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Case Report

Nonextraction Orthodontic Treatment of Severely Impacted Maxillary Canines through Transalveolar Transplantation in a 10-Year-Old Patient: A Case Report with a 6-Year Follow-Up Period

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Abstract: Objective: This case report describes the interdisciplinary treatment of a 10-year-old girl with asymmetric Class III malocclusion, severe maxillary crowding, and bilaterally impacted maxillary canines. Clinical considerations: The clinical decision-making factors regarding treatment alternatives and the final treatment plan are discussed. A two-phase nonextraction therapy was implemented to relieve severe crowding, eliminate the maxillary canine impactions, and compensate for skeletal Class III malocclusion. The first treatment phase involved aligning the left canine through conventional orthodontic traction, while the more deeply horizontally impacted right canine was corrected through transalveolar transplantation. In the second phase, the Class III dental relationship was corrected through mandibular molar retraction. The effective use of various temporary skeletal anchorage devices such as modified c-palatal plates and mini-implants was illustrated. Conclusions: At the end of the treatment, esthetic dental alignment was achieved, along with improved facial balance. The transplanted maxillary right canine showed good health and a favorable long-term prognosis over six years after the procedure.

Keywords: dental autotransplantation; maxillary canine impaction; Class III malocclusion; orthodontic space gaining; temporary skeletal anchorage devices; case report

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1. Introduction

Tooth impaction is a prevalent dental anomaly that affects 2.9% to 14.1% of the population [1,2]. The impaction of the maxillary canine is the second most frequent case, with an incidence rate of 0.9% to 2.2%, preceded only by the impaction of third molars [3]. Also, bilateral maxillary canine impaction tends to occur more frequently in skeletal Class III malocclusion [4]. Clinically, poor occlusion develops in the presence of impacted maxillary canines, since they are often associated with midline deviation, a loss of arch length, dentigerous cyst formation, the root resorption of the affected tooth, and related pain. The successful orthodontic management of the problem is influenced by various factors, such as the age of the patient, position of the impacted canine, amount of available space, and sufficient hard and soft tissue support.

In autogenous transalveolar transplantation, the dental transplant is removed from its original alveolar socket and repositioned into another within the same patient [5]. In contrast, intra-alveolar transplantation involves repositioning the remaining tooth structure

in a more supragingival position within the same socket [6]. Transalveolar transplantation may be indicated for the leveling of severely impacted teeth, managing alveolar cleft, replacing congenitally missing teeth, and closing oroantral communications [7]. The transalveolar transplantation of the impacted maxillary canine may be a viable treatment alternative if surgical exposure and the orthodontic traction of the tooth are not possible due to the severe malposition of the impaction [8]. The advantages of such an approach may include reduced treatment time and the preservation of the periodontal ligament that allows normal orthodontic tooth movement and the uncompromised growth of the alveolar bone structures in growing patients. The success rate of autotransplantation tends to be high, ranging from 75.3% up to 100% [9,10], while the five-year survival rate varies from 81% to 98.2% [11]. In contrast, transalveolar transplanted maxillary canines display inferior success rates spanning from 38% to 67.5% [12,13]. Common types of failure include excessive periodontal defects, tooth mobility, root resorption, incomplete eruption, and ankylosis. However, the above authors also pointed out that the transplantation procedure is technique-sensitive, and the success rates are higher in teeth with open apices. With incomplete root formation, the survival rate of an autotransplanted tooth was 96.9% after 10 years of follow-up [14].

Fortunately, temporary skeletal anchorage devices (TSADs) have expanded the possible orthodontic tooth movement boundaries by providing absolute anchorage with minimum untoward side effects. They may function as a single mini-implant or a combination of mini-implants coupled with individualized appliance units such as modified C-palatal plates (MCPPs) [15]. In either form, TSADs can be effectively applied to distalize the entire dentition or increase the arch length by retracting the molars to aid the nonextraction treatment mechanics. Also, they can be implemented to promote the maxillomandibular orthopedic effect in growing patients [15,16] or to camouflage dentoskeletal disharmony in adults [17,18].

Many factors should be considered when correcting a tooth impaction because impactions often coexist with asymmetry, crowding, and other skeletal discrepancies that may complicate the treatment outcome [4]. Also, it should be recognized that the presence of an impacted tooth is likely to prolong the orthodontic treatment duration, mandate stricter patient compliance, and require additional surgical intervention from other dental specialists. Therefore, the clinical decision to align, extract, substitute, or replace an impacted canine should be reached only after thoroughly evaluating the whole malocclusion and the realistic prioritization of the treatment objectives.

This case report aims to present the interdisciplinary treatment of a Class III malocclusion with bilateral maxillary canine impaction and mandibular asymmetry in an adolescent. Discussions include the successful clinical management of the transalveolar autotransplant without root canal therapy in addition to the complex decision-making process in a two-phase nonextraction orthodontic treatment plan for unfavorable skeletal growth patterns. The patient's chief complaint was addressed with improved esthetics and restored occlusal function.

2. Case Presentation

2.1. Diagnosis and Etiology

A 10-year-old female patient was referred to the orthodontic department of St. Mary's hospital, Seoul, Republic of Korea for orthodontic treatment. She had no significant medical history or parafunctional habits, and her chief complaint was that neither of her upper canines were coming in. In addition, it was requested by the mother that none of the teeth be removed if possible.

A clinical evaluation showed a straight profile with a mildly convex lower third of the face (Figure 1). The nasolabial angle was mildly reduced to 87°. In the frontal view, her mandibular midline was slightly deviated to the right, with a delicate enlargement of the right lower third of her face compared to the left side. When she smiled, her maxillary

dental midline shifted to the left by 0.6 mm, while the mandibular dental midline coincided with the mandibular midline.

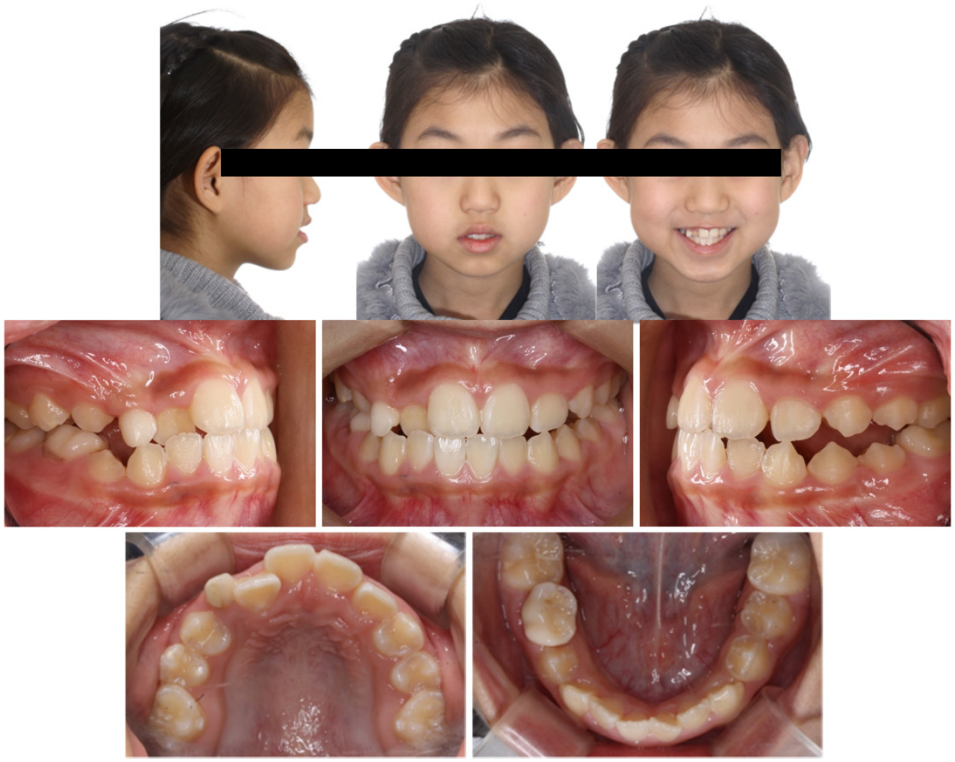

Figure 1. Pretreatment facial and intraoral photographs.

