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Bimaxillary Protrusion with an Atrophic Alveolar Defect: *Orthodontics, Autogenous Chin-Block Graft, Soft Tissue Augmentation, and an Implant*

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Highlights:

1. Augmented alveolar defects are good sites for implants, but space closure of grafted defects is usually contraindicated.

2. Activated pericytes are osteogenic precursor cells. They can be chemically stimulated by growth factors from the wound area to differentiate into osteoblasts.

3. A thick block of autogenous cortical bone resorbs slowly. It can provide adequate support for an implant, and is more stable for long term resistance to labial recession than vital alveolar bone.

Bimaxillary Protrusion with an Atrophic Alveolar Defect: *Orthodontics, Autogenous Chin-Block Graft, Soft Tissue Augmentation, and an Implant*

Abstract

Bimaxillary protrusion in a 28 yr female was complicated by multiple missing, restoratively compromised or hopeless teeth. The maxillary right central incisor (#8) had a history of avulsion and replantation, that subsequently evolved into generalized external root resorption with Class III mobility and a severe loss of supporting periodontium. This complex malocclusion had a Discrepancy Index (DI) of 21, and 8 additional points were scored for the atrophic dental implant site (#8). The comprehensive treatment plan was extraction of four teeth (# 5, 8, 12 & 30), orthodontic closure of all space except for the future implant site (#8), augmentation of the alveolar defect with a autogenous chin- block graft, enhancement of the gingival biotype with a connective tissue graft, and an implant-supported prosthesis. Orthodontists must understand the limitations of bone grafts. Augmented alveolar defects are slow to completely turn over to living bone, so they are usually good sites for implants, but respond poorly to orthodontic space closure. However, postsurgical orthodontics treatment is often indicated to optimally finish the esthetic zone prior to placing the final prosthesis. The latter was effectively performed for the present patient resulting in a total treatment time of ~36 months for comprehensive, interdisciplinary care. An excellent functional and esthetic result was achieved, as documented by a Cast-Radiograph Evaluation (CRE) score of 21 and a Pink & White dental esthetics score of 2.

Introduction

Orthodontists require a broad interactive knowledge of interdisciplinary care to manage partially edentulous malocclusions, and may be the appropriate clinician to head the interdisciplinary team. Failing teeth and alveolar defects in the maxillary esthetic zone are particularly challenging diagnostic problems.[1-5] One of the more perplexing challenges is subsequent orthodontic treatment of teeth with a history of trauma. Theses teeth may fail before, during or after orthodontics. A history of incisor avulsion and replantation is often associated with a compromised long-term prognosis.[6-7] The consequences of tooth avulsion are directly related to the severity of the injury, surface area of the inflamed root surface, damaged root surface that must be repaired, and the treatment rendered at the time of injury.[1] Donaldson and Kinirons[2] found that periodontal ligament (PDL) “dry time” is the most crucial clinical factor associated with the development of subsequent root resorption. If the PDL is left attached to the root surface does not dry out for longer than 15 minutes, the probability of severe root resorption is minimal. Appropriate pulp therapy can also minimize or prevent inflammatory root resorption. Kinirons et al.[3,4] suggest that a replanted teeth with a closed apex should be endodontically treated, as soon as the tooth has achieved adequate stability, ideally within 10 days after the trauma. When pulp extirpation is delayed more than 20 days, the incidence of inflammatory resorption increases.[4] For a tooth with a wide open apex, endodontic treatment may be delayed because revascularization of the pulp is possible, but the patient should be carefully followed for inflammatory resorption.[5]

Despite advances in managing traumatically avulsed teeth, severe cervical and root resorption is common, with a reported prevalence of 57-80%.[2,6,7] Extensive resorption can compromise not only the tooth but also its supporting periodontium. This current case report presents a 28 yr female with a chief complaint of poor esthetics and function, related to a hopeless (previously avulsed and replanted) maxillary central incisor, missing or compromised mandibular first molars, and bimaxillary protrusion (Fig 1). Prescribing and performing appropriate interdisciplinary treatment required the orthodontist to have a thorough knowledge of all aspects of the necessary interdisciplinary care, as well as the relevant basic science. Because of the dynamic nature of the interactive treatment required, an orthodontist led the interdisciplinary team.

Diagnosis and Etiology

A 28-year-old female sought consultation for a mutilated bimaxillary protrusion complicated by a failing maxillary right central incisor (#8) with a severe labial cleft and Class III mobility (Fig 2). There was an etiology of trauma at about nine years of age when the tooth was avulsed and replanted. This is common but highly variable problem affecting up to 16% of children.[1-7] The patient reported that the replanted tooth healed uneventfully, but there was no follow-up pulp evaluation. Tooth #8 remained asymptomatic until mobility was first noted about 5 years previously (Age 23). Mobility and soft tissue recession have progressively increased since that time.

Clinical and radiographic evaluation of tooth #8 revealed extensive external root resorption (>80% of the root surface), enlarged pulp chamber, and a severe loss of periodontal support (Fig 2). In the mandibular arch, the right first molar (#19) was missing, #18 was mesially tipped, the left first molar (#30) was endodontically treated, and the latter was temporarily restored with amalgam (Fig 1). Pre-treatment study casts revealed the patient had an excessive overjet of ~4mm and space deficiency in the upper arch of ~5mm (Fig 3). Pretreatment cephalometric analysis was consistent with a Class I skeletal pattern, convex profile, bimaxillary protrusion, and excessive axial inclination of upper and lower incisors (Fig 4, Table1). The panoramic radiograph showed that all third molars were present and fully erupted (Fig. 5). The American Board of Orthodontics (ABO) Discrepancy Index (DI)[8] was 21 points as shown in the subsequent worksheet 1. The compromised implant site (#8) scored an additional 8 points for complexity (see form below in worksheet 1). Overall, this mutilated malocclusion (Fig. 1-3) was a severe problem requiring a carefully sequenced, interdisciplinary approach.

Treatment Objectives

1. Maintain the dimensions in all three skeletal planes for both the maxilla and mandible.

2. Extract both maxillary first premolars (#5 and 12), hopeless #8, and compromised #30.

3. Full fixed orthodontics therapy to relieve crowding, retract anterior segments to correct bimaxillary protrusion, and close all space except the #8 implant site.

4. Surgically repair the atrophic #8 alveolar defect with an autogenous chin-block graft, and correct the thin gingival biotype with connective tissue grafts.
5. Implant-supported prosthesis to restore #8.
6. Optimize dentofacial esthetics with orthodontics and soft tissue detailing.

Treatment Alternatives

A common option for correcting bimaxillary protrusion is extraction of all four first premolars. However, the present patient had missing or compromised lower first molars, so the appropriate extraction sequence was upper first premolars and lower first molars. This approach presents anchorage problems, but they are manageable with advanced planning.

Omitting the bone graft and closing the space for the extracted #8 (Fig. 2) may be an attractive orthodontic option, but that approach creates extensive restorative problems, such as scaling the incisors to avoid an end-on occlusion and compromised esthetics in the critical maxillary anterior region. A fixed partial denture to replace #8 was not a viable alternative because it would require preparing adjacent virgin teeth. The patient rejected space closure and a fixed partial denture in favor of augmenting the soft and hard tissue defect to restore the incisor with an implant-supported crown. In selecting the latter option the patient was informed that is was a complex treatment plan with multiple steps that may or may not be completely successful. Also, follow-up orthodontics may be necessary for final detailing. After considering the pros and cons of each option, the patient exercised her informed consent by selecting bone and soft tissue augmentation followed an implant-supported prosthesis.

Treatment Progress

After teeth #5, 8, 12 & 30 were extracted, a mixed Ormco (Glendora, CA) .022” fixed appliance was bonded on all teeth, utilizing ICE® clear fixed brackets in the anterior segments. After extraction, the crown portion of tooth #8 was prepared as a pontic and bonded with an ICE® bracket to provide natural esthetics and space maintenance during active orthodontic treatment (Fig. 6). The archwire sequence in both arches was: .016” NiTi, . 016x.022” NiTi, and .016x. 022” stainless steel (SS). Class II elastics were used to close posterior extraction spaces and retract the maxillary anterior segment (Fig. 7). Lingual buttons were bonded on teeth # 31, 28, 21 & 18, and to attach power chains to help close the spaces (Fig 8). Balancing buccal and lingual force can facilitate space closure and help avoid molar tipping and rotation.[9] Tooth # 20 was mesially rotated about 80^0, so it was necessary to rebond the bracket twice during treatment to correct the alignment (Fig. 9).

After twenty-one months of active treatment, all the lower arch spaces were closed, but extraction space remained in the upper arch. Extra-alveolar miniscrews were placed in the mandibular buccal shelves to retract the entire lower dentition.[10-11] Once a positive overjet was achieved, maxillary elastomeric chains were used to close the residual space by retracting the anterior segment (Fig.10).

After twenty-five months of treatment, all spaces were closed except for the #8 implant site (Fig. 11). All fixed appliances were removed and retention was accomplished with an upper clear overlay and a lower fixed retainer.

Autogenous chin block augmentation

The edentulous anterior ridge (area # 8) had severe horizontal and vertical defects (Fig. 12). To repair the deficiency, an autogenous bone block was harvested from the chin area. This is a common donor site for reconstructing severe ridge defects, but the method requires precise surgical technique as will be described, illustrated and discussed.

• Recipient site preparation:

Intrasulcular incisions were made from teeth # 6 to 10 with a No. 15c scalpel blade, and a full thickness flap was reflected. Decortication of the alveolar bone was performed with a small high speed round bur to expose the bone marrow space, accelerate revascularization and increase the regional acceleratory phenomena (RAP).[12-13] The recipient site was recontoured to improve the fit of the graft into the defect (Fig.13-A).[14]

• Donor site preparation:

A horizontal incision was made with a No. 15 blade at the mucogingival junction from tooth #22 to 27. Initially, the blade was held at 45 degrees to create a 5 mm partial thickness reflection and was then turned to 90 degrees to cut to a full thickness flap. The 5 mm partial thickness area allowed for a double layer of sutures when the flap was closed to help capture and stabilize a subperiosteal blood clot to facilitate wound healing (Fig. 13-B.)

