Chapter 4
Decision-making algorithm for regeneration of the periodontally compromised tooth: maintaining these teeth when dental implants provide a compelling alternative treatment option

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Introduction

The use of endosseous dental implants has changed the long-held paradigm of maintaining and conserving failing teeth. Evidence of the high success rates of endosseous implants have caused clinicians to incorporate them as replacements for teeth with severe chronic periodontitis, endodontic failures, and acquired deformities including horizontal or vertical fractures to name a few (Creugers and Kreulen, 2003; Lazzara et al., 1996; Levine et al., 2002; McMillan et al., 1998; Pjetursson et al., 2004; Weber and Sukotjo, 2007). Furthermore, the decision in many cases is no longer whether or not an implant should be used, but rather how soon should it be placed in the site and then into function (Jokstad and Carr, 2007). However, meeting the challenge of the goal of preserving our patients’ natural dentition in health, comfort, and function with the appropriate esthetic outcome should remain paramount whenever this is a realistic treatment outcome.

The question of why this pervasive extraction and implant replacement philosophy has evolved over time is hard to ascertain when one looks at the available evidence. Implants have demonstrated a high level of success based on well-documented studies in the literature (Blanes et al., 2007; Feldman et al., 2004; Gottfredsen and Karlsson, 2001; Jemt and Leckholm, 1993; Steenberghen, 1989). However, the majority of these studies have been of 5-year duration or less (Feldman et al., 2004; Gottfredsen and Karlsson, 2001; Jemt and Leckholm, 1993) and evaluated machined-surfaced implants (Feldman et al., 2004; Gottfredsen and Karlsson, 2001) or other surfaces and designs (Blanes et al., 2007) that are no longer in use today. If one is to adopt this paradigm shift in treatment, then evidence-based data with larger sample sizes and with longer follow-up periods need to be considered.

When reviewing the literature for the treatment and maintenance of periodontally diseased teeth, there is sound long-term clinical evidence to support such care (Goldman et al., 1986; Hirschfeld and Wasserman, 1978; McFall, 1982; Nabers et al., 1988). First, very few teeth appear to be lost in clinical private practices following therapy and maintenance care, even when the tooth prognosis is poor. Second, most of the teeth that are lost occur in a small group of the patients (Hirschfeld and Wasserman, 1978; McFall, 1982; Nabers et al., 1988). Third, these published reports from clinical private practices range up to 10–30 years in duration, which is longer than any of the published implant retrospectives including those with surfaces that are no longer available. Table 4.1 summarizes the number of teeth lost per patient per year for these longitudinal retrospective reports.

One method by which moderate to advanced periodontally involved teeth can be maintained is regenerative therapy. The literature supports the fact that regeneration for teeth with periodontitis is a realistic goal, with human studies demonstrating histological evidence of the formation of a new attachment apparatus with a wide range of materials and techniques (Reynolds et al., 2003; Murphy and Gunsolley, 2003). To qualify as a regenerative procedure, there needs to be histological proof, in humans, of the formation of new bone, cementum, and a functionally oriented periodontal ligament.
on a root surface that was previously exposed to the oral environment.

The literature for regenerative therapy of teeth with periodontitis mirrors that which has been published for more traditional modes of periodontal care (Cortellini and Tonetti, 2004; Nabers, 1984; Nabers et al., 1988). Long-term regenerative evidence (Cortellini and Tonetti, 2004) demonstrates stability of the results achieved when maintenance care is implemented on an appropriate basis, with approximately 4% of the teeth being lost.

So why has maintaining periodontally involved teeth been abandoned when regenerative therapy has been shown to be a predictable and available treatment option? There are studies that have also demonstrated regenerative care to be highly technique sensitive (Tonetti et al., 1998) and no more successful than open flap debridement (Avera et al., 1998; Metzler et al., 1991; Pontoriero and Lindhe, 1995) around certain teeth, that is, maxillary molars. However, newer biological materials are now available that have helped to increase predictability, thereby expanding our envelope of treatment. Furthermore, algorithms of regenerative therapy have been published to increase the likelihood for success. Treating periodontally involved teeth with regenerative techniques relies on experience, an understanding of the procedures, and the evidence to reach a consistent level of success. It is the aim of this chapter to provide a decision-making tree for regenerative treatment. This pathway provides a clear picture of what evidence-based factors contribute to successful outcomes and where maintaining the periodontitis-affected tooth or teeth may or may not be appropriate.

