Ridge Preservation Techniques for Implant Therapy

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Purpose: *The aim of this review was to evaluate the techniques and outcomes of postextraction ridge preservation and the efficacy of these procedures in relation to subsequent implant placement.* ***Materials and Methods:*** *A MEDLINE/PubMed search was conducted and the bibliographies of reviews from 1999 to March 2008 were assessed for appropriate studies. Randomized clinical trials, controlled clinical trials, and prospective/retrospective studies with a minimum of five patients were included.* ***Results:*** *A total of 135 abstracts were identified, from which 53 full-text articles were further examined, leading to 37 human studies that fulfilled the search criteria. Many different techniques, methodologies, durations, and materials were presented in the publications reviewed, making direct comparison difficult.* ***Conclusions:*** *Despite the heterogeneity of the studies, it was concluded that ridge preservation procedures are effective in limiting horizontal and vertical ridge alterations in postextraction sites. There is no evidence to support the superiority of one technique over another. There is also no conclusive evidence that ridge preservation procedures improve the ability to place implants.* Int J Oral Maxillofac Implants 2009;24(suppl):260–271

Key words: *dental implants, extraction, grafting, ridge preservation, socket*

The outcome of implant therapy is no longer measured by implant survival alone, but by long-term esthetic and functional success. Today, implant placement should be based on a restoration-oriented treatment plan with correct three-dimensional (3D) positioning of the implant to allow optimal support and stability of surrounding hard and soft tissues.[1]

Soft tissue contour depends on the underlying bone anatomy, since peri-implant soft tissues have rather constant dimensions.[2] This relationship between hard and soft tissues is important for esthetic outcomes in implant patients. Particularly important are the height and thickness of the facial bone wall and the height of the alveolar bone at interproximal aspects. Incorrect 3D positioning of an implant may result in an inappropriate restoration-implant alignment, which can cause difficulty for the restorative treatment. If the implant is placed too far facially, there is a significant risk of recession of the mucosal margin. If it is placed too far palatally, this may result in a poor emergence profile or even ridge-lapping of the restoration. An inappropriate mesiodistal position can affect the papilla size and shape and may cause poor embrasure form or emergence profile. A coronoapical malposition can cause biological complications if the implant is placed too deep or esthetic complications if the metal of the implant shoulder is visible.

Besides a correct 3D position of the inserted implant, the esthetic outcome can also be affected by the amount of bone available at the implant site. It is well documented that the alveolar ridge undergoes resorptive changes following tooth extraction. These changes lead to a decrease in the dimensions of the ridge.[3,4] Implant placement in postextraction sites can usually be managed with bone augmentation procedures with high predictability, provided that at least two intact bone walls remain.[5,6] However, as the time from extraction to implant placement increases, progressive ridge resorption may result in a loss of bone volume to a degree that simultaneous bone augmentation becomes less predictable.[7] Careful preoperative assessment of the site will reveal the anatomy of the alveolar crest and identify any horizontal or vertical deficiencies. Most critical are vertical

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bone deficiencies, as it is difficult to regain vertical height of the ridge.[8,9]

A series of studies in a dog model have been fundamental for our understanding of healing events in postextraction sites and following immediate implant placement. Cardaropoli et al[10] confirmed the sequence of healing events reported by Amler et al.[11] A more recent study by Botticelli et al[12] found substantial bone resorption from the outside of the ridge following implant placement in an extraction socket. Implants were shown by Araujo et al[4] not to prevent modeling of the extraction socket, and Araujo and Lindhe[13] suggested that the greater facial bone loss compared to the lingual wall was due to the relatively greater proportion of bundle or "tooth-derived" bone facially. Recently, implants placed in extraction sockets were demonstrated not to preserve the dimension of the ridge, especially on the facial aspect, and this resulted in some marginal loss of osseointegration.[14] Most recently, Fickl et al[15] showed that elevation of a mucoperiosteal flap resulted in a more pronounced loss of ridge dimension compared to no flap elevation.

Based on this understanding of healing events in postextraction sites, the prevention of ridge resorption following tooth extraction seems important, particularly if implant placement needs to be delayed for 6 months or longer. Implant placement may be delayed due to loss of bone, especially in the following situations: socket walls and sites with limited bone height (eg, postperiodontal disease and large apical defects), socket morphology preventing implant placement in an ideal restorative position, in young patients where active growth is occurring or still has to occur, where the patient cannot afford implant therapy, or where placement is contraindicated by medical health issues. If the dimensions of the ridge could be maintained, this would reduce the need for further augmentation/surgical procedures and simplify implant surgery at a later time.

The aim of this review was to evaluate the literature on ridge preservation and determine what techniques are available and whether they allow successful implant placement.

MATERIALS AND METHODS

Search Strategy

In MEDLINE and PubMed, searches were performed for papers in the English language using the following terms: *dentistry, implants, dental implants, extraction, socket, socket preservation, ridge preservation, implants-ridge preservation, ridge-socket, ridge alteration-extraction,* and *ridge preservation-extraction*. The bibliographies of reviews from 1999 to March 2008 were assessed for appropriate studies.[16–19] In addition, the following journals' websites were searched: *Journal of Periodontology, Clinical Oral Implants Research, International Journal of Oral & Maxillofacial Implants*, and *Journal of Clinical Periodontology*. Authors' names as identified previously were also used. Reference lists of studies identified were searched for further citations.

