Treatment of a deep impacted and transmigrated mandibular canine of type 2 using a mini-implant and gradual change of traction direction

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Transmigration of a permanent mandibular canine is considered, in most cases, to be an untreatable dental malposition. However, various indicators can be drawn from the study of these two case reports to determine the proper approach in this situation: the impaction and transmigration diagnosis causes and the severity of transmigration; that is, the distance between the apex of the transmigrated canine and the lower border of the mandible, the length of its root, the volume of its crown and the amount of the tooth beyond the mandibular midline, lack of a priori ankylosis, and the patient's age, patience, and willingness. If orthodontic traction is chosen, the following parameters need to be considered: detailed surgical exposure; location and design of the attachment on the crown of the transmigrated canine; the means linking the attachment and the traction-force means, which remain intra-tissue; skeletal anchorage; and vector of force traction, ensuring that the mandibular first premolar and the permanent mandibular incisors remain free from the orthodontic appliance during the initial stages of treatment. The proper decision on whether to extract or to expose and tract the affected tooth is discussed through the presentation of two cases of a permanent mandibular transmigrated canine of type 2. Two female patients are presented, one at the age of 23 years and 2 months, and the other at the age of 11 years and 6 months, successfully and unsuccessfully treated, respectively. (Am J Orthod Dentofacial Orthop Clin Companion 2024;4:229-45)

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The prevalence of permanent mandibular canine impaction ranges 0.31%-1.35%.[1,2] It is a rare biologic phenomenon, and even less common is mandibular canine transmigration, in which, typically, the mandibular canines are affected. The term transmigration, which refers to the migration of the canine through the median mandible suture, was first used by Ando in 1964,[3] when he presented the unphysiological intraosseous migration of the canine across the midline of the mandible. In 1985, another classification was provided by Javid.[4] He stated that when more than half of the length of a cuspid has crossed the midline, it is considered to be transmigrated. The mandibular midline is considered to be the skeletal one in which it crosses the fusion of the lateral halves of the body of the mandible; that is, the symphysis. In 2002, Mupparapu[5] introduced a more complete categorization of the intraosseous transmigrated permanent mandibular canines related to their migration pattern and position in the mandible, defining 5 types (types 1-5).

The treatment alternatives may include observation, orthodontic traction after surgical exposure, autotransplantation, or extraction of the migrated canine.[6-9] The indications for the above-mentioned options depend on the patient's age and occlusion, stage of canine-root development, position of the transmigrated canine, and its relation to the adjacent teeth. However, there are no established guidelines for the treatment of transmigrated mandibular canines that can be routinely applied for the treatment plan.[6]

For this reason, through the treatment of these two cases, an effort has been made to create some guidelines on whether to attempt to move the affected canine into its proper position in the dental arch or to extract. If the decision is made to move the canine, specific guidelines need to be taken into consideration.

The two cases of a deeply impacted and transmigrated permanent mandibular left canine of type 2 presented below were surgically and orthodontically treated by the first author.

The first successful case is fully presented, whereas the second unsuccessful one, for the sake of economy, is presented mainly radiographically, giving the core information of this case which can be extracted in order for the reader to glean the most valuable details.

CASE 1

DIAGNOSIS AND ETIOLOGY

A woman at the age of 23 years and 2 months was self-referred for an orthodontic evaluation. Her chief complaint was the irregularity of her mandibular anterior teeth. She was healthy, with no specific medical problems. Pretreatment facial photographs revealed a mesoprosopic facial type with good symmetry and a concave profile. Furthermore, the patient exhibited a passive lip seal with

Fig 1. Pretreatment facial and intraoral photographs.

Table. Cephalometric measurements

Measurement	Norm ± SD	Pretreatment Case 1	3 y Posttreatment Case 1	Pretreatment Case 2	1 y Posttreatment Case 2
Age		23 y 2 mo	30 y 5 mo	11 y 6 mo	18 y
SNA (°)	82.0 ± 3.5	79.0	79.0	89.0	86.5
SNB (°)	80.9 ± 3.4	76.5	76.5	79.0	79.0
ANB (°)	1.6 ± 1.5	2.5	2.5	10.0	7.5
GoGn-SN (°)	32.9 ± 5.2	36.0	35.5	36.0	37.0
MP-PP (°)	25.0 ± 6.0	26.5	28.0	30.0	31.5
LAFH (ANS-Me/N-Me) (%)	57.0 ± 2.0	53.0	53.0	55.0	54.0
y-axis (°)	66.0 ± 5.0	63.0	64.0	59.0	63.5
U1-FH (°)	111.0 ± 5.9	100.5	110.0	111.5	110.0
U1-PP (°)	106.5 ± 6.5	101.5	113.0	112.0	115.0
U1-NA (°)	25.0 ± 7.0	14.5	26.0	16.0	20.0
U1-NA (mm)	5.0 ± 2.0	3.0	4.5	2.0	3.0
FMA (°)	29.0 ± 5.0	27.5	26.0	32.0	34.0
FMIA (°)	56.0 ± 7.0	68.0	46.0	49.0	37.0
IMPA (°)	95.4 ± 7.8	85.0	109.0	100.0	110.5
L1-NB (°)	22.0 ± 9.0	21.0	39.0	40.0	48.0
L1-NB (mm)	3.5 ± 3.0	3.5	6.5	8.0	11.0
Ls-EL (mm)	−2.0 ± 2.0	−7.5	−6.0	−1.5	−1.0
Li-EL (mm)	−2.8 ± 2.0	−4.0	−1.5	−1.5	1.5

SD, standard deviation.

increased nasolabial angle, slight nasal prominence, and slight lip retrusion. Her smile arc was consonant with the curvature of her lower lip (Fig 1).

The clinical oral examination (Fig 1) revealed that she had mild crowding in the maxillary arch and moderate crowding in the mandibular arch, along with prolonged retention of the deciduous mandibular left canine. The maxillary dental midline coincided with the midsagittal plane, whereas the mandibular dental midline deviated to the left. The curve of Spee was deep on the right side and moderate on the left. Her mandibular anterior teeth were worn, particularly the permanent right canine. Recessions were mainly apparent in the area of the upper premolars because of persistent tooth brushing. There was no functional mandibular shift, and the temporomandibular joints (TMJs) were asymptomatic.

The dental cast analysis revealed a 4 mm overjet and 7 mm overbite, with Class I molar and canine relationships on both sides. The mandibular dental crowding was moderate (5.5 mm). No crossbite was observed.

The lateral cephalometric analysis (Table) indicated a skeletal Class I sagittal relationship (ANB, 2.5^0; SNA, 79^0; and SNB, 76.5^0) with a vertical growth pattern (GoGn-SN, 36^0) and retroinclined maxillary incisors (U1-FH; 100.5^0). The panoramic and the lateral cephalometric radiographs revealed a deep impaction and transmigration of type 2[5] to the right of the permanent mandibular left canine (Fig 2).

TREATMENT OBJECTIVES

The treatment objectives were to (1) move the transmigrated permanent mandibular left canine to its proper position in the dental arch without adverse effects on neighboring teeth, after its surgical exposure, using skeletal anchorage and fixed appliances, (2) preserve Class I molar and canine relationships, (3) correct the mandibular dental

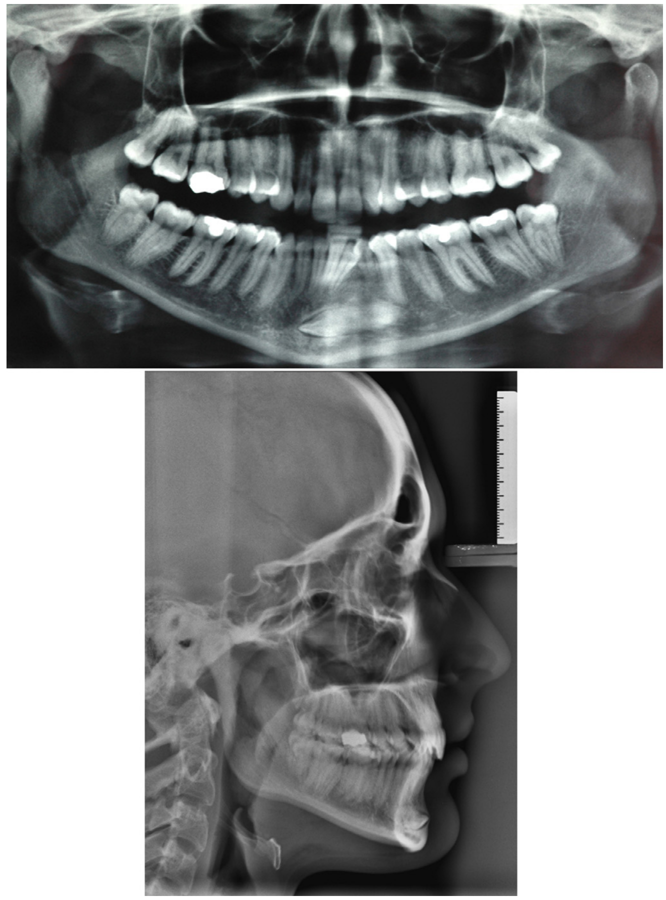

Fig 2. Pretreatment panoramic and lateral cephalometric radiographs.

midline shift and manage the crowding, and (4) establish a functional occlusion with normal overjet and overbite.

