Placement of Implants in Distraction Osteogenesis: A Pilot Study in Dogs

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This study investigated the possibility of achieving osseointegration of implants placed in a distracted site during the consolidation period. Four healthy male mongrel dogs were used in this experiment. A subperiosteal corticotomy around the mandible was performed between the left mandibular premolar and first molar. After a 7-day latency period for soft tissue healing, the distraction was performed at the rate of 1 mm per day for 14 consecutive days to allow for 14 mm of elongation, using an extraoral distraction device. Three weeks after the completion of distraction, screw-type implants were placed in the distracted site. Twenty-four weeks after placement of the implants, they were stable, and osseointegration had been achieved physically, radiographically, and histologically. These results suggest the possibility of shortening the period of implant treatment by using the distraction osteogenesis technique. (Int J Oral Maxillofac Implants 2000;15:185–192)

Key words: *bone regeneration, consolidation period, distraction osteogenesis, osseointegrated implant, osseointegration*

Distraction osteogenesis is a procedure developed over the past 40 years to reconstruct and lengthen the long bones.[1,2] Since 1992, this technique has been clinically applied to correct hemifacial microsomia,[3] micrognathia,[4] or craniofacial deformities,[5] and to repair segmental bone defects in the mandible.[6] This technique has the advantage of initiating new bone growth without bone transplantation and promoting the growth of soft tissues, such as overlying oral mucosa. However, since there are no teeth in the distracted site, patients must be treated with conventional dentistry (removable dentures) or implant-supported prostheses following the procedure. When patients are to be treated with implants, a period of at least 1 year after the completion of distraction is commonly allowed to permit the distracted site to convert into mature bone.[7] At present, there are few reports concerning implants placed in distracted sites,[8,9] and the most appropriate time for the placement of implants in the distracted site is not known. The purpose of this study was to investigate the possibility of achieving osseointegration of implants placed in distracted sites during the consolidation period.

MATERIALS AND METHODS

Animals and Care

The protocol and guidelines for this study were approved by the Animal Care and Use Committee of Osaka Dental University, Japan. Four adult male mongrel dogs in good systemic health were used in this study. The dogs weighed approximately 11 to 13 kg and were fed a standard soft diet throughout the study. Routine dental infiltration anesthesia (2% lidocaine hydrochloride with 1:80,000 epinephrine) followed systemic ketamine hydrochloride (10 mg/kg intramuscularly) and pentobarbital sodium

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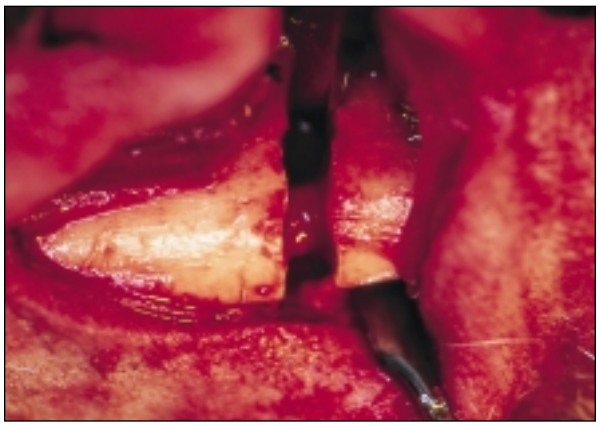


Fig 1 Preserved inferior alveolar nerve, artery, and vein bundle.

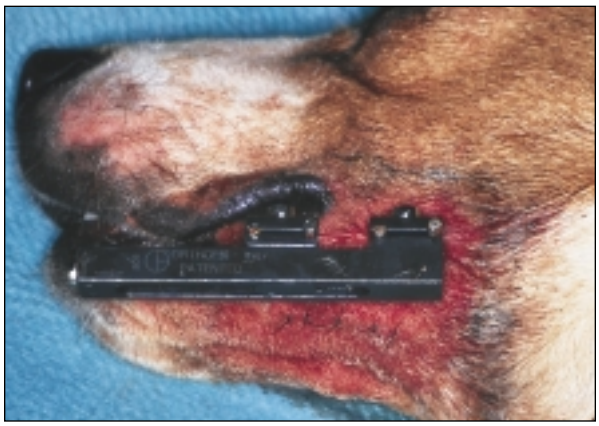


Fig 2 Lateral view immediately after surgery with the lengthening apparatus in place.

