Horizontal Alveolar Ridge Distraction Osteogenesis in Dogs: Radiographic and Histologic Studies

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Purpose: *This study was designed to evaluate the healing process in horizontal alveolar ridge distraction of the narrow alveolus in dogs.* ***Materials and Methods:*** *Six beagle dogs weighing approximately 9 to 10 kg were used in this experiment. Horizontal alveolar ridge distraction was performed in the right mandible, where the premolars had been extracted 12 weeks previously. Twelve days after the completion of distraction, the lengthening apparatus was removed. The distracted site was evaluated at 12 and 24 weeks after the removal.* ***Results:*** *At 12 weeks, thin woven bone was observed at the distracted site growing from the surface of the original lingual cortical bone toward the transport segment. At 24 weeks, the distracted site had fully changed into new mature lamellar bone, but the transport segments had been almost completely resorbed.* ***Discussion:*** *Horizontal alveolar ridge distraction was performed successfully in beagle dogs even though the apparatus was removed 12 days after the completion of distraction. The most important feature of this technique is the resorption of the transport segment.* ***Conclusion:*** *Horizontal alveolar ridge distraction can be a beneficial technique for augmenting the alveolar ridge horizontally in the buccolingually reduced alveolar process before the placement of implants.* Int J Oral Maxillofac Implants 2005;20:837–842

Key words: *alveolar ridge augmentation, alveolar ridge distraction, distraction osteogenesis*

Since 1996, distraction osteogenesis has become one of the techniques used to augment the alveolar ridge vertically for later dental implantation.[1] Many distraction devices have been developed for use with this technique.[2,3] This technique has 2 major advantages: it creates osseous build-up without bone transplantation, and soft tissue is formed simultaneously. Recently, some clinical case reports have been published concerning horizontal alveolar ridge distraction.[4,5] However, there are few basic studies concerning horizontal alveolar ridge distraction, and more study related to the healing process of distracted site is needed. In 2002, a report was published concerning a horizontal alveolar ridge distraction technique in narrow alveoli in dogs. In that study, osseointegration was achieved even though the implants were placed into the distracted site at 12 days after the completion of distraction.[6] Furthermore, the possibility that the transport segment would be resorbed 24 weeks after the placement of implants was noted. The present animal investigation was designed to evaluate the healing process in horizontal alveolar ridge distraction and to consider the progress of the transport segment.

MATERIALS AND METHODS

Animals and Care

All animal experiments were conducted according to the Guidelines for Animal Experimentation at Kobe University Graduate School of Medicine in Japan. Six beagle dogs weighing approximately 9 to 10 kg were used in this experiment. Throughout the study, the animals were fed a standard soft diet. Routine infiltration anesthesia (2% lidocaine hydrochloride with 1:80,000 epinephrine) followed systemic ketamine

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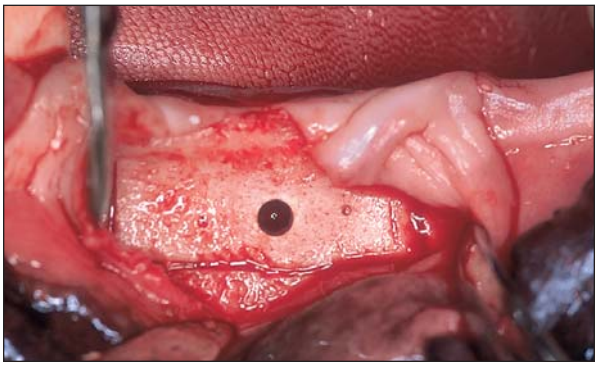


Fig 1a The transport segment was created by a buccal rectangular osteotomy and the hole for the distraction screw.