**Review of regenerative techniques**

The acceptability of any technique into the regenerative armamentarium requires histological proof of principle of its efficacy. The traditional scientific periodontal treatment model adopted to determine whether a material or technique has regenerative potential is to notch a diseased root surface at the most apical extent of calculus and determine histologically whether the formation of new bone, cementum, and a functionally oriented periodontal ligament has taken place (Cole et al., 1980). Furthermore, it has been accepted that this should be validated in humans (American Academy of Periodontology, 1989). The materials/techniques that have demonstrated this histological end point include autogenous bone grafts (Froum et al., 1975; Hiatt et al., 1978), demineralized freeze-dried bone allograft (DFDBA) (Bowers et al., 1989), DFDBA plus bone morphogenetic protein (i.e., osteogenin) (Bowers et al., 1991), DFDBA plus platelet-derived growth factor (PDGF) (Nevins et al., 2003b), bovine-derived xenograft (BDX) layered by a collagen membrane (Mellonig, 2000), BDX coated with collagen both with and without a collagen membrane (Nevins et al., 2003a), polymethylmethacrylate/polyhydroxyethylmethacrylate (PMMA/PHEMA) + CAOH2 (Stahl et al., 1990), enamel matrix derivative (EMD) (Mellonig, 1999; Yukna and Mellonig, 2000), hydroxyapatite alloplast complexed with P-15 on citric acid-treated roots (Yukna et al., 2002), β-tricalcium phosphate (β-TCP) with PDGF (Ridgway et al., 2008), guided tissue regeneration (GTR) with an expanded polytetrafluoroethylene (ePTFE) barrier (Cortellini et al., 1993a), and combination therapy where DFDBA was layered by a bioabsorbable membrane (Harris, 1999).

The decision as to which technique/material should be used for a given defect is determined by a clinician’s preference and experience since histological evidence fails to demonstrate superiority of one material or technique over another for a given defect. For some, this decision may be based on a given technique being more user-friendly. One cannot overlook certain factors associated with case/defect selection in trying to achieve successful outcomes. It has been the preference of the authors of this chapter to use grafts and bone replacement materials for successful results, and therefore this chapter will focus on a treatment algorithm that includes the use of these materials. The following section will outline the decision-making process leading up to a regenerative treatment algorithm. Figure 4.1 will highlight the decision-making path in determining treatment.

### Table 4.1 Summary of long-term periodontal treatment in clinical private practice

<table>
<thead>
<tr>
<th>Article</th>
<th>Patients (teeth)</th>
<th>Duration (years)</th>
<th>Tooth loss rate (teeth/patient/year)</th>
</tr>
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<tbody>
<tr>
<td>Hirschfeld and</td>
<td>600 (15,666)</td>
<td>22</td>
<td>0.08</td>
</tr>
<tr>
<td>McFall (1982)</td>
<td>100 (2627)</td>
<td>19</td>
<td>0.13</td>
</tr>
<tr>
<td>Nabers et al.</td>
<td>1535 (not given)</td>
<td>12.9</td>
<td>0.02</td>
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<tr>
<td>Goldman et al.</td>
<td>211 (5761)</td>
<td>22</td>
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**Case selection criteria for formulating a decision-making tree (factors associated with successful regenerative outcomes)**

**Motivation/plaque control status**

Successful outcomes are dependent on having a motivated patient. It is atypical for the body to regenerate injured/diseased sites. Tissue repair rather than regeneration is the quickest way for the body to fend off an
Fig. 4.1 (a) First portion of the decision tree for determining the feasibility for regenerative therapy. (b) Second portion of the decision tree for determining feasibility for regenerative therapy. (c) Third portion of the decision tree for determining feasibility for regenerative therapy.
invasion. To achieve a successful regenerative outcome, the patient must be highly motivated and follow a frequent schedule of postoperative visits while complying with good plaque control and adherence to maintenance therapy. It is extremely important for the patient to understand that the healing response is a team effort—dentist, patient, and body—and that failure to minimize plaque in the surgical area will not only result in a failed response but may also worsen the situation (Nyman et al., 1977).

Studies have demonstrated the necessity for stringent plaque control for successful treatment and maintenance care with periodontal disease (Axelsson and Lindhe, 1981) and that healing in plaque-infected dentitions (Nyman et al., 1977; Rosling et al., 1976) can adversely affect periodontal wound healing, reducing clinical attachment level gains and probing depth reductions that one could possibly achieve. Furthermore, studies have demonstrated that more optimal clinical results with respect to attachment level gains and probing depth reductions can be achieved if a more frequent/thorough schedule of postoperative visits is followed immediately after surgical treatment (Westfelt et al., 1983) and even beyond this time point (Machtei et al., 1996b), minimizing the development of plaque at the site of care.

Systemic health/medications
Achieving an optimal healing response relies on the patient being free of systemic diseases that might impact wound healing. Ideally, blood supply to the site should be optimal. Diseases such as diabetes (Grossi et al., 1996; Mattson et al., 1998) and collagen vascular diseases can impair the vascular supply to the site, which may limit progenitor cells for regeneration and nutrients for the healing/newly forming tissues. In addition, if the patient has uncontrolled thyroid disease or osteoporosis or suffers from undue distress from life’s events (Boyapati and Wang, 2007), this could decrease the chances of achieving a favorable outcome. Certainly, any systemic condition that would compromise or contraindicate any form of periodontal surgical therapy (i.e., open flap debridement, osseous recontouring, soft tissue grafting) should be considered in case selection when deciding to perform a regenerative procedure.