(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. The dogs showed no discomfort during the period of lengthening or after the placement of implants.

Surgical Procedures

Distraction Osteogenesis. After an external incision was made parallel to the mandible on the left side, circumferential elevation of the periosteum of the mandible was made where the corticotomy was to be done. The corticotomy around the mandible was performed using an electrical handpiece drill, with a fissure bur between the left mandibular premolar and the first molar. Following placement of 4 bicortical pins, an artificial fracture was created without injury to the inferior alveolar nerve, artery, or vein bundle (Fig 1). The periosteum and flap were repositioned and sutured. Finally, the lengthening apparatus (Orthofix, M-100, Verona, Italy) was connected to the pins (Fig 2). After a 7-day latency period for soft tissue healing, distraction was performed at the rate of 1 mm per day for 14 consecutive days to allow for elongation of 14 mm.

Implant Placement. Three weeks after the completion of distraction, the dogs were reanesthetized, a crestal incision at the advanced gingiva was made, and the soft tissue of the distracted site, which was yet to develop new mature bone, was exposed. After creating beds with a trephine bur (3.0 mm in outer diameter), screw-type implants (Astra Tech AB, Mölndal, Sweden; 8 mm in length and 3.5 mm in diameter) were placed in the distracted site. After placement of cover screws, the flap was repositioned and sutured.

Radiologic and Histologic Procedures

Lateral radiographs were obtained before and after distraction and at 4-week intervals following implant placement. The dogs were sacrificed 24 weeks after the placement of the implants.

A perfusion of saline solution from the carotid artery to the neck veins cleared the blood and fixed tissues with 70% ethanol. The mandibles were harvested, and after a soft-ray radiograph was taken, specimens involving the newly formed bone were sectioned. The specimens were dehydrated using a graded ethanol series (from 70% to 100%), stained with Villanueva (Maruto, Tokyo, Japan), and then transferred to acetone prior to embedding 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. The coronal portion of the implants was observed under a light microscope (Microphot-FXA, Nikon, Tokyo, Japan) and a confocal laser scanning microscope (CLSM) (LSM-GB 200, Olympus, Tokyo, Japan). The specimens harvested from the distracted site with the trephine bur were immediately fixed in 10% formalin, decalcified in formic acid, and embedded in paraffin. Five-µm-thick sections were cut, stained with hematoxylin-eosin, and observed under a light microscope.

RESULTS

Clinical Evaluation

The dogs tolerated the surgical procedures well and showed no discomfort during the period of lengthening or after the placement of implants. Displacement of the midline of the mandible to the right

side was observed after the completion of distraction (Fig 3). The overlying oral mucosa had advanced, and the surface and color of the gingiva appeared to be normal. There was no infection or inflammation (Figs 4a and 4b).

Three weeks after the completion of distraction, the tissue of the distracted site felt elastically hard, and the exposed fibrous soft tissue was aligned in the same direction as the distraction (Fig 5a). Creation of the beds with the trephine bur was uncomplicated (Fig 5b), and the hard tissues were felt to be in place. The stability of the placed implants was sufficient to maintain placement (Figs 5c and 5d).

Twelve weeks after placement of the implants, all fibrous soft tissue in the distracted site had healed, and the edges of the corticotomy could not be seen. The implants were fully embedded in new bone and were stable (Fig 5e).

The left side of the mandible, sectioned at 24 weeks after implant placement, was clearly elongated, the overlying soft tissues were normal, and the implants were stable.