TREATMENT ALTERNATIVES

Two treatment alternatives regarding the management of the deep impacted and transmigrated permanent mandibular left canine were considered: (1) extraction of the affected tooth and the deciduous mandibular left canine; space-opening in this region; and, after completion of orthodontic treatment, implant placement and (2) surgical exposure of the transmigrated canine, placement of an attachment on its crown, and an attempt to move this tooth to its proper position in the dental arch by means of skeletal anchorage.

After discussing the treatment alternatives with the patient, it was decided to follow the second option involving surgical exposure.

TREATMENT PROGRESS

Initially, a mini-implant (Ø 1.5 × 8.0 mm — SPIDER SL1-S-K1 Self Ligating, HDC, Thiene VI, Italy) was inserted between the mandibular left first and second premolars. After a week, the surgical exposure of the deep impacted and transmigrated permanent mandibular left canine to the right and the extraction of the deciduous mandibular left canine were carried out, and an attachment was placed on the distal aspect of its crown and not on its lingual surface, thus avoiding unwanted rotation of its crown during traction. In addition to the surgical exposure, the dense mandibular bone was lightened in the traction direction through small engravings using a bur (Fig 3, *A*).

In the same session, the affected canine was joined through a steel ligature wire with a nickel-titanium light force closed coil spring (ORMCO, Glendora, Calif), which was activated by attaching it to the apical hook of the permanent mandibular left first molar's bracket. An indirect skeletal anchorage for the canine traction was achieved through a 0.017 × 0.022-in stainless-steel segmented wire between the mini-implant and the permanent mandibular left first molar (Fig 3, *B*).

The initial aim was to move the transmigrated canine root distally below the root of the mandibular left first premolar without causing any adverse dental side-effects. The generated movements resolved into a horizontal traction component larger than the vertical one, with the help of the following mechanics: appropriate tooth exposure, applied light force, indirect skeletal anchorage, and a vector of diagonally applied force closer to the center of resistance (CRi) of the transmigrated canine (Fig 4).

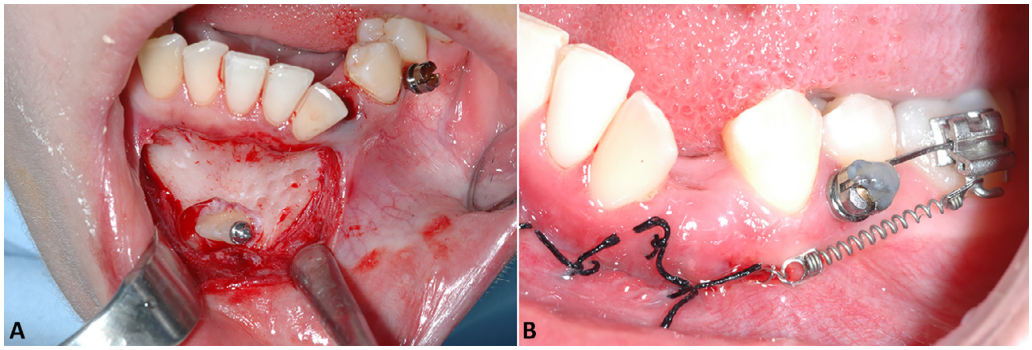

Fig 3. A, Inserted mini-implant, extraction of the deciduous mandibular left canine, and surgical exposure of the crown of the permanent mandibular left transmigrated canine; **B,** One week after exposure and initiation of traction of the affected canine with the help of skeletal anchorage and controlled force vector.

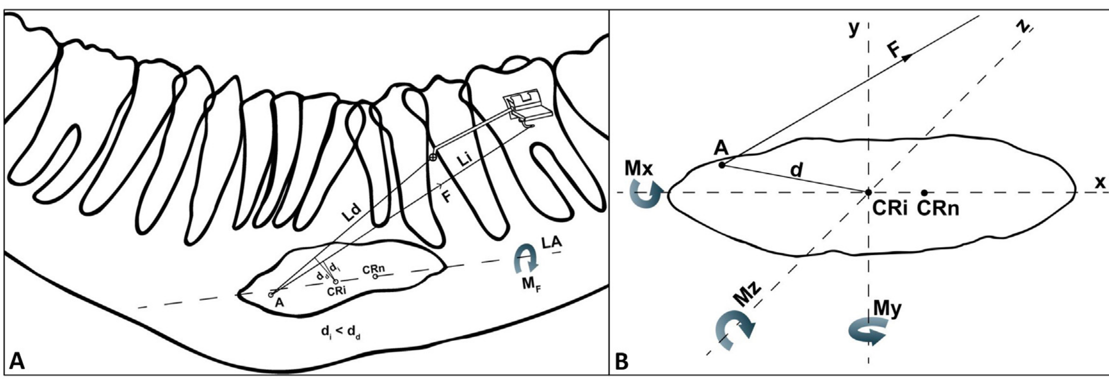

Fig 4. A and **B,** Initially-applied mechanics through a simplified force-movement analysis system of the initial tooth-traction. *A,* the point of force application on the attachment placed initially on the distal aspect of the crown of the affected tooth; *Cri*, center of resistance of the impacted and transmigrated canine, located more coronally to the CRn; *CRn*, center of resistance of a normally erupted permanent mandibular canine; d_d and d_i: distances between the CRi and the lines of action Ld and Li correspondingly ($d_i < d_d$).

A moment (M_F) produced by a force (F) applied on a point of a tooth, $M_F = F \times d$, in which d is the distance between the CR and the line of action (L, the line along which a force or the resultant of any number of forces may be considered to act). To reduce the initial clockwise moment M_F of the transmigrated canine, which was produced by the diagonally applied light force F, three measures were taken: (1) non-extensive exposure of the crown of the affected tooth was performed. The tooth-exposure carried out only in the small area in which the attachment had to be placed after the study of the case, which also reduced the risk of injury to the cervical region of the tooth (cementoenamel junction). The CR of an impacted tooth (CRi) is normally located more coronally in comparison to the normally located CR of the same tooth after its full eruption (CRn). This is because of the bone excess that covers its crown and its cervical region. The opposite is the case; that is, the CR is repositioned more apically, when a tooth loses bone support because of periodontal disease. This means that the more coronally the CR is located, the less the distance between the CR and the line of action (Ld or Li), which entails a reduced movement; (2) the applied force was of a light magnitude, which also reduces the movement; and (3) the point of action on the anchorage unit was located not directly on the inserted mini-implant (Ld) but indirectly on the permanent mandibular left first molar's apical hook (Li), which was located distally and apically to it (Figs 3, *B* and 4, *A*), aimed at the reduction of the angle between the line of action and the long-axis (LA) of the transmigrated tooth. This entailed a reduced distance, di, between the CRi and the line Li, which reduced, in turn, the produced moment M_F (Fig 4).

It should also be mentioned that a second desired counterclockwise moment, Mx (distolingual rotation of its crown), was induced during traction by placing the attachment on the distal surface and not on the lingual surface of the tooth (Figs 3, *A* and 4).

After 12 months of active treatment, retraction and intrusion of the transmigrated canine was achieved to such a magnitude that the force vector could be changed, resulting in a greater eruptive movement (Fig 5, *A*). The distance d between CR and the line of action was increased, aimed at a controlled canine eruption into its proper position in the dental arch (Fig 5, *B* and *C*). The fixed appliances on the maxillary teeth (ceramic clear Q Damon braces and Straight-Wire A COMPANY double buccal tubes, ORMCO, for the molars — in a

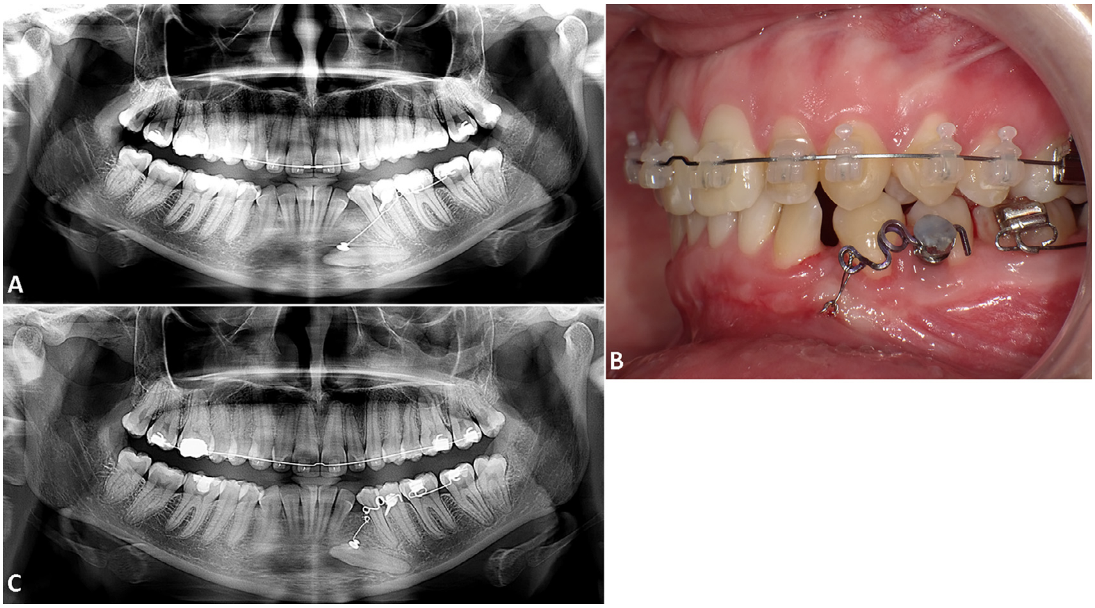

Fig 5. A, Panoramic radiograph showing the initial retraction and intrusion of the root of the affected canine below the root of the mandibular left first premolar after a period of 12 months; **B,** Intraoral photograph of the left side of the patient showing the continuing canine traction through a segmented 0.019 × 0.025-in titanium molybdenum alloy wire (TMA BAF purple, ORMCO, Glendora, Calif). The changing of the force vector resolved to a vertical component larger than the horizontal one; **C,** Panoramic radiograph showing the positive response of the orthodontically moved transmigrated canine to the gradual change of the force direction, 6 months later.

