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Periodontal Regeneration Techniques for Treatment of Periodontal Diseases

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Two techniques with the most successful documentation of periodontal regeneration are osseous grafting and guided tissue regeneration (GTR) [1–3]. Although some regeneration may occur following regenerative procedures [4,5], it is not always predictable and complete regeneration may be an unrealistic goal for many clinical situations. This article describes the biologic basis and clinical applicability of osseous grafting and GTR and the newly developed biologic modifiers that show promising results in periodontal regeneration.

Definitions

- *Regeneration* refers to the reproduction or reconstitution of a lost or injured tissue [6].
- *Periodontal regeneration* is defined as the restoration of lost periodontium or supporting tissues and includes formation of new alveolar bone, new cementum, and new periodontal ligament.
- *Repair* describes healing of a wound by tissue that does not fully restore the architecture or the function of the part [6].
- *New attachment* is defined as the union of connective tissue or epithelium with a root surface that has been deprived of its original attachment apparatus. This new attachment may be epithelial adhesion or connective tissue adaptation or attachment and may include new cementum.

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- *Reattachment* describes the reunion of epithelial and connective tissue with a root surface [6].
- *GTR* describes procedures attempting to regenerate lost periodontal structures through differential tissue responses and typically refers to regeneration of periodontal attachment [6]. Barrier techniques are used for excluding connective tissue and gingiva from the root in the belief that they interfere with regeneration [6].
- *Bone fill* is defined as the clinical restoration of bone tissue in a treated periodontal defect. Bone fill does not address the presence or absence of histologic evidence of new connective tissue attachment or the formation of new periodontal ligament [6].
- *Open probing clinical attachment* is used to describe the tissue seen at re-entry surgery after regeneration procedures [7]. This term has not been commonly used because the clinical attachment cannot be probed in the open environment.

Biologic foundation

Surgical debridement and resective procedures are the traditional surgical treatments used to improve clinical disease parameters and arrest its progression [8–11]. Few reports of minimal regeneration of bone and the tooth-supporting structures after these therapeutic treatments have been described [12]. These methods typically heal by repair, forming a combination of connective tissue adhesion/attachment or forming a long junctional epithelium [13,14].

The concept of ''compartmentalization,'' in which the connective tissues of the periodontium are divided into four compartments—the lamina propria of the gingiva (gingival corium), the periodontal ligament, the cementum, and the alveolar bone—was developed by Melcher in 1976 [15]. From this concept of compartmentalization, GTR procedures developed and barrier membranes were used to accomplish the objectives of epithelial exclusion: cell/tissue repopulation control, space maintenance, and clot stabilization [3,16,17]. GTR is based on the exclusion of gingival connective tissue cells and the prevention of epithelial downgrowth into the wound. By exclusion of these tissues, cells with regenerative potential (periodontal ligament [PDL], bone cells, and possibly cementoblasts) can enter the wound site first and promote regeneration.

Wound healing principles

Research confirms that periodontal surgical wounds go through the same sequence of healing events as all incisional wounds: the formation of a fibrin clot between the flap margin and the root surface and replacement of this fibrin clot by a connective tissue matrix attached to the root surface [18]. When the ''fibrin linkage'' is maintained, it allows for a new connective

tissue attachment to the root surface. In the case of the fibrin linkage being disrupted, a long junctional epithelium–type attachment results [19]. Regenerative failures may be a direct result of the tensile strength of the fibrin clot being exceeded, resulting in a tear [19]. A potential cause of this tear is mobility of the flap (wound margin) adjacent to the potential regenerative site [20]. During the healing of periodontal wounds, there is the presence of multiple specialized cell types and attachment complexes, stromal–cellular interactions, diverse microbial flora, and avascular tooth surfaces that complicate the process of periodontal regeneration [21]. More predictable outcomes following GTR procedures will be achieved as the principles involved in the periodontal wound healing process are better understood.

Techniques used for regeneration

Root surface conditioning

Root surface conditioning with tetracycline or citric acid has been used as a part of regenerative procedures [22,23]. Root surface conditioning was originally suggested because of the ability of acid to modify the root surface by "detoxifying" it [24]. Root surface conditioning also showed that collagen fibrils were exposed within the cementum or dentin matrix [25]. Although animal studies demonstrated new connective tissue attachment following acid demineralization, histologic evaluation in human clinical trials demonstrated limited connective tissue attachment and limited regeneration following citric acid demineralization [26–28]. Recent studies showed that using ETDA, which has a less acidic pH, may also expose collagen fibers and thus promote cell attachment without having a damaging effect on the surrounding tissues [29]. Results from clinical trials using any type of root conditioning agent indicate no additional improvement in clinical conditions [27,30]. A recent meta-analysis systematic review confirmed that the use of citric acid, tetracycline, or EDTA to modify the root surface provides no clinically significant benefit of regeneration in patients with chronic periodontitis [31].