Radiographic Evaluation

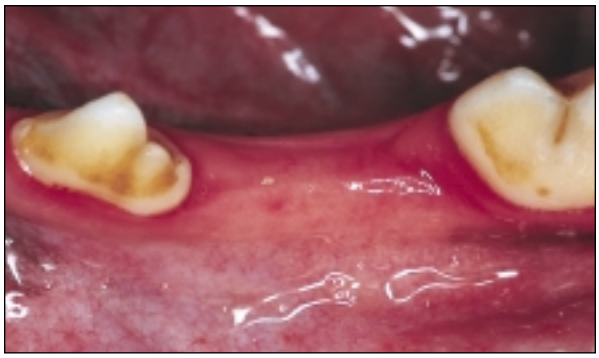
After the corticotomy around the mandible, a gap of approximately 2 mm was observed between the edges of the bone (Fig 6a). On axial radiographs taken 3 weeks after the completion of distraction, the edges of the distraction gap were clearly observed, and parallel columns of bone extending from the edges could be seen (Fig 6b). On lateral radiographs taken immediately after the placement of implants, no bone was observed either in the distracted site or around the implants, except for small columns of bone extending from the edges (Fig 7a). Four weeks after implant placement, the columns of bone had grown, but radiolucent areas were observed both in the central area and around the implants (Fig 7b). Twelve weeks after the placement of the implants, the distracted site had converted completely into new bone, and no radiolucent areas were observed either in the central area or around the implants (Fig 7c).

On axial radiographs taken 24 weeks after the placement of the implants, the left side of the mandible was clearly elongated. The lingual cortical bone of the distracted site could be observed clearly, and the union between the 2 edges was complete (Fig 8a). On lateral radiographs, no radiolucent areas were observed either in the central area or around the implants (Fig 7d). On cross-section radiographs of the specimen, cancellous bone, cortical bone, and the mandibular canal could be clearly observed (Fig 8b).

Histologic Evaluation

Hematoxylin-eosin stained sections, harvested from the distracted site with the trephine bur, demonstrated immature, thin, woven bone. In high-magnification photomicrographs, active osteoblasts could be seen on the surface of the woven bone (Figs 9a and 9b).

Fig 3 Frontal view after the completion of distraction. Note midline change.



Figs 4a and 4b Intraoral views of the distracted site. *(Left)* Before distraction. *(Right)* After the completion of distraction. The overlying oral mucosa appeared to be normal, and there was no infection or inflammation.

Figs 5a to 5e Surgical procedure of placement of implants and views of the distracted site.

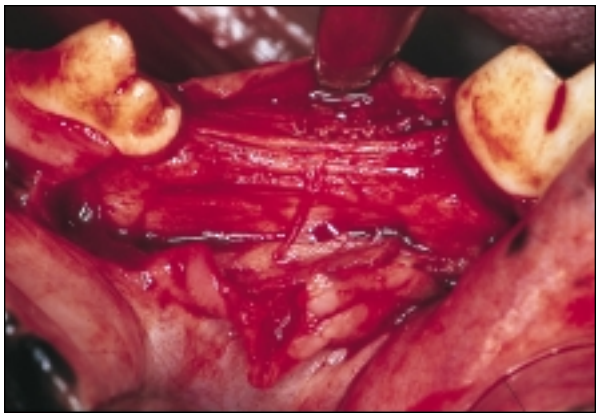


Fig 5a Exposed fibrous soft tissue of the distracted site 3 weeks after the completion of distraction. It was aligned in the same direction as the distraction.

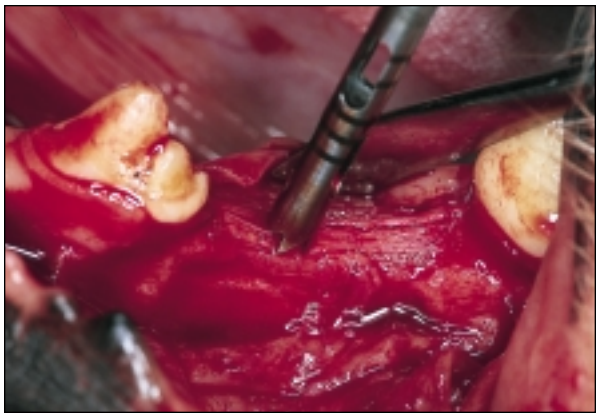


Fig 5b Creation of beds with the trephine bur.

