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A novel approach in orthodontics: Archwise distraction osteogenesis

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ABSTRACT

Distraction osteogenesis can be described as a procedure that is based on the principles of physiologic remodeling and indirect fracture healing. In dentoalveolar level, conventional appliances may present some difficulties such as the need for multiple stages of DO to achieve a good occlusion due to distraction on a straight vector; incompetency to reduce the oronasal fistula in cleft patients; and the difficulty in achieving complete hard and soft tissue reconstruction, especially in cases with large alveolar defects.

ArchWise Distraction Appliance (AWDA) have been developed to overcome these limitations and obtain a regenerated bone curvilinear in shape, similar to the original alveolar bone configuration. This article aims to introduce and explain the AWDA method in detail so that every clinician will be able to perform the treatment. The reader can observe the application of the procedure on a variety of cases including cleft lip and palate, trauma, and bone pathology. Possible complications and their solutions are also explained on actual cases.

Brief history and introduction of distraction osteogenesis

The skeletal system has the ability to remodel in response to physiologic and mechanic strain.[1,2] Compression, weight-bearing and stress-generated potentials are described as the key mediators of physiologic bone remodeling.[3] Distraction osteogenesis (DO) can be described as a procedure that is based on the principles of physiologic remodeling and fracture healing. The osteogenesis is induced through a controlled microtrauma and gradual stretching at the osteotomy site.[4] (Fig. 1) It has also been described as a treatment procedure that provides functional replacement of tissue by promoting endogenous bone formation in a guided mechanical environment.[5,6]

The important aspect of the craniofacial bones (along with the clavicle) that differs from the rest of the skeleton is that they are formed by intramembranous ossification during fetal development.[7] Bone formation in all other skeletal elements occurs by endochondral ossification. A recent literature review suggests that the craniofacial and appendicular skeleton differ in molecular signaling and cellular behavior governing bone formation, repair, and regeneration.[7] It is also concluded that the biomolecular understanding of mandibular DO is more advanced than limb DO regarding development, regeneration, and adjuvant therapy outcomes and that understanding of the biological basis of DO is still necessary for the development of innovative surgical techniques, accelerated bone healing and adjunctive treatments.

Today, DO is a viable treatment option in many cases that involve craniofacial deformation.[4,8-14] Some of the examples from the literature include:

- Intermolar mandibular DO and mandibular symphysial DO,
- Transport DO as an alternative to delayed secondary alveolar bone grafting in cleft lip and palate,
- Dentoalveolar DO in cases of primary failure of dental eruption, and rapid canine retraction,
- Correction of maxillomandibular deformation and hypoplasia in some syndromes like auriculocondylar syndrome, hemifacial microsomia, Crouzon syndrome, cleft lip and palate, Pierre-Robin syndrome, Treacher Collins syndrome
- Alveolar or skeletal lesions due to traumatic, tumoral, cystic, or inflammatory reasons

Philosophy of archwise distraction and technique

Distraction osteogenesis has been shown to be effective in lengthening the craniofacial membranous bone, including the maxilla and mandible, both in the growing facial skeleton and in the adult patients.[4,15] Nevertheless, in dentoalveolar level, there were remaining difficulties of conventional appliances, especially in cleft lip and palate patients. These difficulties can be summarized as: the need for multiple stages of DO to achieve a good occlusion due to

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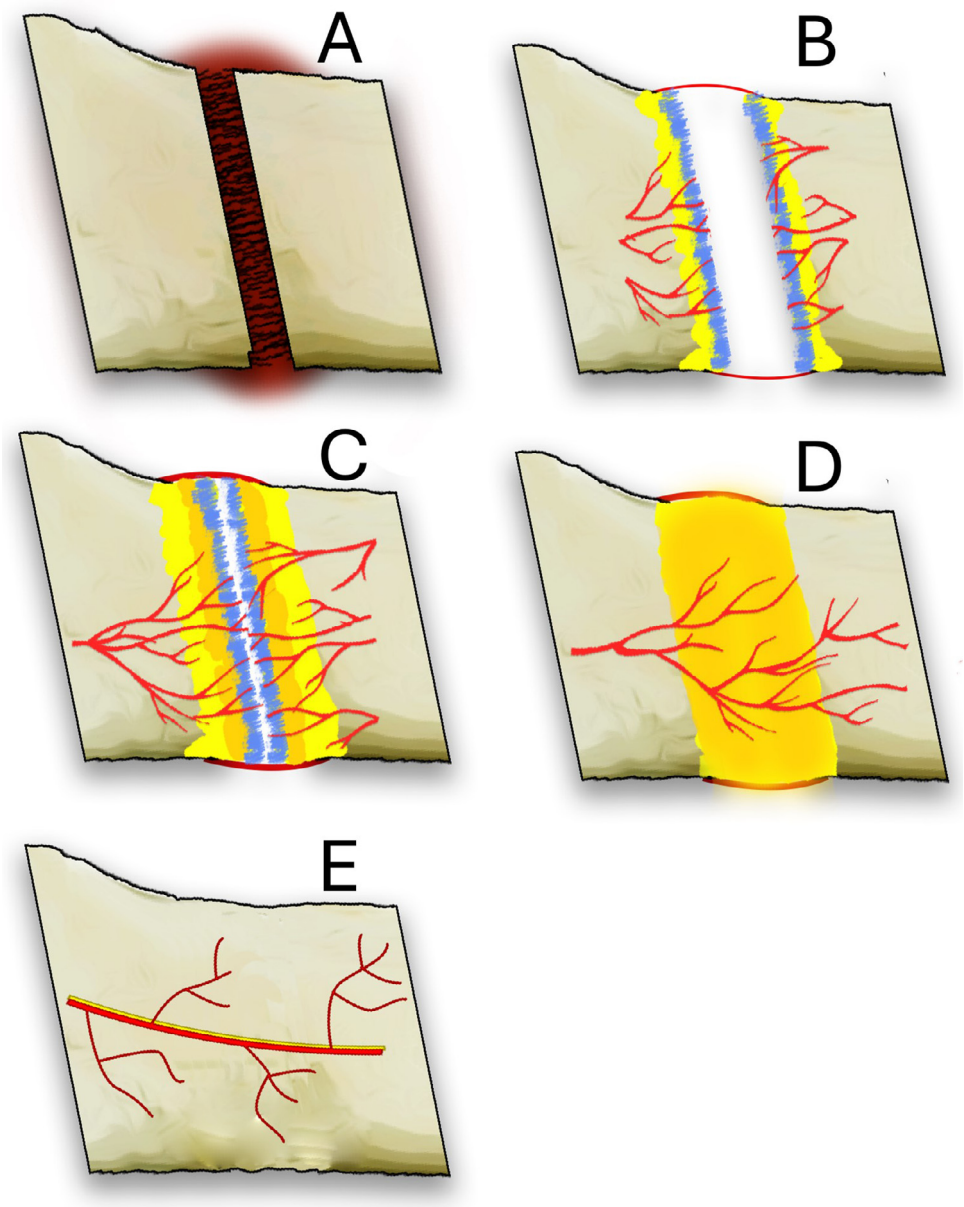

Fig. 1. Schematic representation of the phases of distraction osteogenesis. (a) Latency period. Hematoma and inflammatory response occurs, Proliferative cells start to fill the fractured area during the inflammation process and the organization of the fracture hematoma begins. And formation of the soft callus starts. (b) In the distraction phase, traction forces are applied at a daily rate that may vary between 0.5 − 1 mm. The general approach is a rate of 1 mm/day. Primary bone trabeculae begin to form at the margins of the osteotomized segments ten to fourteen days after the initiation of distraction. And after twenty days, early bone spicules can be observed with the calcification of matrix bound collagen bundles. (c) Consolidation phase. . At this stage the calcification in the distraction gap continues. A stable fixation is important. The average consolidation period is usually 8−12 weeks. (d) Late consolidation period. (e) Bone remodeling and continuity of neurovascular bundle after completion of distraction osteogenesis. Illustrated by Dr. Bashar Shahrure.

distraction on a straight vector; incompetency to reduce the oronasal fistula in cleft patients; and the difficulty in achieving complete hard and soft tissue reconstruction, especially in cases with large alveolar defects. These difficulties have led us to develop Archwise Distraction Appliance (AWDA).

The AWDA method have been developed to obtain a regenerated bone curvilinear in shape, similar to the original alveolar bone configuration. In our contemporary approach this method has several advantages:

- It allows the closure of the defects following the natural arch form.
- Anterior segment can be advanced simultaneously.
- Negative overjet can be corrected in most cases without the need for orthognathic surgery. Therefore, velopharyngeal space and speech are unaffected during advancement.
- Alveolar arch is lengthened.
- Counterclockwise rotation of the transport segments is minimized.
- The size of the alveolar defect is reduced into a small gap that can easily be grafted.
- The newly designed mini distractor is patient friendly with its small dimension and spherical shape.
- The intraoral elements of the appliance are now adapted into the digital workflow and therefore requires less laboratory work and is easier to construct.

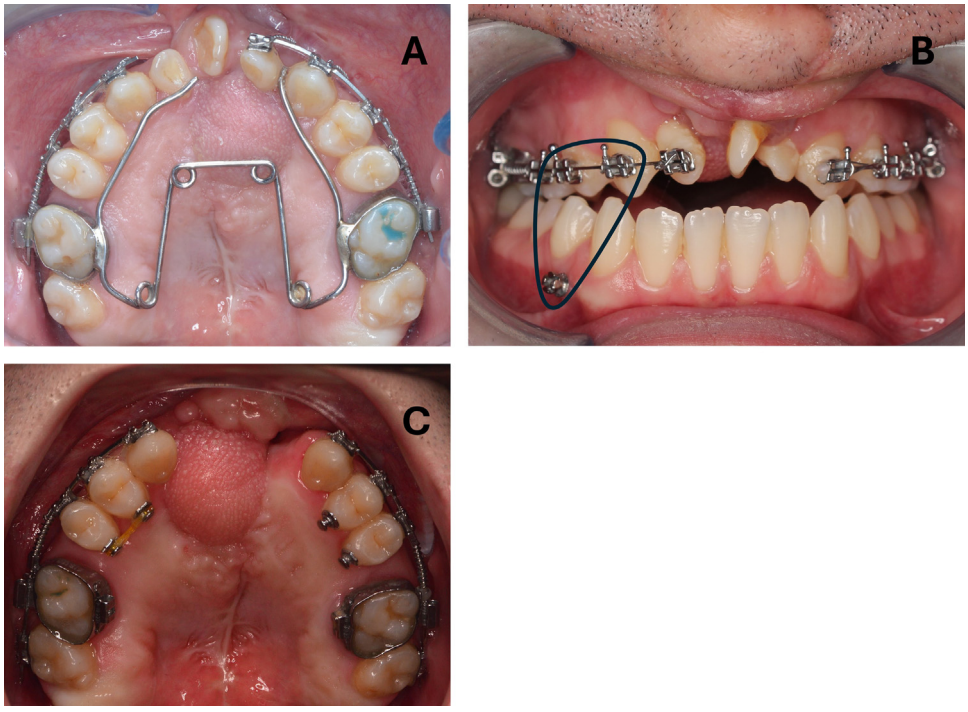

Fig. 2. Orthodontic preparation in 3 planes. A) Transversal correction by expansion with quad-helix; B) Vertical correction of the right upper segment using elastomeric modules (triangular drawing); C) Interdental spaces are prepared for vertical osteotomies.

- The long-term survival of teeth on transport segment has good prognosis. They preserve their vitality during and after DO as long as their roots remain intact during surgery.

