placement of the implant.[8] Surgical stents have also been applied for palatal implants as orthodontic anchorage.[9,10] A guide wire has been used for safe insertion of an orthodontic mini-implant.[11]

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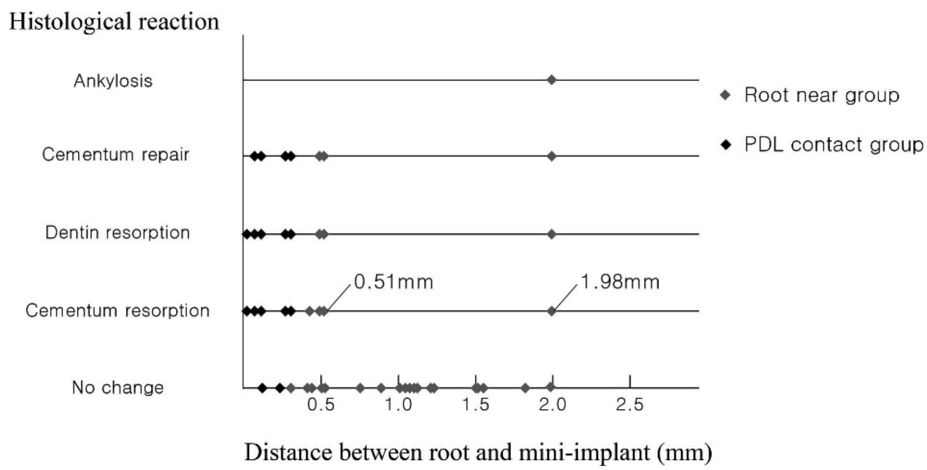

Figure 1. Histological reaction as the distance between the root and the mini-implant of the near-root group and the PDL contact group. The incidence of root resorption increased when the mini-implant was less than 0.6 mm from the root.

However, there is the possibility of root contact because the space between roots is limited.

Root proximity of the mini-implant may induce problems such as failure of the device.[12] Root contact of the mini-implant can cause devitalization of the tooth.[7] The friction of inserting a mini-implant into bone can initiate an inflammatory reaction around the mini-implant, resulting in damages to the bone tissue.[13,14] Inflammation around the root can induce external root resorption.[15]

There may also be direct root contact, which can affect the stability of the mini-implant.[16] The damaged root might be influenced by the periodontal ligament (PDL), the cementoid calcified tissue, or the bone to heal.[16–18] Ankylosis can occur on the resorbed root.[16] However, there are few studies reporting the histological evaluation of root proximity, PDL contact, root contact, or root perforation by a mini-implant or the distance required to induce a histological reaction of the root. Therefore, this study was designed to evaluate the histological reaction of the root, PDL, and bone tissue at various root proximities of the mini-implant and the distance needed to stimulate a histological reaction in the beagle.

MATERIALS AND METHODS

Mini-implants 1.6 mm in diameter and 6.0 mm in length were inserted into the buccal surface of the maxilla and mandible of 4 adult beagles (2 males and 2 females) after drilling to a depth of about 3.0 mm with a 1.0-mm bur to facilitate insertion. Orthodontic loading was applied by a force of 200 g–300 g using a Ni-Ti coil spring between the mesial and distal implants 1 week after insertion.

The subjects were sacrificed for histological evaluation 16 weeks after insertion of the mini-implants. The specimens were fixed, dehydrated sequentially, and embedded in a light-curing resin. The embedded specimens were sliced and ground to 40 μm–50 μm thickness using the Exakt system (Exakt Apparatebau, Nordstedt, Germany).[19] The specimens were stained with hematoxyline and eosin (H-E). The histological observation was performed using an Olympus BX51 microscope (Olympus Co, Tokyo, Japan), which was connected to a computer.

After preparation of the specimens, they were classified as to root proximity. The specimens were divided into four groups: a near-root group—less than 2.0 mm from the root, a PDL contact group—contacted the PDL but not the root, a root contact group—contacted the root on only one side of the mini-implant, and a root perforation group—contacted the root on both sides of the mini-implant. The reason for using less than 2 mm for the near-root group was that the distance between the mini-implant and the root would be less than 2 mm when inserting the 1.6-mm diameter implant. (The interdental space at 5 mm below the alveolar crest at the buccal is about 2.3 mm–3.8 mm.[6]) Cementum resorption, dentin resorption, secondary cementum repair, cementum growth, ankylosis, bone resorption, root cracking, and root fracture were evaluated as reactions to tissue damage by the mini-implant. In the near-root group and the PDL contact group, assessment of cementum resorption, dentin resorption, cementum repair, and ankylosis was done according to the distance between the root and the mini-implant.

