A New Approach to Regeneration of Surgically Reduced Alveolar Ridges in Dogs: A Clinical and Histologic Study
Hyman Smukler, BDS, DMD, HDD/Eliane Porto Barboza, CD, MScD, DScD/Charles Burliss, DMD

Premolar teeth were extracted from dogs and the remaining alveolar bone was surgically reduced to produce Class III ridge defects. Following 2 months of healing, a new technique using allogeneic cortical columns to prop up the raised mucoperiosteal flaps and create space for developing tissue was employed to create space for regeneration of the ridges. In the control sites, the cortical columns alone were used to prop up the mucoperiosteal flap; whereas in the experimental sites, barrier membranes (expanded polytetrafluoroethylene or bone membranes) were interposed between the flaps and the projecting cortical columns. In alternate sites, decalcified allogeneic freeze-dried particulate bone was added to fill the voids between the cortical columns, the underlying host bone, and the membranes. Variations of the new approach that were based on the principles of guided tissue regeneration provided the most significant gains in ridge width, with a mean aggregate gain of 3.31 mm. Histologically, all variations of the basic technique were seen to have augmented the surgically reduced ridges. Osseous regeneration was observed only where the barrier membranes were used. The addition of particulate bone filler did not appear to offer any advantage. This new approach to ridge augmentation meets the requirements for alveolar ridge regeneration.

Key words: bone membranes, cortical columns, guided bone regeneration, regeneration requirements, ridge augmentation, ridge regeneration

Alveolar ridge defects result from a loss of bone volume that is usually related to severely destructive periodontal disease or trauma. These ridge deficits often interfere with restorative efforts to obtain satisfactory esthetics with conventional restorations, and surgical augmentation of such deficient alveolar ridges is usually necessary before esthetic dental restorations can be fabricated. This augmentation has been accomplished by means of pedicle and soft tissue autografts1-4 and by implantation of synthetic materials into deficient ridges.5-7 The reconstruction of deformed ridges with new bone would be a more ideal outcome, particularly if the placement of endosseous implants was envisioned. This type of alveolar ridge augmentation, concurrent8-12 with or precedent13-16 to the placement of implants, has been achieved and does appear to be compatible with the osseointegration of endosseous implants. Recently Schenk et al17 have described the histologic events seen in bone regeneration of surgically created defects using guided tissue regeneration principles as a basis for the treatment. It is even apparent that bone with normal configurations can be regenerated by these methods. Important requirements for the augmentation of deficient ridges by means of alveolar bone regeneration include the creation of space for the regenerating tissues, protection of the
blood clot formed, use of barrier membranes to exclude nonosteogenic gingival tissues from the site, and trephining of the cortical plate on which the regeneration is to occur.13,14,18,19 A number of different materials and methods have been tried for the creation and maintenance of the space so critical to alveolar bone regeneration. These include porous hydroxyapatite blocks,20 titanium washers,11 mini–cortical screws,13 autogenous bone,14 freeze-dried allogeneic bone particles,15,16 and calcium carbonate.21 The barrier membrane used in these studies was generally of the expanded polytetrafluoroethylene (ePTFE) type.

The first objective of this study was to test a new approach for the creation and maintenance of space for augmentation or regeneration of alveolar ridges in surgically created alveolar ridge defects in dogs. The second was to quantitate the amount of regeneration possible with this method, and the third was to histologically identify the nature of the newly formed tissues following the use of two different types of barrier membranes. The effect of adding a particulate freeze-dried bone filler to each variation of the technique was also to be evaluated.

Materials and Methods

Surgical Technique. Four 3-year-old mongrel dogs of comparable size and in good health were used for this study. The dogs were housed in the dog compound of the animal research facility at the West Roxbury Veterans Administration Hospital, Roxbury, MA. During the preparatory phase of the experiment, the dogs were fed 100 to 130 g of kibbled biscuits dog food per 5 to 7 kg of body weight. In the postsurgical period, the animals were provided a soft diet consisting of a 1:1 mixture of the biscuits mixed with ground beef and water ad libitum to avoid trauma to the surgical sites.

