CASE REPORT

Trifocal distraction-compression osteosynthesis in conjunction with passive self-ligating brackets for the reconstruction of a large bony defect and multiple missing teeth

Seung-Hak Baek,[a] Na-Young Kim,[b] Jun-Young Paeng,[c] and Myung-Jin Kim[d]
Seoul and Daejon, Korea

Reconstruction of a maxillary dentoalveolar defect and closure of a wide oronasal fistula in a patient with a traumatic injury are challenging for both orthodontists and surgeons. A conventional bone graft is used to fill the alveolar bone defect, to restore continuity between bony segments, and to provide bony support for tooth eruption adjacent to the defect or for orthodontic tooth movement into the bony defect. However, if the defect is too large to allow for a conventional bone graft, transport distraction osteogenesis can be used for reconstruction of the alveolar bone and implant placement. However, there is usually a discrepancy in the movement rates between the bony segment and the teeth. Passive self-ligating brackets can minimize friction between the bracket and the archwire; therefore, the rate of tooth movement can be balanced with that of the bony segment. By using orthodontic miniscrew and elastomeric traction, the regenerated bony segments can be bent to form a curved arch in the alveolar bone. In the treatment reported here, trifocal distraction-compression osteosynthesis with orthodontic miniscrews and passive self-ligating brackets helped establish bone continuity in a bony defect area, created anterior curvature of the alveolar bone, and provided good-quality regenerated bone for implant placement. (Am J Orthod Dentofacial Orthop 2008;133:601-11)

Reconstruction of a maxillary dentoalveolar defect and closure of a wide oronasal fistula in a patient with a traumatic injury are challenging for both orthodontists and surgeons. This is due to the difficulty in achieving complete closure with a local gingival flap and in obtaining the volume of bone required for the graft. Distraction osteogenesis (DO) was originally introduced for lengthening long bones.[1] In the maxillofacial region, the clinical uses of DO were lengthening the mandible, reconstructing segmental or large bony defects in the mandible, and advancement of the maxilla and the midface.[2-6] In the dentoalveolar region, DO was used for reconstruction of vertical alveolar defects, movement of ankylosed teeth, advancement of the anterior maxilla, acceleration of orthodontic treatment, and resolution of dental crowding.[3,7-10] Both experimentally and clinically, it was shown that tooth movement into the regenerated bone by DO is possible.[11,12]

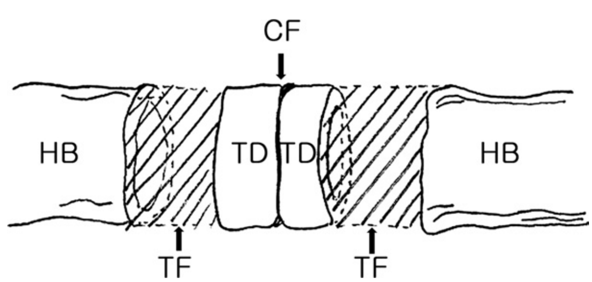

Fig 1. Trifocal distraction-compression osteosynthesis: 2 transport disks are created from the host bone segments and distracted toward the middle of the defect followed by compression. *HB,* Host bone; *TD,* transport disk; *CF,* compressive force; *TF,* tensional force.

Bone transport is defined as the gradual movement of a free segment of bone (transport disk) across a bony defect. The transport disk is cut from the proximal residual host bone segment and is gradually distracted across the defect. Under the influence of tensional

[a]Assistant professor, Department of Orthodontics, School of Dentistry, Dental Research Institute, Seoul National University, Seoul, Korea.
[b]Graduate student, Department of Orthodontics, School of Dentistry, Dental Research Institute, Seoul National University, Seoul, Korea.
[c]Full-time lecturer, Department of Oromaxillofacial Surgery, Daejon Dental Hospital, Wonkwong University, Daejon, Korea.
[d]Professor, Department of Oromaxillofacial Surgery, School of Dentistry, Dental Research Institute, Seoul National University, Seoul, Korea.
Reprint requests to: Seung-Hak Baek, Department of Orthodontics, School of Dentistry, Seoul National University, 28 Yeonkun-dong, Jongro-ku, 110-749, Seoul, Korea; e-mail, drwhite@snu.ac.kr.
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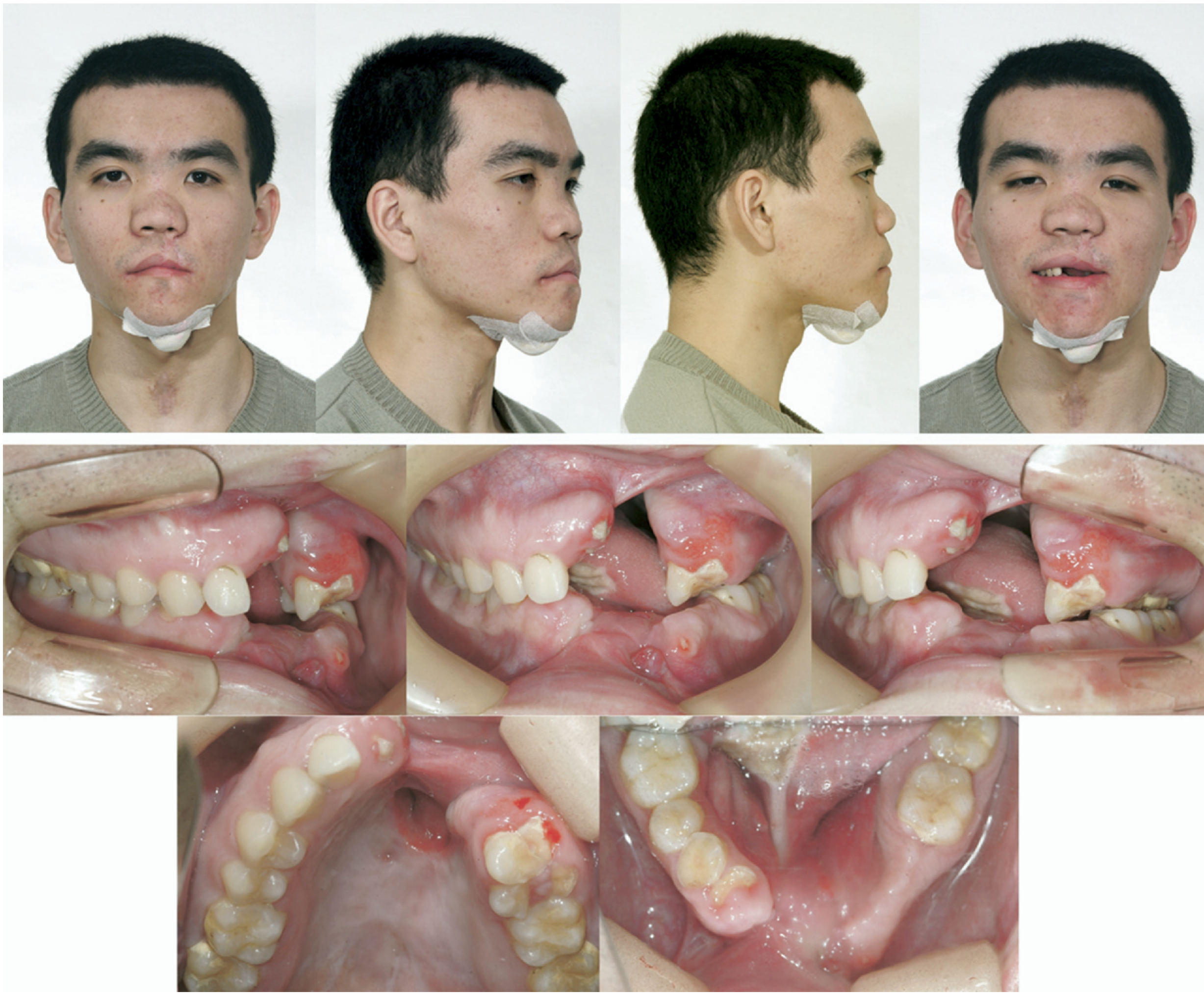