RESULTS

Many of the mini-implants remained under orthodontic load independent of root contact. The success rate was not evaluated because root proximity could not be accurately assessed before preparation of the specimens, and the radiographs could not assure the accuracy of the root proximity assessment.

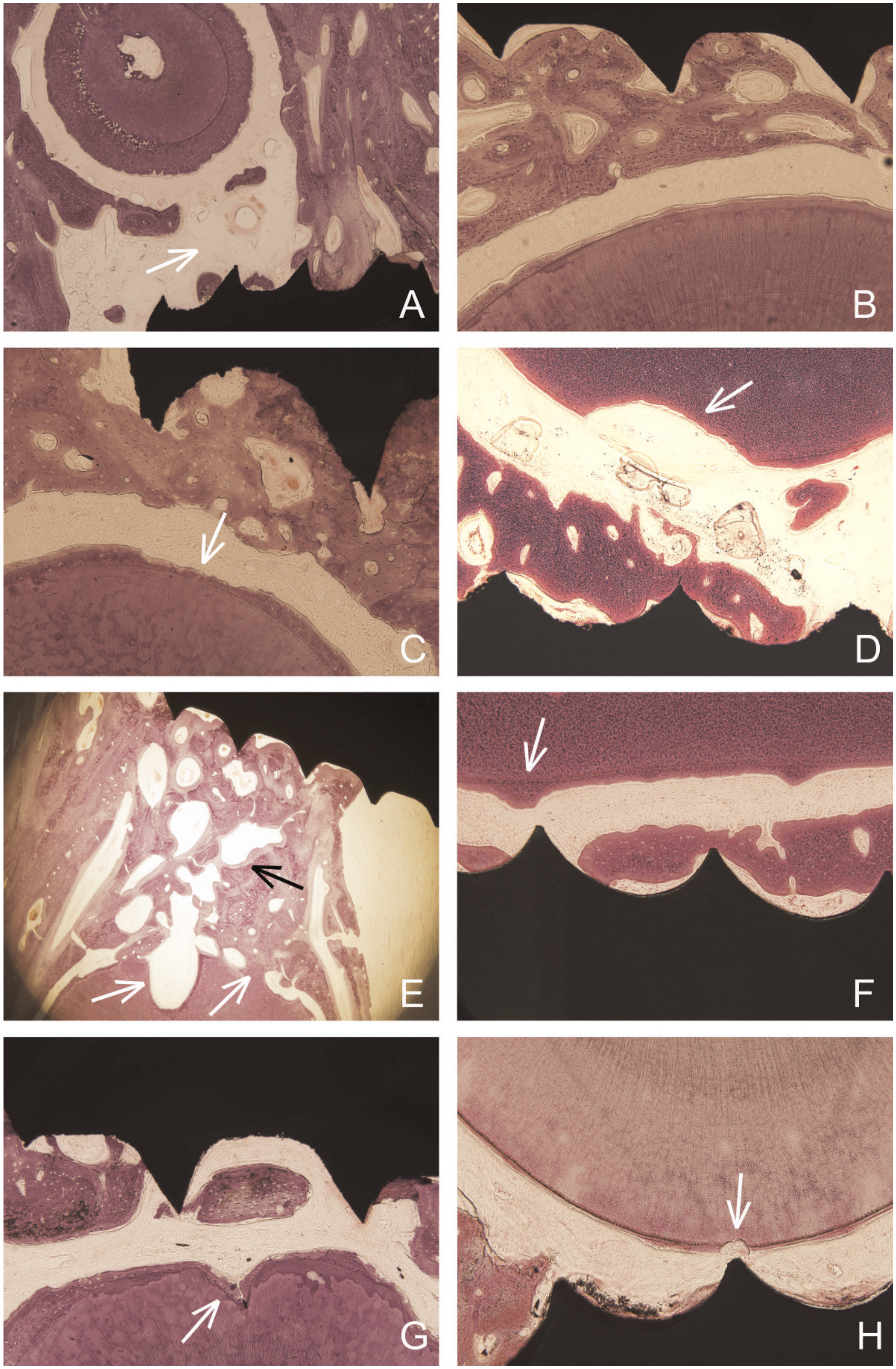
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Table 1. Histological Reaction of Each Group