A fifth dog was sacrificed to provide cortical bone for the preparation of all the demineralized freeze-dried cortical bone grafts used in this study. Upon removal, the long bones from the animal’s extremities were packaged in dry ice and shipped overnight to a tissue processing center (Northwest Tissue Center, Seattle, WA) where the various types of bone grafts were processed for use in this study. Cortical columns (CC) measuring 1 cm × 2 mm × 2 mm and cortical bone membranes (BM) measuring 1 cm × 3 cm × 200 µm were prepared to respectively fulfill the roles of space creator and barrier membrane in the experiment (Fig 1). Particulate bone (PB), with particle sizes of approximately 450 µm, was also prepared for use as a filler between the CCs, the barrier membranes, and the underlying alveolar bone. The PB was placed in randomly selected, alternate sites for each of the experimental variants tested. All bone products were appropriately freeze dried, decalcified, sterilized, and sealed under vacuum in separate glass vials. In those sites in which the BMs were not used, e-PTFE (Gore-Tex Augmentation Material [GTAM], WL Gore, Flagstaff, AZ) membrane was the barrier material chosen.

The sites selected for the experiment were the second (P2) and fourth (P4) premolar teeth in the mandible and the second premolar region in the maxilla. A total of 20 sites were initially prepared, but four in the maxilla were not included in the study because of maxillary sinus involvement during the surgery. This resulted in a total of 16 experimental sites, 13 of which were in the mandibular arch and three in the maxillary arch. Following intravenous sedation with 40 mg/kg of sodium pentathol, the surgical procedures were performed under general anesthesia with 0.5% to 1% halothane and 100% oxygen. The alveolar ridge defects were prepared by raising mucoperiosteal flaps, extracting the selected teeth, and removing facial and interradicular bone in each extraction site with burs under copious saline irrigation (Fig 2a). All defects that were of the Class III variety4 were
allowed to heal for 2 months (Fig 2b). Healing was uneventful, and reduced ridges suitable for the experiment and resembling ridge defects seen in humans were created.

At hour 0 of the experiment, the animals were again anesthetized, and the mucoperiosteal flaps were raised in the experimental sites (Fig 2b). Incisions were made midcrestally and connected with mesial and distal vertical releasing incisions on the facial aspects. The incisions were each started in the alveolar mucosa and carried toward the mesial and distal surfaces of the respective teeth, adjacent to the ridge defects. At their most apical aspects, the buccal mucoperiosteal flaps were separated from the underlying periosteum to ensure sufficient flap mobility and primary closure of the wounds without undue tension. On the lingual sides, vertical releasing incisions 5 to 6 mm in length were also made to permit complete exposure of the ridges.

At each site (Fig 2c), a minimum of two and a maximum of four rectangular holes, approximately 2 mm ́ 2 mm and 3 to 4 mm apart, were prepared with No. 557 cross-cut fissure burs. The holes were designed to receive the cortical columns, which after trimming, were firmly pressed into the holes to project about 3 mm facially (Fig 2d). The CCs were not hydrated in saline to keep them stiff throughout the augmentation surgery. Using No. 3 round burs, the cortical surfaces of the exposed alveolus were trephined between and about the rectangular holes (Fig 2e) to promote bleeding and expose cancellous tissues. When utilized, particulate bone was hydrated in saline for 15 minutes and packed on the underlying bone, between the columns, and underneath the membranes and flaps. The bone membranes were similarly treated and they or their GTAM counterparts were carefully adapted over the columns and to the periphery of the defects in the selected sites (Figs 2e and 2f). The flaps were sutured with 4-0 chromic gut using regular interrupted sutures.

