Report of 302 Consecutive Ridge Augmentation Procedures: Technical Considerations and Clinical Results

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Three hundred two consecutive ridge augmentation procedures (289 in a buccolingual and 13 in an apico-occlusal direction) were performed in 284 patients. Gore-Tex membranes of various configurations were used in conjunction with various nonautogenous particulate materials. Two hundred ninety-one of the augmented ridges (279 buccolingual and 12 apico-occlusal augmentations) demonstrated sufficient regenerated hard tissues for implant placement in ideal prosthetic positions. This represents an overall "success" rate of 96%, 97% for horizontally augmented ridges and 92% for vertically augmented ridges. A total of 574 implants were placed in the augmented ridges; 346 of these implants have subsequently been uncovered and restored. Seven implants failed to achieve osseointegration, and three implants (in one patient) were lost in function, for an overall survival rate of 97% for the uncovered implants.
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Key words: Gore-Tex membranes, osseointegration, ridge augmentation, survival rate

The concept of guided bone regeneration (GBR) has proven to be a great advantage to the clinical dentist. By excluding all nonosteogenic cells from the healing wound site, and by protecting and stabilizing the healing clot, the clinician is able to regenerate lost hard tissues and thus better idealize implant placement for the reception of prosthetic restorations, improved esthetics, and optimal function.[1–4] Numerous reports have documented the possibilities of GBR procedures and have outlined the technical prerequisites to clinical success.[5,6] However, questions still exist with regard to surgical procedure, choice of materials, and predictability in various clinical situations.

Many clinicians have advocated the use of autogenous bone whenever possible, citing its osteoinductive capabilities and unparalleled biocompatability.[5–8] However, such an approach often involves a second surgical site, sometimes extraorally.[9–11] As a result, patient morbidity is increased.

This paper reports the results of 302 consecutively treated ridge augmentation procedures using Gore-Tex membranes and nonautogenous particulate materials. This approach minimizes the surgical trauma and resultant morbidity for the patient.

Materials and Methods

Following a thorough medical history review, patients were deemed unsuitable to receive guided bone regeneration and/or implant therapy based on the following criteria:

1. The presence of uncontrolled diabetes, immune disease, or other contraindicating systemic condition
2. Radiation therapy to the head and neck region in the 12 months prior to proposed therapy
3. Chemotherapy in the 12-month period prior to proposed therapy
4. Uncontrolled periodontal disease, or an unwillingness to undergo needed periodontal therapy involving remaining teeth

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Table 1 Materials Used in Ridge Augmentation Procedures

Materials used	No. of patients	No. of patients with fixation tacks	No. of patients with support screws
DFDB/TCP/GTAM	68	26	45
FDB/TCP/GTAM	9	3	3
FDB/GTAM	2	1	2
DFDB/t-GTAM	87	80	21
FDB/t-GTAM	35	34	0
Bio-Oss/GTAM	13	13	0
Bio-Oss/t-GTAM	60	60	0
t-GTAM only	28	28	2

DFDB = demineralized freeze-dried bone; TCP = tricalcium phosphate; GTAM = Gore-Tex augmentation membranes; FDB = freeze-dried bone; t-GTAM = titanium Gore-Tex augmentation membranes; Bio-Oss = porous bone mineral matrix.

Table 2 Implants Placed Subsequent to Ridge Augmentation Procedures

		No. of implants placed			
Materials used	No. of patients	IMZ TPS cylinder	Hexed TPS cylinder	Screw	ITI TPS screw
DFDB/TCP/GTAM	68	125	6	0	0
FDB/TCP/GTAM	9	16	1	0	0
FDB/GTAM	2	4	0	0	0
DFDB/t-GTAM	87	156	4	9	8
FDB/t-GTAM	35	61	0	2	6
Bio-Oss/GTAM	13	6	0	8	15
Bio-Oss/t-GTAM	60	34	0	29	35
t-GTAM only	28	35	0	9	5

DFDB = demineralized freeze-dried bone; TCP = tricalcium phosphate; GTAM = Gore-Tex augmentation membranes; FDB = freeze-dried bone; t-GTAM = titanium Gore-Tex augmentation membranes; Bio-Oss = porous bone mineral matrix.

5. Severe psychologic problems
6. An unwillingness to commit to a long-term, post-therapy maintenance program

A complete examination of oral hard and soft tissues was carried out for each patient, and an overall dental treatment plan was formulated in conjunction with the treating restorative dentists. Panoramic radiographs were taken of all patients, as were formatted computed tomography scans, when deemed necessary. Diagnostic casts, waxups, and surgical templates were also used as needed, both in the treatment-planning phase of therapy and at the time of subsequent implant placement. All surgical and postoperative therapy was performed by the author.