The alveolar bone on the direction of distraction is another important factor on prognosis. Sometimes, especially in cleft patients, the teeth adjacent to the cleft defect have only a thin alveolar bone wall on their mesial surface. This thin bone can undergo resorption during distraction and the extraction of the tooth can be necessary due to inadequate bone support at the end of DO. Otherwise, they do not have to be replaced with dental implants or require endodontic treatment. One necessity for endodontic treatment can be for

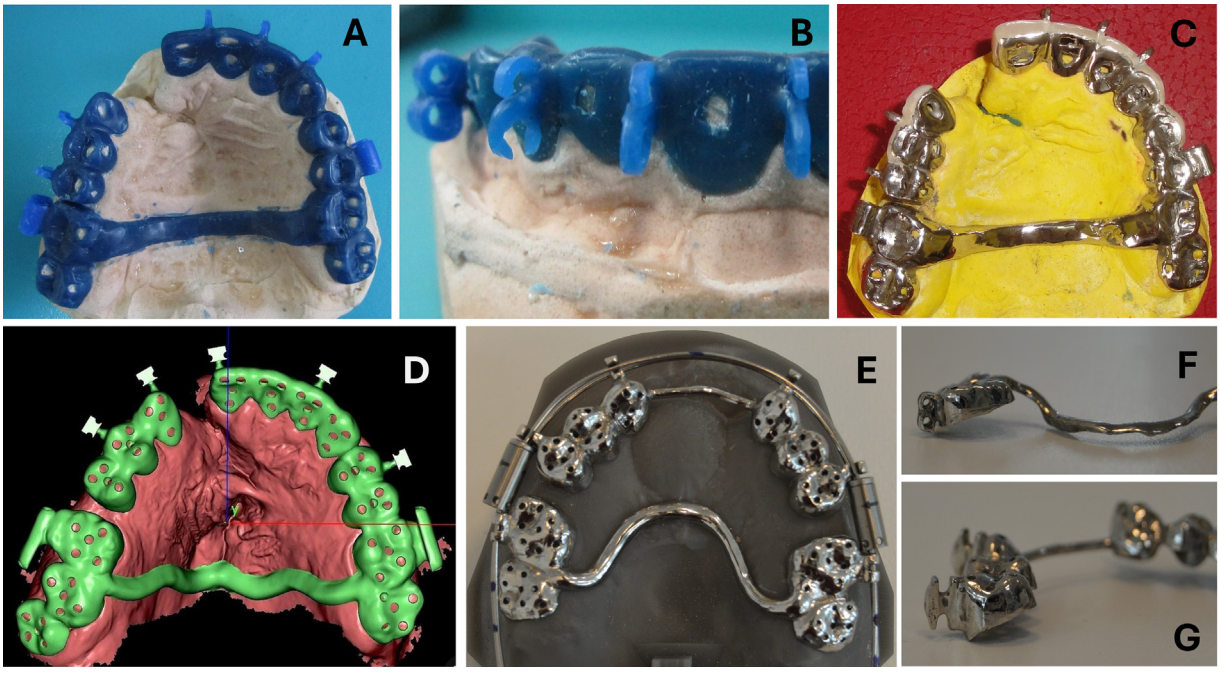

Fig. 3. Preparation stages of AWDA. A-C: Production of the AWDA using conventional laboratory stages; d-G: The contemporary production of the appliance with digital workflow integration. B,F,G: Close up view of the double tubes and the semicircular tubes; D: Digital appliance design; E: AWDA shown with the guiding arch wires and the distractors. Note the anterior bar that connects the transport segments. If anterior distraction is planned, the anterior bar can be kept until anterior movement is completed. Then it can be cut to continue distraction and bring the two segments closer. The marks on the archwire indicate midline, and the distal ends needs to be heated and bent.

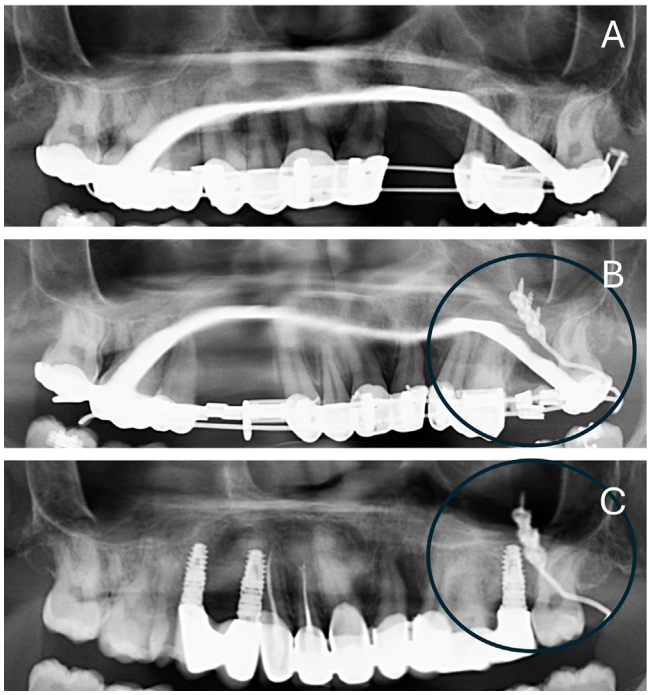

Fig. 4. Reinforcement of the posterior anchorage unit with an infrazygomatic miniplate. A) Upper left second molar as a single unit needs reinforcement. B) Miniplate is placed at the same surgery for DO. The extension arm of miniplate is inserted from the distal into the headgear tube of the molar band. C) It can be seen that the molar axis is unchanged and a possible complication i.e. the distal tipping of the single molar, is prevented.

esthetic reasons during prosthodontic rehabilitation for conversion of posterior teeth into anterior teeth when they are transported mesially to the anterior region.

Pre-distraction orthodontic preparation

For a successful archwise distraction osteogenesis, the orthodontic preparation of the dental arch is important. This phase should include: 1) correction of the transverse and vertical problems, 2) correction of the malalignment, 3) development of the arch form and 4) dental preparation of the osteotomy sites. Moreover, the transport and anchorage segments are determined at the beginning of this stage according to the individual needs of each case (Fig. 2).

In sagittal distractions one (unilateral) or two (bilateral) units of transport segments can be planned according to the size and location of the defect. The transport segment should contain at least two teeth. The

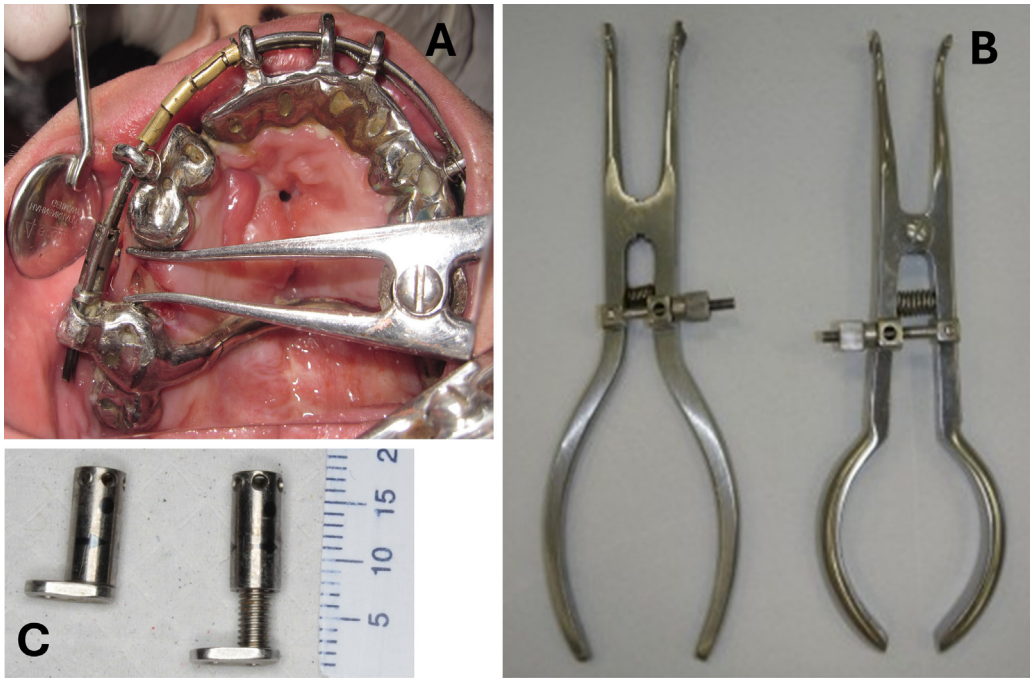

Fig. 5. Mini-distractor and custom-made activation pliers. A) Pliers are used to stabilize the segments and preserve the regenerate while distractors are being closed for reactivation. When distractor is closed, crimpable hooks are placed (preferably distal to the distractor) on the archwire to fix the length. B) The pliers. C) Mini-distractor in closed position and fully opened. Maximum opening capacity of the distractor is 6 mm.

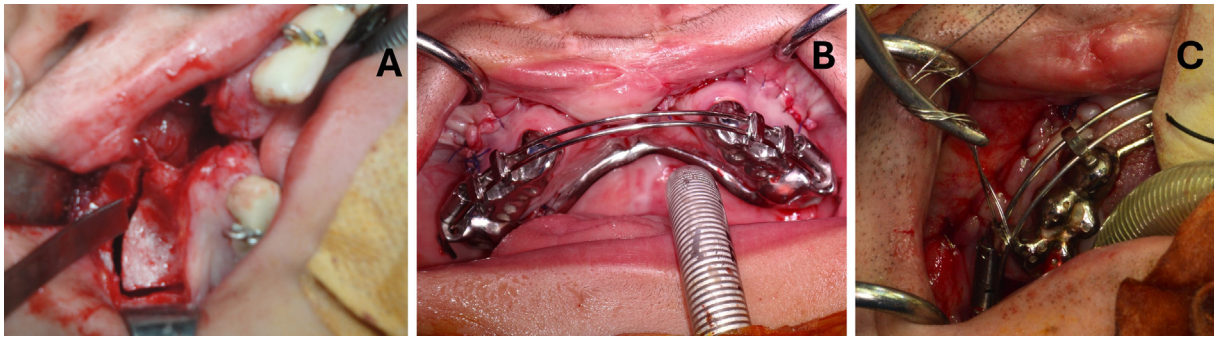

Fig. 6. A) Mucoperiosteal flap is raised, vertical and horizontal osteotomies are made; B) Primary wound closure; C) Distractor and archwires are placed and ligated in the surgery.

anchorage segment should also include enough number of teeth to counteract the distraction forces.

At the planned site of vertical interdental osteotomy, minimum 3−4 mm diastema should be prepared. This gap is necessary because it is advisable to have at least 1−2 mm of bone tissue left on both sides of the osteotomy cut to accommodate callus formation. Moreover, the roots of the teeth mesial and distal to the vertical osteotomy should be deliberately aligned divergently. This will reduce the risk of potential root damage.

When the orthodontic preparation is completed, brackets are removed, and impression or intraoral scan is obtained. To maintain the final positions of the teeth, preferably 2 mm-thick vacuum formed retainer with palatal coverage should be given for full time wear until AWDA appliance is bonded.

Elements of the appliance

- The chromium cobalt crowns with double tubes,
- Two parallel custom-made guiding arch wires and,
- The mini distractor,

constitute the AWDA appliance (Fig. 3). In the upper jaw, a palatal bar is usually placed to reinforce the anchorage by connecting the molar teeth transpalatally. This is especially necessary in complete cleft cases since there is no bone bridge on the palatal vault. Temporary anchorage devices, especially miniplates, can be beneficial to reinforce the anchorage unit in some cases (Fig. 4).

The chromium cobalt crowns with tubes

The chromium cobalt crowns carry the tubes and hooks onto which the two arch wires will be ligated. During the production of crowns, undercuts should be blocked out and the path of insertion should be checked. The crowns should be stable on the dentition without premature contacts on the inner surfaces and they should include drainage holes for the release of excessive cement. These holes will also reduce

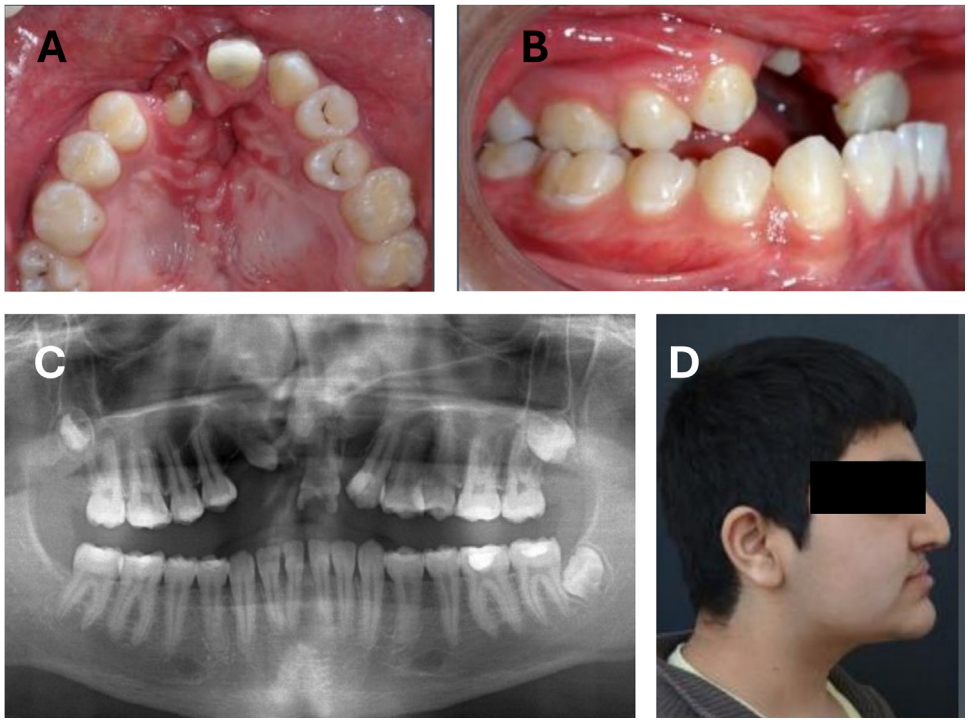

Fig. 7. Pretreatment records of Case 1 (A-D) (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