Fig 2. Pretreatment facial and intraoral photographs.

stress, DO occurs behind the trailing end of the transport disk. When the transport disk reaches the opposite or residual target bone segments, compressive forces are applied at the docking site until fusion of the bony margins of the transport disk and target segments occurs.

According to Ilizarov,[13] the techniques are subdivided into 3 groups based on the number of distraction-compression sites: monofocal, bifocal, and trifocal. In patients with large bony defects, 2 transport disks can be created from both residual bone segments and simultaneously moved centripetally toward each other so that they meet in the center of the defect. This technique is called trifocal distraction-compression osteosynthesis (TDCO) and is usually characterized by 2 simultaneously formed distraction regenerates that are subsequently compressed at the docking site in the center of the defect (Fig 1).

When transport DO is planned to reconstruct the anterior part of the alveolar bone, the clinician should consider the vector of the transport disk to make an arch curvature of the alveolar bone.

In this article, we present the treatment of a patient with a large bony defect of the anterior part of the maxilla and the mandible and multiple missing teeth. He was treated with TDCO and orthodontic miniscrews in conjunction with passive self-ligating brackets.

DIAGNOSIS AND ETIOLOGY

Th patient was a man, aged 21 years 3 months, with a gunshot injury. The bullet penetrated the symphysis, the floor of the mouth, the tongue, the palate, and the nose. One month after the accident, a bony defect of the symphysis was reconstructed by iliac bone graft, but it failed. Abbe's flap surgery was done to reconstruct the lip contour. Although surgery to close the wound with

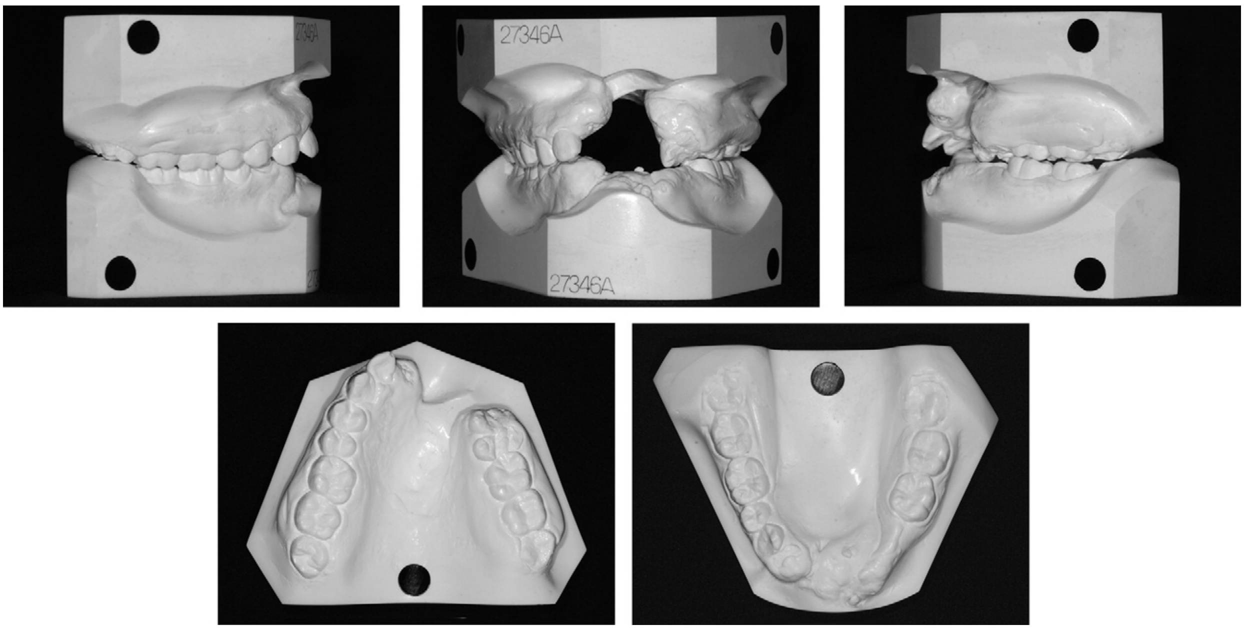

Fig 3. Pretreatment dental casts.

the buccal gingival flap was performed, the wound remained open.