The following materials were used, as deemed necessary, to perform the ridge augmentation phase of therapy (Table 1):

- Demineralized freeze-dried bone allografts (DFDBA) (Musculoskeletal Foundation, Homdel, NJ) with a particle size of 500 to 800 μm
- Mineralized freeze-dried bone allografts (FDBA) (Musculoskeletal Foundation) with a particle size of 500 to 800 μm or 800 to 1,000 μm
- Resorbable tricalcium phosphate (TCP) (Miter, Warsaw, IN)
- Porous bone mineral matrix (Bio-Oss, Osteo Health, Shirley, NY)
- Titanium support screws of various lengths (Implant Innovations, West Palm Beach, FL)
- Expanded polytetrafluoroethylene (e-PTFE) membranes (WL Gore & Associates, Flagstaff, AZ) of various configurations, both with and without titanium reinforcement
- Freos fixation tacks (Interpore International, Irvine, CA)

During the subsequent phase of implant therapy (IP), the following implants were used, as deemed clinically appropriate (Table 2):

- IMZ titanium plasma-sprayed (TPS) implants (Interpore International), of 3.3 or 4.0 mm diameter, in lengths of 8, 10, 11, 13, 15, or 17 mm

- TPS hex-headed cylindrical implants (Interpore International), of 4.0 mm diameter, in lengths of 11, 13, or 15 mm
- Titanium screw-type implants (Implant Innovations), of 4.0 or 5.0 mm diameter, in lengths of 10, 11.5, or 13 mm
- TPS screw-type implants (Straumann, Cambridge, MA), of 4.1 mm diameter, in lengths of 10, 11, 12, or 14 mm

Flap reflection was accomplished by one of the following procedures, depending on the clinical situation:

- A midcrestal incision in keratinized tissue, followed by four releasing incisions (mesio- and distobuccal, and mesio- and distopalatal).
- A split-thickness palatal incision beveled toward the buccal, leaving connective tissue covering the crest of the ridge following reflection of the buccal flap. This connective tissue was then elevated as part of the palatal flap, as described by Langer and Langer,[12] and a set of four releasing incisions were again used.
- Reflection of a "Langer" flap, as described above, followed by the rotation of a connective tissue pedicle from the inner aspect of the palatal flap prior to flap closure, as described by Fugazzotto et al.[13]
- A buccal vestibular split-thickness incision design, as described by Buser et al,[6] coupled with mesio- and distolingual releasing incisions.

GBR procedures were carried out in the following situations:

1. Buccal ridge augmentation of an area of insufficient buccolingual/palatal dimension to place an implant in an acceptable restorative position that would exhibit primary stability, even if a resulting significant dehiscence/fenestration was deemed acceptable.
2. Coronal ridge augmentation of an edentulous area of adequate dimension buccolingually, but of inadequate dimension apico-occlusally to accept implants of sufficient length to provide long-term support of the planned prosthesis.
3. Simultaneous buccolingual/palatal and apico-occlusal augmentation of an edentulous area that presented with both of the clinical inadequacies outlined above.
4. Buccal ridge augmentation of an area of insufficient buccolingual/palatal dimension to place an implant in an acceptable restorative position that would exhibit primary stability, even if a resulting significant dehiscence/fenestration was deemed acceptable, in conjunction with a sinus augmentation procedure.
5. Simultaneous buccolingual/palatal and apico-occlusal augmentation of an edentulous area that presented with both of the clinical inadequacies outlined above, performed in conjunction with a sinus augmentation procedure.

Following flap reflection, all soft tissue excess was removed. The buccal and coronal cortical plates were perforated with a no. 4 round carbide bur under copious sterile saline irrigation, in an attempt to increase both the vascularity and the ingress of bone progenitor cells to the regenerative site.

Prior to the use of titanium-reinforced e-PTFE membranes (t-GTAM), titanium support screws were placed into the edentulous ridge, where necessary, to help prevent the collapse of the membrane during healing. These screws were angled in appropriate directions so as to provide maximum support of the membrane in the desired position. Screw sizes that protruded from the edentulous ridge either 5, 8, or 11 mm after placement were used. The membrane was carefully trimmed and adapted so as to extend beyond the regenerative site by 3 to 5 mm in all directions. Freos tacks were placed as necessary to secure the membrane to the underlying residual ridge.

One of the mixtures of particulate material (see above) was then placed beneath the membrane and compressed to a dense consistency. Final adaptation of the membrane was made, and an additional tack was placed, if necessary, to further secure the membrane. If no fixation tacks were to be used, the particulate material was placed and condensed, and the membrane was placed over the material, again extending 3 to 5 mm beyond the regenerative site in all directions. All flaps were sutured with Gore-Tex sutures. Using the various flap designs and extensive releasing incisions previously discussed, every effort was made to achieve passive primary closure.

