Enhancing Periodontal Regenerative Outcomes With Simultaneous Orthodontic Tooth Movement

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Abstract: Periodontal regeneration of lost tissue, including periodontal ligament (PDL), cementum, and bone, has evolved with regard to surgical techniques, biomaterials, and growth factors. Simultaneous orthodontic therapy and periodontal surgical treatment has been documented previously and shown to enhance the regenerative outcome due to stimulation of the PDL by tooth movement. This combined strategy is becoming increasingly common as clinicians explore the capabilities of a collaborative approach. This article presents a case series that documents three cases in which combined orthodontic and surgical procedures were used to enhance the regenerative outcome in challenging clinical scenarios. The article includes a review of the literature and discusses clinical factors related to increasing predictability in such cases.

Loss of the attachment apparatus around teeth, including gingiva, bone, cementum, and periodontal ligament (PDL) fibers, can lead to mobility, recession, and, ultimately, tooth loss. This loss of attachment has many etiologies, with the most frequent being untreated periodontal disease. It also can be seen following orthodontic tooth movement or when tooth-to-jaw size discrepancies exist. Inflammatory attachment loss, which is seen in periodontal disease, often results in infrabony and suprabony defects around teeth. Orthodontic movement and tooth-to-jaw size discrepancies can lead to buccal or lingual attachment loss or recession defects depending on the final tooth position and jaw discrepancies that are present.[1,2]

The goal for treating lost periodontal attachment, regardless of the etiology, is to regenerate lost PDL tissue and alveolar bone or generate new attachment apparatus at sites originally deficient in these tissues. The final objective of such treatment is the stabilization of the affected tooth/teeth. Periodontal regeneration is defined as regeneration of new supporting tissues, including alveolar bone, cementum, and PDL fibers.[3] Regeneration therapy has shown varying degrees of success; true regeneration, which can only be verified histologically, is not always achieved. Some of the factors affecting predictability include defect depth, number of defect walls, plaque control, mobility, smoking, and the surgical technique used.[4,5]

Currently, the most predictable treatment for restoring lost periodontal attachment in infrabony defects is combination therapy that includes guided tissue regeneration (GTR) with an occlusive membrane, bone replacement grafts, and, often, biomaterials.[6] Systematic reviews have shown improved clinical outcomes—mainly gain in clinical attachment level and probing depth reduction—when treating infrabony defects with GTR approaches compared to open flap debridement.[7-9]

Over the years, clinicians have sought different techniques to enhance the regenerative capacity of periodontal tissues. Minimally invasive surgical techniques were introduced to optimize blood supply, maintain wound stability, and minimize surgical trauma to treated sites.[10-12] Different biologic materials, mainly enamel matrix derivative (EMD) and recombinant human platelet-derived growth factor (rhPDGF), have been utilized to enhance the intrinsic regenerative capacity of the periodontal structures. EMD has been shown to provide improved soft-tissue healing capability and when combined with bone biomaterial may deliver comparable and often superior clinical outcomes compared to GTR.[13] Similar clinical outcomes have been seen with rhPDGF-BB compared with other regeneration treatment modalities.[13]

Another effort to modify the intrinsic regenerative potential of the periodontium is through orthodontic tooth movement (OTM). OTM is a PDL-cell-mediated event in which osteoclasts resorb areas of compression, and osteoblasts deposit new bone at areas of tension. For decades clinicians have used OTM with and without periodontal surgical therapy to aid in bony and soft-tissue defect repair. Case reports have shown elimination of infrabony defects with molar uprighting as well as extrusion and intrusion.[14-16] Forced eruption of teeth with osseous defects allows for migration of the entire attachment apparatus and crestal apposition of bone.[14,17] Intrusion of pathologically extruded teeth with periodontal defects can provide new attachment, gains in overall clinical attachment level, and osseous defect fill.[16,18,19]

More recently, grafting techniques have been combined with orthodontic tooth movement to improve regeneration outcomes. Araújo et al demonstrated in animal models that graft material does not impede orthodontic tooth movement, but rather the graft material degrades more readily in response to tooth movement. Their study also showed that compared to the control side, similar amounts of mineralized bone and bone marrow were present. In addition, PDL widening and root resorption on the compression side of both the orthodontically moved test and control teeth were similar.[20]

This case series presents several scenarios where a dual periodontic-orthodontic treatment approach was used to enhance the intrinsic regenerative capacity of the periodontium, resulting in optimal clinical and radiographic outcomes. Additionally, critical prognostic factors and supportive evidence for this dual therapy approach will be discussed.