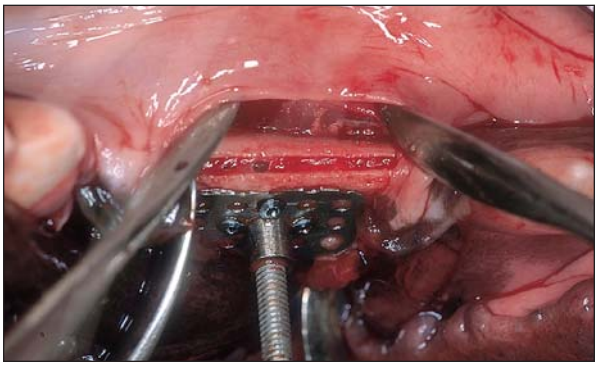


Fig 1b The distraction screw penetrated the transport segment toward the lingual cortical bone. The apparatus was fixed with microscrews.

Fig 1c The flaps were sutured, and the distraction screw was left protruding to the buccal.

Fig 1d After a 7-day latency period, distraction commenced at a rate of 1 mm per day by turning the distraction screw.

hydrochloride (10 mg/kg intramuscularly) and pentobarbital sodium (25 mg/kg intravenously) administration for all surgical procedures. For postsurgical infection control, the dogs received 1 million units of procaine penicillin intramuscularly for 3 days.

Experimental Design

Mandibular premolars were extracted from each dog, and narrow alveolar ridge models were created at week 12 when wound healing was complete. The 6 dogs were divided into 3 groups of 2 dogs. Group 1 was the control group. In this group, 12 weeks after premolar extraction, only the rectangular osteotomy was performed at the extracted site. The dogs were sacrificed 27 weeks after the osteotomy. Groups 2 and 3 were the experimental groups. In these groups, 12 weeks after the extraction of teeth, horizontal alveolar ridge distraction was performed. Twelve days after the distraction was completed, the apparatus was removed. The dogs were sacrificed 12 weeks after the removal of apparatus in group 2, and after 24 weeks in group 3.

Surgical Procedures

Distraction Osteogenesis. After 3 incisions across the alveolar ridge, the periosteum was elevated where the osteotomy was to be done. In group 1, the wound was closed after the buccal rectangular osteotomy. In groups 2 and 3, an original lengthening apparatus was placed following the osteotomy of the alveolar bone (Figs 1a and 1b). The flaps were repositioned and sutured, and the distraction screw was left protruding from the flaps (Fig 1c). After a 7-day latency period of soft tissue restoration, distraction commenced at a rate of 1 mm per day for 5 consecutive days to allow for horizontal elongation of 5 mm at the top of the crest (Fig 1d). In groups 2 and 3, 12 days after completion of the distraction, a crestal incision was made in the advanced gingiva, and the apparatus was removed.

Radiologic and Histologic Procedures. Radiographs were obtained immediately after removal of the apparatus and at 4-week intervals. At 12 and 24 weeks after apparatus removal, the animals were sacrificed and the mandibles were harvested. The specimens were dehydrated using a graded ethanol series (from 70% to 100%) and transferred to acetone prior to being embedded in methyl methacrylate resin (Wako, Osaka, Japan). The specimens were sectioned with a high-precision diamond disk at about 150 μm and ground to approximately 50 μm, then stained with toluidine blue. The coronal portions of the implants were examined under a light microscope.

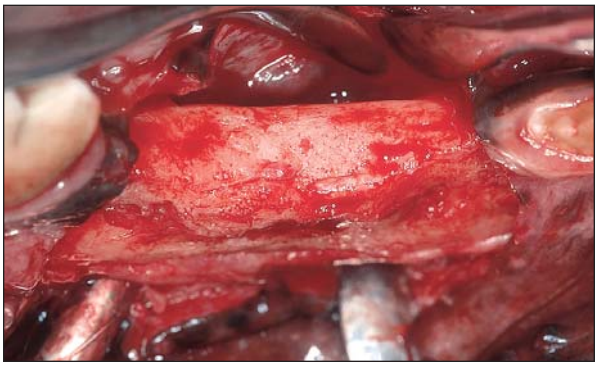


Fig 2a Newly formed bone was observed at the distracted site.