Coronally positioned (advanced) flaps

The periosteum is viewed as having regenerative potential due to its rich structure in osteoprogenitor cells [32]. The regenerative potential is thought to result from a combination of the cellular activity of the periosteum and a barrier-type effect by the repositioned periosteum. When coronally positioned flaps are used to treat mandibular class II furcation defects, the position of the flap margin is away from the critical healing area (the furcation site) and secured [33]. An approximate mean of 50% to 65% (by volume) bone fill in class II mandibular furcation defects has been reported

in studies that performed re-entry surgeries [32]. It is necessary to test a larger number of patients with a longer follow-up period to fully evaluate this technique.

Bone replacement grafts

Bone replacement grafts include autografts, allografts, xenografts, and alloplasts. Bone replacement grafts are the most widely used treatment options for the correction of periodontal osseous defects [34]. It has been proved that bone replacement grafts provide clinical improvements in periodontal osseous defects compared with surgical debridement alone. For the treatment of intrabony defects, bone grafts have been found to increase bone level, reduce crestal bone loss, increase clinical attachment level, and reduce probing pocket depths compared with open flap debridement procedures [34]. Their benefits for the use of furcation defects remains to be determined.

Extra- and intraoral donor sites for autogenous bone grafts

Due to their osteogenic potential, autogenous bone grafts of extra- and intraoral sources have been used in periodontal therapy. Iliac grafts have been used fresh or frozen. Successful bone fill has been demonstrated using iliac cancellous bone with marrow in furcations, dehiscences, and intraosseous defects of various morphologies [35,36]. One common complication is root resorption when using fresh grafts [35]. Iliac grafts have had only limited use because of the difficulty in obtaining the graft material, morbidity, and the possibility of root resorption.

The maxillary tuberosity or a healing extraction site is typically the donor choice for intraoral cancellous bone with marrow grafts. Intraosseous defects grafted with intraoral bone have demonstrated bone fill equal to that obtained with iliac grafts [37–40]. A mean bone fill range of 1.2 to 3.4 mm (filling greater than 50% of the initial defect) has been reported with intraoral grafts [38,40]. Other techniques report bone fill using cortical bone chips [39] and osseous coagulum or bone blend–type grafts [37]. Studies report histologic evidence of regeneration and new connective tissue attachment and the presence of a long junctional epithelium following these procedures [41,42].

Allogenic bone grafts

Allografts involve bone taken from one human for transplantation to another. Iliac cancellous bone and marrow, freeze-dried bone allograft (FDBA), and decalcified FDBA are the types of bone allografts widely available from commercial tissue banks. Grafts are taken from cadaver bone and typically freeze-dried and treated to prevent disease transmission. Typically, frozen iliac allografts are not used due to the need for extensive

cross-matching to decrease the likelihood of graft rejection and disease transmission.

Freeze-dried bone allograft. FDBA works primarily through osteoconduction. The graft does not activate bone growth but acts like a scaffold for natural bone to grow into. Eventually the graft is resorbed and replace by new bone. Freeze-drying the bone decreases the antigenicity of the allograft. Radiographically, FDBA appears radiopaque because it is not demineralized. When using FDBA to treat periodontal defects, trials indicate bone fill ranging from 1.3 to 2.6 mm [43,44]. Using a combination of FDBA with tetracycline has also shown promise in the treatment of defects resulting from juvenile periodontitis [45,46].

Demineralized freeze-dried bone allografts. Urist [47] showed that demineralized FDBA (DFDBA) was osteoinductive (Table 1). DFDBA is believed to induce bone formation due to the influence of bone-inductive proteins called bone morphogenetic proteins (BMPs) exposed during the demineralization process. DFDBA is therefore thought to be osteoinductive and osteoconductive.

DFDBA has demonstrated periodontal regeneration in controlled human histologic studies. Significantly more regeneration was achieved with DFDBA than in nongrafted controls [2,5]. Superior gains in bone fill with DFDBA compared with open-flap debridement have consistently been reported [34]. Human trials using DFDBA have demonstrated bone fill similar to that achieved with FDBA, ranging from 1.7 to 2.9 mm [44,48]. It has been observed in several re-entry studies that grafting with DFDBA yields equal or better results than other graft materials and is always superior to debridement alone when used for the correct indications [49].