Selection of Studies

Randomized clinical trials, controlled clinical trials, and prospective/retrospective studies with a minimum of five patients were included. Where a series of papers reported the same study, the paper with the clinical measurements or details about the implant placement was used.

Evaluation of Treatment Outcome

The following data were obtained from each study: number of patients and treated sites, position of sites, augmentation methods for test and control sites, observation period, soft tissue closure, and complications.

Treatment outcome was evaluated as:

- Change in ridge dimensions (in mm or %)
- Successful implant placement
- Implant survival (%)

RESULTS

A total of 135 abstracts were identified, from which 53 full-text articles were further examined, leading to 37 human studies that fulfilled the search criteria and were used in this review. These publications are listed and briefly described in Table 1. In addition, 10 animal studies were incorporated, as these had direct relevance to the topic.

Definitions

Several terms have been used in the literature, including *ridge preservation*, *site preservation*, and *socket preservation*. As the objective of treatment is to limit vertical and horizontal ridge alterations in postextraction sites, the term *ridge preservation* was considered to be a more precise description and hence was used in this review.

Healing of Extraction Sockets

Healing of an extraction socket is characterized by internal changes that lead to formation of bone within the socket and by external changes that lead to loss of alveolar ridge width and height.[3]

Table 1 List and Description of Articles Included

Study	Study type	No. of patients	No. of sites	Position/ characteristics	Test	Control	Observ period	Soft tissue closure	Results	Outcome	Comments
Vance et al (2004)[32]	RCT	24	24 (12/12)	Nonmolar/ND	CMC/CaS with DFDBA and CaS barrier	Bio-Oss & collagen membrane	4 mo	Partial closure by mucosal advancement	Horizontal ridge width same for both groups; vertical midbuccal putty 0.3 ± 0.7 mm, Bio-Oss 0.7 ± 1.2 mm, no difference in soft tissue	No significant difference between groups and all enabled implant placement	Amount of vital bone: putty 61% ± 9%, Bio-Oss 26% ± 20% with more graft particles remaining
Molly et al (2008)[40]	RCT	8	36 (4 groups of 9)	Mixed/Advanced periodontitis	3 groups: PL/PG sponge; DBBM; Biocoral	Clot	6 mo	Yes; also placed e-PTFE at all sites (removed 2 mo later)	% viable bone and % residual particles: PL/PG 27%, 5%; DBBM 20%, 20%; Biocoral 24%, 12%; Control 30%	Implants placed in 25/36 sites, 9 sites excluded due to mechanical/esthetic issues (which groups ND)	Implants 10–15 mm length and 3.75 or 4 mm diameter
Froum et al (2002)[25]	RCT	19	30	Mixed/Periodontitis and prosthetic issues	10 bioactive glass, 10 DFDBA	10 Unfilled	6–8 mo	Primary closure by mucosal advancement	Amount of vital bone: Bioglass 59.5%, DFDBA 34.7%, control 32.4%	All had implants	
Fiorellini et al (2005)[56]	RCT	80 40/40	19: Control 18: 0 rhBMP 22: 0.75 rhBMP 21: 1.5 rhBMP	Maxillary anterior teeth/ND	Sponge soaked in rhBMP-2 of concentrations 0.0, 0.75, and 1.5 mg/mL	Clot	Adequate alveolar bone, max 4 mo	Primary closure by mucosal advancement	Gradient of effect with increasing concentrations observed; 1.5 mg/mL group most effective at preserving bone width	Sites requiring additional bone augmentation at the time of implant placement: 55% (clot), 41% (0 mg/mL), 45% (0.75 mg/mL), 14% (1.5 mg/mL)	Used palatal wall in calculations
Neiva et al (2008)[55]	RCT	24	12/12	Maxillary premolar teeth/ND	Putty & P15 + bioabsorbable collagen wound dressing with suturing	Clot + bioabsorbable collagen and suturing	4 mo	Partial closure by mucosal advancement	Changes in ridge dimensions. Width: test, 1.31 ± 0.96 mm; control, 1.43 ± 1.05 Height: test, 0.15 ± 1.76 mm; control, 0.56 ± 1.04 Similar % of vital bone	Significant differences in height	Implants placed; low percentage of residual particles ~6%; incipient ridge atrophy at 33% of control sites which required grafting at time of placement, but none at test sites
Iasella et al (2003)[24]	RCT	24	12/12	Nonmolar teeth extractions/ND	Mineralized FDBA and collagen membrane	Clot	4–6 mo	Partial closure by mucosal advancement	Horizontal ridge dimensions: test, - 1.2 ± 0.9 mm; control, - 2.6 ± 2.3 mm Vertical dimensions: mesial, midbuccal, distal, test had significantly less loss than control	Most predictable maintenance of ridge by ridge preservation	Allows direct comparison with 3 other studies
Becker et al (1996)[23]	CCT	15	ND	Mixed/ND	Autologous bone (6), DFDBA (7) (+ e-PTFE [5]), MFDBA (7)	See test	4–13 mo	ND	DFDBA/MFBDA, retention of nonvital graft particles with fibrous connective tissue	Use of membrane didn't make a difference	Too many differences for definite conclusion and unclear whether all sites had implants
Lekovic et al (1997)[50]	CCT	10	2 + per patient	Anterior or premolar teeth/ND	e-PTFE	Clot	6 mo	Primary closure by mucosal advancement	EVM and HM not significantly different; IVM significantly reduced	Nonexposed membranes significantly more socket infill and less loss of alveolar bone height	30% membrane exposure and these sites had the same outcome as the controls