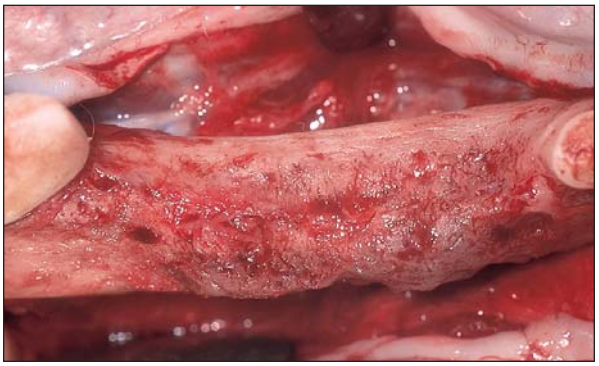


Fig 2b Twenty-four weeks after removal, cortical bone was seen at the distracted site.

RESULTS

Clinical Evaluation

Group 1. The dogs tolerated the surgical procedures well and showed no discomfort after the osteotomies. The alveolar ridge remained narrow.

Groups 2 and 3. The dogs in these groups also tolerated the surgical procedures well and showed no discomfort during the lengthening period or after distraction. Twelve days after the completion of distraction, the overlying oral mucosa had advanced horizontally, and the surface and color of the gingiva appeared to be normal. However, inflammation was observed around the distraction screw. The fibrous soft tissue of the distracted site felt elastically tense and was aligned in the same direction as the distraction. Twelve weeks after removal of the apparatus, no inflammation was observed at the gingiva. Newly formed bone was observed at the distracted site, and the edge of the transport segment still remained (Fig 2a). Twenty-four weeks after removal, cortical bone was observed at the distracted site, but the edge of the transport segment had disappeared, and almost the entire transport segment had been resorbed (Fig 2b).

Radiographic Evaluation

The radiographic findings immediately after placement of the apparatus showed the buccal rectangular osteotomy of the alveolar bone and the penetration of the distraction screw through the transport segment to the lingual cortical bone (Fig 3a). Twelve days after the completion of distraction, the transport segment was moved laterally and the distracted site showed a radiolucent appearance compared to the native mandibular bone (Fig 3b). In the axial radiographs taken 1 week after removal of the apparatus, no bone was observed at the distracted site, but bone defects were seen at the distraction screw site in the transport segment (Fig 3c). Four weeks after removal of the apparatus, newly formed bone was observed at the distracted site, and the transport segment still remained (Fig 3d). Eight weeks after the removal of the apparatus, obvious bone formation could be seen at the distracted site, but the transport segment had a tendency to be resorbed (Fig 3e).

Cross-section Radiographs. In the control group, the width of the buccal cortical bone where the osteotomy had been performed became thinner than that of the lingual (Fig 4a). In group 2, parallel columns of bone extending from the lingual bone toward the transport segment could be seen (Fig 4b). The hole of the distraction screw was clearly visible in the transport segment, and the transport segment had been resorbed considerably. In group 3, the distracted site had converted completely into new bone, and newly formed cortical bone was observed at the top of the crest. Furthermore, the hole of the distraction screw had disappeared, and almost all the transport segment had been resorbed (Fig 4c).

Histologic Evaluation

Group 1. In cross section, the buccal cortical bone became thinner than that of the lingual, and mature lamellar bone was observed at the top of the crest (Fig 5).

Group 2. In cross section, newly formed bone was observed at the distracted site (Fig 6a). Thin woven bone had developed from the lingual cortical bone toward the transport segment and became aligned in the same direction as the distraction (Fig 6b). The transport segment was partially resorbed, and soft tissue was observed at the hole of the distraction screw.

Group 3. In cross section, newly formed mature bone was observed at the distracted site (Fig 7a). Thick mature lamellar bone was observed from the surface of the lingual cortical bone and distracted area (Fig 7b), but almost the entire transport segment had disappeared.