Postoperative management included chlorhexidine rinses twice a day for 21 days, amoxicillin 500 mg four times a day for 10 days (EES 400 mg three times a day for 10 days in penicillin-sensitive patients), ibuprofen 600 mg four times a day for 5 days, unless medically contraindicated, and pain medication (Tylenol with Codeine III or Percocet) as necessary. Sutures were removed 10 to 12 days postoperatively. Ridge augmentation patients were not allowed to use removable prostheses over operated sites until regeneration had been deemed complete. An exception to this rule was made only for patients whose maxillae were edentulous only in the anterior region. In these situations removable prostheses were extensively adjusted and relined for patients to wear

while functioning socially, but never while eating, throughout the course of regeneration.

Peridex rinses were prescribed for 2 weeks postoperatively and for the entire course of membrane retention if membrane exposure occurred. Exposed membranes were removed before 12 weeks only if persistent clinical signs of infection were noted.

Definitions of Success and Failure. Both the quantity and quality of regenerated hard tissue were assessed at the time of implant placement. The extent of buccolingual regeneration was deemed a "success" if implants of at least 4.0 mm in diameter could be placed, without the development of dehiscences and/or fenestrations. Such regeneration was deemed a "partial success" if implants of a diameter less than 4.0 mm had to be used, or if placement of 4.0-mm-diameter implants resulted in the development of dehiscences and/or fenestrations. For the purposes of this investigation, the inability to place implants with a diameter less than 4.0 mm without the generation of dehiscences and/or fenestrations was classified as a "failure." This classification was used even if reduced-diameter implants were placed and the resultant dehiscences were treated with regenerative techniques.

Vertical ridge augmentation results were considered a "success" if they allowed the placement of at least 10 mm of an implant body within hard tissue. Placement of between 8 and 10 mm of an implant body in hard tissue was deemed a "partial success." If less than 8 mm of an implant body could be placed in hard tissue, the result was classified as a "failure."

The regenerated ridge was further classified as mature (if the outer surface of the ridge was hard), partially mature (if the outer 1.0 to 2.0 mm of the ridge was still "osteoid like" in nature), or immature (if the regenerated ridge was soft to a depth of greater than 2.0 mm from its outer surface). This classification was based solely on clinical judgment at the time of reentry.

In patients where implant placement resulted in dehiscence and/or fenestration development, or when the ridge was not deemed fully mature, a membrane was placed over the implants prior to flap closure. In such a situation, the implants were not uncovered for at least 6 months after their placement.

Implants subsequently placed into regenerated ridges and then uncovered and placed into function were deemed successful if they met the following criteria:

1. The implant was immobile
2. There was an absence of pain and/or suppuration
3. There was no evidence of a peri-implant radiolucency
4. Vertical bone loss was less than 1.5 mm in the first year of function, and less than 0.2 mm annually in subsequent years of function

Results

Between March 1990 and June 1996, 302 ridge augmentation procedures were performed in 284 patients (Table 1). Of these patients, 158 were female (56%) and 126 were male (44%). Patient age ranged from 19 to 81 years.

The frequency with which the various flap designs were used is as follows:

- A midcrestal incision, followed by four releasing incisions: 180 patients
- The split-thickness "Langer and Langer"[12] approach: 43 patients
- The rotated palatal pedicle "Fugazzotto et al"[13] approach: 41 patients
- The buccal vestibular "Buser et al"[6] approach: 38 patients

The application of different ridge augmentation approaches was as follows:

- Buccal ridge augmentation (Figs 1a and 1b): 280 patients
- Coronal ridge augmentation: 8 patients
- Simultaneous buccal and occlusal ridge augmentation (Figs 2a and 2b): 4 patients
- Simultaneous buccal ridge augmentation and sinus augmentation: 9 patients
- Simultaneous buccal and occlusal ridge augmentation and sinus augmentation: 1 patient

Primary closure was achieved in 296 of the 302 procedures. Membrane exposure during healing occurred in 71 patients over the course of healing. Added to the 6 patients in whom primary closure was not achieved at the time of suturing, the total number of patients demonstrating membrane exposure during healing was 77 (29%). These exposures ranged from small asymptomatic fenestrations to large areas with purulent exudate. Time of first exposure ranged between 0 to 2 weeks and 10 to 12 weeks postoperatively.

Of the 6 membranes that were not primarily covered at the time of surgery, 3 were removed at 2 to 4 weeks, 2 were removed at 4 to 6 weeks, and 1 was removed at 6 to 8 weeks. The 71 membranes that became exposed during the course of healing were removed between 2 and 4 weeks from the time of implant placement, 4 to 10 months postaugmentation. All membranes except those noted above were removed at the time of implant placement.