Table 1 continued List and Description of Articles Included

Study	Study type	No. of patients	No. of sites	Position/ characteristics	Test	Control	Observ period	Soft tissue closure	Results	Outcome	Comments
Lekovic et al (1998)[51]	CCT	16	2 per patient	Anterior or premolar teeth/ND	Resolut membrane (PL/PG)	Clot	6 mo	Primary closure by mucosal advancement	Test had significantly smaller change in EVM, greater change in IVM and smaller change in HM	Loss of width greater than height	No exposures
Becker et al (1994)[22]	CCT	7	14, 7 paired	ND/Perio (hopeless teeth)	DFDBA	Autologous bone	3–13 mo	Primary wound closure by mucosal advancement	DFDBA does not induce bone formation	DFDBA may impede normal bone healing	All sites implants placed
Tal (1999)[29]	CCT	24	42	Maxillary central incisors/ND	DFDBA	Bio-Oss	4 wk	Soft tissue grafted from palate	Vital bone: no difference between DFDBA and Bio-Oss		Nothing about dimensions and implant placement
Serino et al (2008)[54]	CCT	20	7 Test 9 Control	Monoradicular teeth/ND	Fisiograft	Clot	3 mo	No	Mean bone: test 59.9 ± 22.4%, control 48.8 ± 14.4%	No significant difference; All sites implants	
Serino et al (2003)[53]	CCT	45	26 Test 13 Control	Mixed/ND	PL/PG sponge	Clot	6 mo	No	Midbuccal dimensions: test +1.3 ± 1.9 mm, control −0.8 ± 1.6 mm Well-structured, mature bone in both	All sites implants	Overall less resorption in test group
Luczyszyn et al (2005)[45]	CCT	11	15 pairs	2 Noncontiguous uniradicular teeth/ND	Resorbable HA + ADMG	ADMG	6 mo	Flap replaced in original position	Buccolingual dimension: ADMG only, 5.5 ± 1 mm; ADMG + RHA, 6.8 ± 1.3 mm Histology: ADMG 54% CT/46% bone; ADMG+RHA 57% CT/1% bone/42% RHA	All sites had implants	
Froum et al (2004)[34]	CCT	15	16, 4×4	ND/Periodontitis and prosthetic issues	Group 1 HA + ADMA, Group 2 HA + e-PTFE, Group 3 ABB + ADMA, and Group 4 ABB + ADMA	See test	6–8 mo	Partial coverage by mucosal advancement and a lot of CHX	ADMA/HA vital bone 34.5%, residual graft 4%; ADMA/ABB 41.7%, 12.2%; e-PTFE/HA 27.6%, 11.9%; e-PTFE/ABB 17.8%, 21.4%	Implants in all sites; noted a tendency for greater amount of vital bone with ADMA	Deficient buccal plates; ABB used was Osteograf, 1 ADMA and 6 (75%) e-PTFE removed early
Vasilic et al (2003)[35]	CCT	26	26 pairs	2 or more anterior or premolar teeth/ND	BPBM + collagen membrane	BPBM + autologous fibrinogen/fibronectin	6 mo	Primary closure by mucosal advancement	BPBM/collagen significantly more internal socket fill, less horizontal resorption, less resorption of alveolar bone height	BPBM/collagen better	Abstract only
Howell et al (1997)[57]	CCT	12 (6)	6	Maxillary anterior and premolar teeth/2 Decayed 2 Nonrestored 2 Periodontitis	rhBMP-2 and absorbable collagen sponge	None	16 wk	None	5/6 decreased socket depth	Better than complete infill	Inconclusive