Studies have demonstrated that preparation of allograft material can differ from one distributor to another and that the material may differ in its

Table 1
Comparison of freeze-dried bone allograft and demineralized freeze-dried bone allograft

FDBA	DFDBA
Not demineralized	Demineralized
Better space maintenance	More bone morphogenetic protein expression potential
Slower resorption rate compared with DFDBA	Possible osteoinduction
Osteoconductive	Osteoconductive
More radio-opaque	More radiolucent
Breakdown by way of foreign body reaction	Rapid resorption
Primary indication: bone augmentation associated with implant treatment (eg, guided bone regeneration, sinus grafting, ridge augmentation)	Primary indication: periodontal disease associated with natural tooth

biologic activity [50–52]. DFDBA may vary from batch to batch. Some studies suggest that the quantity of BMPs is too small to induce bone formation and that bone formation occurs by other processes. Commercial bone banks do not verify the specific amount of BMPs or the levels of inductive capacity in any graft material. The development of stricter bone bank standards that evaluate the potency of their preparations, including (1) using bones from individuals under a specific age, using bones from individuals free of bone diseases [53], or using fresh bone, and (2) developing assays that can test the inductive capacity of the material before sales [50], may lead to more consistent and reliable clinical results.

Human mineralized bone. Puros (Zimmer Dental, Carlsbad, California) is a new allograft of cancellous bone on the market. It is human bone that undergoes a tutoplast process involving (1) delipidization with acetone and ultrasound, (2) osmotic treatment, (3) oxidation with hydrogen peroxide to destroy unwanted proteins, (4) solvent dehydration with acetone to preserve the collagenous fiber structure, and (5) low-dose gamma irradiation. Manufacturers believe that this new solvent preservation method preserves the trabecular pattern and mineral structure better than the freeze-drying process, thus being a more osteoconductive material. To date, no controlled clinical trials have compared Puros with other allografts (Table 2).

Grafton demineralized bone matrix (DBM). Grafton DBM (BioHorizons, Birmingham, Alabama) is processed from cadaver long bones by aseptically processing the bone to remove lipid, blood, and cellular components before it is frozen. Cortical bone is milled into elongated fibers of 0.5 mm in diameter or pulverized into particles of 100 to 500 μm. It is combined with a glycerol carrier to stabilize the proteins and improve the graft handling. It can be used in the flex form, as putty, or as matrix plugs (see Table 2) [54,55].

Alloplasts

Alloplastic materials are synthetic, inorganic, biocompatible, or bioactive bone graft substitutes. Alloplast materials are believed to promote bone healing through osteoconduction [6]. Currently, six types of alloplastic materials are commercially available: hydroxyapatite cement, nonporous hydroxyapatite, porous hydroxyapatite (replamineform), beta tricalcium

Table 2
Comparison of allografts

Allograft	Process	Protein	Mineral	Trabeculation	Remodeling
FDBA	Freeze-dried	Yes	Yes	No	Long
DFDBA (eg, Grafton)	Freeze-dried	Yes	No	No	Short
Human cancellous bone (eg, Puros)	Solvent	Yes	Yes	Yes	Short

phosphate, polymethylmethacrylate/hydroxyethylmethacrylate (PMMA/HEMA) calcium-layered polymer, and bioactive glass. Ideally, alloplast bone substitutes should have the following properties [56]: (1) biocompatibility, (2) minimal fibrotic reaction, (3) the ability to undergo remodeling and support new bone formation, (4) similar strength comparable to cortical/cancellous bone, and (5) similar modulus of elasticity comparable to bone to prevent fatigue fracture under cyclic loading.

Tricalcium phosphate and bioactive glass are absorbable. Porous and nonporous hydroxyapatite materials and PMMA/HEMA polymer are nonabsorbable. Grafted sites using nonporous and porous materials have shown significant clinical improvement compared with nongrafted controls and remained stable for a 5-year follow-up [57]. Defects grafted with tricalcium phosphate and PMMA/HEMA polymer have also shown significant clinical improvements compared with nongrafted controls [58,59].

Similar clinical results have been found when bone allografts and alloplasts are compared [60,61]. Histologically, however, alloplast grafts tend to heal encapsulated by connective tissue with minimal or no bone formation [62]. Some histologic evidence shows that a very limited amount of regeneration may be possible following PMMA/HEMA polymer grafts [63].

Bioactive glass is made from calcium salts, phosphate, sodium salts, and silicon [64,65]. Silicon forms a silica gel layer that promotes formation of a hydroxycarbonate-apatite layer. On this layer of hydroxycarbonate-apatite, osteoblasts are claimed to proliferate and form bone [66]. Mixed results have been reported in clinical studies evaluating bioactive glass particles [64,65,67]. Overall, histologic evaluation of bioactive glass shows limited regenerative potential, with minimal bone regeneration and no signs of new cementum or periodontal ligament [68].

Overall, the effect of alloplast material has been inconsistent [34]. It appears that alloplastic materials function as nonirritating fillers.