• Harvesting the autogenous chin block:

The autogenous chin block was harvested with a fissure bur in a surgical hand piece. The fissure bur was used to cut through the cortex and outline the donor site (Fig. 13-C). Then, a straight bone chisel was inserted into the cut and gently tapped with a mallet to free the cortical bone block and elevate it (Fig.13-D). The harvested area followed the “5 mm rule” which means that all the operated area is at least 5 mm away from incisor apices, mental foramen and lower mandibular border.[14] The depth of osteotomy depends on the thickness of bone required by the recipient site, but it should not be over half of the thickness of the mandibular symphysis.

• Donor site closure:

Bone wax was packed into the donor site to control bleeding after the chin block was harvested. A double-layer suture technique was utilized. The first layer was 5-0 chromic gut suture used to attach the inner surface of the flap to the periosteum in the 5mm partial thickness area. The second layer was 5-0 Vicryl® (Ethicon, Johnson & Johnson, New Jersey, USA) to suture the outer flap to the keratinized tissue bordering the donor area (Fig. 13-E).

• Fixation of the chin graft:

The harvested cortico-cancellous bone block was trimmed carefully to fit into the recipient site. An intimate contact of the graft to the recipient site improves blood supply and helps integration. Two screws were used to fix the bone block and prevent rotation (Figs. 13-F, G). The residual gaps were filled with particulate freeze-dried bone allograft (FDBA) and covered with a collagen membrane (Fig. 13-H). The wound was closed with a tension-free flap, and secured with Gore-Tex® sutures (Gore Medical, Flagstaff AZ USA) (Fig. 13-I).

Implant placement

Four months after the autogenous chin block augmentation, the ridge had healed with adequate width and height to accommodate an implant. An acrylic surgical stent was used to properly position the fixture. The stent was designed with a labial border ~1mm short of the desired mucogingival junction. It provides an anatomical reference for placing the implant in an optimal position, relative to supporting bone and attached gingiva (Fig 14).

For implant placement, an intrasulcular incision was made from tooth # 6 to 10 with a No. 15c blade; a full thickness flap was reflected and the bone graft fixation screws were removed (Figs. 15-A, B). The bone crest was measured to be ~4 mm from the cervical contour of the surgical stent (Figs 15-C). According to the 2B-3D rule,[15] the ideal vertical position of the implant is about 3 mm from the predetermined free gingival margin to the implant platform. So the 4 mm stent to bone distance for the present patient was ideal because the stent was ~1mm short of the planned free gingival margin. A guiding pin was used after the pilot drill to check the path of insertion. From the mesial-distal aspect, the implant should be parallel with the adjacent roots; from the buccal-palatal aspect, the implant should be positioned between the incisal edge and cingulum (Figs 15-D). After confirming the path of insertion with a periapical film, the osteotomy site was prepared following standard protocols, and the implant was inserted. Figs 15-E, F show the implant is in an optimal position. Note that a portion of the chin block graft is still visible on the facial aspect of the implant.

Temporary prosthesis fabrication

After a four-month unloaded healing phase, the implant was uncovered and a temporary restoration was fabricated. Since there was sufficient keratinized gingiva on the buccal surface, a 4/5 mm punch (inner diameter 4 mm, outer diameter 5 mm) was used to access the implant instead of raising a flap. A temporary abutment was prepared and attached. A prefabricated temporary crown was relined to achieve optimal form and was then connected to the abutment (Fig. 16). The desired subgingival contour was added with flowable resin to mimic a natural emergence profile (Fig. 17). The purpose of this customized temporary abutment was to guide the soft tissue healing and create a natural gingival contour.

Soft tissue augmentation

After the temporary abutment was finalized, a soft tissue augmentation procedure was indicated to enhance the thin soft tissue biotype. A partial thickness flap was reflected and a connective tissue graft from the right side of the palate was harvested to augment the buccal soft tissue (Figs. 18-A, B). After placing the first connective tissue graft, the recipient site was still concave, so a second connective tissue graft from the left side of the palate was harvested to supplement the augmentation site (Figs. 18-C, D) to produce a more esthetic rounded contour.

Unfortunately, placement of two connective tissue grafts strained the buccal flap closure and the wound opened during the healing phase. The area achieved secondary healing but scar tissue was created on the facial surface (Fig.19). Electrosurgery was used 6 weeks after surgery to cauterize and remove as much scar tissue as possible. To achieve an ideal result, additional orthodontics was indicated, so brackets were placed on the maxillary arch to further refine the positioning of teeth in the esthetic zone (Fig. 20).

Three months later, the soft tissue had healed and the desired orthodontics finish was achieved. Impressions were made for permanent prosthesis fabrication. When the temporary prosthesis was removed, an optimal peri-implant soft tissue profile was evident (Fig. 21). It was imperative to transfer this soft tissue relationship with a customized impression post.[16]

Customized impression post and final restoration

The temporary prosthesis was removed and connected to an implant analog. It was stabilized in a rubber cup and bite registration material was injected to cover the subgingival area of the temporary prosthesis. Once the material was set, the temporary crown was removed and the subgingival soft tissue contour, registered by bite registration materials, was visible (Fig. 22-D). The impression post was connected to the analog and the residual gap was filled with flowable resin (Fig. 22-G). The customized impression post, which recorded the exact subgingival contour of the prosthesis (Fig. 22-H), was returned to the mouth to facilitate the final impression. Subsequently, the permanent prosthesis was fabricated and the restoration was completed (Figs. 22-K, L).

Treatment Results

The post-treatment photographs showed that facial esthetics was improved due to correction of bimaxillary protrusion (Fig. 23). Both maxillary and mandibular anterior segments were retracted and all the lower spaces were closed (Figs 24 and 25). Since premolars were extracted in the upper but not in the lower arch, the occlusion was finished in a molar Class II relationship (Fig 26). The ABO Cast-Radiograph Evaluation (CRE)[17] (worksheet 2) score was 21 points as showed in the subsequent worksheet. Much of this excellent score reflected the follow-up orthodontics treatment prior to fabricating the final prosthesis.

With regard to the implant site, there was some scar tissue on the facial surface and a small dark triangle (insufficient papilla) on the distal aspect. These two problems resulted in a pink and white esthetic score of 2[18] (worksheet 3). Overall, the tissue augmentation procedures and the temporary abutment molding method were successful. The frontal view was pleasing and the buccal prominence of the ridge was satisfactory, as assessed from the occlusal view (Fig 27). The patient was very happy with the final result.

Discussion

When closing spaces to correct bimaxillary protrusion, attention must be paid to the progress of space closure relative to anchorage control in all four quadrants. If space closure in one segment is more rapid than another, it may be necessary to adjust the applied mechanics and/or supplement the anchorage. For the current patient, Class II elastics were used initially as the mechanics in the sagittal plane to close posterior spaces in both arches. Space closure progressed more rapidly in the lower arch compared to the upper. Reassessment produced the following treatment plan changes: 1. power chains in the upper arch to retract the anterior dentition, and 2. miniscrews placed in the mandibular buccal shelf areas to retract the entire lower dentition (Fig 10).[10-11] These changes in mechanics limited the side effects of the Class II elastics and enhanced the lip retraction to correct the bimaxillary protrusion (Fig 23).

For atrophic alveolar ridge augmentation, there are many recommended approaches, including alloplastic bone substitutes, xenografts, allografts, and autogenous bone grafts. Bone grafts may contain bone morphogenic proteins (BMPs), which are purported to have both bone conductive and inductive effects.[19] Autogenous bone grafts are the gold standard for alveolar ridge augmentation, and are classified as follows: (1) endochondral bone, such as iliac crest and long bones, and (2) intramembranous bone, such as mandibular ramus and symphysis. Kusiak et al.,[20] found that intramembraneous (also referred to as membraneous) bone grafts show earlier revascularization compared to endochondral bone blocks. Enhanced invasion of blood vessels promotes bone modeling and remodeling of the nonvital bone graft. Autogenous chin grafts are from bone that is intramembranous in origin. The present bone graft showed good volume, stability and it achieved primary union with the host bone.

Vascular invasion with activated pericytes (Fig. 28) is the initial step for the induction of new bone formation. [21,22] When angiogenesis begins, the capillaries start growing via a budding process and the pericytes propagate to produce more pericytes for the new vascular buds (Fig. 29). [21] The pericytes are osteogenic precursor cells that migrate from the perivascular region to form osteoblasts (Fig. 30). [21] The multipotent pericytes are chemically stimulated to differentiate into osteoblasts by growth factors that are released from the healing reaction in the wound area.[22] Therefore, the early revascularization of an autogenous bone graft accelerates the *de novo* bone formation that is essential for bone graft integration. An allograft or xenograft usually requires at least 6 months to form substantial amounts of living bone in the grafted area. Autogenous bone blocks only require about four months to adequately heal, stabilize and remodel because of an earlier re-vascularization effect.[20] Thus, autogenous bone blocks from sites like the chin can shorten the healing time prior to placing an implant, thereby accelerating the overall progress of treatment.

It is important to realize that all cortical bone grafts are dead, dense bone that is slow to resorb and remodel to new living bone. Once the grafted (largely dead) cortical bone bonds with the host bone (Fig. 15-F), it is a biocompatible material that is a good site for an implant. Dead bone can effectively support an implant and continue to remodel normally. However, moving a tooth into a grafted site, is a much more difficult problem, *because even a small amount of dead bone in the path of tooth movement precludes effective orthodontics.* Consequently, grafted alveolar defects are usually good sites for implants, and the adjacent teeth can be detailed orthodontically, but space closure of a grafted defect is usually contraindicated.

Fig. 15-F shows that a portion of the chin block graft is still visible on the buccal side of the implant, which demonstrates an important biological principle for sites grafted with thick portions of cortical bone. The chin block is a nonvital piece of cortical bone that is a biocompatible graft material because it is autogenous. When reopened for implant placement, previously augmented alveolar defects are a mixture of vital and nonvital bone. A thick block of autogenous cortical bone resorbs slowly but it can still provide adequate support for an implant, and may be more stable for long-term resistance to labial recession than vital alveolar bone.