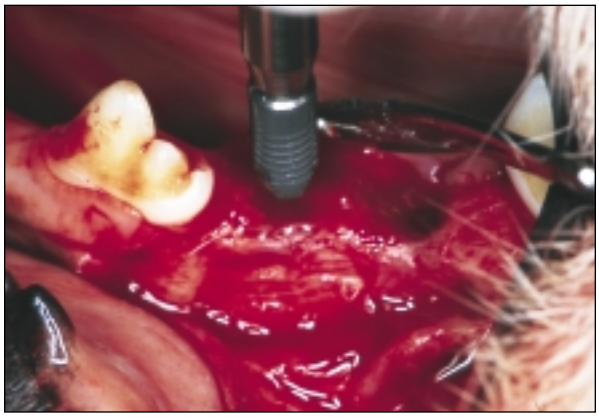


Fig 5c Placement of screw-type implants.

Fig 5d After the placement of implants, cover screws were placed.

Fig 5e Twelve weeks after the placement of implants.

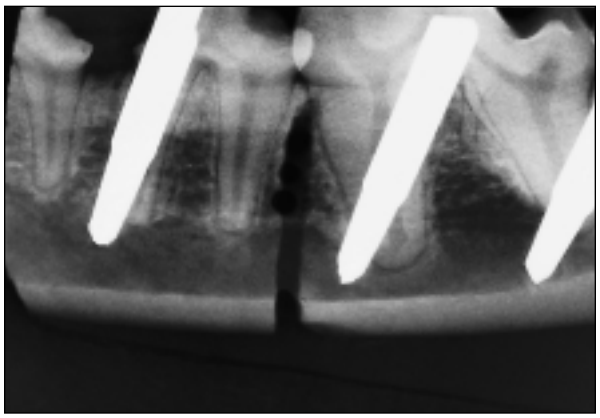


Fig 6a Radiograph taken immediately after the corticotomy.

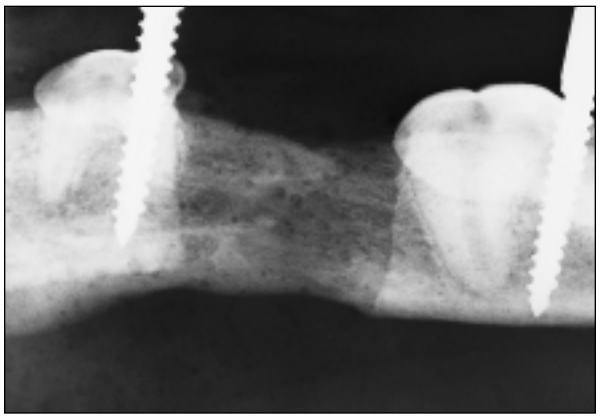


Fig 6b Axial radiograph taken 3 weeks after the completion of distraction. Parallel columns of bone extending from the edges of the site could be seen.

Figs 7a to 7d Lateral radiographs. New bone formation could be observed in the distracted site and around the implants as time progressed after the placement of implants.

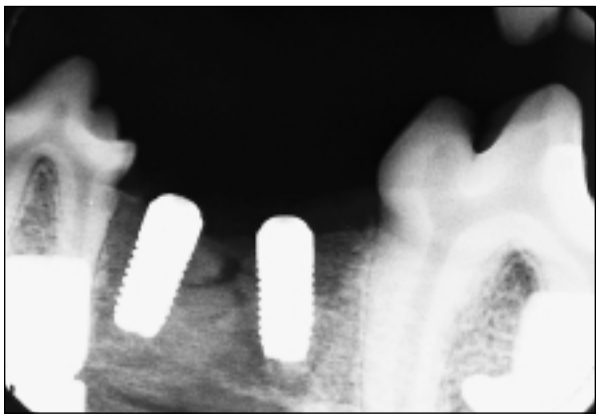


Fig 7a Immediately after the placement of implants. No new bone was observed either in the distracted site or around the implants, except for small columns of bone extending from the edges.

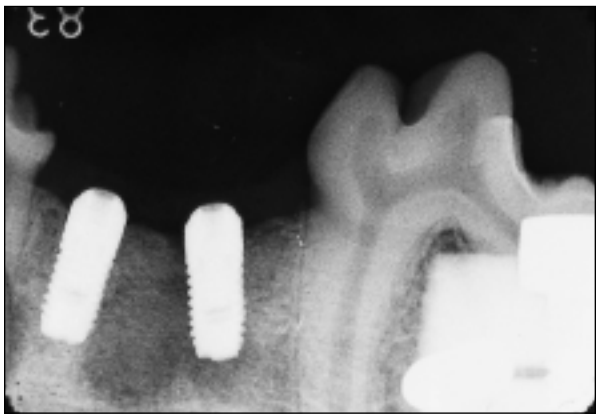


Fig 7b Four weeks after the placement of implants. Columns of bone had developed, but radiolucent areas were observed both in the central area and around the implants.