All animals were given 25 mg of Kefzol (Eli Lilly, Indianapolis, IN) intravenously during the surgery and 1 g/day for 7 days to prevent infection, and 0.01 to 0.03 mg Bupenorphine (Norwich Eaton, Norwich, NY) every 12 hours for control of pain. After 3 months of healing, the animals were anesthetized and sacrificed using a lethal dose of potassium chloride given intravenously.

Data Collection and Analysis. Prior to the augmentation surgery, clinical measurements of the width of the reduced alveolar ridges were made when the animals were anesthetized. The teeth adjacent to the experimental sites were notched at the gingival level on the surfaces facing the sites. A probe was positioned horizontally between the two notches and a second probe was placed vertically at the midpoint between the two notches so that its tip rested on a point in the center of the reduced ridge (Fig 3a). This point was marked with a surgical pen and the procedure was then repeated on the lingual side. The buccolingual width between the two marked points was measured with Vernier calipers (Fig 3b) and recorded. Utilizing the positions of the probe tips (marked points) recorded before the experimental surgery, the ridge width measurements were repeated just prior to sacrifice of the animals. Measurements for each site were recorded, and the preregeneration and postregeneration data were summarized and compared. Kodachrome photographs, 1:1 magnification, were made at critical stages to permit further clinical evaluation of the results.

Histologic Preparation. Following animal sacrifice, the experimental areas were removed and sectioned buccolingually into equal-sized mesial and distal segments. One was used for clinical examination and the other for histologic assessment. Block sections of the sites to be used for the histologic evaluations were fixed in 10% neutral buffered formalin, decalcified in a formic acid solution, washed in running tap water, and dehydrated in
graded ethanol. The specimens were then embedded in paraffin and sectioned serially (8μm thick) in a buccolingual direction. The sections were alternately stained with hematoxylin-eosin and Mallory’s or Masson trichrome stains. The sections were viewed under the light microscope, and photomicrographs of selected sections were made.

**Results**

**Clinical Observations.** Healing was uneventful and no signs of infection or graft rejection were seen. In addition, none of the membranes or cortical columns became exposed during the healing period. When the jaw segments were viewed in cross-section, an increase of width in the ridges was noted indicating augmentation of the previously reduced alveolar ridges. The cortical columns could often be seen defining and maintaining the space between the membranes or flap and the original alveolar bone.

**Mucoperiosteal Flap/Cortical Column (Fig 4).** With this variation of the basic technique, the reduced ridges were seen to be augmented and the columns appeared to successfully support the overlying gingival tissue in the immediate vicinity of the CCs. The areas between and around the columns appeared to be filled with soft tissue. When viewed in profile, the soft tissue covering around the CCs appeared to collapse slightly in an alveolar direction in mucosal areas. These depressions were less obvious where gingiva covered the CCs. The tissues around the CCs were easily compressible upon pressure with a blunt instrument.

**Mucoperiosteal Flap/Cortical Column/ePTFE Membrane (Fig 5).** Regeneration of the alveolar process proportional to the amount of projecting CC appeared to have been achieved with this variation. The superficial gingival tissue was separated from the membrane, and upon removal of the ePTFE membrane, a layer of soft tissue was found covering the hard, noncompressible, regenerated tissue subjacent to it. The reduced ridges were successfully augmented exhibiting well-contoured profiles. The CCs could sometimes be seen projecting facially from the original margins of the reduced ridges for the full width of the regenerated ridge indicating successful space creation and maintenance.

**Mucoperiosteal Flap/Cortical Column/ePTFE/Particulate Bone (Fig 6).** In the sites in which PB had been added, the quantity of regenerated tissue appeared to be equivalent in size and shape to that seen in sites treated with the aforementioned variation. The quality, however, was consistent with hard rubber and could be compressed especially in areas subjacent to the membranes. Deeper layers had the feel of bone and were not compressible. Upon removal of the membrane, soft tissue covering the more dense underlying tissue was again noted.