Table 1 continued List and Description of Articles Included

Study	Study type	No. of patients	No. of sites	Position/ characteristics	Test	Control	Observ period	Soft tissue closure	Results	Outcome	Comments
Carmagnola et al (2003)[33]	CPros	121	11 Bio-Gide only, 7 Bio-Gide + Bio-Oss, 10 clot	ND/Postperio-dontitis	Group A Bio-Gide over socket then 4/12 implant. Group B Bio-Oss & Bio-Gide, then implant 7/12	Group C clot and implant 1–15 y	4 or 6 mo and up to 15 y	Partial closure of test sites by mucosal advancement	Quality of bone: Group A lamellar bone and bone marrow; Group B connec-tive tissue and small amounts of bone around graft with 21% remaining graft; Group C mineralized bone and bone marrow	All sites had implants	
Camargo et al (2000)[43]	Pros	16	16/16	2 Anterior or pre-molar teeth/ND	Biogran to socket height and calcium sulphate	Clot	6 mo	Flaps replaced in original posi-tion	Control slightly better external and internal ver-tical measurements and horizontal width changes		Similar protocol to Lekovic studies
Pinho et al (2006)[41]	Pros	10	10/10	2 Maxillary anterior and premolar extractions/ND	Autogenous bone + tita-nium membrane	Clot + titanium membrane	6 mo	Primary closure by mucosal advancement	No significant differences between groups, and complete fill of socket depth	Use of membrane favored prevention of alveolar ridge loss	25% exposure rate
Dies et al (1996)[26]	Pros	12	12	Mixed, but no molars/11 Max-illa; 1 Mandible	3 groups: e-PTFE (6), e-PTFE + DFDBA (4), e-PTFE + Bio-Oss (2)	See test	Up to 9 mo	Complete by mucosal advancement	e-PTFE moderate-high bone density and quality; e-PTFE+DFBDA and e-PTFE+Bio-Oss moderate-high bone density with some remnants	8/12 planned for implants	3/12 membranes exposed
Smukler et al (1999)[21]	Pros	13	6 Socket preservation, 5 Control, 2 Augmented	Mixed/ND	DFDBA + e-PTFE	Clot	9–23 mo	Complete by mucosal advancement	Confusing. Bone volume maxilla: test 55 ± 15 mm, control 57 ± 11 mm Bone volume mandible: test 57 ± 33 mm, control 41 ± 3 mm	Unable to separate socket preservation from aug-mentation	DFDBA remaining 0%–21.5%
Yilmaz et al (1998)[42]	Pros	10	10 Test	Maxillary incisors/ Severe periodonti-tis with functional and esthetic ridge defects	Bioactive alloplastic graft material	Clot	12 mo	Primary clo-sure by mucosal advancement although not well described	Ridge width at 12/12: test 5.7 ± 1.2 mm, con-trol 3.9 ± 0.8 mm Ridge height: test 8 ± 1.6 mm, control 7 ± 0.5 mm	Demonstrated efficiency of this method in preserv-ing bone	Ridges under FPD pon-tics
Nemcovsky and Serfaty (1996)[46]	Pros	23	10 Control	Maxillary anterior teeth/Perio, space, caries, periapical	Nonresorbable HA crystals	None	12–24 mo	Rotated flap to cover socket	Ridge dimensions de-creased: Vertically 1-2 mm, mean 1.4 mm; buccally 0-2 mm, mean 20.6 mm	20 esthetically satisfac-tory and 3 partially satis-factory	Under FPDs
Brugnami et al (1999)[27]	Pros	8	23	Mixed/Hopeless teeth	DFDBA + e-PTFE	None	3–9 mo	Primary closure by mucosal advancement	DFDBA acts as space maintainer and scaffold for migrating osteogenic cells, well incorporated with osteoblasts and osteoclasts	All sites had implants	

Table 1 continued List and Description of Articles Included

Study	Study type	No. of patients	No. of sites	Position/ characteristics	Test	Control	Observ period	Soft tissue closure	Results	Outcome	Comments
Norton and Wilson (2002)[44]	Pros	18	4 Socket preservation, 3 Augmented 40	Mixed/Periodontitis, endodontic problems, and trauma	Bioactive glass (Perioglass/Biogran) + e-PTFE at sites lacking buccal plate	None	3–11 mo	ND	Absence of bone for all cores harvested within 6/12, bone seen 6/12+ but minimal and at periphery	All sites had implants	CSR 90% at 12 mo and 96.8% at 2–4 y
Simon et al (2000)[31]	Pros	10	19	ND/Periodontitis, caries, and fracture	DFDBA & Resolut membrane	None	4 mo	Primary closure by mucosal advancement	Significant nonuniform loss of augmented alveolar height and width during healing	Implants placed	
Sàndor et al (2003)[49]	Pros	21	48 (17 trauma of anterior maxillary teeth)	Mixed/Trauma or ankylosis	Biocoral	None	24 mo	Primary closure by mucosal advancement	Trauma group initially temporary restoration of dimension but only 17.6% didn't need graft at time of implant placement		Subjects young adults; 6.3% failure rate up to 7 y
Norton et al (2003)[37]	Pros	15	13	Mixed/Periodontitis, endodontic problems, and trauma	Bio-Oss, bone shavings, and Bio-Gide	None	15–44 wk (mean 26 wk)	Primary closure by mucosal advancement if possible	Mix of woven, maturing woven, lamellar bone. Mean amounts: 26.9% bone, 25.6% graft, 47.4% fibrous or other connective tissue	Implants placed at all sites	4 membranes exposed and CHX used until site re-epithelialized; survival rate of implants at time of abutment connection 97%
Kfir et al (2007)[52]	Pros	15	15	Mixed/Fracture, perio, endo	Platelet-rich fibrin and titanium membrane	None	8 wk +	Primary closure	All had sufficient bone	8 implants placed with no additional guided bone regeneration	7 (47%) early exposure of membrane
Guarnieri et al (2004)[47]	Pros	10	10	Mixed single-rooted teeth/ND	Medical grade calcium sulphate	None	3 mo	Primary closure by mucosal advancement	Buccolingual dimension enabled “safe” insertion	All had implants	
Artzi et al (2000)[38]	Pros	15	15	Maxillary single-rooted teeth/ND	Bio-Oss	None	9 mo	Pediculated split palatal flap to close	Overall fill of 82.3%, decreased at dehiscenced buccal plates		Still some graft particles (30%) but well-incorporated
Babbush (2003)[30]	Pros	10	10	Mixed single-rooted teeth/ND	Human FDDBM + collagen in a carrier	None	4–21 mo (mean 7.4 mo)	Partial closure by mucosal advancement	% of bone: mean 57.5% ± 11.1%, range 33.1% to 91.5%	All sites had implants	
Brugnami et al (1996)[28]	Pros	6	7	ND/ND	DFDBA + cell-occlusive membrane	None	3–13 mo	?	Well-incorporated DFDBA within new bone	DFDBA useful for new bone growth in sockets	Abstract only
Wang and Tsao (2008)[48]	Pros	5	7	ND/ND	Solvent-preserved cancellous allograft	None	5–6 mo	No, covered with collagen wound dressing	Vital bone 68.5% average, 3.8% residual graft and 27.7% CT/Bone marrow		
Sclar (1999)[39]	Retrosp	131	248	ND/ND	DBBM + collagen wound dressing	None	6–73 mo	No, covered with collagen wound dressing	94% survival rate of implants		

