Efficacy of Vascularized Periosteal Membranes in Providing Soft Tissue Closure at Grafted Human Maxillary Extraction Sites

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Purpose: *Soft tissue closure is mandatory for optimal healing of extraction sites treated via guided bone regeneration. The objective of this study was to evaluate the efficacy of a flap design based on the extension of palatal tissues to obtain and maintain soft tissue coverage over grafted extraction sockets.* ***Materials and Methods:*** *Adult patients (n = 22) with at least two teeth indicated for extraction were treated. After atraumatic extraction, control sockets were filled with a composite graft (1:1) containing demineralized freeze-dried bone allografts and Bio-Oss. Experimental sockets were treated identically, except that an Atrisorb absorbable barrier membrane was also placed over the graft material before flap closure, which was obtained, in all sockets, by the coronal extension of a vascularized pedicle dissected from the periosteal aspect of the palate.* ***Results:*** *Primary tension-free wound closure was achieved at all treated sites. Exfoliation of the graft material during healing was not observed in either treatment group. High levels of soft tissue closure were maintained throughout the study period for both treatment groups, and membrane exposure was observed in only 7% of treated sites.* ***Conclusion:*** *On the basis of this study it appears that the reported technique was an adequate method of achieving and maintaining complete soft tissue coverage and promoting healing by primary intention in grafted extraction sockets in humans.* Int J Oral Maxillofac Implants 2009;24:81–87

Key words: *bone graft, dental implants, guided bone regeneration*

More than 20 million teeth are extracted in the United States every year, resulting in edentulism in more than 40% of the American population over the age of 60 years.[1] Resorption of alveolar bone is a common complication of tooth extraction.[2] Local and systemic factors, such as disuse, atrophy, and pressure from denture wearing, may increase bone resorption.[2,3] Quantitative analysis of the alveolar bone response following tooth extraction revealed that significant bone loss occurs both apicocoronally and buccopalatally in extraction sites.[4,5] Importantly, the residual ridge dimensions buccopalatally were smaller than 3.5 mm in all studied patients.[4,5] Therefore, significant ridge defects developed, and the amount of residual bone was not sufficient for the placement of conventional endosseous implants.

Localized ridge deficiencies in the anterior regions of the mouth can pose important clinical and esthetic challenges during the restorative phase of treatment.[6–8] Several techniques have been described in the literature for the surgical management of such conditions, including "inlay" and "onlay" grafts of masticatory mucosa from the palate[7,8]; several "pouch" procedures or "tunnel" preparations for grafting or implantation of autogenous (bone or connective tissue), allogeneic (bone), or alloplastic materials[7,8]; guided bone regeneration (GBR)[4,5]; and some special flap procedures,[9–14] designed to be used alone or in combination with other techniques.

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Table 1 Distribution of Teeth According to Treatment Regimen and Frequency of Complications

	Site location*		Complications	
Patient	Experimental	Control	Experimental	Control
1	24	15	–	–
2	16, 17	16, 17	–	–
3	11	22	–	–
4	12	11	–	–
5	21, 22	11, 22	–	–
6	23	22	–	–
7	12, 13	21, 11	–	–
8	23	25	–	–
9	12, 13	14, 15	–	–
10	17	26	–	FN
11	11	21	–	–
12	25	14	–	–
13	16	26	FN, ME	FN
14	12	23	–	–
15	14, 15	21, 23	–	–
16	17	27	ME	–
17	14	15	–	–
18	14	25	–	–
19	11, 12	21, 22	–	–
20	21	14	–	–
21	12	22	–	–
22	14	24	–	–

*Sites listed according to FDI tooth numbers.
ME = membrane exposure; FN = flap necrosis; – = no complications noted.

Soft tissue closure, undisturbed healing, and preservation of membranes completely covered by the gingival tissues appear to be mandatory for optimal healing of extraction sites treated via guided bone regeneration.[15–18] Unfortunately, clinical studies evaluating GBR procedures for socket preservation after tooth extraction[4,5,9,19,20] or during placement of immediate implants in extraction sockets treated with GBR procedures[16,21–25] have shown alarming rates of membrane exposure. Early membrane exposure has been shown to inhibit bone regeneration in GBR sites.[26,27] Therefore, technical refinements in soft tissue manipulation to enhance soft tissue closure in conjunction with GBR procedures are still necessary.