The pretreatment facial photographs show the tissue defect in the midface and the scar tissue from the surgeries (Fig 2). The pretreatment intraoral photographs (Fig 2) and the dental casts (Fig 3) show many missing teeth, large defects of the maxillary and mandibular alveolar bone, and a wide oronasal fistula on the palate. A posterior crossbite was present on the left side.

Cephalometric analysis showed a skeletal Class I relationship (Fig 4, *A,* and Table). In the posteroanterior cephalogram, the metal fragments indicate the bullet's path (Fig 4, *B*). The pretreatment panoramic radiograph showed that the maxillary right central incisor had a retained root, and many teeth were missing: the maxillary left central incisor to the canine, the mandibular left central incisor to the second premolar, and the mandibular right central and lateral incisors. The crowns of the maxillary left premolars and the mandibular right canine and the first premolar were vertically fractured (Fig 4, *C*).

TREATMENT OBJECTIVES

The treatment objectives were as follows: (1) reconstruct the bony defect of the maxillary and mandibular alveolar bone to establish continuity of the arch; (2) minimize the oronasal fistula; (3) place implants in the regenerated alveolar bone; (4) achieve proper occlusion, capable of masticating food, by fabricating the final prosthesis; and (5) support the lip contour with regenerated bone and an esthetic prosthesis.

TREATMENT ALTERNATIVES

To restore the bony defects, 2 options were presented to the patient: (1) conventional bone graft with autogenous bone, or alloplastic or allogenic materials; and (2) TDCO with tensile and compressive forces.

The drawbacks of the first method were the limited autogenous bone that could be obtained, the inevitable morbidity of the donor site, and the lack of soft tissues to cover the wound. Although alloplastic and allogenic materials can avoid the shortcoming of donor site morbidity and have the advantage of obtaining an ideal shape, the risk of immunologic rejection and questions about long-term durability make these options problematic.

TDCO can provide an alternative solution for repairing large bony defects in the maxillofacial region and the extremities. It can regenerate new bone in an existing defect. Therefore, the second option was selected for this patient.

TREATMENT PROGRESS

The first stage was TDCO of the maxilla. Because the position of the distractor is more gingival than that of an orthodontic archwire, the rates of movement of the bony segment and the teeth could differ. High

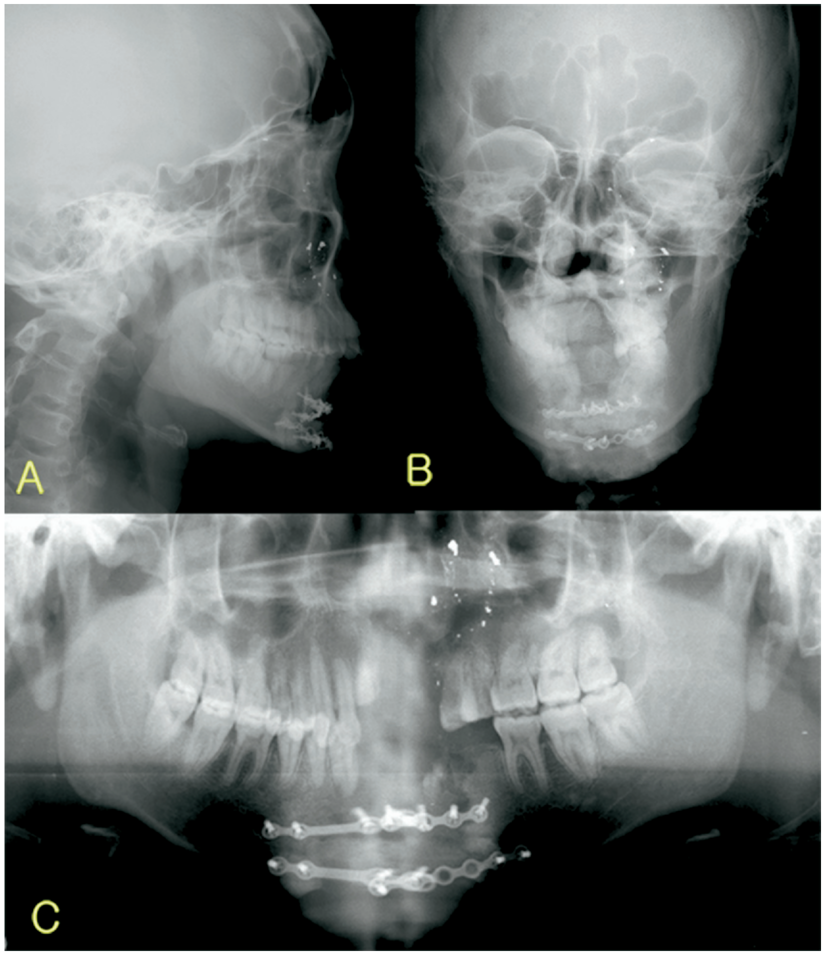

Fig 4. Pretreatment radiographs: **A,** lateral cephalogram; **B,** posteroanterior cephalogram; **C,** panoramic radiograph.

Table. Pretreatment lateral cephalometric analysis

Measurement	*Mean*	*Pretreatment*
Björk sum (°)	393.9	395.6
Mandibular body length/ACB	1.08	0.91
SNA angle (°)	81.77	78.7
SNB angle (°)	80.22	77.8
ANB angle (°)	1.78	0.9
Facial height ratio (%)	66.4	68.4
FMA (°)	26.78	26.6
Pog-NB (mm)	2	−2.4
ODI (°)	73.3	73.7
APDI (°)	85.98	78.5
A-N perp (mm)	1.1	−2.5
Pog-N perp (mm)	−0.3	−16.7
Facial axis angle (°)	88.7	82.48
E-UL (mm)	1.04	−1.13
E-LL (mm)	0.26	0.05

ODI, Overbite depth indicator; *APDI,* anteroposterior discrepancy indicator; ACB, anterior cranial base length.

frictional resistance between archwire and brackets makes the teeth move slowly. For balanced movement of the teeth and the bony segment, passive self-ligating brackets (Damon 2 brackets; Sybron Dental Specialties, Ormco, Orange, Calif) were used. These brackets have a passive slide on the outside face and produce less frictional force than conventional brackets.[14-16]

The brackets were bonded to the maxillary teeth, and a soldered labiolingual arch was cemented on the maxillary arch. Before TDCO, sectional 0.019 × 0. 025-in stainless steel wires were placed (Fig 5).