ABB = anorganic bovine bone mineral; ADMA = acellular dermal matrix allograft; ADMG = acellular dermal matrix graft; BPBM = bovine porous bone mineral; CaS = calcium sulfate; CCT = controlled clinical trial; CHX = chlorhexidine; CMC = carboxymethylcellulose; CSR = cumulative survival rates; DFDBA = demineralized freeze-dried bone allograft; e-PTFE = expanded polytetrafluoroethylene; EVM = external vertical measurement; FDBA = freeze-dried bone allograft; FDDBM = freeze dried demineralized bone matrix; FPD = fixed partial denture; HA = hydroxyapatite; HM = horizontal measurement; IVM = internal vertical measurement; MFDBA = mineralized freeze-dried bone allograft; ND = not described; PG = polyglycolide; PL = polylactide; Pros = prospective study; RCT = randomized controlled trial; Retrosp = retrospective; RHA = resorbable hydroxyapatite; rhBMP = recombinant human bone morphogenetic protein; rhBMP-2 = recombinant human bone morphogenetic protein 2.

When a tooth is removed, there is hemorrhage, followed by formation of a blood clot that fills the entire socket.[11] The concomitant inflammatory reaction stimulates recruitment of cells to form granulation tissue. Within 48 to 72 hours, the clot starts to break down as granulation tissue begins to infiltrate the clot, especially at the base and periphery of the socket. By 4 days, the epithelium proliferates along the socket periphery, and immature connective tissue is apparent. After 7 days, the granulation tissue has completely infiltrated and replaced the clot. At this stage, osteoid is evident at the base of the socket as uncalcified bone spicules. Over the next 2 to 3 weeks (3 to 4 weeks after extraction), this begins to mineralize from the base of the socket coronally. This is accompanied by continued re-epithelialization, which completely covers the socket by 6 weeks post-extraction. Further infill of bone takes place with maximum radiographic density at around 100 days.

A number of factors may affect the healing of sockets. The size of the socket is important, with wider sockets requiring more time to bridge the defect than narrower sockets. The sockets of teeth with horizontal bone loss heal more quickly, as the reduced level of the alveolar ridge means less infill is required. Bone does not regenerate to a level coronal to the horizontal level of the bone crest or to the level of the neighboring teeth; ie, 100% socket fill does not occur.[3]

A recent study by Araujo and Lindhe[13] showed that in the first 8 weeks following extraction in a dog model there is marked osteoclastic activity, resulting in the resorption of the facial and lingual bone walls in the crestal region. They noted that the reduction of height was more pronounced at the facial wall. Loss of ridge height was accompanied by a horizontal loss on both facial and lingual walls.

When the healing events are disturbed, pain may result with impaired bone infill. The sequelae may range from hemorrhage, dry socket, and suppurative or necrotizing osteitis to fibrous healing with a lack of bone formation, depending on the stage of healing at the time of interruption. Significant inflammation may result not only in loss of bone infill, but also in sequestration. The end point of disturbed healing may prevent implant placement.[20]

Bone dehiscences or fenestrations that are present at the time of extraction, particularly in the facial or lingual walls, are most likely to be filled by fibrous reparative tissue, which may occupy considerable space in the socket itself. This leads to reduced bone volume and difficulty in ideal implant placement. Dehiscences and fenestrations may result from periapical pathology; tooth position in the alveolus; cracking or fracture of endodontically treated teeth; removal of the facial bone during extraction; or removal of teeth with curved roots or multiple roots, ankylosis, or root fractures.[19]

Materials Used for Ridge Preservation Techniques

The materials used for ridge preservation are those that have been used for guided bone regeneration (GBR) or guided tissue regeneration (GTR), and reflect what is available commercially.