The objective of this study was to evaluate the efficacy of a flap design, based on the extension of palatal tissues, to obtain and maintain soft tissue coverage over grafted extraction sockets with or without the use of an absorbable barrier membrane.

MATERIALS AND METHODS

Study Population and Experimental Design

Adult patients with at least two teeth indicated for extraction for periodontal or prosthetic reasons were treated. Smokers, patients with immunosuppressive systemic diseases (ie, cancer, acquired immunodeficiency syndrome, diabetes), and patients with general contraindications for oral surgery were not included in the present study. Informed consent was obtained from all patients after they were fully informed about the character, purpose, and procedures of the study. The study was conducted in accordance with the guidelines of the Helsinki Declaration of 1975, as modified in 2000, and was approved by the institutional review board.

Surgical Procedure

Intrasulcular incisions were performed circumferentially in experimental teeth with no. 15C surgical blades after adequate local anesthesia was obtained by means of regional blocks, followed by papillary intraseptal and palatal infiltration. Teeth were carefully luxated and extracted atramautically. No fractures of the cortical plates occurred during the extraction procedures. The sockets were carefully curetted and irrigated with sterile saline solution. Sockets were then completely filled with a 1:1 mixture of decalcified freeze-dried bone allograft material (DFDBA) (Pacific Coast Tissue Bank, Los Angeles, CA) and an anorganic bovine bone mineral (Bio-Oss, Geistlich, Wolhusen, Switzerland)(Fig 2d). A total of 28 extraction sites received this treatment and served as the control group. An equal number of extraction sockets from the experimental group were treated in the same way as the controls, but after graft insertion they were also completely covered with an absorbable barrier membrane (Atrisorb, Atrix Labs, Fort Collins, CO) according to the principles of GBR. Closure of the extraction socket was obtained via the coronal extension of vascularized palatal periosteal membranes (Figs 2c and 2e). Distribution of teeth according to treatment regimen is shown in Table 1.

Vascularized Periosteal Membrane Technique

A mesiodistal incision is performed at the midcrest or slightly (2 to 4 mm) buccal to the ridge crest (Fig 1a). Two secondary parallel perpendicular incisions are created and connected to the primary incision. This incision extends 10 to 15 mm apically. A full-thickness palatal flap is then elevated (Fig 1b). In the most apical location of the periosteal aspect of the flap, a tertiary linear horizontal incision is performed perpendicular to the surface of the flap (Fig 1c). This tertiary incision connects both of the secondary

