Interdisciplinary orthodontic treatment with digitally-guided autotransplantation in a patient with a missing permanent maxillary left lateral incisor and a supernumerary mandibular incisor

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This case report describes the interdisciplinary orthodontic treatment of a patient with a congenitally missing and a supernumerary tooth. A 15-year-old boy presented with a retrognathic convex profile, generalized maxillary and mandibular dental spacing, deep overbite, peg-shaped maxillary right permanent lateral incisor, missing permanent maxillary left lateral incisor, and a supernumerary mandibular incisor. The permanent maxillary left canine had ectopically erupted in the missing lateral incisor position, and the primary maxillary left canine was retained. Fixed orthodontic treatment with miniscrew implant-facilitated anchorage and extraction of the primary maxillary left canine was performed to bodily distalize the maxillary left permanent canine into Class I position while creating space for restoration of the missing permanent maxillary left lateral incisor. Cone-beam computed tomography was used for digitally-planned autotransplantation of the mandibular supernumerary incisor to the space of the congenitally missing lateral incisor. Root canal treatment of the donor tooth was performed the week before the extraction because of the complete root development of the tooth. A 3-dimensional printed surgical guide and tooth replica were used for socket preparation in the edentulous space. After 6 weeks of semirigid fixation of the transplanted tooth, a composite build-up of the peg-shaped and transplanted tooth was performed, and orthodontic treatment resumed to close residual spaces and detail the occlusion. Acceptable occlusion and facial esthetics were achieved with no adverse outcomes up to 1 year and 9 months after autotransplantation. (Am J Orthod Dentofacial Orthop Clin Companion 2024;XX:XX-XX)

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Dental malocclusion can be a debilitating condition leading to both functional and esthetic concerns and negatively affecting patients' quality of life.[1] The etiology of malocclusion is multifactorial and includes both genetic and developmental origins. It can be defined as a malalignment of the dentition and/or a deviation from typical dental anatomy.[2] This can consist of hyperdontia or hypodontia, in which an abnormality in the number of teeth can be seen, malformation of teeth showing abnormal anatomy, and ectopic eruption of teeth in an atypical position. These dental conditions can profoundly influence smile esthetics while impairing masticatory function and the longevity of the dentition.[3,4] These malocclusions may confound the treatment required for successful outcomes, both from a restorative and orthodontic perspective.

Recent advancements proposed in the dental literature offer effective and efficient methodologies to address the difficulties faced when treating malocclusions. The advent of temporary anchorage devices has allowed clinicians to move teeth over longer distances without sacrificing anchorage loss while eliminating patient compliance factors.[5] This advancement can be ideal for the distalization of ectopic mesially-erupted maxillary canines in patients with congenitally missing maxillary lateral incisors for increased bone preservation, esthetics, and lateral incisor restorability potential, as described by Kokich et al.[6] In addition, implementing autotransplantation of teeth with the use of 3-dimensional (3D)-printed tooth replicas has offered a promising option for replacing missing dentition with positional accuracy.[7,8] The proposed method for digitally-guided autotransplantation presented by Strbac et al[9] addresses issues surrounding agenesis of maxillary lateral incisors. This method allows for the restoration of esthetics while conserving the physiology of the natural dentition, which is particularly important in growing patients. Augmentations to conventional orthodontic treatment, such as these, must be considered for the successful treatment of patients with complex dental conditions.

This case report describes the interdisciplinary orthodontic treatment of a growing patient with a peg-shaped permanent maxillary right lateral incisor, congenitally missing permanent maxillary left lateral incisor, and a supernumerary mandibular incisor. Orthodontic treatment with fixed appliances, miniscrew implant (MSI)-facilitated anchorage, digitally-guided autotransplantation, and composite build-ups was successfully performed.

DIAGNOSIS AND ETIOLOGY

A 15-year-old boy presented at the orthodontic residency clinic at the Eastman Institute for Oral Health, University of Rochester, NY, with the chief complaint of wanting the spaces closed between his maxillary anterior teeth. He also had a congenitally missing permanent maxillary left lateral incisor, a peg-shaped permanent maxillary right lateral incisor, and a supernumerary mandibular incisor. The patient had no contributory medical history or signs and symptoms of temporomandibular joint disorders. He had a retrognathic, slightly convex facial profile with reduced lower anterior facial height. His lips were well-positioned and competent at rest. The patient was symmetrical with a lower lip deviation when smiling. He had reduced tooth display when smiling and a flat smile arc. All his teeth were present from permanent second molar to second molar, except for the congenitally missing permanent maxillary left lateral incisor. The permanent maxillary left canine had ectopically erupted in the missing lateral incisor position, and the primary maxillary left canine was retained. He had a Class I occlusion, except for the permanent maxillary left canine, which was in a full-step Class II relationship. There was moderate generalized interdental spacing in the maxillary arch with 1.5 mm diastema and mild spacing in the mandibular arch with the presence of the supernumerary mandibular incisor. The patient had a 2 mm overjet, 50% deep overbite, and the maxillary dental midline was centered with the middle of the 5 mandibular incisors. The oral soft tissues, including periodontal tissues, were within normal limits, and oral hygiene was good (Fig 1).

Model analysis showed a significant Bolton discrepancy with mandibular anterior excess (2 mm) and a 1 mm curve of Spee (Fig 2). Cephalometric analysis revealed a skeletal Class III relationship (ANB, −0.8°) because of a retrusive maxilla (SNA, 78.4°). He had a normodivergent vertical pattern with a mandibular plane angle (FMA) of 24.9°. His cervical vertebrae maturation stage was 4. The patient had slightly proclined maxillary and mandibular incisors. All third molars were developing, as observed in the panoramic radiograph (Fig 3), and there was no evidence of root resorption. On the basis of the American Board of Orthodontics Discrepancy Index, the patient received an initial score of 15.

TREATMENT OBJECTIVES

The treatment objectives related to facial esthetics were to maintain the patient profile and lip position while providing a consonant smile arc and coincident dental midlines. The skeletal objectives were limited to maintaining or slightly increasing the mandibular plane angle and lower anterior facial height. Dentally, the main objectives were to close maxillary and mandibular dental spaces with incisor retraction and retroclination. The goal was also to reduce the overbite with a combination of posterior tooth eruption and mandibular incisor intrusion. To address the congenitally missing and supernumerary incisors, the objective included creating space for the missing permanent maxillary left lateral incisor by extracting the primary left canine and distalizing the permanent left canine with maximum MSI-supported anchorage. After creating adequate space, the goal was to perform root canal treatment followed by extraction of a mandibular incisor to perform digitally-planned autotransplantation on the missing

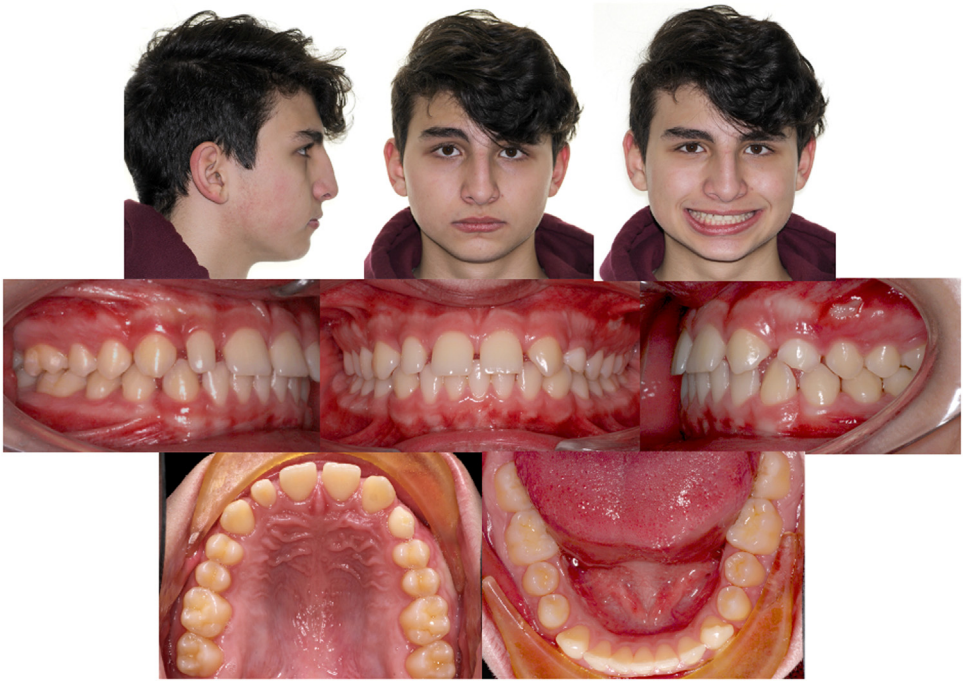

Fig 1. Pretreatment facial and intraoral photographs at 15 years old.

maxillary left lateral incisor region. Composite bonding was planned for the peg-shaped right lateral and left transplanted incisor to address the Bolton discrepancy and enhance dental esthetics.