There are some important details for enhancing the healing of autogenous bone grafts. First, use a small round bur to perforate the cortical bone and promote bleeding. Capturing a healthy blood clot within and around the autogenous graft provides a natural source of growth factors to promote vascular invasion and osteogenesis. Site preparation induces a regional acceleratory phenomenon (RAP), which induces remodeling of the bone adjacent to the graft site. Frost [12,13] described the postoperative RAP as an enhanced remodeling of both soft and hard tissue in that area. These effects usually start a couple of days after surgery and maximize one or two months later. In some cases, the RAP can last 6-24 months.[23,24]

When a chin graft is harvested, blood is often oozing from the marrow space, which can cause a hematoma or ecchymosis (bruised spot) on the face. To minimize post-operative bleeding, bone wax is packed directly into the osseous wound to control bleeding points at the donor site. The hemostatic material Surgicel® (Ethicon, Johnson & Johnson, New Jersey, USA) is *not* recommended because it does not effectively control oozing from wounded bone.

When suturing the recipient site, two layers of sutures are used. The first layer is a resorbable suture, such as 5-0 Vicryl®, to reposition the mentalis muscle and periosteum back in their original positions. This is an important step to prevent ptosis (drooping) of the chin and lip incompetence.[25] The second (more superficial) layer of 5-0 sutures can be resorbable Vicryl® or non-resorbable products like Gore-Tex® or nylon. The mucosa should be carefully approximated to minimize scarring.

Patients may be concerned about a change in the chin profile after harvesting the chin block, but follow-up studies show that these concerns are unwarranted. Radiographs six months after the surgery show the original bone contour has almost recovered, and after two years the donor site is completely healed.[26]

Some patients may experience an altered sensation of the mandibular anterior teeth or lower lip, but the problem is usually resolved within 6-12 months.[27] As long as the harvested area is no closer than 5 mm to mental foramen and root apices of the adjacent teeth, the chance of permanent damage to the anterior loop of the mental nerve and/or teeth is minimal.[28]

Overall, the autogenous chin graft is a safe and efficient procedure for reconstructing severe ridge defects. Understanding the biological principles and adhering to safety rules, minimizes the chance of significant complications. However, once a bone graft is placed in an alveolar defect, the clinician has committed to a prosthetic solution to replace the tooth, because the slow turnover to viable bone precludes orthodontic space closure.

Conclusions

Adult orthodontic patients often present with complex malocclusions complicated by periodontal and prosthodontic problems due to hard and soft tissue deficiencies. An integrated interdisciplinary approach usually provides patients with the best results. Managing complex malocclusions in adults is challenging, but providing effective treatment for these difficult problems is quite rewarding. Clearly, orthodontic preparation of the edentulous area, as well as the adjacent and opposing teeth, often enhances the final outcome. Clearly, orthodontists must have a good understanding of all the subsequent surgical and prosthetic procedures to provide an optimal service.

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FIGURE LEGENDS

Fig 1. Pre-treatment facial and intraoral photographs

Fig 2. Upper right central incisor (#8) presented with Class III mobility as well as marked hard and soft tissue deficiencies. A periapical radiograph shows external root resorption and a severe loss of periodontal support.

Fig 3. Pre-treatment dental models (casts)

Fig 4. Pre-treatment cephalometric radiograph

Fig 5. Pre-treatment panoramic radiograph

Fig 6. Tooth # 8 was extracted and the crown portion of the tooth was prepared to serve as a space maintainer for the implant site.

Fig 7. Class II elastics were used to close the extraction spaces in both arches, as well as to retract the maxillary anterior segment.

Fig 8. Lingual buttons and power chains were used to facilitate space closure and avoid rotations.

Fig 9. Class II elastics were used to close the extraction spaces in both arches and retract the maxillary anterior segment.

Fig 10. Extra-alveolar mini-screws were placed in the mandibular buccal shelves to retract the lower arch and create overjet to permit retraction of the maxillary anterior segment.

Fig 11. All posterior spaces were closed and the roots of the teeth were well aligned.

Fig 12. Severe horizontal and vertical ridge deficiencies were noted in the edentulous area of # 8.

Fig 13. Clinical procedures are shown for harvesting the cortico-cancellous chin block graft and for fixing the graft in the recipient site.

Fig 14. Four months after autogenous chin block augmentation, the ridge in the implant site had sufficient width and height. The acrylic surgical stent is fitted to serve as a guide for implant placement. The ideal free gingival margin is 1 mm apical to the margin of the surgical stent in the edentulous area.

Fig 15. Clinical procedures are shown for removing fixation screws and for placing an implant with a surgical stent. Note that a portion of chin block graft is still visible on the facial aspect of the implant (E, F)

Fig 16. Following an unloaded healing phase, a 4/5 mm punch was used to access the implant. A temporary abutment was then fabricated.

Fig 17. Flowable resin was added to the subgingival aspect of the temporary restoration to mold an appropriate emergence profile.

Fig 18. A partial thickness flap was reflected, and a connective tissue graft was placed (A, B). A second connective tissue graft was placed to further augment the site (C, D).

Fig 19. Placement of two connective tissue grafts caused excessive tension on the labial flap, causing the wound to open. The area healed secondarily, but some scar tissue was formed. From left to right, the post-operative course is shown at 1, 2, 3 and 4 weeks.

Fig 20. Electrosurgery was used to remove scar tissue, and then brackets were replaced to achieve the final alignment of the maxillary anterior segment.

Fig 21. After removal of the temporary prosthesis the soft tissue profile is evident. This favorable gingival result was due to the molding by the temporary crown. It was imperative to register this profile and transfer it exactly to the permanent prosthesis.

Fig 22. The sequential clinical procedure is shown for making a customized impression post.

Fig 23. Post-treatment facial photographs

Fig 24. Post-treatment intraoral photographs

Fig 25. Post-treatment dental models (casts)

Fig 26. Cephalometric tracings are superimposed on the anterior cranial base, maxilla and mandible: black is pre-treatment and red is post-treatment.

Fig 27. The final result is shown for the implant- supported prosthesis, which replaced the maxillary right central incisor (#8). The buccal prominence of the alveolar ridge superior to the implant was satisfactory (right).

Fig 28. Activated pericytes are osteoblasts precursors.

Fig 29. Pericytes propagate along the surface of an elongated capillary sprout. (Reprinted with permission Chang et al., 1996 [21])

Fig 30. Pericytes are stimulated by growth factors to migrate away from blood vessels and differentiate into osteoblasts.

Table 1. Cephalometric summary

Worksheet 1. The American Board of Orthodontics (ABO) Discrepancy Index (DI)

Worksheet 2. The American Board of Orthodontics (ABO) Cast-Radiograph Evaluation (CRE)

Worksheet 3. Pink and White esthetic score

Fig 1. Pretreatment facial and intraoral photographs.

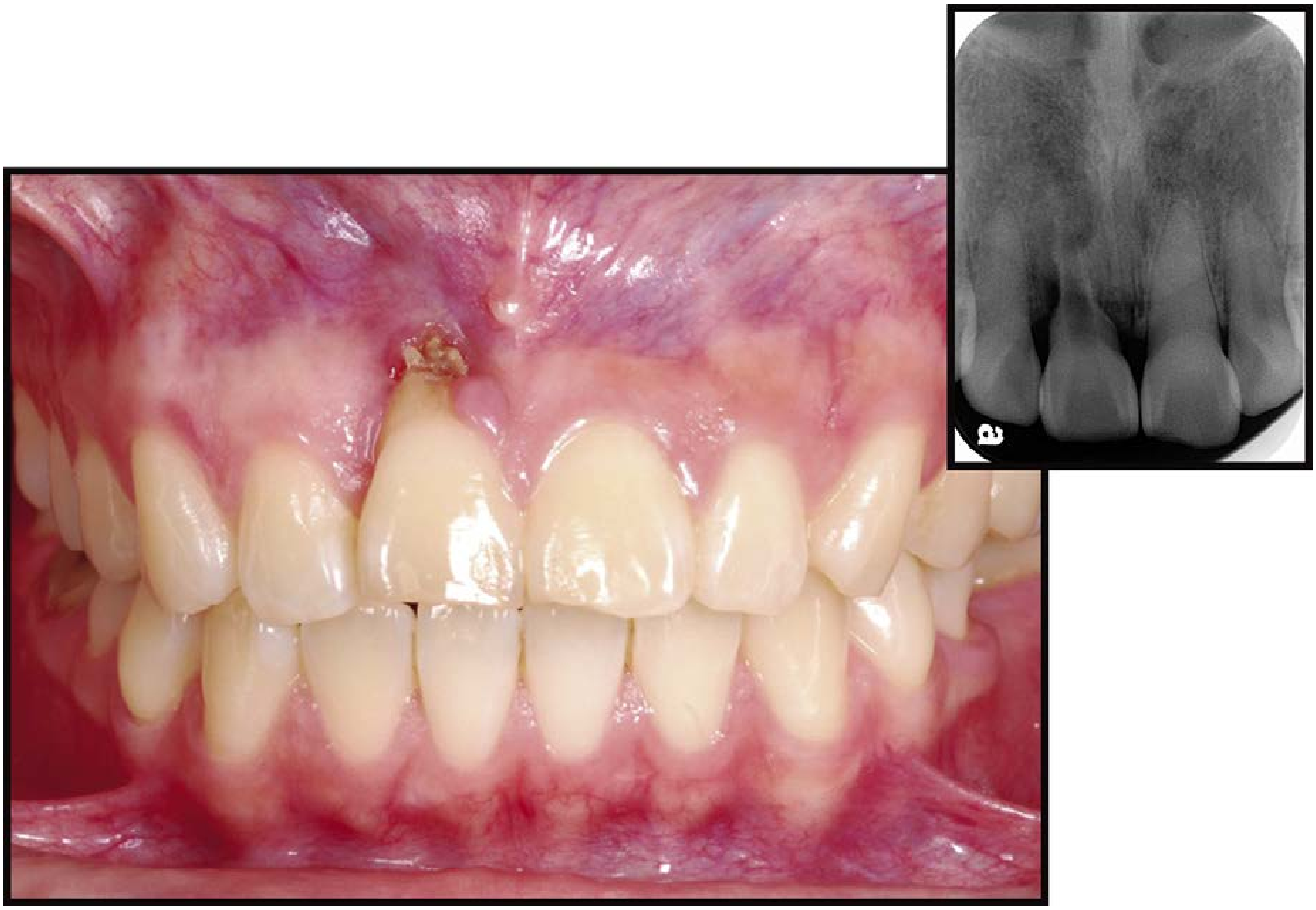

Fig 2. The maxillary right central incisor had Class III mobility and marked hard and soft tissue deficiencies. A periapical radiograph shows external root resorption and severe loss of periodontal support.