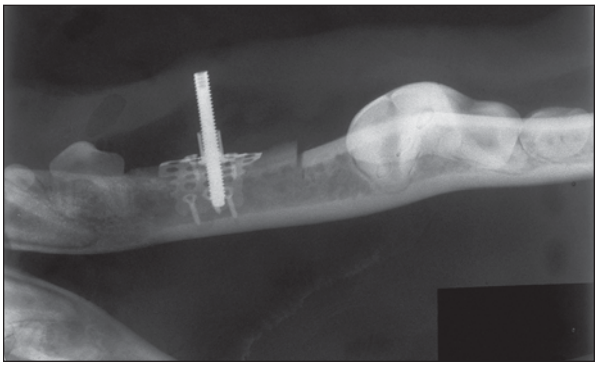


Fig 3a The distraction screw penetrated the transport segment toward the lingual cortical bone.

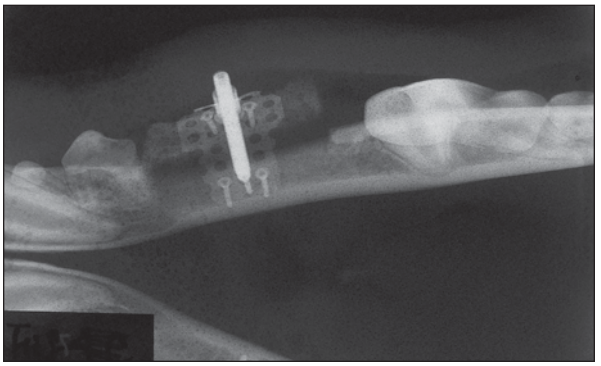


Fig 3b Twelve days after the completion of distraction, the transport segment had moved laterally.

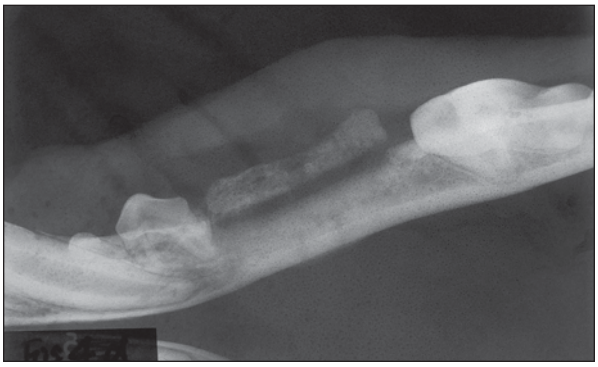


Fig 3c One week after removal, no bone was observed at the distracted site, and bone defect existed at the distraction screw site in the transport segment.

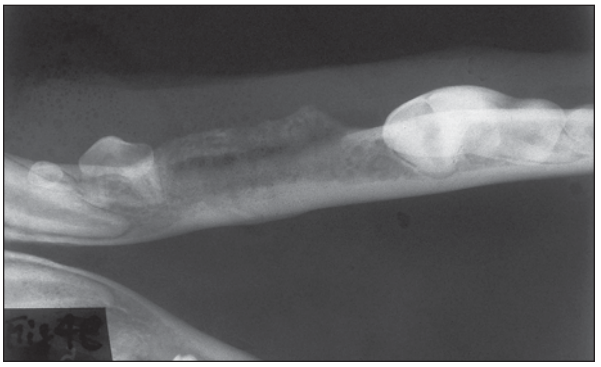


Fig 3d Four weeks after removal, newly formed bone was observed at the distracted site.

