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Interdisciplinary treatment for a compensated Class II partially edentulous malocclusion: Orthodontic creation of a posterior implant site

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A 36-year-old woman with good periodontal health sought treatment for a compensated Class II partially edentulous malocclusion associated with a steep mandibular plane (SN-MP, 45°), 9 missing teeth, a 3-mm midline discrepancy, and compromised posterior occlusal function. She had multiple carious lesions, a failing fixed prostheses in the mandibular right quadrant replacing the right first molar, and a severely atrophic edentulous ridge in the area around the mandibular left first and second molars. After restoration of the caries, the mandibular left third molar served as anchorage to correct the mandibular arch crowding. The mandibular left second premolar was retracted with a light force of 2 oz (about 28.3 cN) on the buccal and lingual surfaces to create an implant site between the premolars. Modest lateral root resorption was noted on the distal surface of the mandibular left second premolar after about 7 mm of distal translation in 7 months. Six months later, implants were placed in the mandibular left and right quadrants; the spaces were retained with the fixed appliance for 5 months and a removable retainer for 1 month. Poor cooperation resulted in relapse of the mandibular left second premolar back into the implant site, and it was necessary to reopen the space. When the mandibular left fixture was uncovered, a 3-mm deep osseous defect on the distobuccal surface was found; it was an area of relatively immature bundle bone, because the distal aspect of the space was reopened after the relapse. Subsequent bone grafting resulted in good osseous support of the implant-supported prosthesis. The relatively thin band of attached gingiva on the implant at the mandibular right first molar healed with a recessed contour that was susceptible to food impaction. A free gingival graft restored soft tissue form and function. This severe malocclusion with a discrepancy index value of 28 was treated to an excellent outcome in 38 months of interdisciplinary treatment. The Cast-Radiograph Evaluation score was 13. However, the treatment was complicated by routine relapse and implant osseous support problems. Retreatment of space opening and 2 additional surgeries were required to correct an osseous defect and an inadequate soft tissue contour. Orthodontic treatment is a viable option for creating implant sites, but fixed retention is required until the prosthesis is delivered. Bone augmentation is indicated at the time of implant placement to offset expected bone loss. Complex restorative treatment may result in routine complications that are effectively managed with interdisciplinary care. (Am J Orthod Dentofacial Orthop 2018;153:422-35)

Permanent teeth may be lost to trauma, caries, or periodontal disease. Marked reductions in width and height of the alveolar ridge can occur after tooth extraction[1,2] and often compromise prosthetic restoration.[3] Preprosthetic ridge augmentation with onlay bone grafting is often required before or in conjunction with implant placement.[4] If the periodontium is healthy, orthodontic site development is a viable alternative for producing new bone and attached gingiva.[5-9] Movement of a healthy tooth through an edentulous area to increase the ridge dimensions to receive an implant is a promising method, but there is a risk of lateral root resorption.[7] Orthodontic tooth movement

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Fig 1. Pretreatment facial and intraoral photographs.

can expand the alveolar process,[3,7,8] and placing implants in these sites has been suggested,[5-9] but to our knowledge, there are no documented reports for implant placement in orthodontically generated sites in posterior segments. This case report describes routine complications associated with orthodontically generated implant sites, and how these minor complications were solved efficiently. An excellent functional and esthetic result was achieved, as documented by a Cast-Radiograph Evaluation score of 13.

DIAGNOSIS AND ETIOLOGY

A 36-year-old woman sought consultation for space management in the mandibular left posterior area (Figs 1 and 2) and was treated to an excellent dentofacial result (Figs 3 and 4). She was diagnosed with a skeletal Class I and a compensated dental Class II malocclusion with a missing maxillary left canine (Figs 1 and 2). The etiology of the complex malocclusion was unrestorable caries and the extraction of the mandibular left first and second molars, about 7 years previously (Fig 5). The adjacent third molar drifted mesially and tipped into the space, resulting in an atrophic edentulous space that was about 14 mm in length (Figs 2 and 5). Clinical and radiographic evaluations showed multiple carious lesions and a failing mandibular right fixed prosthesis replacing the first molar (Figs 1 and 5). In addition, the mandibular left central incisor was missing, resulting in a mandibular midline deviation of about 3 mm to the left (Figs 1 and 2). The patient reported that her upper right first premolar and upper left canine were extracted by her family dentist when she was 13 years of age, because they were blocked out to the buccal aspect (Fig 1). The maxillary right second molar was missing (unknown etiology), and the adjacent third molar had drifted into the second molar space. The American Board of Orthodontics Discrepancy Index[10] was 28 points as shown in the Supplemental material. The implant sites (mandibular right and left first molars) scored an additional 4 points for complexity (Supplemental material). Overall, this mutilated malocclusion was a severe problem requiring

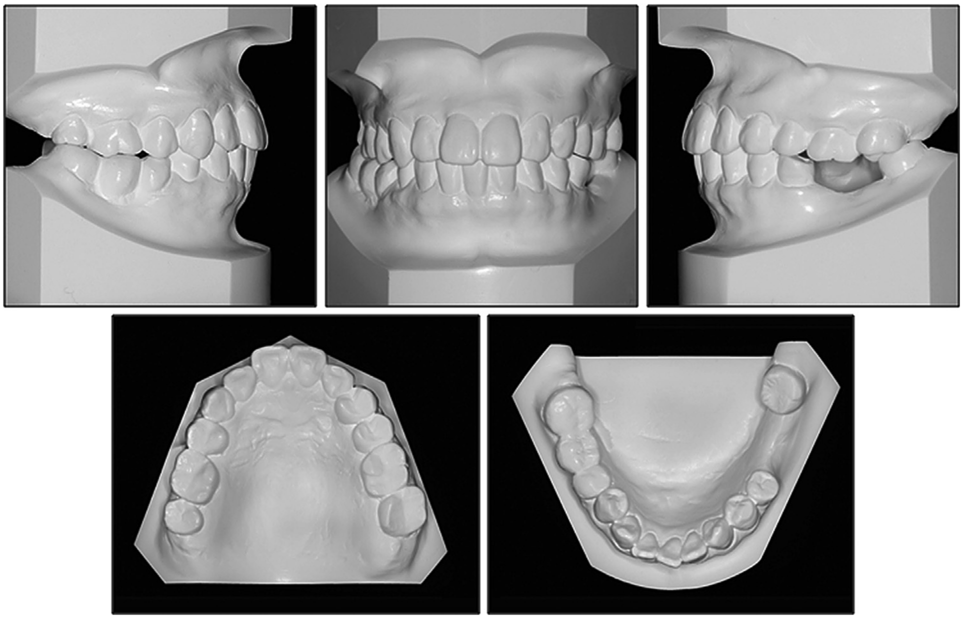

Fig 2. Pretreatment dental models (casts).

Fig 3. Posttreatment facial and intraoral photographs.