slot of 0.022 × 0.028-in Roth) are apparent as well (Fig 5, *B*). It was also noticeable that the mandibular left first premolar and the permanent mandibular incisors were left free from the fixed appliances to be able to self-adjust, adapting to the distally moving root and crown of the transmigrated canine.

After 6 more months, a larger rotation of the affected canine around its CR was needed, and the distance between the point of the force applied and the CR had to become longer to achieve a larger rotational moment. Consequently, the crown of the affected tooth was re-exposed, the first attachment was removed, and a new one was placed as coronally as possible (Fig 6, *A*). In this phase of treatment, the placement of the lower braces (Damon Q, from a second left premolar to a second right premolar and Straight-Wire A COMPANY double buccal tubes, for the permanent first molars — in a slot of 0.022 × 0.028-in Roth) was adjudged. The transmigrated canine had been moved close enough to the occlusal plane, so that the risk of the root resorption of the permanent mandibular left lateral incisor had been virtually eliminated. The traction was continued with the expected response (Fig 6, *B* and *C*).

After the levelling of the mandibular arch and space-opening, a Copper-nickel-titanium overlay wire (0.014-in Damon Cu-NiTi, ORMCO) was used to move the permanent mandibular left canine closer to the occlusal plane (Fig 7, *A*). Although a low torque Damon bracket was used on the permanent mandibular left lateral incisor and 0.019 × 0.025-in Titanium-molybdenum alloy Ortho Form III wires (3M Unitek, Monrovia, Calif) were used as the final wires in a slot of 0.022 × 0.028-in in the Damon Q braces to achieve proper torque-control, two additional Warren anterior torquing springs of Elgiloy Green .011 - 0.297 mm heat-treated for 0.016 × 0.022-in wire (RMO, Denver,

Fig 6. A, Placement of the remaining fixed orthodontic apliances on the mandibular teeth, except on the left first premolar; re-exposure of the crown of the transmigrated canine aiming at replacing the first attachment with a new one placed more coronally; **B** and **C,** Continuation of the canine traction.

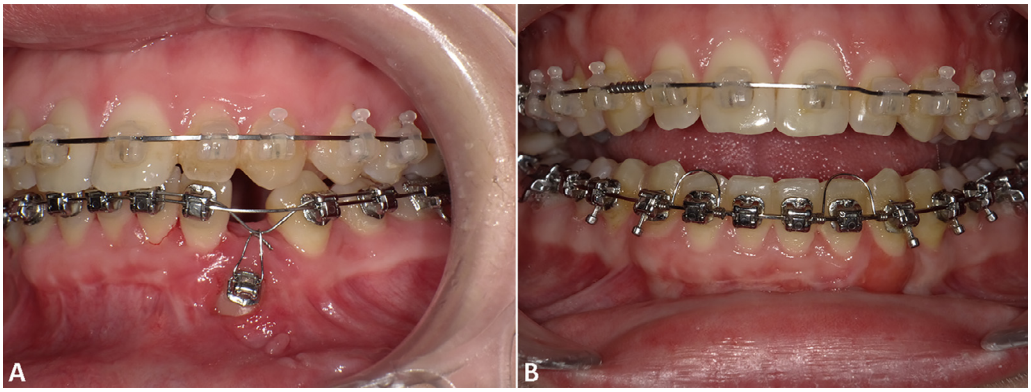

Fig 7. A, Finally, an overlay wire was used to bring the affected tooth closer to the occlusal plane; **B,** Finishing details in both arches.

Fig 8. Posttreatment facial and intraoral photographs. Deterioration of the pretreatment recessions mainly in the area of the maxillary premolars, right lateral incisor, and right canine because of persistent exaggerated tooth brushing.

Colo) were finally used on both permanent mandibular lateral incisors (Fig 7, *B*).

TREATMENT RESULTS

This first case was treated successfully (Figs 8-10).

After 4 years and 3 months of active orthodontic therapy, a successful outcome was attained (Figs 8-10). The deep impacted and transmigrated permanent mandibular left canine was placed in its proper position in the dental arch, and an improved smile harmony was apparent. There were no significant anteroposterior and vertical changes in

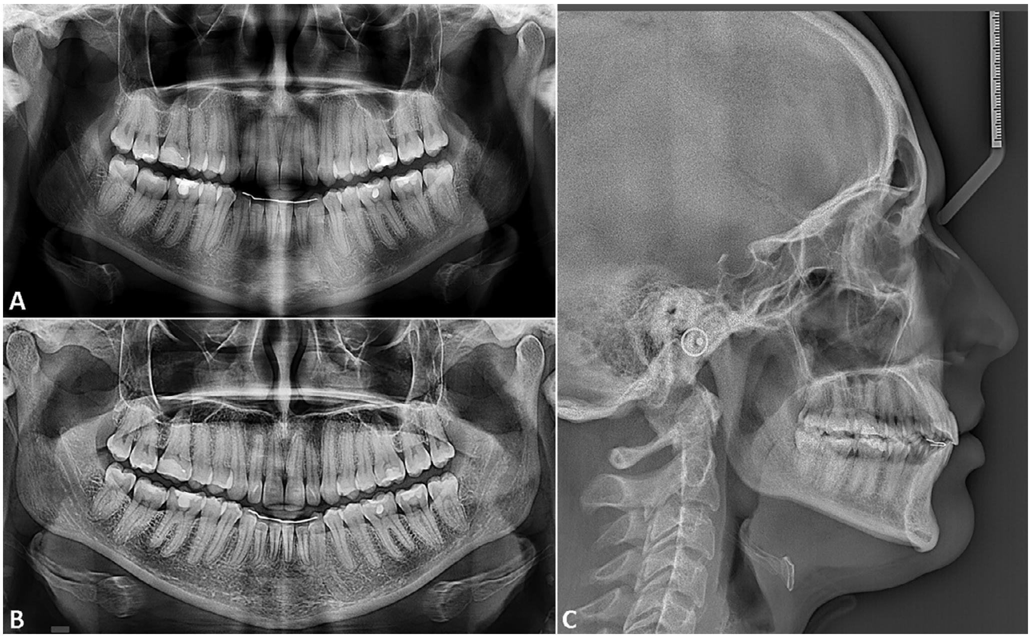

Fig 9. **A,** Posttreatment panoramic radiograph; **B** and **C,** Posttreatment panoramic and lateral cephalometric radiographs after 3-year retention.