The medications that a patient is taking should be considered when planning a regenerative procedure. For example, anticoagulants (i.e., clopidogrel, warfarin, acetylsalicylic acid) should be halted presurgically for an appropriate time if possible and this should only be done in conjunction with the prescribing physician. If these medications are not discontinued, bleeding could be excessive. Thus, site visualization could become obscured or clot formation might be either delayed or exuberant, which would be detrimental to the stability of the graft and wound, thereby compromising the results. More recently, there have been reports (Ruggiero et al., 2004) of patients who have been given either the oral or intravenous form of bisphosphonates who have experienced osteonecrosis of the jaw following dental procedures. Given that periodontal disease affects not only the supporting bone of the teeth but also the medullary bone, appropriate care must be taken. The likelihood of developing bisphosphonate osteonecrosis (BON) of the jaw in patients on the oral forms of the medication has been reported to be extremely low (Edwards et al., 2008). Nevertheless, the clinician may wish to proceed cautiously and work in conjunction with the patient’s physician to avoid a significantly adverse consequence (Edwards et al., 2008).

Smoking status
There have been a number of articles on the subject of the adverse effect that smoking has on clinical outcomes with regenerative therapies, which include both bone grafting (Rosen et al., 1996) and GTR (Hoffmann et al., 2006; Rosenberg and Cutler, 1994; Tonetti et al., 1995), and combination therapy where a bone replacement graft combined with GTR (Bowers et al., 2003). Rosen et al. (1996) reported that smokers exhibited significantly diminished improvements relative to baseline for clinical attachment level gain versus nonsmokers at 1 year postsurgical treatment. This remained true from 2 to 5 years as well. A similar but nonsignificant trend was also found for reductions in probing depth relative to pretreatment levels. Moreover, it should be noted that the smokers in these studies smoked less than one pack of cigarettes per day.

The adverse impact of smoking on the healing surgical wound may relate to the deleterious cellular effects of nicotine (Raulin et al., 1988) or its by-product, cotinine (McGuire et al., 1989), and on fibroblasts and polymorphonuclear leukocytes (Kenney et al., 1977). Smoking may also cause vasoconstriction of the gingival blood vessels, diminishing the vascular supply and healing response (Baab and Oberg, 1987). Tobacco smoking reduces the short-term oxidation–reduction potential of dental plaque, which can enhance the proportion of anaerobic bacteria (Palmer, 1988).

Prior to attempting a regenerative procedure, either a smoking cessation program should be considered or at the very least, the patient must be counseled about the diminished expectation for success. If the procedures are still performed, consideration should be given to a stringent postoperative anti-infective program including aggressive use of local and systemic agents for plaque control (Machtei et al., 2003). Additionally, the use of a periodontal dressing might also reduce the direct contact of the smoke with the healing surgical site, albeit this
benefit has never been studied. One must also bear in mind that while smoking may impair the outcome achieved, there is evidence that shows regeneration is possible even in a smoker (Mellonig, 1999).

**Pulpal/endodontic status**

It is important to determine tooth vitality prior to treatment. It cannot be assumed that the intrabony or furcation lesion is strictly of periodontal origin. Pulpal lesions do not necessarily manifest themselves at the apices of the roots but may occur along the lateral aspect of a root or in the furcation region of a molar due to accessory canals that may be present (Rubach and Mitchell, 1965; Vertucci and Williams, 1974). The use of either an electric pulp test or thermal sensitivity is essential to rule out pulpal pathosis/causality. Furthermore, it had been a long-held paradigm that prior endodontic care has an adverse influence on regenerative outcomes (Morris, 1963; Sanders et al., 1983). Prichard stated in his treatment algorithm with the intrabony defect that final endodontic fill should not be performed until after surgical success had been achieved (Prichard, 1972).

The concern with final endodontic obturation has its merits, especially if the tooth is poorly instrumented and prone to endodontic failure or if the materials used in the obturation might be cytotoxic to fibroblasts attaching to the root surface. However, an in vitro study by Dunlap et al. (1981) demonstrated that if done properly, attachment and spreading of fibroblasts can be possible. Cortellini and Tonetti (2001) also refuted an adverse effect of endodontic treatment on the healing response of deep intrabony defects treated with GTR therapy. Furthermore, they reported that GTR therapy, in deep intrabony defects, did not negatively influence tooth vitality (Cortellini and Tonetti, 2001). Figure 4.2 demonstrate that clinical regeneration, as evidenced by bone fill, is indeed possible for a class II furcation on a mandibular left second molar that had received prior endodontic care.