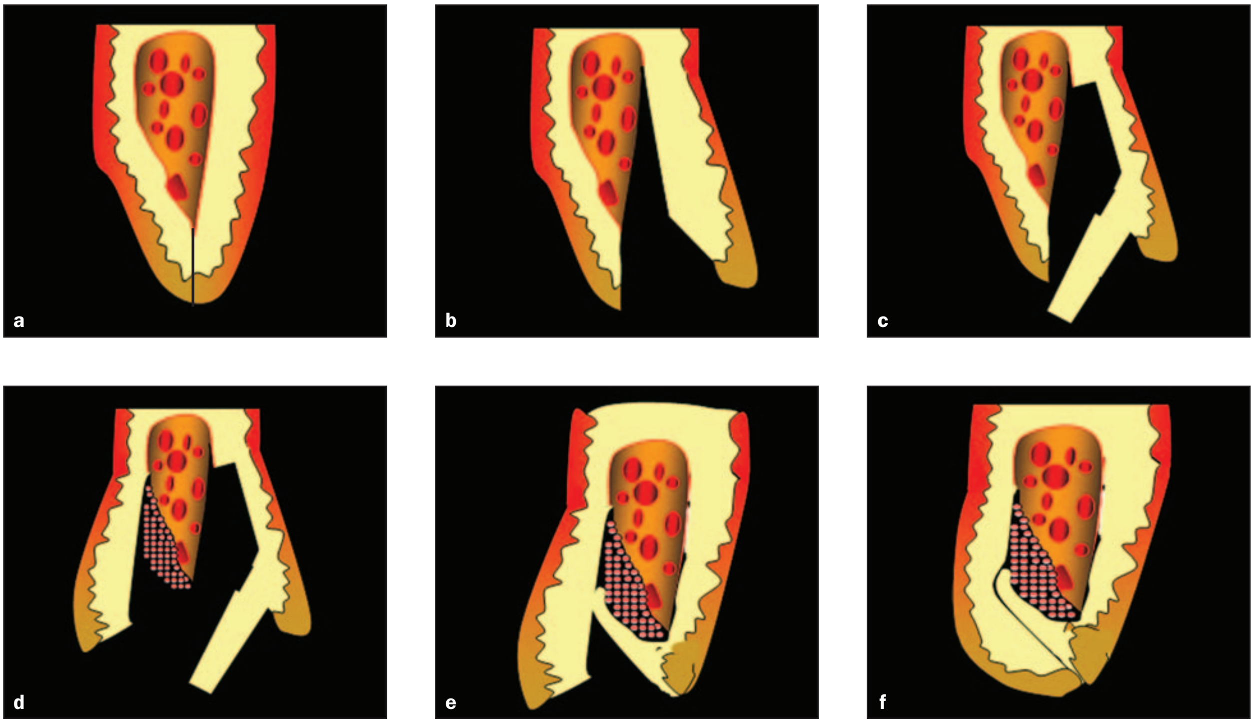

Fig 1 Schematic drawing of the vascularized periosteal membrane (VPM) technique. *(a)* Primary incision. *(b)* Periosteal reflection. *(c to e)* Dissection of the VPM. *(f)* Periosteal extension and wound closure.

incisions, ie, the lateral borders of the flap, and extends to a depth that is approximately half the thickness of the palatal flap tissue. The blade is then positioned parallel to the flap surface, and the palatal flap is split in half (Fig 1d). This sharp dissection is performed in the incisal direction, to 3 or 4 mm apical to the most coronal border of the flap. When the split periosteal extension is separated from the original palatal flap, it maintains a pedicle via the aforementioned 3- to 4-mm nonsplit coronal border of the palatal flap. Consequently, the periosteal aspect can extend coronally, maintaining its vascularization via the pedicle. This extension constitutes the coronally positioned split-thickness palatal flap. The periosteal margin of the palatal flap is then adapted below the buccal flap/pouch tissue and above any grafted material, if present (Fig 1e). The wound margins are carefully joined together with single interrupted sutures (Fig 1f). Identical surgical flap procedures were performed in both the experimental and control groups (Fig 2).

Bone Measurements

At the time of the surgery, just prior to graft placement, direct measurements of the width of the bone crest (BCW) were made from the crest of the buccal bony wall to the crest of the palatal bony wall with the use of a calibrated periodontal probe at a point corresponding to half the mesiodistal socket diameter. Six months after tooth extraction, full-thickness buccal and palatal flaps were elevated to expose the alveolar crest, and the measurements were repeated. All measurements were rounded to the nearest 0.5 mm.

Perioperative and Postoperative Care

Provisional restorations were checked and adjusted to eliminate contact with the surgical area. Sutures were removed after 10 days, the wound was carefully cleaned with sterile gauze soaked in saline, and the field was then evaluated. The patient was prescribed a 0.12% chlorhexidine solution, twice daily, for chemical bacterial plaque control and was instructed to use a routine plaque control regimen, except in the operated area. Analgesics and antibiotics were prescribed according to individual needs. Weekly maintenance visits were scheduled for the first month, and biweekly visits continued in the second and third postoperative months. The patients were instructed to refrain from mechanical oral hygiene at home in the operated area during the first month following surgery; during this time professional care was provided weekly for this purpose.

Fig 2 *Surgical procedures in a treated patient.*

Fig 2a Initial view.

Fig 2b Atraumatic flapless tooth extraction.

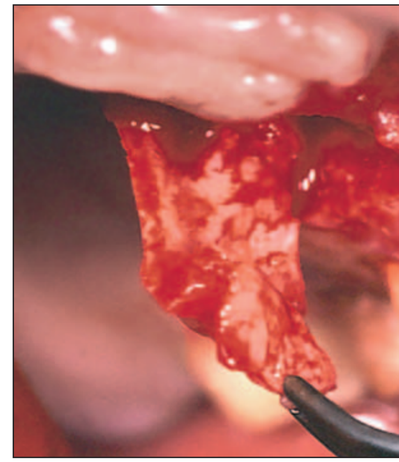

Fig 2c Dissected vascularized periosteal membrane.