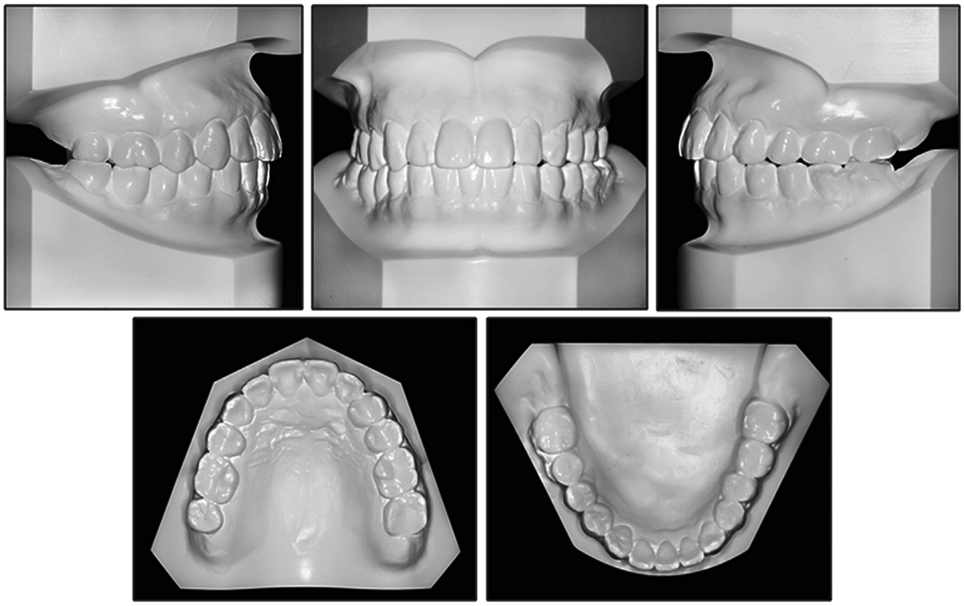

Fig 4. Posttreatment study models (casts).

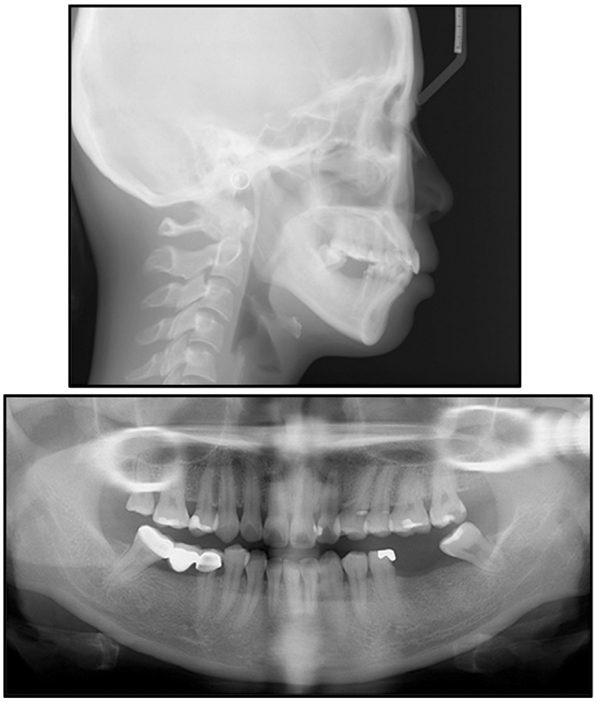

Fig 5. Pretreatment cephalometric (*above*) and panoramic (*below*) radiographs.

a carefully sequenced, interdisciplinary approach. The posttreatment radiographs (Fig 6) and superimposed cephalometric tracings (Fig 7) documented the interdisciplinary treatment.

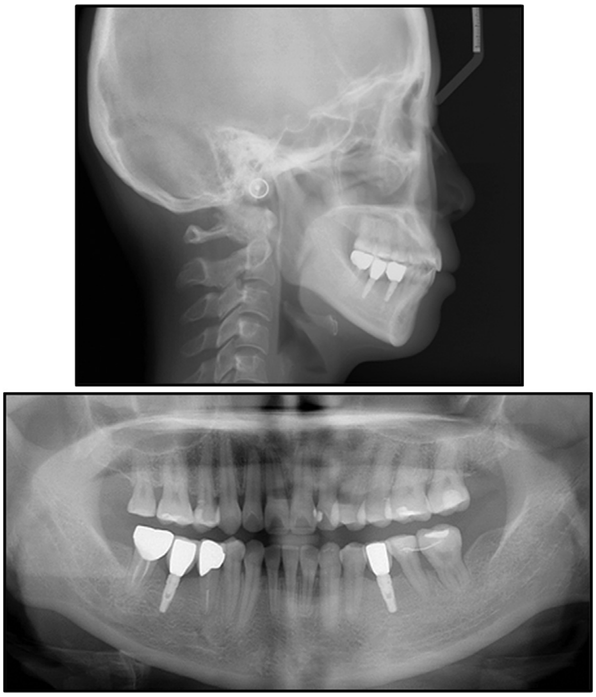

Fig 6. Posttreatment cephalometric (*above*) and panoramic (*below*) radiographs.

TREATMENT OBJECTIVES

The treatment objectives were to (1) restore all carious lesions; (2) maintain the skeletal dimensions of the maxilla and the mandible for all 3 planes; (3) perform

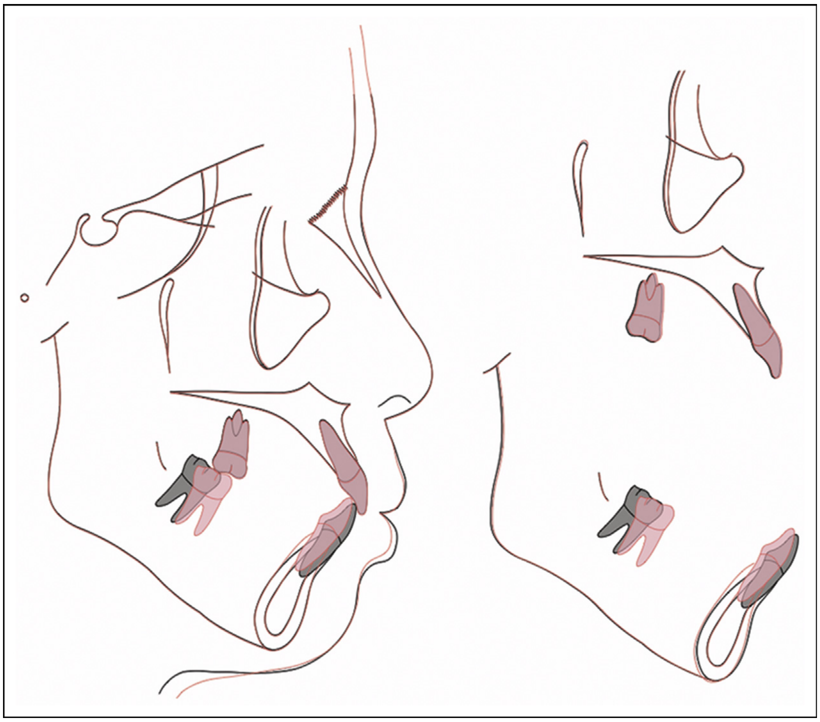

Fig 7. Superimposed cephalometric tracings showing protraction and uprighting of the mandibular left third molar and retraction of the mandibular incisors.