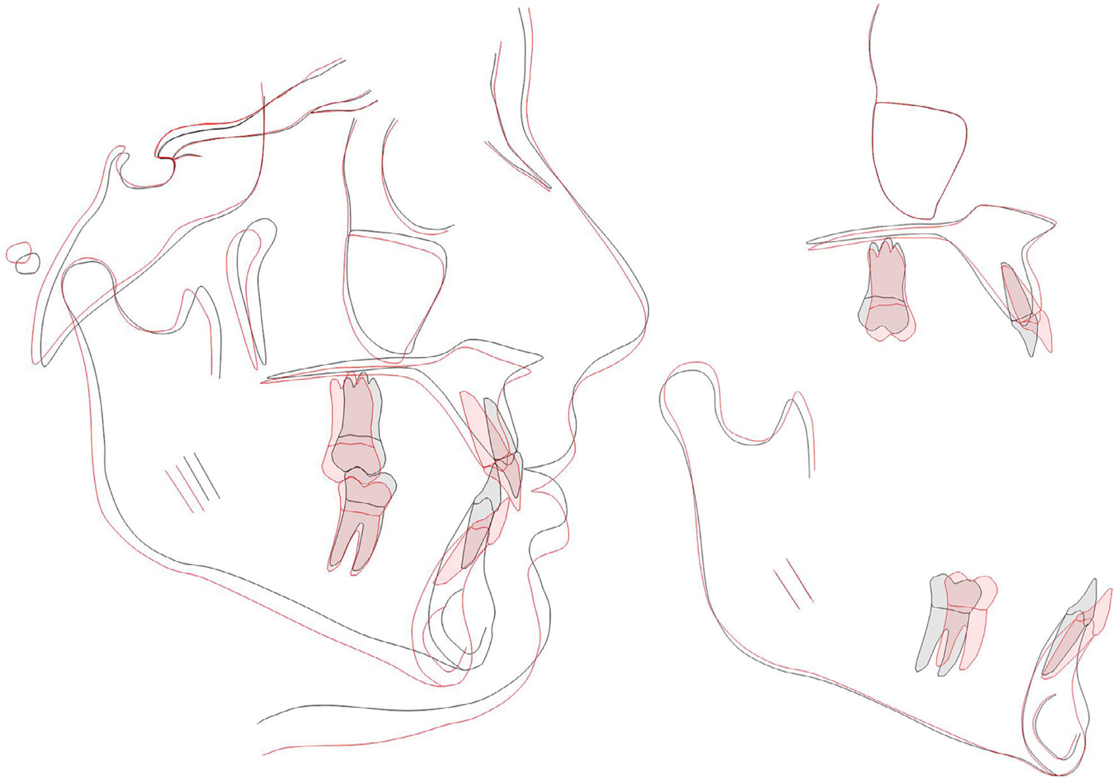

Fig 10. Cephalometric tracings pretreatment (*black*, at the age of 23 years and 2 months) and posttreatment, after 3-year retention (*red,* at the age of 30 years and 5 months) superimposed on the inner contour of the anterior wall of sella turcica, the anterior contour of the zygomatic process, and the anteroinferior contours of the chin just below pogonion. The form of the inner contour of the cortical plate at the lower border of the symphysis has changed after the alignment of the transmigrated canine.

the cephalometric analysis (Table), as had been expected, apart from the improvement of the inclination of the maxillary incisors (U1-FH, 110^0; U1-PP, 113^0).

CASE 2

DIAGNOSIS AND ETIOLOGY

A girl at the age of 11 years and 6 months visited our private practice with her parents. She had been referred by a general dentist because of the retained deciduous mandibular left canine, whereas the permanent mandibular right canine was fully erupted.

The clinical examination showed a convex profile, vertical growth pattern, slight lip incompetence at rest, and internal derangement of the right TMJ: clicking, multiple episodes of locking, and pain.

The cephalometric analysis (Table) indicated a skeletal Class II sagittal relationship (ANB, 10^0; SNA, 89^0; and SNB, 79^0) with a vertical growth pattern (GoGn-SN, 36^0) and proclined mandibular incisors (IMPA, 100^0). The pretreatment panoramic radiograph revealed a deep impaction and transmigration to the right of the permanent mandibular left canine, two supernumerary teeth, one in the anterior region of the maxilla and the other in the anterior region of the mandible, as well as an abnormal shape of the right condyle. More specific information regarding the location of the transmigrated canine and the supernumerary teeth was obtained through cone-beam computed tomography (CBCT) (Fig 11, *C*).

Intraorally, the patient exhibited a Class II, Division 1 malocclusion, with three quarters of Class II and one quarter of Class II molar relationships on the left and right sides, respectively, maxillary dentoalveolar protrusion, increased overjet of 7 mm, mild maxillary crowding (1.5 mm), mandibular and dental midline shift to the left, prolonged retention of the deciduous mandibular left canine, and the eruption of a supernumerary tooth palatally of the permanent upper right incisors (Fig 11, *A* and *B*).

TREATMENT OBJECTIVES

The primary treatment objectives were to (1) manage the TMJ disorder, (2) correct the skeletal Class II malocclusion and the mandibular shift, promoting proper mandibular growth, (3) move the transmigrated permanent mandibular left canine to its proper position in the dental arch after its surgical exposure and extraction of the supernumerary teeth, without causing any adverse effects to the neighboring teeth, using skeletal anchorage and fixed appliances, and (4) establish a functional occlusion with normal overjet and overbite.

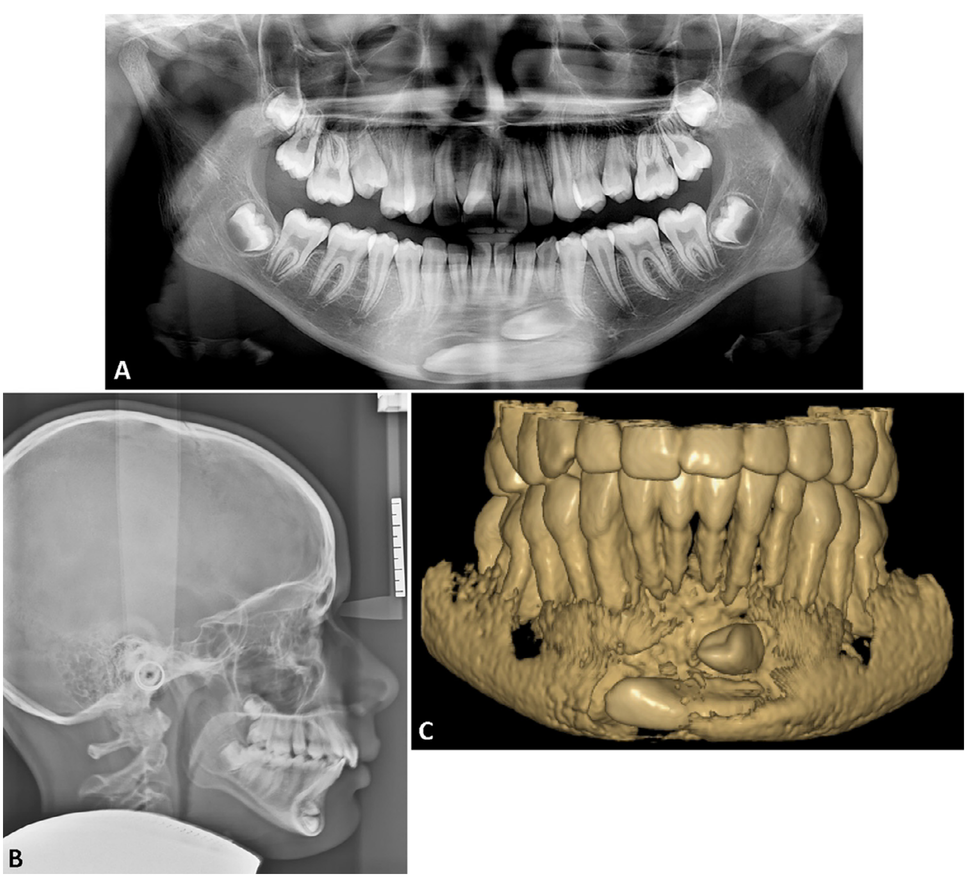

Fig 11. A and **B,** Pretreatment panoramic and lateral cephalometric radiographs; **C,** CBCT image.

TREATMENT ALTERNATIVES

Two treatment alternatives regarding the management of the deep impacted and transmigrated permanent mandibular left canine were considered: (1) extraction of the affected tooth and the deciduous mandibular left canine; space opening in this region; and securing the space and implant placement after completion of growth and (2) surgical exposure of the transmigrated canine and placement of an attachment on its crown and an attempt to move this tooth to its proper position in the dental arch by means of skeletal anchorage.

After discussing the treatment alternatives with the patient and her parents, it was decided to follow the second option involving surgical exposure.

TREATMENT PROGRESS

The Bite-Jumping appliance[10] was used for correcting the skeletal Class II malocclusion and the mandibular shift to the left. The TMJs of the young patient reacted positively to this functional therapy.

In the first surgical session, the deciduous mandibular left canine was extracted, and a mini-implant (Ø 1.9 × 7.0 mm - SPIDER K2, Long Neck, HDC) was inserted between the mandibular left premolars (Fig 12, *A*). After that, part of the crown of the affected tooth was exposed, and the supernumerary teeth, along with the neighboring inflammatory tissues, were removed (Fig 12, *B* and *F*). An attachment was bonded on the exposed crown, and a ligature wire was connected to it (Fig 12, *C*).

The significant bone defect, created after the removal of the abnormal and inflammatory tissues, was covered through a natural bone mineral of bovine origin for bone grafting (Bio-Oss, Geistlich, Wolhusen, Switzerland) and a resorbable bilayer membrane (Bio-Gide, Geistlich) shielded, in its turn, the bone mineral for optimal tissue regeneration (Fig 12, *D* and *E*). The removed tissues were sent for histologic examination to the Department of Oral Pathology & Medicine and Hospital Dentistry of the Dental School of the National and Kapodistrian University of Athens. The histologic findings were: "The histologic segments consist of cellular and angioblastic fibrous connective tissue with numerous islands of inactive odontogenic epithelium, some of which show peripheral hyalinization. Mild lymphoplasmacytic inflammatory infiltrates and hemorrhagic permeability are also distinguished. Conclusion: findings are compatible with dental follicles of impacted teeth."

The decision to use bone grafting was made considering that the lack of bone coronal to the impacted tooth at the initiation of traction would enhance its eruptive moment, altering the location of CR of the impacted tooth to a more apical displacement so that its root could more quickly reach the caudal compact bone border of the mandible before it reached the area below the mandibular first premolar. If this happened, the fate of the tooth would be determined very soon.