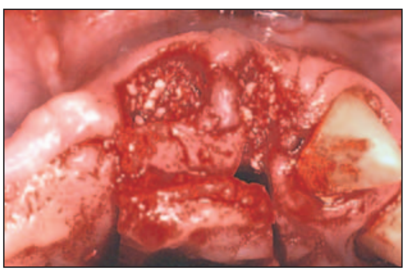

Fig 2d Periosteal extension over grafted extraction sockets.

Fig 2e Wound closure.

Fig 2f Final healing at 6 months.

Data Collection and Statistical Analyses

Soft tissue coverage was evaluated dichotomously at the time of surgery and again 6 months after surgery. Intergroup comparisons of the total frequencies of distributions of postsurgical complications were analyzed via the chi-square test. Intergroup comparisons of the bone crest width were analyzed via the Mann-Whitney test. Statistical significance was declared if the results were either at or above the 95% probability ($P < .05$).

RESULTS

Twenty-two patients (14 men, eight women), 26 to 63 years old with a mean age of 42 ± 8 years, were treated. Primary tension-free wound closure was achieved at all treated sites. Exfoliation of graft material during healing was neither observed nor reported by the patients in either treatment group. No signs of erythema, edema, swelling, or suppuration were noticed in the soft tissues of the experimental group. Soft tissue healing at sites treated with the absorbable membrane did not appear to be different from that at the control sites, suggesting that the material was well tolerated by the gingival tissues.

Postsurgical complications were minimal for both treatment modalities tested (Table 1). Differences in the total frequencies of distributions of postsurgical complications between the groups were not statistically significant (χ^2 test, $P = .2879$). Partial necrosis of the palatal flap was observed at two sites (one experimental and one control). These were minimal and closed spontaneously by granulations emanating from the wound margins in 1 to 2 weeks. Partial necrosis of the palatal donor site was observed at two control sites and one experimental site. Palatal necroses were small (less than 5 mm in diameter) and healed uneventfully by secondary intention within 2 weeks. Membrane exposure was observed in two of 28 sites (7.14%). Exposed parts of the membranes were cut away, and the resulting exposed membrane margins seemed to disappear concurrently with healing of the soft tissues. No signs of infection or suppuration were observed in exposed membrane sites.

Baseline measurements of the ridge dimensions (BCW) revealed a mean of 7.9 ± 0.9 mm for the control sites and 8.2 ± 0.8 mm for the experimental sites ($P = .736$). Repeated measurements obtained 6 months after tooth extraction showed that the experimental and control groups performed equally well. Mean BCW in the controls was 6.9 ± 0.7 mm, and in the experimental sites it was 7.5 ± 0.8 mm. This small difference did not reach statistical significance ($P = .237$).

DISCUSSION

Soft tissue closure appears to be mandatory for optimal healing of extraction sites treated via GBR.[15–18] Early membrane exposure has been shown to inhibit bone regeneration at treated sites.[26,27] This article describes a technique for the management of extraction socket grafts based on extension of the palatal soft tissues. The results of the present study showed that both techniques were effective in obtaining and maintaining soft tissue closure over grafted extraction sockets. The presence of a barrier membrane did not increase the incidence of soft tissue dehiscence, and high levels of soft tissue closure were maintained throughout the study period. Membrane exposure was observed in only 7% of the experimental sites. This result compares favorably with previous reports evaluating GBR procedures for socket preservation after tooth extraction,[4,5,10,19,20,28–37] with authors reporting membrane exposure rates between 13% and 30%. Moreover, previous reports of immediate implants in extraction sockets treated with GBR procedures also revealed a very high rate of membrane exposure ranging from 39% to 73%.[16,21–25] In view of the reported variations in frequencies of barrier exposure following GBR procedures reported in the literature, as well as findings of reduced bone regeneration in cases of early membrane exposure,[26,27] the results of the present study suggest that the reported technique holds promise in optimizing the clinical results of GBR protocols.