**Restorability**

Poorly restored teeth with overhanging/overcontoured restorations or margins that invade the furcation area could be a cofactor in the genesis of the periodontal lesion (Jeffcoat and Howell, 1980). Without their removal or correction, successful efforts to establish good plaque control could compromise the regenerative result (Fig. 4.3). It may be necessary to restore the tooth, even if it is provisionalized, until after the completion of the regenerative care. An appropriate time for finalizing the restorative work would be 6–12 months posttreatment to allow the stabilization of the regenerative outcome and implementation of an appropriate maintenance program.

The provisional should be well fitting to avoid excessive plaque accumulation. Moreover, the provisional should be removed periodically to check for temporary cement washout and recurrent caries.

**Mobility**

Mobility can be a critical determinant to tooth prognosis and treatment outcome. Retrospective evaluation from longitudinal studies has demonstrated that teeth with mobility (Fleszar et al., 1980; Wang et al., 1994) and with furcation invasion (Wang et al., 1994) are more likely to be lost. There has also been an association with baseline mobility and diminished regenerative outcomes when using GTR therapy (Cortellini et al., 2001). While no critical mobility value can be given to where treatment outcomes become affected, it would behoove the clinician to perform a thorough evaluation for both mobility and fremitus. If either are present, occlusal adjustment is indicated and quite possibly stabilization with either splinting or a removable appliance such as a Hawley with an anterior biteplane. The clinician should bear in mind that mobility patterns may also transiently increase following surgery (Galler et al., 1979). While this may not adversely affect other surgical procedures, this may be critical for regenerative therapy, where graft/clot stability is extremely important. During the postsurgical healing, it is extremely important to monitor for fremitus and mobility patterns and make corrective adjustments or interim splinting as seen fit.

**Access**

Successful treatment of periodontal disease relies on the ability to render the root free of bacterial plaque, calculus, and altered cementum. Paramount is the clinician’s ability to access the area and successfully render the root surface free of any plaque or calculus. Some of the challenges to the clinician achieving this are the location of the tooth (Metzler et al., 1991) (i.e., mesial vs. distal surface, anterior vs. posterior sextant), anatomical irregularities such as grooves or furrows (Gher and Vernino, 1980), the size and shape of the curette tip size relative to the opening of a furcation (Bower, 1979), the patient’s ability to open, gag reflex, and so on. Methods to overcome these factors include surgical access to visualize the lesion, the use of ultrasonics (Matia et al., 1986) and rotary instrumentation (Kishida et al., 2004) to gain better access to the root surface, and surgical magnification to enhance visualization of the area.

**Defect morphology and layering approaches**

Not all lesions are the same. Historically, it has been the prevailing belief that the more walls that are present to
a periodontal lesion, the greater the capacity for regeneration (Cortellini et al., 1993b). Prichard (1972) demonstrated through case reports that the three-wall intrabony lesion predictably filled with bone if the root surface was debrided and the epithelium was excluded from the lesion through soft tissue resection. An example of such a lesion is seen in Fig. 4.4. Cortellini et al. (1993) evaluated regenerative treatment using reentry procedures and found that the three-wall component was the most predictably filled while the one-wall component/lesion (Fig. 4.5) was least predictably regenerated. This similar trend has also been seen when using osseous grafts (Quintero et al., 1982; Sanders et al., 1983). Studies also suggest that the steeper the angle of the lesion, the more likely the defect will fill (Tonetti et al., 1994).

Furcation lesions have historically been the most challenging to treat with regenerative therapy (Avera et al., 1998; Pontoriero and Lindhe, 1995). The results of some
Implant site development

Once the clinician has factored into his or her decision all of these listed considerations and is able to control their potential effects, then regenerative therapy can be confidently approached.

The pathway to successful outcomes relies on understanding how to apply the most effective currently available technologies. Success is contingent upon proper planning. To this end, the authors currently embrace using a graft-biologic combination. The theory behind this is to provide an optimal bioactive scaffold that provides space, stabilizes the clot, and attracts the appropriate cells to attach and spread leading to regeneration. Furthermore, strict maintenance therapy is needed to nurture the healing site and allow for proper maturation to occur.

**Clinical decision tree**

The preliminary clinical considerations and risk factors involved in the decision to treat or not to treat a specific periodontal defect with regenerative therapy have been outlined in Fig. 4.1. When the decision has been made to proceed with regenerative therapy, there are certain treatment guidelines that should be followed to optimize success. Figure 4.6 provides an overview of the key elements to this decision-making process. Not all of the information in this section is listed in this figure.