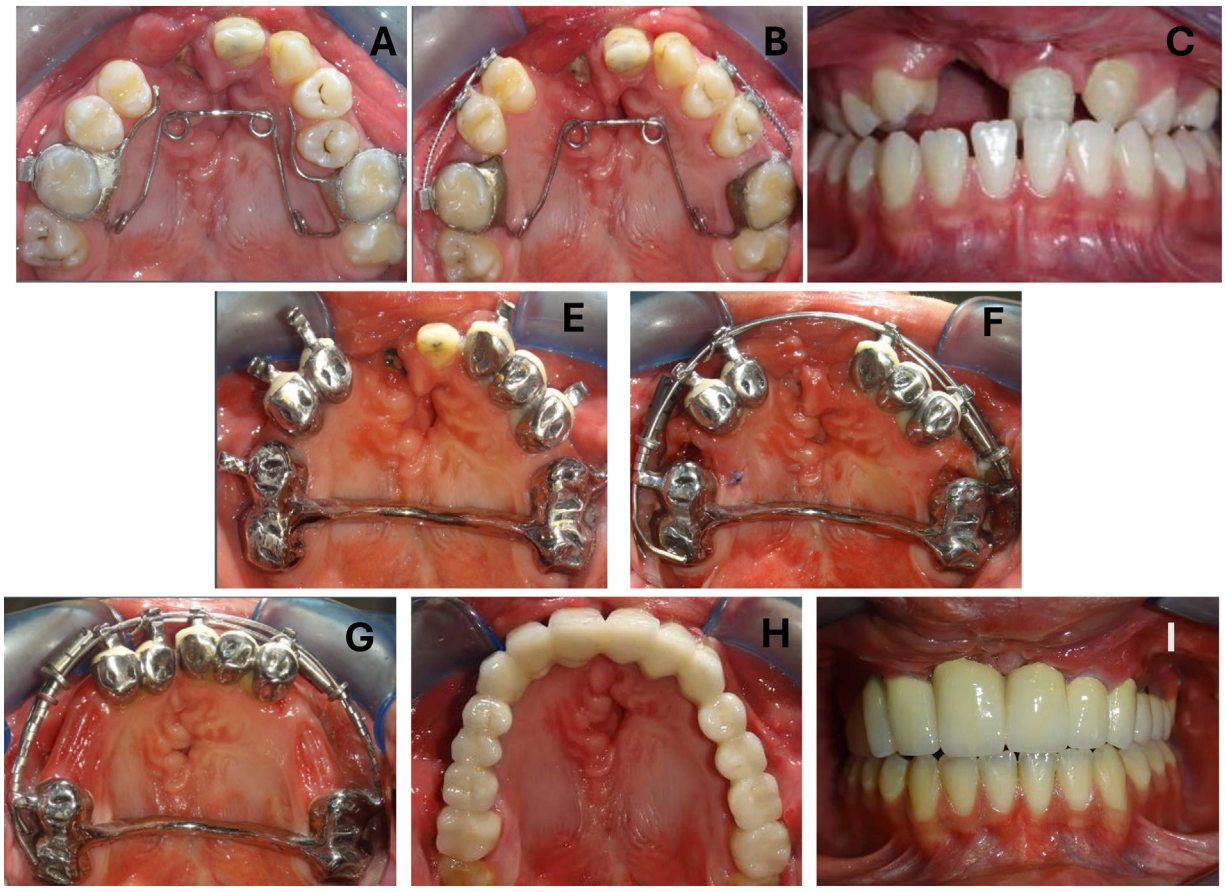

Fig. 8. Treatment progress and finishing with implants and prosthodontic rehabilitation. A,B) Orthodontic preparation; C) Initial anterior intraoral photo; D) AWDA cemented prior to surgery; E) Distraction in progress; F) Consolidation; G,H) Case finished with prosthodontic rehabilitation. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

the resistance of the crowns and be helpful during the debonding of the appliance. These crowns are cemented onto the teeth with glass ionomer cement one or two days before the operation. The crowns of the anchorage segment are produced as one combined unit. Similarly, the crowns of each transport segment are produced as one combined unit.

During the production stage of the crowns, double tubes, and double semicircular tubes (hooks) are placed either manually during wax modelling or digitally during appliance design. (Fig. 3) Their main function is to house the guiding wires on which the distractors are placed. Double tubes are placed bilaterally on the anchorage unit, usually the first molars. They have an inner diameter of 1 mm and a length of 4–5 mm. They should be placed as mesially as possible on the anchor teeth. This will help to prevent tissue impingement on the distal ends of the wires.

The semicircular double tubes are placed on the rest of the dentition according to the needs of the segments. Having these hooks both on the mesial and distal ends of the transport segments will control and decrease the rotational movements. At this point, enough clearance should be left for the distractor placement between the double tube and the semicircular tube at the level of osteotomy.

All the tubes on the appliance should be on the same vertical level to allow easy and straight placement of the arch wires. This should be checked and ensured at the laboratory stage before the final production. The base thickness of the tubes should also be arranged bucco/labio-palatal when necessary, so that the stiff, arch-formed wires can fit passively.

Custom-made guiding arch wires

Two parallel arch wires are prepared after the production of the crowns. They are prepared from 0.9 mm-thick round stainless steel orthodontic wires. The wires are the guiding railways for the transport segment. Therefore, they should be prepared meticulously. They should be 1) parallel to each other in the arch form, 2) flat on the table surface, 3) fitting passively in the tubes, and 4) without plier marks so that the transport segment will slide with minimum friction. If the wire ends need cinch-back, for example to fix the arch length in a case that doesn't need sagittal advancement, they should be heated effectively to become dead-wire for ease of bending. When sagittal advancement of the segment is planned, the distal wire extensions should be prepared longer accordingly.

The archwires and distractor are placed during the surgery after the mobilization of the segments. Then, the arch wires are ligated onto the semicircular tubes and finally distal ends are bent.

The mini distractor

The new design of the distractor (designed by the author Nejat Erverdi; manufactured by Tasarimmed, Istanbul, Turkey) consists of an interlocking telescopic mechanism with an extension, that connects it to the two arch wires and eliminates the risk of inter-rotation of the distractor on the wire. (Fig. 5) The authors recommend placing the distractor on the cervical wire. The device is activated by the patient using a key.

Fig. 9. Extraoral photographs of Case 1. A,B) Pretreatment; C,D) Posttreatment. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

Maximum opening capacity of the distractor is 6 mm but, the distractor can be activated innumerable times with the aid of C-rings. (Fig. 5) The continuous reactivations are performed by closing the device and crimping the C-rings next to the extension end onto the cervical wire to hold the achieved distraction. This design has advantages of eliminating the mucosal irritation and easier activation by the patient.

The surgical procedures

To raise mucoperiostal flap on the labial or buccal side, horizontal incision is made along the mucogingival junction from the distal of the transport segment towards its docking end. The palatal or lingual mucosa must be kept intact to maintain vascularization of the bone segments. (Fig. 6) Following the soft tissue incisions, the guiding wires and the distractor should be placed. Then, the horizontal osteotomy is made 4–5 mm above the root apices and the vertical osteotomy is made to mobilize the transport segment. In most cases, bone irregularities at the docking surfaces of the transport and opposing segments should be removed for maximum contact. To ensure the mobility of transport segment, distractor can be activated 3–4 mm to observe the distraction gap formation and then can be closed to its original position. In case of bilateral transport DO in maxilla, the authors recommend placing mentoplate/ chin-plate at the same surgery. With this approach, counterclockwise rotation of the segments can be prevented by using elastomeric modules between AWDA and the mentoplate.

Docking site surgery is a second surgical intervention that aims for the closure of the remaining soft tissue defects and creating an intact bone bridge with bone grafting. This surgery can be performed during the consolidation phase while the distractor is still in place. According to Liou and Chen, alveolar bone grafting can be performed when the alveolar cleft is wider than 2 mm, whereas gingivoperiosteoplasty is performed when the cleft is less than 2 mm.[16]

Treatment of some complicated cases by Archwise distraction

Cleft palate treatment

Case 1

A 14-year old male patient was admitted to our department. (Figs. 7-9) Patient presented with bilateral complete cleft lip and palate. Lateral cephalometric analysis showed low angle vertical growth pattern, skeletal Class III malocclusion due to maxillary retrognathism, severe negative overjet. In the clinical and radiologic examination, maxillary constriction and a large defect area was observed, the premaxilla did not have a strong bone support and was mobile. There were impacted teeth

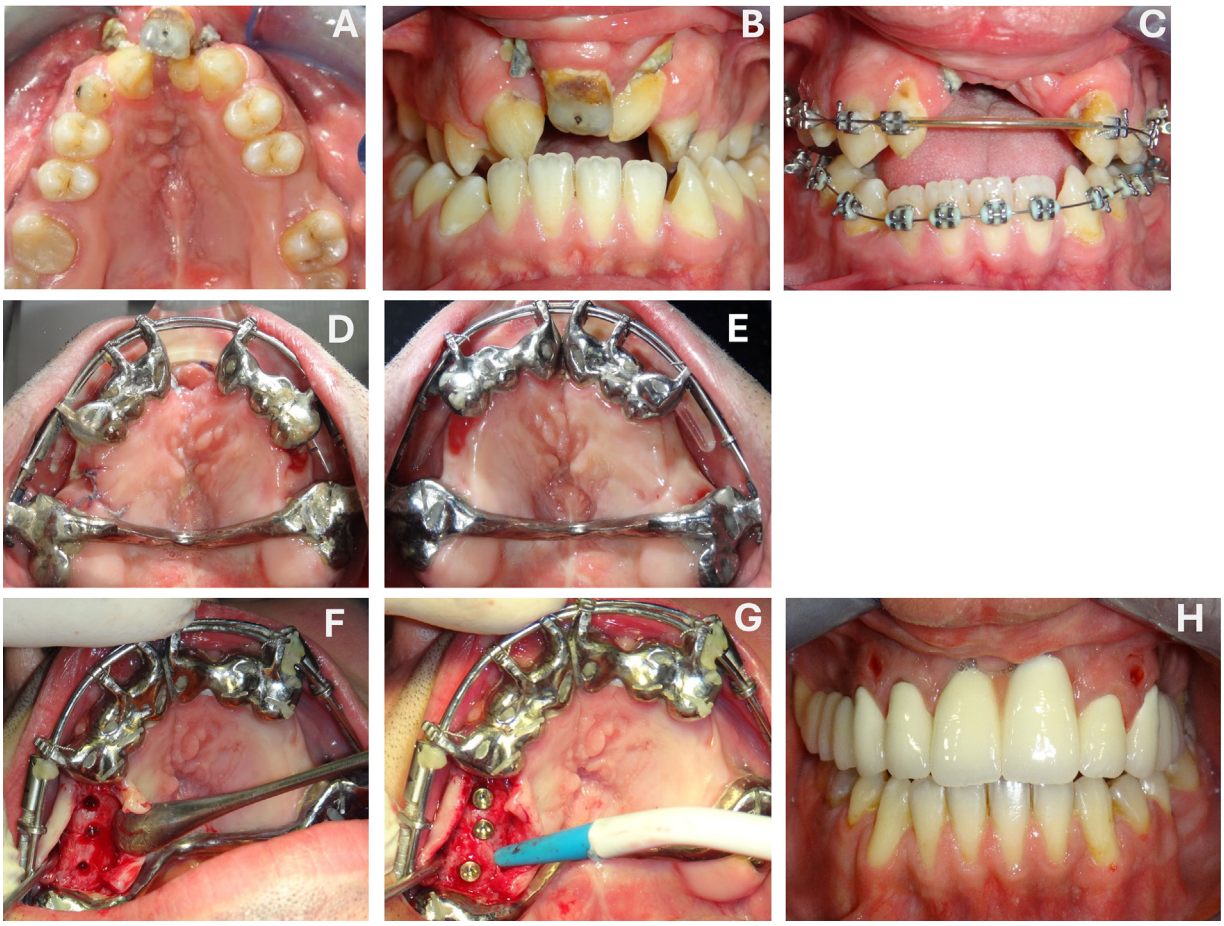

Fig. 10. Intraoral photographs of Case 2. A,B) Pretreatment; C) Orthodontic preparation; D,E) Progress and completion of alveolar transport DO; F,G) The quality of the newly formed bone can be observed during implant surgery; H) Case finished with prosthodontic rehabilitation. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