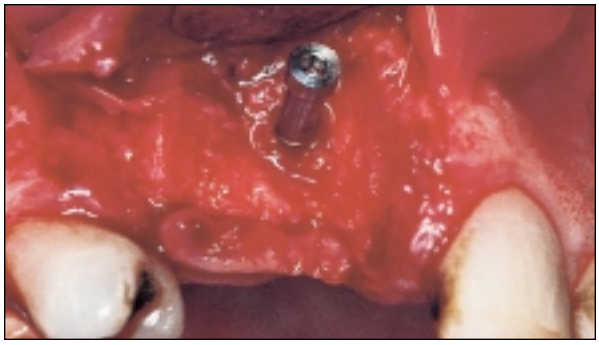

Fig 1a A self-tapping support screw is placed in the damaged alveolar ridge. An occlusal view demonstrates the extent of regeneration that will be attempted around the placed screw.

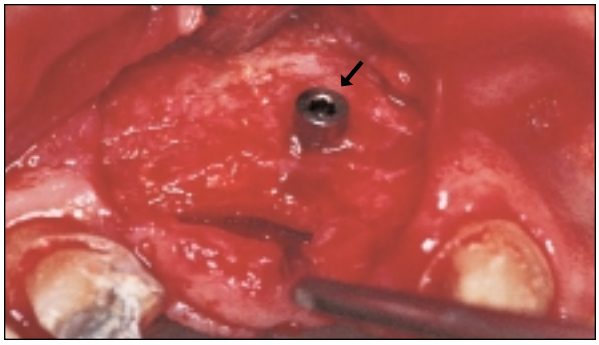

Fig 1b Eight months postoperatively, marked regeneration has occurred. Note the exposure of the support screw head, resulting from collapse of the GTAM membrane.

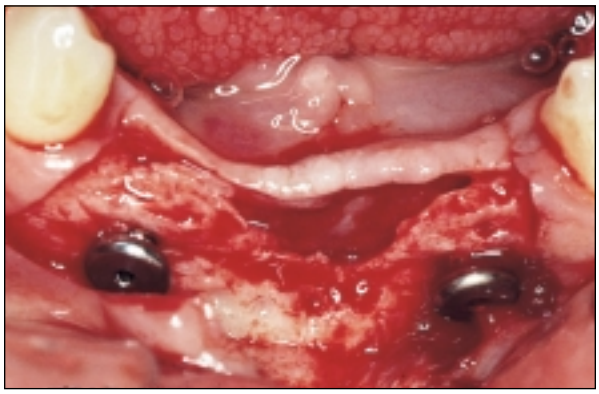

Fig 2a After tapping the alveolar bone, first-stage surgical sealing screws are placed to help support the Gore-Tex membrane that is to follow.

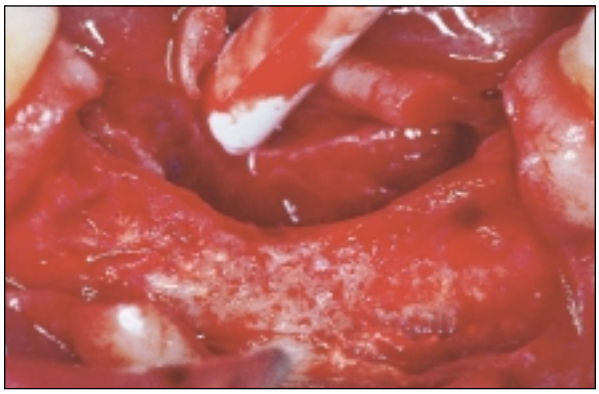

Fig 2b Reentry of the area, approximately 6 months after treatment with demineralized freeze-dried human bone, resorbable tricalcium phosphate, and a Gore-Tex membrane, demonstrates significant regeneration.

At the time of surgical reentry, a less mature ridge surface was generally encountered when primary closure had been lost. In patients where primary closure was maintained, ridge maturity increased as the time afforded for regeneration increased. The greatest difference was noted at the 6-month period; patients in whom the bone had matured for 6 months or longer exhibited a significantly higher incidence of a mature ridge surface than those in whom the bone had been reentered before 6 months had passed.

Residual particles of resorbable tricalcium phosphate were noted clinically in 53 of the 77 situations in which it was placed. While residual TCP was less evident when a greater amount of time was allowed for regeneration, particles could still be noted in some 8- and 9-month postoperative specimens. When clinical reentry occurred at least 6 months postoperatively, none of the 73 patients treated with Bio-Oss demonstrated any clinically visible residual particles. Biopsies taken from 9 of these patients at the augmented ridge during the time of implant placement were also free of residual Bio-Oss particles.