Incisions at the surgical site should be made with the goal of achieving primary closure at the conclusion of suturing (Sanders et al., 1983). For example, if there is an
interproximal intrabony lesion, incisions should optimally try to preserve the papillary tissue (Cortellini et al., 1995; Murphy, 1996; Takei et al., 1985). Maintaining continuous soft tissue coverage at these interproximal sites might be best achieved with diagonal incisions or interproximal papillae preservation incisions (Cortellini et al., 1995; Murphy, 1996; Takei et al., 1985). Submarginal beveled incisions around the direct facial and/or palatal/lingual of the teeth being treated is another method of increasing the interproximal soft tissue coverage of the graft. To obtain proper flap reflection for tension-free closure, the flap may have to be extended one tooth mesially and/or distally to the site being treated. One other technique is to perform periosteal releasing incisions of the flap to allow for coronal advancement. This will help provide better primary graft/wound coverage and in the case of a tooth with a furcation involvement, possibly move the inner epithelial lining of the flap away from the grafted site (Gantes et al., 1988; Martin et al., 1988).

The need for surgical access is essential to allow for better visualization of the site and total root debridement (Fleischer et al., 1989; Matia et al., 1986). In many instances, there is no other way to remove all of the deposits of plaque and calculus (Brayer et al., 1989) (i.e., biofilm) and its associated endotoxin (Hatfield and Baumhammers, 1971). The use of rotary and/or ultrasonic instruments is necessary to reach areas that are inaccessible to handscalers and curettes. These areas include the base of deep intrabony lesion, the dome of a furcation (Svärdström and Wennström, 1988) and the concavities in the root (Gher and Vernino, 1980). Furthermore, calculus often penetrates into the root surface (Zander, 1953) or may have developed in cementum irregularities such as separations (Moskow, 1969) and tears and the use of a high-speed handpiece with a finishing bur will speed up what might be a very arduous manual process. Modification of the root surface with chemotherapeutic agents such as citric acid (Cole et al., 1980; Register and Burdick, 1976), tetracycline (Terranova et al., 1986), or ethylenediaminetetraacetic acid (EDTA) (Blömlof et al., 1996) is preferred by the authors. There is some question as to whether the literature supports the need for such agents. This conclusion is based to a great extent on quantitative and not on qualitative outcomes. One cannot totally discount citric acid as part of the regenerative response (Cole et al., 1980), inducing connective tissue regeneration on periodontally diseased roots (Lopez, 1984), or in its ability to remove the smear layer (Polson et al., 1984), detoxify the root (Daly, 1982), or create a surface that will stabilize the clot (Polson and Proye, 1983). Tetracycline also has been shown to have the ability to remove the smear layer while creating a root surface compatible with regeneration (Blömlof et al., 1996) when combined with other agents (Blömlof et al., 1996). Its added benefit is to minimize the negative effect that the more acidic agents may have on healthy tissues (Blömlof and Lindskog, 1995). Remember, bone does not form in an acidic environment. The conditioned root surface should

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**Fig. 4.6** Clinical decision tree outlining material implementation to achieve success.
be thoroughly irrigated with sterile saline or water following the application of the conditioning agent.

Intramarrow penetration, also referred to as decortication, is performed following root debridement to further increase the availability of progenitor cells (Majzoub et al., 1999). This may enhance the blood supply to the site and hopefully enable progenitor cells to repopulate the healing area. Intramarrow penetration is more essential when the site is chronic and the cortical bone is more intact within the lesion.

Following the application of these chemotherapeutic cleansing agents and site decortication, a biological agent should be applied to the root surface (Mellonig, 1999; Nevins et al., 2003b; Ridgway et al., 2008; Yukna and Mellonig, 2000; Yukna et al., 2002). This will facilitate the attraction of fibroblasts to repopulate this site. Care should be taken to avoid any salivary contamination at this site when performing this since contamination will compete with binding to the root and negate the positive effects. The question always arises as to what one does if there is excessive bleeding into the area, which may interfere with these agents. There is no alternative answer for this. Some clinicians advocate injecting the site with local anesthetic. However, a negative impact is possibly caused by reducing the blood supply and later by vascular rebound causing increased bleeding at a later stage. The authors advocate using nonwoven gauze strips with positive pressure to help control bleeding until a clot forms.

The use of a bone graft has been an effective means to achieve successful regeneration (Bowers et al., 1989; Froum et al., 1975; Hiatt et al., 1978; Mellonig, 2000; Nabers, 1984; Reynolds et al., 2003; Stahl et al., 1990). Historically, there have been many grafting materials used in an attempt to regenerate the lost attachment apparatus around teeth (Reynolds et al., 2003). The benefits of using a bone replacement graft include being osteogenic, as is the case with hip marrow (Dragoo and Sullivan, 1973); being inductive for the cells needed for regeneration (e.g., DFDBA) (Bowers et al., 1989); acting as a scaffold for the cells needed at the regenerative site (osteconductive); maintaining space; stabilizing the clot; excluding epithelium; and delivering a growth factor to the area to stimulate periodontal regeneration (Papadopoulos et al., 2003). Our graft preferences have been human allografts due to the enhanced attachment and spreading of human periodontal ligament fibroblasts on this material when compared with other alloplasts and xenografts (Lallier et al., 2001).