Group	Number	Histological Reaction (Number, %) Cementum Resorption	Dentin Resorption	Cementum Repair	Cementum Growth	Ankylosis	Bone resorption	Tooth cracking	Tooth fracture
Near-root group	24	4 (16.67%)	3 (12.50%)	2 (8.33%)	1 (4.17%)	1 (4.17%)	2 (8.33%)	0 (0.00%)	0 (0.00%)
PDL contact group	7	5 (71.42%)	5 (71.42%)	4 (57.14%)	1 (14.28%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Root contact group	8	8 (100.00%)	8 (100.00%)	8 (100.00%)	0 (0.00%)	1 (12.50%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Root perforation group	7	7 (100.00%)	7 (100.00%)	3 (42.86%)	0 (0.00%)	2 (28.57%)	0 (0.00%)	6 (85.71%)	1 (14.29%)
Total	46	24 (52.17%)	23 (50.00%)	17 (36.96%)	2 (4.35%)	4 (8.70%)	2 (4.35%)	6 (13.04%)	1 (2.17%)

The 46 specimens were composed of 24 in the near-root group, 7 in the PDL contact group, 8 in the root contact group, and 7 in the root perforation group (Table 1). Cementum resorption occurred in 52.17% of all specimens, although the near-root group showed less cementum resorption (16.67%) than the other groups. In the near-root and PDL contact groups, the incidence of cementum resorption increased when the distance between the mini-implant and the root was less than 0.6 mm (Figure 1). However, some specimens of the near-root and PDL contact groups showed cementum growth.

Near-Root Group

Although there was no root resorption in some specimens whose roots were as near the mini-implant as 1.09 mm and 0.42 mm (Figure 2A, B), other specimens showed resorption in the cementum and dentin (Figure 2C, D). The incidence of root resorption increased when the mini-implant was less than 0.6 mm from the root, (Figure 1). There was bone resorption between the mini-implant and the root (Figure 2A). One specimen showed root resorption and ankylosis even though the mini-implant was 1.98 mm away from the root (Figure 1E).

PDL Contact Group

Although there was no root resorption, there was cementum growth in one specimen (Figure 2F); most specimens of the PDL contact group showed root resorption (Figure 2G, H). The resorbed dentin was repaired with secondary cementum (Figure 2G). However, a specimen wherein the mini-implant was close to the root showed minimal root resorption (Figure 2H).

Root Contact Group

All specimens in the root contact group showed root resorption (Figure 3A,C,E). There was extensive root resorption around the mini-implants (Figure 3C). The bone tissue grew toward the resorbed root, and ankylosis occurred between the resorbed root and the bone.

Root Perforation Group

Although there was a partial root fracture (Figure 3F), most specimens showed localized root cracks around the mini-implant (Figure 3G,H). There was ankylosis and root resorption on the side opposite the mini-implant insertion (Figure 3H).

DISCUSSION

Although mini-implants have been used as effective anchorage, there have been few studies about their side effects such as anatomical damage. Some studies have reported that root contact of the mini-implant might reduce its stability.[13] Most of the mini-implants in this study sustained a load of about 300 g for 16 weeks. This might mean that implant stability depends on the condition of the bone around it and bone remodeling, although root contact of the mini-implant can affect stability.

Resorption of cementum and dentin occurred in the near-root and PDL contact groups (Figure 2C,D,G,H), meaning that proximity of the mini-implant to the root can cause root resorption,[16] although secondary cementum repaired the resorbed roots. There was a tendency for lacunae to form on the resorbed root surfaces (Figures 2H, 3B), which is similar to bone