The location of the CR of a fully erupted single-rooted tooth depends on many factors, including the size, length, and morphology of its root; its periodontal ligament and its relationship with the alveolar bone; the alveolar bone quantity and quality around the tooth; the patient's age; the tissue response to forces applied; and the degree of humidity of neighboring osseous structures and the tooth's axial inclination.[11]

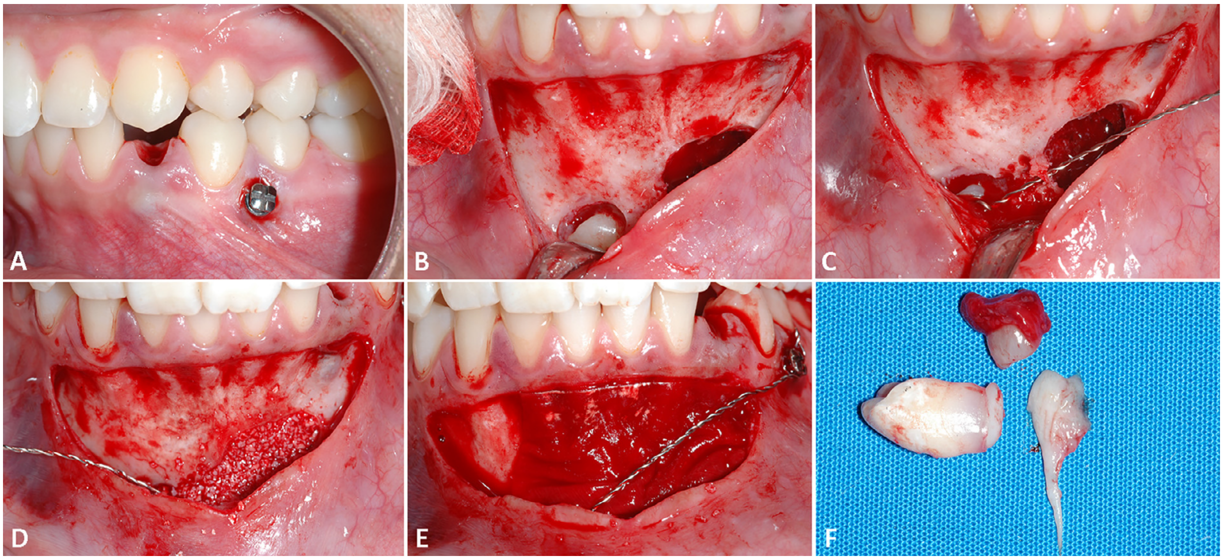

Fig 12. A, Extraction of the deciduous mandibular left canine and insertion of a mini-implant between the mandibular left premolars; **B** and **C,** Surgical exposure of the permanent mandibular left canine; removal of the supernumerary teeth; and placement of a Caplin hook on the exposed crown and a ligature wire connecting the attachment with the traction means; **D** and **E,** Bone grafting; **F,** Extracted supernumerary teeth.

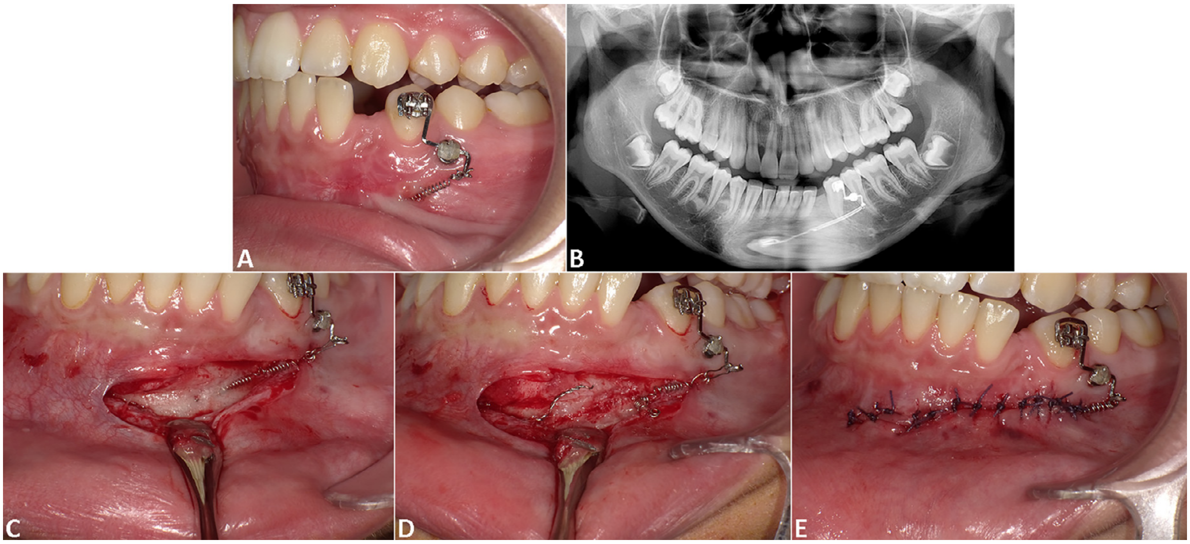

Fig 13. **A,** Stainless steel segmented wire attached on the mini-implant and closed coil spring connection; **B,** Panoramic radiograph one year after initiation of traction; **C,** Re-exposure of the area of the transmigrated canine; **D,** The release of the traction means (ligature wire and spring) and removal of them; **E,** Sutured flap.

Although in the prescription of the bone grafting materials used (Geistlich brochure), it was mentioned that mobility by mechanical loading (compression loading) of the Geistlich Bio-Oss augmented area should be avoided for 6 months. After two weeks from the exposure day, the traction of the affected tooth began. The tooth traction began without waiting for 6 months because a closed exposure technique had been decided upon. This means that an attachment was fixed on the exposed crown of the transmigrated canine, and a ligature wire connected the attachment with the traction means. In such cases, the immediate traction procedure is of vital importance. Otherwise, connective tissue and bone could invade the traction means and hinder the tooth movement,[12] which happened nonetheless (Fig 13, *C* and *D*). A 0.017 × 0.025-in stainless steel segmented wire was attached to the mini-implant so that the vector of the applied force would be as close as possible to the CR of the transmigrated canine, resulting in a horizontal traction component larger than the vertical one. At the apical end of the aforementioned wire, a Sentalloy closed coil spring medium 150 g (GAC, Islandia, NY) was attached and connected with the ligature wire (Fig 13, *A*). After one year of traction, the panoramic radiograph indicated minor changes in the location of the affected tooth. Its crown had moved minimally coronally, and its apex had also moved caudally closer to the mandibular border. Additionally, two supernumerary teeth had become apparent on the right side of the mandible (Fig 13, *B*).

Because of this poor response to the traction, and bearing in mind what could happen to the soft tissue and bone in contact with the ligature wire and the coil spring,[12] it was decided to re-expose the crown of the affected tooth. In this surgical intervention, the bony and inflammatory tissues were removed, and the traction means were released (Fig 13, *C-E*). At this exposure, a new ligature wire and a closed coil were placed.

After 3 years and 7 months from the initiation of treatment, with no significant clinical improvement, the tooth was re-exposed once again, and it was assessed for ankylosis.[12] This was not the case, but something that was unclear until this time was obstructing the canine from being freely moved. The only element that was very unclear to the experienced surgeon was the extremely hard bone density, which was noticeable in every exposure of the affected canine when invasive bony tissue, which covered the traction means (Fig 13, C and D), and the affected canine had to be removed. The apex of the tooth was in contact with the mandibular borders. Nevertheless, the age of the patient was optimal for a positive tooth-movement response, and the uprighting moment for the impacted canine was increased. However, the bone remodeling process above the canine crown, in the area in which the supernumeraries were located, was unusual. The young patient had shown remarkable patience and perseverance, but now her motivation was over. Therefore, it was decided to remove the attachment, and the traction means, close the surgical wound by repositioning a soft tissue flap at this session, and plan for the extraction of the transmigrated canine.

Subsequently, the transmigrated canine was extracted; the treatment, with the help of the aforementioned functional appliances, was finished; and fixed appliances (Damon Q braces, ORMCO, and Victory Series superior Fit MBT Rx buccal tubes nonconvertible single, 3M, in a slot of 0.022 × 0.028-in) were placed in both dental arches.

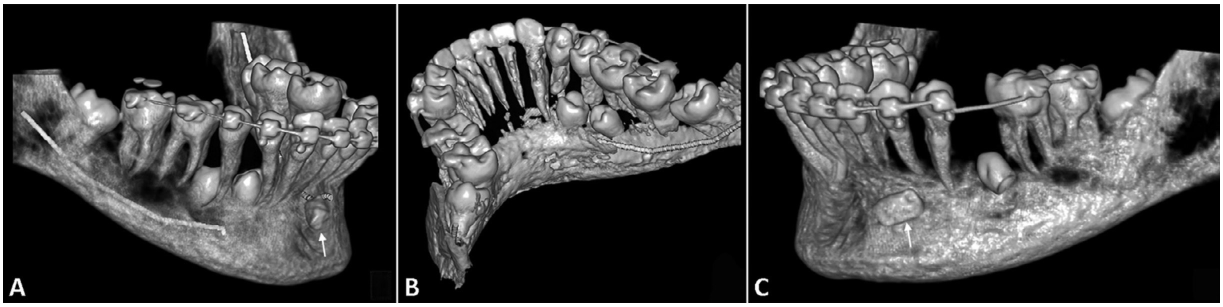

Fig 14. A-C Three-dimensional volumetric renderings; **A** and **C,** *arrows* indicate the asymptomatic radiopaque bone formation.