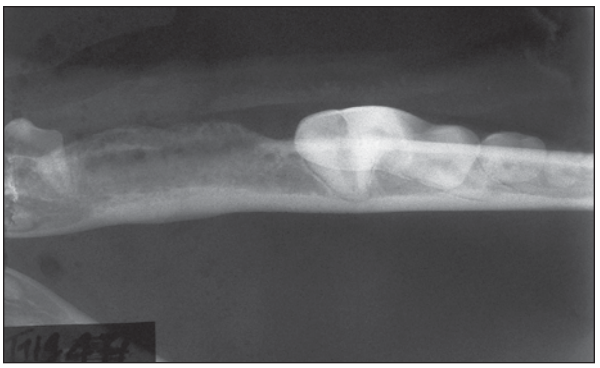


Fig 3e Eight weeks after removal, obvious bone formation could be seen at the distracted site, but the transport segment had a tendency to be resorbed.

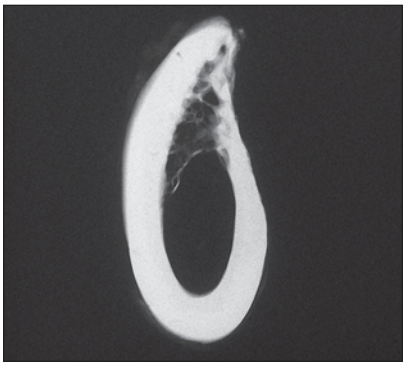


Fig 4a A specimen from group 1. The buccal cortical bone where the osteotomy had been performed became thinner than the lingual cortical bone.

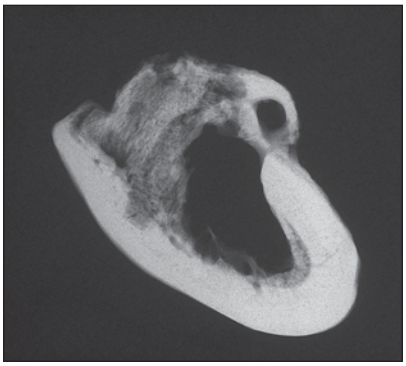


Fig 4b A specimen from group 2. Parallel columns of bone extending from the lingual bone toward the transport segment could be seen.

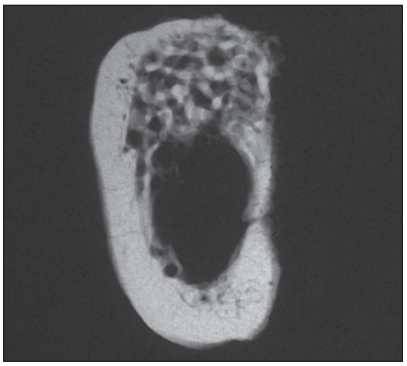


Fig 4c A specimen from group 3. The distracted site had converted completely into new bone, and newly formed cortical bone was observed at the alveolar crest.

Fig 5 A specimen from group 1. The buccal cortical bone became thinner than that of the lingual (toluidine blue; original magnification ×2).

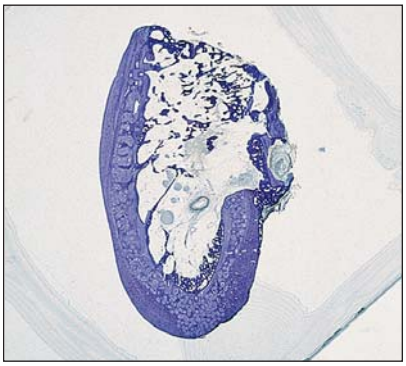


Fig 6a A specimen from group 2. Newly formed bone was observed at the distracted site (toluidine blue; original magnification ×2).