TREATMENT ALTERNATIVES

This was a complex case, and various treatment alternatives were considered. One major consideration was to address the presence of the supernumerary mandibular incisor, given the absence of dental crowding and the presence of generalized spacing in both arches. The alternative option of maintaining the mandibular supernumerary incisor was rejected because of the underlying Bolton discrepancy, which would not have permitted the closure of the interdental spaces in the maxillary arch. Regarding the maxillary arch, the main decision was whether to perform space closure (unilateral left canine substitution) or distribute space for tooth restoration to address the

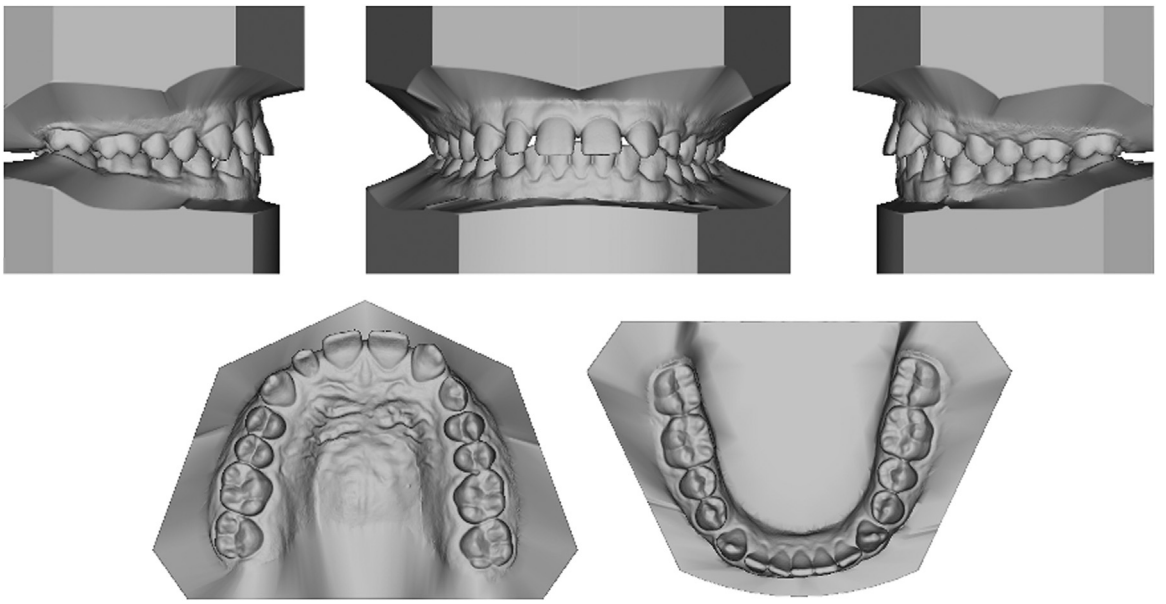

Fig 2. Pretreatment dental casts.

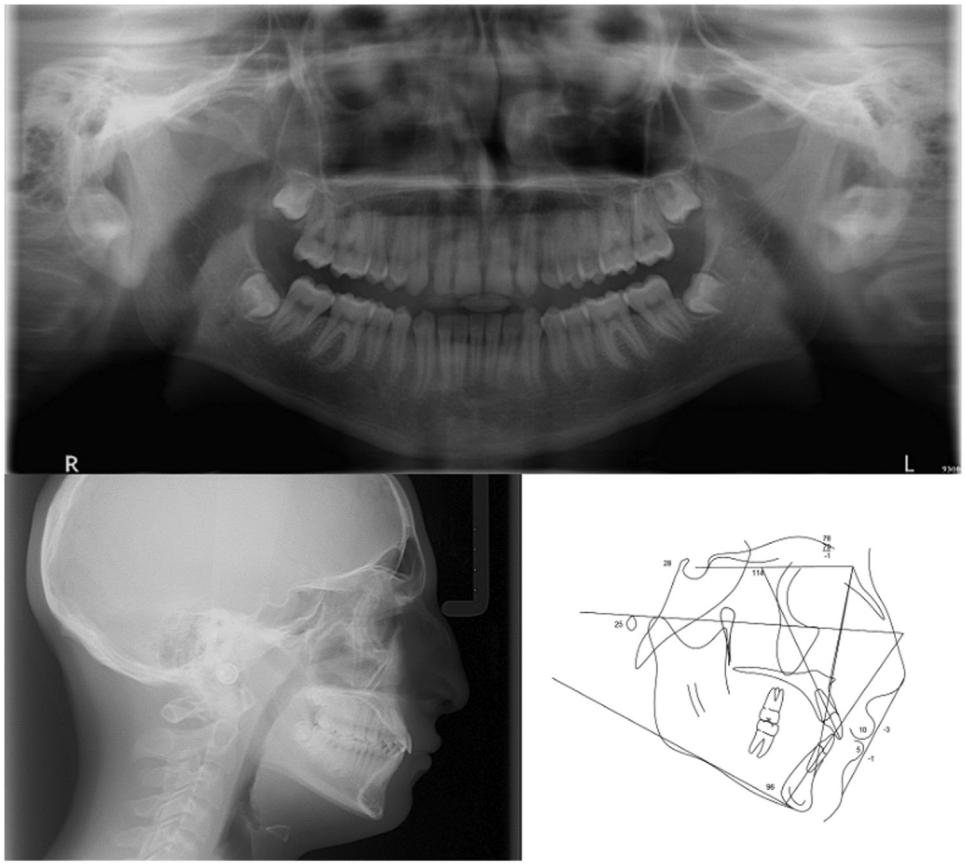

Fig 3. Pretreatment panoramic radiograph, lateral cephalogram, and tracing.

congenitally missing maxillary left incisor. The unilateral canine substitution option was not selected because of several factors, including (1) the presence of generalized spacing in the maxillary arch, (2) the underlying skeletal Class III relationship, and (3) the difficulty in maintaining a symmetrical maxillary dental midline with unilateral space closure. Therefore, the decision was made to replace this missing tooth. Alternative methods of tooth replacement included fixed dental or implant-supported prostheses either in the maxillary left lateral incisor region (after distalization of the permanent canine) or at the primary canine region (with prosthetic recontouring of the permanent canine to mimic the missing lateral incisor) and after growth cessation. In such patients, the primary canine could have been maintained until the growth was complete. However, given the unique dental presentation of this patient, having a supernumerary incisor and one missing incisor, the autotransplantation option was considered the most biologically oriented approach. Nonetheless, the risks of autotransplantation, including inflammatory or replacement root resorption (ankylosis), were thoughtfully considered and reviewed with the patient and parents. In case of an adverse outcome regarding the autotransplantation, the plan would be traditional prosthetic alternatives for the maxillary left lateral incisor replacement.

