Orthodontic treatment of a skeletal Class III malocclusion with severe root resorption of the maxillary anterior teeth.

Autotransplantation using a 3-dimensional printed replica of the donor tooth

Au Sasaki,† Mai Fujimoto,† Kouta Fujimoto,† Rei Shinagawa,† Takuya Sonokawa, ‡ Toru Takusagawa, ‡ and Naoto Suda†

Sakado, Saitama, Japan, and Boston, Mass

This case report describes the successful orthodontic treatment of a 12-year-old girl with skeletal Class III malocclusion and severe root resorption of the maxillary anterior teeth. Ectopic eruption and mesial inclination of the bilateral maxillary canines caused severe root resorption of the right central and lateral incisors and the left lateral incisor. These 3 teeth were extracted, and traction was applied to the maxillary right and left canines toward the extracted right central incisor and left lateral incisor, respectively. In the mandibular arch, the bilateral first premolars were extracted, and the crowding was corrected. The extracted mandibular right first premolar was transplanted after extraction of the maxillary right lateral incisor. To prepare for the tooth transplantation, a cone-beam computed tomography image was used to fabricate a 3-dimensional printed replica of the donor tooth. The crown shape of the maxillary anterior teeth was corrected, and the patient achieved functional occlusion with pleasing esthetics. Root resorption was negligible in the transplanted tooth. This study demonstrates the satisfactory treatment outcome and an effective 3-dimensional simulation for tooth transplantation. (Am J Orthod Dentofacial Orthop 2021; ■: ■ - ■ )

Autotransplantation of teeth offers a unique treatment option, especially when this is combined with orthodontic treatment.1,2 Many orthodontic patients in which anterior or posterior teeth have to be extracted replace a missing tooth with a natural tooth rather than with a dental implant or bridge-work.3,4 The advantage of tooth transplantation, unlike dental implants, is that transplanted teeth have living periodontal ligaments. Thus, the sense of mastication and occlusion can be perceived, and orthodontic tooth movement can be performed. However, ankylosis, root resorption, and pulp necrosis are the most common complications.5

The key point for successful tooth transplantation to avoid complications is atraumatic preservation of the periodontal ligament of the donor tooth.6,7 In addition, the recipient alveolar socket must be slightly larger and deeper than the donor tooth root for a satisfactory prognosis.8,9 In patients whose posterior tooth is to be transplanted into the socket of an extracted anterior tooth, rotation of the tooth is an effective approach.10 All these precise plans and preparation must be considered and arranged before and during transplantation.

This case report describes the orthodontic treatment of a growing Japanese girl with severe root resorption of 3 maxillary incisors because of ectopic canine eruption.
Three incisors had to be extracted, and the 2 canines underwent traction. During alignment of the mandibular arch, 1 premolar was extracted and used as a donor tooth for transplantation as a replacement for the maxillary incisor. In the preparation and planning of tooth transplantation, we used a 3-dimensional (3D) printed replica of a donor tooth using a computer-aided design–computer-aided manufacturing technique. The treatment outcome was excellent, and the satisfactory long-term prognosis of the transplanted tooth is reported here.

**DIAGNOSIS AND ETIOLOGY**

A girl aged 12 years visited our orthodontic clinic with a chief complaint of impaction of the bilateral maxillary canines and a distally inclined maxillary left lateral incisor. Her facial appearance was symmetrical and without excessive gingival exposure (Fig 1). Her profile was slightly concave with upper and lower lips to the E-line measurements of −4.0 and −3.0 mm, respectively (Table). The maxillary left lateral incisor was distally inclined (Fig 1). The bilateral deciduous second molars were retained in the maxillary arch, and the right second molar and the bilateral permanent canines had not yet erupted. An Angle Class I molar relationship was seen on both sides, and the overjet and overbite were 1.5 and 1.0 mm, respectively (Fig 2; Table).

The patient had a skeletal Class III intermaxillary relationship (ANB, −1.5°) because of the protruded mandible (SNB, 85.5°) and low angle (FMA, 20.5°) (Table). Panoramic radiography and cone-beam computed tomography (CBCT) showed mesially inclined bilateral maxillary canines surrounded by cyst-like clear radiolucent areas. Severe root resorption was seen in the right central incisor and the bilateral lateral incisors (Fig 3). She saw a general dental practitioner investigate the unerupted maxillary canines; however, she was told they would erupt soon, and no x-rays were taken. The maxillary right second premolar was inclined distally, and the formation of the tooth roots of the bilateral mandibular second premolars was incomplete.