Several surgical techniques have been designed to achieve primary closure of extraction sites, including coronally advanced buccal flaps,[21] rotated flaps from proximal buccal areas,[38,39] free autogenous epithelialized[40,41] and connective tissue grafts,[42,43] and extension of palatal tissues.[9–12] Most of these flaps or pedicled grafts require dissections in multiple planes to maintain satisfactory vascularization to the pedicle; this limits their applicability to areas of very thick palatal tissues. The technique described in the present report is simpler. The dissection is performed in a single plane, leading to maximum incorporation of palatal thickness at the pedicle. The reported rate of soft tissue complications, ie, palatal necrosis, for other split-thickness flap designs used for extraction socket preservation varies between 16% and 22%,[10,19,44] and graft exfoliation has been a frequent finding. The present study demonstrated a frequency of necrosis of the flap plus the donor area of 8.6% and no graft exfoliation during healing. The flap procedures described here are versatile and have been used clinically by the authors since 1995 for horizontal and vertical augmentation of the alveolar ridge, protection of grafts during ridge augmentation, socket preservation, primary coverage and protection of barrier membranes employed for GBR, and primary coverage of immediate endosseous implant sites; the technique has also been used as a grafting procedure to create or augment the keratinized tissue area around dental implants. Taken together, these findings suggest that the present surgical protocol performed well and may also be an attractive alternative for socket preservation after tooth extraction.

No signs of erythema, edema, swelling, or suppuration were noticed in the soft tissues of the experimental group. Soft tissue healing at sites treated with the absorbable membrane did not appear to be different from that observed at the control sites. Moreover, in the few areas where the membranes were exposed during healing, the exposed parts of the membrane margins appeared to disappear concurrently with healing of the soft tissues. No signs of infection or suppuration were observed in exposed membrane sites, suggesting that the material was well tolerated by the gingival tissues. These findings are in accordance with previous animal experiments, which had demonstrated excellent tissue response and biocompatibility of the test barrier material.[45] The barrier membrane tested has been widely used for periodontal applications[46-49]; however, evidence for its usefulness in GBR is scarce and has focused on the treatment of dehiscence and fenestration bone defects associated with immediate implant placement.[50] The findings of the present study demonstrated that this material may also be suitable for alveolar ridge preservation in conjunction with composite bone grafting. Possible negative influences of early membrane exposure and/or flap necrosis during healing could not be ideally assessed in the present report because of the low prevalence of such events and the lack of paired, complication-free controls. Additional evaluations with increased sample size are currently in progress to further investigate this issue.

Of particular interest was the adequate clinical response in the control sites. Similar to what was noticed in the experimental sites, no signs of erythema, edema, swelling, or suppuration were noticed in the soft tissues of controls, and exfoliation of graft material did not occur during healing. Interestingly, direct measurements of BCW revealed virtually identical results for the control and experimental groups.

Therefore, in the present sample, the vascularized periosteal membrane performed as well as a synthetic barrier membrane in maintaining the alveolar crest width.

Within the limitations of the present study, it was concluded that the vascularized periosteal membrane was an adequate choice for achieving and maintaining complete soft tissue coverage and healing by primary intention of grafted extraction sockets in humans. The procedures allowed for optimal levels of complete coverage of absorbable membranes during healing; however, the use of an absorbable membrane provided no additional clinical benefits.