Xenografts

A xenograft (heterograft) is a graft taken from a donor of another species and is referred to as anorganic bone [6]. Proprietary processes are suggested to remove all cells and proteinaceous material. What is left behind is inert, absorbable bone scaffolding. It is on this scaffolding that revascularization, osteoblast migration, and woven bone formation supposedly occur [69]. Resorption of xenografts has been reported to occur very slowly [69].

To date, there are minimal clinical data supporting the use of xenografts in periodontal defects; only one study shows improvements in clinical parameters similar to DFDBA [70]. Positive clinical outcomes were reported when the combination of bovine hydroxyapatite and collagen membrane was used for the treatment of intrabony defects [71,72]. Signs of periodontal regeneration have been reported with xenografts [70,72]; however, most data support a bone fill or repair of bone for guided bone regeneration around implants, sinus lift procedures, and ridge augmentation [73,74]. Recently,

concern about the risk of transmission of prion-mediated diseases from bovine-derived products has arisen [75]. It should be noted that prions have not been found in bone. The World Health Organization has labeled bone as type IV (no transmission) for prion diseases [76].

Guided cell repopulation/guided tissue regeneration

The concept of GTR is based on the exclusion of gingival connective tissue cells and prevention of epithelial downgrowth into the wound, thereby allowing cells with regenerative potential (PDL and bone cells) to enter the wound first. GTR has proved to be more effective than open-flap debridement in the gain of clinical attachment and probing depth reduction in the treatment of intrabony and furcation defects [77]. Absorbable and nonabsorbable membranes have been advocated and no differences have been detected among barrier types [77]. Because nonabsorbable membranes require a second surgical procedure for removal, biodegradable membranes are now commonly used [43].

Nonabsorbable membranes

The first nonabsorbable membrane available was made of expanded polytetrafluoroethylene. This membrane is composed of two parts: (1) a coronal collar with an open microstructure allowing ingrowth of connective tissue but preventing apical migration of the epithelium and (2) the remaining occlusive part that prevents the gingival tissue from interfering with the healing process at the root surface. Studies using expanded polytetrafluoroethylene to treat intraosseous defects show bone fill averaging approximately 3.0 to 5.0 mm with or without graft materials [30,78]. Results tend to vary depending on the type of defect treated. Three-wall defects typically respond the best [30,79].

Although nonabsorbable membranes are superior to open-flap debridement, they do not appear to be superior to DFDBA alone. No significant differences were found between sites treated with an expanded polytetrafluoroethylene membrane plus DFDBA versus allograft alone [80]. The use of DFDBA in combination with barrier membranes has questioned the value of adding bone graft materials for this type of defect [81]. For the treatment of mandibular class II furcation defects, significant clinical improvement has been shown [82]. The treatment of furcation defects with a combination of GTR barriers and bone replacement grafts appears to produce greater clinical improvements than GTR alone [83].

Absorbable membranes

Currently, polylactic acid and collagen membranes have reported clinical improvements comparable to nonabsorbable membranes [84–86]. The main

advantage of absorbable membranes is that they do not require a second surgical procedure.

Collagen membranes are also effective in inhibiting epithelial migration and promoting new connective tissue attachment [85,87,88]. An advantage of collagen membranes is their hemostatic function of inducing platelet aggregation, which facilitates early clot formation and wound stabilization. Early clot formation and wound stabilization are considered essential for successful regeneration [89]. Collagen also possesses a chemotactic function for fibroblasts that aids in cell migration to promote primary wound closure [90]. When using bone replacement grafts and absorbable collagen membranes, clinical results are improved in furcations but not in intrabony defects [87,91].

Degradable polymers of polylactic acid, polyglycolic acid, or mixtures of both have had similar clinical results compared with other membranes [92–94]. Regeneration of periodontal tissues has been demonstrated [95]. Recently, a study comparing polylactic acid with polyglycolic acid, a type I collagen membrane in the treatment of intrabony defects, has reported similar clinical improvements for both membranes [96].

Biologic modifiers

Bone morphogenetic proteins

BMPs have unique properties in inducing ectopic bone formation [47] and new cementum formation. Several animal research studies reported improved regenerative results when BMP-2 and BMP-7 were used for the treatment of periodontal defects [97–99]. The first human study indicated that osteogenin combined with DFDBA significantly enhanced regeneration of a new attachment apparatus [100]. A higher incidence of ankylosis has been noted in animal studies [97]; however, this has not been observed in sites treated with BMP-7 [98]. Future research is needed to clearly understand the applicability of BMPs in periodontal regeneration.