TREATMENT PROGRESS

The patient was bonded with 0.018-in preadjusted self-ligating brackets (SPEED System Orthodontics, Cambridge, Ontario, Canada) on all teeth. Anterior bite turbos were bonded on the palatal surface of the maxillary central incisors. Leveling and alignment were performed with a conventional sequence of nickel-titanium archwires (0.014-in, 0.018-in, and 0.016 × 0.022-in). The patient progressed to 0.016 × 0.022-in stainless steel (SS) archwires with compensatory and reverse curves of Spee in the maxillary and mandibular arch, respectively, for space closure. Four months after bonding (Fig 4, *A*), a 9.0 × 1.5-mm orthodontic MSI (Infinitas; DB Orthodontics, Inc, Silsden, West Yorkshire, United Kingdom) was placed buccally between the permanent maxillary left second premolar and first molar to provide maximum indirect anchorage for the bodily retraction of the mesially-positioned maxillary left permanent canine. The primary left canine was extracted, and elastomeric power chains and a nickel-titanium open coil (between the permanent maxillary left central incisor and canine) were used to distalize the permanent maxillary left canine into Class I position. This would also create space for autotransplantation to replace the missing maxillary left lateral incisor. Power chains were used in the mandibular arch to consolidate any spaces. Full bodily retraction

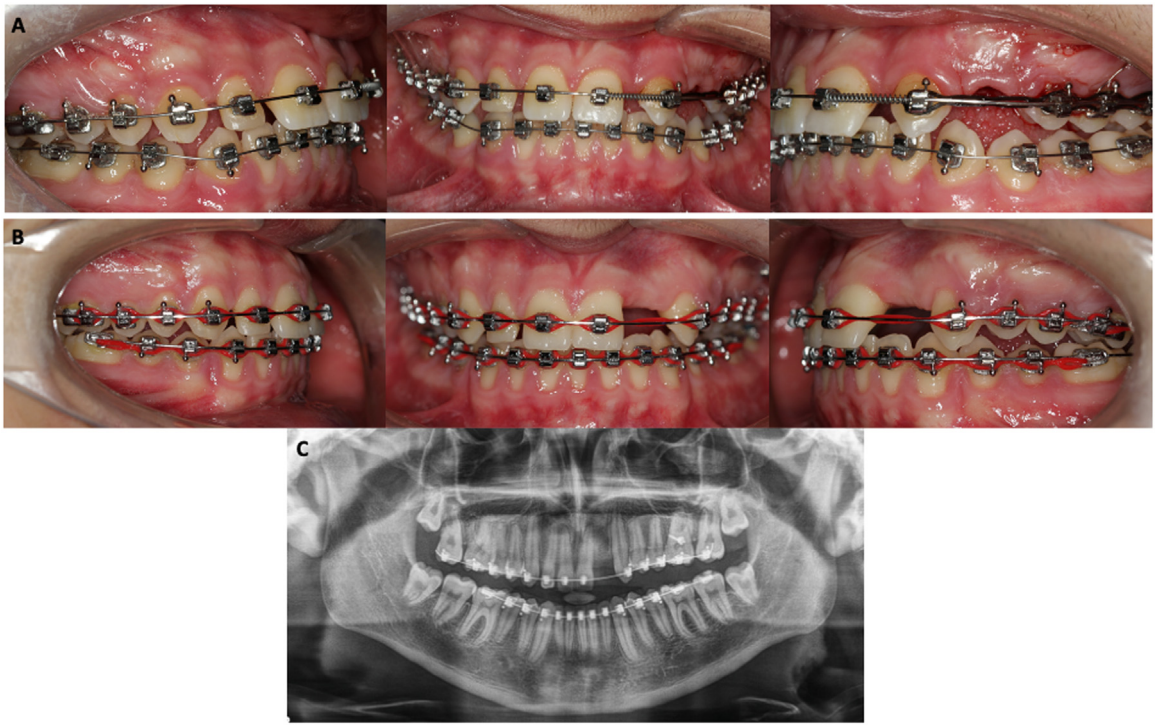

Fig 4. Intraoral photographs (**A** and **B**) and panoramic radiograph (**C**) illustrating treatment progress: **A,** Four months after bonding, use of MSI for indirect anchorage for maxillary left canine distalization with elastomeric power chains; **B** and **C,** One and a half years after bonding showing bodily distalization of maxillary left canine with maximum anchorage.

of the permanent maxillary left canine with no anchorage loss was achieved after 1.5 years of treatment (Fig 4, *B*), and a progress panoramic radiograph revealed good root parallelism (Fig 4, *C*).

The maxillary arch was temporarily debonded to prevent scattering when obtaining the presurgical cone-beam computed tomography (CBCT) and to allow the placement of a surgical guide during autotransplantation surgery. An interim maxillary full-coverage thermoplastic retainer (Essix; Dentsply Sirona, Sarasota, Fla) was provided to prevent relapse during autotransplantation. After obtaining the CBCT, a thorough assessment was made among the interdisciplinary team to select the most appropriate mandibular incisor for autotransplantation. Factors such as crown shape, root length, root development, and presence of root dilacerations or preexisting root resorption were considered. The second mandibular incisor to the left of the mandibular right canine was selected as the donor's tooth because of adequate root length and lack of significant dilacerations. Root canal treatment was completed in one appointment a week before the surgery on the future donor tooth as the tooth had an already closed apex, and pulp formation had ceased.

Digital imaging and communications in medicine file were generated from the presurgical CBCT and imported into the Blue Sky Plan software (Blue Sky Bio, LLC, Libertyville, Ill) (Fig 5). The supernumerary mandibular right incisor was virtually segmented (Fig 5) and converted into a stereolithographic (STL) file. Subsequently, the STL file of the donor tooth was superimposed to the digital imaging and communications in the medicine file over the recipient site to evaluate the adequacy of available alveolar ridge dimensions and space between the adjacent teeth (Fig 6). Similarly to virtually planning the placement of dental implants, the ideal angulation, orientation, and depth of the donor's tooth were determined. The STL file of the donor tooth at the recipient site was superimposed with a virtual dental implant (Fig 6) to match donor tooth angulation/position and depth within the alveolar bone. Next, a surgical guide was designed with a 5-mm diameter metal sleeve positioned based on the predetermined position and orientation. The digitally-planned surgical splint with the metal sleeve, guided-surgery drill handles, and drills would achieve the desired osteotomy diameter, depth, and orientation. The required space for the blood clot to form between the root and the walls of the alveolar bone and for the periodontal ligament to develop were also considered. Finally, the segmented donor tooth and surgical guide were exported as STL files and 3D-printed (Straumann CARES, P30; Institute Straumann AG, Basel, Switzerland) with biocompatible resin material (P pro Surgical Guide Clear; Institute Straumann AG) (Fig 7).

On the day of the surgery, the patient was premedicated with a loading dose of antibiotics (2 g of amoxicillin

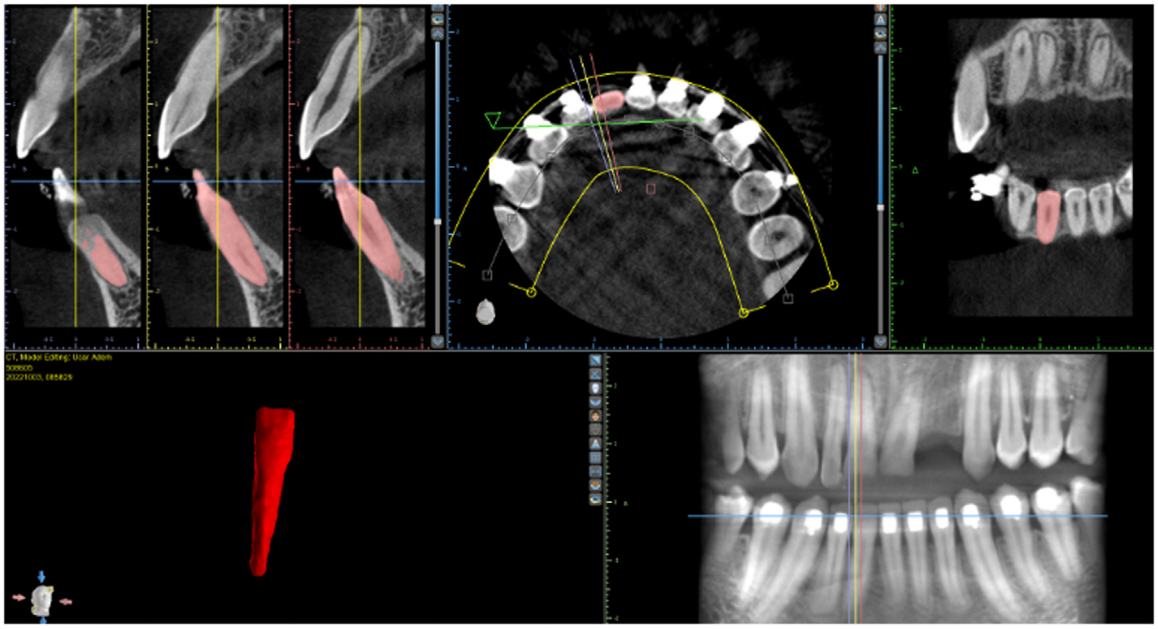

Fig 5. Digital segmentation of donor's tooth on CBCT for 3D replica fabrication.