Vertical osteotomy lines were made distal to the maxillary right lateral incisor and mesial to the left first molar. A Zürich pediatric maxillary distractor on the right side and an alveolar distraction device (both, KLS Martin, Tüttlingen, Germany) on the left side were placed. A 5-day latency period was allowed for the formation of the reparative callus. After latency, the

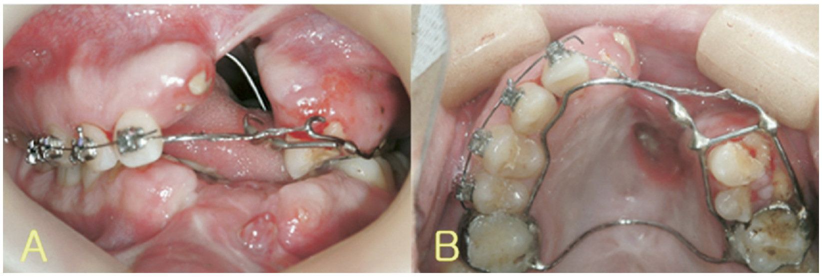

Fig 5. Intraoral photographs before TDCO of the maxillary arch: **A,** frontal view; **B,** occlusal view.

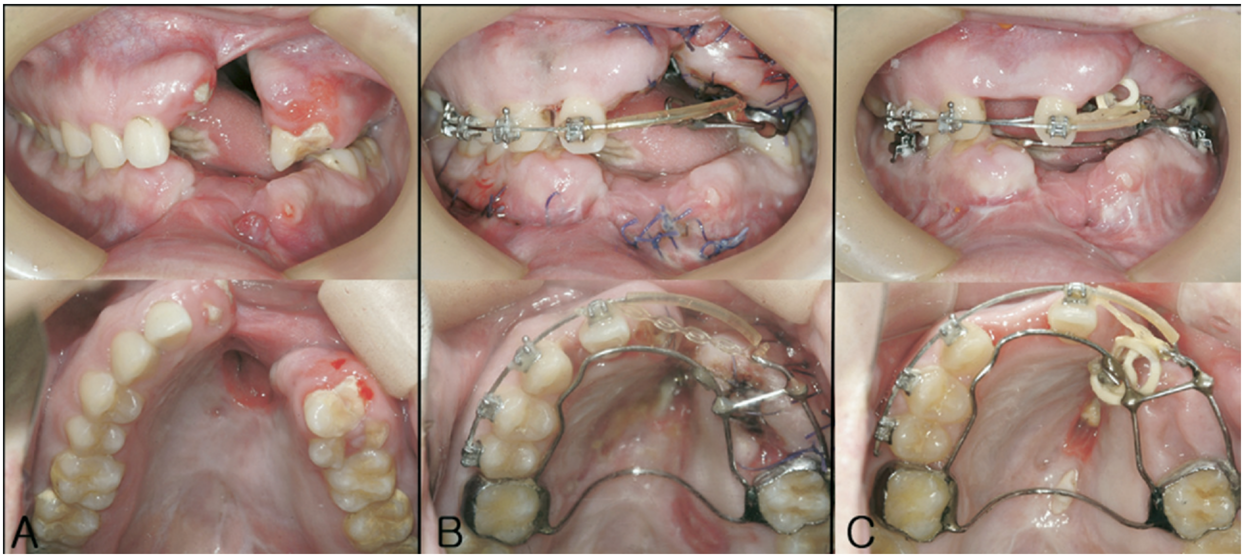

Fig 6. Intraoral photographs before, during, and after TDCO of the maxillary arch. The maxillary right lateral incisor moved along the curve of the dental arch. **A,** Before TDCO; **B,** during TDCO, using elastomerics for control of the movement direction of the maxillary lateral incisor; **C,** after TDCO.

transport disks were distracted at a rate of 0.5 mm twice per day. Once the transport disks reached the docking sites, gingivoperiosteoplasty was performed. Significant compressive forces between transport disks were applied to cause necrosis of the fibrocartilage, thereby allowing bony fusion. The amounts of distraction were 16 mm on the right side and 10 mm on the left side (Fig 6).

Due to the anterior curvature of the alveolar bone (Fig 6, *A*), the distraction directions of the bony segment and the teeth should be changed during the distraction phase. Elastic force was applied between the maxillary right lateral incisor and the left labial hook on the labiolingual arch (Fig 6, *B*). Therefore, the maxillary right lateral incisor and the bony segment could move along the archwire (Fig 6, *C*). To create alveolar bone with enough vertical height and labiolingual thickness for implant placement in the area of the missing maxillary left central incisor, the maxillary right lateral incisor was moved along the archwire to the end of bony segment. To prevent palatal movement of the left bony segment, an orthodontic miniscrew (diameter, 1.6 mm; length, 8.0 mm; OSAS, Epoch Medical, Seoul, Korea) was placed on the left side on the palate, and elastic force was applied to the labial hook on the labiolingual arch (Fig 6, *C*).

To allow complete consolidation, removal of the distractors was delayed for 6 months until implant placement.