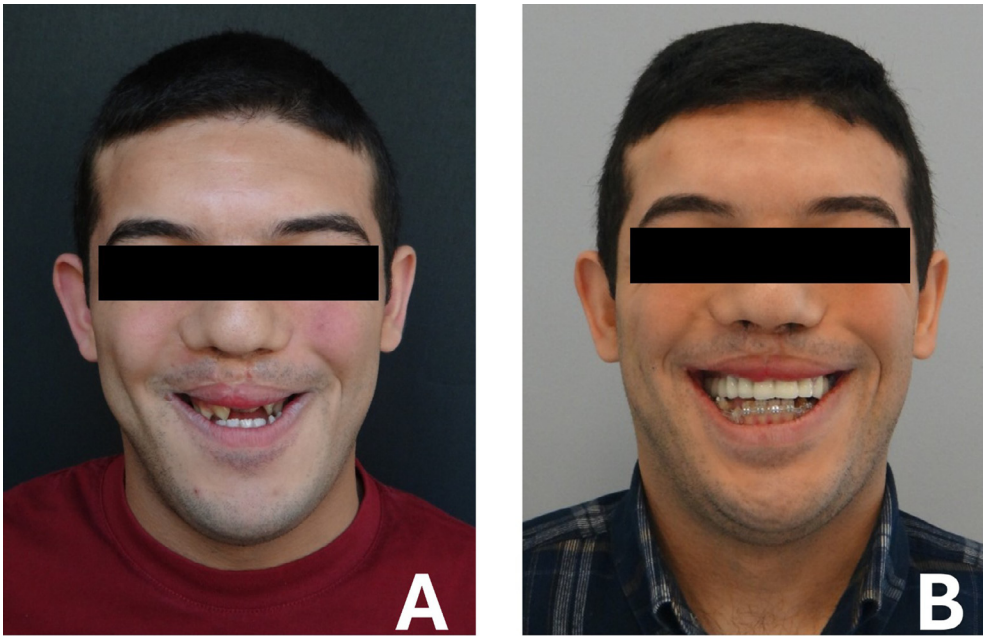

Fig. 11. Extraoral photographs of Case 2. A) Pretreatment; B) Posttreatment. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

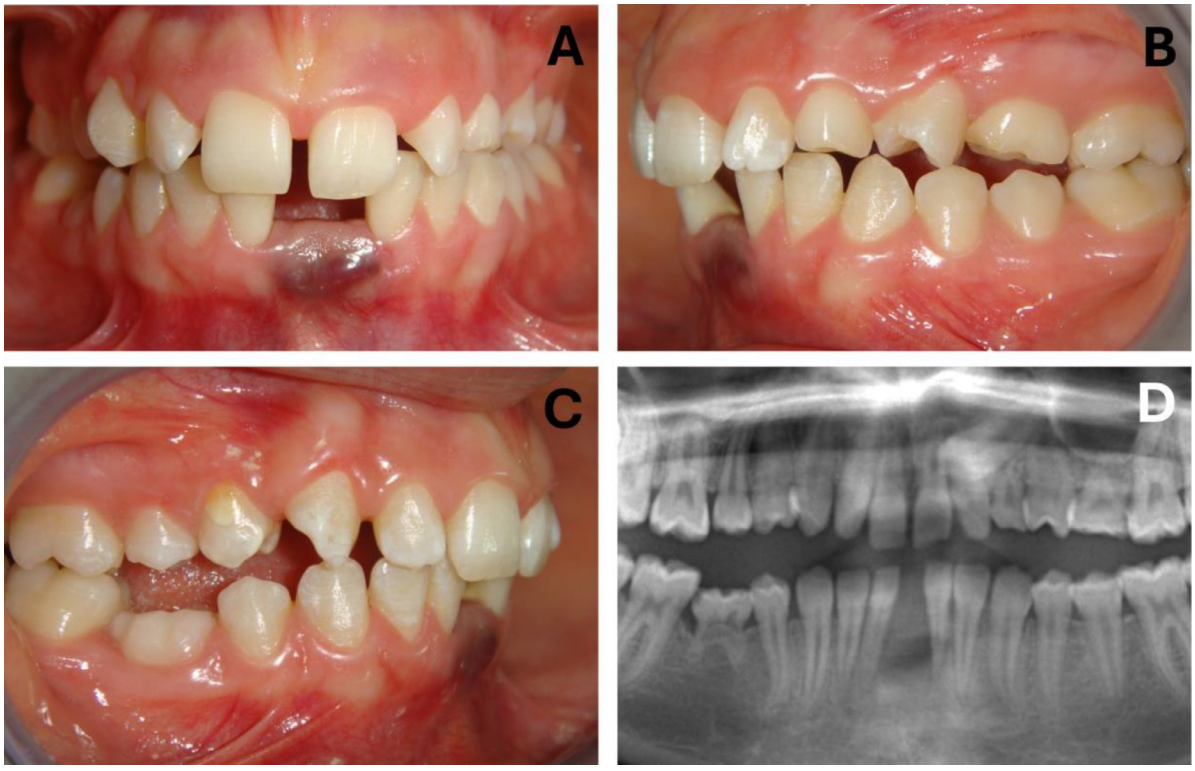

Fig. 12. Pretreatment records. A-C) Intraoral photos; D) Radiographic evaluation showed a radiolucent bowl-like defect at the lower midline. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

in the defect area. Oronasal fistula was present. Archwise alveolar DO was planned.

DO completed successfully and a minimum of 20 mm of space was gained bilaterally with healthy regenerate bone mesial to the anchorage unit, anterior defect area was repaired, and the overjet was corrected. (Fig. 8) Facial esthetics improved significantly. (Fig. 9) The negative overjet and concavity of the profile was treated without orthognathic surgery. The velopharyngeal space and the speech were not disturbed. Patient had adequate incisor display at rest and smile.

Case 2

An 18 year-old male patient presented to our orthodontic department with the chief complaint of bilateral complete cleft and palate. Clinical and radiographic examination revealed skeletal Class III malocclusion

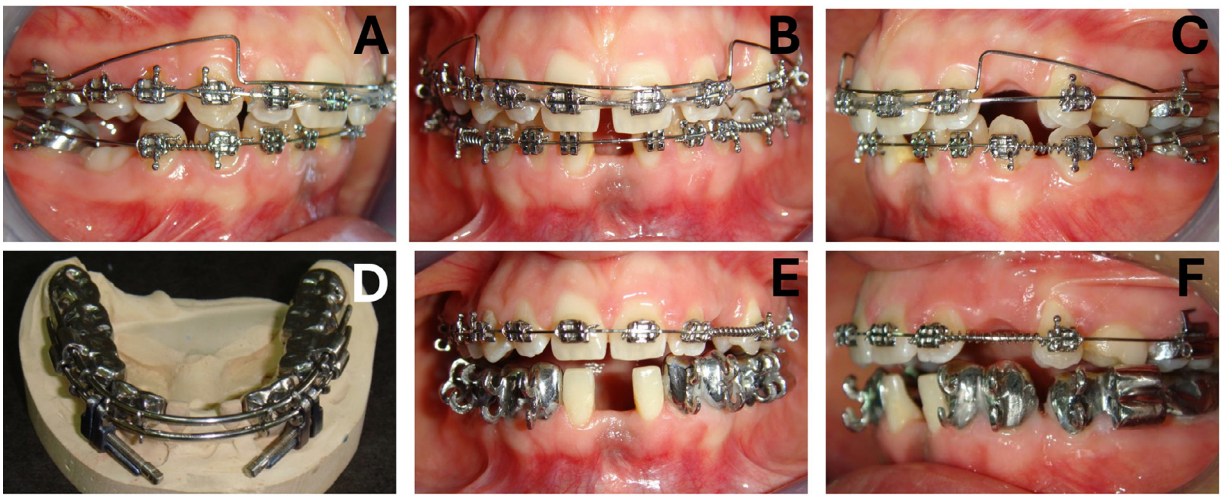

Fig. 13. Progress. A-C) Fixed orthodontic mechanics. D) Metal-cast appliance prepared on stone model; E-F) Appliance is cemented. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

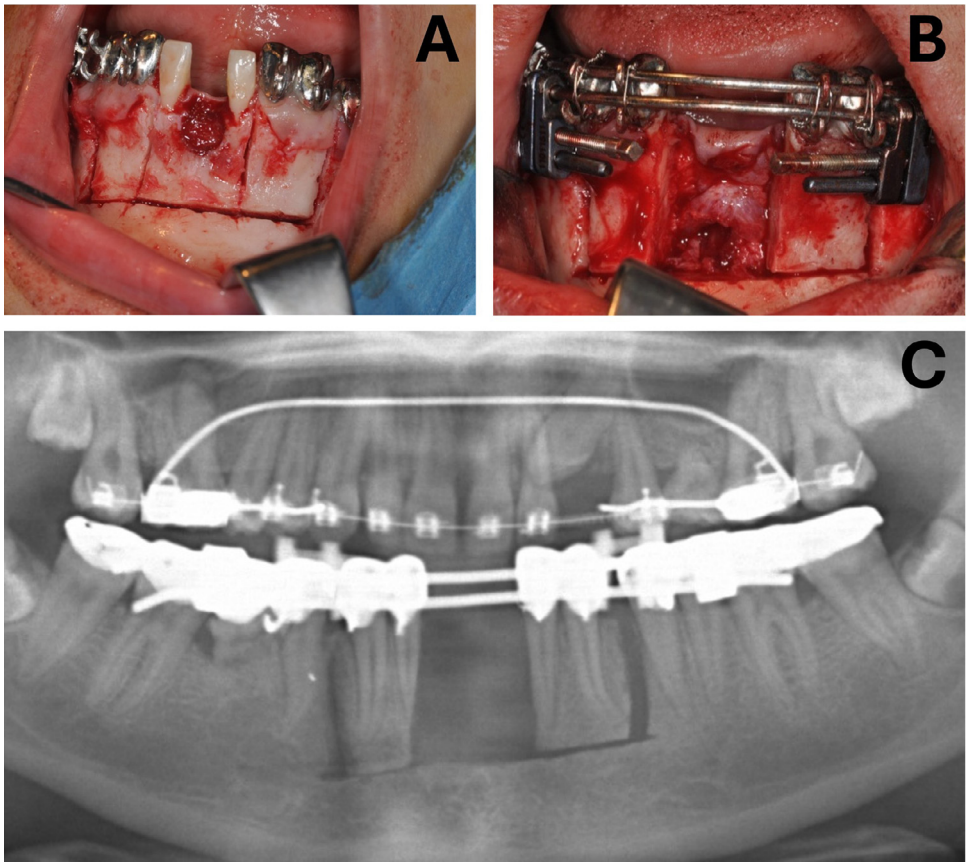

Fig. 14. Surgery stage. A) Before removal of the lesion, horizontal and vertical osteotomies are made; B) Lesion is removed, bilateral transport segments are mobilized, archwires are placed and ligated; C) Panoramic radiograph at latency period. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

due to maxillary hypoplasia and maxillary constriction. The premaxilla was out of the arch, and the incisor teeth had poor prognosis. Patient had no incisor show at rest and smile. (Figs. 10, 11) The treatment plan involved archwise alveolar DO because of the large defect size.

Postoperative period proceeded as in Case 1. Activation was continued bilaterally until the desired amount of premaxillary augmentation, including 30 % overcorrection, was achieved. Three dental implants were placed in the newly regenerated bone on each side. After a 3-month osseointegration period, the patient was referred to a prosthodontist for final restoration. (Figs. 10, 11)

Restoration of huge bony defects

Some pathologic lesions such as tumoral, cystic or inflammatory lesions create defects in the bone. They can require removal of the lesion along with some surrounding healthy tissue. When the defect size is large, it requires a complicated reconstruction treatment and distraction osteogenesis becomes a viable option. The AWDA appliance provides successful results in these cases.

A 19-year-old female patient had a chief complaint of large diastema between the lower central incisors. Clinical examination revealed Class II malocclusion with increased overbite, retained primary maxillary canine and purple discoloration on the gingiva at the site of the diastema. Patient reported a feeling of pressure on the neighboring teeth and a recent increase in diastema. Radiologic examination supported the initial diagnosis of peripheral giant cell granuloma. Treatment plan involved preoperative orthodontic treatment to correct deep bite, and to open interdental spaces for the vertical osteotomies; followed by surgical removal of the lesion, and archwise alveolar DO to repair the resulting gap. (Figs. 12-15)

Restoration of trauma cases

In trauma cases, bone grafting is usually the first treatment option. Distraction osteogenesis is also a reliable method for bone augmentation in case of unsuccessful grafting or large defects. The following case presents an adolescent patient with a history of trauma. (Figs. 16-19) The trauma had caused avulsion of upper left central incisor and other incisor teeth were intruded into the alveolar process. The patient didn't receive immediate treatment after the incidence. Only the incisal edges of the intruded teeth could be seen clinically, and they showed discoloration. A vertical bone defect was observed radiographically, and clinical evaluation revealed 16 mm of probing depth at the deepest region. Considering the vertical and transversal size of the defect, DO with AWDA appliance was the primary treatment option for reconstruction.

Implant site development

Adequate bone height and bone width, along with good cortical bone thickness are important factors for successful and sustainable implant placement. There are various methods for implant site development such as bone grafting, guided bone regeneration, orthodontic extraction of teeth with poor prognosis, and distraction osteogenesis of alveolar bone. Distraction osteogenesis has some advantages: overcorrection of bone height and width, and soft tissue regeneration (distraction histogenesis) can be achieved. Soft tissue regeneration is essential in the restoration of esthetic zone.