**Mucoperiosteal Flap/Cortical Column/Bone Membrane (Fig 7).** Remarkable augmentation of the experimentally produced ridges was achieved with this technique. The CCs and BMs appeared to have achieved excellent space creation and maintenance that was notable when the segments were viewed in profile. The amount of new tissue appeared be related to the height of the projecting CC. Clinically, the new material had the feel of bone and was not compressible by pressure with a blunt instrument. After the gingiva more than one half of experimental site was separated from the underlying bone membrane, the membrane could not be peeled off the underlying tissue.

**Cortical Columns/Bone Membrane/Particulate Bone/Mucoperiosteal Flap (Fig 8).** The amount of augmentation seen appeared to be proportional to the height of the columns. Consistency of the newly formed tissue subjacent to the membrane was that of very hard rubber, and could be indented by firm pressure with an instrument. Closer to the host bone, the new tissue once again had the feel of calcified tissue. Following removal of the soft
tissues external to the bone membrane, attempts to separate the membrane from the underlying regenerated tissues were generally unsuccessful. In those few areas in which the membrane could be lifted, a layer of soft tissue appeared to cover the firmer tissue underneath it.

Data. The mean gain in width of the ridges treated by each of the different modalities is shown in Table 1. Those ridges treated by the CC + MP flap did not exhibit significant gains. The ridges treated by the other methods, which were all based on guided tissue regeneration principles, demonstrated gains which were clinically significant. The mean overall gain in width for the methods including CCs + flaps was 2.79 mm, whereas the remaining modalities showed an aggregate mean gain of 3.31 mm.

Histologic Observations. Histologic evidence of inflammatory activity was not observed within or about any of the experimental sites. Bone regeneration within the confines of the barrier membranes around and on the CCs was a ubiquitous finding, but was not seen in the surgical control, which did not include the use of a barrier membrane. Microscopic evaluation of all the allogeneic bone graft materials used in the experiment revealed that they were generally not completely resorbed or reconstituted within the experimental period of 3 months, regardless of the method used. The cortical columns or the bone membranes were, for the most part, shown to be relatively unaltered in size, shape and acellular, yet were well integrated or assimilated with the host bone wherever they were in contact with it. In some areas, vascular and cellular penetration of the bone membrane and cortical columns could already be seen occurring. Resorption and remodeling of some of the particulate bone spicules was also noted in a few areas.

Mucoperiosteal Flap/Cortical Column (see Fig 4B). In these sections, the CCs were well assimilated with the host bone in which they had been embedded. Connective tissue filled all the space around the CCs and fibers arranged in parallel bands could be seen dipping down over one CC and then rising up again over the adjacent one. New bone formation had taken place around the CCs within the host bone but was not seen on the projecting CCs. At this stage, the bone surrounding the CCs exhibited the characteristics of advanced cortication. No bone regeneration was seen external to the reduced ridge surface, but the ridges were augmented by the protruding CCs and surrounding connective tissue.