REFERENCES

1. Marcus SE, Drury TF, Brown LJ, Zion ZR. Tooth retention and tooth loss in the permanent dentition of adults: United States 1988–1991. J Dent Res 1996;75:684–695.
2. Atwood DA, Coy WA. Clinical, cephalometric and densitometric study of reduction of the residual alveolar ridge. J Prosthet Dent 1971;26:280–291.
3. Devlin H, Fergusson MWJ. Alveolar ridge resorption and mandibular atrophy. A review of the role of local and systemic factors. Br Dent J 1991;170:101–104.
4. Lekovic V, Kenney EB, Weinlaender M, et al. A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. J Periodontol 1997;68:563–570.
5. Lekovic V, Camargo PM, Klokkevold P, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. J Periodontol 1998;69:1044–1049.
6. Garber DA, Rosenberg ES. The edentulous ridge in fixed prosthodontics. Compend Contin Educ Dent 1981;2:212–223.
7. Seibert JS. Treatment of moderate localized alveolar ridge defects. Preventive and reconstructive concepts in dentistry. Dent Clin North Am 1993;37:265–280.
8. Seibert J, Lindhe J. Esthetics in periodontal therapy. In Lindhe J, Karring T, Lang NP (eds). Clinical Periodontology and Implant Dentistry, ed 3. Copenhagen: Munksgaard, 1997.
9. Nemcovsky CE, Serfaty V. Alveolar ridge preservation following extraction of maxillary anterior teeth. Report on 23 consecutive cases. J Periodontol 1996;67:390–395.
10. Nemcovsky CE, Artzi Z. Split palatal flap. I. A surgical approach for primary soft tissue healing in ridge augmentation procedures: Technique and clinical results. Int J Periodontics Restorative Dent 1999;19:175–181.
11. Tinti C, Parma-Benfenati S. Coronally positioned palatal sliding flap. Int J Periodontics Restorative Dent 1995;15:298–310.
12. Hurzeler MB, Weng D. Functional and esthetic outcome enhancement of periodontal surgery by application of plastic surgery principles. Int J Periodontics Restorative Dent 1999;19:37–43.
13. Adriaenssens P, Hermans M, Ingber A, Prestipino V, Daelemans P, Malevez C. Palatal sliding strip flap: Soft tissue management to restore maxillary anterior esthetics at stage 2 surgery: A clinical report. Int J Oral Maxillofac Implants 1999;14:30–36.
14. Bahat O, Koplin LM. Pantographic lip expansion and bone grafting for ridge augmentation. Int J Periodontics Restorative Dent 1989;9:345–353.
15. Gelb DE. Immediate implant surgery: Three-year retrospective evaluation of 50 consecutive cases. Int J Oral Maxillofac Implants 1993;8:388–399.
16. Gher ME, Quintero G, Assad D, Monaco E, Richardson AC. Bone grafting and guided bone regeneration for immediate dental implants in humans. J Periodontol 1994;65:881–891.
17. Buser D, Dula K, Belser U, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. I. Surgical procedure in the maxilla. Int J Periodontics Restorative Dent 1991;11:19–45.
18. Buser D, Dula K, Belser UC, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. II. Surgical procedure in the mandible. Int J Periodontics Restorative Dent 1995;15:10–29.
19. Nemcovsky CE, Artzi Z, Moses O. Rotated split palatal flap for soft tissue primary coverage over extraction sites with immediate implant placement. Description of the surgical procedure and clinical results. J Periodontol 1999;70:926–934.
20. Diés F, Etienne D, Bou Abboud N, Ouhayoun JP. Bone regeneration in extraction sites after immediate placement of an e-PTFE membrane with or without a biomaterial. A report on 12 consecutive cases. Clin Oral Implants Res 1996;7:277–285.
21. Mellonig JT, Triplett RG. Guided tissue regeneration and endosseous dental implants. Int J Periodontics Restorative Dent 1993;13:109–119.
22. Becker W, Dahlin C, Becker BE, et al. The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: A prospective multicenter study. Int J Oral Maxillofac Implants 1994;9:31–40.
23. Landsberg CJ, Grosskopf A, Weinreb M. Clinical and biological observations of demineralized freeze-dried bone allografts in augmentation procedures around dental implants. Int J Oral Maxillofac Implants 1994;9:586–592.
24. Lorenzoni M, Pertl C, Keil C, Wegscheider WA. Treatment of peri-implant defects with guided bone regeneration: A comparative clinical study with various membranes and bone grafts. Int J Oral Maxillofac Implants 1998;13:639–646.
25. Augthun M, Yildirin M, Spiekermann H, Biersterfeld S. Healing of bone defects in combination with immediate implants using the membrane technique. Int J Oral Maxillofac Implants 1995;10:421–428.
26. Simion M, Baldoni M, Rossi P, Zaffe D. A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. Int J Periodontics Restorative Dent 1994;14:167–180.
27. Lekholm U, Becker W, Dahlin C, Becker B, Donath K, Morrison E. The role of early versus late removal of GTAM membranes on bone formation at oral implants placed into immediate extraction sockets. An experimental study in dogs. Clin Oral Implants Res 1993;4:121–129.
28. Tal H. Autogenous masticatory mucosal grafts in extraction socket seal procedures: A comparison between sockets grafted with demineralized freeze-dried bone and deproteinized bovine bone mineral. Clin Oral Implants Res 1999;10:289–296.
29. Camargo PM, Lekovic V, Weinlaender M, et al. Influence of bioactive glass on changes in alveolar process dimensions after exodontia. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:581–586.
30. Vasilic N, Henderson R, Jorgenson T, Sutherland E, Carson R. The use of bovine porous bone mineral in combination with collagen membrane or autologous fibrinogen/fibronectin system for ridge preservation following tooth extraction. J Okla Dent Assoc 2003;93:33–38.