Figs. 20-23 present a case where implant site was developed with AWDA. A 24-year-old male patient was presented with an alveolar bone defect in the upper left central regions due to facial trauma. Due to the size of the defect and the history of previous failed attempts of bone

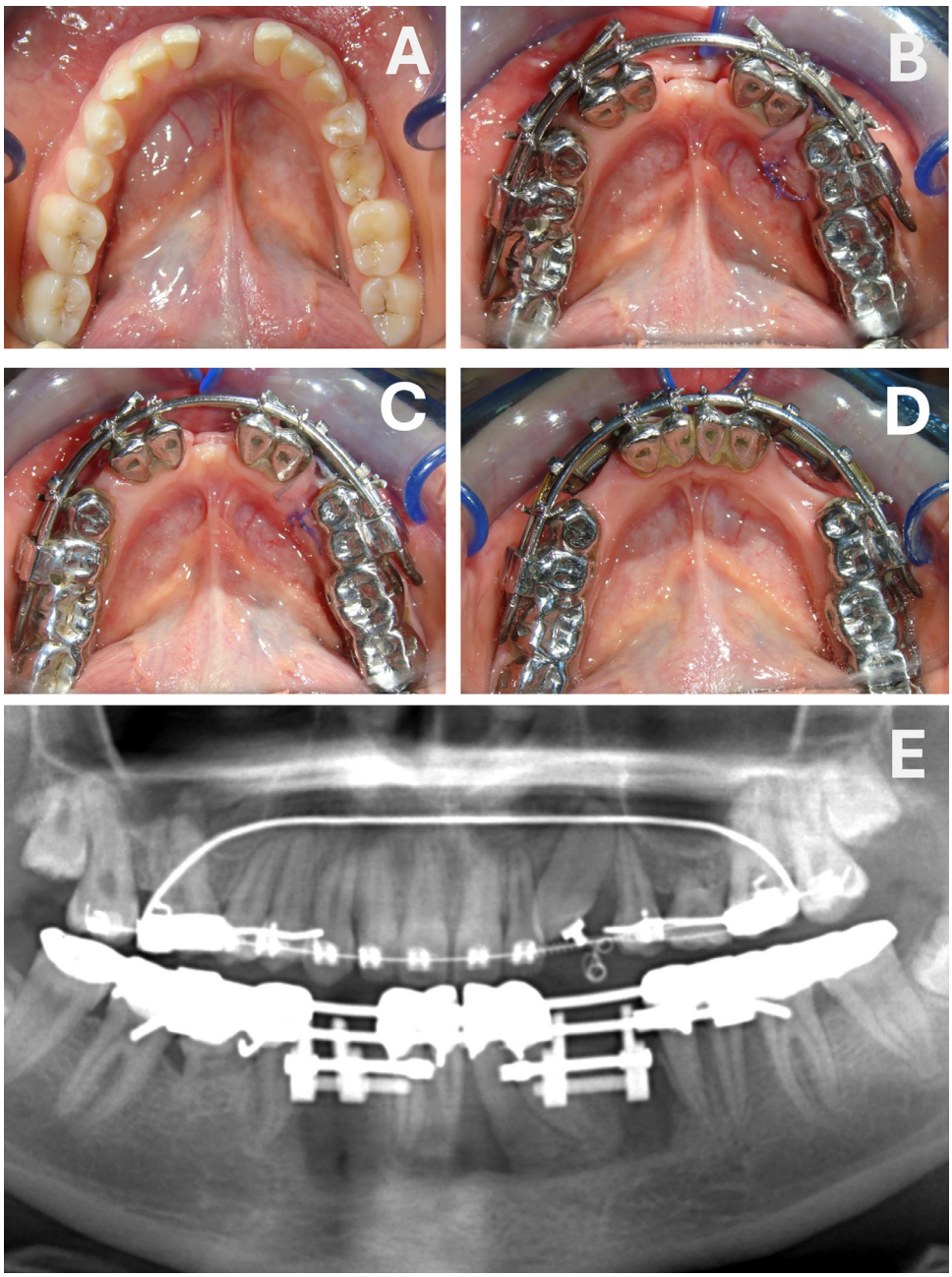

Fig. 15. Stages of the alveolar distraction osteogenesis. Lower occlusal photographs at: A) Pretreatment; B,C) During active distraction; D) Consolidation. E) Panoramic radiograph at the end of active distraction. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

grafting, horizontal transport DO with the AWDA technique was adopted as the primary treatment method.

Possible complications and how to handle them

Loosening of the crowns

In appliance construction, passive insertion and close fitting of the crowns is important. The metal cast crowns must be controlled in the mouth before cementation. Sometimes, reconstruction of the crowns can be necessary. If the crowns provide a perfect and passive fit, they can be cemented with a good-quality glass ionomer cement after periodontal polishing.

When there is a problem in the mechanical and chemical retention of the appliance, the crowns can become loose during activations. (Fig. 24) The rigidity of archwires, mobility of the transport segment and the sensitivity of the callus prevent removal and re-cementation of the crowns.

Proximity of vertical osteotomy to the teeth

Ideally, minimum 2 mm of bone tissue should be present on both mesial and distal sides of the vertical osteotomy. Proximity of the vertical osteotomy to the teeth may cause complications such as root injury and failure of osteogenesis. () When a thin layer of bone tissue is left on the side after the osteotomy, the residual bone wall may not resist the traction forces of the distraction. This can prevent bone regeneration and result in failure of the distraction osteogenesis process. Therefore, the pre-distraction orthodontic preparation is very important. The required interdental space and root divergency should be provided at this stage.

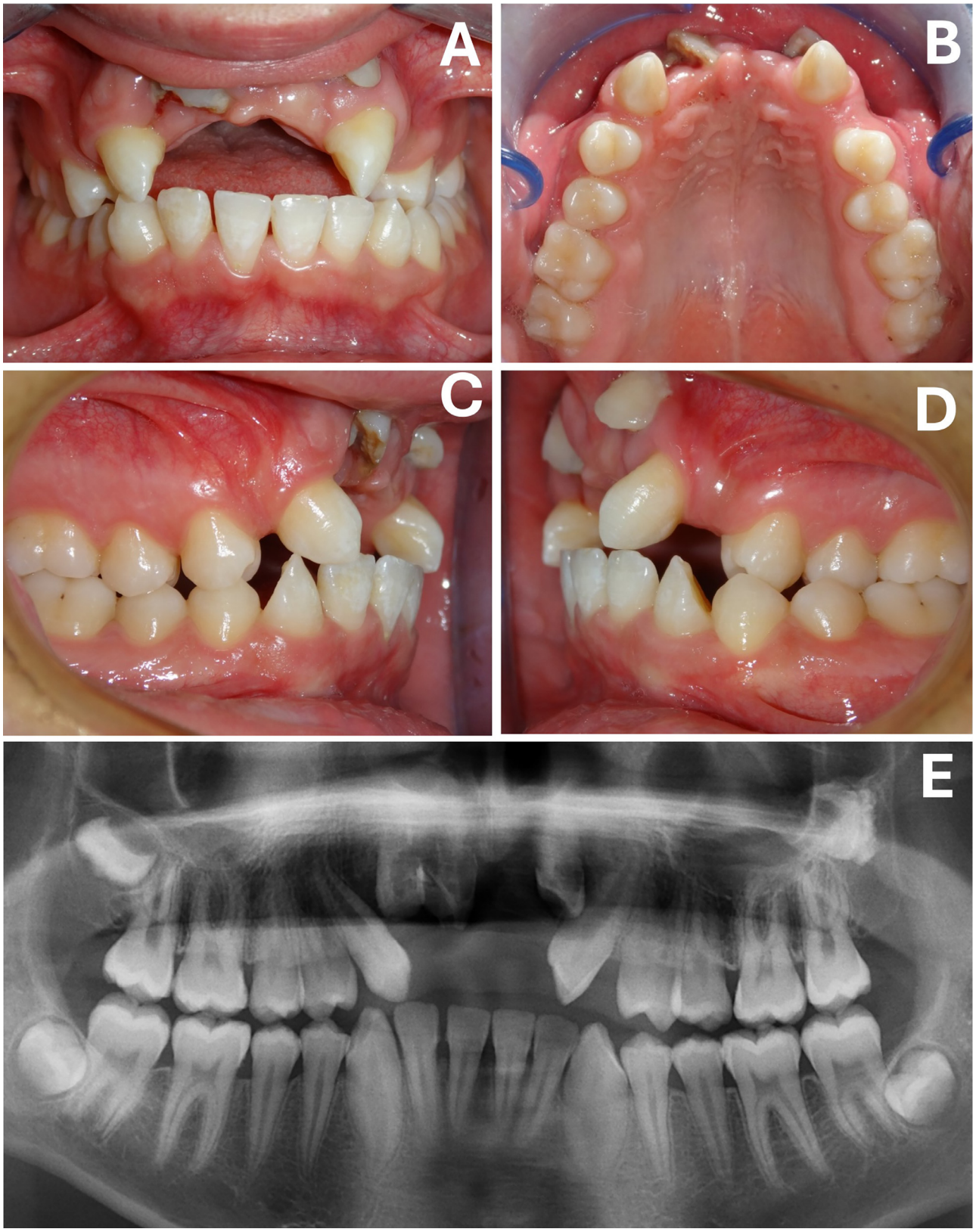

Fig. 16. Pretreatment intraoral (A-D) and radiographic (E) records of the patient showing the large defect and intrusion of incisors. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

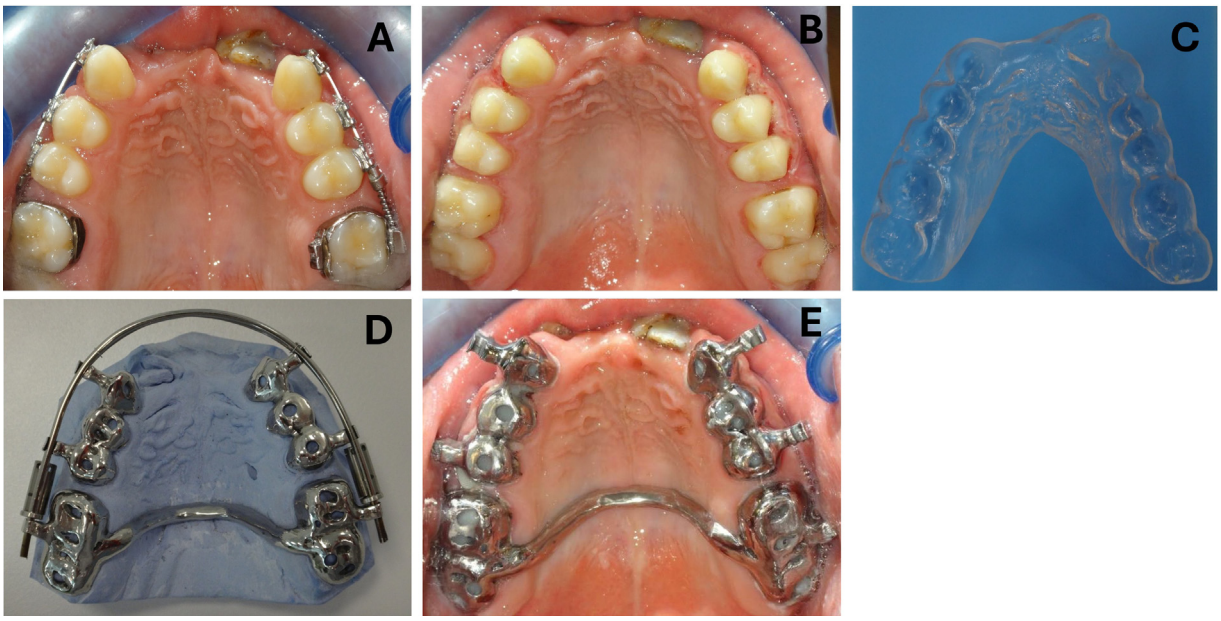

Fig. 17. A) Orthodontic preparation; B) Fixed appliances are removed and impression taken; C) Until AWDA was cemented, patient used 1 mm thick thermoplastic retainer with palatal coverage; D) Appliance is constructed and E) cemented. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