Case 1

A 32-year-old Caucasian man with localized, severe chronic periodontitis and class 1 malocclusion presented for treatment. Clinical examination revealed a thin biotype and crowding of the maxillary and mandibular arches (Figure 1). The patient expressed interest in OTM to align his teeth, but due to the periodontal status, complete periodontal therapy was indicated prior to OTM. A deep, two-wall infrabony defect was detected on the mesial of tooth No. 19 with probing depths of 13 mm on the mesio-buccal aspect and 11 mm on the mesio-lingual. Periapical radiographs revealed the large infrabony defect extending to the apical third of the mesial root of No. 19 (Figure 2).

After initial therapy, which included scaling and root planing of indicated sites, surgical treatment was performed. Surgical therapy included flap debridement of the lower left quadrant and application of EMD to the partially contained, two-wall defect at the mesial root of No. 19. Re-evaluation of the infrabony defect approximately 2 months post-surgery revealed incomplete defect fill and minimal attachment gain. During periodontal treatment, an orthodontic evaluation was performed. Due to the patient's thin

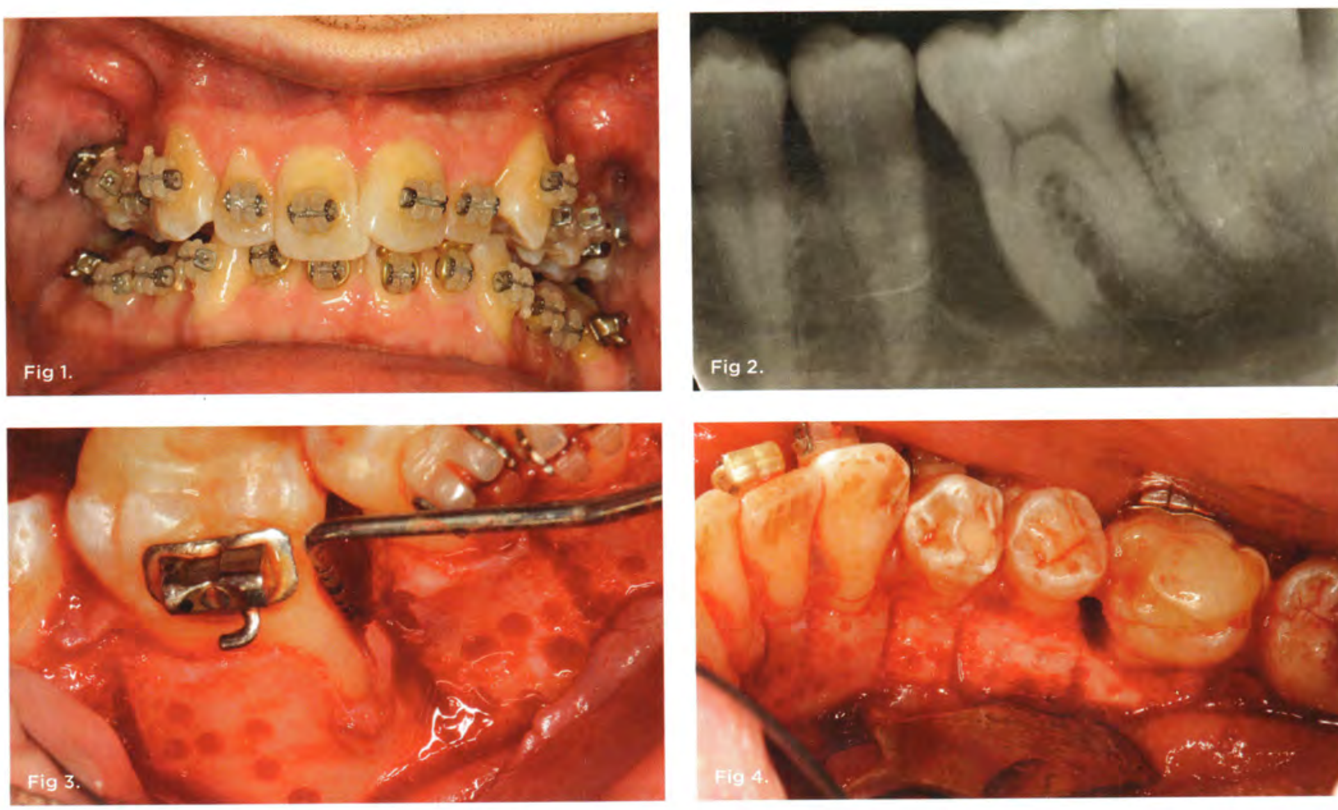
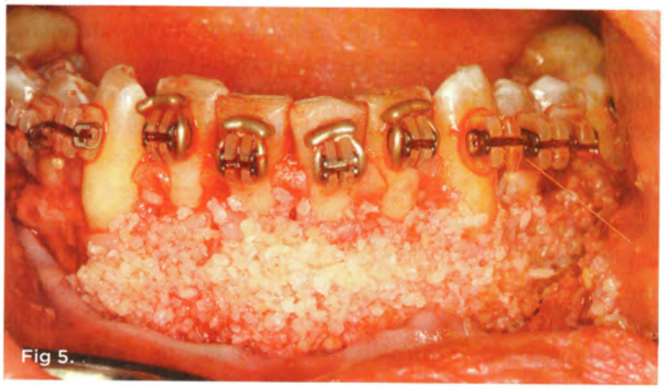