Intraorally, her mandibular dental midline was off by 1.8 mm from the facial midline on the right but in line with the mandible (Figure 1). Both molar relationships displayed Class I. The right and left permanent maxillary canines were both impacted. Her right primary canine was still present, but there was insufficient space for her maxillary right canine to erupt properly within the arch. On the other side, her maxillary left canine was completely blocked by the positive interproximal contact between her left lateral incisor and first premolar. There was also a crossbite in the right maxillary lateral incisor. Both overjet and overbite were 0 mm, measured from the mesial incisor corner of the left maxillary central incisor. In addition, there was a small amount of tooth size asymmetry between the two maxillary lateral incisors, with the right being 0.6 mm larger than its contralateral counterpart. The maxillary arch displayed severe crowding with about 10.7 mm of deficiency, but the mandibular arch showed a mild length discrepancy of 4.7 mm.

A panoramic radiographic examination showed that the maxillary right canine was horizontally impacted high above the root apices of the premolars (Figure 2). The impacted maxillary left canine crown was positioned high on the distal radicular surface of the adjacent lateral incisor. Also, cone-beam computed tomography (CBCT) images of the canines exhibited that, while both were labially impacted, the right canine was directed more medially and anteriorly deep in the palate, while it was almost ready to penetrate the cortical plate of the anterior maxilla (Figure 3). The patient's periodontal health was unremarkable (Figures 1 and 2).

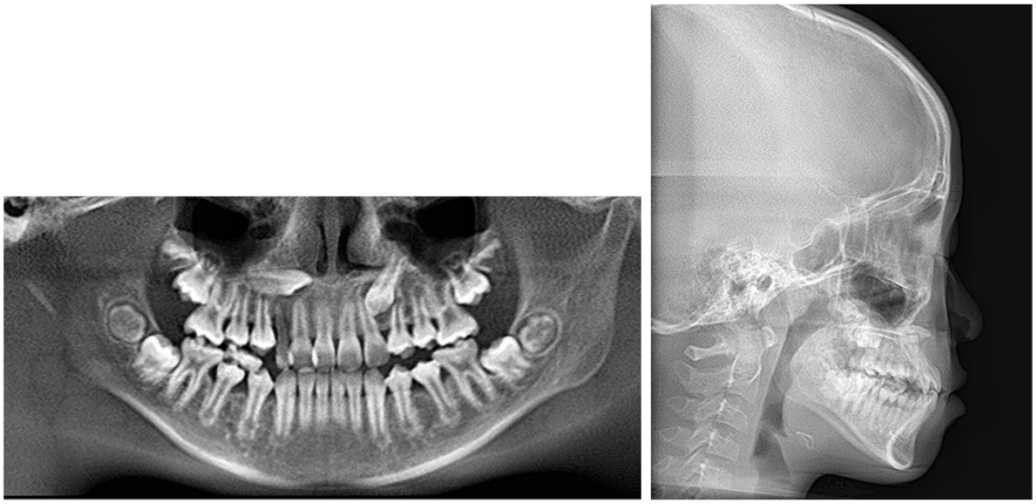

Figure 2. Pretreatment panoramic radiograph and lateral cephalogram.

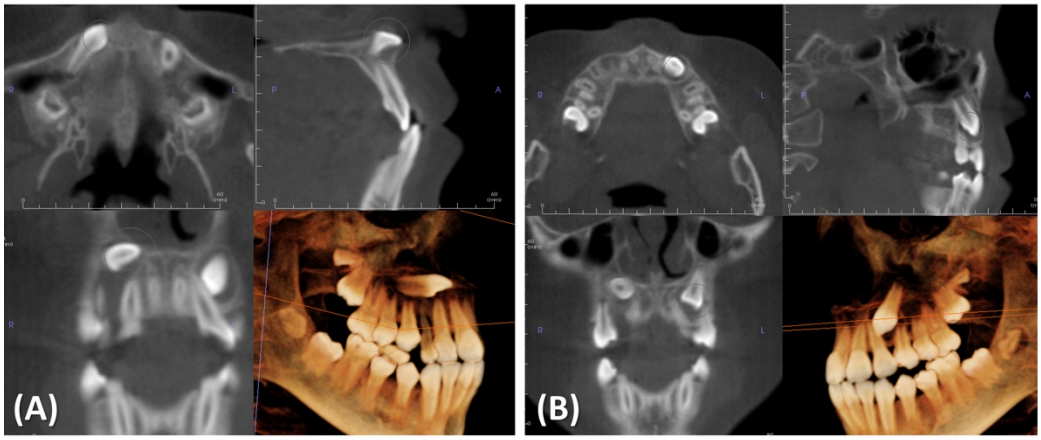

Figure 3. Pretreatment 3D cone-beam computed tomography data showing the location and angulation of the impacted (**A**) right and (**B**) left maxillary canines in axial, sagittal, 3D rendering, and coronal views in clockwise order beginning from the upper left corner.

A lateral cephalometric evaluation showed that the patient had a mild Class III growth tendency (ANB: 2.2°; Wits: −4.2 mm) with a steep mandibular plane angle (SN-MP: 39.7°) (Table 1). The maxillary incisor inclination was within normal limits; however, the mandibular incisors were retroclined (L1 to MP: 78.1°). In relation to the E-line, the patient's upper lip was unremarkable, while her lower lip protruded by 5.1 mm. In addition, the patient's pretreatment cervical vertebral maturation indicated stage I with a great potential for future growth. Also, the patient's mother noted that none of her close family members had been diagnosed with either severe Class III malocclusion or mandibular asymmetry.

Table 1. Cephalometric measurements.