preprosthetic tooth movement, including protracting and uprighting the mandibular third molar to reduce the edentulous space (Figs 8 and 9), retracting the second premolar to the position of the first molar, and placing an implant in the space opened between the second and first premolars (Figs 9 and 10); (4) perform prosthetics, including removing the mandibular right fixed prosthesis and restoring the second premolar and first molar with crowns, and placing a dental implant-supported prosthesis in the edentulous ridge of the area of the first molar; (5) manage the soft tissues, including when uncovered, evaluate each implant for an apically repositioned flap or free gingival graft to increase the buccal keratinized tissue and soft tissue volume; and (6) finish the orthodontics, including optimizing dentofacial esthetics with orthodontic detailing.

TREATMENT ALTERNATIVES

The first alternative for restoring the mandibular left edentulous area was to augment the ridge and place 2 implants. However, that approach required an additional implant and was less predictable because of the complexity of the surgeries to augment the severe bone atrophy of the implant site. In addition, the mesial inclination of the mandibular left third molar (Fig 5) was at risk for long-term periodontal problems, periodontitis, or peri-implantitis, caused by food impaction and plaque accumulation between the third molar and the distal implant. The second option was a removable partial denture to replace the missing mandibular left molars, but the mesial inclination of the third molar was expected to encroach on the path of denture insertion. That problem would require extraction of the third molar or restorative procedures to prepare it for a surveyed crown. The patient rejected both alternative treatment approaches because of additional surgery, the potential for the long-term compromise of the virgin third molar, and the increased risk of periodontal problems.

TREATMENT PROGRESS

A full fixed Damon Q appliance (Ormco, Glendora, Calif) was used with the archwires and accessories specified by the manufacturer. Mechanics began in the mandibular arch with a 0.014-in nickel-titanium archwire, and 5 months later a 0.014 × 0.025-in nickel-titanium archwire was inserted. Lingual buttons and power chains were placed on the mandibular canine and second premolar to control rotation. In the month 7 of treatment, the mandibular archwire was switched to a 0.017 × 0.025-in beta-titanium alloy wire. Another

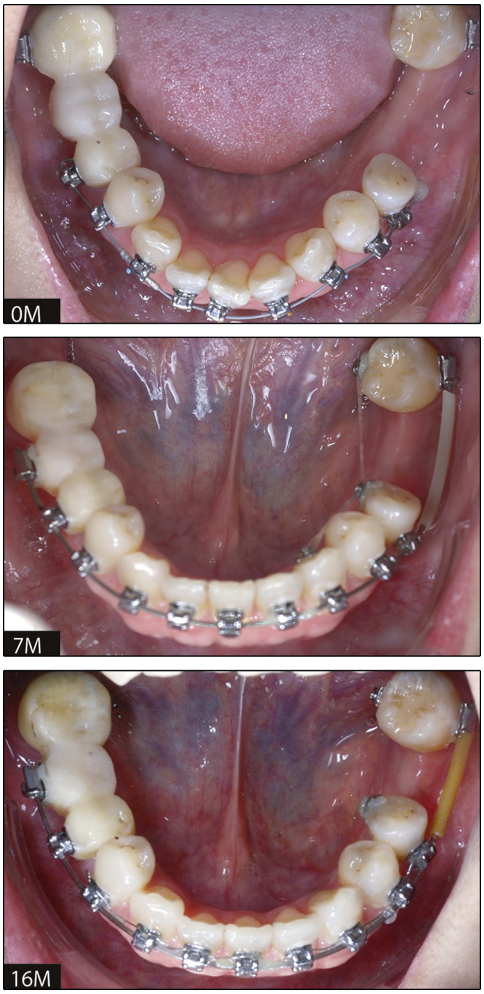

Fig 8. Month 0, irregular dentition at the start of active treatment. Month 7, the mandibular left segment is being aligned, and the edentulous space is decreased; note the lingual elastic chain between the left molar and second premolar. Month 16, the initial alignment is complete.

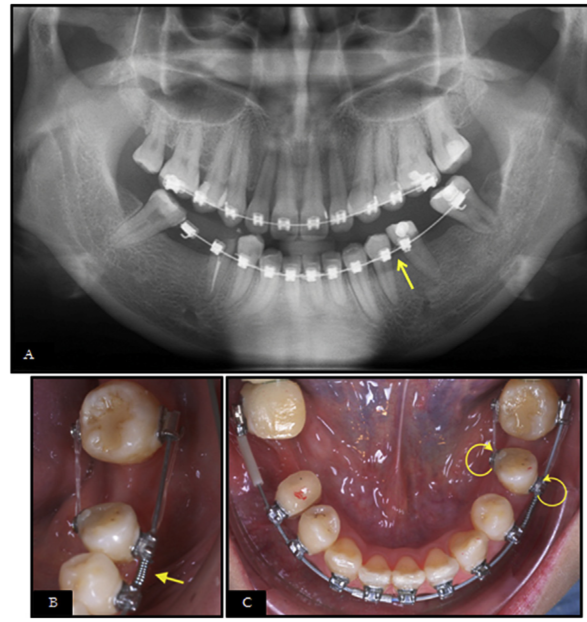

Fig 9. A, The mandibular left space (first molar) was reduced, space opening begins (*arrow*), and the mandibular right space (first molar) was maintained. **B,** The edentulous ridge for the right first molar space was very narrow, so the second premolar was moved distally with an open-coil spring (*arrow*) on the buccal surface. **C,** Buttons with power chains on the lingual surface resulted in equal retraction loads on both surfaces.

lingual button and power chain were placed on the mandibular left third molar to provide a mesial protraction force (Fig 9). By the end of month 16 of treatment, all rotations were corrected, and the edentulous space was reduced to 8 mm (Fig 8), but the width of the edentulous ridge was still narrow (about 3 mm) due to severe resorption of the buccal plate of bone (Fig 9). The mandibular left second premolar was retracted orthodontically to generate an implant site between the premolars. Buccal and lingual forces were applied with an open-coil spring placed on the archwire between the first and second premolars, and lingual buttons with a power chain were placed between the first premolar and the third molar (Fig 9). The force was applied very gently, about 2 oz (28.3 cN) on each surface to control lateral root resorption. After 7 months of retracting the mandibular left second premolar at a rate of 1 mm per month, the orthodontically generated implant site was about 7 mm in length (Fig 10). The space was maintained for 6 months with fixed appliances. A periapical radiograph showed only minor lateral root resorption on the distal side of the root of the second premolar (Fig 10).