The 302 ridge augmentation procedures were performed in all regions of the maxilla and mandible (Tables 3 to 5). Of the 302 regenerative procedures carried out, 13 were apico-occlusal ridge augmentations. Based on the criteria outlined above, 9 (69%) of these were deemed successful, 3 (23%) were judged to be partially successful, and 1 (8%) was classified as a failure. Of the 289 buccolingual ridge augmentation procedures carried out, 250 (87%) were considered successful, 29 (10%) were classified as a partial success, and 10 (3%) were deemed failures. Overall, 259 (86%) were considered successful, 32 (11%) were classified as a partial success, and 11 (3%) were deemed failures. Of the 11 failures, 4 occurred in situations where primary closure had never been achieved and the membranes had been removed in 6 weeks or less; 6 were instances where significant membrane exposure, including evidence

Table 3 Success/Failure of Ridge Augmentations by Location

	Maxilla			Mandible		
	Anterior	Premolar	Molar	Anterior	Premolar	Molar
No. of patients	59	46	44	24	50	79
No. (%) of successes*	57 (97)	42 (91)	40 (91)	22 (92)	39 (78)	59 (75)
No. (%) of partial successes	2 (3)	4 (9)	1 (2)	2 (8)	9 (18)	14 (18)
No. (%) of failures	0	0	3 (7)	0	2 (4)	6 (7)

*All 9 ridge augmentations performed in conjunction with sinus augmentation procedures were successful.

Table 4 Success/Failure of Buccolingual Ridge Augmentations by Location

	Maxilla			Mandible		
	Anterior	Premolar	Molar	Anterior	Premolar	Molar
No. of patients	57	44	42	21	48	77
No. (%) of successes	55 (96)	41 (93)	39 (93)	19 (90)	38 (79)	58 (75)
No. (%) of partial successes	2 (4)	3 (7)	0	2 (10)	8 (17)	14 (18)
No. (%) of failures	0	0	3 (7)	0	2 (4)	5 (7)

Table 5 Success/Failure of Apico-occlusal Ridge Augmentations

Area treated	Materials used	Complications	Success/failure	No. of implants placed
Maxillary anterior	DFDBA, TCP, SS, GTAM	None	Success	2
Maxillary anterior	Bio-Oss, t-GTAM	None	Success	3
Maxillary premolar	Bio-Oss, t-GTAM	None	Success	2
Maxillary premolar*	DFDBA, TCP, SS, GTAM	Membrane exposure	Partial success	2
Maxillary molar*†	Bio-Oss, t-GTAM	None	Success	2
Maxillary molar	FDBA, SS, GTAM	Membrane exposure	Partial success	3
Mandibular anterior	DFDBA, TCP, SS, GTAM	None	Success	2
Mandibular anterior*	Bio-Oss, t-GTAM	None	Success	2
Mandibular anterior*	Bio-Oss, t-GTAM	None	Success	3
Mandibular premolar	DFDBA, TCP, SS, GTAM	Membrane exposure	Partial success	1
Mandibular premolar	FDBA, t-GTAM	None	Success	1
Mandibular molar	Bio-Oss, t-GTAM	None	Success	2
Mandibular molar*	FDB, t-GTAM	Membrane exposure and infection	Failure	0

*Simultaneous buccolingual augmentation.
†Simultaneous sinus augmentation.
SS = support screws.

of exudate, had occurred within 4 to 6 weeks of the procedure, necessitating immediate membrane removal; and 1 was an instance where primary closure had been maintained throughout healing.

Five hundred seventy-four implants were placed in the augmented ridges (Table 2; Figs 3a to 3c); 346 have subsequently been uncovered following 3 to 6 months of osseointegration. Seven implants failed to achieve osseointegration; 3 implants (one patient) subsequently failed in function (Table 6). Three hundred thirty-six (97.1%) were judged to be successful by the previously stated criteria.

Discussion

The use of guided bone regeneration procedures to augment atrophic alveolar ridges for subsequent implant placement is well documented in both animal and human studies.[1–6,14,15] While a wide range of armamentaria and techniques have been reported in animal studies, ranging from membranes alone to the concomitant use of various particulate materials or block grafts, most human case studies have advocated the placement of block grafts under the membranes when significant augmentation is required.[5–11] With

Table 6 Results of Ridge Augmentations Performed Between March 1990 and June 1996

Materials used	No. of patients	Implants placed	Implants lost at uncovering	Implants lost/failing in function
DFDB/TCP/GTAM	68	131	6 (2 patients)	3 (1 patient)
FDB/TCP/GTAM	9	17	1	0
FDB/GTAM	2	4	0	0
DFDB/t-GTAM	87	177	0	0 (of 81 total)
FDB/t-GTAM	35	69	0	0 (of 59 total)
Bio-Oss/GTAM	13	29	0	NA
Bio-Oss/t-GTAM	60	98	0	0 (of 26 total)
GTAM only	28	49	0	0 (of 9 total)