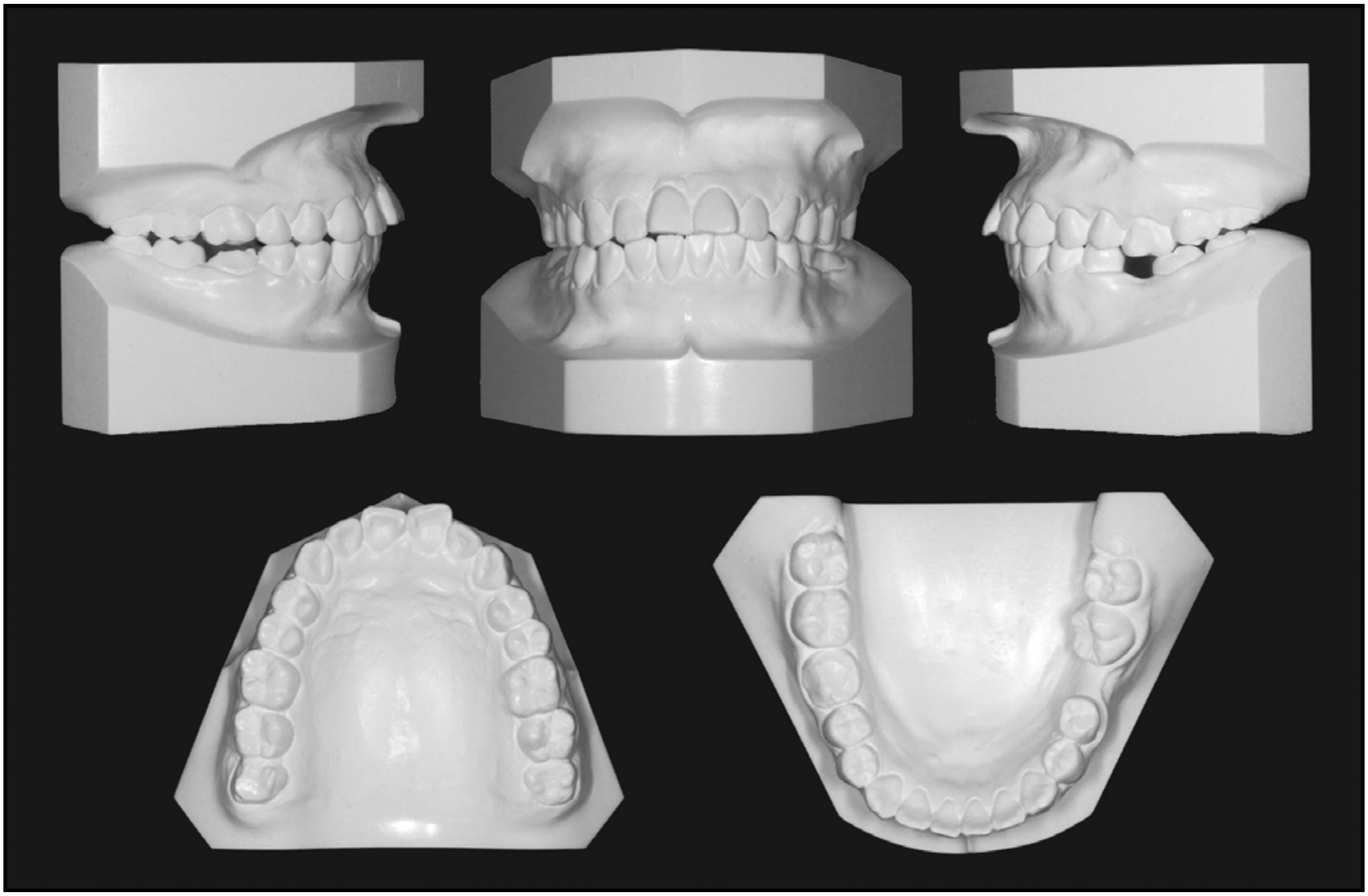

Fig 3. Pretreatment dental models.

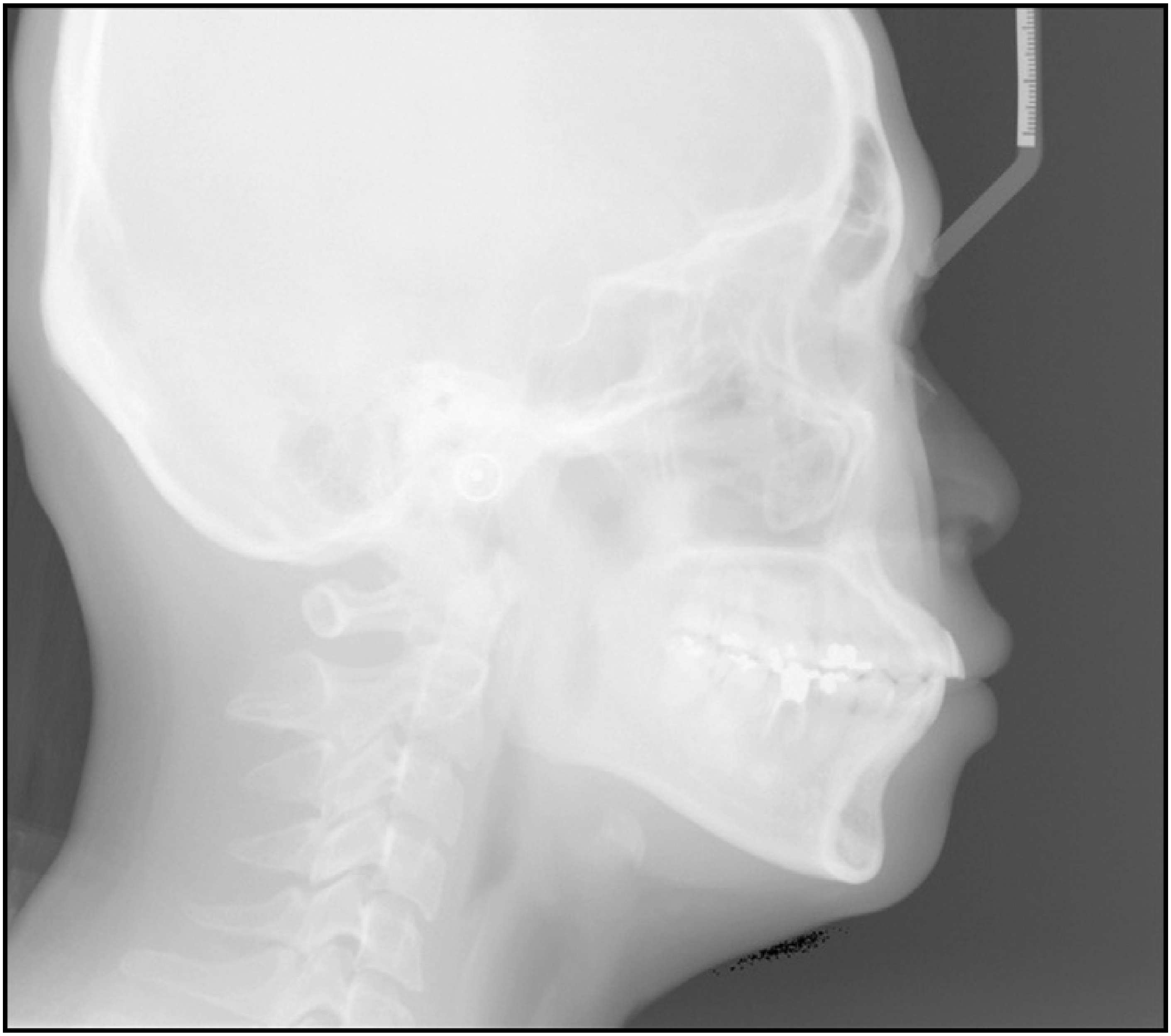

Fig 4. Pretreatment cephalometric radiograph.

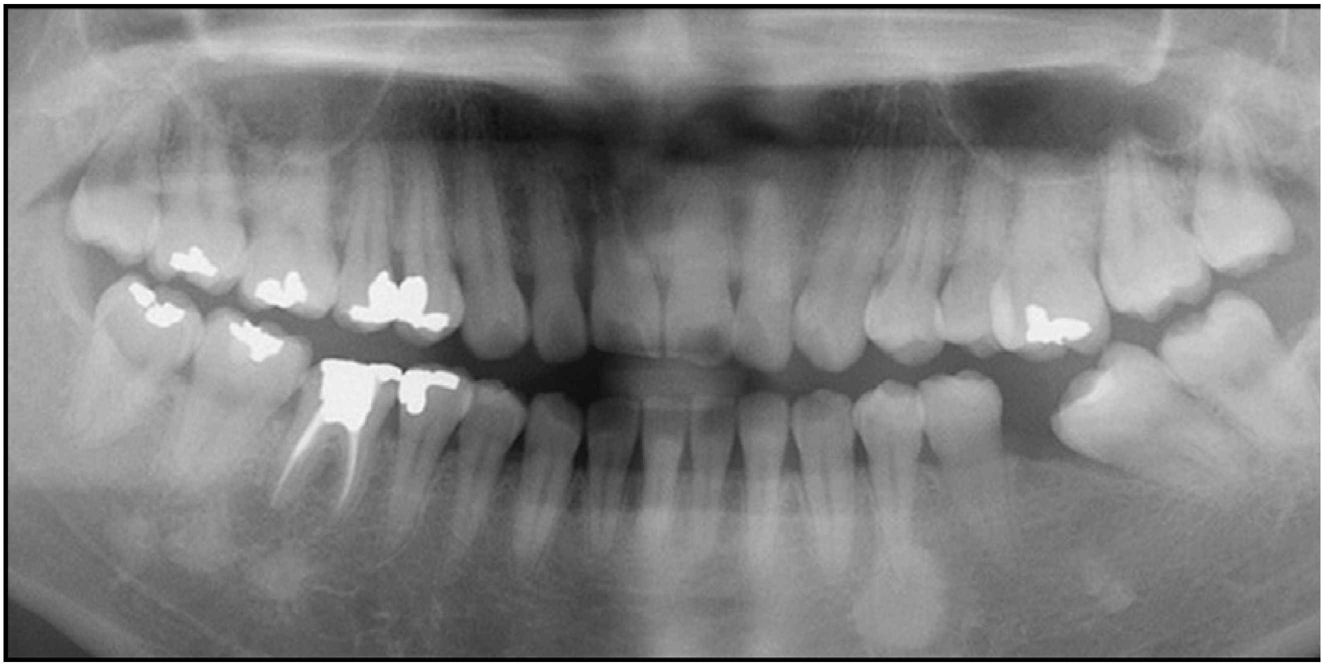

Fig 5. Pretreatment panoramic radiograph.