The development of biological agents has shifted the authors toward combining their use with a bone replacement graft material. There are a number of reasons for adding a biological agent to the graft. First, the combined use of a graft with a biological agent has been an effective means to achieve regeneration (Nevins et al., 2003b; Ridgway et al., 2008). Second, studies have demonstrated that the processing of a graft can diminish its biological activity (Shigeyama et al., 1995). Third, there has been a lack of inductive consistency between commercially available grafts based on the batch and tissue bank of origin (Schwartz et al., 1996). Fourth, the addition of biological agents to allografts have demonstrated synergistic effects that may improve regenerative outcomes (Nevins et al., 2003b; Papadopoulos et al., 2003; Shigeyama et al., 1995). Finally, the addition of a biological agent to a graft has always demonstrated equivalence if not superiority to the use of a biological agent alone (Gurinsky et al., 2004; Lekovic et al., 2000; Velásquez-Plata et al., 2002) or the graft alone (Hoidal et al., 2008).

The use of bone replacement grafts has been more popular versus other techniques since they present an unlimited supply and are rather easy to handle and manipulate. When placing the graft-biologic into the defect, the clinician should use light pressure since compressing the graft might occlude neovascularization into the grafted site. The authors advocate only slightly overfilling the defect with the graft-biologic to account for some possible loss. However, if overfill is too excessive, the clinician’s ability to achieve primary closure of the wound will be compromised, which may impact success. (Sanders et al., 1983)

The next decision is whether to use the graft-biologic alone (Bowers et al., 1991; Nevins et al., 2003b; Ridgway et al., 2008) or cover it with a barrier membrane (Rosen and Reynolds, 2002). Reynolds and Bowers (1996) reported that graft containment is critical to success. Defect morphology may play a role in determining if a combined graft-biologic-membrane approach is warranted. It is important to maintain/contain the graft-biologic for clot stability. In broader and/or multisurface lesions, the ability to stabilize the clot with a graft alone may be difficult. This is particularly true for moat-type defects that may occur distal to second molars following third molar extractions. The depth of these lesions, however, may not be as critical for graft containment as is the width. However, recent reports have demonstrated that combination therapy improved results compared with membranes alone at sites with deeper probing pocket depths (Tonetti et al., 2005). No study has determined what constitutes a “critical size” defect width beyond which a barrier should be placed. It has been our experience that when defect width measures 3 mm or more, a barrier should be used to contain the graft-biologic. Figure 4.7 highlight the differences between two three-wall intrabony defects. Figure 4.7a requires only a graft-biologic, while Fig. 4.7b requires the addition of a barrier membrane to contain the graft-biologic.

The use of a barrier membrane can also be important when the periodontal lesion is located at an interproximal site (Fig. 4.8) where wound edge necrosis of the flap
could lead to exposure of the graft and the newly forming granulation tissue, both of which would have an adverse impact on outcome. The use of a barrier membrane, on the other hand, when the interproximal space and lesion between teeth is narrow is contraindicated. Figure 4.9 illustrates a site where successfully fitting of a barrier membrane to aid with regeneration would have been extremely difficult and the potential for compromise of the overlying flap would have been a risk. In the case of furcation lesions, the use of a barrier membrane is
Implant site development with a graft-biologic, may adversely impact success. This may be related to the by-products produced during the degradation of the polymers, which negatively affect the biological agent. Barrier degradation can also negatively affect alloplastic bone replacement graft materials such as β-TCP. The lactic acid by-products produced in barrier absorption/biodegradation may cause early breakdown of the graft causing diminished results at the site. It is incumbent upon the clinician to evaluate what materials are being used in a given situation to avoid these adverse consequences. The authors, more recently, have favored collagen products due to their ease of use, occlusivity, and ability to allow for the slower release of some of the growth factors when soaked in them. Regardless of which membrane has been selected, the stability of the membrane, graft, and clot are essential prior to, during, and following suturing of the flap. To immobilize certain membranes, absorbable sutures may be needed to secure their position.

Flap coverage of the site following the placement of the graft or graft-membrane combination is critical for success and the next step in treatment. If flap repositioning will not completely cover the regenerative materials, coronal repositioning is recommended (Fig. 4.10a–d), which necessitates further freeing of the flap prior to its advancement. A good indication if flap coverage is sufficient is to reposition the buccal and lingual flaps back over the defect and materials and see if it passively covers the surgical site without the sutures. If there is still difficulty with coverage, particularly if this is interproximally, consider removing a small collar of the flap’s gingival tissue, which corresponds to the direct facial and lingual or palatal of the tooth. This may help increase the interproximal coverage of the site by “elongating” the papilla.