Growth factors/cytokines

Transforming growth factor β, platelet-derived growth factor, insulin-like growth factor, and fibroblast growth factor act as mitogens or differential factors on regenerating periodontal tissues. Limited human clinical data are available. One human clinical trial using recombinant platelet-derived growth factor and insulin-like growth factor has shown promising results in intrabony defects and furcations [101]. Another study showed that the use of purified recombinant human platelet-derived growth factor BB mixed with bone allograft results in robust periodontal regeneration in class II furcations and in interproximal intrabony defects [102]. More studies are

needed to fully evaluate the potential of growth factors for enhancing periodontal regeneration.

Other emerging materials (enamel matrix derivative, Pep-Gen p-15)

Enamel matrix derivative is a group of enamel matrix proteins isolated from developing porcine teeth [103–107]. It has recently been approved by the Food and Drug Administration for use in achieving periodontal regeneration in angular bony defects [107,108]. The freeze-dried protein extract is solubilized in a propylene glycol alginate carrier solution. This solution is then applied to debrided and root-conditioned periodontal intrabony defects [109]. Human case reports have reported inconsistent histologic evidence of regeneration [110–112]. A recent in vivo study showed that enamel matrix derivative was not an osteoinductive material but was osteoconductive (named osteopromotive by some) [113]. Although clinical trials of enamel matrix derivative have demonstrated significant improvements in probing measurements and radiographic evidence of bone fill, long-term benefits have not been established [114]. Enamel matrix derivative appears to offer some potential for regenerative therapy around natural teeth. To determine the long-term benefit of enamel matrix derivative, additional studies are needed.

Pep-Gen p-15 is another material recently introduced for periodontal regeneration. It is a putative collagen-binding peptide that uses a combination of an anorganic bovine-derived hydroxyapatite matrix and a synthetic 15–amino acid sequence type I collagen (P-15) [115]. P-15 is a collagen-derived cell-binding peptide that is reported to attract and bind fibroblasts and osteoblasts and to promote PDL fibroblast attachment to the anorganic bovine-derived hydroxyapatite matrix carrier [116,117]. Few clinical trials have reported greater regeneration compared with open-flap debridement, DFDBA, [115], or anorganic bovine-derived hydroxyapatite matrix alone [118,119]. Additional clinical and histologic data are needed to establish true periodontal regeneration using this material.

Factors that may influence regenerative therapy

The number of bony walls and the depth of the intrabony component are critical for positive GTR results (Box 1) [120]. Defects with 3-wall defects [30,79,121] and 4 mm or greater in depth [81] achieve the best results. Thin tissues have been found to show significantly less clinical improvement and percentage of root coverage [122].

The best results have been observed in healthy, nonsmoking patients demonstrating good plaque control and compliance with recommended oral hygiene measures [86]. The effects of bacterial contamination have been noted in studies reporting an inverse relationship between observed plaque contamination of retrieved membranes and clinical attachment gain [123].

Box 1. Indications and contraindications for guided tissue regeneration

Indications
- Narrow 2- or 3-wall infrabony defects
- Circumferential defects
- Class II molar furcations
- Recession defects

Contraindications
- Any medical condition contraindicating surgery
- Infection at defect site
- Poor oral hygiene
- Smoking (heavy)
- Tooth mobility >1 mm
- Defect <4 mm deep
- Width of attached gingiva at defect site ≤1 mm
- Thickness of attached gingiva at defect site ≤0.5 mm
- Furcations with short root trunks
- Generalized horizontal bone loss
- Advanced lesions with little remaining support
- Multiple defects

Data from Wang HL, Carroll WJ. Using absorbable collagen membranes for guided tissue regeneration, guided bone regeneration, and to treat gingival recession. Compend Contin Educ Dent 2000;21(5):399–406 [quiz: 414].

Smoking, poor plaque control, and premature exposure of the barrier have often resulted in poor regeneration outcomes [124,125].

Surgical principals for regenerative therapy

Clinical applications

Common clinical uses for periodontal regeneration include the treatment of furcations, intrabony defects, and recession defects.

Furcation defects

GTR procedures compared with open-flap debridement controls show more favorable gains in vertical probing attachment level, reductions in vertical probing depth, and improvement in horizontal open probing attachment measurements. The most favorable results are in class II mandibular furcations [77,82,85]. Less favorable results are found in

Table 3
Effect of various osseous grafts on defect fill and probing depth reduction

Graft	Defect fill (%)	Probing depth reduction (mm)
Autograph	75–80	2.5–3.0
Allograft	60–70	1.7–2.0
Synthetics (alloplast)	<50	1.0
Open-flap debridement	<50	2.0

Data from Murphy K, Gunsolley J. Guided tissue regeneration for the treatment of periodontal intrabony and furcation defects. A systematic review. Ann Periodontol 2003;8; 266–302.

mandibular and maxillary class III defects [7,126] and maxillary class II defects [127,128]. The best results are found using a combination of GTR and bone replacement grafts (91% overall improvement). Least favorable results are found with open-flap debridement (15% overall improvement). GTR procedures for furcation treatment should be limited to mandibular and some maxillary buccal class II furcation defects.