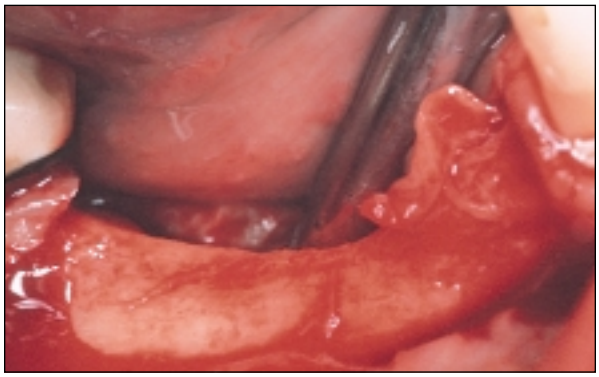

Fig 3a Flap reflection reveals a thin atrophic residual ridge.

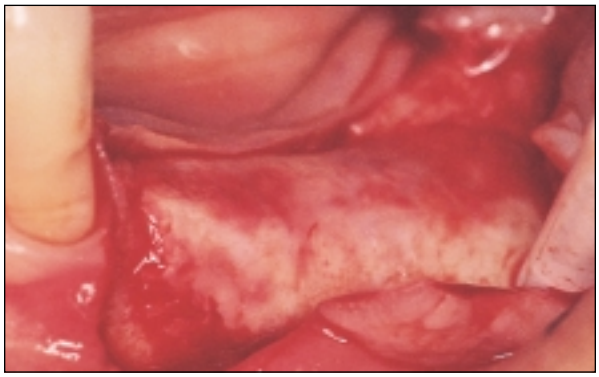

Fig 3b Eight months postoperatively, extensive regeneration of the atrophic ridge is evident. This area was treated with only a titanium reinforced Gore-Tex membrane.

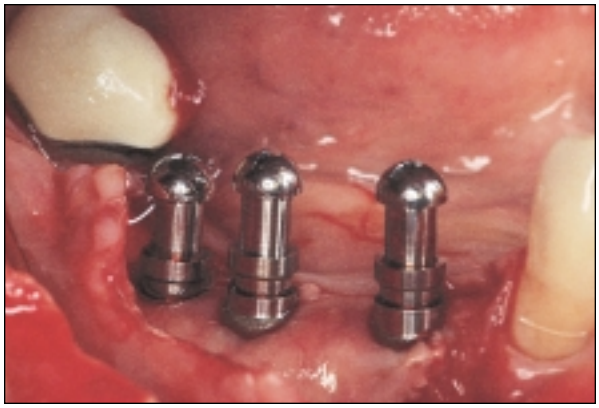

Fig 3c Three IMZ implants have been placed in the regenerated ridge at the time of reentry.

the exception of individual case reports or the treatment of relatively small defects, there is little documentation of predictable ridge augmentation using particulate materials beneath the membranes.[15–17]

This investigation of 302 consecutive cases demonstrates that the use of e-PTFE membranes, in conjunction with various particulate materials, can result in significant, predictable ridge augmentation in a horizontal dimension. Two hundred ninety-one of the treated ridges demonstrated sufficient augmentation with regenerated hard tissue to support implants in acceptable restorative positions. Of these, 29 required additional regenerative procedures at the time of implant placement. In 4 patients, the extent of augmentation allowed 5.0-mm-wide implants to be placed without dehiscing.

Because of the small number of vertical ridge augmentation situations treated,[13] no significant conclusions may be drawn; however, when examined simply as individual patient reports, only one of these procedures was judged a failure in accordance with the criteria previously outlined. Performing a simultaneous sinus augmentation procedure did not appear to influence the success of the ridge augmentation therapy. However, the number of patients treated in such a manner was small,[10] and therefore of limited value as a true indicator.

The assessment of success and failure based on the materials used is not possible. Table 1 represents a fairly accurate temporal progression of the materials used in the author's treatment of atrophic ridges. The earliest patients were treated using DFDB, TCP, and GTAM. The most recent cases were treated with the placement of Bio-Oss and t-GTAM. Also, later treatment has almost always incorporated membrane stabilization via tacking, a technology that was not readily available when this series was begun. In addition, the early procedures were subjected to two additional compromises: the author's clinical inexperience with the procedure, and the fact that many of the factors crucial to optimization of the regenerative result had not yet been fully elucidated. Nevertheless, evaluation of the results from this relatively large series of patient studies, coupled with the comparison of results achieved as surgical techniques developed, has underscored the importance of a number of principles that must be adhered to if optimal GBR results are to be attained.