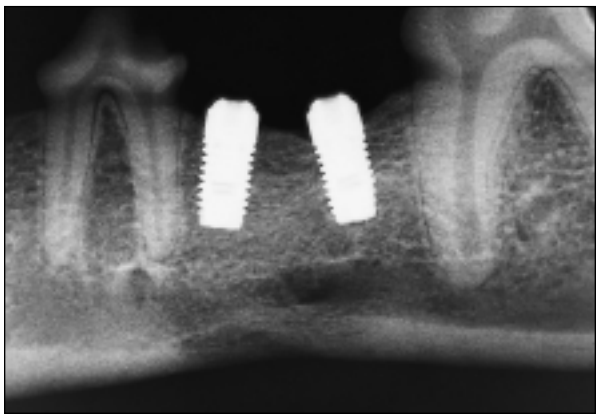


Fig 7c Twelve weeks after the placement of implants. The distracted site had converted completely into new bone, and no radiolucent areas were observed either in the central area or around the implants.

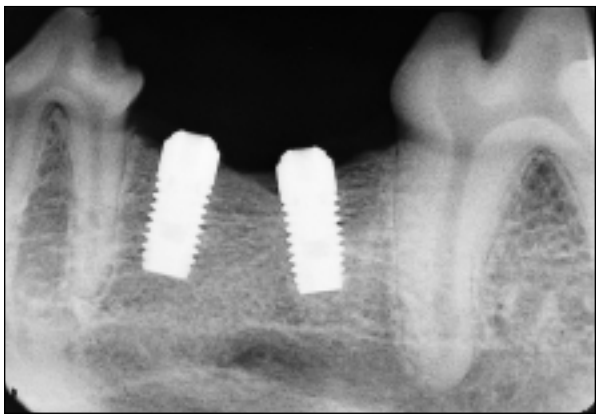


Fig 7d Twenty-four weeks after the placement of implants. The distracted site remained slightly more radiolucent than the preexisting mandible.

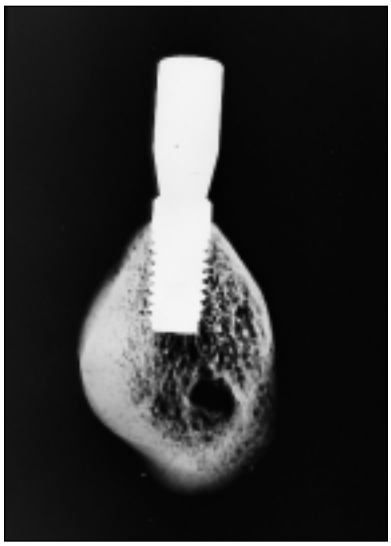
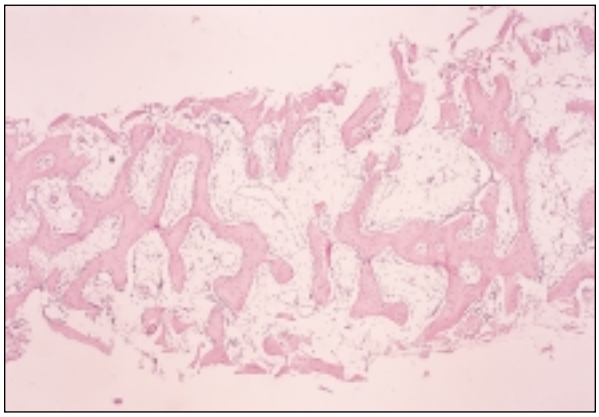
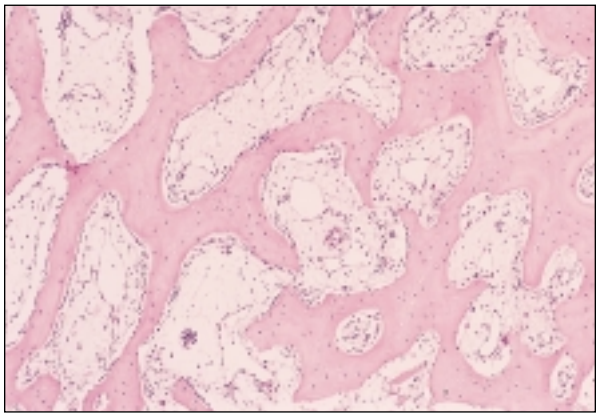


Fig 8a *(Left)* Axial radiograph 24 weeks after the placement of implants. The left side of the mandible was clearly elongated.