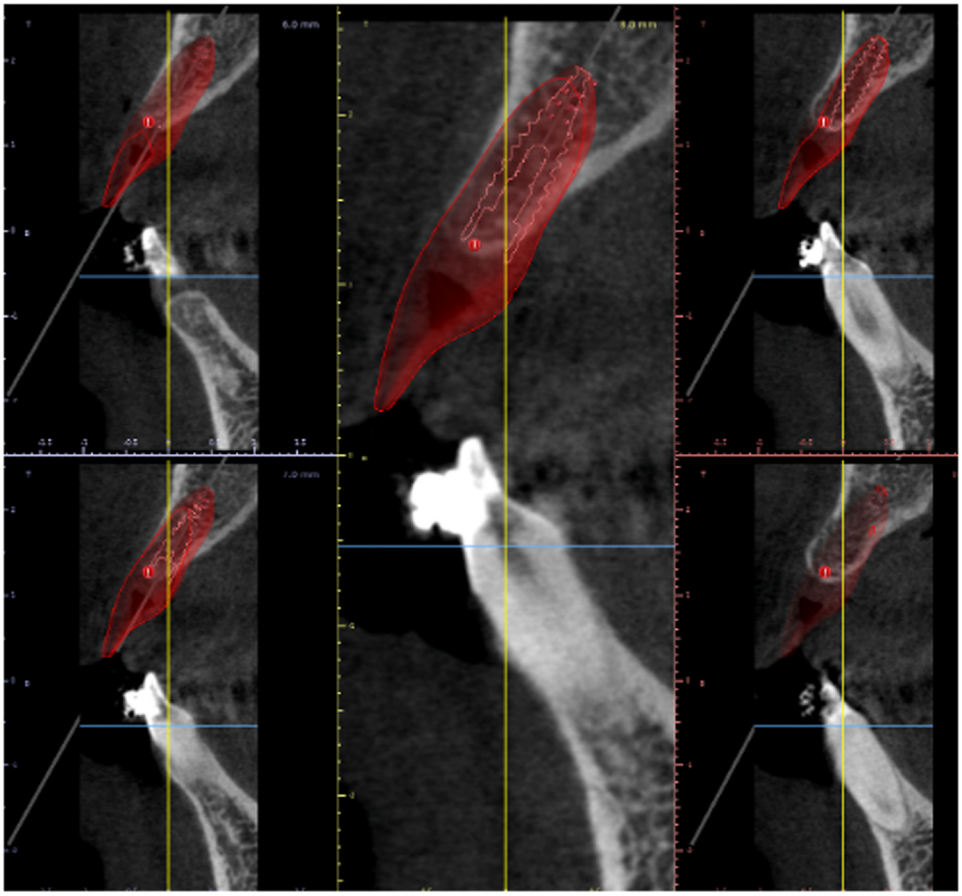

Fig 6. Digital positioning of the segmented donor tooth at the edentulous recipient site for the design of the surgical guide.

Fig 7. Three-dimensionally printed donor tooth replica and surgical guide.

1 hour before the procedure), and the oral cavity was disinfected using 0.12% chlorhexidine gluconate mouthwash. Profound anesthesia was delivered, and a midcrestal incision was performed at the recipient's edentulous site, extending with intrasulcular incisions on the adjacent central incisor and canine. Full-thickness buccal and palatal flaps were reflected. The 3D-printed surgical guide with the metal sleeve was positioned, and proper seating was confirmed (Fig 8, *A*). Subsequently, a sequence of guided-surgery drill handles and drills (Institute Straumann AG) was used to prepare the tooth socket to the planned diameter, orientation/angulation, and depth (Fig 8, *B*). The tooth replica was positioned in the prepared tooth socket, and further adjustments were made with a round bur to size the socket accordingly and until the 3D replica was properly seated based on the digitally predetermined position (Fig 8, *C-E*). Afterward, the donor supernumerary tooth was elevated and carefully extracted with forceps, minimizing damage to the root and periodontal ligament as much as possible. Within 20 seconds of extraction, the enamel matrix derivative (Emdogain, Institute Straumann AG) was adjunctively applied on the root surface without prior root conditioning (Fig 8, *F*). The tooth was immediately positioned in the prepared recipient socket with light pressure and the cementoenamel junction being 1-2 mm supracrestally (Fig 8, *G* and *H*). On confirmation of the tooth position, only minor mobility of the transplanted tooth was observed, and it was semirigidly splinted with the adjacent teeth at the recipient site with Ortho Flextech retention wire (Reliance Orthodontic Products, Itasca, Ill) and resin composite (Fig 8, *I-K*). The buccal and palatal flaps were firmly repositioned around the transplanted tooth, and simple interrupted sutures with 4-0 polytetrafluoroethylene (Cytoplast; Osteogenics Biomedical, Lubbock, Tex) were placed bilaterally. It was ensured that the transplanted tooth was not occluding in maximum intercuspation lateral or protrusive jaw movements. Hemostasis was achieved, medications (600 mg ibuprofen 3 times daily for 5 days, 500 g amoxicillin 3 times daily for 7 days, and 0.12% chlorhexidine gluconate mouth rinse twice daily for 2 weeks) were prescribed, and a soft diet was suggested postoperatively. A periapical radiograph (Fig 8, *I*) indicated the close approximation of the transplanted tooth root to the recipient bed and the proper positioning relative to the cementoenamel junction of the adjacent teeth.

The patient was followed up at 2, 4, and 6 weeks after the surgery (Fig 9, *A* and *B*). At 2 weeks, the tissues surrounding the transplanted tooth healed within normal and with no signs of infection or increased tooth mobility, and the sutures were removed. At 6 weeks, the semirigid splint was removed, and reduced tooth mobility was observed. The transplanted tooth and the peg-shaped maxillary right permanent lateral incisor were restored with direct composite restorations to improve dental esthetics (Fig 9, *B*). The patient was introduced to a regular 4-month periodontal maintenance schedule until the end of orthodontic treatment. The intervals were extended to 6 months after the removal of the fixed appliances.

The maxillary arch was rebonded 6 weeks after the autotransplantation, and the transplanted tooth was bonded passively to minimize force levels and root movement. Space closure, including the mandibular incisor extraction space, was performed on 0.016 × 0.022 SS wires with curves to control incisor torque. In the mandibular arch, sequential space closure to the left was performed, and intermaxillary elastics were used as needed to ensure coincident dental midlines. Space closure was completed 11 months after the autotransplantation (Fig 9, *C*). Any minor bracket repositioning (along with brief bonding of erupted third molars) was performed as needed. Detail bends and vertical elastics were used to finalize and settle the occlusion (Fig 9, *D*). No signs of ankylosis of the transplanted tooth were observed. Periapical radiographs were taken immediately after, and at 4 and 7 months after autotransplantation, revealed a continuous periodontal ligament space along the root, stable interproximal crestal bone levels, and only slight external apical root resorption that remained stable after that (Fig 10,).

The patient was debonded after 3 years and 4 months of interdisciplinary orthodontic treatment (Figs 11, 12, and 13). To prevent space reopening, a fixed retainer (Reliance Orthodontic Products) was bonded from mandibular canine to canine. Maxillary and mandibular full-coverage thermoplastic retainers (Essix; Dentsply Sirona) were also delivered, and the patient was instructed to wear them full-time for the first 6 months and then nighttime indefinitely.