	Norms	1st Phase Pretreatment	1st Phase Post-Treatment	2nd Phase Pretreatment	2nd Phase Post-Treatment
Skeletal analysis					
SNA (°)	81.5 ± 3.5	81.6	81.7	81.2	81.5
SNB (°)	77.7 ± 3.2	79.4	79.9	79.3	78.8
ANB (°)	4.0 ± 1.8	2.2	1.8	1.9	2.7
SN-MP (°)	33.0 ± 1.8	39.7	43.0	45.0	45.4

Table 1. *Cont.*

	Norms	1st Phase Pretreatment	1st Phase Post-Treatment	2nd Phase Pretreatment	2nd Phase Post-Treatment
Dental analysis					
U1-NA (mm)	3.9 ± 2.1	2.7	4.8	4.9	4.7
U1-NA (°)	24.0 ± 4.0	23.5	26.4	27.9	25.6
U1-SN (°)	108.2 ± 5.4	107.1	109.4	109.0	107.1
L1-NB (mm)	6.6 ± 2.8	6.1	7.1	6.8	5.8
L1-NB (°)	25.0 ± 5.0	25.7	27.8	28.7	22.0
L1-MP (°)	96.8 ± 6.4	78.1	82.3	84.3	77.8
U1-L1 (°)	124.2 ± 8.0	128.9	124.1	121.5	129.7
Facial analysis					
E-line/UL (mm)	−1.1 ± 2.2	0.4	0.8	−0.4	−0.4
E-line/LL (mm)	0.5 ± 2.5	5.1	6.0	6.1	5.2

2.2. Treatment Objectives

The goals of our treatment were aimed at repositioning the canines in the arch in accordance with the patient's wishes. Specifically, we aimed to expose and align her maxillary left canine with conventional orthodontic traction force, surgically transplant the maxillary right canine to achieve occlusal function, secure the required maxillary canine space by distalizing the maxillary posteriors, relieve the anterior crossbite, improve the dental midlines to better match with the facial midlines, correct the overbite and overjet mainly by the retraction of the mandibular anteriors, improve the soft tissue esthetics by the retraction of the lower lip, and minimize the risk of worsening her mandibular asymmetry and Class III relationship by monitoring her maxillomandibular growth during the treatment period.

2.3. Treatment Alternatives

Several key clinical factors had to be considered before the most viable treatment alternative could be considered [19,20]. The large maxillary arch length deficiency and the deeply impacted right canine could increase the treatment time and complicate the application of biomechanics. Additionally, the presence of the initial mandibular asymmetry and edge-to-edge bite combined with a skeletal Class III growth pattern would make it difficult to predict the future impact of her pubertal growth spurt that was expected to occur during the active treatment phase.

The first treatment option was to extract the patient's four first premolars. The extraction space could be utilized to align the impacted canines, correct the dental midlines, establish Class I molar and canine relationships, and correct the overjet and overbite.

The second alternative was to extract only the maxillary first premolars. With this more conservative approach, the goal was to distalize the posterior segment of the mandibular arch rather than to take advantage of the premolar extraction space.

The third alternative plan was somewhat unconventional. It was similar to the second option but dissimilar in that the impacted maxillary right canine was to be extracted, while the adjacent first premolars would remain substitutes for the missing canine.

The fourth treatment alternative did not involve permanent tooth extractions, as space for the impacted canine would be created through the distalization of the maxillary posterior teeth. Also, the impacted maxillary right canine would be surgically transplanted into the desired position within the arch. In addition, this approach would divide the active treatment into two phases. The goal of the first phase was to gain space in the maxillary arch, align the impacted canines, and monitor the mandibular growth during the patient's pubertal growth spurt before the second phase. The second phase aimed at retracting the mandibular arch to reach the post-treatment occlusion with improved overbite and overjet

in a Class I molar–canine relationship. Table 2 summarizes the pros and cons of the four treatment alternatives.

Table 2. Summary of treatment alternatives.

Pros	Treatment Alternatives	Cons
Space gained for the impacted #13 and #23 Class I molar and canine at the end of treatment	**Option 1** ***Extraction of #14, #24, #34, and #44***	Extraction of 4 healthy permanent teeth Risk of failure in aligning the highly impacted #13
Space gained for the impacted #13 and #23 More conservative than Option 1	**Option 2** ***Extraction of #14 and #24***	Extraction of 2 healthy permanent teeth Risk of failure in aligning the highly impacted #13
Reduced treatment time More conservative than Option 1	**Option 3** ***Extraction of #13 and #24*** ***Substitution of #14 for #13***	Extraction of 2 permanent teeth Risk of periodontal defects near #13 extraction site
Most conservative among the available options Class I molar and canine at the end of treatment Closer monitoring of unfavorable mandibular growth	**Option 4** ***No Extraction*** ***Autotransplantation of #13***	Potential risk of endodontic treatment for the autotransplanted #13 Longer treatment time due to 2-phase treatment approach

Of the available treatment alternatives, our patient selected the fourth one. The first option was rejected due to the required extraction of four healthy permanent premolars. We advised against the second option due to the severity of the maxillary right canine impaction, making establishing proper alignment difficult, even with premolar extraction. The extraction of the impacted right canine in the third treatment option would eliminate this difficult exposure and the alignment procedures and significantly shorten the treatment period, but the trade-off would require more complex asymmetric biomechanics and include the risk of periodontal defects at the extraction site from unfavorable alveolar healing. In addition, by approaching this treatment in a single phase, both the second and third options would have the potential risk of unfavorable mandibular pubertal growth. Also, any attempt to retract the mandibular dentition posteriorly at the patient's young age could result in a compromised outcome because of the immature developmental status of the permanent second molar roots. Of the four treatment options, the fourth one was the most conservative while addressing the patient's chief complaints. Her maxillary molars and premolars could be efficiently distalized with the use of TSADs. Upon space opening, the transalveolar transplantation of the impacted right canine would be highly predictable, with its apex still open at stage G of the Demirjian dental developmental classification [21]. Any unforeseen asymmetric Class III mandibular outgrowth could be ruled out during the follow-up period. Finally, the retraction of the mandibular posteriors aided by TSADs during the second phase would improve the soft tissue profile. This approach, however, had the downside of extended treatment time. The patient understood this limitation after considering it would increase the predictability of treatment results. More details, including the pros and cons of the elected treatment plan, were thoroughly communicated, and informed consent was obtained from the patient.

2.4. Treatment Progress

Brackets with a Roth prescription and a 0.022 inch (in) slot were used to bond the maxillary arch (Clarity and Victory series; 3M Oral Care, St. Paul, MN, USA), and a 0.014 in nickel-titanium (NiTi) alloy archwire (Ormco, Brea, CA, USA) was tied as an initial archwire. Next, an MCPP was installed in the paramedian region of the midpalatal suture with three 8.0 mm × 2.0 mm mini-implants (Dual Top Anchor System; Jeil Medical Corp., Seoul, Republic of Korea). Also, a palatal retraction arch was cemented on the maxillary first molars, and distalization was initiated with elastomeric power chains engaged between the anterior part of the retraction arch and two extended lever arms of the MCPP to produce about 300 g of retraction force (Figure 4A). Once the maxillary arch was leveled enough to receive a 0.016 in stainless steel (SS) archwire, NiTi open coil springs were placed between the lateral incisors and first premolars to facilitate space opening. After 9 months of active molar retraction, sufficient space was gained for both impacted canines (Figure 4B,C), and the MCPP and palatal retraction arch were removed.