Mucoperiosteal Flap/Cortical Column/ePTFE Membrane (Figs 5B and 9 to 11). The CCs in these sections were also well assimilated, exhibiting fusion with newly formed bone which appeared to have grown towards and on the surface of columns from the lateral borders of the ridge defects and the underlying bone in which the CCs had originally been embedded. For the most part, the CCs were noncellular but, in the most deeply embedded areas, cells resembling osteocytes and blood vessels within old Haversian canals were seen. The new bone substantially filled the space between the host bone and the undersurface of the ePTFE membrane and about the columns. At this stage, the newly formed bone was mainly still woven in nature. In areas closer to the periphery, lamellation of the newly formed bone could already be seen. On the surface of this newly formed bone, ongoing cellular activity indicated that bone formation was still taking place, manifesting ongoing remodeling. Beneath the ePTFE membrane, a dense layer of connective tissue covering the most external portions of the CCs and regenerated tissues was always seen. The membranes themselves were well adapted to the host bone and were not associated with any inflammatory change. A notable amount of alveolar ridge regeneration was seen to have occurred, with the new ridges assuming well-contoured forms.
Mucoperiosteal Flap/Cortical Column/ePTFE/ Particulate Bone (Figs 6B, 12, 13a and 13b). In these sections, the CCs were once again well assimilated and new woven bone was seen on their lateral aspects and filling some of the space around and between the columns. The amounts formed were not as great as those seen in the experiments where PB had not been added. In all sections, the CCs were for the greater part acellular, but the presence of osteocytes and vascularity was noted in the deeper portions of the embedded CCs. In a few areas, some bone particles appeared to have fused with one another. Reconstitution of the spicules was seen, as evidenced by the appearance of osteocytes and what appears to be osteoclastic and osteoblastic cellular activity. Higher power examination of these situations exhibited some cellular activity that appeared to be associated with these changes. The predominantly unaltered particulate bone, surrounded by connective tissue, filled the space between the newly formed bone external to the host bone and the connective tissue subjacent to the membrane. As was seen in the other experiments, the deeper portions of the regenerated bone exhibited a more mature trabecular arrangement with adipose tissue seen in the trabecular spaces. Thus, the newly formed tissue was a conglomerate of regenerated woven bone that manifested some remodeling, some more mature bone configurations, and mostly unaltered freeze-dried bone particles enveloped by fibrous tissue.

Mucoperiosteal Flap/Cortical Column/Bone Membrane (Figs 7B, 11A, and 14). With this variation of the basic technique, the alveolar ridges appeared to have been extensively regenerated and well contoured. As with the other variations, the new height of the ridge appeared to be influenced by the distance the CC projected facially from the reduced ridge. The most striking feature seen with this modification was that the CCs were surrounded by and fused with newly formed woven bone, some of which was already exhibiting active remodeling and early lamellation. In more peripheral areas, cortication of the new bone was seen. Once again the newly developed bone appeared to be growing from the host bone outward into the defects, with the cortical columns appearing to act as highways for regeneration arising in the host bone. In some specimens, the new bone could even be seen growing over the ends of the CCs and fusing with the bone membrane external to it (Fig 11A). The bone membrane performed successfully as a barrier and seemed to be fused to the new bone growing along the undersurface, which appeared to have emanated from the lateral portions of the defects. The area between the bone membrane and the host bone was almost completely filled with a mixture of woven and some lamellar bone. Reconstitution of the acellular nonvital BM and CCs was occasionally seen in deeper areas. The BM was very well adapted to and integrated with the peripheral host bone to which it had originally been fitted.

Flap/Cortical Column/Bone Membrane/Particulate Bone (Figs 8 and 15). The contour of the reformed ridge was also reestablished by this variation of the new technique. The new ridge dimension was attained by a combination of alveolar ridge regeneration and augmentation with particulate bone enveloped by fibrous tissue, which is clearly demonstrated in all the sections. The new bone around the columns was mainly woven in nature and consistently exhibited evidence of active remodeling. Layers of osteoblasts could be seen on the surface of the newly formed bone adjacent to osteoid and cement lines, indicating active bone deposition. The space between the regenerated bone and the BM external to it appeared to be filled with unreconstituted bone particles, which were encompassed by mature connective tissue. In these sections, the bone membrane was also well integrated into the sites, and in some sections, appeared to be fused to the tops of the
columns. No bone formation was seen on the undersurface of the BMs. The CCs, BMs, and PB all appeared to be nonvital, just as they did throughout the experiment. However, evidence of reconstitution was noted in isolated areas, just as it was with other variations of the new technique.

Discussion

Using the principles of guided tissue regeneration (GTR) as a basis for therapy, it has been possible to regenerate some of the periodontal attachment lost as a result of periodontal disease. More recently, it has become obvious that this concept could also be used to regenerate alveolar bone, either concurrent with or precedent to the placement of endosseous root form implants. The present study confirmed that utilization of guided tissue regeneration principles can result in augmentation of surgically created ridge defects in dogs.