Fig 8b *(Right)* Cross-section radiograph 24 weeks after the placement of implants. Cancellous bone, cortical bone, and the mandibular canal were clearly observed.





Figs 9a and 9b Histologic appearance of the specimens harvested from the distracted site at 3 weeks after the completion of distraction. *(Left)* Immature thin woven bone could be seen (hematoxylin-eosin stain, original magnification ×10). *(Right)* Active osteoblasts are present on the surface of the woven bone (hematoxylin-eosin stain, original magnification ×80).

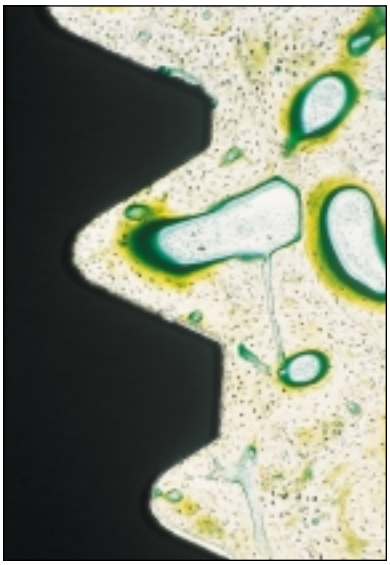
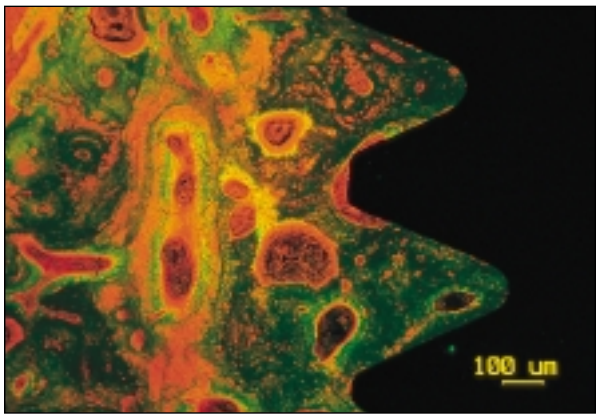
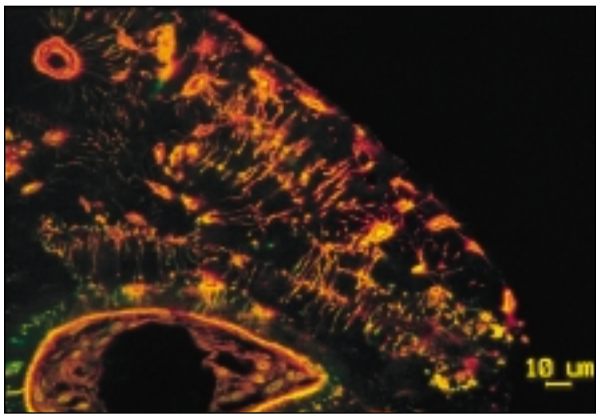
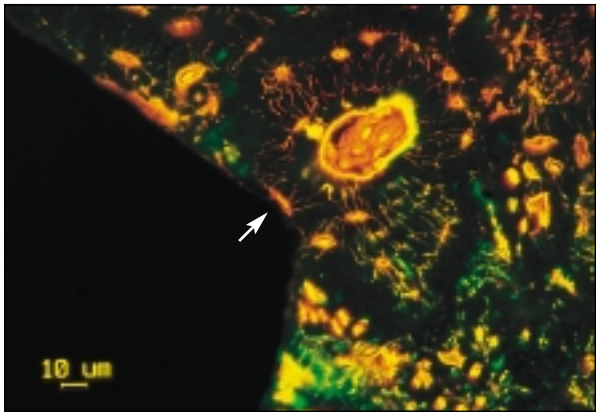


Fig 9c Histologic appearance of the specimens 24 weeks after the placement of implants. Newly formed mature lamellar bone was observed around the implant. Direct bone contact with the implant surface could be seen (Villanueva stain, original magnification ×80).