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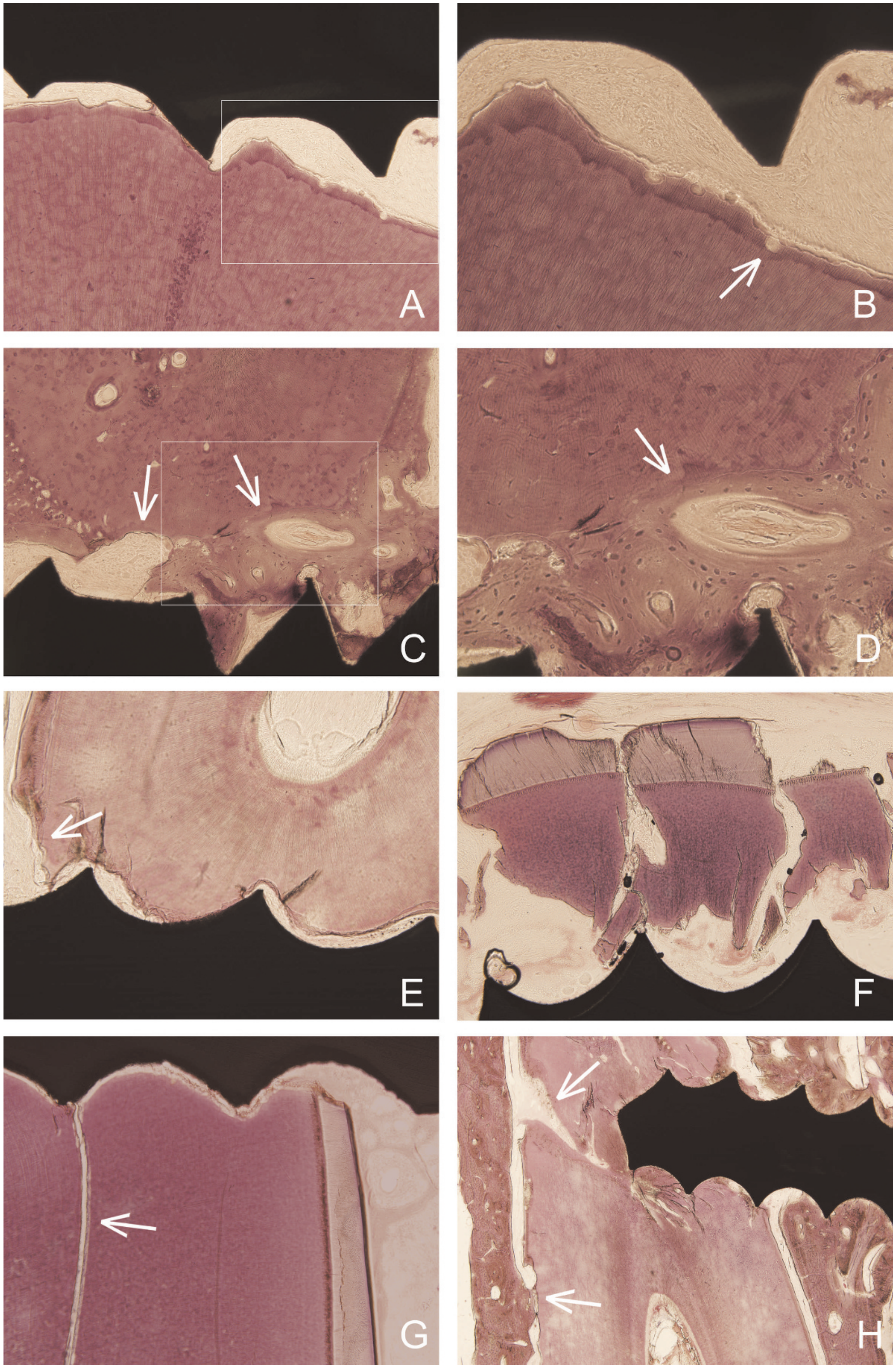
Figure 2. Specimens of the near-root group and the PDL contact group (H-E staining). (A–E) PDL near group. (A) Bone resorption (arrow) between root and mini-implant (original magnification ×4). (B) Sound root despite being close to mini-implant (about 0.42 mm) (original magnification ×10). (C) Slightly resorbed cementum (arrow) (original magnification ×10). (D) Resorbed cementum and dentin (arrow) (original magnification ×10). (E) Bone remodeling (black arrow), resorbed root (left white arrow), and ankylosis (right white arrow) of root 1.98 mm from mini-implant (original magnification ×4). (F–H) PDL contact group. (F) Cementum growth without resorption (arrow) (original magnification ×10). (G) Broad dentin resorption following cementum repair (arrow) (original magnification ×10) (H) Minimal root resorption with lacunae (arrow) (original magnification ×10).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resorption.[20] Small lacunae seemed to initiate extensive bone resorption. The stimulus to the PDL by the mini-implant may trigger a reaction such as defense and repair of the root.