Decortication of the Residual Ridge. All mandibular cortical plates, as well as maxillary areas as deemed necessary, were decorticated with a round carbide bur as advocated by a number of authors, to increase vascularity and the ingress of bone progenitor cells into the area. While theoretically sound, the need to perform this procedure is still unproved.[5,6] Decortication was a routine part of the armamentarium; however, this study does not evaluate its efficacy.

The Use of Particulate Materials Beneath the Membrane. The theoretical and practical basis for placing particulate materials beneath the membranes to aid ridge augmentation underwent a number of changes during the course of the investigation. Freeze-dried bone allografts, in either a mineralized (FDBA) or demineralized (DFDBA) state, were initially used because of the theoretical osteoinductive effects of their bone morphogenic proteins (BMPs).[18] DFDBA was always mixed with equal parts of resorbable tricalcium phosphate (TCP), in an effort to maintain the space beneath the membrane until sufficient tissues had regenerated, so as to prevent membrane collapse. It was hypothesized that DFDBA alone would resorb too quickly to demonstrate significant space-maintaining capabilities. TCP was often combined with FDBA for the same reasons, although FDBA was used alone when the space beneath the membrane was considered small enough to be maintained for a sufficient length of time without the TCP.

The clinical significance of the amount of BMP found in DFDBA or FDBA has recently been challenged in a number of publications.[19–22] As a result, the author has discontinued the use of these materials beneath the membranes, as they do not offer any space-maintaining advantages over other materials and are a potential cause of patient apprehension. TCP use has also been discontinued because its resorptive pattern was not found to be predictable. Clinical examination demonstrated the continued presence of TCP particles up to 1 year postoperatively. This was deemed unacceptable, as the ridge augmentation procedures were performed in advance of implant placement (ie, implants have been shown to bond intimately to bone, not to TCP, at a light microscopic level).

The advent of titanium-reinforced Gore-Tex (t-GTAM) membranes has significantly lessened space-maintenance concerns. As a result, t-GTAM has been used alone in the treatment of relatively small defects. Particulate materials are still placed beneath the t-GTAM, for the purpose of clot stabilization, when larger defects are treated. It has been well established that the stability and protection of the forming clot is of paramount importance in the attainment of successful GBR results.[5–7,14,15,23] Particulate materials may contribute to this stabilization in the early stages of healing.[16,17,23,24] Thus, the material chosen should be morphologically suited to the task and should resorb at a predictable rate. At this time, the only particulate material that the author places beneath the membranes during GBR procedures is Bio-Oss. Its morphology is such that it immediately helps to form a stable clot. Its resorption pattern is also predictable. The author has found no distinct clinical or histologic evidence of Bio-Oss particles beyond 7 months postoperatively. In biopsies of over 200 consecutively treated sinus augmentations at least 8 months postoperatively, Fugazzotto et al[25] found no distinct Bio-Oss particles. However, the results of this study should not be seen as absolute justification for choosing one particulate material over another, for the aforementioned reasons.

Space Maintenance. Prior to the advent of titanium-reinforced Gore-Tex membranes, particulate materials and/or block grafts were often relied on for space maintenance beneath the membrane.[2,5–8,15–17] In addition, support screws were used when it was judged that the morphology of the defect mandated additional membrane support.[5–7,16,17,26] While the use of support screws was helpful, they could not completely eliminate the problem of membrane collapse when used in conjunction with particulate materials. A common finding was that of localized membrane collapse lateral to the screw head, resulting in a compromise of the GBR result. The use of t-GTAM, with support screws if deemed necessary, has essentially eliminated this problem.[27–30]

Membrane Stability. Membrane stability was achieved during early ridge augmentation procedures through extensive reflection of the tissue flaps and passive suturing techniques. However, there is no doubt that some membrane movement occurred, which is a concern for a number of reasons. First, the goal of precise membrane positioning is compromised with any membrane movement. Second, such movement may result in membrane collapse. Finally, it has been suggested that membrane movement will lead to a greater soft tissue thickness beneath the membrane, and thus a poorer quality of regenerated bone. In all later patients treated, membrane stability was assured through the use of proper flap design and the Freos tacking system.

The Question of Primary Closure. Controversy exists as to the necessity of obtaining and maintaining primary closure to achieve the desired GBR results. While some authors consider primary closure to be an absolute prerequisite to successful GBR procedures,[5,6,28–31] others state that comparable clinical results are achieved with and without primary closure.[3] This has not been the author's experience. Of the 11 failures reported, 4 resulted from procedures where primary closure was not achieved, and the membranes had to be removed by or before 6 weeks postoperatively.