Demineralized freeze-dried bone allograft (DFDBA)[21–31] and deproteinized bovine bone mineral (DBBM)[26,29,32–40] have been used extensively. Other graft materials include autologous bone,[22,23,41] bioactive glass,[25,42–44] hydroxyapatite,[34,45,46] calcium sulphate (CMC/CaS),[47] solvent-preserved cancellous allograft,[48] and biocoral.[40,49]

Membranes placed were most commonly expanded polytetrafluoroethylene (e-PFTE) membranes[21,23,26,28,40,44,48,50] or collagen membranes.[24,31–33,35,37] In addition, a polylactic/polyglycolic membrane was assessed by Lekovic et al[51] and Simon et al.[31] Further membranes investigated were those manufactured from titanium[41,52] or acellular dermal matrix graft (ADMG).[34,45]

Sponges made of polylactic/polyglycolic acid (PL/PG)[53,54] or collagen[39,40,55–57] have been placed in extraction sockets to preserve the ridge. The collagen sponges acted as a carrier for either recombinant human bone morphogenetic protein 2 (rhBMP-2)[56,57] or synthetic cell-binding peptide P-15.[55]

Augmentation Methods Used for Ridge Preservation

From these studies, nine different methods of ridge preservation were identified. The most commonly used method was a graft that was placed in the extraction socket, covered by a membrane followed by flap advancement to achieve complete or partial primary closure.[21,23,24,26,28,30–34,37,40,41,44] The second most commonly employed technique was covering a graft by coronal advancement or rotation of the flap, but without a membrane.[22,25,29,35,36,38,42,46,47,49] Third, membranes alone were placed over the extraction socket and the soft tissue was used to fully or partially cover it.[26,33,40,50–52] Other methods investigated include placement of the graft alone,[43] covering the grafted socket with a membrane alone,[45] ridge preservation solely by coverage with a membrane,[45] placing a graft and covering with a collagen wound dressing,[39,48] placing a sponge in the socket without any coverage,[53-55,57] or placing a sponge with soft tissue coverage.[40,56] Flap elevation was required for all techniques involving a membrane, but not for all procedures with a graft or sponge.

Table 2 Effectiveness of Ridge Preservation Compared to Normal Healing from Studies Using a Comparable Methodology

Study	Method	Duration (mo)	Vertical change (mm, mean ± SD)		Horizontal change (mm, mean ± SD)	
			Test	Control	Test	Control
Lekovic et al (1997)[50]	e-PTFE membrane	6	−0.3 ± 0.3	−0.9 ± 0.3	−1.7 ± 0.6	−4.4 ± 0.5
Lekovic et al (1998)[51]	PL/PG membrane (Resolut)	6	−0.4 ± 0.2	−1.5 ± 0.2	−1.3 ± 0.2	−4.6 ± 0.2
Iasella et al (2003)[24]	FDBA and collagen membrane	4–6	1.3 ± 2.0	−0.9 ± 1.6	−1.2 ± 0.9	−2.6 ± 2.3

e-PTFE = expanded polytetrafluoroethylene; FDBA = freeze-dried bone allograft; PG = polyglycolide; PL = polylactide.

Outcomes of Ridge Preservation

Ridge Preservation Versus Healing by Clot Alone. In a study examining the healing of premolar and molar extraction sockets and measuring dimensions on study casts, Schropp et al[3] reported that the width of the alveolar ridge was reduced by 50%, from a mean of 12 mm to 6.1 mm at 12 months. Two-thirds of the loss occurred in the first 3 months. The loss of height was less substantial, but almost all of the dimensional change took place in the first 3 months. The authors suggested that the bone level at the extraction site rather than the bone level of the adjacent teeth dictated the level to which the bone crest healed after extraction.

Of the studies selected, six included a comparison with an ungrafted socket allowed to heal normally. In all but one study, ridge preservation resulted in statistically significantly greater ridge width and height. Using a bioactive alloplastic graft, Yilmaz et al[42] reported the mean width of the test sites to be 5.7 (± 1.2) mm compared to 3.9 (± 0.8) mm at the control sites. The dimensions for the ridge height were 8.0 (± 1.6) mm for the test and 7 (± 0.5) mm for the control sites. Three of the studies used similar methodology, allowing direct comparison, shown in Table 2 and reproduced from the well-performed study by Iasella et al.[24] All showed significantly better maintenance of ridge width using ridge preservation compared to allowing healing by the clot alone. Iasella et al[24] also reported significantly less change in soft tissue thickness in the test versus the control sites. Camargo et al[43] used the same measurements as the Lekovic studies,[50,51] filling the test sockets with bioactive glass and then calcium sulphate. The authors reported that the unfilled sockets showed slightly better results. Serino et al[53] investigated the effect of filling the extraction socket with a PL/PG sponge and reported that after 6 months the mean distance between the ridge and reference points was +0.2 (± 1.5) mm for the test sites and –0.7 (± 1.2) mm for the controls.

Comparison of Different Grafting Materials. Only three cited publications that reported on the comparison of grafting materials presented clinical measurements. A study by Vance et al[32] compared CMC/CaS mixed with DFDBA against DBBM and a collagen membrane, and found no significant differences between the groups. Using ADMG with or without HA, Luczyszyn et al[45] reported that ADMG alone better maintained ridge width, and use of HA allowed an increased width of keratinized tissue. Neiva et al[55] investigated the placement of a collagen wound dressing with and without Putty/P15, and showed that the addition of the putty resulted in significantly less loss of height.