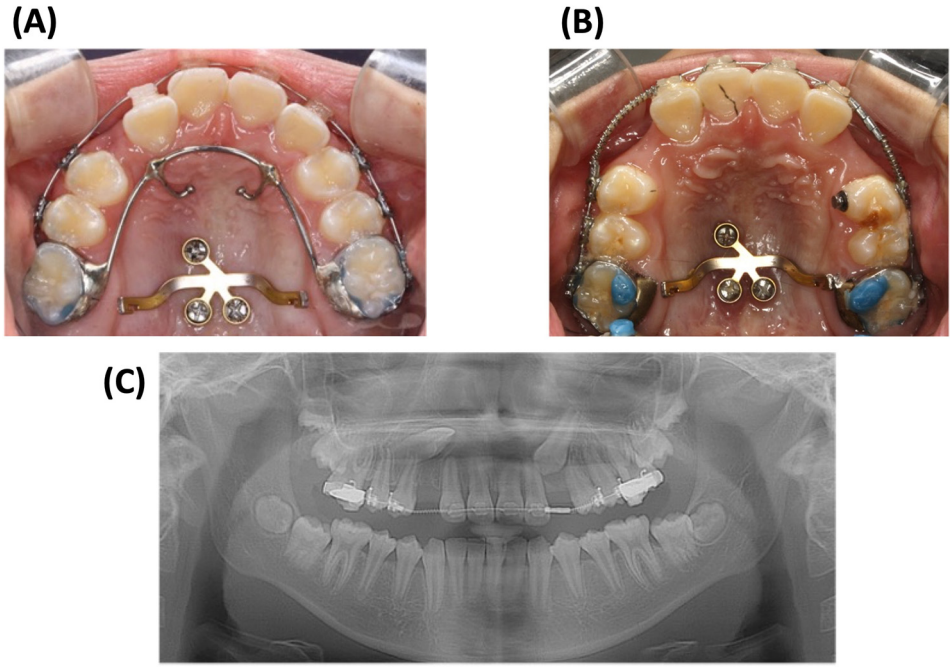

Figure 4. (**A**) An occlusal photograph was taken at initial bonding after the installation of the MCPP. (**B**,**C**) After 10 months of treatment, the maxillary occlusal photograph and panoramic radiograph showed that a sufficient amount of space was gained for the impacted canines by the distalization of the maxillary molars.

The transalveolar transplantation of the impacted right canine was accomplished in the twelfth month (Figure 5). The dimensions of the impacted right canine at the cemento-enamel junction (CEJ) were 5.1 mm in the mesiodistal and 7.0 mm in the buccolingual direction, while the root length from the CEJ to the apex was 10.7 mm, based on the 3D CBCT taken before the surgery. The oral surgeon had extensive experience in autotransplantation surgical procedures and decided not to use a 3D-printed donor replica as the single-rooted canine had a simple form.

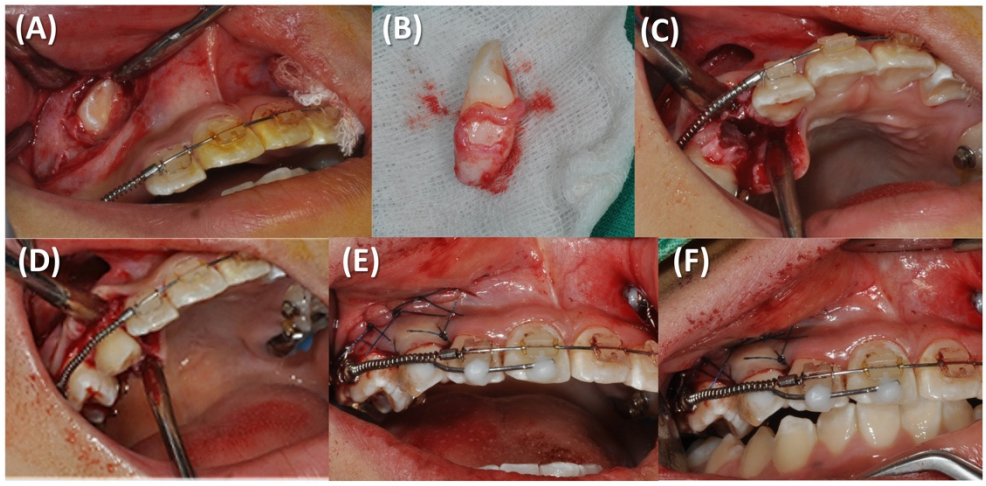

Figure 5. Transplantation of the maxillary right canine included (**A**) its exposure and the atraumatic extraction of the transplant, (**B**) temporary storage on the gauze soaked in a saline solution, (**C**) the preparation of the recipient alveolar socket, (**D**) transplantation to the recipient site, (**E**) the application of the surgical sutures and segmental wire splint, and (**F**) the absence of heavy occlusal contact on the transplant.

After the disinfection of the surgical field and the local injection of lidocaine, a full-thickness flap was elevated at the recipient site. Then, the recipient socket was prepared using surgical round burs and implant drills under copious irrigation with saline solution. The floor and surrounding walls of the recipient bed were gradually deepened and enlarged, during which the preservation of the bordering labial and palatal cortical plates was ensured, until the dimensions of the developing recipient socket reached beyond those of the donor canine, especially in the apical direction. Next, a vestibular semicircular incision was made to expose the impacted maxillary right canine, and its proximal alveolar bone was carefully removed. In the process, special attention was paid to the tooth's atraumatic extraction since it was imperative that the periodontal ligament remain intact on the transplant.

The extracted donor canine was placed into the prepared socket, which was reshaped until a satisfactory fit was achieved between the donor tooth and the recipient bed. During the third attempt, the stability of the transplant was confirmed while it was positioned deep within the recipient socket away from the occlusal force. The extra-alveolar time for the transplant was less than 5 min. After the flaps were sutured, the segmental wire splint was bonded to the transplant and adjacent incisors, and the absence of occlusal contacts was re-confirmed for initial stability.

As per the post-operative instructions, the patient was asked to rinse her mouth with 0.5% chlorohexidine gluconate solution two times a day and to avoid chewing on the side of the transplant. Additionally, the patient was prescribed Augmentin 375 mg (Dae Woo Pharmaceutical, Busan, Republic of Korea) and ibuprofen 200 mg three times a day for 5 days as post-surgical medications. After the health of the transplant and gingival healing around the exposure site were confirmed 8 weeks after the procedures (Figure 6), the wire splint was replaced with a bracket on the right canine, and orthodontic force was applied with a 0.014 in NiTi archwire for its alignment within the arch.

Figure 6. The transplanted right canine exhibited healthy healing 8 weeks after the procedure, and the left canine was ready for traction force application after window opening.

Meanwhile, the impacted left canine was exposed using a gingival window opening procedure and was bonded with a button. Next, an orthodontic traction force of 60 g was applied to the left canine with elastomeric thread. As the leveling of the maxillary left canine progressed, an overlay of 0.016 in copper NiTi (CuNiTi) was engaged to the left canine via a 0.018 in SS main archwire.

Nineteen months after the maxillary arch was bracketed, the mandible was initially bonded with a 0.014 in CuNiTi archwire (Figure 7). The maxillary right canine displayed normal tooth movement without any remarkable symptoms in reaction to the applied orthodontic force. A series of periapical radiographs also confirmed the healthy status with the absence of any significant radiographic pathologies (Figure 8). To alleviate the

midline deviation and tooth size discrepancy of the enlarged maxillary right lateral incisor, a mild interproximal reduction was conducted on the upper and lower anterior teeth. Once 0.016 × 0.022 in SS archwires were in place, 3/16 inch 4.5 ounce Class III elastics were prescribed.