Extraction of blocked-out permanent teeth (maxillary right second molar and first premolar, and left canine) during adolescence corrected crowding in the maxillary arch, so only minor orthodontic treatment was needed to correct the mesial-in rotation of both lateral incisors (Fig 11). After bonding with the Damon Q appliance, interproximal reduction was performed on the maxillary right and left incisors to create space. The archwire sequence was 0.016-in nickel-titanium, 0.016 × 0.022-in nickel-titanium, and 0.016 × 0.022-in stainless steel to align the dentition (Fig 12). After 32 months of active treatment, both arches were well aligned, and the bilateral edentulous spaces in the mandibular first molar areas were prepared for implants (Figs 12, *A*, and 13, *A*).

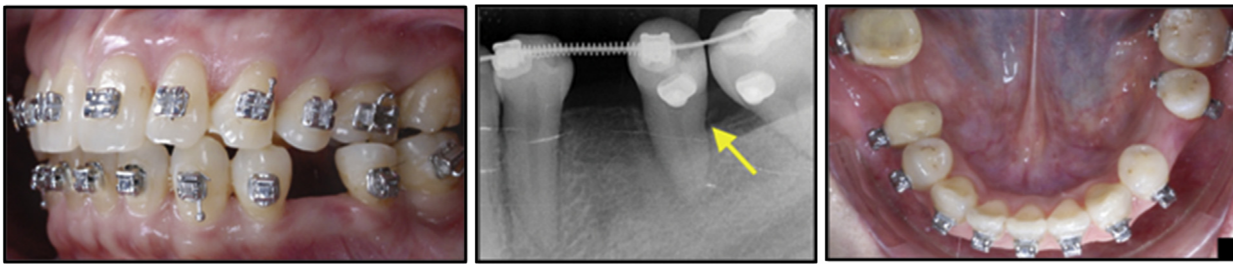

Fig 10. The mandibular left second premolar was moved into the edentulous ridge in the area of the first molar, and a small area of lateral root resorption was noted (*arrow*).

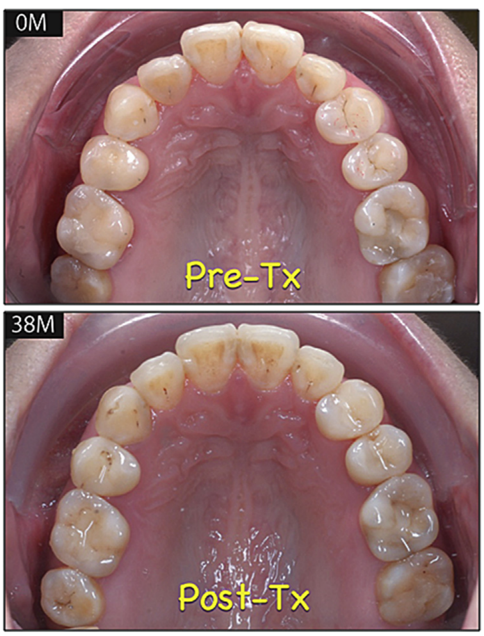

Fig 11. The pretreatment (*Pre-Tx*) maxillary arch form (0M) is compared with the posttreatment (*Post-Tx*) result at 38 months.

A horizontal incision was made with a number 12 blade from the lingual line angle of the mandibular left first premolar to the mesial line angle of the second premolar (moved into the position of the first molar). Two vertical releasing incisions were made with a number 15 blade and joined with the horizontal incisions. The incisions were 1.5 mm from the adjacent teeth for maintenance of the periodontal attachment to control gingival recession postoperatively (Fig 12, *C*). A full-thickness flap was reflected, and a surgical gauge measured the 6-mm wide ridge (Fig 12, *D* and *E*). A surgical stent was used to check the projected soft tissue height (Fig 12, *F*), and the crestal bone was recontoured with a round bur (Fig 12, *G*) to create a 3-mm clearance to the bone crest, as required for the biologic width of the attachment (Fig 12, *H*).[11] A guide pin (Fig 12, *I*) was used to check the insertion path and orientation of the osteotomy. The osteotomy site was prepared according to the protocol of the manufacturer, and a 3.5 × 10-mm implant was installed (Prima; Keystone Dental, Burlington, Mass). As shown in Figure 12, *J* and *K*, the implant was placed in the center of the ridge and was completely embedded (submerged) in bone. Furthermore, about a 1.5-mm thickness of bone remained on the buccal surface after implant placement (Fig 12, *J*). There was primary closure of the wound with interrupted 5-0 nylon sutures (Fig 12, *L*).

A similar procedure was performed on the mandibular right edentulous ridge in the area of the first molar (Fig 13, *A-H*). However, the ridge was narrower in the crestal area and after implant placement, there was a 1-mm bony dehiscence noted at the buccal crest of the implant (Fig 13, *F*). The healing abutment was installed, and a composite particulate bone graft was placed (Fig 13, *G*), composed of freeze-dried bone allograft (Maxxeus Dental, Kettering, Ohio) and Bio-Oss (Geistlich Pharma North America, Princeton, NJ). The flap was then primarily closed with 5-0 nylon. Freeze-dried bone allograft is composed of cortico-cancellous human bone granules that serve as a scaffold for osteoconduction, but the graft material is eventually remodeled to living bone. Bio-Oss is a preparation of sterile, dense bovine cancellous granules that also serves as a scaffold for bone deposition, but the graft material is turned over to bone slowly.

Both wounds healed uneventfully, and the arch spaces were maintained with a plastic sheath on the right side (Fig 14, *A*) and an open-coil spring on the left (Fig 14, *B*). After 6 months of stabilization with no activation, all fixed appliances were removed, and clear overlay retainers were fabricated for both arches. Cooperation with the mandibular overlay retainer was inadequate; in 1 month, the left second premolar relapsed to the mesial aspect (Fig 15). Fixed appliances were reapplied to the mandibular arch with power chains and open-coil springs