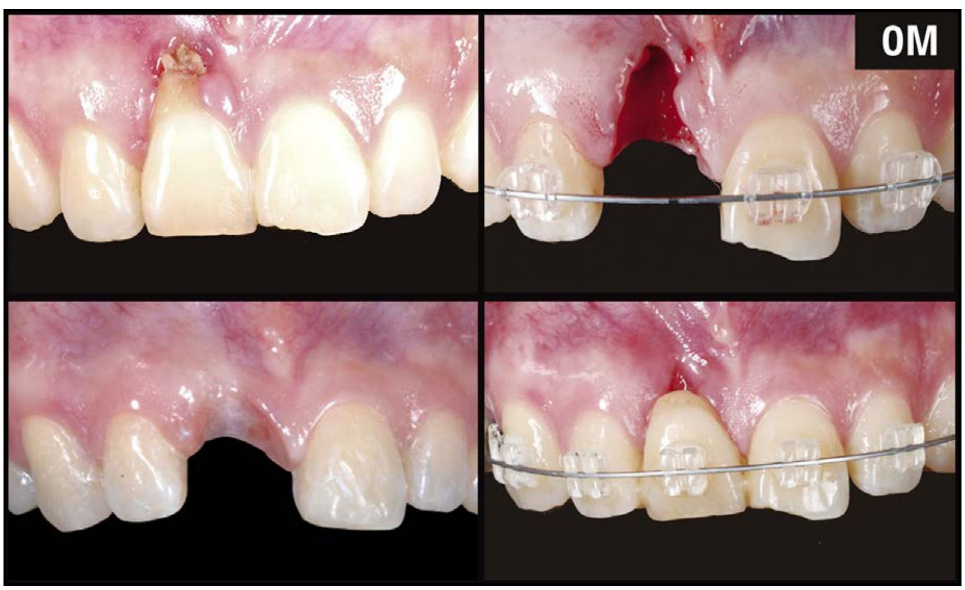

Fig 6. The maxillary right central incisor was extracted, and the crown portion was prepared to serve as a space maintainer for the implant site.

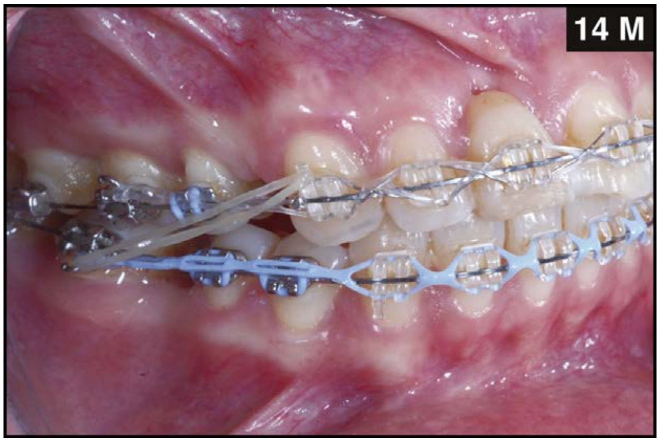

Fig 7. Class II elastics were used to close the extraction spaces in both arches and retract the maxillary anterior segment.

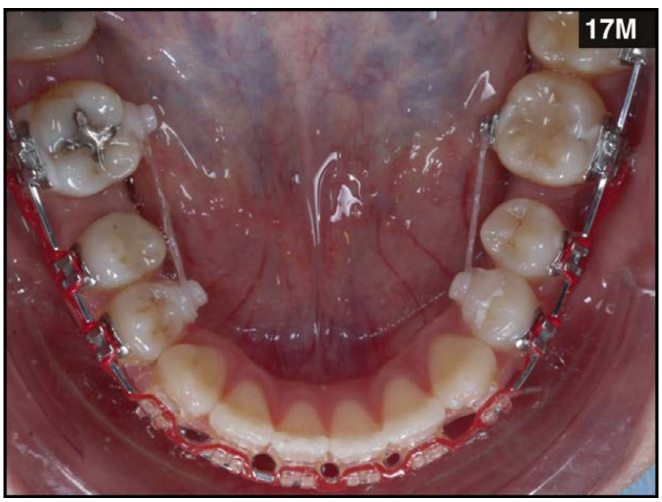

Fig 8. Lingual buttons and power chains were used to facilitate space closure and prevent rotations.

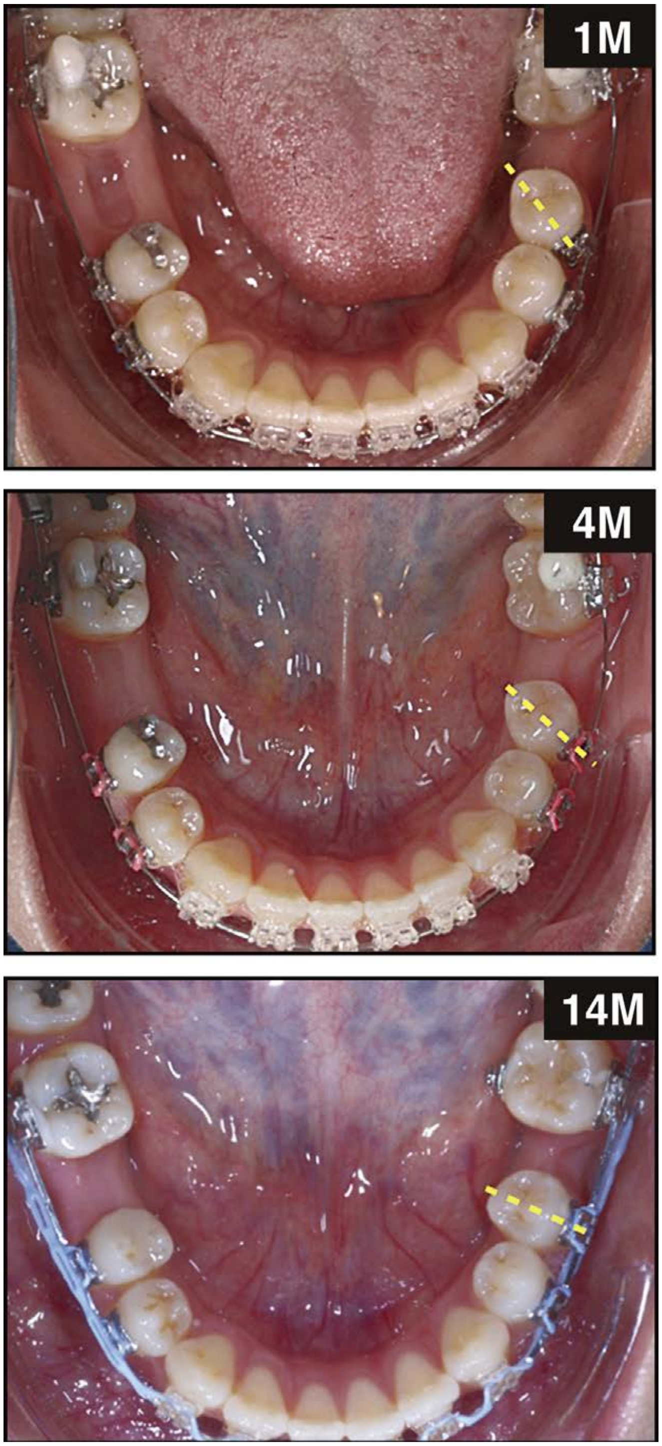

Fig 9. The bracket on the lower left 2nd premolar (#20) was repositioned twice to correct the mesial-in rotation.

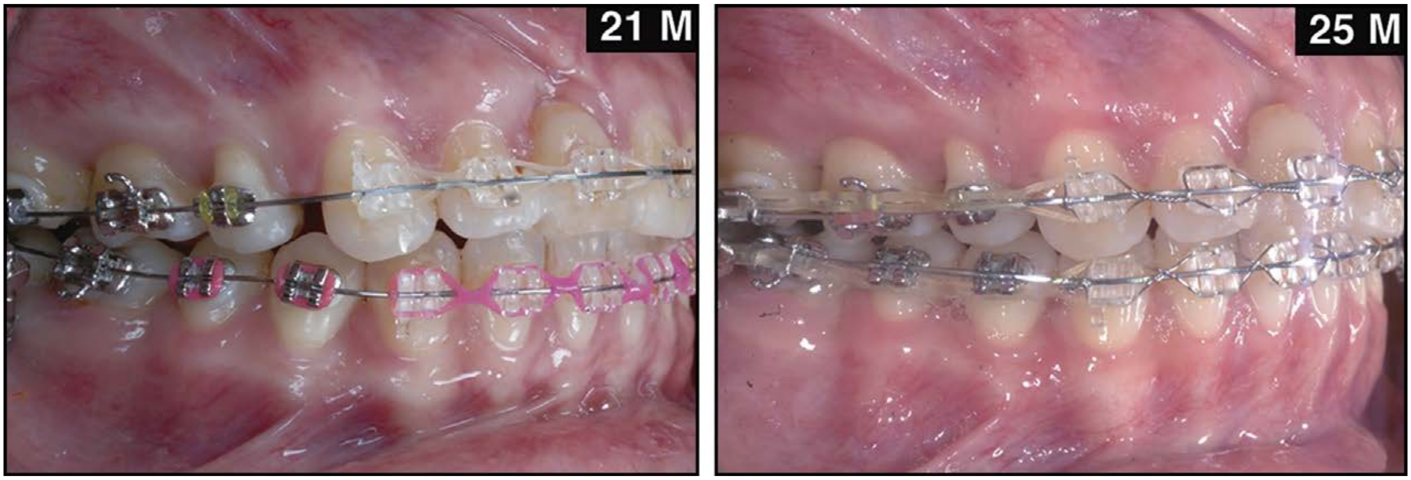

Fig 10. Extra-alveolar miniscrews were placed in the mandibular buccal shelves to retract the mandibular arch and create an overjet to permit retraction of the maxillary anterior segment.