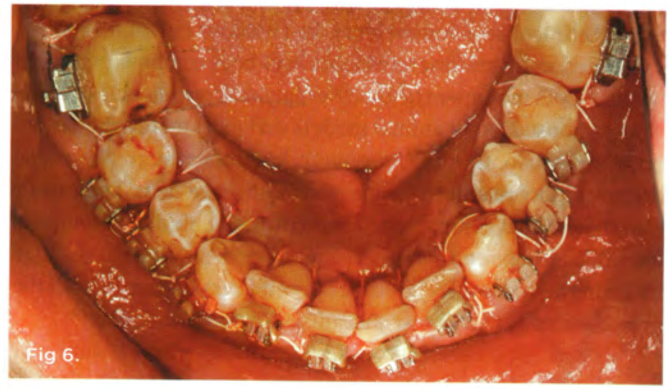
Fig 1. Pre-orthodontic photograph showed patient with class 1 malocclusion with crowding of the mandibular and maxillary dentitions. (Brackets were in place at time of photograph, though pre-orthodontic movement is shown.) **Fig 2.** Pre-orthodontic radiograph showed the extent of the infrabony defect on tooth No. 19. **Fig 3.** Full-thickness mucoperiosteal flap reflection on the buccal and lingual revealed persistent two-wall infrabony defect at the mesial of No. 19, with a depth of approximately 11 mm. Vertical and round corticotomies were made on buccal and lingual aspects of all teeth as indicated for traditional POPA procedures. **Fig 4.** Lingual view of the infrabony defect at No. 19. Note the lingual wall was intact.

biotype, minimal buccal bone thickness identified by cone-beam computed tomography (CBCT), and persistent osseous defects, a combined periodontal-orthodontic treatment plan was created. The plan included the use of full-mouth, fixed orthodontic appliances to level, align, and buccally tilt teeth in each arch combined with full-arch pre-orthodontic periodontal augmentation (POPA).

The mandibular augmentation procedure was performed 5 months after the initial attempt to regenerate the infrabony defect at No. 19. A full-thickness mucoperiosteal flap was elevated from teeth Nos. 18 through 31 with buccal and lingual corticotomies made between each tooth root (Figure 3 and Figure 4). Freeze-dried bone allograft (FDBA) reconstituted with saline was used to augment the buccal and lingual surfaces of each tooth (Figure 5). Bone graft material was also placed in the deep, residual infrabony defect at the mesial root of No. 19 (Figure 5). Primary flap closure was obtained with 5-0 polytetrafluoroethylene (PTFE) sutures (Figure 6). A radiograph taken immediately post-surgery showed the grafted defect filled with bone biomaterial.

OTM was initiated the day after the surgical procedure, and healing was uneventful. The patient remained in orthodontic therapy