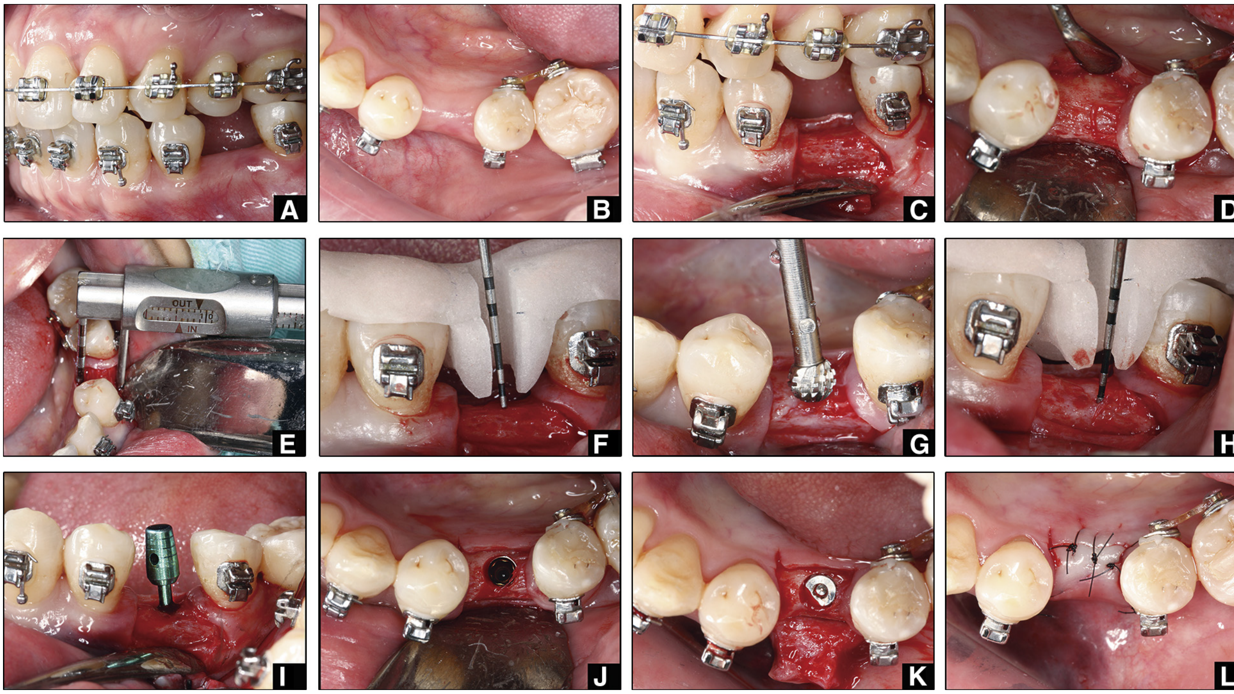

Fig 12. The steps for placing an implant in the orthodontically generated space are illustrated: **A,** the mandibular left second premolar was moved distally to produce a space between the premolars; **B,** occlusal view of the prepared implant site; **C,** a horizontal crestal incision and 2 vertical releasing incisions were made 1.5 mm from adjacent teeth; **D,** occlusal view of the exposed osseous ridge; **E,** ridge width was measured at about 6 mm; **F,** a surgical stent showed that the cervical position of the proposed crown was only 1 mm from the bone crest; **G,** crestal bone was removed with a round bur; **H,** 3 mm of clearance from the cervical contour of the surgical stent to the bone crest was created to achieve the necessary biologic width; **I,** a guide pin showed the angulation of the osteotomy; **J,** a 3.5 × 10-mm implant was placed completely within the bone; **K,** a cover screw was seated; and **L,** primary closure of the wound was achieved with 5-0 nylon.

to correct the relapse (Fig 15). After 5 months of retreatment, the second premolar was repositioned in a well-aligned arch.

The total healing time for the mandibular left implant was about 12 months, including the postoperative relapse of the space opening, along with the follow-up orthodontics to reopen the space. Implant uncovering was accomplished with horizontal and vertical incisions made with number 12 and 15 blades, respectively (Fig 16, *A* and *B*). An apically positioned flap was planned to move the keratinized tissue on the crest to the buccal aspect of the implant, but when the full-thickness flap was reflected, an osseous defect was found on the distobuccal surface of the fixture that exposed more than 2 mm of rough implant surface (Fig 16, *C*). The stability of the implant was carefully evaluated, and there was no mobility. A healing abutment was placed, and a particulate bone graft of freeze-dried bone allograft and Bio-Oss as previously described was applied on the buccal surface to cover the exposed portion of the implant. The wound was closed with 5-0 nylon. Two months after the second surgery, all fixed appliances were removed, and clear overlays were again provided to retain both arches. It was emphasized that the patient should wear the clear overlays for 24 hours a day for the first 3 months and nights only thereafter. In addition, a fixation wire was bonded between the mandibular left second premolar and second molar to prevent reopening of the space (Fig 16, *F*). A screw-retained, final implant-supported prosthesis was fabricated and installed on the implant.

The mandibular right implant-supported prosthesis was completed according to the standard protocol and functioned normally, but the patient complained that food was often impacted on the buccal surface. Clinical examination showed a 0.5-mm width of keratinized gingiva that was associated with a deep concave depression in the distal cervical area adjacent to the buccal

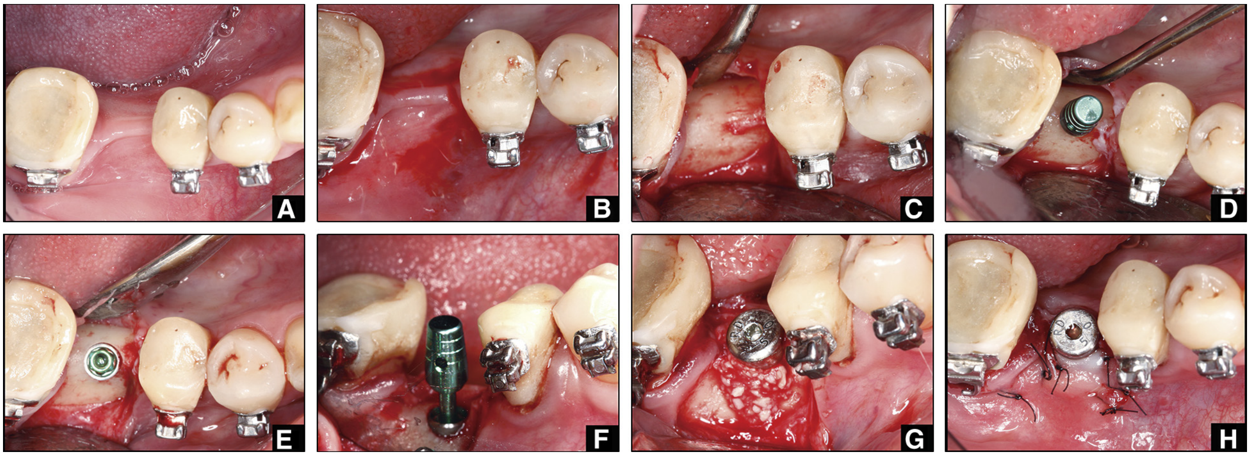

Fig 13. **A,** Occlusal view of the edentulous ridge in the area of the mandibular right first molar; **B,** a horizontal crestal incision and 2 vertical incisions were made; **C,** the edentulous ridge is exposed; **D,** a guide pin was placed to check the path of insertion relative to the osteotomy orientation; **E,** a 3.5 × 10-mm implant was placed; **F,** there was exposed implant interface (rough surface); **G,** the healing abutment was connected, and a particulate bone graft (freeze-dried bone allograft and Bio-Oss) was placed on the buccal side to cover the exposed implant surface; **H,** the wound was primarily closed with 5-0 nylon. See text for details.