31. Serino G, Biancu S, Iezzi G, Piattelli A. Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: A clinical and histological study in humans. Clin Oral Implants Res 2003;14:651–658.
32. Zubilaga G, Von Hagen S, Simon BI, Deasy MJ. Changes in alveolar bone height and width following post-extraction ridge augmentation using a fixed bioabsorbable membrane and demineralized freeze-dried bone osteoinductive graft. J Periodontol 2003;74:965–975.
33. Iasella JM, Greenwell H, Miller RL, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: A clinical and histologic study in humans. J Periodontol 2003;74:990–999.
34. Vance GS, Greenwell H, Miller RL, Hill M, Johnston H, Scheetz JP. Comparison of an allograft in an experimental putty carrier and a bovine-derived xenograft used in ridge preservation: A clinical and histologic study in humans. Int J Oral Maxillofac Implants 2004;19:491–497.
35. Fiorellini JP, Howell TH, Cochran D, et al. Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation. J Periodontol 2005;76:605–613.
36. Nevins M, Camelo M, De Paoli S, et al. A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. Int J Periodontics Restorative Dent 2006;26:19–29.
37. Pinho MN, Roriz VM, Novaes AB Jr, et al. Titanium membranes in prevention of alveolar collapse after tooth extraction. Implant Dent 2006;15:53–61.
38. Becker W, Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: Surgical techniques and case reports. Int J Periodontics Restorative Dent 1990;10:376–391.
39. Novaes AB Jr, Novaes AB. Soft tissue management for primary closure in guided bone regeneration: Surgical technique and case report. Int J Oral Maxillofac Implants 1997;12:84–87.
40. Evian CI, Cutler S. Autogenous gingival grafts as epithelial barriers for immediate implants: Case reports. J Periodontol 1994;65:201–210.
41. Landsberg CJ. Socket seal surgery combined with immediate implant placement: A novel approach for single tooth replacement. Int J Periodontics Restorative Dent 1997;17:141–149.
42. Edel A. The use of a connective tissue graft for closure over immediate implant covered with an occlusive membrane. Clin Oral Implants Res 1995;6:60–65.
43. Chen ST, Dahlin C. Connective tissue grafting for primary closure of extraction sockets treated with an osteopromotive membrane technique: Surgical technique and clinical results. Int J Periodont Rest Dent 1996;16:349–355.
44. Nemcovsky CE, Moses O, Artzi Z Gelernter I. Clinical coverage of dehiscence defects in immediate implant procedures: Three surgical modalities to achieve primary soft tissue closure. Int J Oral Maxillofac Implants 2000;15:843–852.
45. Santana RB, Trackman PC. FGF-2 released from a resorbable membrane stimulates bone regeneration. J Dent Res 2001;80:56.
46. Polson AM, Southard GL, Dunn RL, et al. Periodontal healing after guided tissue regeneration with Atrisorb barriers in beagle dogs. Int J Periodontics Restorative Dent 1995;15:574–589.
47. Garrett S, Polson AM, Stoller NH, et al. Comparison of a bioabsorbable GTR barrier to a non-absorbable barrier in treating human class II furcation defects. A multi-center parallel design randomized single-blind trial. J Periodontol 1997;68:667–675.
48. Pereira SL, Sallum AW, Casati MZ, et al. Comparison of bioabsorbable and non-resorbable membranes in the treatment of dehiscence-type defects. A histomorphometric study in dogs. J Periodontol 2000;71:1306–1314.
49. Stoller H, Johnson LR, Garrett S. Periodontal regeneration of a class II furcation defect utilizing a bioabsorbable barrier in a human. A case study with histology. J Periodontol 2001;72:238–242.
50. Rosen PS, Reynolds MA. Guided bone regeneration for dehiscence and fenestration defects on implants using an absorbable polymer barrier. J Periodontol 2001;72:250–256.