Figure 7. After 20 months of treatment, both impacted canines were in level alignment.

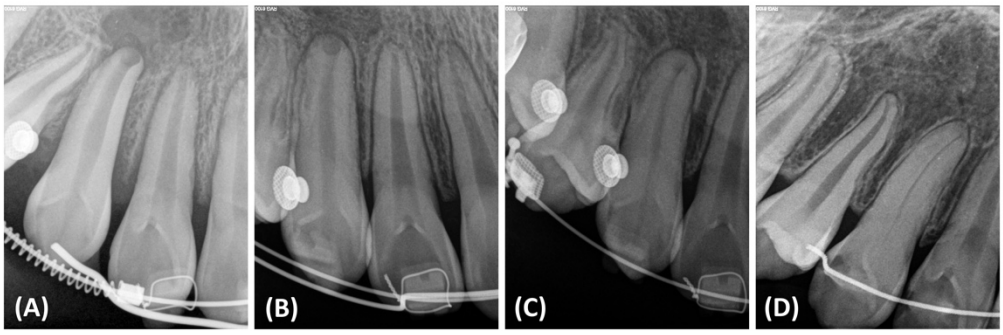

Figure 8. Periapical radiograph of the transplanted maxillary right canine taken (**A**) after 1 week, (**B**) after 5 months, (**C**) after 9 months, and (**D**) after 24 months.

After 27 months of active fixed-appliance therapy, the patient still exhibited an unresolved Class III molar canine relationship on the left side, a persistent mandibular deviation to the right, and an anterior edge-to-edge bite. At this point, it was decided to terminate the ongoing first-phase orthodontic treatment and follow up with the patient's growth for the opportunity to intervene during the second-phase treatment when she was more mature (Figures 9 and 10). With the patient's and parents' consent, the brackets were removed and fixed, and removable retainers were delivered. During the retention period, the patient was recalled periodically for retainer adjustment and growth monitoring.

The treatment results remained stable without significant changes in the occlusal relationship during the 2.5 years of retention (Figures 11 and 12). The lateral cephalogram confirmed that her pubertal growth peak was well passed, with a cervical vertebral maturation stage of IV [22], and that the mandibular asymmetric Class III occlusion was not likely to worsen substantially during her remaining skeletal growth. At age 15, the patient's second-phase treatment began by bonding both arches with 0.022 in slot Roth prescription brackets. The archwire size gradually increased from 0.016 in NiTi to 0.016 × 0.022 in SS in the upper and 0.019 × 0.025 in SS in the lower arch.

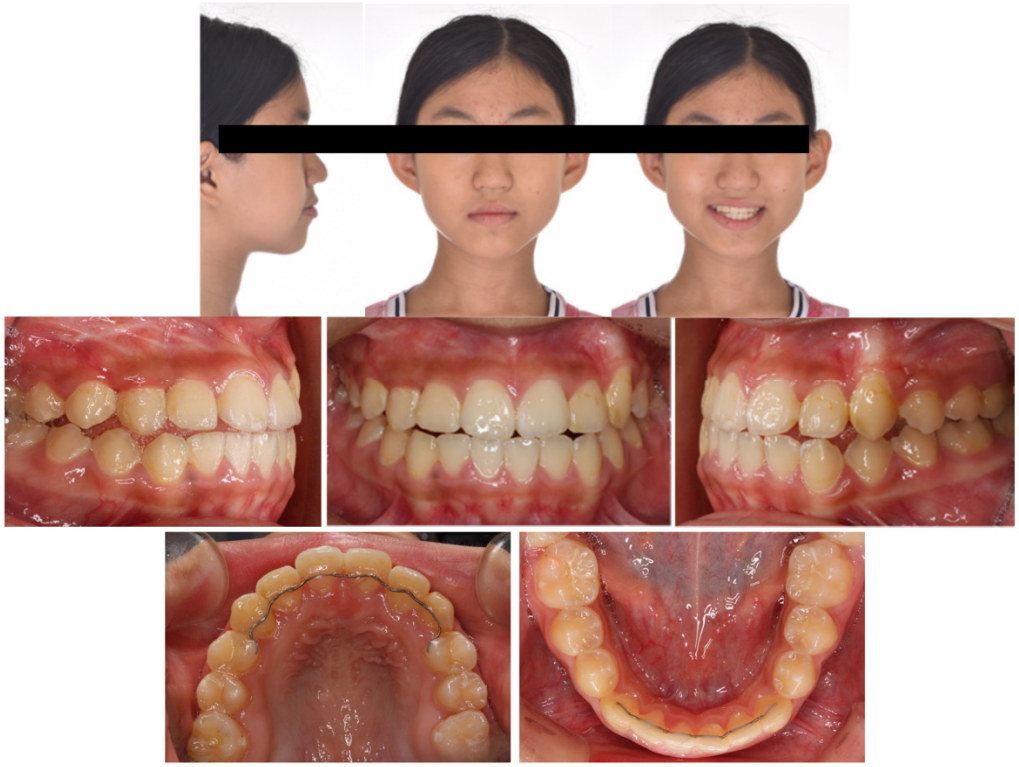

Figure 9. First-phase post-treatment facial and intraoral photographs.

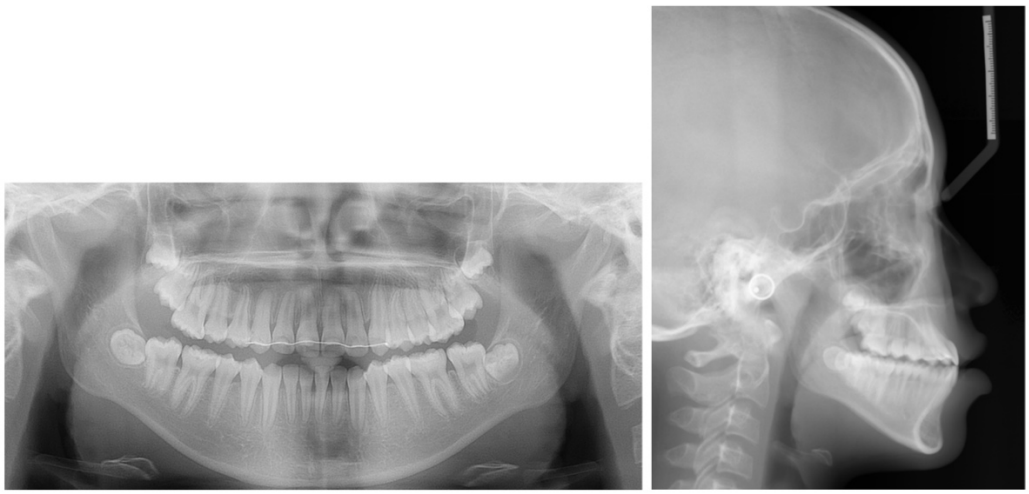

Figure 10. First-phase post-treatment panoramic radiograph and lateral cephalogram.