TREATMENT RESULTS

The patient's chief complaint was addressed. Treatment objectives were met, including closure of all spaces while addressing congenitally missing, supernumerary, and peg-shaped teeth with a minimally invasive and biologically tailored approach. The achieved treatment changes are depicted by the pretreatment and posttreatment

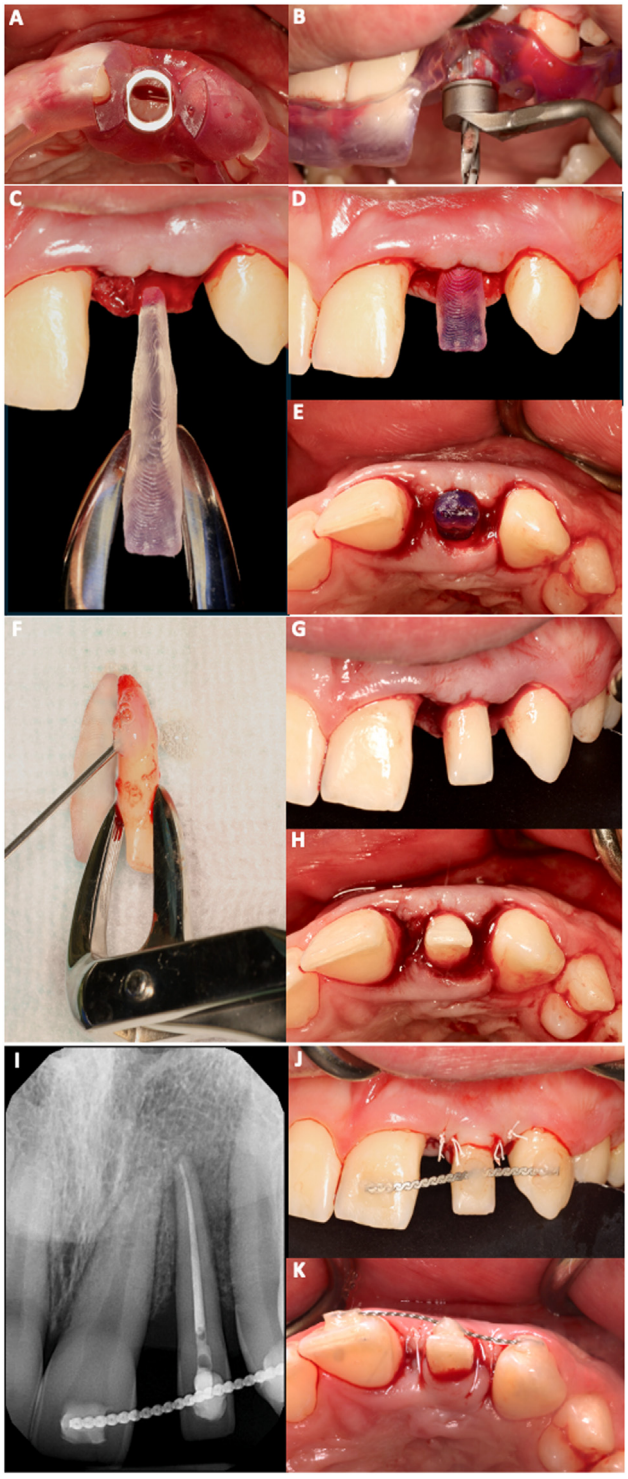

Fig 8. Autotransplantation surgery: **A,** Surgical guide seated on the maxillary arch; **B,** Flap reflection and tooth-socket preparation through surgical guide at the recipient site; **C-E,** Confirmation of proper seating of donor tooth replica in the prepared tooth socket; **F,** Extraction of supernumerary donor tooth and application of enamel matrix derivative on the root surface; **G** and **H,** Transplantation of extracted donor tooth at the recipient site; **I,** Periapical radiograph of the transplanted tooth after semirigid splinting; **J** and **K,** Replaced and sutured flap and semirigid splinting with orthodontic SS multistrand wire and composite.

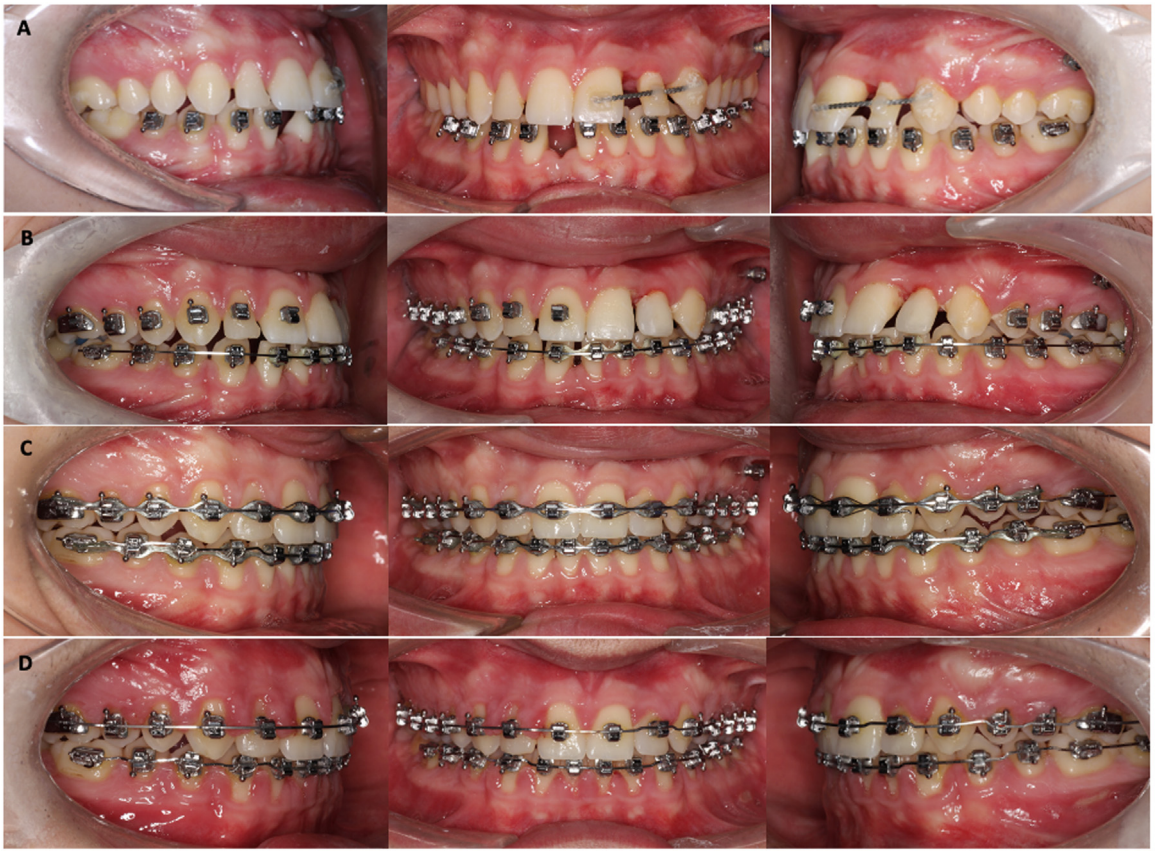

Fig 9. Intraoral photographs: **A,** Four weeks after the autotransplantation and before splint removal; **B,** Six weeks after the autotransplantation, the splint was removed and transplanted tooth received composite build-up; **C,** Eleven months after autotransplantation, space closure was achieved with elastomeric power chains in 0.016 × 0.022-in SS rectangular archwires; **D,** Fifteen months after autotransplantation, orthodontic detailing was done with detail bends to settle the occlusion.

cephalometric superimpositions (Fig 14). Regarding facial esthetics, lip support was adequately preserved during space closure, and the position of the upper lip was maintained while the lower lip, chin, and nose protruded with growth. A consonant smile arc was achieved, and the maxillary incisor display when smiling was increased because of the relative extrusion of the maxillary central incisors (Fig 11). Clinically, the soft tissues surrounding the transplanted tooth were pink and firm, there was no midfacial recession of the gingival margin, and adequate