In the near-root and PDL contact groups, cementum growth occurred (Table 1; Figure 2F), meaning that being close to the mini-implant can cause the root to undergo not only cementum resorption, but also cementum growth. The latter may be mildly stimulated to grow by a signal from the PDL.[21]

There may be precursor cells in the PDL[21,22] that differentiate into cementoclasts or cementoblasts from a signal. The root contact group showed greater root resorption and cementum repair than the root perforation group, which had close contact with the root and the microcrack or fracture (Figure 3). This means that the root contact group was nearer the PDL so might be more affected by differentiated cells such as cementoclasts or cementoblasts from the PDL than the root perforation group.[21,23]

Root resorption almost occurred within 0.6 mm from the mini-implant (Figure 1), which means that a mini-implant closer than 0.6 mm from the root can stimulate root resorption. Therefore, the implant should be placed more than 0.6 mm from the root. Because the interdental space between the second premolar and the first molar is usually about 3.0 mm,[6] it might be difficult to obtain sufficient distance from the root with a thick mini-implant. A thin mini-implant would be more likely to reduce root damage, although there is increased risk of instability.

There was bone resorption (Figure 2A) and bone remodeling with root resorption and ankylosis (Figures 2E, 3C). This means that severe bone damage during insertion of the mini-implant can cause active bone remodeling and induce root resorption. If the PDL barrier is extensively injured and bone grows toward the resorbed root, the PDL cannot protect the root and ankylosis can occur, although ankylosis can have other causes (Figure 3C).[24]

In the root perforation instances, there was root resorption and ankylosis on the side opposite the insertion (Figure 3H), indicating that insertion pressure on the root can induce root resorption and ankylosis on the opposite side. To avoid root perforation, the path of insertion should be changed if resistance is felt because the root is harder than alveolar bone. The mini-implant per se does not have sufficient cutting power or hardness to perforate a root, but deep drilling may enable the min-implant to perforate the root. If drilling is limited to the hard cortical bone, there is less chance of root perforation.

There were few changes and little cementum growth in some specimens of the near-root and PDL contact groups (Figure 2B,F), meaning that root resorption might be triggered by a stimulus to activate the PDL in differentiating cementoclasts. Root resorption can be minimized if the mini-implant is inserted with minimal injury under the threshold triggering root resorption. Heavy damage during implant insertion may induce root resorption even though the device is far from the root (Figure 2E).

Reducing damage during insertion would help avoid extensive root resorption and other side effects such as ankylosis. Therefore, the insertion torque should be low to reduce the damage to the bone tissue and the root.[25] To reduce the stimulus to the PDL, it is important to place the mini-implant as far from the root as possible. A short, thin mini-implant with low insertion torque is recommended to avoid root contact and to reduce damage. However, a smaller mini-implant may have a lower success rate as orthodontic anchorage. To enhance the stability of the small mini-implant, it is helpful to improve the shape, thread, surface treatment, and insertion method.[14,25,26] The use of 3-D CT or an appliance to avoid root contact can be useful for safe insertion of the mini-implant.[6] Future studies should investigate how to enhance mini-implant stability and decrease damage during insertion.

CONCLUSIONS

- In the near-root and PDL contact groups, the incidence of root resorption increased when the distance between the mini-implant and the root was less than 0.6 mm.
- Bone resorption and ankylosis were observed in the near-root group.
- In the root perforation group, root resorption and ankylosis occurred on the side opposite the insertion. Some specimens in the PDL contact and root contact

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Figure 3. Specimens of the root contact group and the root perforation group (H-E staining). (A–E) Root contact group. (A) Broadly resorbed root repair (original magnification ×10). (B) Secondary root resorption with lacunae (arrow) (original magnification ×20). (C) Ankylosis (left arrow) after root resorption (right arrow) and bone growth (original magnification ×10). (D) Ankylosis of denuded dentin (arrow). (E) Extensive root resorption of contact area with PDL (arrow) (original magnification ×10). (F–H) Root perforation group. (F) Root fracture (original magnification ×10). (G) Crack parallel to root surface (arrow original magnification ×10). (H) Root resorption (upper arrow) and ankylosis (lower arrow) on side opposite insertion (original magnification ×4).

groups had cementum growth or little root resorption in spite of the mini-implant's being close to the root.
- Avoiding root contact and reducing bone damage may favor a decrease in root resorption and ankylosis. The smaller mini-implant may permit reducing root contact and tissue damage, although implant stability may need to be enhanced.
- We suggest that root perforation and tissue damage can be prevented by a minimum of drilling.

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