To distalize the mandibular dentition in correction with the anterior crossbite and Class III relationship, 1.6 mm × 8.0 mm mini-implants (Dual Top Anchor System; Jeil Medical Corp., Seoul, Republic of Korea) were placed in the buccal gingiva between the first and second molars in the sixth month. Elastomeric chains between the mini-implants and the anterior part of the lower archwire were changed at each monthly visit to maintain approximately 300 g of constant retraction force until the Class I molar and canine relationships were achieved bilaterally. Once the upper arch was engaged with 0.016 × 0.022 in SS, Class II elastics were also added on the right side to facilitate the mandibular midline correction. After 18 months of lower retraction, the desired overbite and overjet were attained (Figure 13). At this point, several dental caries were found during the patient's orthodontic adjustment visit, and she was referred for restorations. Once the

caries were under control, the final orthodontic finishing and detailing continued with multiple posterior vertical elastics between the premolars and molars.

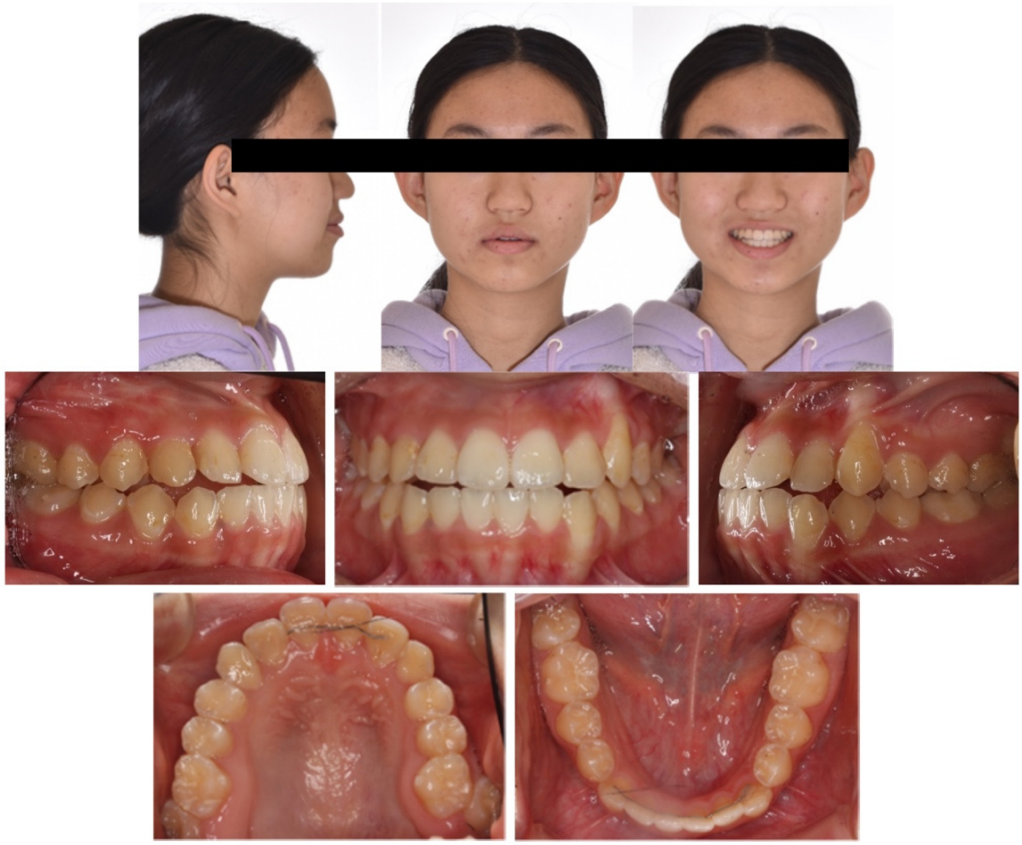

Figure 11. Facial and intraoral photographs taken after 3 years of retention and at the beginning of the second-phase orthodontic treatment.

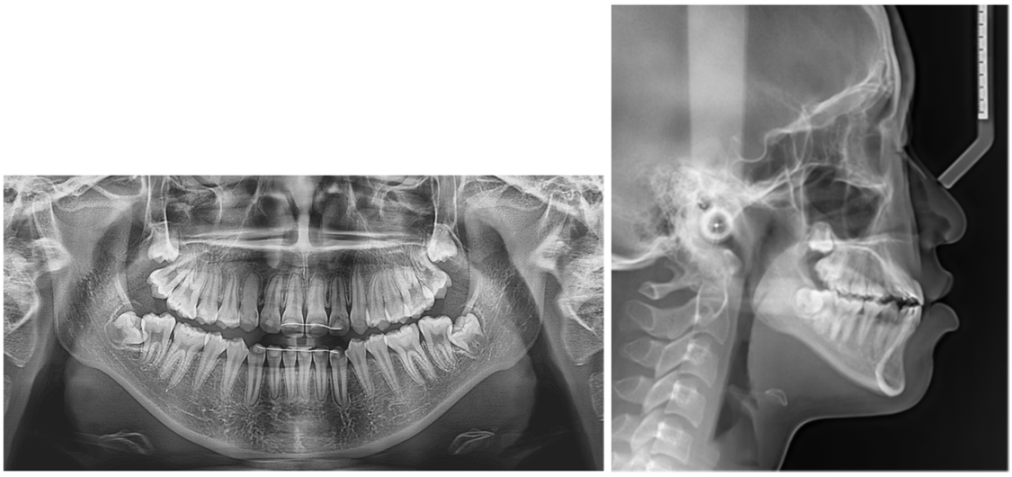

Figure 12. Panoramic radiograph and lateral cephalogram taken after 3 years of retention and at the beginning of the second-phase orthodontic treatment.

Figure 13. The intraoral photographs showed that the Class I molar and canine relationship was reached after 24 months of treatment.

When an esthetically pleasing overbite, overjet, and overall alignment were gained with Class I molar and canine relationships, it was decided to end the ongoing fixed-appliance therapy (Figures 14 and 15). The second-phase orthodontic treatment concluded after 31 months of active treatment. All brackets and mini-implants were removed, and a lower fixed wire retainer was bonded. In addition, the patient was instructed to wear her removable Hawley retainers full-time for the first year, and then at night thereafter.