In summary, there is strong evidence that ridge preservation significantly maintains more ridge width and height, with most grafting materials being effective and only slight differences between them.

Is Primary Wound Closure Necessary? The question of whether ridge-preserved extraction sites require complete soft tissue coverage was not directly addressed. Techniques used ranged from simply placing the graft in the extraction socket[55,57] to raising and replacing a flap in the original position with[45] or without a membrane exposed to the oral cavity.[32,43,53,54] Partial closure without use of a membrane was reported by Yilmaz et al[42] and Babbush.[30] Iasella et al[24] and Carmagnola et al[33] achieved partial closure but covered the exposed socket/graft with a collagen membrane, whereas Froum et al[34] left e-PTFE or ADMG exposed, advising the patients to use chlorhexidine for a prolonged period of time. One study reported the use of a soft tissue graft to completely close the socket.[29] However, the majority of studies reported primary closure. This was either by a coronally advanced flap covering the graft/socket alone[22,25,35,47,56] or covering a membrane[21,26,27,31,41,50–52] or by a pediculated split-thickness palatal flap covering the graft.[38,46]

Given the diversity of soft tissue closure and concomitant procedures, an assessment of whether primary wound closure is necessary for successful outcome is difficult. It would appear that ridge preservation can be successful irrespective of closure technique.

Effect of Tooth Type, Position, and Reason for Extraction. No information was presented showing the effect of tooth type or position in the oral cavity on ridge preservation. The majority of the studies

investigated anterior maxillary single-rooted teeth. In this area, ridge preservation seemed to maintain ridge dimension. Some publications reported on the reason for tooth loss, which included periodontal disease, endodontic failure, restorative failure, caries, fracture, and trauma. However, no comments were made in any of the papers about the cause of tooth removal and the effect this might have had on ridge preservation. It appears that ridge preservation is successful irrespective of the cause of tooth loss.

Use of Antibiotics. Twenty-six of the papers reported the use of antibiotics, either during (4 studies) or after (22 studies) the procedure. Seven studies reported antibiotics not being used, and two studies did not report antibiotic use. Antibiotics used included doxycycline, amoxycillin, augmentin, metronidazole, penicillin V, erythromycin, and cephalosporin, with some used for 5 days, some for 7, and others for 10 or 12 days. Given the wide variety of antibiotics and dose regimes, few conclusions can be drawn regarding the use of antibiotics.

Could Implants Be Placed? The ideal end point of ridge preservation is the ability to place an implant with an appropriate diameter and length in the desired restorative position. In some studies, the end point was not the ability to place an implant, but the amount and type of bone formed or the difference in dimensional changes between augmentation methods. However, implants were reported to have been placed in many of the papers.[22,23,25,28,30–34,40,44,45,47,49,52–56] These studies did not report the size of the implants placed or whether they were placed in an ideal 3D position. Interestingly, Dies et al[26] reported that only 8 out of 12 subjects received implants, but did not state why they could not be placed in the remaining 4 subjects. Sàndor et al[49] grafted anterior maxillary sockets immediately following trauma, but found that only 17.6% of sites did not require further grafting at the time of implant placement. Where studies used a control site filled with a clot alone, very often implants were placed in these sites as well.[50,51,56] In addition, Fiorellini et al[56] noted that 55% of sockets allowed to heal with blood clot alone required subsequent simultaneous augmentation, compared to fewer of the test sites. Most recently, Molly et al[40] reported that 27 of 36 ridge-preserved sites had implants placed. Implants could not be placed in the remaining sites for esthetic and biomechanical reasons.

The evidence would suggest that implants can be placed in both test and control sites, but sites that healed naturally may require adjunctive augmentation procedures. Further studies are required to assess whether an implant of the appropriate dimensions can be placed in the correct restorative position following ridge preservation.

Is Bone Formed in "Preserved" Ridges? The amount and type of bone formed has been the main focus of ridge preservation studies. Healing of a socket follows the outline described previously, and the amount of bone formed depends on the time point when the socket content is examined during the healing process.[26,44] For example, Norton and Wilson,[44] investigating the use of DBBM and an e-PTFE membrane in extraction sockets, noted that sites with fewer than 6 months of healing had no bone, whereas sites with more than 6 months had some bone, but this was minimal and confined to the socket periphery. Techniques for assessing the amount or proportion of newly formed bone in sockets varied, which makes direct comparison problematic. However, in most studies there was some new bone formed.

Overall, DFDBA seemed to be well-incorporated in newly formed bone in the socket,[27,28] and comprised between 35% and 62% of the socket content.[21,25,30,32] However, this did not result in significantly more bone than in control sites with a clot alone[21] or with DBBM.[29] Smukler et al[21] reported that up to 21.5% of the socket was made up of residual DFDBA graft particles. These studies varied in duration from 4 weeks up to 23 months.