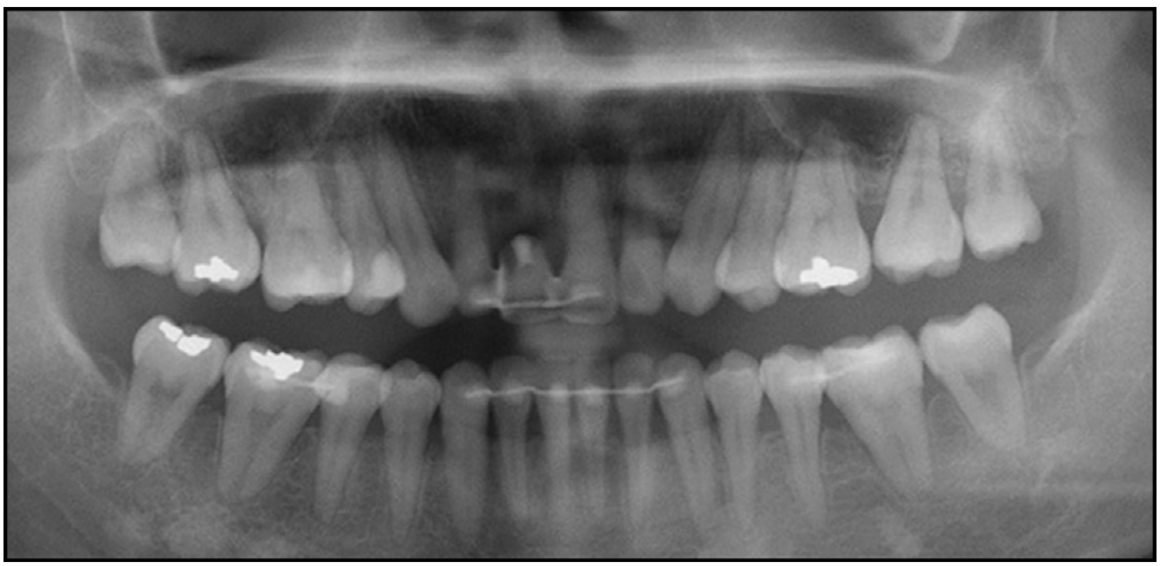

Fig 11. All posterior spaces were closed, and the roots of the teeth were well aligned.

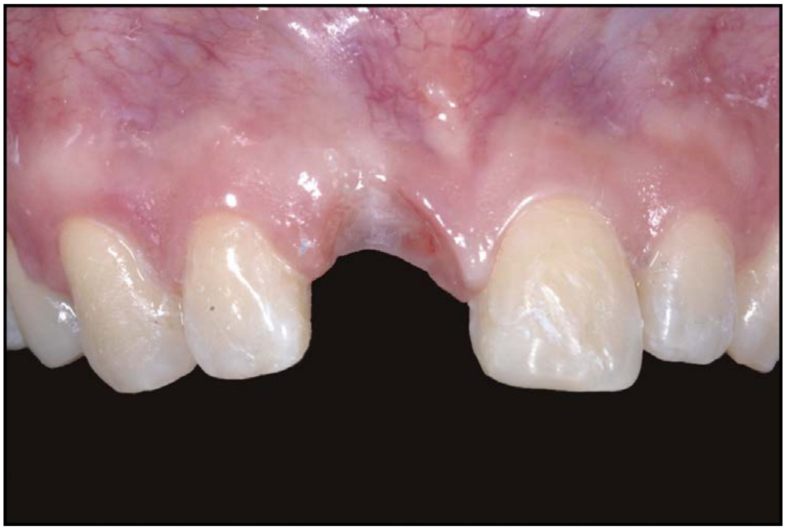

Fig 12. Severe horizontal and vertical ridge deficiencies in the edentulous area of the maxillary right central incisor.

Fig 13. Clinical procedures of harvesting the cortico-cancellous chin-block graft and fixation of the graft to the recipient site.

Fig 14. Four months after the autogenous chin-block augmentation, the ridge in the implant site had sufficient width and height. The acrylic surgical stent is fitted to serve as a guide for implant placement. The ideal free gingival margin is 1 mm apical to the margin of the surgical stent in the edentulous area.

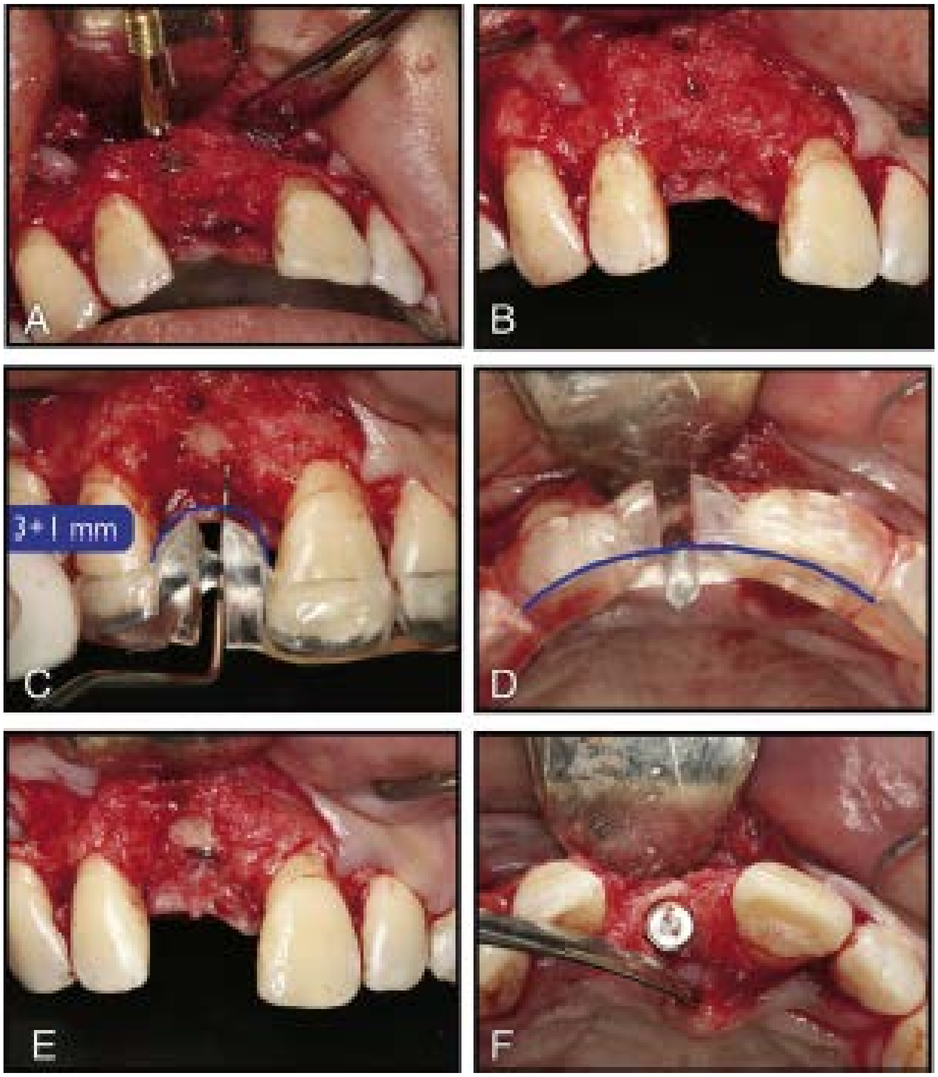

Fig 15. Clinical procedures of removing the fixation screws and placing the implant with a surgical stent guide. A portion of the chin-block graft is still visible on the facial aspect of the implant (E and F).

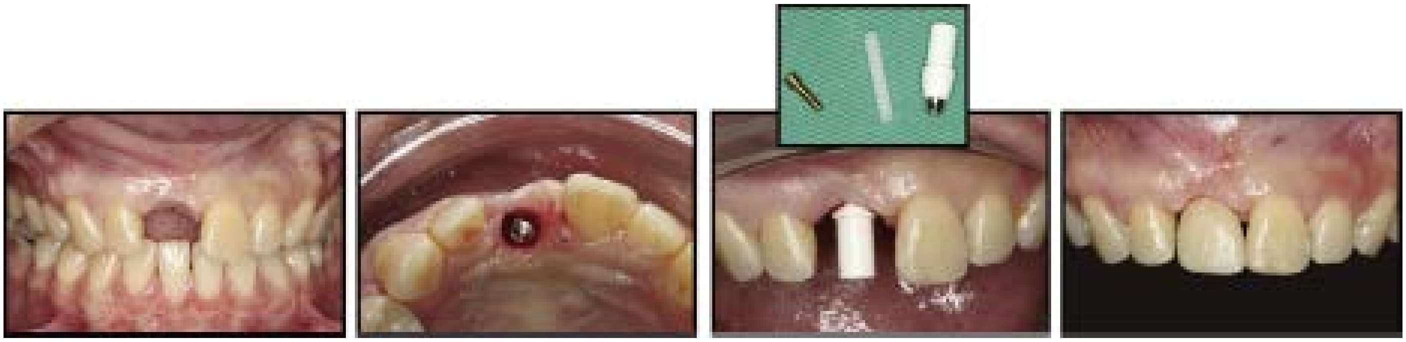

Fig 16. After an unloaded healing phase, a 4/5 mm punch was used to access the implant. A temporary abutment was then fabricated.