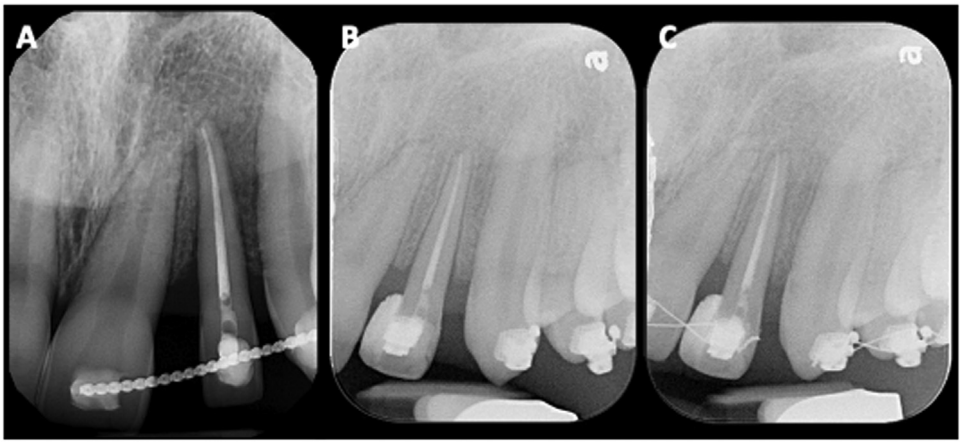

Fig 10. Periapical radiographs of transplanted tooth at recipient site: **A,** Immediately after autotransplantation; **B,** Four months after autotransplantation; **C,** Seven months after autotransplantation.

Fig 11. Posttreatment facial and intraoral photographs at the age of 18 years and 6 months (total interdisciplinary treatment duration of 3 years and 4 months).

interproximal papilla fill was observed (Fig 11). Moreover, the periodontal tissues of the transplanted tooth were healthy with normal probing depths (<4 mm), and the clinical attachment levels were within normal limits (<5 mm). There was physiological tooth mobility of the transplanted tooth and absence of pain or discomfort during palpation, percussion, and normal function such as during mastication.

Skeletally, both the maxilla and mandible moved downward and forward with growth, and the mandibular plane angle was approximately maintained. There was a slight increase in the ANB angle during treatment. There was maxillary and mandibular posterior tooth eruption, which was balanced by vertical alveolar bone growth during treatment (Fig 14). There was retraction with slight relative extrusion of the maxillary and mandibular incisors because

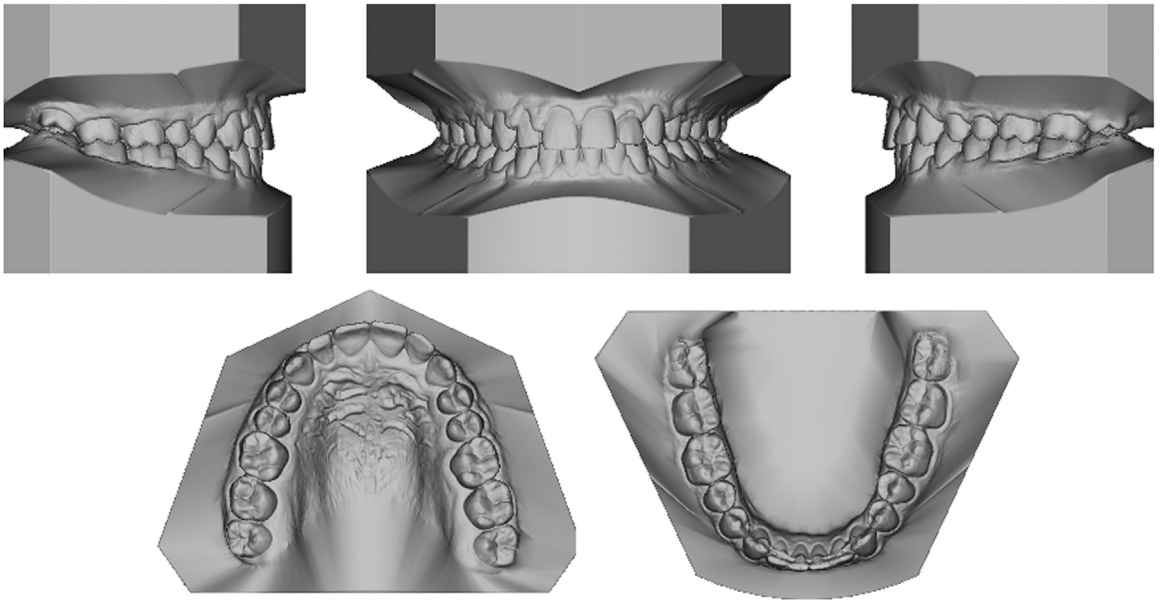

Fig 12. Posttreatment dental casts.

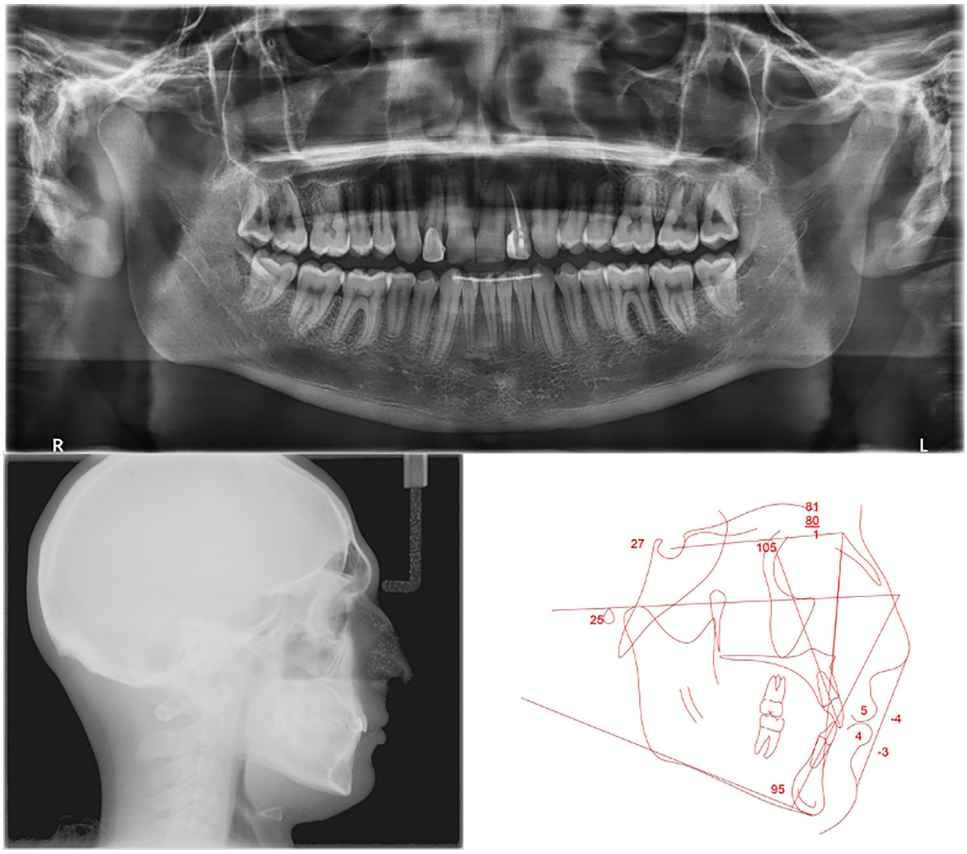

Fig 13. Posttreatment panoramic radiograph, lateral cephalogram, and tracing.

of space closure, and proper final incisor positioning was achieved (SN-U1, 104.5°; IMPA, 95.3°). The cephalometric analysis is summarized in the Table.

The posttreatment dental casts demonstrated proper alignment and leveling of the teeth and the establishment of a Class I occlusion with good interdigitation, including the erupted third molars. A proper overjet and overbite were achieved, and the patient had coincident dental midlines (Fig 12). The posttreatment panoramic radiograph (Fig 13) showed overall tooth root parallelism and that the interproximal bone levels of the transplanted tooth, as well as the apical third of the root and the periodontal ligament space, appeared to be stable. There was no periapical radiolucency noted and minimal apical root resorption of the transplanted tooth that appeared to have ceased after 4 months post-autotransplantation. The American Board of Orthodontics Cast-Radiograph Evaluation was scored as 15.