![Fig 1. Pretreatment facial and intraoral photographs (12 years, 4 months).](image)
The urgent treatment objective was to prevent root resorption of the maxillary left central incisor. Because of the severe root resorption of the maxillary right central incisor and left lateral incisor, these 2 teeth had to be extracted, and the traction of the bilateral canines was planned to replace the extracted teeth. Extraction of the right lateral incisor was also required, and transplantation of an extracted mandibular tooth was planned before the initiation of the alignment of the mandibular arch. Because the patient was only aged 12 years and had a skeletal Class III internmaxillary relationship with a protruded mandible, alignment of the mandibular arch and extraction of the mandibular teeth were planned for after further mandibular growth. The maxillary right deciduous second molar was extracted to induce a normal eruption of the distally tipped maxillary right second premolar.

**Table.** Cephalometric analysis

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Japanese norm</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Postretention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>12 y, 4 mo</td>
<td>16 y, 4 mo</td>
<td>18 y, 7 mo</td>
</tr>
<tr>
<td>SNA°</td>
<td>81.5 ± 4.2</td>
<td>84.0</td>
<td>84.5</td>
<td>84.5</td>
</tr>
<tr>
<td>SNB°</td>
<td>77.1 ± 3.8</td>
<td>85.5</td>
<td>85.0</td>
<td>85.0</td>
</tr>
<tr>
<td>ANB°</td>
<td>4.4 ± 4.0</td>
<td>−1.5</td>
<td>−0.5</td>
<td>−0.5</td>
</tr>
<tr>
<td>Facial angle°</td>
<td>83.0 ± 2.9</td>
<td>89.0</td>
<td>89.5</td>
<td>89.5</td>
</tr>
<tr>
<td>FMA°</td>
<td>34.0 ± 3.8</td>
<td>20.5</td>
<td>21.0</td>
<td>21.0</td>
</tr>
<tr>
<td>U1 to FH°</td>
<td>111.5 ± 5.0</td>
<td>117.5</td>
<td>110.0</td>
<td>110.0</td>
</tr>
<tr>
<td>IMPA°</td>
<td>95.4 ± 6.3</td>
<td>81.5</td>
<td>78.0</td>
<td>78.5</td>
</tr>
<tr>
<td>Upper lip to E-line, mm</td>
<td>−1.3 ± 1.7</td>
<td>−4.0</td>
<td>−6.5</td>
<td>−6.5</td>
</tr>
<tr>
<td>Lower lip to E-line, mm</td>
<td>0.9 ± 2.0</td>
<td>−3.0</td>
<td>−6.5</td>
<td>−6.5</td>
</tr>
</tbody>
</table>

Note. The mean ± standard deviation represent the age-matched Japanese norm (Iizuka, 1957). S, Sella turcica; N, nasion; A, point A; B, point B; Me, menton; FH, Frankfort horizontal plane; FMA, angle between FH and mandibular plane; U1, long axis of the maxillary central incisor; U1 to FH, angle between maxillary incisor axis and FH plane; IMPA, angle between long axis of mandibular central incisor and mandibular plane.

Fig 2. Pretreatment dental casts (12 years, 4 months).
TREATMENT ALTERNATIVES

Extraction of the maxillary right central incisor and the bilateral lateral incisors was inevitable. After extraction, it was reasonable to align the bilateral canines to the position of the extracted right central incisor and the left lateral incisor.

After the alignment of the bilateral canines, some treatment alternatives could be considered. One option was to mesialize the maxillary right premolars and molars and close the extraction space orthodontically. The other option was to keep the extraction space and perform bridgework or dental implants.

The patient sought orthodontic treatment for alignment of both arches. Extraction of the mandibular premolars was considered. To prevent further retrusion of both lips, nonextraction treatment for the mandibular arch was thought to provide a better treatment outcome. However, the pretreatment overbite was somewhat small, and the better vertical control was likely to be obtained by extraction of the mandibular premolars. After discussing treatment objectives and alternatives with the patient, she preferred to take advantage of the mandibular premolar extraction and the tooth transplantation. It was decided to keep the maxillary right lateral incisor as long as possible until mandibular growth was completed.

TREATMENT PROGRESS

A lingual arch was placed in the maxillary arch, and traction of the bilateral canines was initiated at the age of 12 years, 4 months. Ten months later, the right
canine and the left canine had moved into the positions of the extracted right central and the left lateral incisors, respectively (Fig 4). The mesial tipping of both canines had improved but was still observable in the radiographs (Fig 5). The short roots of the mandibular incisors were noted. The maxillary right second premolar had erupted after the extraction of the deciduous right second molar.