The site should be sutured with a monofilament material (Fig. 4.10d) that will minimize bacterial wicking (Leknes et al., 2005). Techniques have been offered to maintain continuous coverage of the regenerative site (Cortellini et al., 1999, 2001; Martin et al., 1988). For some, these can be very sensitive techniques to master. The important element to remember is to suture the area to allow the flap to be held firmly while not under tension, which could cause either flap tear or necrosis. The sutures, if nonabsorbable, should not be removed for at least the first 2–3 weeks following the surgery to allow for wound quiescence (Garrett and Bogle, 1993) (Fig. 4.10e).

The decision on whether or not to use a dressing resides with each clinician. There is no clear evidence that supports or refutes the use of a dressing with regenerative care. The decision must take into account whether the dressing will provide an adverse cosmetic appearance to the patient, deter the patient from eating on the site, reduce plaque control, provide the patient with...
Fig. 4.10  (a) Pretreatment view of a mandibular right first molar with a class II furcation lesion. The soft tissue barely covers the furcation area. (b) The furcation lesion has been exposed after reflection of a full-thickness flap with periosteal release. The furcation has been debrided with rotary instrumentation and citric acid. (c) A polylactic acid barrier has been sutured in place over a graft of demineralized freeze-dried bone allograft. The membrane has been coronally placed to be secured on the flat surface of the tooth, thereby avoiding a gap. (d) The flap has been coronally advanced to completely cover the graft and membrane and secured in place using a monofilament suture of expanded polytetrafluoroethylene. (e) The area of treatment at 3.5 weeks postsurgery when the sutures are removed.
greater peace of mind, or minimize the likelihood of postsurgical bleeding. If the decision is made to use a dressing, care should be taken not to compress it apically, which will reduce flap height, and to not push the dressing into the wound itself causing the sutures to open.

**Maintenance care: intervals, antibiotics, and plaque control**

Stringent postoperative care during the healing phase is essential to achieving the best results (Heitz-Mayfield et al., 2006; Machtei et al., 2003; Nyman et al., 1977; Rosling et al., 1976; Westfelt et al., 1983). Healing requires both cellular recruitment and organization/maturation of the site. Studies have demonstrated that there are certain aspects to postoperative care that are essential to avoid impeding this very delicate process. The frequency of maintenance visits is critical (Cortellini et al., 1994; Machtei et al., 1996a; Westfelt et al., 1983). It is especially important that patients be recalled every 7–14 days during the first 2 months following the surgery. Westfelt et al. (1983) demonstrated that a more frequent interval such as this will achieve the greatest gains in clinical attachment level. Beyond the first 2 months, patients should be recalled every 2–3 months for their maintenance visits. This frequency may be altered throughout the patient’s lifetime, depending on the level of plaque control, since any favorable gains in clinical attachment may diminish if the patient resumes a biannual interval (Machtei et al., 1996a).

Plaque control in the early phase of wound healing should be accomplished by both topical applications of a chemotherapeutic mouthrinse with antimicrobial benefits and through the administration of a systemic antibiotic. During the first 3–4 weeks of the postoperative period, the patient should swab the site with the mouthrinse twice daily. Most of the successful studies and case series articles listed in this chapter have used chlorhexidine products as mouthrinse. This is the agent of choice in the authors’ regimen. The reason for swabbing the site versus rinsing is to limit the potential for stain in other areas.

The use of a systemically administered antibiotic is necessary when using a bone graft since it has been associated with better bone fill in the grafted sites versus those patients that did not receive antibiotics (Sanders et al., 1983). Several studies have demonstrated how reinfection with red complex-associated bacteria at GTR sites can diminish clinical success (Cortellini et al., 1994; Froum et al., 2001; Heitz-Mayfield et al., 2006; Machtei et al., 1996a). A bactericidal agent such as amoxicillin or amoxicillin combined with clavulanic acid can help to reduce this possibility. If this is not possible, then other medications should be considered whose coverage may be similar.

Mechanical plaque control efforts are essential but should not be instituted for the first month following surgery. The belief behind this is to provide for quiescence of the wound (Anderegg et al., 1991; Gantes et al., 1988; Garrett and Bogle, 1993; Martin et al., 1988; Pontoriero et al., 1987; Rosen and Reynolds, 2002; Schallhorn and McClain, 1988), which will allow for stabilization and maturation of the clot-graft-biologic in the defect. Figures 4.11, 4.12a–e, 4.13a–g, and 4.14 provide case examples of successful clinical care with regenerative therapy following the algorithm presented.

**Complications**

A brief mention must be made concerning treatment complications. Certainly, an entire chapter itself could be devoted to this subject alone. The management of complications is best done by preventing them since once they have occurred they are, in many instances, difficult to treat. If the clinician follows the “clinical decision tree” and treatment algorithm provided, many of the complications including site infection, excessive tooth mobility, flap necrosis and graft loss, membrane exposure, and others can be avoided. These decisions have been based on exhaustive review of the evidence, prior algorithms offered by others (Cortellini and Tonetti, 2005; Froum et al., 2001) and personal experience. The following is a list of management tips.