The patient was referred for periodontal maintenance, including debridement and prophylaxis, to address the mild gingivitis posttreatment (Fig 11). He was then placed on a 2-month orthodontic retention follow-up schedule. The option for final restoration of the maxillary right lateral incisor and transplanted tooth with crowns or veneers on completion of growth was also discussed. Follow-up facial and intraoral photographs during retention (Fig 15) illustrate occlusal stability, improvement in gingival health, and good soft tissue esthetics of the transplanted tooth 1 year and 9 months after the autotransplantation with no signs of ankylosis.

DISCUSSION

The orthodontic management of patients with various types of malocclusion may be complicated by preexisting dental conditions such as the presence of congenitally missing, malformed or peg-shaped, supernumerary, and/or ectopically erupted permanent teeth.[10-12] The permanent maxillary lateral incisors are among the most common congenitally missing teeth (excluding third molars and mandibular second premolars), with an overall prevalence of 3.77% and a female predisposition.[10,13] Moreover, the occurrence of a unilateral congenitally missing maxillary lateral incisor often coexists with the presence of a peg-shaped maxillary lateral incisor in the contralateral side and/or ectopically erupted maxillary canines.[14] The presence of supernumerary teeth in the permanent dentition has been reported to be approximately 2% in schoolchildren, with the most common location being in the area of the maxillary midline (mesiodens).[14] The presence of supernumerary teeth has been associated with several

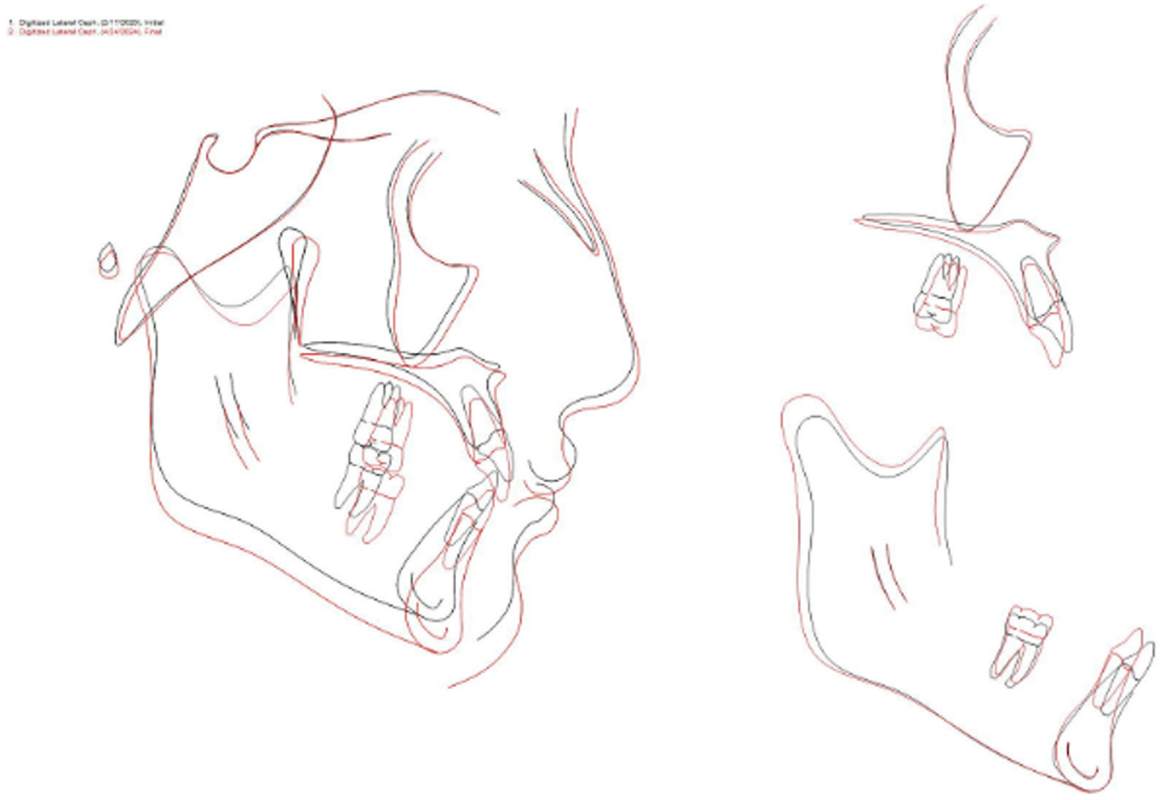

Fig 14. Cephalometric tracings before treatment (*black* indicates 15 years old) and after treatment (*red* indicates 18 years 6 months old) superimposed on the inner contour of the anterior wall of the sella turcica, anterior contour of the zygomatic process, and inner contour of the cortical plate at the lower border of the symphysis.

Table. Cephalometric analysis

Cephalometric measurements	White norms (male adolescent)[†]	*Pretreatment aged 15 y 0 mo*	*Posttreatment aged 18 y 6 mo*
SNA (°)	82.0 ± 3.5	78.4	81.0
SNB (°)	80.9 ± 3.4	79.2	80.2
ANB (°)	1.6 ± 1.5	−0.8	0.8
Mp-SN (°)	32.9 ± 5.2	27.6	26.4
FMA (°)	22.9 ± 4.5	24.9	24.7
U1-NA (mm)	4.3 ± 2.7	9.9	4.9
SN-U1 (°)	103.1 ± 5.5	114.3	104.5
L1-NB (mm)	4.0 ± 1.8	5.4	3.3
IMPA (°)	95.0 ± 7.0	96.3	95.3
Upper lip/E-line (mm)	−8.0 ± 2.0	−2.5	−4.3
Lower lip/E-line (mm)	−2.0 ± 2.0	−1.0	−2.7

[†]Values are normal cephalometric values ± standard deviation values for the patient's gender and racial classification derived from Dolphin Imaging and Management Solutions software (Chatsworth, Calif).

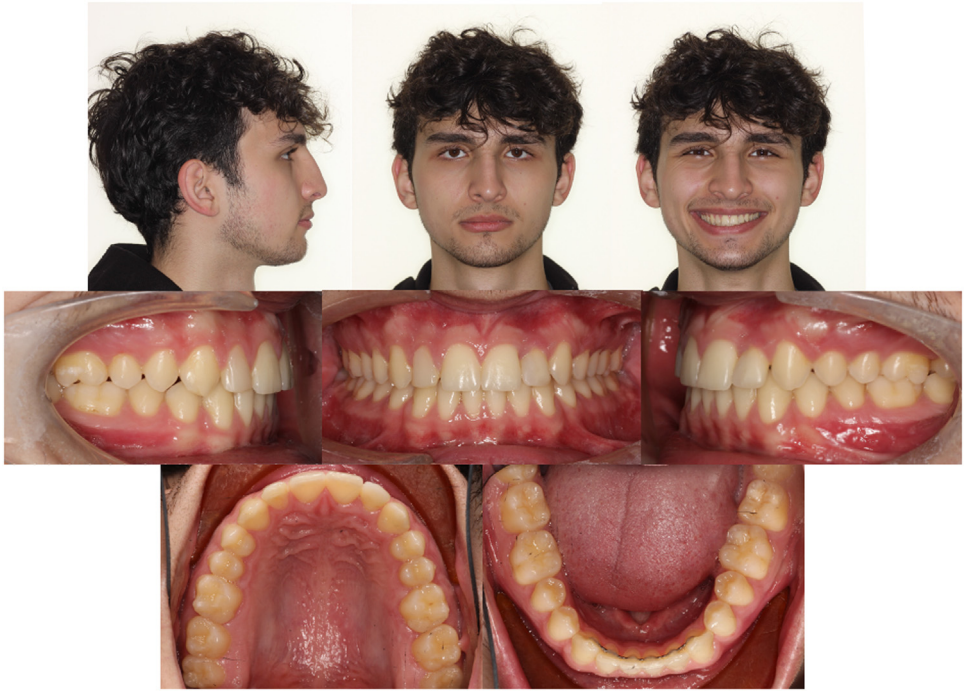

Fig 15. Retention phase facial and intraoral photographs (3 months after debonding, 1 year after the autotransplantation, and 9 months after the autotransplantation).

syndromes or conditions, including Gardner syndrome, cleft lip and palate, and cleidocranial dysplasia, but may also occur in patients with no other associated diseases or syndromes.[14] The presence of a supernumerary mandibular incisor has been reported to be very rare, with a prevalence ranging 0.02%-0.13%.[15,16] This case report describes the interdisciplinary orthodontic treatment of a nonsyndromic growing patient with a unique combination of dental conditions, including a congenitally missing permanent maxillary left lateral incisor, peg-shaped maxillary right lateral incisor, ectopic/mesially-erupted permanent maxillary left canine, and a supernumerary mandibular incisor. These dental conditions were accompanied by the presence of generalized interdental spacing, midline diastema, and a dental deepbite Class I malocclusion, which required the implementation of an interdisciplinary orthodontic treatment approach.