The second stage was TDCO of the mandible. Zürich pediatric maxillary distractors were used on the both sides in the mandible. Because there were no mandibular anterior teeth, brackets could not be placed. Therefore, a lingual arch was cemented (Fig 7, *A*). The mandibular right first premolar was extracted because of a vertical crown fracture. Vertical osteotomy lines

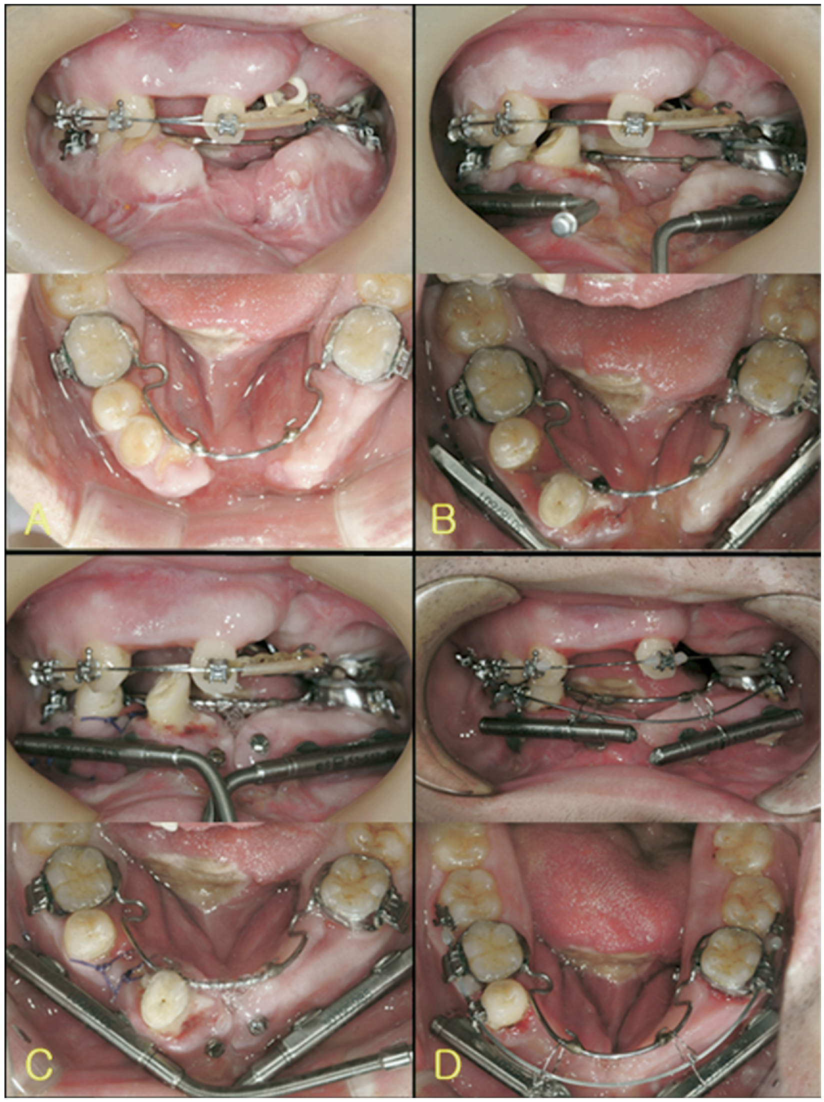

Fig 7. Intraoral photographs before, during, and after TDCO of the mandibular arch. **A,** before TDCO; **B,** during TDCO, the straight direction of the distractors could cause a V-shaped arch; **C,** bone bending stage: the mini-implants were placed on the labial side of the alveolar bone and connected with the hooks of the lingual arch by elastomerics to bend the segments; **D,** after TDCO, the regenerated bony segments were curved and connected.

were made mesial to the mandibular right second premolar and mesial to the left first molar (Fig 7, *A*). A 6-day latency period was allowed. Distraction was done at a rate of 0.25 mm 3 times per day for 7 days and then 4 times per day (Fig 7, *B*).

To avoid creating a V-shaped mandibular arch, 2 orthodontic miniscrews (diameter, 1.6 mm; length, 8.0 mm; OSAS, Epoch Medical) were placed on the buccal side of the anterior part of the transport disks on both sides. Elastic force was applied between the hooks on the lingual arch and the miniscrews to bend the regenerated bony segments during the distraction phase (Fig 7, *C*).

Gingivoperiosteoplasty was done, and significant compressive forces were applied between the transport disks. During the consolidation period, the mandibular right second premolar and the second molar and the left second molar were bonded and aligned (Fig 7, *D*).

Next was the prosthetic stage. After 6 months, the 4 distractors were removed from the maxilla and the mandible, and 4 implants were placed in each arch. The quality of the regenerated bone was sufficient to place

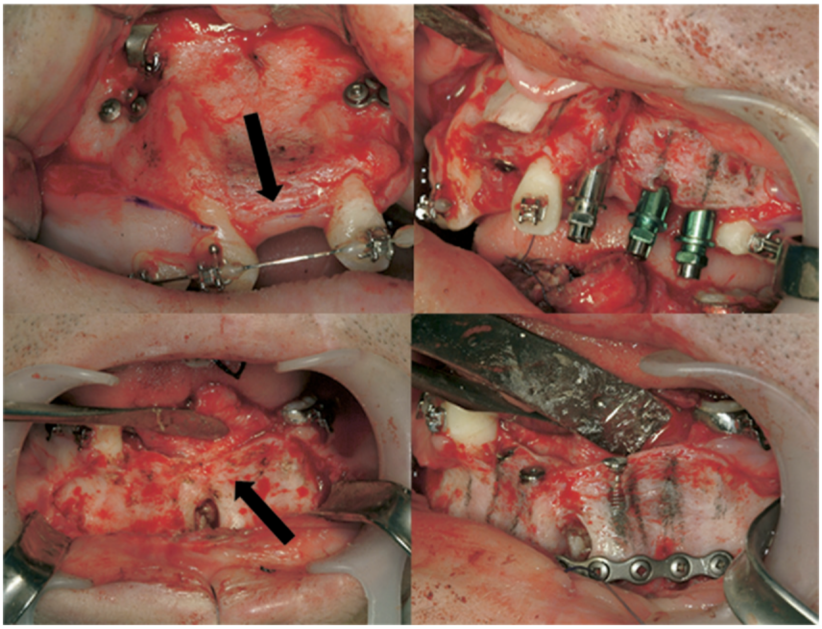

Fig 8. Implant placement: *upper*, maxilla; *lower,* mandible.