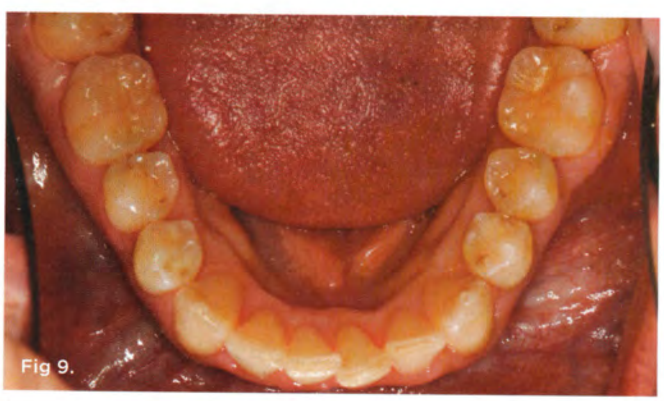


Fig 5. Buccal augmentation was indicated due to the buccal movement and tipping of the teeth during orthodontic tooth movement. Mineralized cortico-cancellous FDBA was applied to the buccal aspects of the mandibular anterior segment and the infrabony defect at No. 19. **Fig 6.** Tension-free primary closure and hemostasis was gained using a variety of simple, interrupted, and horizontal mattress sutures. PTFE sutures were used. **Fig 7.** Radiograph made 3 months post-orthodontic movement. Note the complete radiographic fill of the mesial infrabony defect and re-establishment of the lamina dura. **Fig 8.** Radiograph made 4 years post-orthodontic movement. Note the complete radiographic fill of the mesial infrabony defect with continued remodeling and re-establishment of the lamina dura. **Fig 9 and Fig 10.** Four-year post-orthodontic follow-up, occlusal view (Fig 9) and left side buccal view (Fig 10), which indicated stable, healthy gingival levels at No. 19 with no obvious signs of inflammation.

for approximately 20 months before brackets were removed. The patient sustained continuous periodontal maintenance visits and carried out avid plaque control during orthodontic treatment.

Follow-up visits after bracket removal revealed a stable, healthy periodontium with a more esthetic and functional occlusion. Specifically, clinical examination revealed healthy gingival tissue around tooth No. 19 with probing depths less than 4 mm. Following OTM, periapical radiographs of No. 19 were obtained at 3 months (Figure 7) and 4 years (Figure 8) after the mandibular POPA procedure. The radiographs showed a completely resolved mesial defect at No. 19, including a well-defined trabecular network and PDL. Clinical and radiographic evaluations of No. 19 indicated a significant gain in attachment and bony defect fill. Figure 9 and Figure 10 demonstrate post-treatment results.

Case 2

A 73-year-old Caucasian woman with chronic gingivitis on a reduced periodontium and failing endodontic therapy of tooth No. 26 presented for comprehensive treatment (Figure 11). Radiographs revealed localized, severe horizontal bone loss in the mandibular anterior region with a large periapical lesion associated with teeth Nos. 25 and 26 (Figure 12). Clinical examination revealed a thin periodontal biotype with probing depths less than 4 mm throughout the dentition and minimal inflammation. The mandibular anterior teeth exhibited moderate crowding. All mandibular incisors had recession of 3 mm to 5 mm and attachment loss of 5 mm to 8 mm with class 1 mobility. Tooth No. 26 was deemed hopeless based on attachment loss, mobility, and failed endodontic therapy.

Because predictable esthetic and restorative options are limited in these types of clinical situations, OTM was considered as an approach to resolve the crowding and align the incisors. The main treatment goals were to resolve the residual defects associated with teeth Nos. 25 and 26 and provide a functional and esthetic result without extensive prosthetic or implant therapy.

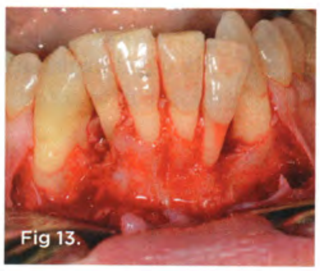
At the time of extraction of tooth No. 26, a full-thickness mucoperiosteal flap was elevated (Figure 13). Buccal and lingual corticotomies were provided around the roots of all mandibular anterior teeth, and demineralized freeze-dried bone allograft (DFDBA) was placed to augment the buccal and lingual alveolar bone (Figure 14 and Figure 15). DFDBA was also placed in the socket of No. 26 and the distal defect of tooth No. 25 (Figure 15). All bone graft material was covered with platelet-rich fibrin membranes to contain the grafting material and aid in soft-tissue healing. Tension-free primary closure and hemostasis was obtained with a series of horizontal mattress and simple, interrupted sutures using 4-0 PTFE suture material.

After 2 months of uneventful healing, orthodontic brackets were placed and OTM was initiated (Figure 16). After approximately 9 months of OTM, a leveled and aligned mandibular anterior dentition was evident. Treatment terminated when the mandibular anterior segment was aligned with closure of the space created by extraction of tooth No. 26 (Figure 17). A bonded lingual retainer was then inserted from teeth Nos. 22 through 27 to provide retention. The patient followed strict periodontal maintenance protocols and maintained intense personal oral hygiene measures throughout treatment.

Clinical examination post OTM revealed a healthy, stable periodontium with probing depths less than 4 mm (Figure 17). Recession and clinical attachment levels of the mandibular anterior teeth remained stable, ranging from 3 mm to 6 mm and 5 mm to 8 mm, respectively. Radiographic analysis throughout treatment demonstrated a progressively maturing bone fill in the area of the extracted tooth and distal defect of tooth No. 25 (Figure 12 and Figure 18 through Figure 20). Radiographs taken 2 years post-orthodontic treatment showed what appeared to be fully matured mineralized bone and PDL around tooth No. 25 (Figure 20). At the time of this writing, the patient has remained stable and functional up till the most recent re-evaluation at 4 years post-orthodontic treatment.