The treatment plan elected for this patient was biologically driven in the sense of using the supernumerary mandibular incisor to replace the congenitally missing maxillary incisor. Several factors further complicated this treatment approach: (1) the root development of all 5 mandibular incisors was completed, and the root apices were closed; (2) there was no preexisting tooth socket in the congenitally missing maxillary left lateral incisor area; and (3) the maxillary left permanent canine had erupted in the missing lateral incisor position and was in a full-step Class II occlusal relationship. The existing literature has supported high success rates regarding tooth autotransplantation, with survival rates of 96%.[17] Common reported complications with autotransplantation include inflammatory or replacement (ankylosis) root resorption and additional outcomes such as pulpal necrosis or obliteration, tooth mobility, and even tooth failure.[17] Negative prognostic factors for autotransplantation have been identified, including completed root development with a closed apex of the donor's tooth, increased patient age, posterior vs anterior donor teeth, and absence of a preexisting tooth socket at the recipient site.[17,18] Regarding recipient site location, the anterior maxillary region has been reported to be the most favorable site for autotransplantation.[19] In this patient, several strategic decisions led to a successful autotransplantation outcome. First, thorough digital planning and donor tooth selection were performed because of a complete digital workflow. Second, because the donor tooth was accessible before surgery, root canal treatment was completed 1 week before the autotransplantation.[20] It has been well described that most autotransplanted teeth with a closed apex require root canal treatment,[21] as pulpal revascularization and healing rarely occur and to prevent the development of inflammatory conditions such as external root resorption and ankylosis.[22] Third, the digital planning of the surgical procedure contributed toward the precise surgical preparation of the tooth socket at the recipient site while minimizing the surgical time and extra-alveolar exposure of the donor's tooth root before reimplantation. Preparation of the recipient socket before the extraction of the donor's tooth also helped minimize any

damage to the periodontal ligament that may have been caused by multiple tries of the donor's tooth in the recipient socket. Other case reports support the incorporation of digital technology to aid surgical autotransplantation.[9,23,24] Verweij et al,[7] in a multicenter prospective study of 100 transplanted teeth, demonstrated the use of a printed donor tooth replica to reduce fitting attempts of the donor tooth intraoperatively. Moreover, in this patient, an enamel matrix derivative was applied on the donor tooth root surface immediately before implantation, to enhance the regeneration of the periodontal ligament.[8,25,26] In addition, a semirigid fixation was applied post-autotransplantation for 6 weeks. It has been proposed that semirigid fixation provides adequate stability during the early healing phase while allowing small degrees of functional movement of the transplanted tooth in its respective socket.[27,28] Rigid and extended fixation for >4-6 weeks increases the risk of potential adverse events such as root resorption and ankylosis.[22] Furthermore, care was taken to ensure no occlusal contacts between the transplanted tooth and opposing dentition at rest or functional movements during the healing period. Finally, after the stabilization period, light orthodontic forces were applied to the transplanted tooth to minimize the risk of inflammatory root resorption. It is noteworthy that minimal (approximately 0.5 mm) external apical root resorption was noted in the 4-month periapical radiograph post-autotransplantation, which remained stable after that (Figs 10 and 13). Intraoral clinical photographs taken 1 year and 9 months post-autotransplantation revealed good soft tissue esthetics of the transplanted tooth, with no midfacial nor interproximal recession and with favorable crown size/morphology after composite restoration and no signs of ankylosis.

In this patient, MSI-supported indirect anchorage was used to enable bodily retraction of the mesially-erupted maxillary left permanent canine into Class I occlusion after extraction of the primary maxillary left canine. Canine distalization was performed in rectangular SS wires with compensatory curve of Spee to minimize crown tipping during canine retraction. In a randomized controlled trial by Sharma et al[29] it was shown that MSIs placed between the maxillary second premolars and first molars could be successfully used for canine retraction and may provide absolute anchorage compared with conventional anchorage devices such as the transpalatal arch. In a systematic review and meta-analysis by Becker et al,[30] it was found that minor anchorage loss may still occur when MSIs are used with indirect vs direct anchorage for canine and/or incisor retraction. The MSI failure rates were reported to be 9.9% and 8.6% with direct and indirect anchorage, respectively.[30] Nonetheless, results still favored MSIs over conventional anchorage devices. Various factors have been associated with MSI failures, such as placement of MSIs too close to the periodontal ligament of the adjacent teeth, placement in the mandible vs the maxilla, decreased alveolar cortical bone thickness, and low bone density, volume, and thickness at the insertion site, younger patient age, and excess pressure during placement leading to microfractures of the trabecular bone, among other factors.[31,32] In this patient, the MSI remained stable throughout treatment and facilitated bodily canine retraction of approximately 7 mm without clinically relevant anchorage loss.

Although the presence of the permanent maxillary left canine into the missing maxillary lateral incisor position in this patient complicated the treatment biomechanics and led to an overall increased treatment time of over 3 years, it was biologically beneficial for the patient in terms of permitting and preserving adequate alveolar ridge dimensions in the congenitally missing lateral incisor region.[33,34] It has been reported that orthodontically distalizing the maxillary canine while creating space for the restoration of the missing lateral incisor makes it possible to preserve the volume of the maxillary alveolar bone.[33,34] This may have contributed to favorable skeletal and soft tissue posttreatment outcomes around the transplanted tooth. Furthermore, in this patient, autotransplantation of the supernumerary mandibular incisor on the missing maxillary incisor region and composite build-ups of the transplanted and peg-shaped incisors enhanced dental esthetics while addressing the underlying Bolton discrepancy because of mandibular anterior excess. This permitted space closure, establishment of interdental contacts, and a good occlusal outcome while enhancing stability during the retention phase of orthodontic treatment.[35] A systematic review and meta-analysis on the long-term prognosis of autotransplanted teeth concluded high survival rates ranging 75.3%-91.0%.[36] Thus, tooth autotransplantation can be a viable treatment alternative to conventional prosthetic treatments, offering a biological and economical treatment option for tooth replacement, particularly in growing patients when dental implants are contraindicated.[37]

CONCLUSIONS

This case report illustrates the successful and biologically oriented interdisciplinary orthodontic treatment of a growing patient with a peg-shaped permanent maxillary right lateral incisor, congenitally missing permanent maxillary left lateral incisor, and a supernumerary mandibular incisor. Our results show that digitally-guided autotransplantation of a closed-apex supernumerary mandibular incisor can successfully address a congenitally missing maxillary incisor. An acceptable occlusion and facial esthetics were achieved with no adverse outcomes up to 1 year and 9 months post-autotransplantation.

CONFLICTS OF INTEREST

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

DISCLAIMER

This case report was awarded first place in the 2024 Case Display of the American Board of Orthodontics at the American Association of Orthodontists annual meeting in New Orleans, La, in May 2024.

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AUTHOR CREDIT STATEMENT

Christopher Burns contributed to investigation, original draft preparation, and manuscript review and editing; Elli Anna Kotsailidi contributed to conceptualization, investigation, original draft preparation, and manuscript review and editing; Fares Alshuraim, Konstantina Tzouma, and Ignacio Pedrinaci contributed to investigation and manuscript review and editing; Shaahin Dadjoo contributed to conceptualization, investigation, and manuscript review and editing; Paul Emile Rossouw contributed to supervision and manuscript review and editing; and Dimitrios Michelogiannakis contributed to conceptualization, supervision, original draft preparation, and manuscript review and editing.

STATEMENT OF INFORMED CONSENT

The informed consent was obtained by the patient.

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