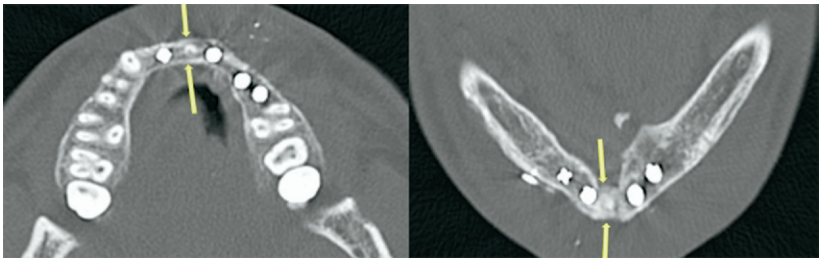

Fig 9. CT after placement of the implants. *Left,* maxilla; *right,* mandible.

the implants (Fig 8). The implants were well positioned in the alveolar housing, which was regenerated by TDCO (Fig 9). The second surgery, to expose the implant heads, was done 4 months later, and the final prostheses were fabricated (Figs 10 and 11).

TREATMENT RESULTS

TDCO created new alveolar bone in the maxillary (26 mm) and mandibular arches (25 mm). After TDCO, the occlusal radiographs and the computed tomography (CT) scan showed that the bony continuity between right and left segments of the maxillary (Fig 12) and mandibular arches (Fig 13) was restored. Because regenerated segments were bent by using mini-implants and elastomeric traction during the distraction phase, almost normal contour of the anterior curvature of both arches could be established. After a consolidation phase, the implants were placed in the regenerated bone.

Superimposition of the lateral cephalograms before and after TDCO showed that A-point moved forward due to the regeneration of the alveolar bone (Fig 14). In the comparison of the posteroanterior cephalograms before and after TDCO, the maxillary right lateral incisor moved to the position of the missing maxillary left central incisor to maintain the alveolar bone in that arch (Fig 15).

DISCUSSION

Transport DO of the posterior alveolar segment was developed as a strategy for closing a large alveolar cleft that could not be closed with conventional bone grafts. Bone grafts sometimes fail because of inadequate covering of the cleft with the surrounding soft tissue, marked scar formation, or large defects.

TDCO can minimize size of the bony defect and the oronasal fistula and create new alveolar bone for rapid orthodontic tooth movement. The creation of soft tissue

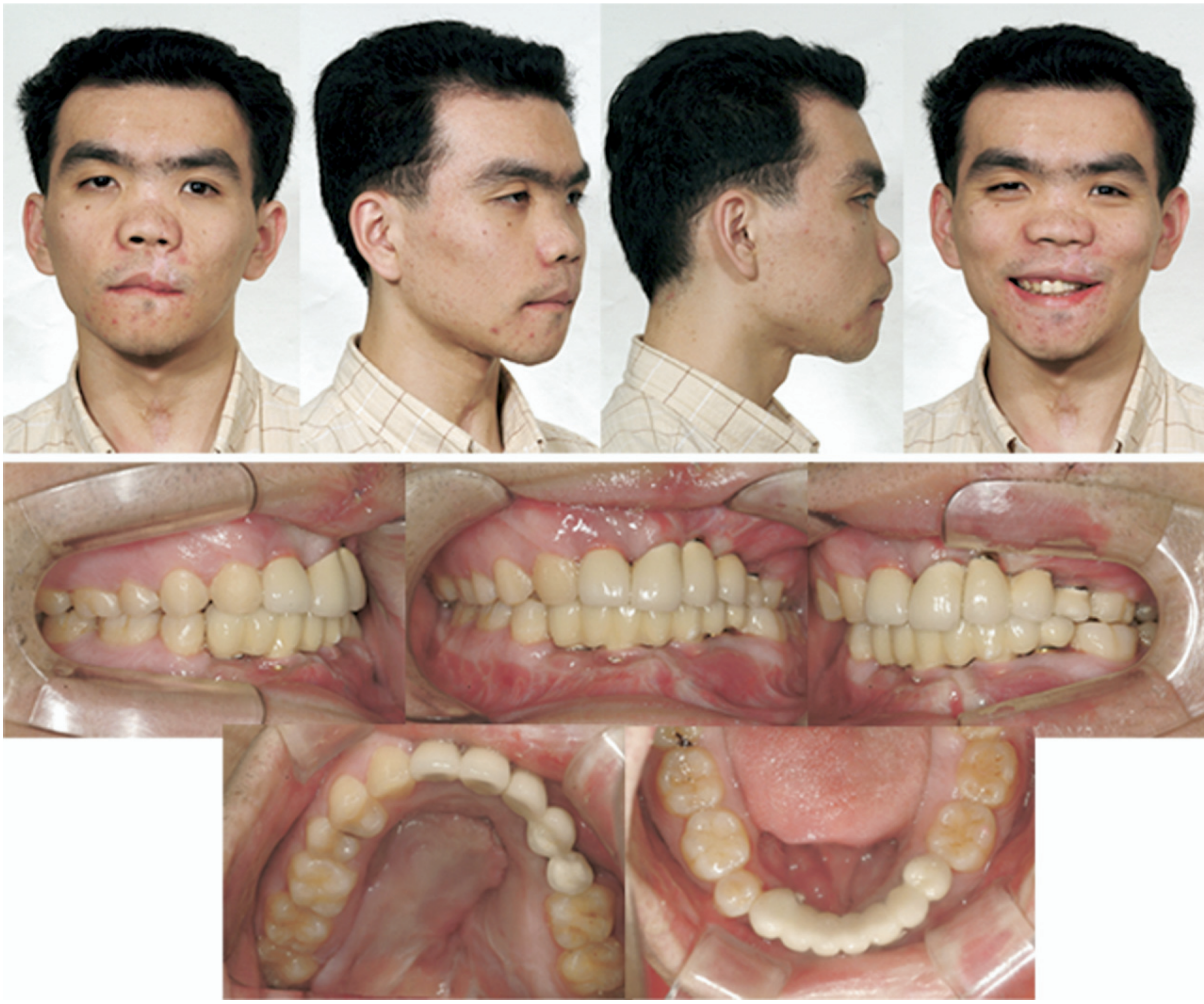

Fig 10. Posttreatment facial and intraoral photographs.

during the bony transport procedure can allow adequate soft-tissue covering of the bony defect. In this patient, the labiolingual thickness of the regenerated alveolar bone was as wide as that of the original bone and enough for the placement of dental implants.