Figs 10a to 10c Confocal laser scanning microscope images of the implant surface 24 weeks after placement. *(Above)* Direct bone contact with the implant surface can be seen (bone emits green, and vessels or cells emit red). *(Above right)* The arrangement of osteocytes on the surface of the implant was observed, and they were connected to each other with a gap junction. *(Right)* Haversian system was observed very close to the surface of the implant. The osteocytes were arranged concentrically, and one of them was closely positioned to the surface of the implant *(arrow)*.

Microscopic examination of Villanueva-stained sections revealed newly formed mature lamellar bone around the implant. Direct bone contact with the implant surface could be seen (Fig 9c).

The CLSM image of the implant surface also revealed direct bone contact with the implant surface (bone emits green, and vessels or cells emit red) (Fig 10a). In high-magnification photomicrographs of CLSM, the arrangement of osteocytes on the surface of the implant was observed. They were connected to each other with a gap junction (Fig 10b). Another section demonstrated Haversian systems very close to the surface of the implant. The osteocytes were arranged concentrically, and one of them appeared to be attached to the surface of the implant (Fig 10c).

DISCUSSION

Distraction osteogenesis has become an appropriate option for the correction of hemifacial microsomia,[3] micrognathia,[4] or craniofacial deformities[5] and for the repair of segmental bone defects in the mandible.[6] Although most recent reports on distraction osteogenesis for the maxillofacial region have focused on functional and esthetic improvement,[10,11] dental prosthetic reconstructions of the distracted site have not been investigated. A conventional removable prosthesis would be difficult to wear in many situations because of problematic postoperative anatomy of the mandible. On the basis of positive results with implant-supported prostheses,[12,13] the use of implants in the distracted site can significantly help stabilize the prosthesis. However, it normally takes a long time to begin implant treatment in such cases, because it is assumed that the distracted site probably should be allowed to convert into mature bone. Nevertheless, the study showed that it was possible to achieve osseointegration of implants placed in a distracted site even during the consolidation period.

The direction of the implant is one of the most important factors in the success of implant treatment. Three weeks after the completion of distraction, the overlying oral mucosa was normal and endured the surgical procedure of implant placement. There was no apparent mature bone in the

distracted site, but the parallel columns of bone extending from the edges were firm enough to maintain the direction of the placed implants. On radiographic evaluation, the direction of the implants was identical to that on the images taken 24 weeks after the placement of implants. Therefore, 3 weeks after the completion of distraction seemed to be the most appropriate time for the placement of implants in the distracted site during the consolidation period. The condition of gingiva and the formation of columns of bone extending from the edges would seem to be the most important indicators for deciding the time for the placement of implants when applying this technique to patients.

There are few reports concerning the effectiveness of surgery of the distracted site during the consolidation period.[8,9] Four weeks after implant placement, columns of bone had grown, but radiolucent areas were observed in the central area. Twelve weeks after the placement of implants, the distracted site had fully changed into new bone, and no radiolucent areas were observed in the central area. The process of bone formation in the distracted site was similar to that seen in previous studies on bone lengthening after osteotomy.[14,15] These results suggested that the placement of implants at 3 weeks after the completion of distraction does not disturb bone regeneration.

Twenty-four weeks after the placement of implants, the distracted site was seen to have fully changed into apparently mature lamellar bone, and osseointegration had been achieved physically, radiographically, and histologically. These results indicate that it is possible to achieve osseointegration of implants placed in a distracted site, even during the consolidation period. The results suggest the possibility of shortening the period of implant treatment through the use of distraction osteogenesis.

CONCLUSIONS

1. The placement of implants at 3 weeks after the completion of distraction did not disturb bone regeneration.
2. It was possible to achieve osseointegration of implants placed in the distracted site, even during the consolidation period.
3. These results suggest that it is possible to shorten the period of implant treatment by means of the distraction osteogenesis technique.

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