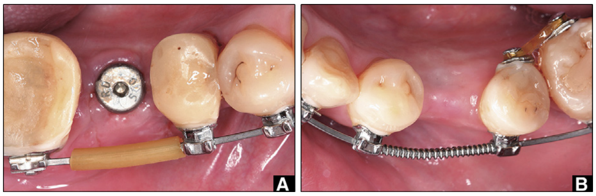

Fig 14. **A,** The mandibular right first molar space was maintained with the fixed appliances, and a plastic sheath was placed on the archwire to control soft tissue irritation; **B,** an open-coil spring on the archwire maintained the orthodontically generated implant site in the space.

vestibule (Fig 17). A free gingival graft as illustrated in Figure 18 was required in the right posterior segment to increase the soft tissue thickness, contour, and width of the keratinized gingiva. A horizontal incision was made apical to the attached gingiva from the mandibular right second premolar to the second molar, and a partial thickness flap was reflected (Fig 18, *B*). The periosteum was left intact as the recipient bed for a free gingival graft (Fig 18, *C*). Before the grafting procedure, the donor site was covered with platelet-rich fibrin that was prepared by drawing venous blood from the patient.[12] The blood was centrifuged and decanted under sterile conditions, leaving the fibrin matrix with platelets, cytokines, and growth factors (Fig 18, *D*). A 5 × 15-mm free gingival graft was harvested from the right side of the palate, all adipose tissue was removed, and the graft was sutured over the recipient site with 5-0 nylon (Fig 18, *E*). A Coe-Pak (GC America, Alsip, Ill) dressing was applied to protect the graft and to prevent the buccal flap from reattaching to the recipient bed (Fig 18, *F*). Six months later, the free gingival graft was well integrated, and the objectives were achieved: increased soft tissue thickness, improved contour, and a wider band of keratinized gingiva (Fig 19). The concave gingival area was corrected with nonmobile keratinized tissue that deflected the flow of masticated food into the vestibule, thereby reducing buccal impaction.

TREATMENT RESULTS

Overall, the dental and facial esthetics as well as the masticatory function were well managed (Figs 3 and 4; Table). The cast-radiograph evaluation[13] score was 13 points, as shown in the Supplemental material. The only significant detraction from this excellent score was buccal tipping and insufficient occlusal contacts on the maxillary left quadrant (Figs 3 and 4). That problem was associated with the missing maxillary left canine. Achievement of ideal interdigitation and optimal posterior occlusal contacts is a common problem when a compensated occlusion lacks a maxillary canine.

The severe atrophic ridge (area of the mandibular left first molar) was successfully developed from 3 to 7 mm with orthodontic space opening. With light forces, the mandibular left second premolar was translated distally at a relatively rapid rate of 1 mm per month, and the

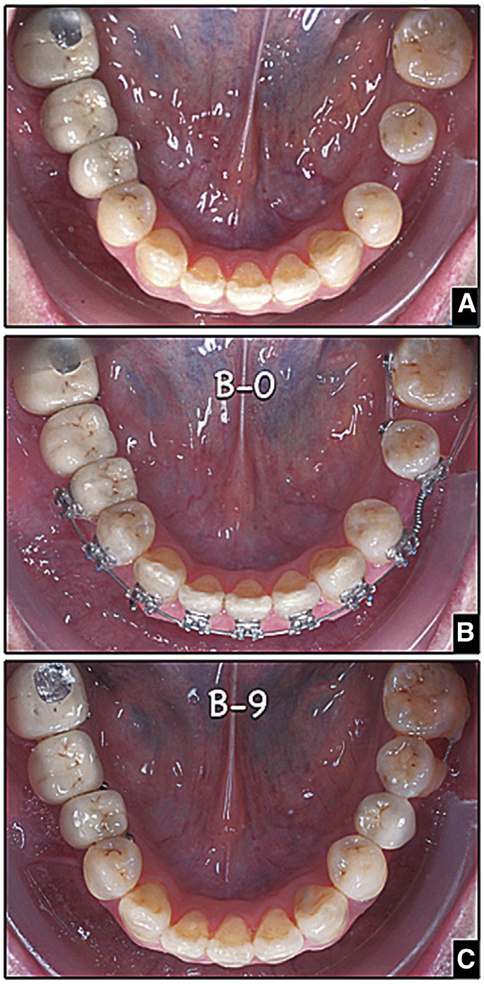

Fig 15. A, One month after the fixed appliances were removed, the mandibular left second premolar relapsed into the site where the implant was healing; **B,** *B-0* denotes the start of retreatment to correct the relapse with power chains and an open-coil spring; **C,** *B-9* is an occlusal view of the completed mandibular arch at the 3-month recall visit after treatment was completed, which was 9 months after the start of retreatment phase. A fixed retainer was bonded on the buccal surfaces of the mandibular left second premolar and third molar to prevent relapse.

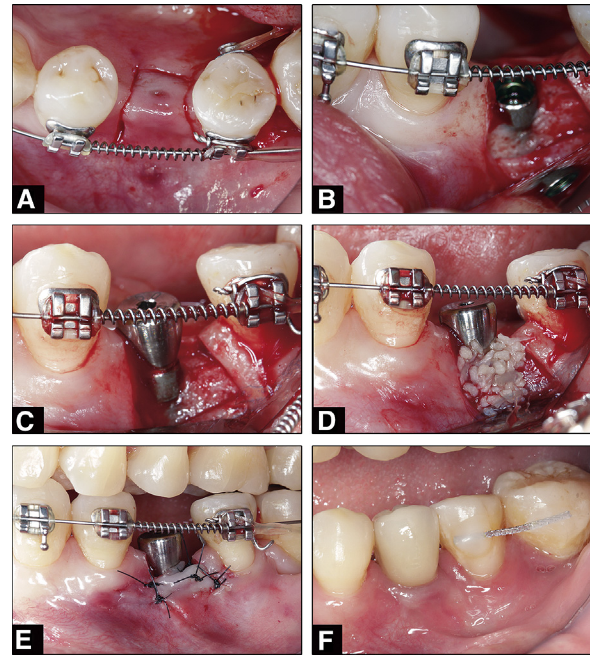

Fig 16. A, The mandibular left implant (second premolar area) was uncovered with a horizontal crestal and 2 vertical incisions; **B,** after flap reflection, >2 mm of rough implant surface was exposed; **C,** a healing abutment was installed; **D,** a particulate bone graft of freeze-dried bone allograft and Bio-Oss was placed over the exposed implant interface; **E,** primary closure of the wound was achieved; **F,** 2 months later, an implant-supported prosthesis was fabricated to restore occlusion (*center*) and a fixed retainer was bonded on the buccal surface.

only adverse effect was a slight lateral root resorption on the distal root where it engaged the most dense aspect of the knife-edge ridge (Fig 10). Occlusal function was considerably improved by restoring both mandibular first molars with implant-supported prostheses (Figs 15 and 18). The design of an apically positioned flap and free gingival graft on the mandibular right buccal surface (Fig 18) successfully increased the keratinized gingiva and improved the long-term stability of the soft tissues supporting the implant-supported prosthesis (Fig 19). The increased tissue volume and improved gingival curvature improved the flow of food during mastication, which reduced the prevalence of buccal food impaction (Fig 19).