Costantino et al[17] reported a case of bifocal DO on the mandible, in which the regenerated bone was similar to the original mandible. Kuriakose et al[18] and Sawaki et al[4] reconstructed mandibular bony defects using TDCO. This method is more efficient because the time of bone regeneration would be decreased by half under the same rate of distraction. In our patient, the result of the maxillary TDCO was similar to case reports of mandibular TDCO.

There are 2 types of the distractors: tooth-borne and bone-borne devices. Some experiments showed that tooth-borne devices cause more dental movement than bony segment movement.[19,20] Therefore, the nasal side of the alveolar defect could not be completely closed. Because the bone-borne distractor is placed more gingivally than the teeth, it can solve this problem, and bony defects can be repaired without bone grafting.[21]

Frictional resistance between bracket and archwire can prevent the teeth and the bony segment from moving at the same rate. By eliminating steel or elastic ligatures, passive self-ligating brackets can significantly reduce friction during TDCO.[14,15,22-24] For this reason, we used passive self-ligating brackets to treat our patient.

The distractor we used was a unidirectional intraoral distraction device without a curvature-forming mechanism. When transport DO is planned to reconstruct the anterior part of the alveolar bone, 3-dimensional vector control of the regenerated bony segment is

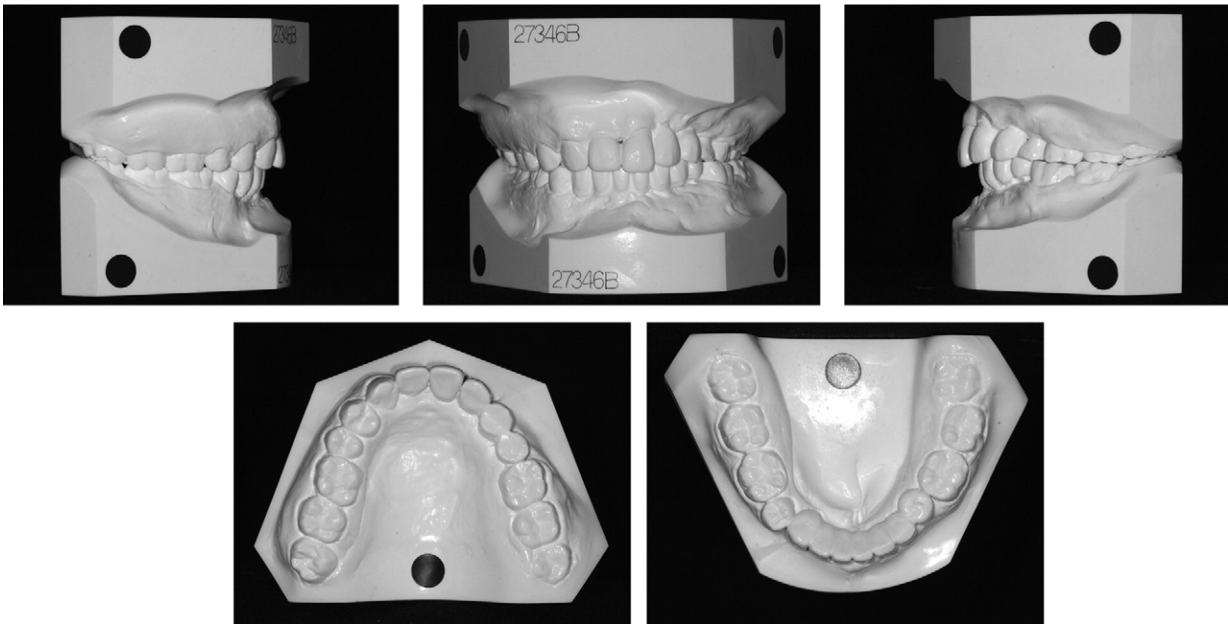

Fig 11. Posttreatment dental casts.

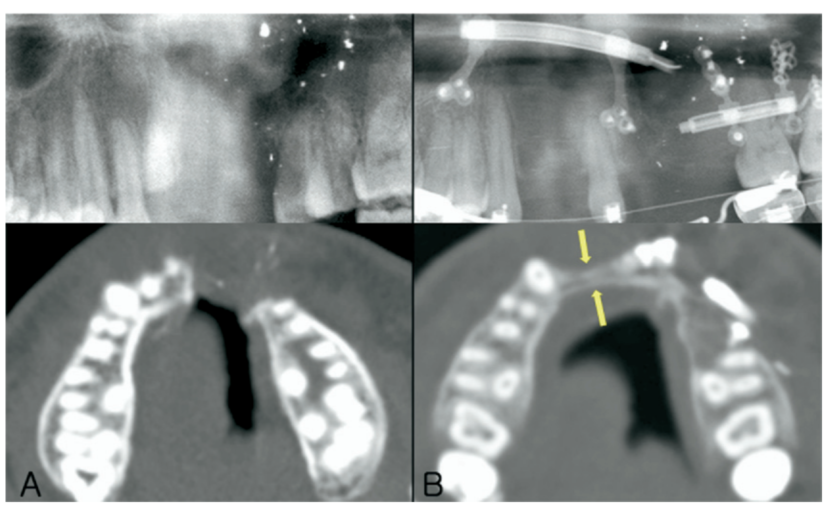

Fig 12. Comparison of the maxilla with panoramic radiographs and CT between **A,** pretreatment and **B,** posttreatment.

needed.[11,25] To close the large bony defect on the maxillary and mandibular anterior segment, the regenerated bone should be bent. In this patient, we used orthodontic mini-screws to control the transport vector and bend the regenerated bone in conjunction with the lingual arch, the passive self-ligating brackets, the orthodontic archwire, and elastomeric traction. Eventually, the distraction vector of the bony segments changed and resulted in the creation of the almost normal anterior curvature of the alveolar bone.