Intrabony defects

GTR procedures compared open-flap debridement controls result in significantly more favorable gains in clinical attachment level and probing depth reduction (Table 3) [77–79,87]. GTR is an effective treatment modality for the management of intrabony defects. No advantage has been found with the use of grafting materials in addition to membrane barrier in the treatment of intrabony defects [77]. Therefore, additional usage of bone graft in GTR for the treatment of intrabony defects is often unnecessary.

Gingival recession defects

GTR-based root coverage has an average of 76.4% ($\pm$11.3%) root coverage. In about 33.1% ($\pm$20.4%) of the treatments, 100% root coverage has been observed. Connective tissue grafting appears to be superior to GTR-based root coverage approaches [129]. Although GTR-based root coverage procedures are clinically effective in promoting root coverage, they are less predictable [130,131]. A critical factor is adequate flap thickness ($\geq$0.8 mm in the defect area). With adequate flap thickness, there is a significant improvement in the percentage of root coverage (26.7% versus 95.9% in thin versus thick tissue, respectively) [131,132]. Therefore, case selection is critical for a positive outcome.

Technique

Suggestions for GTR placement are as follows (Figs. 1–3):

- Initial incision should be made away from the defect so that closure is not directly over the defect [133].

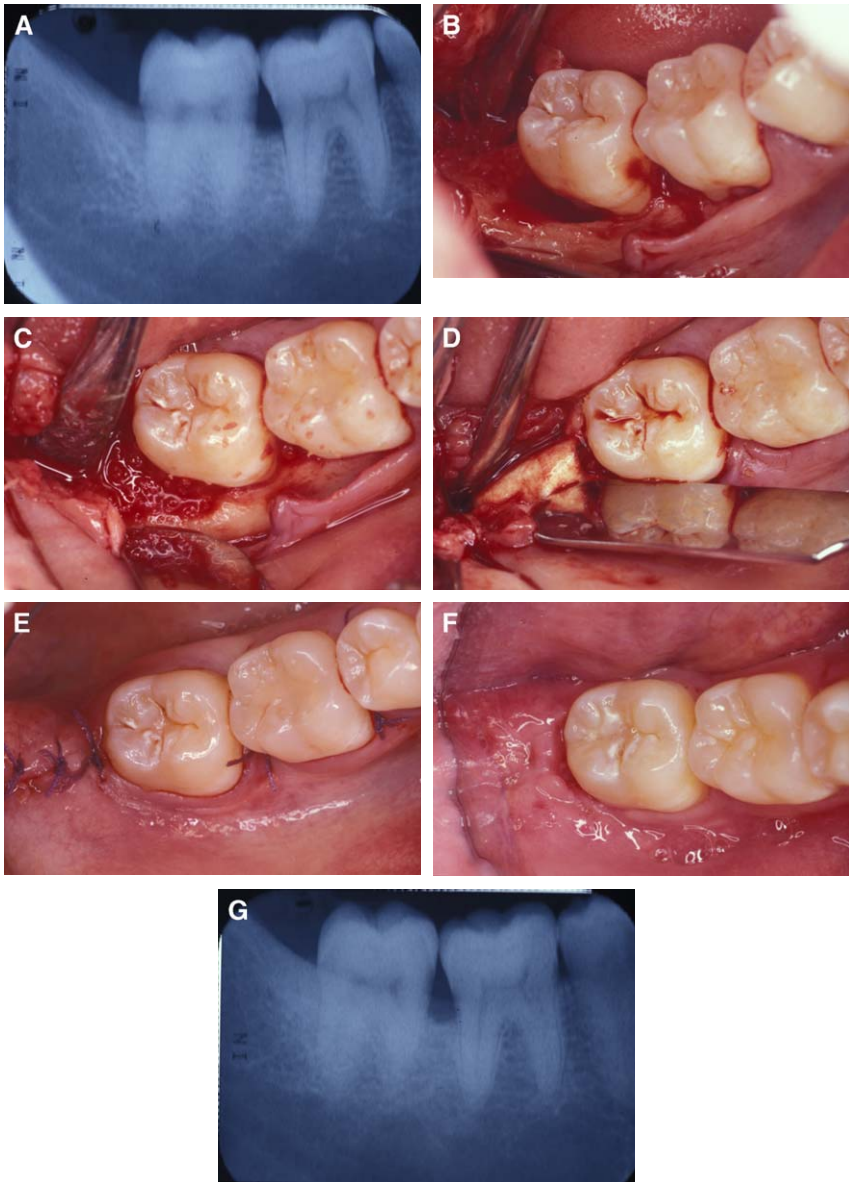

Fig. 1. (*A*) Preoperative radiograph showing the infrabony defect on the distal of no. 31. (*B*) The extent of the osseous defect (8 mm) after flap elevation. (*C*) Human mineralized allograft (Puros) placed. (*D*) Collagen membrane (BioMend, Zimmer Dental Inc., Carlsbad, California) in place. (*E*) Flap coronally repositioned and sutured with 5-0 Vicryl suture (Ethicon, Somerville, New Jersey). (*F*) Two weeks post surgery. (*G*) Postoperative radiograph at 1 year showing complete bone regeneration.