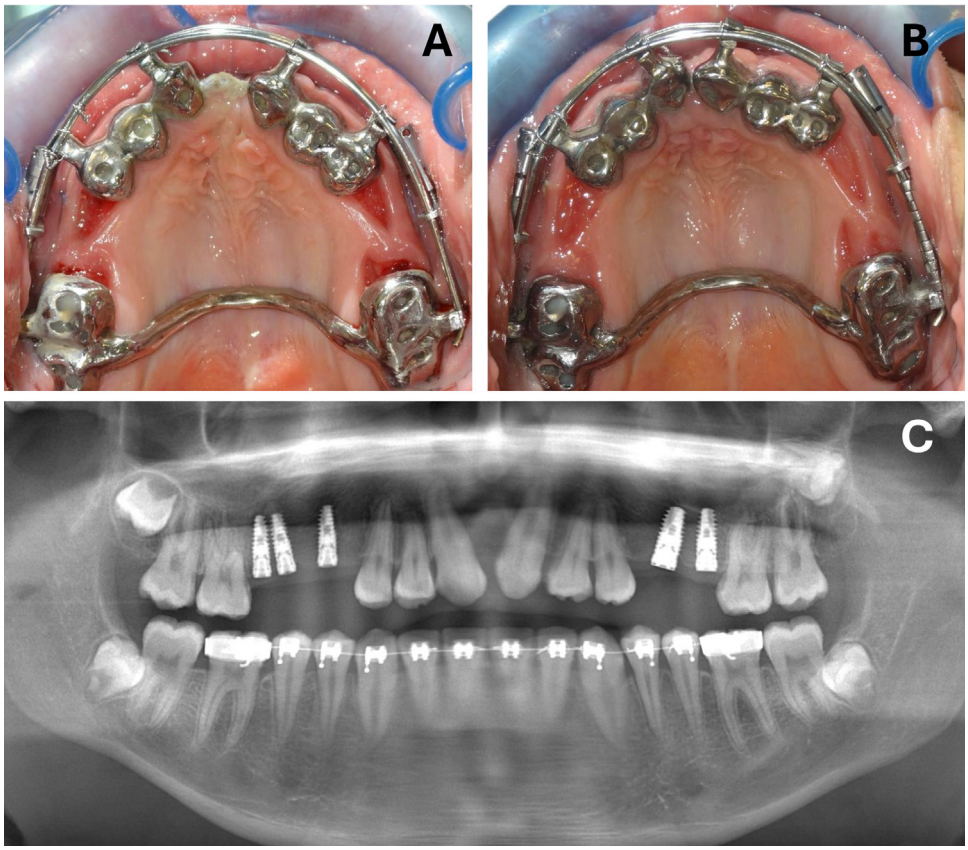

Fig. 18. Progress. A) During active distraction; B) Consolidation; C) Consolidation completed and appliance is debonded. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

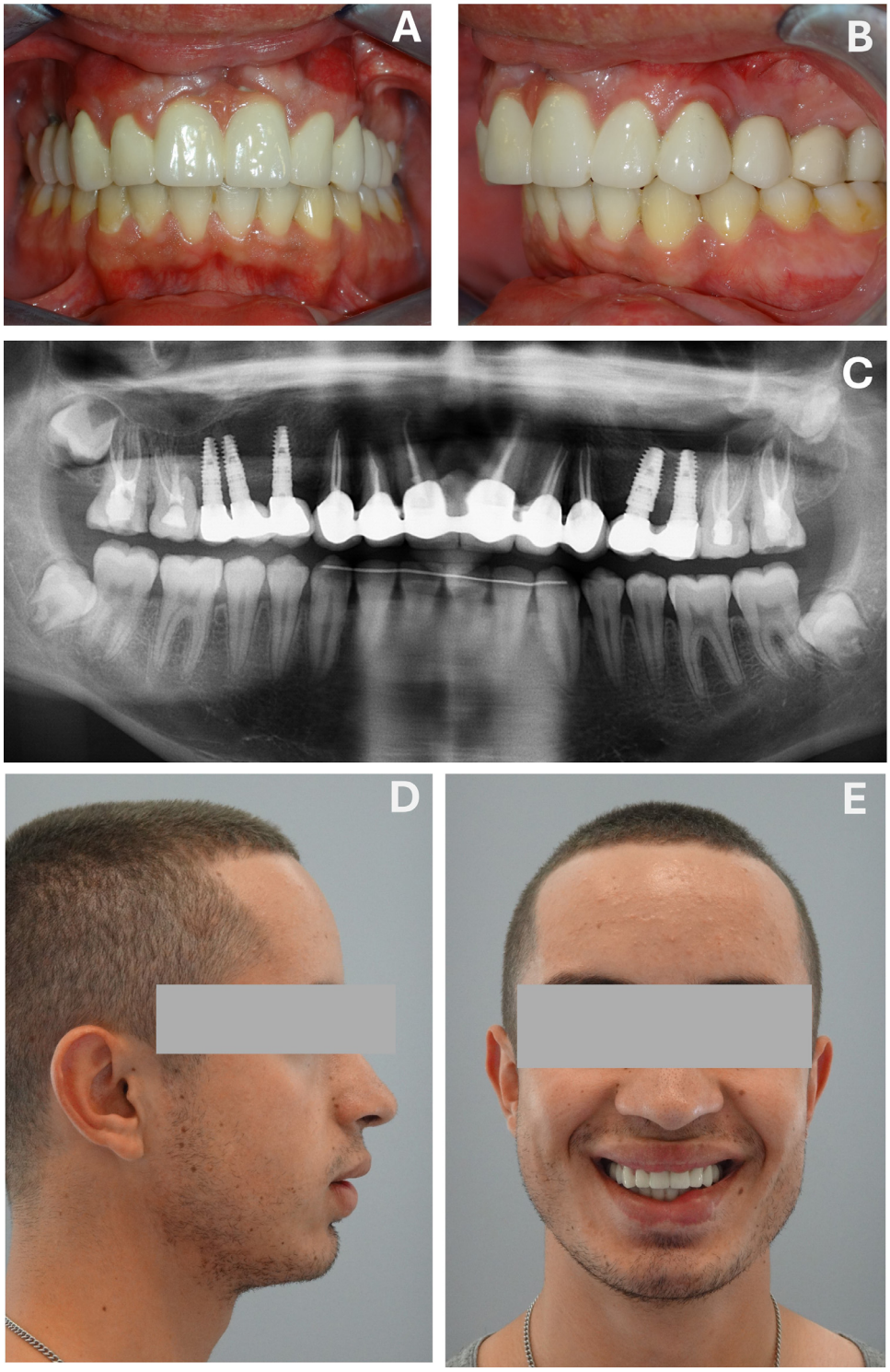

Fig. 19. One year follow-up. A,B) Restorations completed with dental implants (C). D,E) Extraoral esthetics and quality of life are improved significantly.

In Fig. 25, root injury occurred due to proximity of vertical osteotomy to the teeth. In this case, distraction was stopped and reversed on the injured side. Depending on the case, one of the two options can be adopted: 1) one side can be continued to be distracted or 2) a second surgery at a different osteotomy site can be planned after healing.

Iatrogenic root injury during surgery

Iatrogenic root injury is a possible complication during surgery. This complication can be encountered in cases where root morphology has deviations such as long or dilacerated roots; and in cases where the

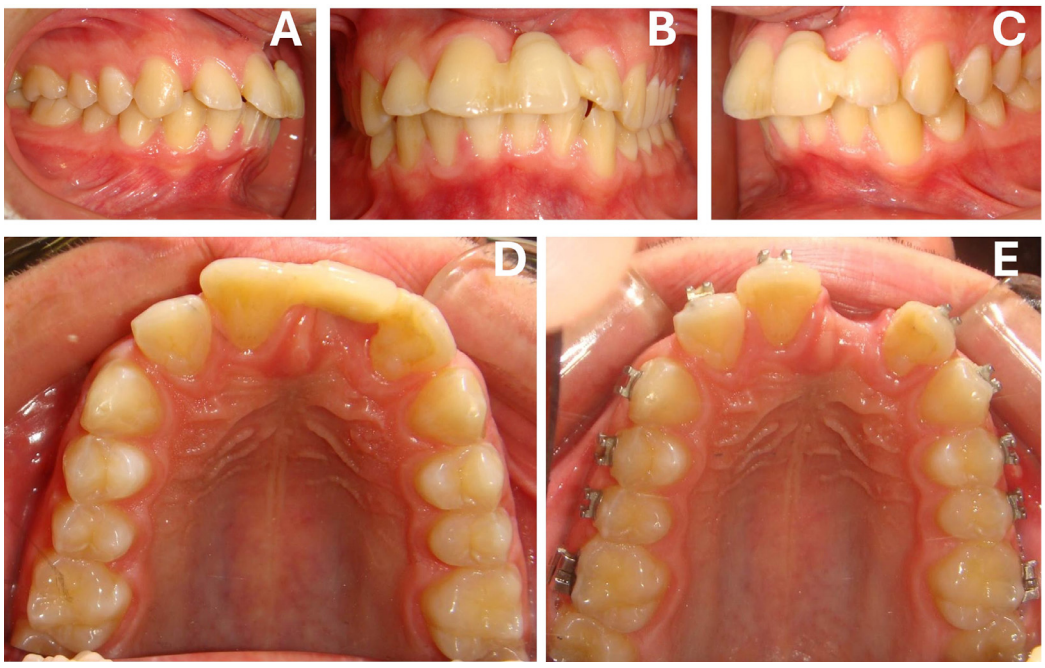

Fig. 20. Intraoral records. A-D) Pretreatment clinical situation with a pontic incisor bonded to adjacent teeth; E) Orthodontic preparation for osteotomy sites. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

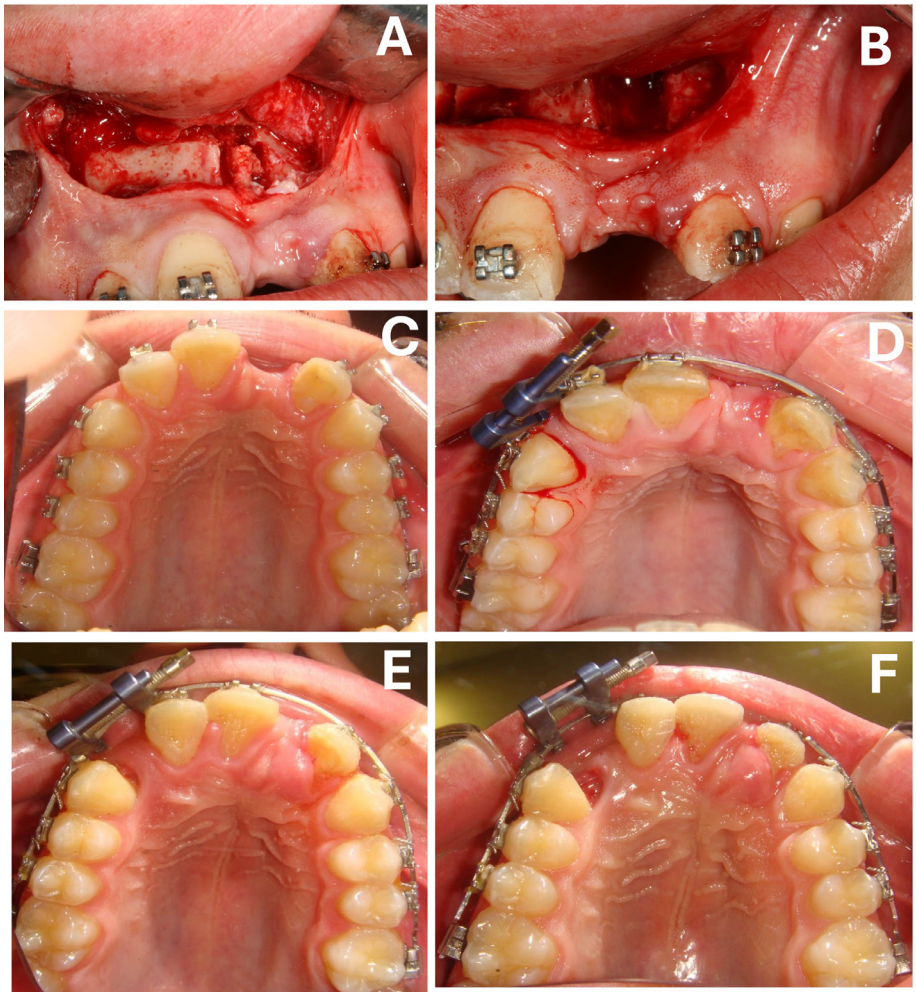

Fig. 21. Progress. A,B) Osteotomies and mobilized transport segment are prepared; C-F) From orthodontic treatment stage through end of distraction. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

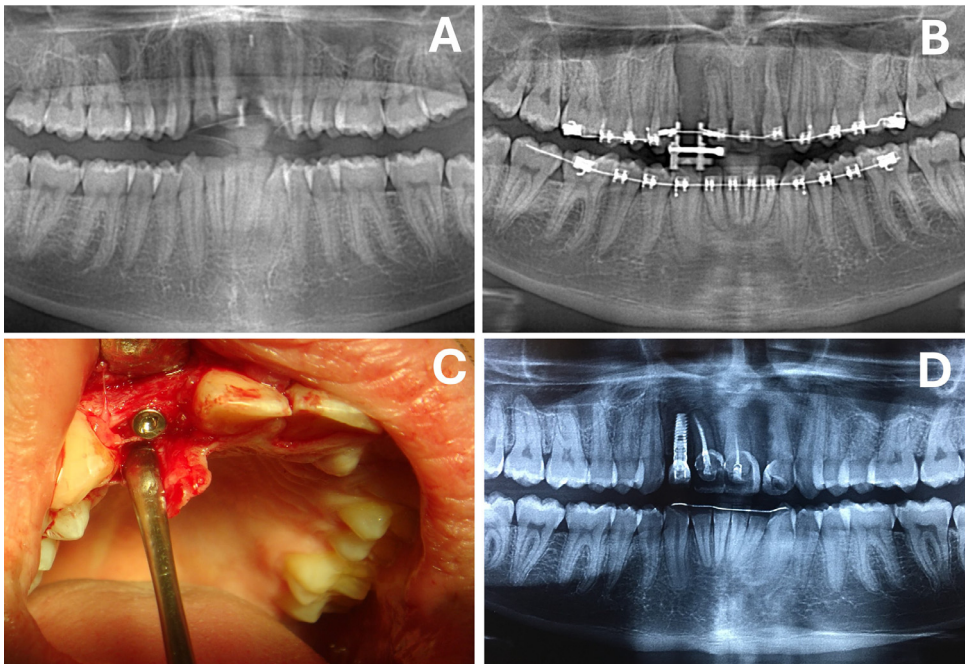

Fig. 22. A) Pretreatment x-ray showing the defect area at the missing incisor area; B) post-distraction panoramic x-ray at the end of 3-months consolidation period; C) New bone regeneration and the fusion of bone on the docking site was noted. Therefore, there was no additional need for bone grafting; D) Dental implant osteointegration was successful and prosthodontic rehabilitation completed. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