The quality and texture of the regenerated bone were good enough for implant placement, and the implants were successfully osseointegrated. Laster et al[26] reported that marginal bone resorption around implants was not observed after 12 months of follow-up. However, the labiolingual thickness and the vertical height stability of the regenerated alveolar bone should be checked. Therefore, a follow-up study of the success rate and the stability of implants in regenerated alveolar bone is needed.

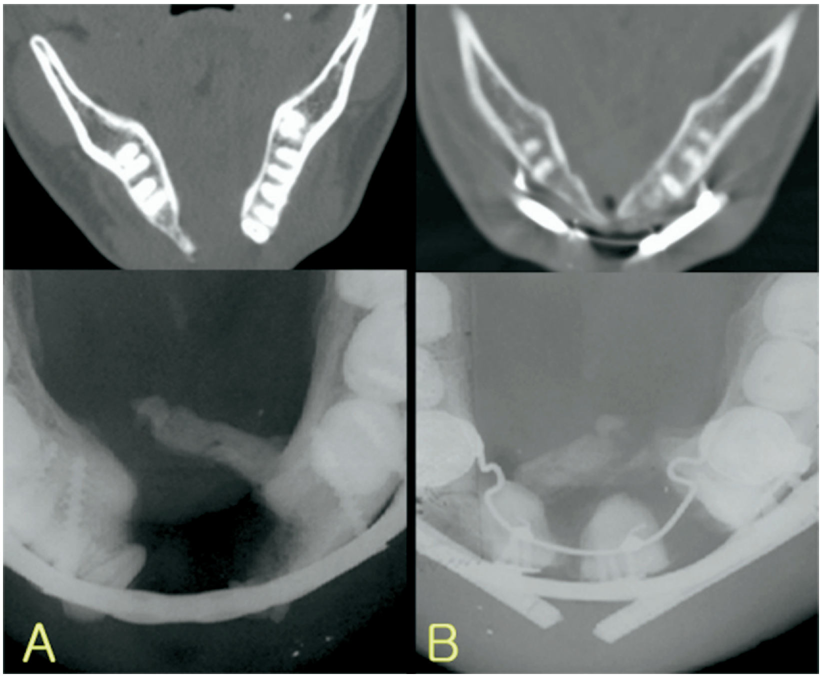

Fig 13. Comparison of the mandible with CT and occlusal radiographs between **A,** pretreatment and **B,** posttreatment.

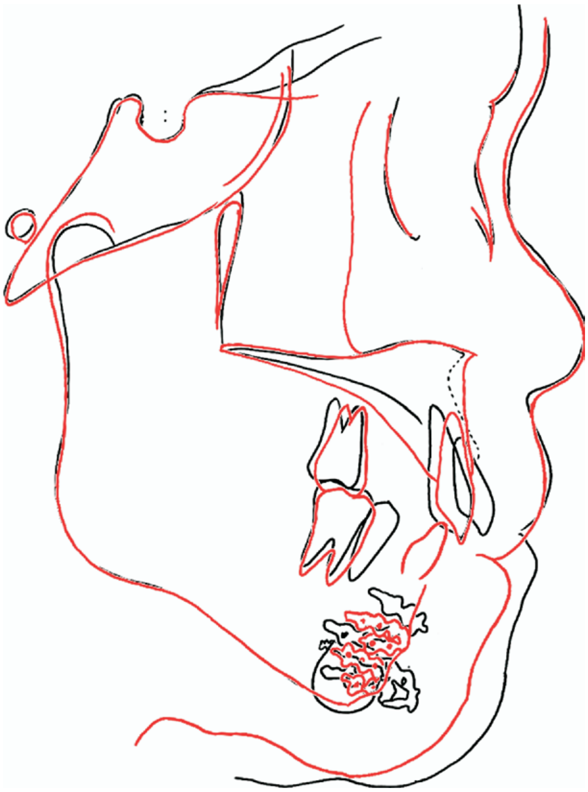

Fig 14. Superimposition of pretreatment (*black line*) and posttreatment (*red line*) lateral cephalogram tracing.

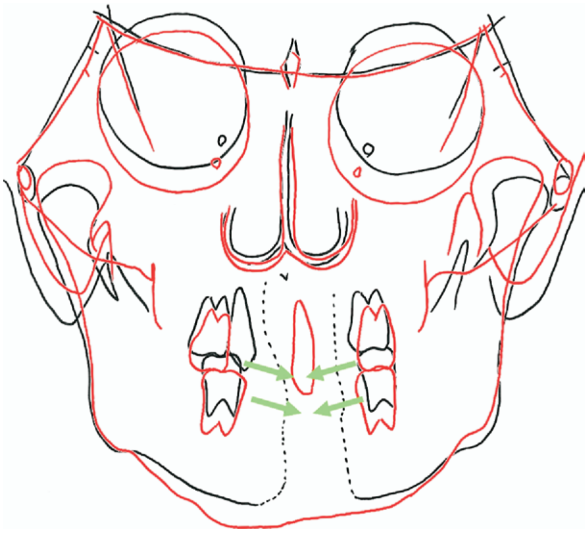

Fig 15. Superimposition of pretreatment (*black line*) and posttreatment (*red line*) posteroanterior cephalogram tracing. *Arrows* indicate TDCO of the transport disk.

CONCLUSIONS

TDCO with orthodontic mini-screws and passive self-ligating brackets was used to establish bone continuity in bony defect areas, create the anterior curvature of the alveolar bone, and provide good-quality regenerated bone for implant placement.

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