After one and a half years, the active therapy using the fixed appliances was almost complete. Before the removal of these appliances, a CBCT was carried out aimed at the preparation of the scheduled extraction of the supernumerary teeth on the right side of the mandible. From this CBCT, the following diagnostics were ascertained: the accurate location of the supernumerary teeth and their relationships to the adjacent teeth, the anatomic structures on the right side of the mandible (Fig 14, *A* and *B*), and a radiopaque bone formation (Fig 14, *A* and *C*) in the anterior region of the mandible. The supernumerary teeth and the inflammatory tissues were extracted from this region during the first surgical exposure, and the bone grafting procedure was performed in that area.

TREATMENT RESULTS

This second case was treated unsuccessfully relating to the transmigrated canine but successfully for the skeletal malocclusion (Figs 15 and 16).

After five and a half years of active orthodontic therapy, an improved outcome was attained regarding the skeletal Class II malocclusion of the patient (Table), the profile esthetics, the lip closure, lower lip posture, and the right TMJ, which was now free of clicking, locking, and pain — the repair has resulted in the flattening of the articular surface. However, an unsuccessful result was attained in the case of the deep impacted and transmigrated permanent mandibular left canine, which was extracted (Fig 15), and in the dental midlines accordance. Nevertheless, the

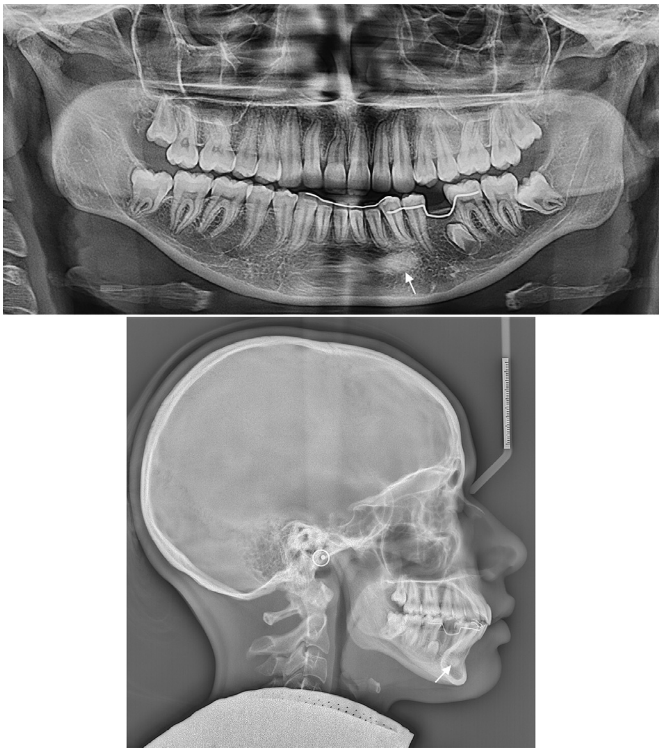

Fig 15. Posttreatment panoramic and lateral cephalometric radiographs after 1-year retention. The *arrows* indicate the radiopaque bone formation.

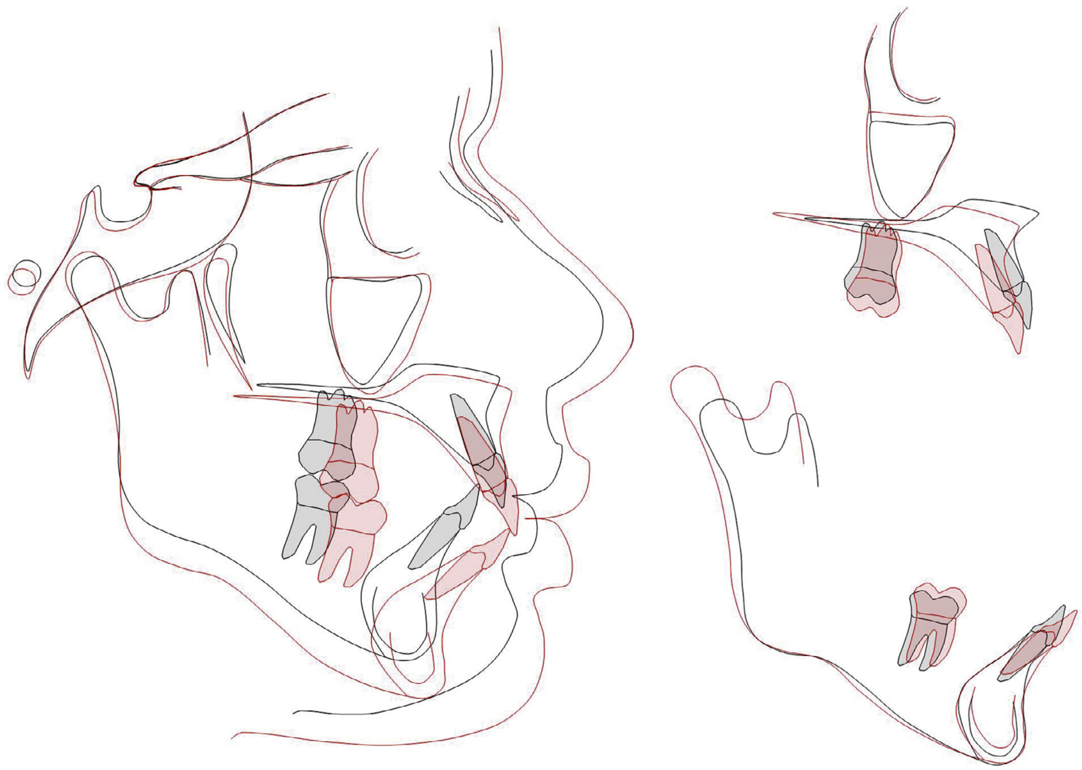

Fig 16. Cephalometric tracings pretreatment (*black,* at the age of 11 years and 6 months) and posttreatment, after retention of one year (*red,* at the age of 18 years) superimposed on the inner contour of the anterior wall of sella turcica, the anterior contour of the zygomatic process, and the anteroinferior contours of the chin just below pogonion. The form of the inner contour of the cortical plate at the lower border of the symphysis has changed since the extraction of the supernumerary teeth and the transmigrated canine.

mandibular left premolars were successfully moved mesially, and a functional and physiological occlusion was obtained. The space distal to the mandibular left second premolar was secured using a fixed retainer, which will remain until the eruption of the supernumerary tooth in this area. In the final panoramic and lateral cephalometric radiographs, the radiopaque formation in the anterior area of the mandible in the same location (Fig 15) was still apparent.

DISCUSSION

The main reason that there are only a few studies[5,6,13-15] based on a large number of cases researching this unphysiological canine intra-tissue migration is that mandibular canine transmigration is a rare biologic phenomenon.[1,2]

Mandibular transmigrated canines are found noticeably apically closer to the lower border of the mandible and in a horizontal angulation.[16] Additionally, transmigration is significantly connected with an absence of contact with adjacent teeth and the canine's apex not reaching the mandibular cortical bone.[16]

The surgical removal of the transmigrated canine is the most common therapeutic alternative.[16,17] Nevertheless, there are cases in the bibliography that have been successfully treated.[18,19] Our aim was to contribute concrete insights to the therapeutic orthodontic management of these teeth.