Case 3

A 21-year-old Caucasian woman presented with a chief complaint of orthodontic relapse that resulted in an unesthetic appearance



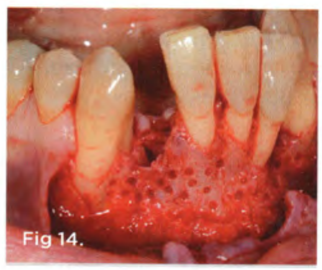


Fig 11. Mandibular anterior presented with moderate to severe crowding. **Fig 12.** Initial radiographic presentation. Note the large periapical defect that was affecting the supporting bone of both teeth Nos. 25 and 26. **Fig 13.** A full-thickness mucoperiosteal flap was elevated on the buccal and lingual aspects of the mandibular anterior teeth. Note the moderate to severe bone loss and thin buccal plate associated with all mandibular incisors. **Fig 14.** Atraumatic extraction of tooth No. 26 was performed. Round corticotomies were made on the buccal aspect of the mandibular anterior bone. **Fig 15.** Bone biomaterial was packed into the extraction socket and buccal aspect of the mandibular anterior teeth. All bone biomaterial was covered with platelet-rich fibrin membranes. **Fig 16.** Bracket placement and activation of orthodontic tooth movement, 2 months after extraction-site grafting and POPA surgery. **Fig 17.** Debonding after 10 months of orthodontic tooth movement. A fixed bar was cemented on the lingual aspects of teeth Nos. 22 through 27 to provide retention. **Fig 18.** Radiograph made immediately post-extraction and POPA surgery. **Fig 19.** Radiograph after 8 months of orthodontic tooth movement. Tooth No. 25 was being moved directly into and through the grafted extraction site of No. 26. Note the increased radiopacity of the bone biomaterial, indicating formation of mineralized native bone. **Fig 20.** At 2 years post-orthodontic tooth movement, note the continuing maturation of the grafted extraction site and the development of the lamina dura and PDL space.

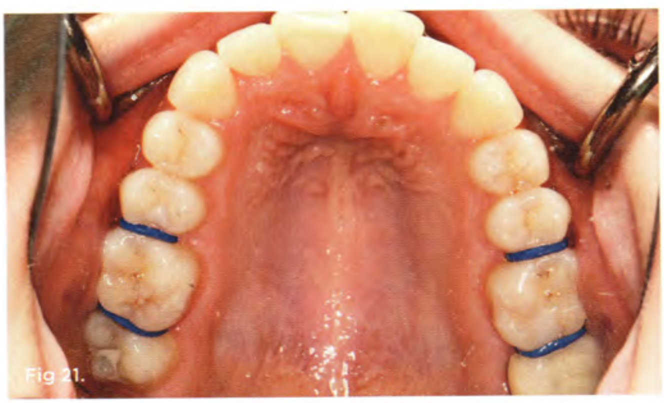
and difficult interproximal plaque control (Figure 21 and Figure 22). She described a history of 3 years of previous comprehensive orthodontic therapy as an adolescent.

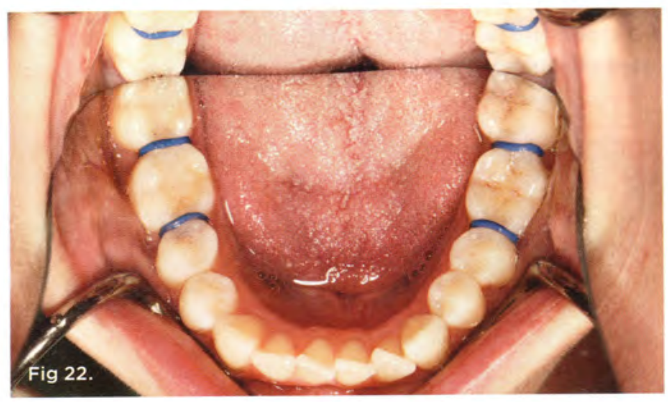
While the patient reported a noncontributory health history and no drug allergies, her dental history included severe post-orthodontic apical root resorption of most single-rooted teeth and gingival recession (Figure 23). She also presented with a mildly inflamed periodontium, a thin tissue biotype, and a tooth size–alveolar bone volume discrepancy. Initial periodontal treatment included comprehensive scaling and root planing combined with detailed home care instruction that emphasized interproximal plaque control.