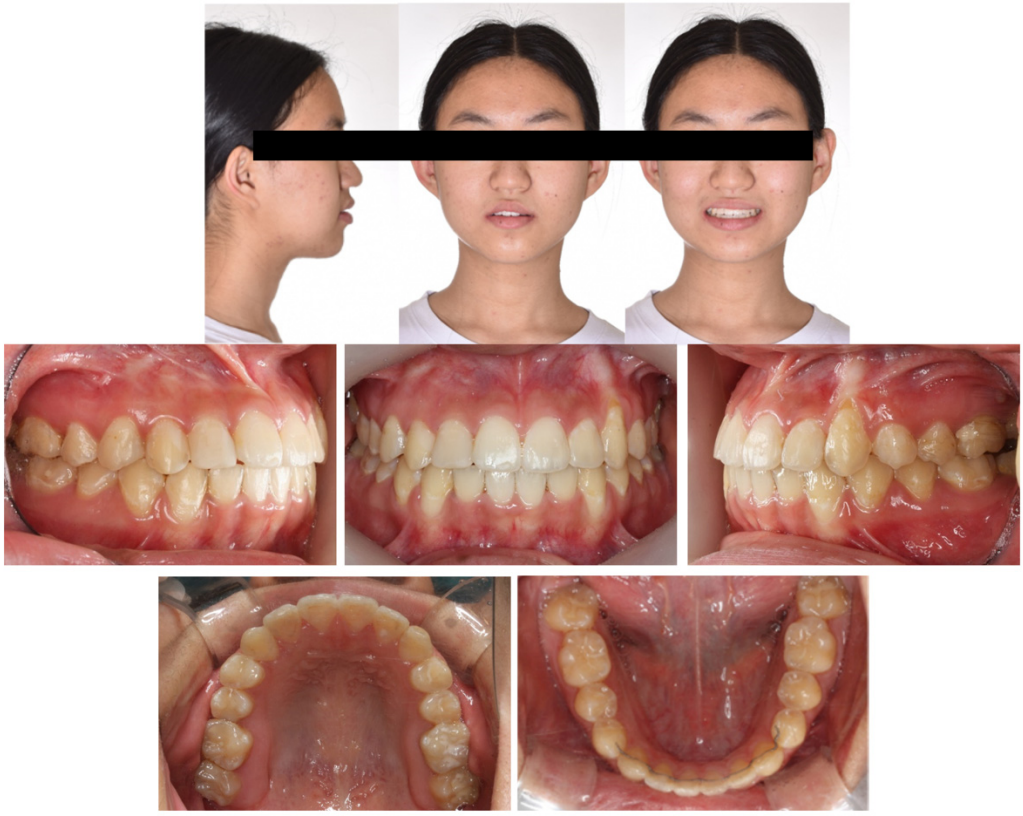

Figure 14. Second-phase post-treatment facial and intraoral photographs.

Figure 15. Second-phase post-treatment panoramic radiograph and lateral cephalogram.

2.5. Treatment Results

The treatment duration for the first phase was 27 months. The treatment concluded after both impacted maxillary canines were aligned. The upper dental midline was in line with the facial midline, but overall, the convex lower third of the patient's face had not significantly changed, and her chin was still deviated to the right (Figure 9). Intraorally, the severe upper crowding was relieved, and the crossbite of her right lateral incisor was eliminated. The amount of lower dental midline shift remained virtually the same. Also, the anterior open bite and Class III relationship were significantly worse compared to the pretreatment occlusion.

The post-treatment panoramic radiograph showed the upper canine roots to be healthy with no evidence of periodontal defects (Figure 10). A cephalographic evaluation demonstrated that the maxillary first molars were retracted by 3.7 mm (Figures 10 and 16). Also noteworthy was the significant forward, downward growth of the mandible. This pronounced clockwise skeletal Class III growth was reflected in the decrease in the ANB angle of 0.5° and the increase in the mandibular plane angle of 3.3° (Table 1). The maxillary incisors proclined by 2.3° and 2.1 mm, while the mandibular incisors also proclined by 4.2° and 1.0 mm. In addition, the lower lip protruded further by 0.9 mm.

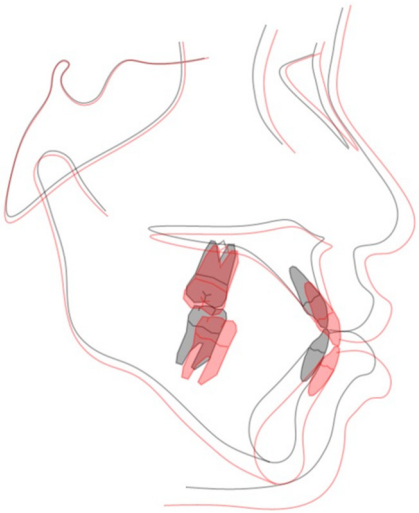

Figure 16. Cephalometric superimposition of the first-phase treatment: Black, Pretreatment; Red, Posttreatment.

After a 32-month interim retention period, the patient, now 15, returned to continue the second-phase orthodontic treatment. The total treatment duration of the second-phase treatment lasted 31 months, and the outcome was successful, as shown in Figure 14. As expected, the patient's facial features remained mostly unchanged. In contrast, her dental esthetics improved significantly, with a pleasing appearance of anterior alignment. The anterior open and edge-to-edge bite were corrected with an ideal overbite and overjet of 1.6 mm and 1.5 mm, respectively. Class I molar and canine relationships were present on both sides. The lower dental midline improved but remained shifted to the right by 0.9 mm due to the insistent right deviation of the mandible.

There were healthy periodontal conditions without any sign of significant root resorption or bone loss, as seen in the posttreatment panoramic radiograph (Figure 15). There were plans to extract the impacted mandibular third molars in the retention period. The superimposition of the lateral cephalograms demonstrated a mildly improved skeletal Class III relationship with an increase in the ANB angle of 0.8° and a slight clockwise rotation of the mandible with an elevation in the SN-MP of 0.4° (Figure 17, Table 1). The mandibular left first molar was retracted by 2.0 mm on the right and 4.5 mm on the left side through the mini-implant-facilitated distalization. As a result, a positive overjet and overbite were achieved mainly by a 1.0 mm and 6.5° retroclination of the mandibular incisors. Meanwhile, the maxillary incisors were also slightly retroclined by 0.2 mm and 1.9°. From an esthetic perspective, the lower lip was also retracted by 0.9 mm.

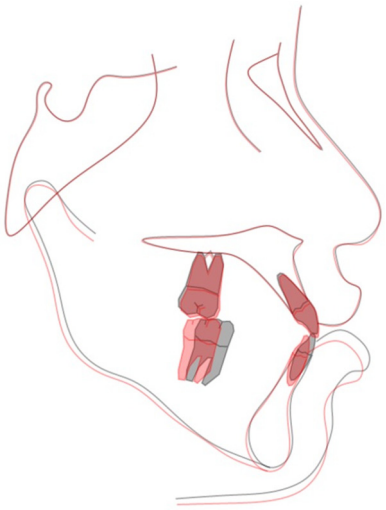

Figure 17. Cephalometric superimposition of the second-phase treatment: Black, Pretreatment; Red, Posttreatment.

The transplanted maxillary right canine displayed no signs of ankylosis, root resorption, alveolar defects, or periodontal deterioration throughout the active orthodontic treatment and retention period. However, its radiographic changes over time during the first-phase treatment showed that its pulp chamber and the canal had gradually been obliterated, though it was vital according to the test and free of symptoms, without any crown discoloration. Responding normally to the routine orthodontic force, the transplant exhibited no significant radiographic changes or symptoms during the second-phase treatment. Overall, the transplanted canine showed a good prognosis and should continue to be followed for any future indications that might require endodontic procedures.

3. Discussion

In orthodontic treatment planning, it is imperative to recognize that sometimes, not every aspect of the malocclusion can be solved with a single therapy. When faced with such clinical situations, the treatment objectives should focus on addressing the patient's chief complaint first and then the rest of the prioritized problems as it becomes opportune to do so. While resolving the impending impactions could not wait, our patient's initial

cervical vertebral maturation stage I status suggested that her peak growth could not be expected anytime in the near future [22]. To avoid the risk of the mandible growing beyond the treatment results during her later pubertal growth spurt, it was decided to accept a two-phase orthodontic treatment approach where the impacted canines would be aligned in the first phase.