This study also tested a new approach to augmentation/regeneration of alveolar ridges utilizing assimilable allogeneic freeze-dried cortical columns as space creators and maintainers, together with bone or ePTFE membranes as the physical barriers to gingival tissue ingrowth. That this method was successful is demonstrated by the clinically significant increases in ridge width that were noted. Within the context of this study, and notwithstanding the small number of sites tested, the mean amount of augmentation of the ridges, which clinically and histologically appeared to be related to the height of facial projection of the CCs, was an impressive 2.85 mm. This occurred irrespective of the technique used and suggests that any one of these techniques may be used to augment ridges. However, it should be noted that the use of CCs with mucoperiosteal flaps performed inferiorly when compared with the other methods. The gains in ridge width were not statistically significant at P < .05 levels, whereas those treatments based on guided tissue regeneration principles did demonstrate significant gains at the same levels. When the CC + flap data were excluded, the aggregate mean gain increased to 3.31 mm. The increase in width tends to indicate that the new techniques can successfully create and maintain space that is essential to augmentation and regeneration of reduced alveolar ridges.

Requirements for successful regeneration of alveolar ridges include creation and maintenance of space for the regeneration, protection of the blood clot formed, trepanation of the cortical plate on which the regeneration is to occur, and use of a barrier membrane to prevent invasion of the site by undesirable gingival tissue elements. Recently, Buser et al. suggested the term guided bone regeneration (GBR) be applied to this type of alveolar regeneration. In our study, it appears as though the new technique utilized can affect and guide alveolar bone regeneration in experimentally reduced alveolar ridges in dogs. The cortical column space maintainers and barrier membranes appeared to satisfy the requirements for GBR when used even without the addition of particulate bone. Although not measured histomorphometrically, the sites in which the bone membrane was used as a barrier appeared to have a slight advantage in terms of the amount of bone regenerated, when compared to those situations in which ePTFE membranes were used. The surface of the ePTFE membrane abutting the columns was always related to a layer of connective tissue approximately 1 mm thick, while the bone membrane was generally more intimately integrated with the CCs or the newly regenerated bone subjacent to it. This perhaps accounts for the differences perceived.
Previous techniques\textsuperscript{11,13-16,20} for augmenting/regenerating alveolar ridges required that either the space creator, or the barrier membrane, or both needed to be removed at some time in the treatment sequence. The advantage of using assimilable materials as were used in this study is that while they also satisfy the requirements for ridge augmentation/regeneration, they need not be removed.

Bone allografts of varying particle size have been shown to be osteoductive inductive in various experiments with different experimental modalities and animal models.\textsuperscript{31-35} These studies indicate the resorption and replacement of the allogeneic transplants with new bone formed by the host. This does not appear to have been the case in our study. The particulate bone allografts were not reconstituted to form new bone but retained their nonvital, mostly unaltered, nature and were largely encompassed by connective tissue. These findings seem to agree with those of Becker et al.\textsuperscript{36} It is likely that with time, this nonvital allogeneic bone could be reconstituted or totally replaced by bone emanating from the host tissues.

There is some evidence in humans that this appears to be the case and that it may take as long as 14 months for the graft to be replaced with mature alveolar bone.\textsuperscript{37} By extrapolation, this would indicate that it was still too early in our experiment for this transformation to have occurred. The cortical columns and bone membranes used in this study also remained noncellular and in a nonvital condition throughout the experiment, but bone formation on their surfaces was seen. This type of bone deposition on hard bone surfaces has been described.\textsuperscript{17} The finding that the columns were not being replaced meant that they served admirably to support the “roofs” or membranes, thus creating and maintaining space necessary for regeneration of alveolar bone.