Fig 17. Flowable resin was added to the subgingival part of the temporary restoration to mold an appro-priate emergence profile

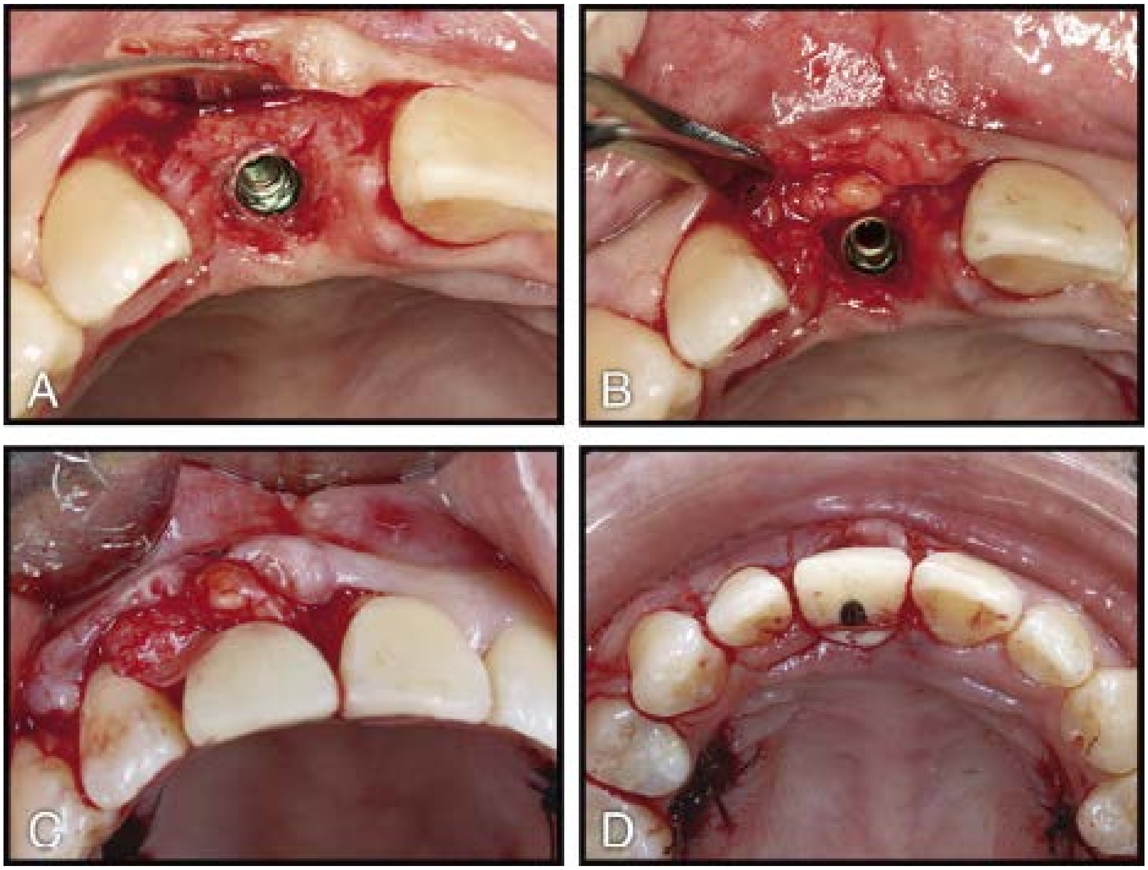

Fig 18. A and B, A partial-thickness flap was reflected, and a connective tissue graft was placed. C and D, A second connective tissue graft was placed to further augment the site.

Fig 19. Placement of 2 connective tissue grafts caused too much tension on the labial flap, opening the wound. The area achieved secondary healing, but some scar tissues were formed. From left to right, the postoperative course is shown at 1, 2, 3, and 4 weeks.

Fig 20. Electrosurgery was used to remove scar tissue, and brackets were replaced to achieve final alignment of the maxillary anterior segment.

Fig 21. After removing the temporary prosthesis, the soft tissue profile developed by the temporary crown was visible. It was imperative to keep this profile and transfer it exactly to the permanent pros-thesis.

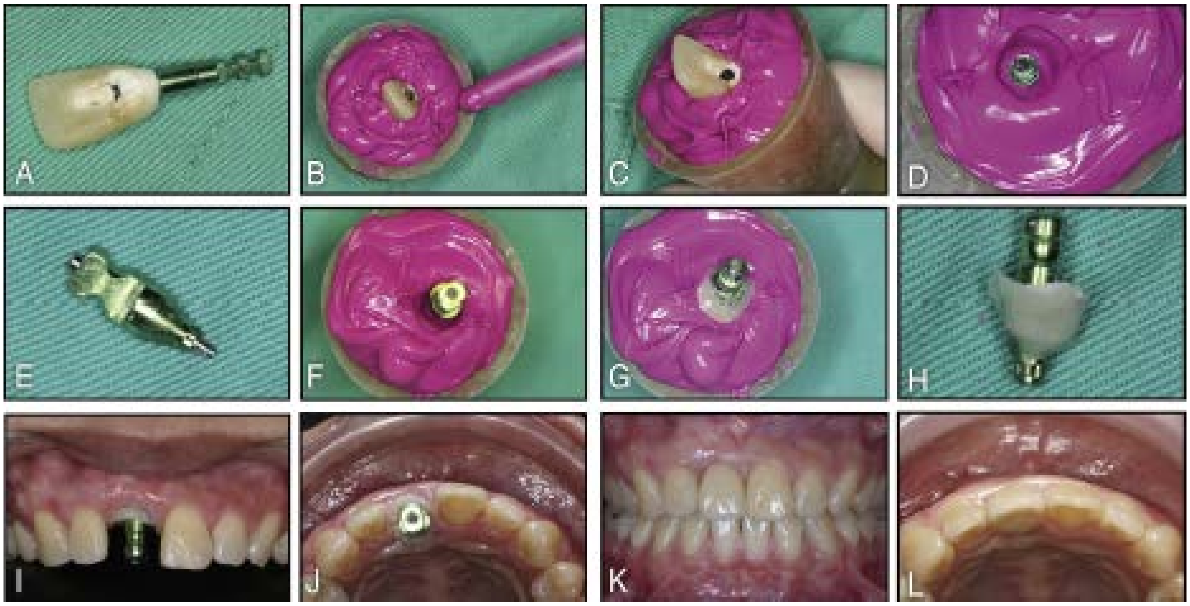

Fig 22. The sequential clinical procedure is shown for making a customized impression post. After soft tissue molding, the prosthetic crown (A) is fitted to an analogue and inserted into a cylinder filled with impression material (B and C). After the material is sets, the temporary crown is unscrewed from the implant analogue to reveal the soft tissue contour. An impression post (E) is screwed into the analogue (F), resin is flowed in to fill the open space and then polymerized (G), and the customized impression post (H) is removed from the mold. The customized impression post is fitted into the mouth (I and J) and final impression is made, The permanent crown is fabricated and set (K and L).

Fig 23. Posttreatment facial and intraoral photographs

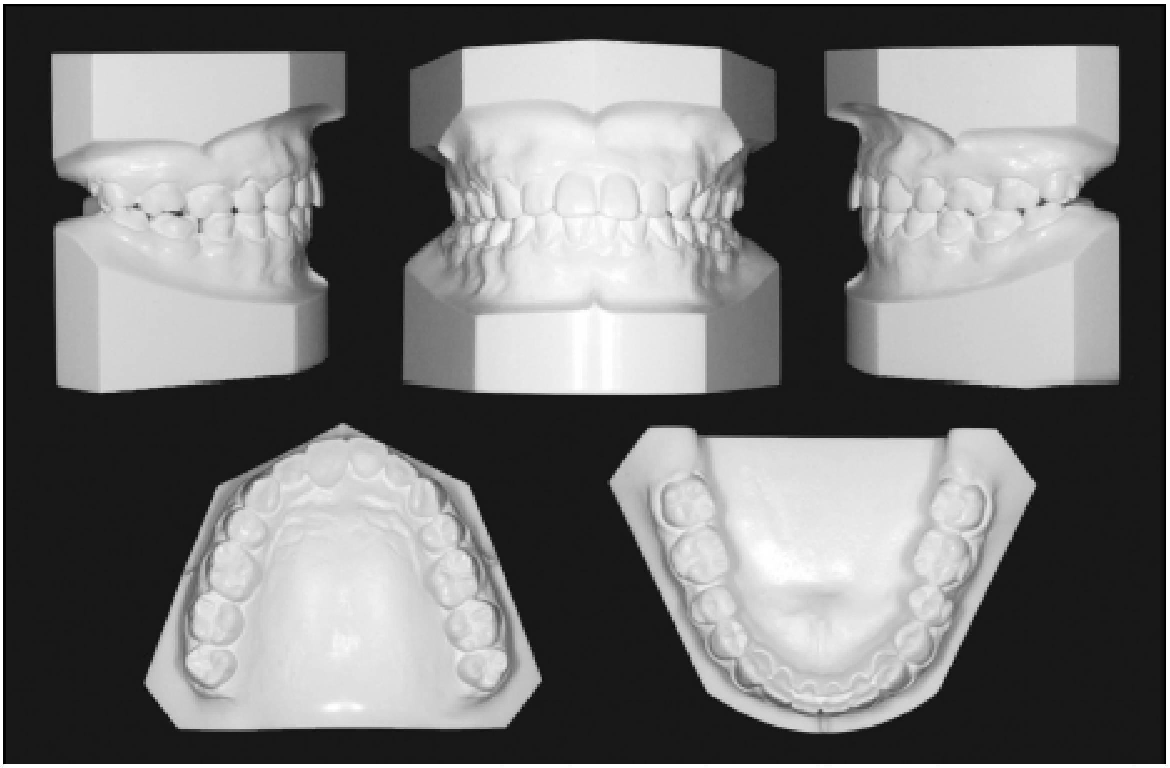

Fig. 24. Posttreatment dental models.