After initial therapy, a combined periodontal-orthodontic treatment plan was established that included extractions of all four second premolars with maxillary and mandibular POPA treatment. Concurrent orthodontic fixed appliance therapy, aimed at leveling, aligning, and de-crowding the patient's anterior dentition, was initiated simultaneously.

During the surgical phase of treatment, teeth Nos. 4, 13, 20, and 29 were atraumatically extracted (Figure 24). Deep corticotomies were created both facially and lingually utilizing a piezoelectric surgical unit (Figure 25). All sockets and sites treated with corticotomy incisions were grafted using a mixture of two parts deproteinized bovine bone to one part demineralized bone allograft, reconstituted with venous blood. Graft material was covered with acellular dermis allograft before closure, and tension-free primary closure was achieved after flap release. The treating periodontist immediately inserted orthodontic arch wires. Postoperative antibiotics and pain control and inflammation reduction medications were prescribed.

The patient's postoperative course was uneventful. Sutures were removed at 2 weeks, and the patient was then referred back for adjustments of the orthodontic arch wires. Adjustments were routinely made every 2 weeks until OTM was successfully completed. The necessary space allocation to de-crowd the anterior teeth was achieved through the uneventful, bodily movement of the first premolar and first molar into the grafted extraction sockets (Figure 26). A functional occlusion was achieved along with a highly esthetic result that the patient both liked and appreciated. Radiographs indicated PDL re-establishment around all teeth moved into grafted extracted sites (Figure 26). The patient was provided with removable





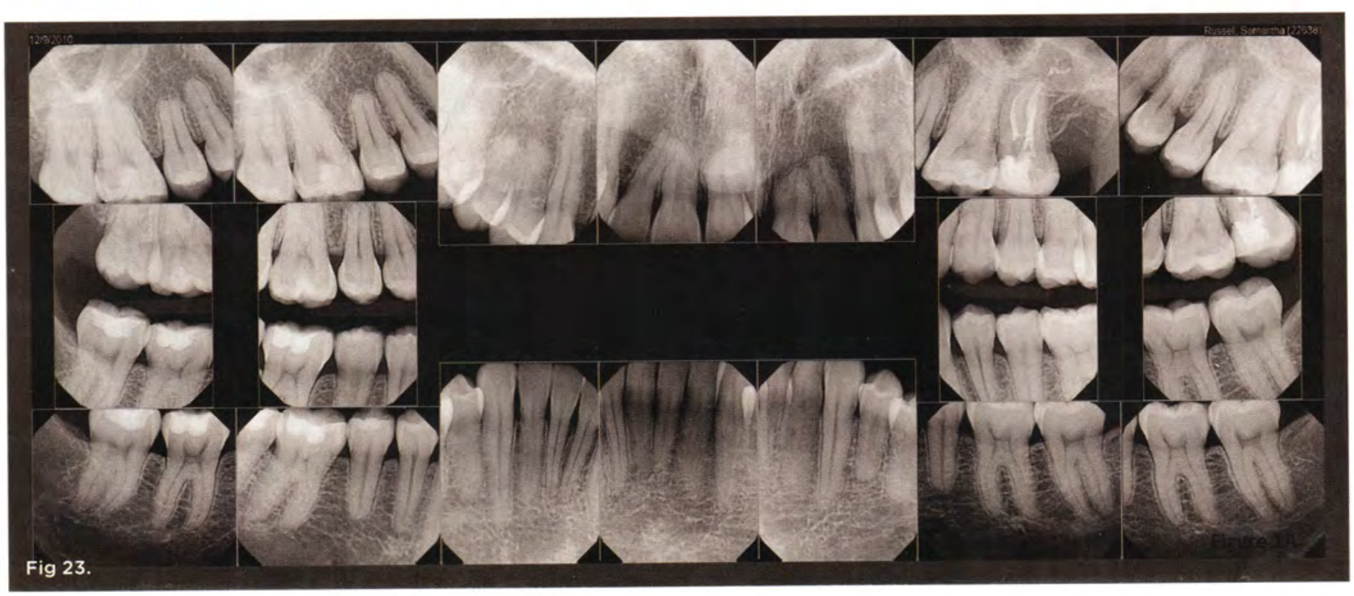


Fig 21. Maxillary occlusal view, pretreatment. **Fig 22.** Mandibular occlusal view, pretreatment. **Fig 23.** Full-mouth x-ray series. Note the root resorption of all premolars and maxillary incisors.

Hawley retention devices. After 3 years of follow-up, there was no evidence of further relapse, gingival recession, or additional apical root resorption (Figure 27).