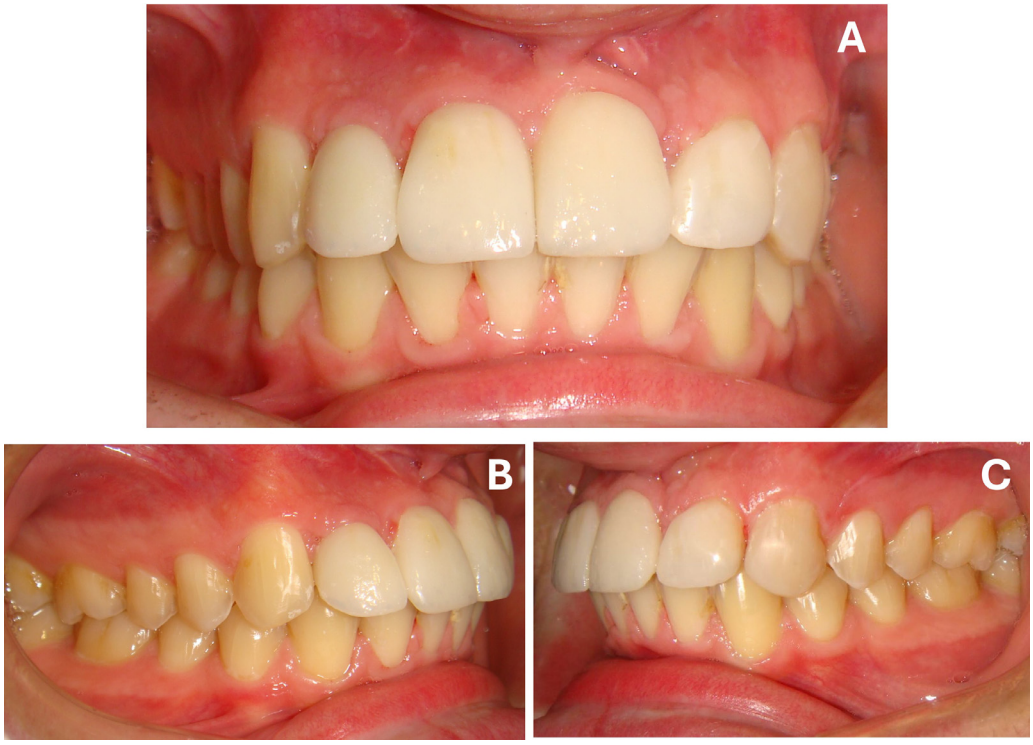

Fig. 23. Finishing. A-C) Dental and gingival esthetics were successfully achieved. (Reproduced with permission from Springer Nature: Erverdi N, Motro M. Alveolar Distraction Osteogenesis. 2nd ed. Cham, Switzerland: Springer Nature; 2020.).

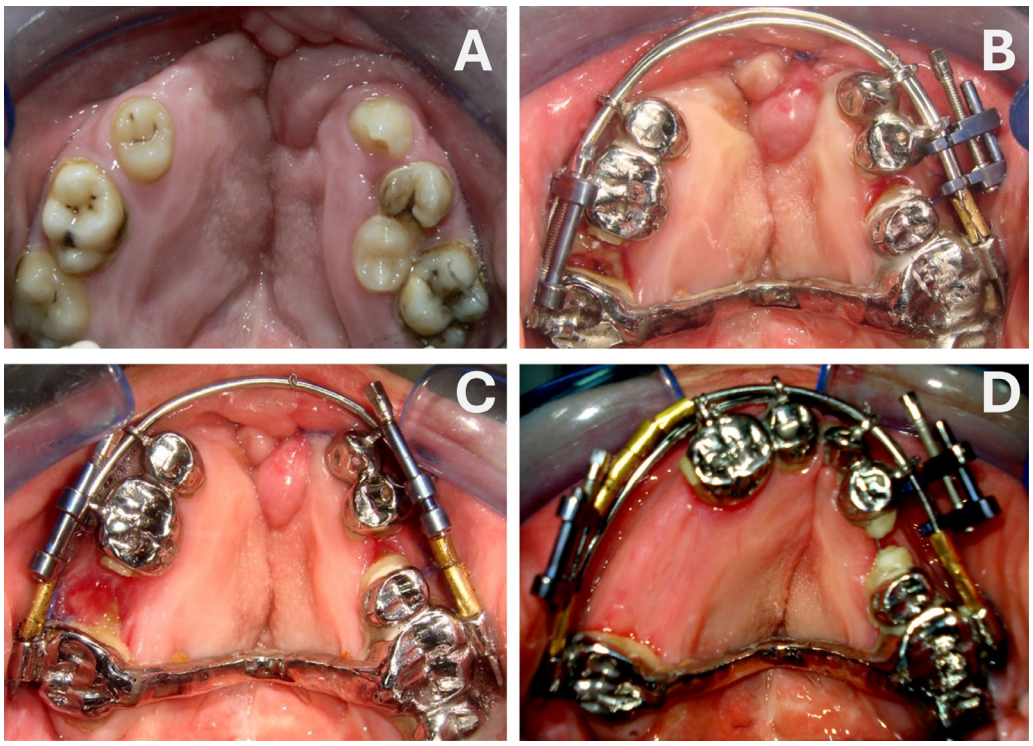

Fig. 24. In this case, the crowns on the left side became loose. at an early stage of active DO. A) Pretreatment; B) The mesial side of left premolar crown can be seen from underneath the metal cast; C) Distraction on left side was stopped and right side continued; D) Arch form was acceptable due to the archwise design of the appliance, the premolars and molar were treated endodontically and converted to incisor teeth with the restorations.

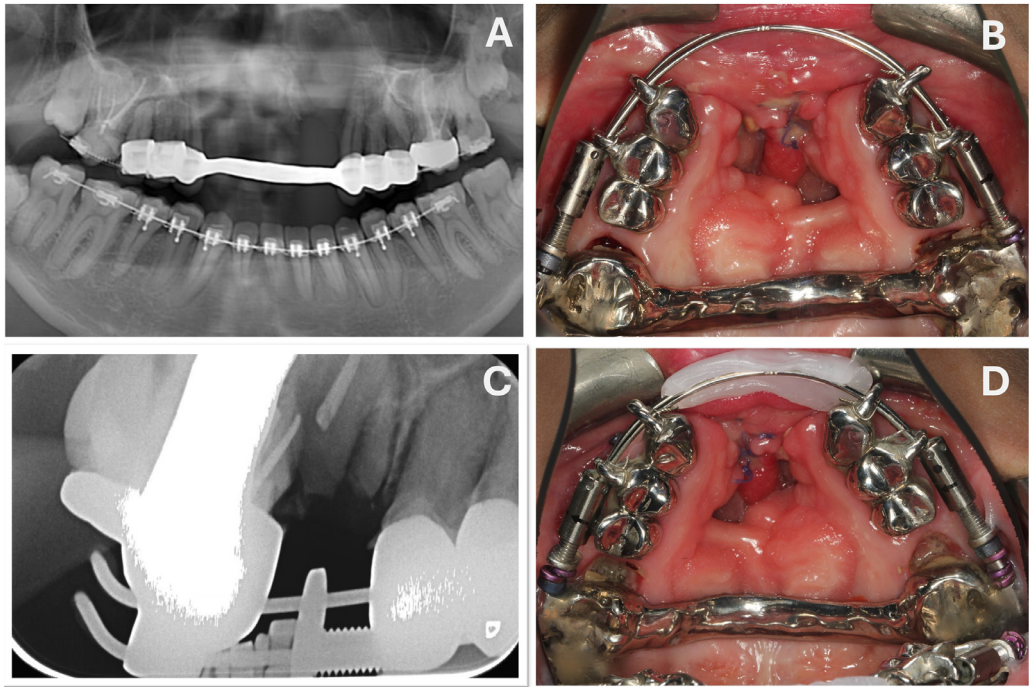

Fig. 25. Root injury due to proximity of vertical osteotomy to the teeth. A) Pretreatment panoramic radiography of the case; B) After surgery, intraoral presentation of the case during DO; C) Periapical radiography showing root injury of the upper right molar during vertical osteotomy; D) DO failed on the right side, root surface could be observed clinically as well in close inspection.

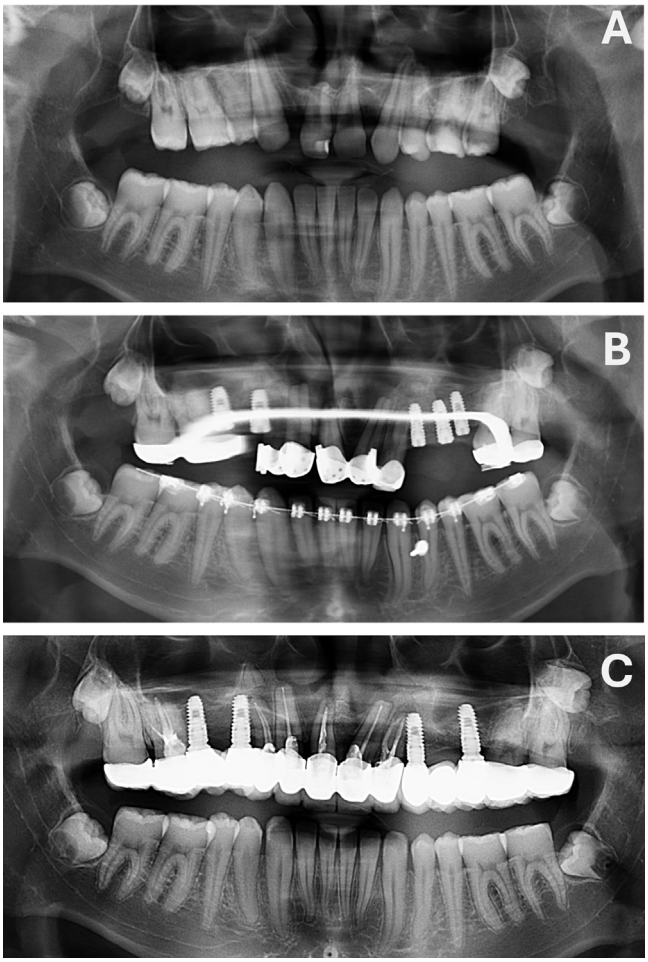

Fig. 26. Iatrogenic root injury Case 1. A) Maxillary canines had long roots that were near the nasal base and extended above the horizontal osteotomy line; B) Root apices of the canines had to be cut intentionally during the operation; Distraction protocol continued and completed without any patient discomfort. C) After removal of the AWDA appliance, teeth were treated endodontically; No adverse effects were observed in the root apices during annual controls.

interdental space and root divergency for vertical osteotomy is limited or inadequate. Therefore, pretreatment radiologic evaluation of the roots by orthodontists and surgeons is important.

Cutting the roots during the horizontal osteotomy does not disturb the formation of regenerate. In cases where root injury is anticipated due to long roots, endodontic treatment can be performed before the surgery. This can prevent complications and patient discomfort that may arise later. (Figs. 26)

However, cutting the roots during vertical osteotomy causes failure of callus formation. (Fig. 27) In such cases, the authors recommend to stop and reverse the distraction so that transport segment returns to original position. After healing, distraction should be planned from another site.

Lack of vector control

Especially in bilateral transport DO in cleft maxilla, the mobile segments tend to rotate counterclockwise (CCW) towards the nasal base during DO. There are two reasons for this tendency: 1) the force is being applied from the distal and below the center of resistance of the transport segment, creating a CCW moment; 2) there is lack of bone support at the nasal base to guide the movement.

In unilateral transport, this complication is hardly an issue because the appliance and the anchorage from the contralateral side provide enough rigidity to counteract the rotational forces. The pretreatment vertical alignment of the alveolar segment adjacent to the cleft area is also a contributing factor. During orthodontic preparation, the vertical position of the segments must be addressed as in Fig. 2.