After analyzing these two fully-treated cases by the same practitioner, surgically and orthodontically, the following differentiating features between the success and failure of these two cases were ascertained:

1. The patient's age in the unsuccessful second case (11 years and 6 months) compared with the age of the successful first patient (23 years and 2 months) would normally be optimal. Nevertheless, the specific treatment carried out, relating to the artificial material that could influence the physiological bone remodeling process, meant that the advantage of age was no longer a determining factor in the treatment outcome.
2. Initially, the aim of our technique was to move the transmigrated canine root distally below the root of the mandibular left first premolar without causing any adverse dental side-effects. The generated movement, with the help of the above-mentioned mechanic, skeletal anchorage—vector of diagonally applied light force close to the CR of the transmigrated canine, resolves into a horizontal traction component larger than the vertical one. Accordingly, in the second case,

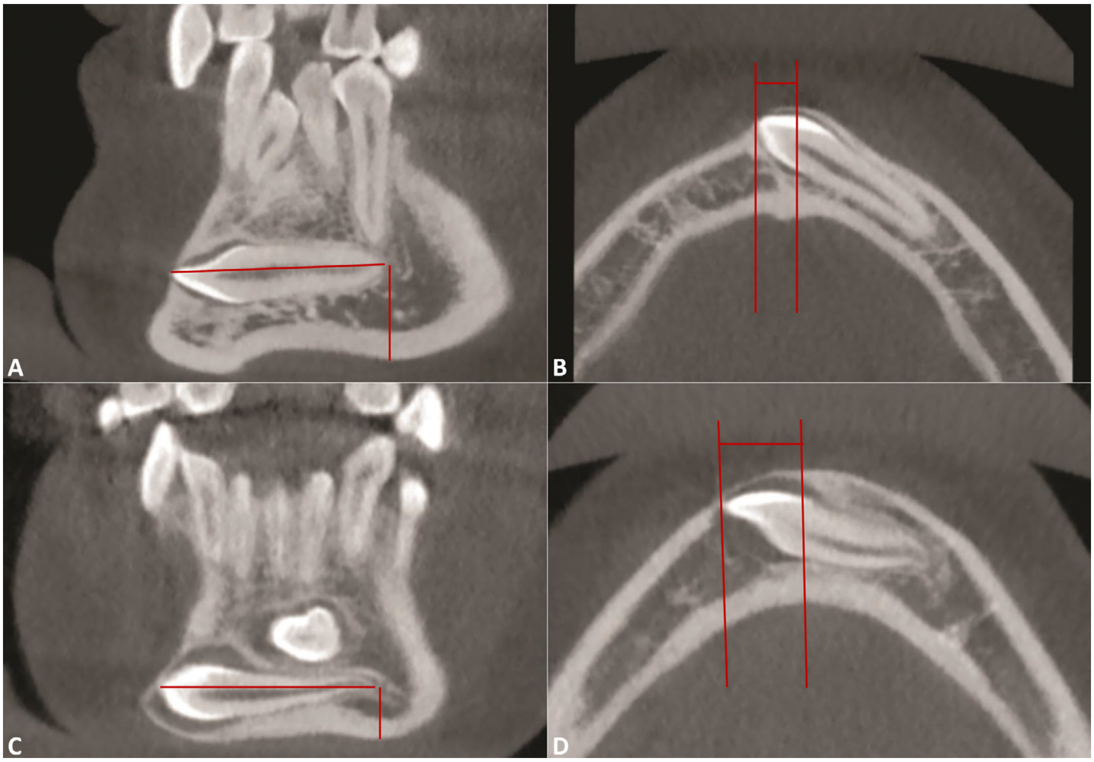

Fig 17. **A** and **C,** The lengths of the teeth in the successful and unsuccessful cases correspondingly, as well as the distances from the apex of the affected teeth to the mandibular border on the pretreatment CBCT images; **B** and **D,** The distance beyond the mandibular midline in the successful and unsuccessful cases correspondingly, on the pretreatment CBCT images.

the force vector during this first stage of traction was optimized with the help of a segmented wire extended apically to the mini-implant (Fig 13, *A*), bringing, in this way, the location of the applied force much closer to the CR of this tooth.

3. The distance from the apex of the affected tooth to the mandibular border, in the successful case, was 10.7 mm (Fig 17, *A*), whereas the same measurement was far less (5.7 mm) in the unsuccessful case (Fig 17, *C*). This distance is of vital importance for the first stage of the aforementioned movement in order to bring the root of the affected tooth distally below the root of the first premolar before having contact with the mandibular borders. The mandibular symphysis dimensions between the apex of the transmigrated tooth and the mandibular border allow or restrict the possibility of tooth movements. In the case of a transmigrated canine with a horizontal angulation (type 2), as the affected tooth is located deeper, there is less space available in its apex area for a positive outcome, which indicates the severity of transmigration in the vertical plane.
4. The length of the tooth in the unsuccessful case (Fig 17, *C*) was also longer, 24.8 mm with a root not yet fully developed at the onset of treatment, than the length of the tooth (Fig 17, *A*) in the successful case (24.0 mm).
5. The severity of transmigration in the horizontal plane in the unsuccessful case (Fig 17, *D*) 11.8 mm beyond the mandibular midline, compared with 4.1 mm in the successful case (Fig 17, *B*), was of great importance.
6. In our opinion, a finding that played a significant role in the adverse outcome of the unsuccessful case was the asymptomatic radiopaque bone formation (Figs 14, *A* and *C*, 15, and 18, *A* and *B*) located in the anterior area of its mandible, from which the supernumerary teeth and inflammatory tissues were removed during the first exposure session and where the bone grafting procedure was performed (Figs 11 and 12). From our point of view, this very dense bone area, located in the direction of motion of the transmigrated tooth, impeded its physiological tooth movement most. This region in the bone could be a "dense bone island,"[20] a pearl-shell structure,[21] a new supernumerary tooth, or another tissue that could hinder bone remodeling. A pearl-shell structure as the "dense bone island," are lesions most commonly found in the premolar and molar sites. The possibility of a supernumerary tooth was ruled out because of its radiographic characteristics. There was no evidence of the density of the mass and the shape presenting an enamel layer of a tooth, as was the case in Figure 18, *C*. This radiographic finding had an appearance of compact bone. In our opinion, this very dense

Fig 18. CBCT images of the second case treated unsuccessfully taken 1 year and 6 months after the extraction of the transmigrated canine close to the end of active treatment. **A,** Axial view of a CBCT image reconstruction apically of the mandibular teeth presenting the asymptomatic radiopaque bone formation; **B,** Three-dimensional CBCT image reconstruction focusing on the radiopaque bone formation located in the anterior area of the mandible, from which the supernumerary teeth and inflammatory tissues were removed during the first exposure session; **C,** Axial view of a CBCT image reconstruction, more coronally compared to the axial view in (**A**) focusing on the location of the supernumerary teeth. The *arrows* indicate the physiological radiopacity of the enamel in these teeth.

bone tissue formation, which did not exist at the beginning of therapy, was created through the Geistlich Bio-Oss augmented xenograft. A histologic examination of this affected area would be the only method to securely diagnose the cause of its hindered bone remodeling. Nevertheless, the patient remains in control having specific recalls and radiographic evaluation of this region of her mandible.

A bone graft is considered to be a living tissue able to aid bone healing when transplanted into a bony defect, either alone or in combination with other materials.[22] The four basic biologic characteristics of osseointegration, osteogenesis, osteoconduction, and osteoinduction are essential in performing this role effectively. These natural bone graft materials may also be categorized into four subdivisions: autografts, allografts, xenografts, and phytogenic materials.[22]

Autologous bone, removed from the patient's own body, is the benchmark for bone grafting but has some disadvantages, such as unsure prognosis, surgery at the donor site, and restricted availability. Other options for medium and small-sized defects comprise allografts (from human donors), xenografts (from animals), and synthetic materials with osteoconductive characteristics.[23]

Xenografts are the bone grafts most commonly used by dental surgeons. Various other studies comparing mainly autologous bone, but also other materials, with xenografts confirm their efficacy. Bio-Oss is the best-known xenograft for dental surgeons. It is extracted from bovine hydroxyapatite, and one of its main features is its similarity in chemical composition to human hydroxyapatite.[23]

The histologic findings show that the Bio-Oss particles are interconnected through bone bridges and covered by newly formed bone tissue.[24]

In a case series clinical examination of long-term complications associated with the use of bovine-derived graft materials (xenografts), the following pathologic issues were diagnosed: the sinus and maxillary bone pathologies, displacement of the graft materials, implant failure, foreign body reactions, encapsulation, chronic inflammation, soft-tissue fenestrations, and associated cysts. Bovine-derived graft materials were not biodegradable. There is a need for long-term clinical studies to pinpoint the biologic complications of xenografts, which are used extensively in dentistry.[25]

Alveolar bone remodeling in orthodontic tooth movement (OTM) is a highly regulated process that coordinates bone resorption by osteoclasts and new bone formation by osteoblasts. Mechanisms involved in OTM include mechano-sensing, sterile inflammation-mediated osteoclastogenesis on the compression side, and tensile force-induced osteogenesis on the tension side. Several intracellular signaling pathways and mechanosensors, including the cilia and ion channels, transduce mechanical force into biochemical signals that stimulate the formation of osteoclasts or osteoblasts.[26]

In our opinion, because xenografts are not biodegradable,[25] in the unsuccessful case, the natural alveolar bone remodeling[26] could have been disturbed through Bio-Oss augmentation.[27-30] Therefore, the impediment of the alveolar bone remodeling in OTM should be taken into account when using such materials.[30]

Patients with alveolar bone resorption leading to severe periodontal attachment loss, who have been treated or have to be treated by the periodontist, are encountered in an everyday orthodontic practice. If a xenograft has already been used, this should be taken into account by the orthodontist in relation to any tooth movement in the affected area. But, if the periodontal osseous defects have to be treated in order for the periodontal disease to be managed before the orthodontic therapy, a comprehensive discussion is essential between the orthodontist and the periodontist focusing on the type of guided bone regeneration to be used and whether it is absolutely necessary.

Patients with cleft lip and palate, treated for secondary alveolar bone grafting to allow proper eruption of the permanent maxillary canine and to close the oronasal fistula, are most commonly treated using autologous bone from the iliac crest.[31] In such cases, xenografts may also be used in order to reduce morbidity.[32] If solely autologous bone has not been used in the graft, but a combination of autologous bone and a xenograft or a xenograft by itself, natural tooth eruption or tooth movement within the affected area could be severely impaired.

