“PASS” Principles for Predictable Bone Regeneration

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Guided bone regeneration is a well-established technique used for augmentation of deficient alveolar ridges. Predictable regeneration requires both a high level of technical skill and a thorough understanding of underlying principles of wound healing. This article describes the 4 major biologic principles i.e., *PASS) necessary for predictable bone regeneration: primary wound closure to ensure undisturbed and uninterrupted wound healing, angiogenesis to provide necessary blood supply and undifferentiated mesenchymal cells, space maintenance/creation to facilitate adequate space for bone ingrowth, and stability of wound and implant to induce blood clot formation and uneventful healing events. In addition, a novel flap design and clinical cases using this principle are presented. Implant Dent 2006;15:8–17)*

Key Words: guided bone regeneration, bone grafts, horizontal bone augmentation, implants

Guided bone regeneration (GBR) describes a surgical technique that increases and augments alveolar bone volume in areas designated for future implant placement, or around previously placed implants. The principle of GBR is based on the principles of guided tissue regeneration.[1-4] The principles delineated by Melcher[5] described the need for cell exclusion to enable the healing wound to be populated by cells thought to be more favorable for regeneration. In GBR, the cells that are required to repopulate the wound are primarily osteoblasts. Osteoblasts are responsible for laying down new alveolar bone and for future bone remodeling. By selectively excluding epithelium and connective tissue with the use of bone grafting and barrier materials, bone is “guided” into the desired position. Dahlin *et al*[6] were the first to show that bony defects created in rat mandibles could be successfully closed using guided tissue regeneration procedures.

The success and predictability of GBR have since vastly broadened the applicability of implant therapy. Implants can now be placed in areas of previously deficient bone volume, with success rates reported higher than 95 .[7-11] However, to ensure predictability of this technique, clinical procedures should be based on sound biologic principles. This article outlines the 4 major principles underlying successful GBR (Fig. 1): primary wound closure, angiogenesis, space creation/maintenance, and stability of both the initial blood clot and implant fixture (PASS).

Primary Closure

The 2 basic methods of wound healing are termed healing by primary intention and secondary intention, respectively. In healing by primary intension, the edges of a wound are placed together in virtually the same position they held before the injury. Secondary intention describes healing that occurs when wound edges cannot be closely approximated, resulting in a wound that is slower to heal, requires more collagen remodeling, and is more likely to result in scar formation. Realistically, true healing by primary intention is often difficult to achieve. However, primary wound closure is a fundamental surgical principle for GBR because it creates an environment that is undisturbed/unaltered by outside bacterial or mechanical insult.

Passive closure of wound edges enables the wound to heal with less reepithelialization, collagen formation and remodeling, wound contraction, and overall tissue remodeling. In addition, postoperative discomfort may be reduced as a result of less exposure of underlying connective tissue. Most investigators have advocated the necessity of primary closure following implant placement to ensure predictable GBR outcomes,[7,12-15] while others have disputed its importance.[16,17] Nonetheless, there is a consensus that primary wound coverage should be accomplished whenever possible.

Examining the effect of membrane exposure on bone volume gains highlights the importance of primary wound closure. Machtei[18] performed a metaanalysis to evaluate the effects of membrane exposure on treatment outcomes in guided tissue regeneration and GBR. When looking at guided tissue regeneration cases alone, exposed membranes showed only 0.47 mm less attachment gain compared to membranes that remained submerged. In comparison, membrane exposure seemed to have a significant deleterious effect on bone formation. In cases in which the membrane remained submerged, a mean 3.01 mm of new bone

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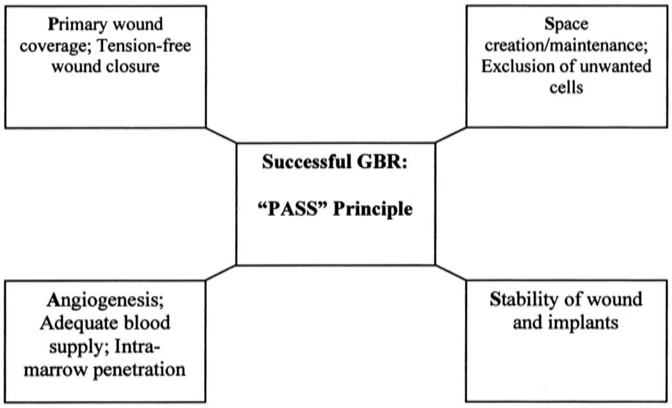

Fig 1 Principles of successful GBR.

was noted, whereas in cases with membrane exposure, an average of 0.56 mm of new bone was noted.

Similar results of a reduced amount of bone formation subsequent to membrane exposure have been reported.[11,18-22] Simion *et al*[20] examined membrane exposure in cases of GBR at the implant placement. The investigators found that 99.6 bone regeneration was obtained around fixtures where membrane exposure did not occur for 6-8 months following implant placement. In contrast, only 48.6 of bone regeneration was found when membrane exposure occurred earlier. Other studies have examined early *versus* late membrane exposure or removal.[19,23,24] It seems that if a membrane can remain covered for a significant period, up to 6-8 months, bone regeneration is predictable.