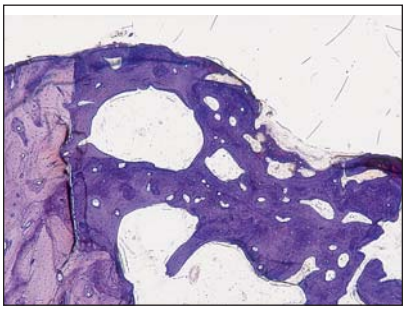
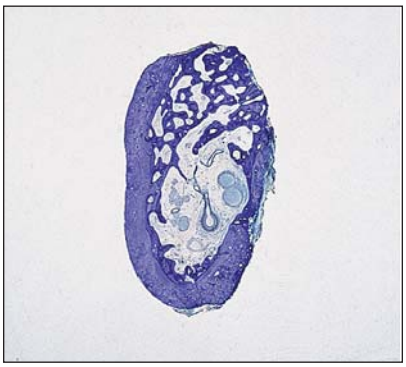
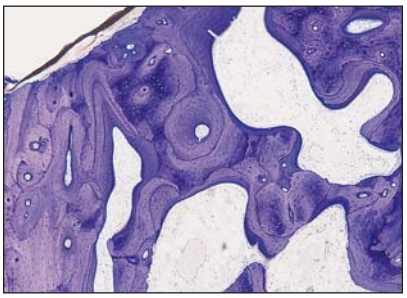


Fig 6b A specimen from group 2. Thin woven bone had developed from the lingual cortical bone (toluidine blue; original magnification ×80).

Fig 7a A specimen from group 3. Newly formed mature lamellar bone was observed at the distracted site (toluidine blue; original magnification ×2).

Fig 7b A specimen from group 3. Thick mature lamellar bone was observed from the surface of the lingual cortical bone (original magnification ×80).





DISCUSSION

In the vertical alveolar distraction technique, the distraction apparatus is usually removed 8 weeks after the completion of distraction.[1,7] But during the consolidation period, the risks of infection and discomfort related to the apparatus have been reported.[7] Therefore, following distraction, the apparatus should be removed as soon as possible. In this study, as the distraction screw penetrated the distracted area, the apparatus was removed 12 days after completion of the distraction to avoid infection. New bone forma-

tion could be observed at the distracted site from 8 weeks after the removal of apparatus. In group 2, the distracted site was transformed into thin woven bone despite the hole from the distraction screw remaining in the transport segment. In group 3, thick mature lamellar bone was observed at the distracted site. Horizontal alveolar distraction was performed successfully in the narrow alveolar ridge models in dogs even though the apparatus was removed early.

In group 1, buccal cortical bone became thinner than the lingual cortical bone; in groups 2 and 3, the transport segment had a tendency to be resorbed. These results suggest that the technique of the osteotomy for the transport segment led to interruption of the blood supply to the segment from the periosteum. Therefore, horizontal alveolar distraction should be performed until there is at least 5 mm of callus elongation, and implants should be placed within the distracted site to avoid the exposure of threads from the bone.

Neither infection nor wound dehiscence was observed during the study. Owing to the advancement of overlying gingiva at the distracted site, wound closure could be performed easily after the placement of implants. When bone transplantation,[8] guided bone regeneration,[9] or bone splitting[10] is applied in the narrow alveolar ridge, lack of soft tissue usually occurs, and the risk of infection and wound dehiscence increases. Therefore, the advancement of gingiva appeared to be one of the advantages of horizontal alveolar distraction.

It has been reported that implants placed in the distracted site during the consolidation period can achieve osseointegration.[6,11,12] The process of bone formation at the distracted site in this study was similar to that of bone adjacent to the implant. Thus, the placement of implants at the distracted site during the consolidation period never disturbed bone regeneration.

It was confirmed that the horizontal alveolar distraction technique can augment the narrow alveolar ridge and advance the overlying gingiva safely. However, the most important problem, resorption of the transport segment, still remains. To resolve this problem, improvement of the apparatus is required, but the authors believe that horizontal alveolar ridge distraction can be a beneficial technique for the placement of implants in the narrow alveolar ridge.

CONCLUSIONS

- Horizontal alveolar distraction was successfully performed in beagle dogs, even though the apparatus was removed 12 days after the completion of distraction.
- Newly formed bone was observed at the distracted site, and overlying gingiva was advanced enough for the placement of implants.
- The transport segment had a tendency to be resorbed; therefore, distraction should be performed excessively to address resorption of the transport segment.

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