During the traction of both maxillary canines, her mandibular growth was mainly downward, and alignment of both arches was initiated with a multibracket appliance (0.022-in slot Roth-prescription brackets; A-Company Orthodontics, San Diego, Calif) at the age of 14 years, 1 month. The mandibular right first premolar was extracted. Before extraction, CBCT images were taken and used for a 3D simulation for tooth transplantation. Using CBCT images, a resin replica (Clear Resin; Formlabs Inc, Somerville, Mass) of the mandibular right first premolar was fabricated by a 3D printer (Form2; Formlabs Inc) with 50 μm of stacking pitch. Because this replica was used to prepare the extraction socket of the maxillary right lateral incisor immediately before the transplantation, the used resin material had to be harmless but not necessarily to be biocompatible. The labiolingual width of the extracted alveolus was insufficient for transplantation of the mandibular right first premolar, and it was decided to rotate the donor tooth by 90° at transplantation (Fig 6, A-G). A 0.018 × 0.025-in stainless steel wire was placed as an initial wire to stabilize the transplanted tooth (Fig 6, G), and it was bent so that it could be placed passively to all the maxillary teeth. This wire was placed for 16 weeks until the mobility of the transplanted tooth was within the physiological range, and it was then changed to a light continuous nickel-titanium wire. The transplanted mandibular first premolar had completed the entire root formation, and the root canal treatment was performed 2 weeks after transplantation. The mandibular left first premolar was extracted, and the mandibular arch was further aligned. When the patient was aged 15 years and 5 months, the tips of the bilateral maxillary canines, placed after the extraction of the right central incisor and the left lateral incisor, were trimmed.

Fig 4. Facial and intraoral photographs after the canine traction (13 years, 7 months).
Fig 5. Radiographs after the canine traction (13 years, 7 months): A, panoramic radiograph; B, CBCT. 3D-reconstructed image (left) and the sagittal slice image showing the maxillary right lateral incisor (right).

Fig 6. Transplantation of the mandibular right first premolar to the extraction socket of the maxillary right lateral incisor (14 years, 1 month): A, fabrication of the replica (right) of the mandibular right first premolar (donor tooth denoted by arrow) from CBCT (left); B, extraction of the maxillary right lateral incisor (insert; extracted lateral incisor with resorbed root); C, schema of the donor tooth and recipient socket (left, dotted and solid lines denote the extracted socket and predicted recipient socket from the replica, respectively), and planning of the donor tooth rotation by 90°; D, trial of the rotated replica (distal surface was placed labially) into the extracted socket (insert, reshaping of the extracted socket); E, extraction of the mandibular right first premolar (insert, extracted donor tooth); F, donor tooth placed in the prepared recipient site; G, fixation of the donor tooth with 0.018 × 0.025-in stainless steel wire.
A resin restoration was performed for the right canine to mimic the crown shape of the right central incisor at the age of 16 years, 1 month.

**TREATMENT RESULTS**

The multibracket appliance was placed for 27 months, and the total treatment duration was 48 months. Favorable occlusion with an overjet of 2.0 mm and an overbite of 2.0 mm was achieved (Figs 7 and 8). The crown of the transplanted tooth was reshaped to mimic the maxillary right lateral incisor. A skeletal Class III intermaxillary relationship was seen posttreatment (16 years, 4 months) and postretention (18 years, 7 months) with an ANB of \( -0.5^\circ \) (Table). This relationship did not worsen during or after the treatment. The proclined maxillary incisors were corrected by 7.5\(^\circ\) and the mandibular incisors were retroclined by 3.5\(^\circ\) by the treatment. A periodontal ligament space was noted in the dental x-rays, and no ankylosis was seen (Figs 9 and 10). Mandibular growth was negligible after the active treatment (Table; Fig 11). At 2 years, 3 months after the active orthodontic treatment (age 18 years, 7 months; and 4 years, 6 months after the tooth transplantation), a stable occlusion was maintained, and the maxillary and mandibular incisors maintained the inclination (Figs 12 and 13). Mobility of the transplanted tooth was within the physiological range, and the gingiva was healthy after the active orthodontic treatment. Slight root resorption was seen after the treatment (Fig 14), and the color of the crown was darkened slightly during retention (Figs 7 and 12). Three thirds molars will be extracted.

**DISCUSSION**

In this case, there were multiple options for the timing of the alignment of the mandibular arch. The alignment of the mandibular arch could have been initiated at the same time as the maxillary canine traction at the age of 12 years, 4 months. At this stage, the root formation was not yet complete (Fig 3, A). Some studies have reported that donor teeth with incomplete root formation have favorable survival and success rates and fewer complications after tooth transplantation.\(^9,12,13\) The survival rates after transplantation with incomplete root formation were 97.4%, 97.8%, and 96.3% at 1, 5,
Fig 8. Posttreatment dental casts (16 years, 4 months).

