Timing of force application affects the rate of tooth movement into surgical alveolar defects with grafts in beagles

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Introduction: The purpose of this study was to investigate the influence of the timing of orthodontic force application on the rates of orthodontic tooth movement into surgical alveolar defects with bone grafts in beagle dogs. **Methods:** Twelve beagles were randomly divided into 2 groups according to the surgical procedure: alveolar osteotomy alone (control) or osteotomy with bone graft (experimental group). The maxillary second premolars were protracted for 6 weeks into the surgical sites: immediately, at 2 weeks, and at 12 weeks after surgery. The orthodontic tooth movement rates and alveolar remodeling concomitant with surgical defect healing were evaluated by model measurements and histomorphometry as well as microcomputed tomography and histology. One-way analysis of variance and the Scheffé post hoc comparison were performed for investigating the rates of orthodontic tooth movement and mineralized bone formation. **Results:** Both the orthodontic tooth movement rate and the mean appositional length of mineralized bone in the tension side of teeth were significantly accelerated when force was applied at 2 weeks in the control group and immediately in the experimental group ($P < 0.001$). The 2-week control group showed a dramatic increase in apposition rate during 4 to 6 weeks after force application, whereas the immediate protraction experimental group did within the first 3 weeks ($P < 0.001$). Decreased orthodontic tooth movement rates and reduced bone remodeling activities were apparent in the 12-weeks groups, especially in nongrafted defects. **Conclusions:** A bone graft into the surgical defect can not only allow immediate force application for accelerating orthodontic tooth movement with favorable periodontal regeneration, but also decrease the risk of inhibited orthodontic tooth movement in case of delayed force application after surgery. (Am J Orthod Dentofacial Orthop 2014;145:486-95)

Accelerated tooth movement aided by alveolar surgery such as osteotomy,[1] corticotomy,[2] alveolar distraction,[3] selective decortication,[2] and minimally invasive cortical activation[4] has been popularized in orthodontic practices to shorten treatment periods. Among these, alveolar segmental osteotomy as an intentional surgery is widely used for various purposes during orthodontic treatment.[1,5] Its benefits are faster retraction or intrusion of target teeth followed by immediate esthetic improvement, and minimizing anatomic limitations that impede orthodontic tooth movement (OTM) such as poor bone quantity and quality associated with insufficient cancellous remodeling, poor periodontal support, already resorbed or short roots, and severely uprighted incisors surrounded by thin cortices.[5,6] Moreover, it has the potential to provide a solution for more challenging patients with constricted alveolar ridge after extractions, alveolar defects caused by trauma, or alveolar cleft, if combined with bone graft procedures.[7-9]

As bone graft materials and techniques have been innovated in tissue engineering, accelerating tooth movement into the alveolar osteotomy site can be ensured in practice with healthy defect regeneration. A few studies have tried OTM into a bone defect area with bone grafts[9,10] but they focused on defect regeneration, graft stability, and any side effects around the moved teeth or the periodontium.[11-15]

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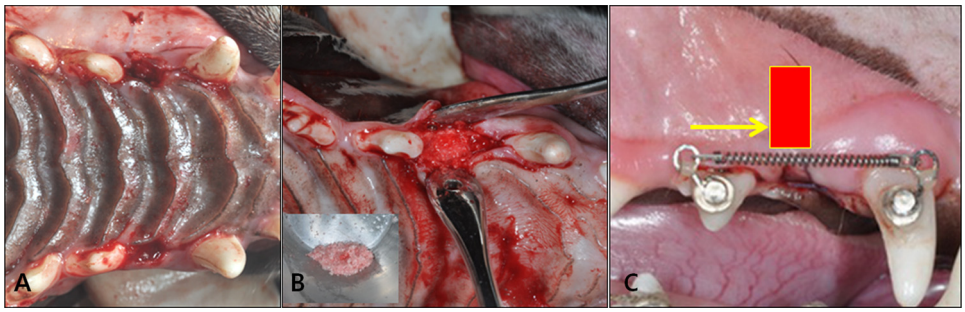

Fig 1. The surgical procedures and orthodontic force application: **A,** extraction of the first premolar and surgical defect formation; **B,** application of graft materials; **C,** application of the orthodontic appliance. The second premolar was protracted toward the surgical site.