The induction mechanisms involved in the regeneration of the alveolar ridges in this study are not known. Certainly cytokinal mobilization of endogenous factors such as bone morphogenic protein and various platelet-derived and insulinlike growth factors must be implicated because they play a role in the healing of all wounds.\textsuperscript{38-44} These are abundantly released from the bone matrix exposed by the surgical injury. The type of cell responding to injury has been investigated, and Friedenstein\textsuperscript{45} has identified the determined (DOPC) and induced (IOPC) osteogenic precursor cells. The DOPCs exist in periosteal, endosteal, and marrow enclaves and can form bone directly in response to injury. The IOPCs are found in subcutaneous and intramuscular sites and can be induced to form bone indirectly. Osteoprogenitor cells in the cambial layers of the periosteum can also be stimulated by surgical injury.\textsuperscript{46,47} When this layer is damaged by flap elevation, the osteogenic activity is initiated in the undamaged but surgically stimulated periosteum at the periphery of the wound. This could well have been an important contribution to the regeneration seen progressing from the periphery towards the center of the lesion.

Predetermined osteogenic precursor cells, which respond to surgical injury of cortical bone, have been considered to be osteoinductive, and Frost\textsuperscript{48} has described this transient “localized burst of bone remodeling” as the regional accelatory phenomenon. In describing the healing events around endosseous implants, Roberts and others\textsuperscript{49,50} have also suggested that the necrosed bone resulting from injury to cortical bone during implant placement is osteoinductive. The nonvital allogeneic bone grafts used in our experiment did not appear to have an inductive capacity, as evidenced by the lack of bone formation seen in the areas in which it had been placed. Evidence from other studies\textsuperscript{51-54} tend to support this finding. However, it is likely that all of these endogenous inductive mechanisms played a role in the alveolar bone regeneration seen in the surgically created defects.
The regenerated bone seen in this study was mainly of the woven type, but after 3 months lamellation could already be seen in the newly formed bone. In some areas nearer the host bone at the peripheries of the lesions, remodeling of the bone to the type of cortical bone normal for dogs could be seen. Such changes have been noted by others. Roberts et al48,49 demonstrated that in dogs, the healing, remodeling, and maturation of bone repair and regeneration can take up to 6 months. This was seen in experiments concerned with implant placement, where bone formation exhibited a natural progression from woven through to mature lamellar bone with time. Similarly, Schenk et al17 also described healing patterns in surgically created defects in dogs over a 4-month period of time. Although our study was of slightly shorter duration, almost 1 Sigma cycle, the patterns of bone formation seen appear to agree with these investigators. If this information is extrapolated to the human situation, this would mean that at 6 months the nature of the new bone seen would possibly not yet be suitable for supporting implant placement. Thus it would appear that longer periods of observation are necessary to determine whether more mature bone arrangements capable of supporting dental implants will occur. It is our impression that bone configurations normal for the alveolus of dogs would be the end result of a longer study and that this type of bone could support implant placement.

Conclusions
Within the confines of this study it may be concluded that:
1. The principles of guided tissue or bone regeneration can be used to augment or regenerate surgically reduced ridges.
2. The new surgical approach described satisfies the requisites for alveolar ridge augmentation or regeneration.
3. The use of allogeneic cortical columns can be successfully used to create space for alveolar ridge regeneration.
4. The allogeneic bone membrane appears to be an effective barrier to nonosteogenic gingival tissue ingrowth in alveolar ridge regeneration procedures.
5. Significant increases in ridge width can be accomplished by means of the new technique described.
6. For the duration of this study, the allogeneic transplants were not yet totally resorbed or reconstituted.
7. Histologically, the new osseous tissue formed in these experiments was a complex of woven bone and woven bone undergoing lamellation and beginning to take on the character of cortical bone.
8. The use of assimilable materials for space creation and nonosteogenic tissue exclusion may be an important advantage in bone regeneration.
9. The development and successful use of the new approach provides interesting prospects for the augmentation of alveolar ridges with volume deficits.

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