DISCUSSION

Orthodontic tooth movement into edentulous areas is a viable option for providing a prosthesis abutment or enhancing the ridge dimensions to serve as an implant site.[3,7] A longitudinal study with an average follow-up of 9.6 years showed that the orthodontically moved teeth were well maintained with excellent gingival conditions, but there was a slight marginal bone loss.[3,8] However, radiologic evaluation often detects lateral root resorption on the pressure side of the moved tooth at the level of the knife-edge bone crest of an atrophic ridge, as shown in Figure 10.[3,7,8] The prevalence of lateral root resorption is 40.6%; the mean depth of the lesion was 0.7 mm (SD, 0.3), and the mean length was 2.3 mm (SD, 0.6).[3] In another study, lateral root resorption was found in almost all orthodontically treated teeth.[7] The root resorption was independent of periodontal

Fig 17. There was a deep concave area on the cervical portion of mandibular right implant-supported prosthesis (right first molar area) superior to the buccal vestibule. In addition, there was only a 0.5-mm width of keratinized gingiva. Although the tissue was healthy, the recessed interproximal areas were an irritating food trap for the patient.

parameters such as plaque index or gingival index, but it was directly related to orthodontic force.[8] An orthodontic load induces inflammation in the periodontium, particularly in the periodontal ligament (PDL).[14] This reaction is necessary for tooth movement, but it may also be associated with unwanted side effects such as root resorption. When a tooth is moved distally, stress can induce necrosis in the PDL on the distal side of the tooth.[15] Stress levels exceeding the necrotic threshold are associated with root resorption.[16,17] In the edentulous area, the presence of thin, predominantly compact bone at the crestal site produces the most accumulated pressure (stress) as a tooth starts to move, thereby contributing to lateral root resorption.[7] For this patient, only minor lateral root resorption was observed in the crestal area (Fig 15); it may have been related to the light continuous force (2 oz or 26.3 cN per side) that was used to translate the mandibular left second premolar distally. A serendipitous benefit associated with reduced PDL stress was rapid translation (1 mm/month) of the second premolar. This is twice as fast as initial molar movement and 3 times faster than sustained molar root movement in the posterior quadrant.[18] The relatively rapid premolar translation for this patient suggests that the levels of stress in the PDL were relatively low, resulting in continuous tooth movement that was relatively free of pressure necrosis. The force used was 26.3 cN on the buccal and lingual surfaces for a total of less than 57 cN, which is a much smaller load than typical space closure loops (3 N).[18] Another factor in accelerating the rate of tooth movement is the root morphology. A single-rooted tooth such as a mandibular premolar moves faster than a molar because the trailing root of the molar must resorb the dense bone formed by the leading root.[18] Translation of molars is another option when considering the orthodontic formation of an implant space. Molars move slower and form denser bone, but there are no documented reports for implants placed in molar-generated sites.[18]

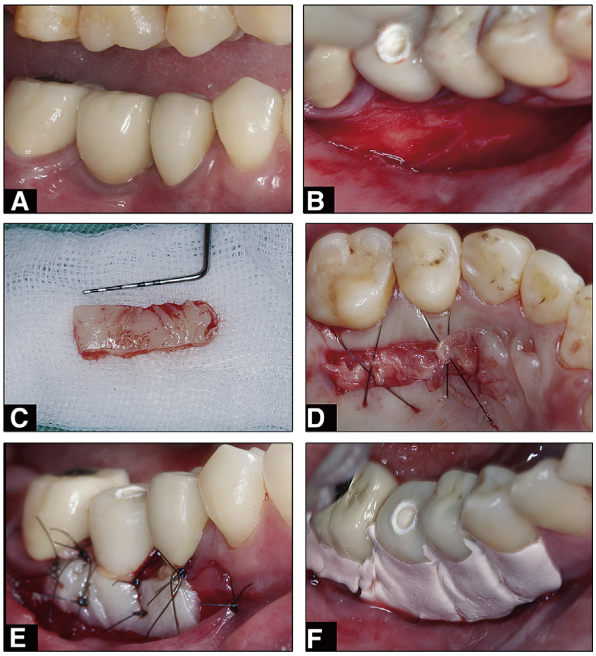

Fig 18. A, Preoperatively, a slightly more anterior view demonstrated that the recessed area on the distal aspect of the implant-supported prosthesis was the most pronounced (*center*); **B,** a horizontal incision was made apically to the attached gingiva from the mandibular right second premolar to the second molar, and a partial thickness flap was reflected; **C,** a 5 × 15-mm free gingival graft was harvested from the right palatal mucosa; **D,** the donor site was covered with platelet-rich fibrin to enhance wound healing and was cross sutured with 5-0 nylon; **E,** the free gingival graft was sutured to the recipient site with 5-0 nylon; **F,** a Coe-Pak dressing was placed to protect the graft and prevent the buccal flap from competing with the graft for attachment to the inferior portion of the recipient bed.

Previous studies have noted repair of root resorption after the termination of active tooth movement.[7,19,20] After tooth movement, areas of tooth resorption are repaired by deposition of new cementum.[19] This reparative process is time dependent and is less responsive after the application of a heavy orthodontic force.[19] All considered, the continuous light force minimized PDL necrosis, and the long retention time (6 months) may have enhanced cementum repair. Those were probably the principal factors resulting in minimal lateral root resorption, despite root translation to prepare a 7-mm wide implant site in the posterior mandible.

Fig 19. After the postoperative healing, the free gingival graft increased the width of the attached tissue (*left arrow*) and corrected the contour for food deflection into the buccal fold during mastication (*right arrow*).

Orthodontically produced potential implant sites are decreased by 11% in the buccolingual dimension at the end of space-opening mechanics, and the atrophy progressed to 15% a year later.[7] For this patient, a similar result was observed despite placing a completely submerged implant with 1.5 mm of buccal bone thickness in the orthodontically generated space (Fig 12, *J*). There was about 3 mm of crestal bone loss on the buccal surface when the implant was uncovered (Fig 16, *B* and *C*). This phenomenon is uncommon when an implant is placed in a mature osseous site. However, for this patient, there was another variable: relapse of the space in width after the implant was placed and subsequent orthodontics to recover the space for an implant-supported prosthesis. It appears that much of the bone that was resorbed when the implant was uncovered was related to the relapse incident. This clinical experience indicates that retention of implant sites created with orthodontics is important, both before and after placing the implants. It is unwise to use removable retainers because patients may not cooperate. Thus, fixed retainers are indicated until the prosthesis is delivered.