It is also important to mention the following factors, which should be taken into serious consideration regarding the preparation of an orthodontic treatment of a mandibular transmigrated canine:

1. Detailed clinical examination and meticulous observation and study of the diagnostic means (severity of transmigration in the vertical and horizontal planes-distance between the apex of the transmigrated canine and the lower border of the mandible, the amount of the tooth beyond the mandibular midline, length of its root, volume of its crown, mandibular symphysis dimensions, and lack of an a priori ankylosis, which can be ascertained through a CBCT).[12]
2. Impaction and transmigration diagnosis and causes.
3. The earlier the diagnosis and the surgical intervention the better (age).
4. Method of surgical intervention and proper placement of the attachment.
5. Use of only autogenous bone graft if absolutely necessary.
6. Use of skeletal anchorage.
7. Appropriate traction means (eg, closed coil spring, ligature wire, and chain) between attachment and skeletal anchorage, which remain intratissue.
8. The study of force vectors, direction of traction and its gradual change, required for predictable tooth movement and the location and design of the attachment on the crown of the transmigrated canine according to its optimal crown and root movement is crucial.
9. Quality of bone remodeling around the transmigrated tooth during traction.
10. Leaving mandibular first premolar and permanent mandibular incisors free from orthodontic appliances during first stages of traction.
11. Patience, willingness, and motivation of the patient play a vital role and are indicators for this decision.

CONCLUSIONS

To move a transmigrated mandibular canine of type 2 into its physiological position in the dental arch should not be considered to be a heroic effort when the issues mentioned in the discussion above are seriously taken into account: meticulous observation and detailed study of the case, appropriate surgical exposure and proper placement of the attachment, use of only autogenous bone graft if absolutely necessary, use of skeletal anchorage, appropriate traction methods, gradual change of traction vector, keeping first premolar and permanent mandibular incisors free from orthodontic appliances during the first stages of traction, and a cooperative and motivated patient.

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AUTHOR CREDIT STATEMENT

Koutzoglou Stylianos: conceptualization, methodology, validation, investigation, project administration, writing — original draft preparation, resources, and writing — review and editing. Koutzoglou Eleni and Koutzoglou Despoina: software, data curation, and investigation.

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CONFLICTS OF INTEREST

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

STATEMENT OF INFORMED CONSENT

Informed consent was obtained from the first patient and from the mother of the second patient.

REFERENCES

1. Sajnani AK, King NM. Impacted mandibular canines: prevalence and characteristic features in southern Chinese children and adolescents. J Dent Child (Chic) 2014;81:3-6.
2. Aras MH, Halicioğlu K, Yavuz MS, Çağlaroğlu M. Evaluation of surgical-orthodontic treatments on impacted mandibular canines. Med Oral Patol Oral Cir Bucal 2011;16:e925-8.
3. Ando S, Aizawa K, Nakashima T, Sanka Y, Shimbo K, Kiyokawa K. Transmigration process of the impacted mandibular cuspid. J Nihon Univ Sch Dent 1964;6:66-71.
4. Javid BR. Transmigration of impacted mandibular cuspids. Int J Oral Surg 1985;14:547-9.
5. Mupparapu M. Patterns of intra-osseus transmigration and ectopic eruption of mandibular canines: review of literature and report of nine additional cases. Dentomaxillofac Radiol 2002;31:355-60.
6. Plakwicz P, Abramczyk J, Wojtaszek-Lis J, Sajkowska J, Warych B, Gawron K, et al. The retrospective study of 93 patients with transmigration of mandibular canine and a comparative analysis with a control group. Eur J Orthod 2019;41:390-6.
7. Shapira Y, Kuftinec MM. Intrabony migration of impacted teeth. Angle Orthod 2003;73:738-43. discussion 744.
8. Mazinis E, Zafeiriadis A, Karathanasis A, Lambrianidis T. Transmigration of impacted canines: prevalence,

management and implications on tooth structure and pulp vitality of adjacent teeth. Clin Oral Investig 2012;16:625-32.

9. Plakwicz P, Wojtaszek J, Zadurska M. New bone formation at the site of autotransplanted developing mandibular canines: a case report. Int J Periodontics Restorative Dent 2013;33:13-20.
10. Tränkmann J. Die Plattenapparatur in der Kieferorthopädie. Berlin: Quintessenz; 1985.
11. Papageorgiou IS. The center of resistance of teeth in Orthodontics. Hellenic Orthod Rev 2005;8:41.
12. Koutzoglou SI, Kostaki A. Effect of surgical exposure technique, age, and grade of impaction on ankylosis of an impacted canine, and the effect of rapid palatal expansion on eruption: a prospective clinical study. Am J Orthod Dentofacial Orthop 2013;143:342-52.
13. Joshi MR. Transmigrant mandibular canines: a record of 28 cases and a retrospective review of the literature. Angle Orthod 2001;71:12-22.
14. Kara MI, Ay S, Aktan AM, Sener I, Bereket C, Ezirganli S, et al. Analysis of different type of transmigrant mandibular teeth. Med Oral Patol Oral Cir Bucal 2011;16:e335-40.
15. Dalessandri D, Parrini S, Rubiano R, Gallone D, Migliorati M. Impacted and transmigrant mandibular canines incidence, aetiology, and treatment: a systematic review. Eur J Orthod 2017;39:161-9.
16. Bertl MH, Frey C, Bertl K, Giannis K, Gahleitner A, Strbac GD. Impacted and transmigrated mandibular canines: an analysis of 3D radiographic imaging data. Clin Oral Investig 2018;22:2389-99.
17. Martínez-Rodríguez C, Martínez-Rodríguez N, Alamán-Fernández JM, Ruiz-Sáenz PL, Santos-Marino J, Martínez-González JM, et al. Dental transmigration: an observational retrospective study OF52 mandibular canines. Biology 2022;11:1751.
18. Peerlings RHJ. Treatment of a horizontally impacted mandibular canine in a girl with a class II division 1 malocclusion. Am J Orthod Dentofacial Orthop 2010;137:S154-62.
19. Scribante A, Beccari S, Beccari G, Pascadopoli M, Gandini P, Sfondrini MF. Orthodontic repositioning of a lingually positioned transmigrated mandibular canine. Am J Orthod Dentofacial Orthop 2023;163:272-84.
20. Mariani GC, Favaretti F, Lamazza L, De Biase A. Dense bone island of the jaw: a case report. Oral Implantol 2008;1:87-90.
21. Araki M, Matsumoto N, Matsumoto K, Ohnishi M, Honda K, Komiyama K. Asymptomatic radiopaque lesions of the jaws: a radiographic study using cone-beam computed tomography. J Oral Sci 2011;53:439-44.
22. Zhao R, Yang R, Cooper PR, Khurshid Z, Shavandi A, Ratnayake J. Bone grafts and substitutes in dentistry: a review of current trends and developments. Molecules 2021;26:3007.
23. Ferraz MP. Bone grafts in dental medicine: an overview of autografts, allografts and synthetic materials. Materials (Basel) 2023;16:4117.
24. Moreira AC, Silva JR, Samico RP, Nishioka GNM, Nishioka RS. Application of Bio-Oss in tissue regenerative treatment prior to implant installation: literature review. Braz Dent Sci 2019;22:147-54.
25. Rodriguez AE, Nowzari H. The long-term risks and complications of bovine-derived xenografts: a case series. J Indian Soc Periodontol 2019;23:487-92.
26. Jeon HH, Teixeira H, Tsai A. Mechanistic insight into orthodontic tooth movement based on animal studies: a critical review. J Clin Med 2021;10:1733.
27. Reichert C, Götz W, Smeets R, Wenghöfer M, Jäger A. The impact of nonautogenous bone graft on orthodontic treatment. Quintessence Int 2010;41:665-72.
28. Ru N, Liu SSY, Bai Y, Li S, Liu Y, Wei X. BoneCeramic graft regenerates alveolar defects but slows orthodontic tooth movement with less root resorption. Am J Orthod Dentofacial Orthop 2016;149:523-32.
29. Ru N, Liu SSY, Bai Y, Li S, Liu Y, Zhou G. Microarchitecture and biomechanical evaluation of boneceramic grafted alveolar defects during tooth movement in rat. Cleft Palate Craniofac J 2018;55:798-806.
30. Alalola B, Asiri A, Binmoghaiseeb I, Baharoon W, Alrassi Y, Alanizy B, et al. Impact of bone-grafting materials on the rate of orthodontic tooth movement: a systematic review. Cureus 2023;15:e44535.
31. Dasari MR, Babu VR, Apoorva C, Allareddy S, Devireddy SK, Kanubaddy SR. Correction of secondary alveolar clefts with iliac bone grafts. Contemp Clin Dent 2018;9:S100-6.
32. Aly LAA, Hammouda N. Secondary closure of alveolar cleft with resorbable collagen membrane and a combination of intraoral autogenous bone graft and deproteinized anorganic bovine bone. Ann Maxillofac Surg 2016;6:165-71.