A conventional treatment approach to solve maxillary canine impaction generally involves surgical exposure and orthodontic traction to the functioning occlusal plane. However, the treatment plan can have several variations depending on the severity of the impaction, the condition of the adjacent teeth roots, and the health of the supporting tissue structures. Recently, it was demonstrated that inferior treatment outcomes and prolonged treatment time were associated with a higher vertical position, greater alpha angle, and more mesial sector of the canine impaction [9]. In our patient, the impacted right canine was directed anteriorly and superiorly apical to the premolar roots, which suggested an unfavorable prognosis. Although seldom considered, extraction or autotransplantation have been suggested as attractive alternatives for severely impacted maxillary canines [8,12,13,23]. Interestingly, transplanted maxillary canines have shown a high survival rate close to 83% and an average duration of 14.5 years [12]. Also, it was recently reported that an autotransplanted tooth exhibited long-term health after orthodontic movement [24]. Therefore, the unfavorable position of the right canine impaction in our patient was approached by autogenous transalveolar transplantation as the treatment of choice. The treatment was chosen to preserve all the teeth and the natural profile of the patient. For more than 6 years after the procedure, the transplanted maxillary right canine exhibited normal orthodontic tooth movement, continuous periodontal ligament space, and healthy gingival alveolar architecture.

Among the factors known to influence the survival rate of the autogenous transplant are minimum damage to the root surface, a short extraoral handling time, increased primary postoperative stability, and an incomplete root formation stage [25]. The favorable healing of the periodontal ligament of the transplant was our primary interest during the transplantation procedure. In our case, favorable healing was assured by gentle atraumatic extraction, expedited socket preparation, and less than 30 min of storage time for the transplant in physiological saline. Initially, the narrow buccal, palatal alveolar width of the recipient site was concerning due to the possibility of an insufficient amount of remaining bone support after the socket preparation. Fortunately, the root formation of the transplant continued its development to completion without any periodontal defects, underscoring the importance of primary stability aided by a wire splint and postoperative occlusion adjustment.

Major complications of autotransplantation include ankyloses, root resorption, and pulp necrosis. Analogous to the traumatically avulsed tooth, root canal therapy (RCT) has often been considered mandatory to minimize undesirable events [8,10]. For a transplanted tooth with a completed root apex, it has been recommended that RCT should be performed within 2 weeks after transplantation [26]. Recently, it was shown that 59% of autotransplants with complete root formation did not require RCT and had no signs of pathology for at least 5 years post-treatment [27]. In the autotransplantation of incomplete root formations similar to our case, the complication rate was reportedly less than 4% [28], and a wait-and-see strategy was more acceptable owing to the greater potential of revascularization [8,14]. In our treatment, the transplanted maxillary canine was not followed by RCT, but it was allowed to continue its root formation to a more mature state. Even so, our transplanted canine was not completely free of complications because it displayed gradual pulp canal obliteration during the early follow-up period. Without symptoms or discoloration of the crown, RCT implementation would not be recommended as a preventive measure [29,30]. Subsequently, periodic radiographic monitoring was planned during retention.

The proficiency of MCPPs in the distalization of the maxillary dentition has been well characterized in the literature [15]. In our first-phase treatment, the maxillary first molar retraction was 3.7 mm, which was in accordance with previous studies [15]. Interestingly,

the maxillary incisors protruded by 2.1 mm in our treatment, while most of the other investigations on MCPPs have reported the opposite retrusive movement. These seemingly conflicting results may have occurred because our objective was to increase the upper arch length with the MCPP to secure space for the impacted canines in our treatment of the Class III malocclusion while maintaining the incisors in their initial anterior position. We accomplished this by keeping the distal end of the main archwire uncinched so that the molars could slide posteriorly along the wire. If we had been treating a Class II malocclusion, on the other hand, it would then become crucial to keep the main archwire cinched so the upper incisors would retract together with the molars for the net effect of overjet reduction.

Similar to MCPPs in the maxillary arch, mini-implants were used to distalize the mandibular molars by 2.0 mm on the right and by 4.5 mm on the left side in the second-phase treatment. A recent investigation reported that the mean distalization of the mandibular first molar was 1.8 mm, coupled with 0.6 mm of intrusion after mini-screw-assisted mandibular retraction in patients with Class III malocclusion [31]. Also, it was shown that the occlusal plane rotated slightly counterclockwise by 2.2°, and the lower lip retracted by 0.6 mm. Our treatment results were consistent with the previous study in terms of the amount of molar and lower lip retraction, but the rotation of the mandible was not observed, probably because the intrusive molar movement was countered by the judicious use of posterior vertical elastics.

Several important strengths may be noted in this case presentation. Firstly, the treatment plan decision-making steps were discussed in detail. The two-phase orthodontic therapy was determined after prioritizing the dental problems that required immediate attention, such as severe impactions and the unfavorable asymmetric skeletal Class III malocclusion, which required a longer observation period throughout the remaining skeletal growth. In addition, the simple and effective use of TADs was clearly described in both arches. Specifically, the MCPP was employed to distalize the maxillary posteriors to gain additional arch length, while mini-implants were utilized to retract the mandibular posteriors more to the left for asymmetrical correction. Thirdly, the successful outcome of the maxillary canine transplantation was facilitated by the transplant's immature, still-open root apex and the clinical expertise of our experienced oral surgeon. Subsequently, the root of the transplanted canine had fully completed root formation without the need for root canal therapy following the operation. On the other hand, a recent investigation reported that only a small portion of dentists routinely consider dental autotransplantation a viable treatment alternative, despite its proven benefits [32]. The study also suggested that the autotransplantation method should receive more attention in the dental curriculum and literature [32]. Therefore, case reports such as this may help shift the focus in a more positive direction.

There were several limitations to our treatment of this case. We could not fully correct the lower dental midline during the second-phase treatment. We could have resolved it by either increasing the amount of interproximal reduction or augmenting the mandibular molar distalization after the early extraction of the third molars, but both options were rejected by the patient because she was pleased with the outcome. She later decided to remove her third molars when she was more mature. Another limitation was that techniques such as piezosurgery and a 3D replica of the transplanted canine were not employed in our transplantation procedure. However, our oral surgeon was able to proceed successfully without them. The transplanted maxillary right canine showed excellent clinical outcomes that persisted for more than six years after the surgical procedure. In the future, the autotransplanted canine could be evaluated for its long-term survival rate with a sufficient follow-up period. Finally, the treatment time was prolonged with the two separate treatment phases. Approaching the dental and skeletal problems in two separate treatment regimens was necessary in this case to avoid unforeseen risks associated with growth, and the treatment outcomes were pleasing to the patient as she understood the situation.

4. Conclusions

Impacted teeth can be resolved by various treatment approaches. The position and severity of the impaction, as well as the patient's age and expectations, all play a significant role in shaping the final treatment plan. Treatment modalities incorporating such features as autotransplantation and TSADs may enhance treatment efficiency while simplifying the associated biomechanics and producing more predictable positive outcomes. Also, it is important to understand that the management of malocclusion, growth, and skeletal disharmony mandates individually prioritized treatment objectives, a clear understanding of the rationale by the patient, and effective collaboration among various dental specialists to deliver successful results. The following key clinical lessons may be highlighted from the present case report:

1. Dental autotransplantation offers valuable treatment alternatives for the management of severe impaction cases.
2. Root canal treatment may not be required for autogenous transplanted teeth with incomplete root formation.
3. TSADs can provide simple yet versatile and efficient treatment mechanics in various clinical situations.

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