Discussion

The innate potential for true regeneration in periodontal tissues has been studied under ideal conditions in animal models.[21,22] While such ideal situations are unrealistic for clinical scenarios, the animal models have provided biologic principles necessary for periodontal regeneration, including primary wound closure, wound stability, and space maintenance.[23] Primary wound closure is a difficult but crucial aspect of periodontal regeneration that provides protection of newly formed, immature tissue from the oral environment. Wound stability refers to the formation and stability of fibrin blood clot underneath a gingival flap and against the tooth root surface; this provides a scaffold for periodontal regeneration and prevents epithelial migration onto the root surface. Space maintenance is the term used to describe the provision of the necessary space to allow blood clot formation and the cell-mediated processes of periodontal regeneration to take place.

Periodontal regeneration depends heavily on the activity of PDL cells. PDL cells have the ability to differentiate into various cell types with the capability of forming cementum, bone, and extracellular matrix of the PDL. While bone-forming cells are important, only cells from the PDL can provide regeneration of the PDL and connective tissue attachment to root surfaces.[24] OTM has been shown to be a PDL-cell-mediated event that results in an increase in the release of molecular signaling molecules, including cytokines and growth factors, from various cells that migrate to the PDL. In addition, a significant increase in PDL cell second messengers is evident during OTM, indicating stimulation of these cells.[25] If the necessary surgical principles for regeneration can be maintained during orthodontic tooth movement, when PDL cell activity and osteogenic activity is increased, regenerative outcomes may be improved.

The cases presented in this report highlight scenarios where periodontal regeneration was achieved and most likely improved by simultaneous orthodontic therapy. Surgically assisted orthodontic therapies have been shown to expedite and enable increased OTM.[26] However, an additional and more significant therapeutic benefit of a combined approach is enhanced periodontal regenerative outcomes induced by orthodontic tooth movement.

Guided tissue regeneration and traditional POPA procedures often require the use of bone graft material and membranes. Concerns associated with the use of these biomaterials in conjunction with OTM include the prevention of tooth movement by bone grafting material, the ultimate outcome of the bone biomaterial during OTM, and the fate of the PDL in grafted sites. Resorbable

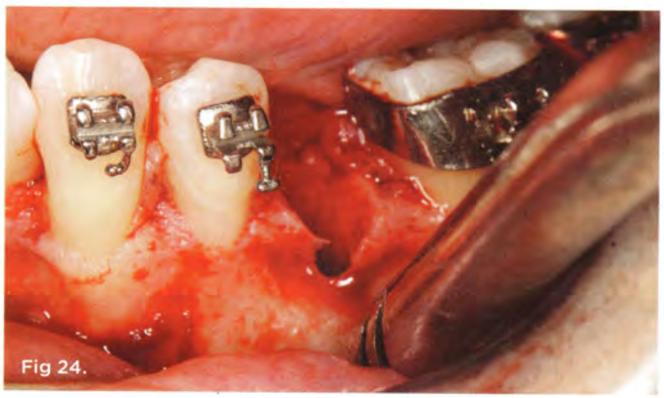


Fig 24.

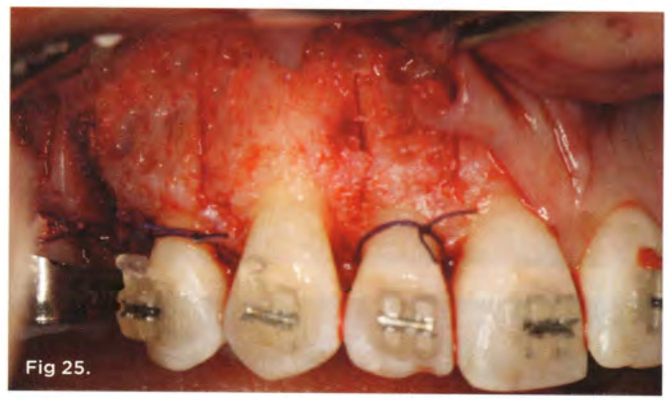


Fig 25.


Fig 26.


Fig 27.