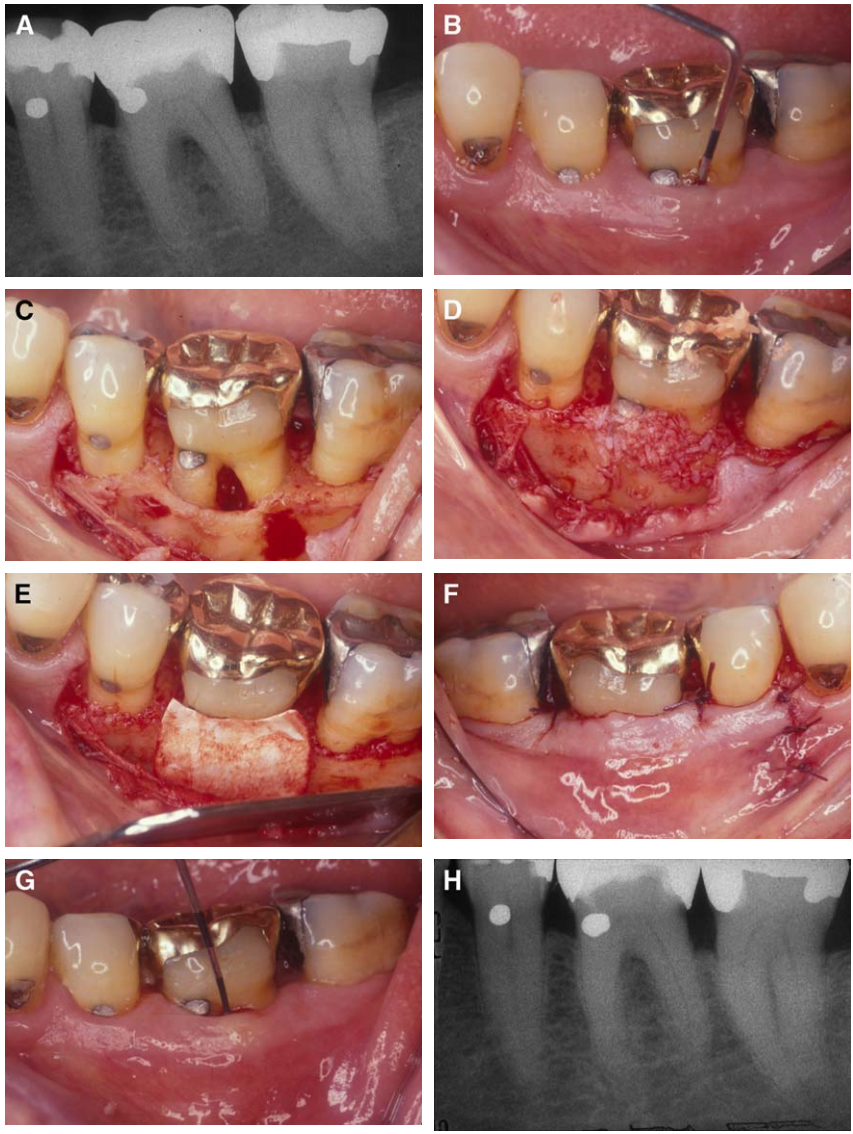

Fig. 2. (*A*) Preoperative radiograph suggesting furcation involvement on no. 19. (*B*) Intraoperative view of class II furcation with 6-mm probing pocket depth. (*C*) The extent of the furcation involvement shown after flap elevation. (*D*) Human mineralized allograft (Puros) placed. (*E*) Collagen membrane (BioMend) in place. (*F*) Flap coronally repositioned and sutured with 5-0 Vicryl suture. (*G*) One year postoperative clinical probing showing 3-mm probing pocket depth. (*H*) Postoperative radiograph at 1 year showing furcation bone fill.