The greatest concern is with premature exposure of the regenerative site and its underlying newly forming granulation tissue. Perforation of the flap, wound edge necrosis, traumatic oral hygiene, and food impaction are some of the reasons for its occurrence. To avoid this, patients should avoid eating on the area for at least the first month or to consider having a dressing placed. If exposure of the newly forming granulation tissue does occur, the frequency of maintenance care should be instituted on a weekly basis until the site heals over. Tonetti et al. (1994) have reported on the need to maintain wound coverage for success. The weekly recall frequency may be able to overcome the plaque burden that is placed on the site.

Posturgical bleeding is a concern for both the patient and clinician. Clear instructions must be given to the patient both verbally and in writing in case this occurs. Hand pressure with gauze over the wound for 4–5 minutes will usually control most bleeding. Should bleeding or “seeping” continue after 12 hours, the patient should be instructed to return to the dental office for professional evaluation. In the office, pressure may be applied with gauze saturated with a vasoconstrictor...
Fig. 4.11 (a) Pretreatment radiograph of an advanced osseous lesion at the distal of the maxillary left lateral incisor in a healthy 63-year-old male. (b) Pretreatment clinical view of the lateral incisor. (c) Flap reflection reveals a combination of a one-, two-, and three-wall lesion at the distal aspect of this tooth. (d) The root was treated with citric acid followed by enamel matrix derivative (EMD). The placement of freeze-dried bone allograft (FDBA)-EMD was accomplished into the defect after decortications were completed. (e) Suturing of the flap using a monofilament suture achieved primary closure. (f) Clinical view of the site at 7 years postoperative. Bleeding is currently absent and probing depth is 3 mm at the distal of the lateral incisor. (g) Digital radiograph taken at 7 years suggests stable osseous fill of the site.
Fig. 4.12  (a) Pretreatment radiograph of a maxillary left lateral incisor in a 51-year-old healthy male. (b) Pretreatment clinical view of the lateral incisor. (c) Flap reflection reveals calculus on the root and a one- and two-wall lesion that is advanced. (d) Root treatment was accomplished by hand and ultrasonic instrumentation along with a finishing bur using a high-speed handpiece. The root surface was modified with tetracycline application for 2 minutes followed by copious rinsing with sterile water and subsequent application of recombinant platelet-derived growth factor-BB (rhPDGF-BB). (e) A combination of freeze-dried bone allograft (FDBA) hydrated with rhPDGF-BB was placed into the lesion after decortications. (f) A collagen barrier was impregnated with the rhPDGF-BB and used to allow for slow release of the biological agent along with trying to contain the graft material and aid in wound stability/closure. (g) Suturing of the flaps was performed with ePTFE suture with primary closure being achieved. (h) This clinical view was taken 3 years postsurgery. The site has a clinical attachment level of 5 mm, with a probing depth of 2 mm. Mobility remains unchanged and the patient’s plaque control efforts remain good. (i) Digital radiograph suggests substantial regeneration of the site at 3 years postsurgery.
The most frequent complication reported with regenerative care has been root sensitivity (Tonetti et al., 2004). This has been reported to vary between 35% and 45% of the time (Tonetti et al., 2004) and is related to both the mechanical and chemotherapeutic management of the root. The best strategies for managing this include preparing the patient for this potential problem and instituting the topical use of fluoride agents as soon as this is reported.

**Conclusion**

Periodontal therapy has proven to be a predictable means to maintain teeth with severe periodontitis. As a part of the overall treatment armamentarium, regenerative therapies have proven successful with both short
Fig. 4.14  (a) Pretreatment radiograph suggests a class II furcation on the maxillary right second molar of a 49-year-old healthy male. (b) Presurgical clinical view of this area following local anesthesia. (c) Flap reflection reveals a class II furcation confined to the buccal aspect of this tooth. The lesion was treated with rotary and ultrasonic instrumentation, citric acid root conditioning, intramarrow penetration, and application of EMD to the root surfaces. (d) Beneath this polylactic acid barrier is freeze-dried bone allograft (FDBA) mixed with EMD. (e) The flap was coronally advanced and secured with ePTFE sutures. (f) Reentry procedure at 9 months postsurgery demonstrates complete furcation fill with hard tissue. (g) Clinical view of the site at 5 years postsurgery. The furcation maintains clinical closure and cannot be probed into with a Nabers probe. (h) Radiograph taken at 5 years postsurgery suggesting that the closure of the furcation is with hard tissue.
and long-term case series reports and studies attesting to their efficacy. Utilizing the evidence available from the literature and combining this with the newer technologies available today, clinicians can offer their patients a high predictability for success. Patients should now, more than ever, be offered the opportunity to maintain their periodontally involved teeth. The alternative, extraction possible site augmentation, implant placement and restoration is usually costly, time-consuming, requires more surgery, involves more patient discomfort, and has the potential for more complications.

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