While primary closure was achieved in 296 of the 302 procedures, the closure was not always passive and stress-free during healing. As a result, 71 of the 296 primarily closed treatment situations (24%) exhibited some degree of membrane exposure during the course of healing. As more sophisticated flap designs, offering greater reflection and extension, were adopted, the incidence of membrane exposure decreased dramatically. While varying degrees of membrane exposure occurred in 67 of the first 132 procedures (51%), only 10 of the last 170 ridge augmentation procedures exhibited membrane exposure (6%).

While many areas that did not maintain primary closure demonstrated successful augmentation of the treated ridges, the quality and quantity of the tissues beneath the membrane did not appear to be equal to those found when primary closure was maintained. There was generally a thicker soft tissue layer beneath the exposed membranes, as well as greater tendency for the surface of the tissue to be immature and more delicate. In areas where partial exposure of the membrane had occurred, the tissues directly beneath the exposure were softer and less mature and had smaller quantities of regenerated hard tissue than adjacent areas under unexposed portions of the same membrane. In addition, a thicker soft tissue layer remained coronal to the membrane following membrane removal when primary closure had been maintained. This thicker soft tissue allows the clinician greater flexibility when dealing with the esthetic component in the anterior region.

As a result of these continuous findings, flap design was often modified to help ensure passive primary closure of the soft tissues at the time of surgery. Such modifications included greater mesiodistal extension of the flaps; greater vertical extension of the releasing incisions; horizontal release of the vertical incisions at their base; and rotated palatal pedicles. As a result of these changes in flap design, only 10 of the last 170 (6%) ridge augmentation procedures exhibited any membrane exposure, in contrast to 67 of the first 132 procedures (51%).

Timing of Reentry. Proper timing of the reentry procedure for implant placement, which has not been conclusively established, is influenced by a number of factors.[5–8,32–34] If primary closure has not been maintained, or if soft tissue inflammation around the retained membrane is evident, implant placement should not be attempted at the time of membrane removal. The soft tissue cover is often inadequate and, in the presence of soft tissue inflammation, the surface of the underlying bone is of poor quality. In such instances, reentry 4 weeks after membrane removal to place the implants will result in a more favorable clinical situation.

If asymptomatic primary closure has been maintained, timing of the reentry procedure will be dependent on the regenerative materials used and on the morphology of the original defect. Marx[35] has indicated that defects treated using autogenous bone grafts may be reentered at 4 to 5 months. The author has previously reported that upon reentry in ridges augmented with nonautogenous materials, the surface of the regenerated hard tissues is still soft at 6 months.[16] Such a finding was commonplace in this series. Prolonging the time afforded for regeneration appeared to result in a higher degree of ridge maturity, both at the surface and beneath, as discovered at the time of implant placement. As a result, unless relatively small areas have been treated, reentry procedures are now carried out 8 to 9 months after the original augmentation has been performed.

One-Stage Versus Two-Stage Surgery. If they can be placed in an ideal prosthetic position, and not in an area of esthetic concern, the implants are placed at the time of the regenerative surgery. Any resulting dehiscences are then treated during the simultaneous ridge augmentation procedure. However, the implants are placed during a second surgical procedure if their placement at the time of the regenerative surgery would result in any restorative compromises or difficulties. In areas of esthetic concern, the author prefers first to regenerate the lost

alveolar bone and then to place the implants during a second surgery. This ensures the attainment of adequate hard and overlying soft tissue for optimal esthetics. By placing the implants at the time of the regenerative procedure, the clinician runs the risk of being left with a functional but esthetically compromised result if the regenerative results are not ideal.

When the protocol described here was followed, ridge augmentation procedures were found to be highly predictable, resulting in acceptable implant placement in 291 of 302 augmented ridges (96%). If only the second half of the statistics are examined after the surgical protocol had been refined, then ridge augmentation procedures afforded the opportunity for acceptable implant placement in 149 of 151 cases (99%). A total of 574 implants were placed in the augmented ridges. Of the 346 that have been uncovered and placed into function, 336 (97.1%) have been successful when judged by the previously stated criteria. Of the 10 failures, 7 were lost at uncovering, and 3 (in one patient) were lost in function. Such a success rate demonstrates the ability of ridges augmented with particulate materials and Gore-Tex membranes to support osseointegrated implants in function over time.

Conclusion

Nonautogenous particulate materials, when used in conjunction with Gore-Tex membranes, have been shown to be successful in effecting bone regeneration in the treatment of 302 consecutive atrophic edentulous ridges. Such augmentation demonstrated success in both apico-occlusal and buccolingual dimensions. A number of technical considerations are crucial in attaining predictable results. In addition, maturity of the regenerated hard tissues appears to be somewhat time dependent, as treatment sites, reentered less than 6 months after the augmentation had been performed, demonstrated a higher degree of surface immaturity.

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