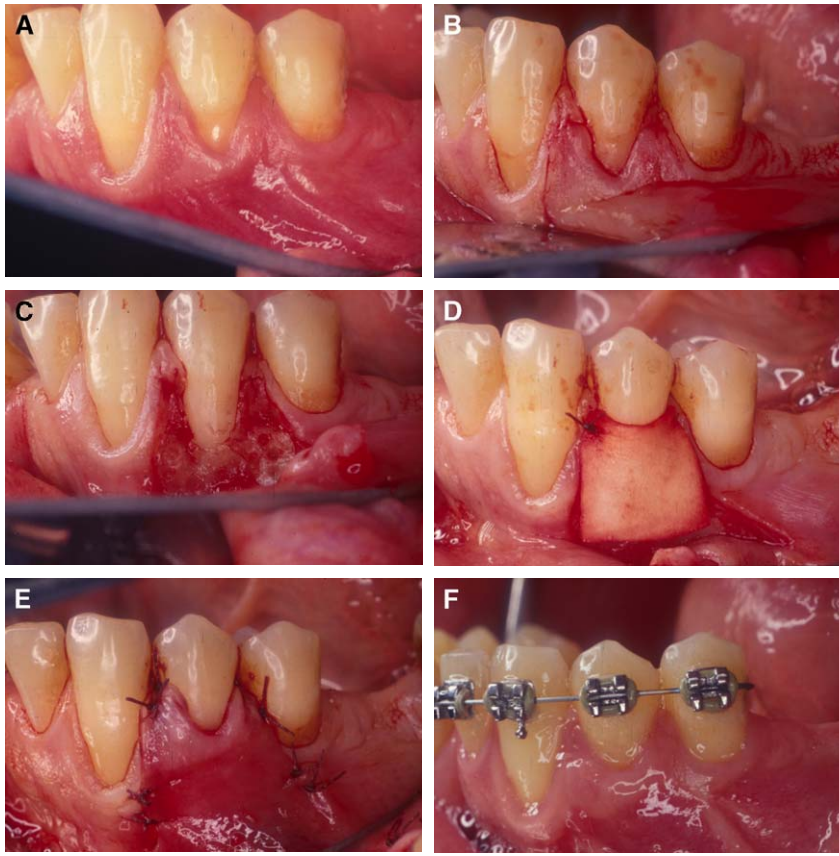

Fig. 3. (*A*) Preoperative view of a recession defect. (*B*) Initial incision (two diverging vertical releasing incisions). (*C*) Flap reflection. (*D*) Collagen membranes tacked to place with 5-0 gut suture. (*E*) Flap coronally repositioned and sutured with 5-0 silk suture. (*F*) Healing at 6 months post surgery showing 100% of root coverage.

- A full-thickness mucoperiosteal flap should be reflected 2 to 3 mm beyond the defect. Apical to the mucogingival junction, a partial-thickness flap is continued by blunt dissection to free the flap from tension [134].
- Granulation tissue is removed and curettes or burs are used to root plane and contour the exposed root surface [133,134].
- Where appropriate, interdental papillae are de-epithelialized with a blade or diamond bur to provide a bleeding tissue bed. Epithelium should also be removed from the inner surface of the flap with a sharp curette or diamond bur [120].
- The membrane should be trimmed so that it extends 2 to 3 mm beyond the margins of the defect in all directions. A trial membrane can serve as

a template for the final membrane. The membrane should be hydrated in sterile saline or sterile water for 5 to 10 minutes before use to improve handling [120].
- The flap should be trimmed if needed to achieve primary tension-free closure [120,134].
- Cortical perforations with a 1/2 round bur are made to create bleeding at the defect site to allow progenitor cells to egress from bone to the site [120,134].
- Graft material or biologic modifier is placed at the defect site to support the membrane [133].
- The membrane is adapted to the site and if stable, fixation is not necessary. If needed, pins, sutures, bone screws, or tacks can be used to achieve membrane stability [133].
- The suture site should be closed with Vicryl, expanded polytetrafluoroethylene, or silk sutures with passive tension [133]. Dressings should be used with caution because they may displace the graft material and collapse the membrane at the defect site.
- Postoperative care should consist of the following:
    - Antibiotic (amoxicillin) for a minimum of 10 days
    - Warm salt-water rinses for the first 2 to 3 weeks
    - Chlorhexidine gluconate 0.12% mouthrinse for the next 3 weeks
    - Sutures are removed at 10 to 14 days
    - Gentle brushing with a soft brush can resume at 3 weeks and flossing after 1 month
    - The surgical site is checked every 2 weeks for 2 months [120,133,134]

Summary

Several options are available for GTR and grafting materials. Many critical factors are involved to achieve optimal results, such as case selection, flap management, patient management, technique, and graft selection. Clinicians need to be able to select the proper cases for the appropriate treatment and use the appropriate graft material when indicated. As new materials are developed such as BMPs, growth factors, and enamel matrix derivative, one must evaluate the literature critically and use these materials when properly indicated.

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