Fig 9. Posttreatment lateral cephalogram, cephalometric tracing, and panoramic radiograph (16 years, 4 months).
and 10 years, respectively. Transplantation of teeth with incomplete root formation can offer the advantage of pulp revascularization and reinnervation, eliminating the need for endodontic treatment.

When transplantation is performed with teeth complete root formation, endodontic treatment is required to prevent or halt the development of periodontal or pulp-related diseases. Based on these studies, there was an advantage in extracting the mandibular tooth with incomplete root formation and initiating the alignment of the mandibular arch immediately after the first visit. However, the patient had a skeletal Class III skeletal pattern with a pretreatment ANB angle of $1.5^\circ$, and there was a risk that her intermaxillary relationship would worsen with mandibular growth. Thus, we decided it would be safer to observe the mandibular growth for a while.

Stabilization of the donor’s teeth is an important factor in the prognosis. It has been reported that a transplanted tooth fixed with sutures has a significantly lower survival rate than those stabilized with wire and resin. However, some studies report that a light continuous force exerted with a flexible superelastic nickel-titanium archwire can apply stable biologic loading to prevent ankylosis. In the present case report, a 0.018 $	imes$ 0.025-in stainless steel wire was placed in 0.022-in Roth-prescription brackets to stabilize the transplanted tooth somewhat rigidly for 16 weeks (Fig 6, G), because the transplanted tooth showed some mobility immediately after transplantation. Stabilization for 16 weeks was rather long after transplantation and had a risk to cause ankylosis. The transplanted tooth began to show less mobility after

Fig 10. Dental x-rays: A, before transplantation (13 years, 9 months); B, immediately after transplantation (14 years, 1 month); C, before root canal treatment (14 years, 2 months); D, after root canal treatment (14 years, 6 months); E, 2 years, 3 months after transplantation (16 years, 4 months); F, 4 years, 6 months after transplantation (18 years, 7 months).

Fig 11. Superimposed cephalometric tracings. Pretreatment (black; 12 years, 4 months), posttreatment (red; 16 years, 4 months), and postretention (green; 18 years, 7 months).
Fig 12. Postretention facial and intraoral photographs (18 years, 7 months; 4 years, 6 months after the tooth transplantation, and 2 years, 3 months after the active orthodontic treatment).

Fig 13. Postretention dental casts (18 years, 7 months).
stabilization. However, the transplanted tooth, placed with 0.022-in Roth-prescription brackets and 0.018 × 0.025-in wire, was exposed to physiological pressures from the lip, tongue, and bolus of food. Thus, the transplanted tooth could mobilize within the physiological range during the 16 weeks of stabilization period. This physiological range of mobility is thought to avoid ankylosis of the transplanted tooth.

Before transplantation, a 3D printed replica was fabricated from CBCT images. Several advantages of this technique have been reported.4,7,20 First, before transplantation, the location, placement, and angulation of the donor tooth can be examined with the replica. In this patient, it was decided to rotate the mandibular first premolar by 90° to accommodate the tooth within the labiolingual width of the maxillary alveolus. Second, the replica can prepare the recipient socket and provide a better fit for the donor tooth. In the present patient, the donor tooth was placed in the desired position without problems. Third, the replica helps to minimize the extraalveolar time of the donor tooth at transplantation. It is reported that the use of a replica could reduce the transplantation procedural time of the conventional method without using a replica by 40-90 minutes to 30-45 minutes.21 In this study, the procedural time was approximately 30 minutes and the extraalveolar time of the donor tooth was 45 seconds. The mobility of the transplanted tooth was within the physiological range with a periodontal ligament space. There was no tooth ankylosis and negligible root resorption. These satisfactory treatment outcomes are likely to have been related to the use of the replica.

**CONCLUSIONS**

Ectopic eruption and mesial inclination of the bilateral maxillary canines caused severe root resorption of the right central and lateral incisors and the left lateral incisor in a 12-year-old female. These 3 teeth were extracted, and traction was applied to the right and maxillary left canines. In the mandibular arch, the extracted
mandibular right first premolar was transplanted after extraction of the maxillary right lateral incisor. A 3D-printed replica of the donor tooth was fabricated and used for tooth transplantation. The effective 3D simulation at tooth transplantation was performed by this replica, and a satisfactory treatment outcome was obtained.

AUTHOR CREDIT STATEMENT

Conceptualization: Au Sasaki, Mai Fujimoto, and Naoto Suda; investigation: Au Sasaki and Mai Fujimoto; resources: Takuya Sonokawa and Toru Taku-sagawa; data curation: Mai Fujimoto and Kouta Fujimoto; writing-original draft preparation: Au Sasaki and Naoto Suda; project administration: Au Sasaki and Naoto Suda; and funding acquisition: Au Sasaki and Naoto Suda.

REFERENCES