DBBM-treated sites showed between 18% and 64% bone fill and 20% to 30% residual DBBM particles at 6 to 9 months.[32–34,37,38,40] However, these particles were well-incorporated.[38]

Using bioactive glass, Froum et al[25] reported mean new bone formation of 59.5%, compared to 34.7% with DFDBA and 32.4% in control sites after 6 to 8 months of healing. A similar percentage was observed by Vance et al[32] using bone putty, a mixture of carboxymethylcellulose (CMC), calcium sulphate (CaS), and DFDBA. Serino et al[54] noted 59.9% bone infill using a PL/PG sponge as opposed to 48.8% in sockets with clot alone. The use of hydroxyapatite resulted in a range of bone, from 1%[45] to 34.5%.[34] Bioactive glass resulted in either very little bone[44] or substantial infill.[25] Wang and Tsao[48] showed a high percentage of vital bone 5 to 6 months after placement of a solvent-preserved cancellous allograft. Molly et al,[40] in a comparative study of three materials, reported a greater mean percentage of vital bone in the sponge group than the DBBM or biocoral groups. However, control sites had the highest amount of vital bone.

Comparative studies have shown mixed evidence that one grafting material is better than another or better than just the clot alone in terms of amount of newly formed bone. Vance et al[32] suggested that the mixture of CMC, CaS, and DFDBA was better than DBBM. Froum et al[34] found that bioactive glass was better than DFDBA or the clot alone. Both Smukler

et al[21] and Serino et al[54] showed that the amount of newly formed bone was the same in both test and control sites. Carmagnola et al[33] reported that the quality of the bone was better with just the clot or a collagen membrane than with DBBM and a collagen membrane.

Many studies used a bone graft material in conjunction with a membrane. It was reported that DBBM or HA used with an ADMG membrane produced markedly better results than with an e-PTFE membrane.[34] Luczyszyn et al[45] reported an ADMG membrane to be much more effective on its own than with an HA graft. Lastly, Pinho et al[41] placed autogenous bone and covered this with a titanium membrane, but showed that the membrane alone was just as effective after 6 months.

Membrane exposure was frequent and affected the amount of bone infill.[50] Not all studies mentioned exposure rates, but Pinho et al[41] reported a rate of 25%. Using a partial-coverage technique, Froum et al[34] had to remove 75% of e-PTFE and 12.5% of ADMG membranes, which may account for the poorer results in the e-PTFE groups. An exposure rate of 31% was noted using a collagen membrane by Norton et al,[37] but this complication could be controlled by intensive use of chlorhexidine, after which the membranes re-epithelialized.

In summary, the use of grafting material allows new bone formation in extraction sockets. However, the different grafting materials and differing healing periods make comparisons between studies difficult. Membranes may increase the amount of newly formed bone in the preserved ridges, but exposure can be detrimental to the regenerative outcome. A substantial number of the publications reported remnants of graft particles, up to 75% in some sites.[37] The long-term effect of residual grafting material on implant survival and success was not reported. The material chosen may reflect operator preference, the substitution rate, the length of time before the implant is to be placed, and what is commercially available. There is a need for standardized studies comparing materials with each other and the clot over fixed time periods.

Long-term Evidence for the Stability of Ridge Preservation or Implants Placed. The majority of papers selected for this review were short-term, with observation periods of less than 6 months. There were few studies that lasted for 12 months or more. Within these short time frames, most techniques seem to maintain ridge dimensions sufficiently for implant placement. Nemcovsky and Serfaty[46] and Yilmaz et al[42] reported that the width of the ridge gained by ridge preservation was maintained under pontics for up to 12 and 24 months, respectively.

Concerning implant survival, only four papers reported such details. In sockets grafted with bioactive glass, Norton and Wilson[44] showed a cumulative success rate of 90% at 1 year and 88.6% at 18 months. In sites grafted with DBBM, Norton et al[37] showed a survival rate of 97% at baseline, the time from implant placement to restoration, which was 13 to 33 weeks. In their cohort of children/young adults, Sàndor et al[49] found 93.7% of implants still to be in function after 3 to 7 years. Lastly, in a retrospective study, Sclar[39] reported a 94% survival rate for implants placed in 248 ridge-preserved sites over 6 to 73 months using the Bio-Col technique.

There is a lack of long-term information on the longevity of preserved ridges and the survival/success of implants placed. There is almost no information on which technique or material provides a more stable long-term result. It would seem prudent not to recommend a particular technique until this information is available.

CONCLUSIONS

The publications reviewed for this paper presented many different techniques, methodologies, durations, and materials, making direct comparison difficult. Irrespective of the heterogeneity of the studies, the following conclusions were reached:

- Ridge preservation procedures are effective in limiting horizontal and vertical ridge alterations in postextraction sites.
- Ridge preservation procedures are accompanied by varying degrees of bone formation and residual graft materials in the extraction socket. This depends on the materials and techniques used.
- There is no evidence to support the superiority of one technique over another.
- The use of membranes requires soft tissue coverage to optimize treatment outcomes. Exposure of membranes may lead to compromised results. e-PTFE membranes that become exposed are more problematic than collagen membranes.
- Primary closure is not always necessary.
- Long-term data on stability of ridge and implant survival and success are limited.
- There are no data on esthetic outcomes.
- There is no conclusive evidence showing that ridge preservation procedures improve the ability to place implants.

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