Some crestal bone resorption is common when an implant is restored and is in contact with the oral environment.[21] This phenomenon is often a biologic width violation: about 3 mm of soft tissue is required between the cervical margin of the crown and the alveolar bone crest.[22] On average, it was found that the cervical height of the bone contact can be adjusted to 1.5 to 2.0 mm below the implant shoulder when the implant is exposed, anticipating additional bone loss that will result in the desired 3 mm of biologic width.[23] When an implant is completely buried in the alveolar process, the bone is usually still covering the implant when it is uncovered. However, for our patient, the bone loss was found before the implant was exposed to the oral environment. As previously discussed, this probably was related to the immaturity of the bone when the implant was placed, but there was the added challenge of the mandibular left second premolar relapsing into the space after the implant was placed. Moving that tooth back into position was expected to generate new bone on the distal surface of the implant, but if the distobuccal bone defect on the implant had already occurred, there may have been no subsequent bone formation to refill the space. The relapse of that tooth probably resulted in resorption of all or most of the bone on the distal aspect of the implant and thereby contributed to the osseous dehiscence on the mandibular left implant when it was uncovered.

Table. Cephalometric analysis

	Pretreatment	*Posttreatment*	*Difference*
Skeletal			
SNA (°)	79	79	0
SNB (°)	76	76	0
ANB (°)	3	3	0
SN-MP (°)	45	45	0
FMA (°)	35	35	0
Dental			
U1 to NA (mm)	5.6	5.6	0
U1 to SN (°)	105	105	0
L1 to NB (mm)	9	8	1
L1 to MP (°)	97	95	2
Facial			
E-line to upper lip (mm)	2	1.3	0.7
E-line to lower lip (mm)	4.3	2.6	1.7

The alveolar process is a tooth-dependent tissue that is induced from competent neural crest cells. It develops and adapts in conjunction with the eruption or movement of the teeth.[24,25] There are fundamental requirements for both tooth eruption and orthodontic tooth movement: (1) mediation of biologically active soft tissues: ie, the dental follicle for eruption and the PDL for tooth movement; (2) regulation of both bone modeling and remodeling[25]; and (3) bone turnover (remodeling) that is temporarily and spatially regulated to facilitate specific translocations of teeth through alveolar bone.[24] When orthodontic force is applied to a tooth, the strains (proportional to stress) created in the PDL initiate many biologic processes that lead to cell proliferation and apoptosis.[26] These competing processes control the cell population in the PDL and lead to different biologic consequences for the PDL itself, as well as the alveolar bone and cementum. When orthodontic treatment is initiated, the PDL and supporting bone responds to the applied load, leading to bone resorption on the compression side and deposition on the tension side of the PDL.[27] However, there is also much modeling along the subperiosteal surfaces as well as internal remodeling of the alveolar process.[28] These bone modeling and remodeling processes continue as the tooth moves relative to the basilar bone. The volume and the shape of the alveolar process are modified accordingly. Therefore, when the tooth is moved into the narrower edentulous ridge, there is initially a high stress concentration, and lateral root resorption may occur where the PDL engages the dense knife-edge ridge (Fig 15). The compressive loading of the edentulous ridge results in subperiosteal osteogenesis to increase the ridge dimension of the site into which the tooth is moved (Fig 10).[28] In contrast, when tooth movement results in an edentulous ridge, the alveolar bone is no longer adequately loaded and undergoes disuse atrophy, which results in a decrease in the height of the ridge and loss of the buccal plate.[2] This process continues until the residual bone in the implant site reaches a steady-state equilibrium between the competitive physiologic bone formation and resorption processes.[28]

The progressive loss of bone in an orthodontically generated edentulous area is similar to the atrophy in height and width of the alveolar ridge after an extraction.[1,7,27] This healing process has more pronounced resorption on the buccal aspect than on the lingual aspect of the ridge. Araujo and Lindhe[2] in an experimental study with 12 mongrel dogs, found that the crestal region of the buccal hard tissue wall is made up exclusively of bundle bone that formed after the tooth had erupted. The lingual plate was composed of bundle bone and more mature lamellar bone that had undergone remodeling. Bundle bone is a variation of lamellar bone that is formed on bone appositional surfaces of ligament and tendon attachments, such as the PDL.[28] It is characterized by vertical striations that are mineralized PDL fibers (Sharpey's fibers) with bone formed around them. Araujo and Lindhe demonstrated that the reduced ridge dimension was more pronounced in the buccal and crestal aspects of the edentulous space, due to a high rate of bundle bone resorption. They noted that there were 2 phases related to the postoperative bone atrophy: phase 1 was surgical trauma, avascular necrosis, and wound healing resulting in loss of bundle bone and replacement with woven bone; phase 2 was sustained resorption on the outer surfaces of both the buccal and lingual plates. Although Araujo and Lindhe had no explanation for this sustained bone loss, the physiologic mechanism appeared to be biomechanics. When bone is no longer internally loaded by the root of a tooth, there is disuse atrophy of the most peripheral aspects of the bone, alveolar crest, and buccal plate.[28] In effect, disuse atrophy tends to produce bone resorption at the same time that implant wound healing and bone grafting are enhancing bone formation. This competitive process appears to be an important factor for why bone defects tend to occur on the buccal aspect (Figs 8 and 15) rather than the lingual aspect. The buccal surface is the most peripheral aspect of a curved cortical bone surface, so it is the most likely to be affected by disuse atrophy.[29]

CONCLUSIONS

Adult orthodontic patients often have missing teeth and atrophic edentulous ridges. Assuming that the adjacent teeth are periodontally healthy, a narrow ridge can be expanded with orthodontic tooth movement. The process is a distraction of the PDL to produce bundle bone: mineralized collagen bundles (Sharpey's fibers) within bone. Lateral root resorption is common when the leading surface of the root engages the dense cortical bone of the narrow atrophic ridge. Light forces for mandibular premolar translation were expected to reduce PDL necrosis and the expression of lateral root resorption, but they also substantially increased the rate of tooth movement. When space is opened between teeth to create an implant site, the newly established ridge is predominantly immature bundle bone, and it begins to atrophy in height and buccal width as soon as it is formed. Ridge augmentation is recommended at the time of implant placement to compensate for the additional expected bone loss. A fixed retainer is strongly advised for space maintenance until the implant-supported prosthesis is completed. Despite bone and soft tissue problems in the implant sites, an excellent overall outcome was achieved, as evidenced by a Cast-Radiograph Evaluation score of 13 (Supplemental material).

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SUPPLEMENTARY DATA

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