Current approach of the authors is to place mentoplate at the same surgery with DO when bilateral alveolar transport DO is planned. (Fig. 28) Intermaxillary elastics are applied between the AWDA hooks of transport segment and the hooks of mentoplate. This force vector creates a clockwise moment and prevents the rotation, enabling parallel transport. Figs. 28 and 29 show that the direction of the distraction can be modified during the active phase of DO with the use of elastics from a skeletal anchorage unit. This effect is provided by the molding of the regenerate bone. Minimal dentoalveolar remodeling can also accompany this. Depending on the amount and timing of the vertical modification, intermaxillary elastics can be continued in the consolidation phase for retention.

Exposure of callus

Surgical procedure is an important aspect of the whole distraction osteogenesis process. Piezosurgery can be a practical method. The buccal mucosa must be kept intact except a horizontal incision to raise mucoperiostal flap. Palatal mucosa is completely intact. Vertical incision should not be made. (Fig. 30)

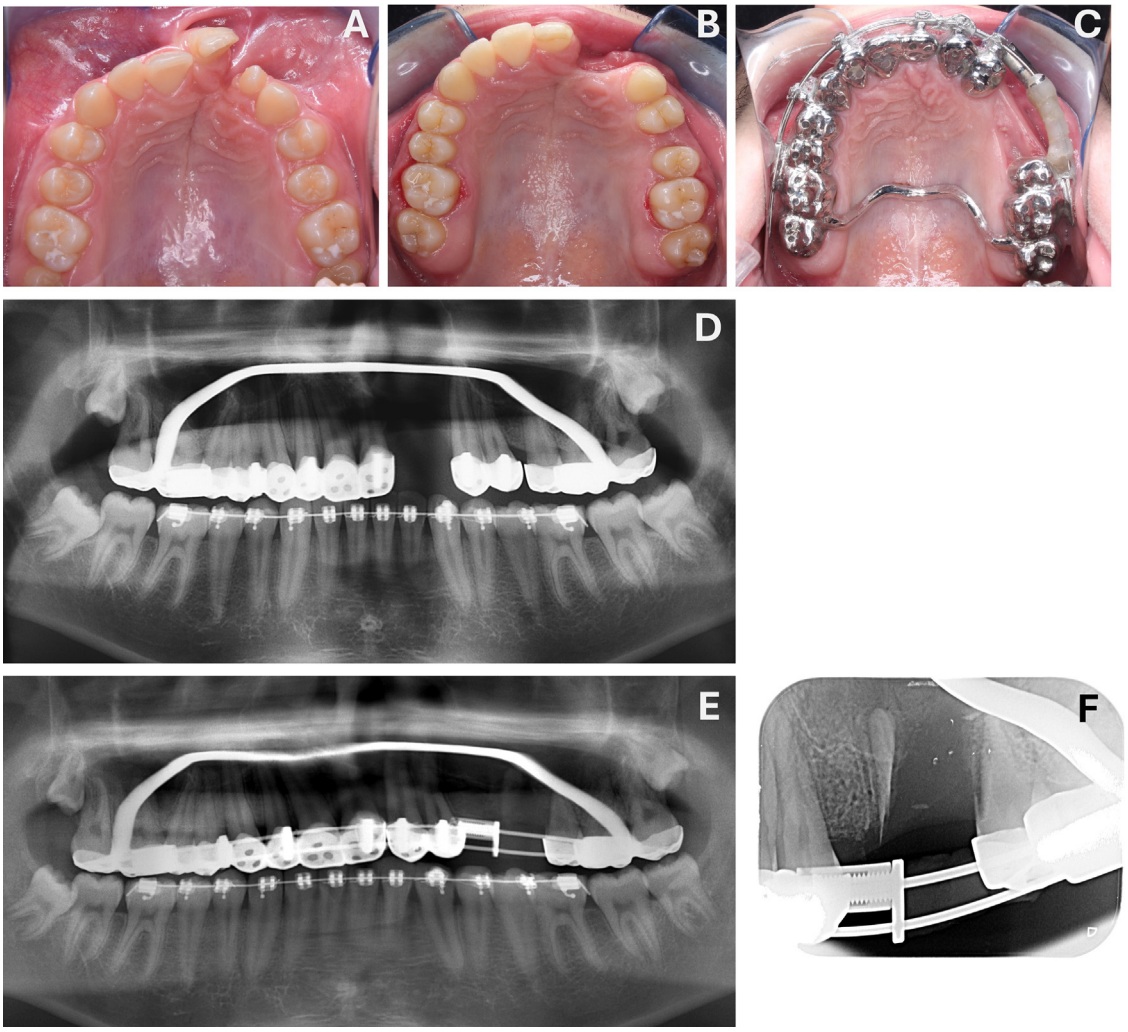

Fig. 27. Iatrogenic root injury Case 2. A,B) Pretreatment records; C) Consolidation phase; D) Pre-surgery x-ray, root divergence was obtained orthodontically between upper left premolars; E) While the vertical osteotomy was made, an iatrogenic injury affected the root of second bicuspid; F) Bone defect can be observed in the area between the anchor unit and the root piece in the periapical radiograph.

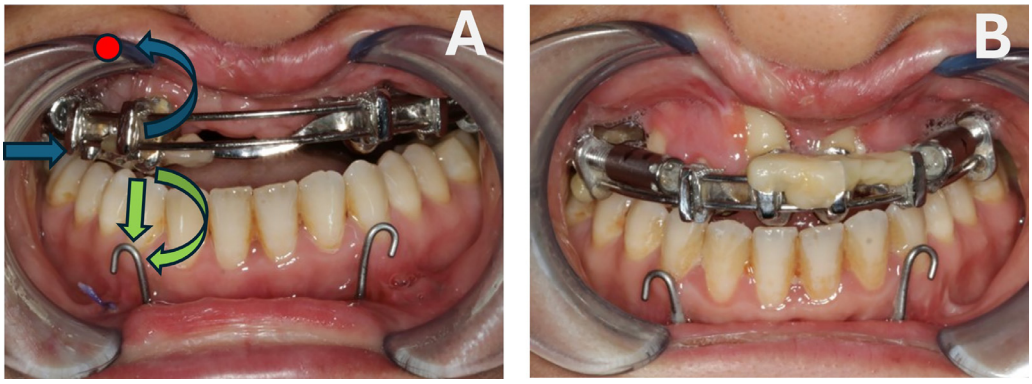

Fig. 28. Improvement of the vertical control during DO using **mentoplate**. A) Red dot: Estimated center of resistance; Blue arrows: force and moment from the distractor; Green arrows: force and moment from the elastics to the mentoplate; B) Bilateral distraction completed without rotation of the transport segments.

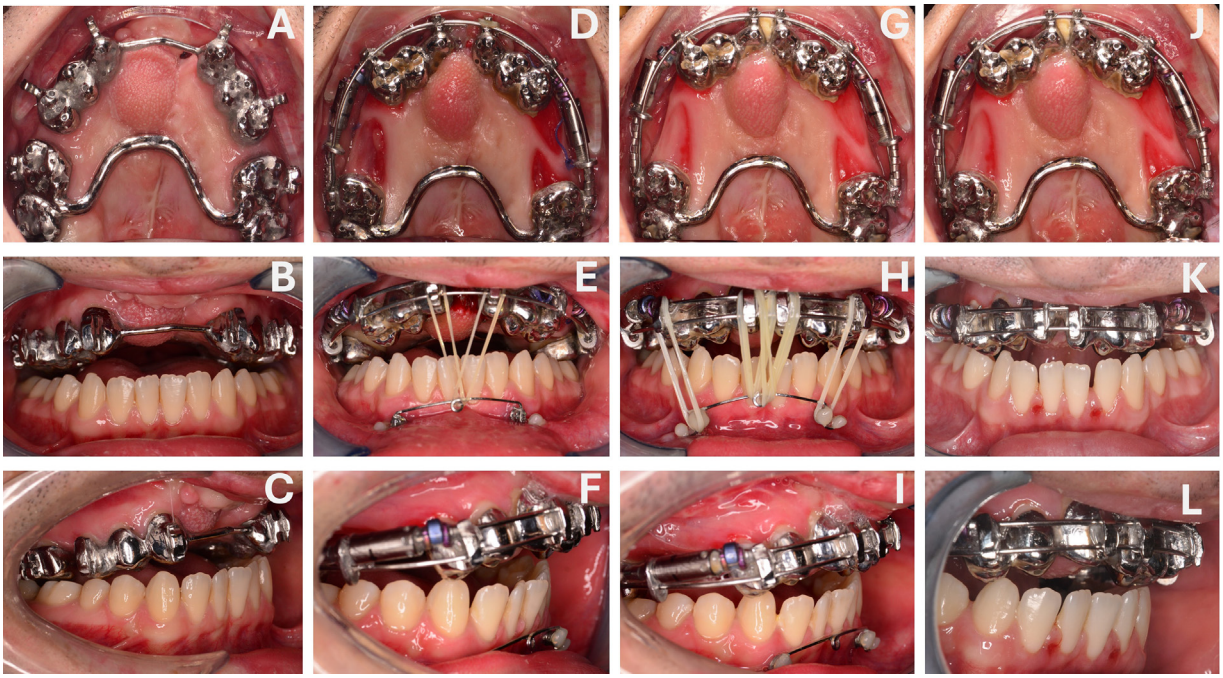

Fig. 29. A-C) Before surgery; d-F) 18 days after surgery. However, note the opening of the bite due to counterclockwise rotation of the segments. Two interradicular miniscrews were placed in the lower anterior region and a stainless steel archwire was bent with a helical loop. Full time elastics were applied. G-I) 4 weeks after miniscrew placement, elastics were increased in the meantime. J-L) 14 weeks after miniscrew placement, elastics were continued as long as possible until the failure of the miniscrews. Bite closure was improved.

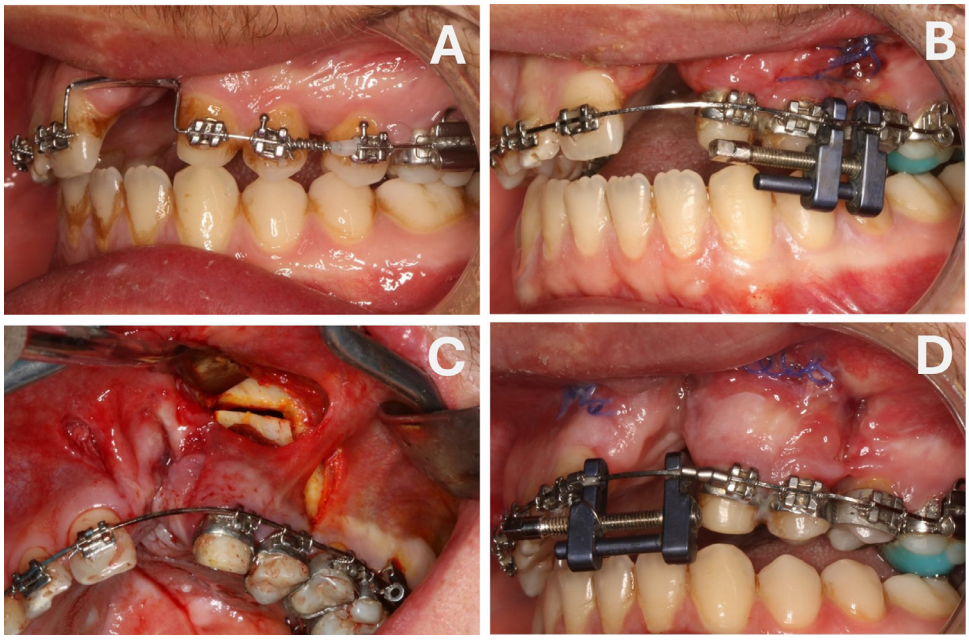

Fig. 30. Exposure of callus. A) Case was prepared orthodontically, vertical osteotomy was planned between the premolars; B) Post-surgery, distraction in progress; In this case, in addition to the horizontal incision, a vertical incision was also made on the buccal mucosa by error. The vertical incision was sutured at the surgery. Activation started after 6 days of latency. C) Sutured surgical incision opened, and wound dehiscence occurred, callus was exposed. D) The distractor was removed and replaced so that the transport segment was reversed back to original position. Wound healing was awaited, and a second surgery was planned for 6 months later.

Conclusions

- ArchWise Distraction Appliance (AWDA) provides successful and stable results in reconstruction of large bone defects that involve both the maxillary and mandibular dentoalveolar structures.
- It provides overcorrection of bone height and width. Soft tissue regeneration (distraction histogenesis) can be achieved simultaneously. This is essential for esthetics in the anterior region.
- Orthodontic treatment planning and preparation is an important stage of the total treatment procedure.
- The possible complications that may occur during the process are presented along with their possible solutions.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Ahmet Nejat Erverdi: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization. **Yasemin Bahar Acar:** Writing – original draft, Resources, Investigation, Formal analysis, Conceptualization. **Banu Mert:** Writing – review & editing, Visualization, Resources, Data curation.

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