There was no investigation on the rate of OTM in relation to the graft characteristics or orthodontic force characteristics. Inconsistent experimental setups among studies, especially regarding protocols of orthodontic force application, made it difficult to obtain guidelines for clinical applications.

An osteotomy or a bone graft cannot guarantee accelerated tooth movement. Immediately after segmental surgeries, OTM toward the surgical defect can be accelerated because of less tissue resistance associated with the regional acceleratory phenomenon. However, the accelerated rate decreases over time along with disappearance of the regional acceleratory phenomenon, and OTM into the surgical site might be inhibited if the postoperative orthodontic adjustment was not performed properly. To maximize the effects of accelerated tooth movement aided by alveolar surgery, a standardized protocol for postsurgical orthodontic intervention should be established based on the healing progression of surgical sites with or without a graft.

The aim of this study was to investigate the effect of the timing of orthodontic force application after surgery on the rates of OTM into surgical alveolar defects with bone grafts, considering the healing state of the surgical sites in beagle dogs.

MATERIAL AND METHODS

Twelve male beagles aged 18 to 24 months and weighing 10 to 13 kg were used for the experiments. They were randomly divided into 2 groups according to the surgical procedure: alveolar osteotomy alone (O, control group; n = 6) and osteotomy with bone graft (OG, experimental group; n = 6). Each group was further divided into 3 subgroups (n = 2) based on the timing of orthodontic force application: immediately (OG-0 and O-0), 2 weeks after surgery (OG-2 and O-2), and 12 weeks after surgery (OG-12 and O-12). The experimental protocols for each group were approved by the ethics committee on animal research of Kyung Hee University (KHMC-IACUC 11-007), Seoul, Korea, before the study.

The maxillary first premolars were extracted under general anesthesia by intramuscular injection of Zoletil 50 (0.25 mg/kg; Virbac Laboratory, Carros, France), and 4-walled critical size defects of approximately 5 mm (mesiodistal) × 5 mm (buccolingual) × 7 mm (vertical), including the extraction socket, were generated using a 2.0-mm round bur (Fig 1, *A*). The distal wall of each defect was approximately 1.5 mm mesial from the mesial root of the maxillary second premolars to prevent immediate fracture of the interseptal wall. In the osteotomy with bone graft groups, the defect was immediately filled with a 1:1 mixture of deproteinized bovine bone mineral (Bio-Oss; Geistlich Sons, Wolhusen, Switzerland) and demineralized bone matrix (OrthoBlast II; IsoTis, Irvine, Calif). The particles were mixed with saline solution and carefully packed to fill the bone defect (Fig 1, *B*). The mucosa was adjusted to allow full coverage of the surgical defect and subsequently sutured. After surgery, antibiotics (Gentamycin; Komipharm International Co, Shiheung, Korea) and anti-inflammatory analgesics (Ketopro; Uni Biotech Co, Chungnam, Korea) were administered via intramuscular injection twice daily for 6 days, and a 0.12% chlorhexidine gluconate solution dressing was applied simultaneously.

Orthodontic buttons (Ormco, Milwaukee, Wis) were bonded onto the labial surfaces of the maxillary canines (anchorage teeth) and the second premolars (target teeth) with Superbond C&B (Sun Medical, Shiga, Japan). To apply the force close to the center of resistance, an extension hook was connected to the orthodontic buttons. The second premolars were protracted mesially by a nickel-titanium closed-coil spring (light force; 3M Unitek, Monrovia, Calif) between the canine and the second premolar, exerting a force of approximately 100 g per side (Fig 1, *C*).[16,17] OTM was continued for 6 weeks in all groups.