Fig 24. Extraction socket of tooth No. 20. Second premolars in all four quadrants were extracted atraumatically. **Fig 25.** Corticotomies were made on the buccal and lingual aspects of all teeth exposed in the surgical sites. **Fig 26.** Periapical radiographs at 3-year follow-up showed mesialization of all first molars into the grafted extraction sockets of the second premolars. This radiograph shows the upper right as an example. Note the re-establishment of the PDL on the mesial of the first molar and minor clefting interproximally from the residual socket. **Fig 27.** Panoramic radiograph at 3-year follow-up. Root resorption appeared to be stable.

collagen membranes or dermal matrix materials can be used to contain bone biomaterials, prevent soft-tissue encapsulation of graft material, and help increase soft-tissue thickness. Many popular bone biomaterials used today have been investigated in conjunction with tooth movement.[27] While autogenous bone is considered the optimal material for any bone grafting procedure, promising results and even enhanced biomaterial resorptive rates have been shown with other materials when used in conjunction with orthodontic tooth movement. Araújo et al showed in an animal model that movement of a tooth through an extraction socket filled with xenograft did not impede tooth movement.[20] The histological findings of the orthodontically moved root showed typical compression side features, such as minimal root resorption, active bone resorption, and disorganized PDL fibers, in both control and test groups. The proportion of xenograft material to mineralized bone and bone marrow was smaller on the compression side of the root versus the portion of the extraction socket that was unaffected by orthodontic movement.[20] In addition, xenograft material was not found on the tension side of the root that had moved entirely from natural bone into the grafted extraction socket. The authors concluded that when xenograft-augmented sites were challenged by a physical stimulus, such as OTM, the biomaterial degraded more readily.[20]

Other animal studies have shown mixed results when evaluating tooth movement through other types of graft material, such as hydroxyapatite. These mixed results range from no adverse effects to dental malformations, inflammation of surrounding tissue, and prevention of OTM.[27] Other biomaterial like alloplastic matrices and beta-tricalcium phosphate have shown promise in regard to not hindering orthodontic outcomes, but they are limited in their augmentation qualities because they resorb so quickly.[27]

Human clinical reports have confirmed the positive outcomes of animal studies regarding tooth movement through grafted defects. Cardaropoli et al showed effective treatment of infrabony defects and malaligned teeth in the esthetic zone with a combined approach. In these case reports bony defects were treated with bovine bone biomaterial, and tooth movement into the grafted defects was successfully executed.[28-30] In other human case studies utilizing CBCT scans after periodontally accelerated orthodontic and osteogenic techniques, it has been shown that bone can be augmented with allograft and maintained over long periods of time on the buccal surfaces of orthodontically moved teeth.[31] These previously documented case reports, like the ones presented in this report, indicate the safety, efficacy, and stability of a combined periodontic-orthodontic approach.

An important consideration for any combined procedure aimed at periodontal regeneration of alveolar defects is the timing of OTM. Animal models evaluating alveolar decortications have shown that surgically induced tissue turnover peaks around 3 weeks and plateaus at approximately 11 weeks.[32] Classic periodontal regeneration and wound healing studies have shown that many of the important bone-forming and PDL-cell-mediated events occur within the first 3 weeks.[23] With surgically facilitated orthodontic treatments, it has been advocated that to take advantage of OTM during peak tissue turnover, activation of the orthodontic appliances should begin immediately or within a few weeks after the surgical procedure.[31] Although the orthodontic movements in Case 2 were not activated immediately after the surgical procedure, the authors believe that to ensure maximum regenerative potential, the activation timing should be initiated as soon after surgery as possible.

In each of the presented cases, a combined periodontic-orthodontic approach was used to address a variety of issues simultaneously. Obviously, the need for orthodontic treatment, whether it be limited or comprehensive, is a prerequisite for a combined approach. Additional prerequisites are factors that apply to classic orthodontic and surgical regeneration cases, such as thorough execution of cause-related therapy, including plaque control with adequate home therapy, and initial gingival inflammation control through scaling and root planing. Orthodontic cases either with a thin periodontal biotype or that require alveolar expansion due to crowding are indications for simultaneous augmentation procedures and surgically facilitated orthodontic therapy. Adult orthodontic patients with localized, infrabony defects (eg, Case 1) associated with normally oriented or tipped teeth that require either limited or comprehensive orthodontic treatment are ideal cases for a combined approach. Other indications include dental arch expansion or space consolidation where teeth may be moved into extraction defects (eg, Case 2 and Case 3). In addition, bodily movement and intrusion and extrusion of teeth with the presence of infrabony defects are also indications for a combined approach.

Conclusion

The main reason for combining surgical periodontal therapy and OTM is to take advantage of stimulated cellular activity and the subsequent osteopenic environment created by the respective individual therapies. The significant benefit of a combined case is the increased alveolar bone and periodontal cell activity, which improves the innate regenerative potential of the periodontium. The cases presented in this series demonstrate a few ways in which a combined periodontic-orthodontic approach may improve the periodontal regenerative outcomes of various challenging alveolar defects.

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