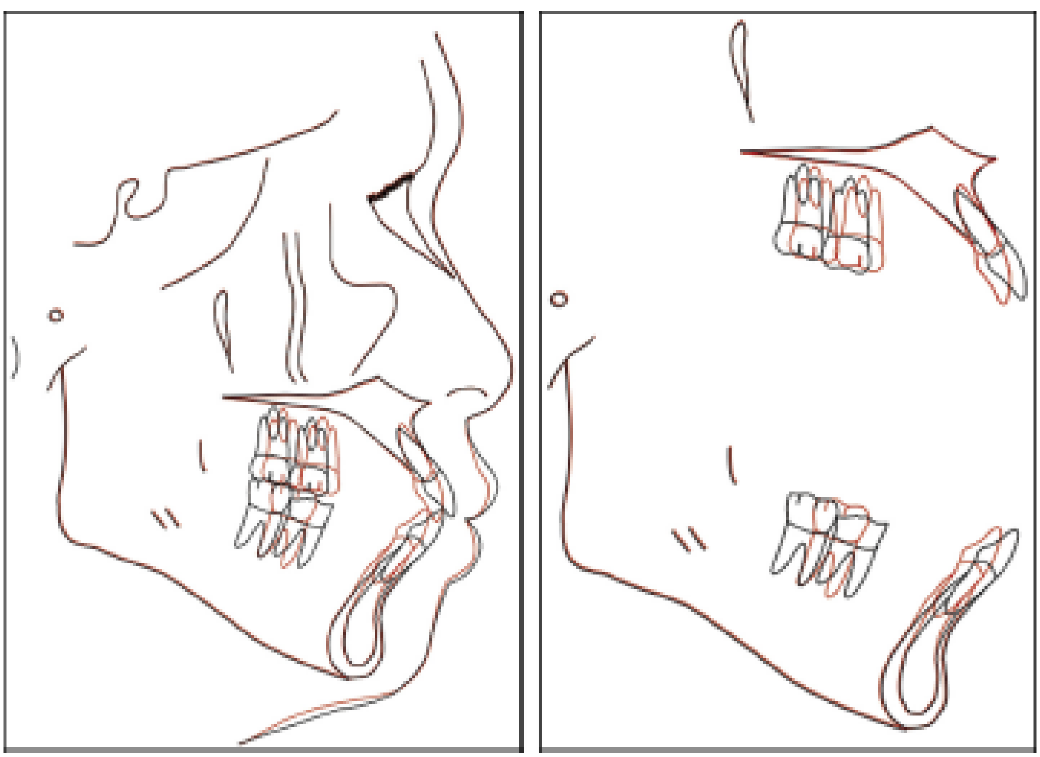

Fig 25. Cephalometric tracings superimposed on the anterior cranial base, maxilla, and mandible. Black, pretreatment; red, posttreatment.

Fig 26. Final result for the implant-supported prosthesis replacing the maxillary right central incisor. The buccal prominence of the alveolar ridge over the implant was satisfactory (right).

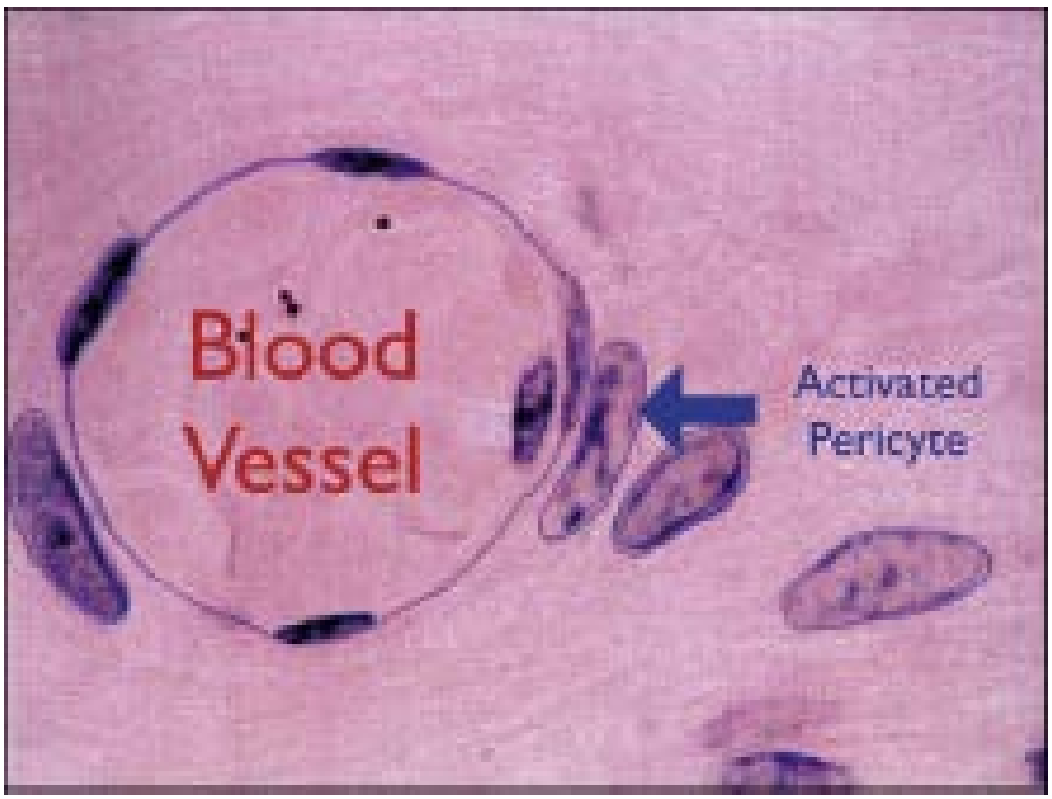

Fig 27. Activated pericytes are precursors for osteo-blasts.

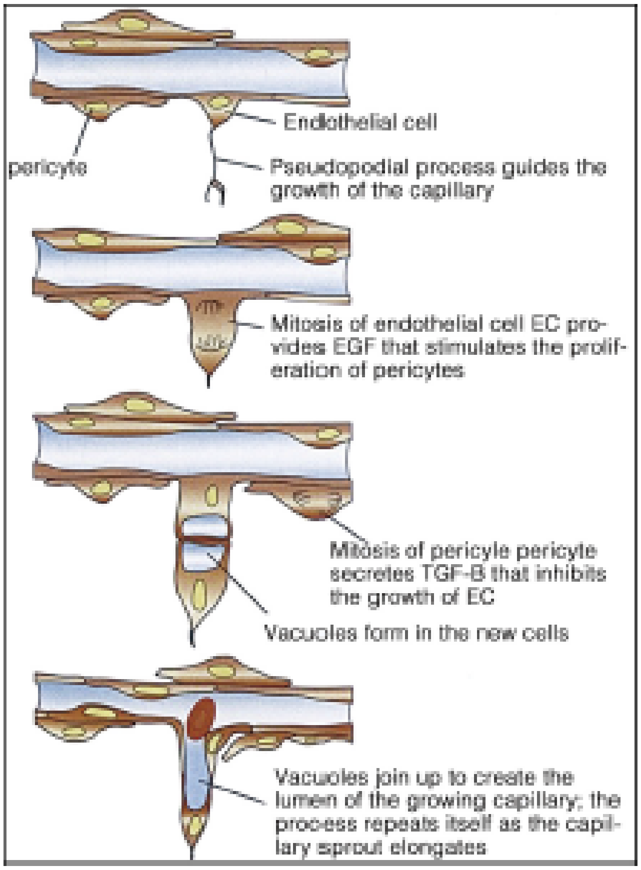

Fig 28. Pericytes propagate along the surface of an elon-gated capillary sprout. (permission to reuse obtained from Chang et al[21])

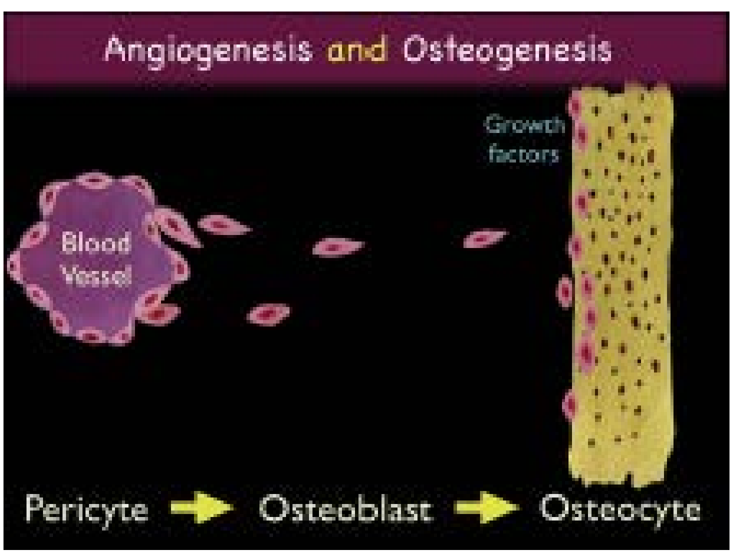

Fig 29. Pericytes are stimulated by growth factors to migrate away from blood vessels and differentiate into os-teoblasts.

Table. Cephalometric summary			
	Pretreatment	*Posttreatment*	*Difference*
Skeletal analysis			
SNA (°)	87	87	0
SNB (°)	83	83	0
ANB (°)	4	4	0
SN-MP (°)	29	29	0
FMA (°)	22	22	0
Dental analysis			
U1-NA (mm)	10	6	4
U1-SN (°)	120	113	7
L1-NB (mm)	13	9	4
LI-MP (°)	105	102	3
Facial analysis			
E-line-upper lip (mm)	5	3	2
E-line-lower lip (mm)	5.5	4.5	1

Table 1. Cephalometric summary