Factors that impede wound healing in an otherwise healthy individual are foreign materials, necrotic tissue, compromised blood supply, and wound tension. These factors may partly explain the reduced bone formation around exposed membranes. Other possible reasons for the reduced amount of bone formation are contamination of the membrane with oral microflora caused by an open wound.[25-28] More rapid resorption of bone grafting materials in areas of membrane exposure has also been reported. Jovanovic *et al*[29] examined 11 patients with dehiscence defects on the facial aspect of 19 threaded implants. A unique method of providing space was by placing the membrane over the implants and fixating them with the implant cover screw. Primary closure was attained, and clinical evaluation was performed after 4 months of healing. In cases in which the membranes remained covered, 14/19 sites with dehiscence showed 100 bone fill in the space created by the membrane. However, in the areas of membrane exposure, little bone regeneration occurred. These findings have further been confirmed in a beagle dog model[30,31] and more recently in human beings.[32]

The majority of membrane exposure data relate to nonresorbable membranes, both reinforced and nonreinforced. The development and widespread use of absorbable collagen membranes may circumvent this problem. Indeed, in addition to a reduced risk of membrane exposure,[22] the reported advantages of these membranes are a lack of need for second stage surgery and physiologically favorable properties of the membranes themselves, such as hemostatic, chemotactic, and cell adhesion functions.[33-35]

Advantages of collagen membranes include their hemostatic function by platelet aggregation, which facilitates early clot formation and wound stabilization. Both early clot formation and wound stabilization are considered essential for successful regeneration.[36] Collagen also possesses a chemotactic function for fibroblasts that assists in cell migration to promote primary wound closure.[37] Collagen membranes are also effective in inhibiting epithelial migration and promoting new connective tissue attachment.[38-42] Predictable treatment outcomes have been shown using absorbable collagen membranes in conjunction with bone mineral as a supporting and space maintaining device.[43-45]

In a series of 2 reports on localized ridge augmentation using GBR, Buser *et al*[46,47] advocated primary soft tissue healing, to avoid membrane exposure, by using a lateral incision technique. Other techniques that have been advocated in an effort to gain tension-free primary wound closure include a buccal rotational flap,[48] coronally positioned palatal sliding flap,[49] split palatal rotated flap,[50] and, more recently, a palatal advanced flap.[15] Together, the aforementioned studies highlight the importance of primary wound closure. Correct flap design, tension-free flap approximation, and postoperative care of the wound site are keys to achieving, and maintaining, primary closure. Flaps should be carefully designed and executed to ensure passive closure without tension on the wound margins. Collagen membranes, with their chemotactic function, may facilitate primary wound coverage, even after membrane exposure.[42]

Angiogenesis

Wound healing around implants is similar to wound healing events in other parts of the oral cavity, with several important exceptions. In particular, bone regeneration progresses in a sequence that closely parallels its normal formation.[51] The surface of the implant provides a platform on which an initial blood clot may form. The addition of bone grafting materials and membranes, in accordance with the principles of GBR, serves to create space and mediate osteogenesis *via* potential release of bone morphogenetic proteins. Following implant placement, the first 24 hours are characterized by formation of a blood clot around implant and in the space created by membranes and bone grafting material. The initial blood clot is removed by neutrophils and macrophages, and initial formation of granulation tissue begins within the next days and weeks. The granulation tissue is rich in blood vessels, and it is these vessels that are key to osteoid formation and subsequent mineralization to woven bone.[52] Primarily deposited woven bone will be converted into mature lamellar bone by secondary remodeling.[53]

There is an intimate relationship between newly formed blood vessels and de novo bone formation.[54] It has been shown that between 6 and 9 months are needed to fill completely the wound space, initially filled with blood clot, then with new bone.[55] Buser *et al*[47] found that introducing cortical perforations (*i.e.,* intra-bone marrow penetration) allowed migration of cells with angiogenic and osteogenic potential. Nonetheless, some studies have showed that bone regeneration can occur even from a noninjured cortical layer.[56,57] Future studies in this area are certainly encouraged.

The concept of a regional acceleratory phenomenon was introduced several decades ago.[58-61] Melcher and Dryer[62] also emphasized the importance of the blood clot in healing of bony defects. Several potential advantages of decortication exist. Providing communication with marrow spaces may enhance revascularization. Growth factors, such as platelet derived growth factor, and bone morphogenetic proteins can be released to enhance periodontal regeneration[63] and peri-implant bone formation.[64] Osteogenic cells important to bone healing can be derived from 3 main sources: the periosteum, endosteum, and undifferentiated pluripotential mesenchymal cells. The marrow provides a rich source of these undifferentiated cells that can be transformed into osteoblasts and osteoclasts. In addition, the perforations through the cortical bone provide a mechanical interlock with the newly regenerated bone. It has even been suggested that the cortical plate may act as a temporary hindrance for access of desirable cells and tissue components from the marrow because resorption of the cortical bone has to take place before access to bone forming components is achieved.[65]

Beneficial effects of regional acceleratory phenomenon have been reported in several animal studies.[52,66-68] Larger perforations have been associated with a shorter time to obtain bone fill but without any differences in the total amount of new bone formed.[68] Misch[69] has advocated the use of both buccal and lingual decortication to enhance bony healing 2-10 times higher than normal. However, conflicting reports regarding the beneficial effect of regional acceleratory phenomenon have also been reported.[65,70,71] Lundgren *et al*[65] used a rabbit calvarial model to evaluate the effects of decortication. There were 2 titanium cylinders with titanium lids inserted in the skulls of 8 rabbits. In each animal, the test side had the outer layer of cortical bone removed, while the control side was left with an intact cortex. Block section and histology performed at 3 months in all animals revealed no difference in total amount of augmented tissue (75.5 compared to 71.2) or the augmented mineralized bone tissue (17.8 compared to 16.0). Together, the aforementioned literature shows the need for adequate blood supply and angiogenesis for bone regeneration to occur. Although, to date, no consensus has been established on the beneficial effect of cortical perforation.

Space Creation/Maintenance

Providing adequate space for bone regeneration is a fundamental principle of GBR. Space is needed to ensure the proliferation of bone forming cells while excluding unwanted epithelial and connective tissue cells. For example, in areas of natural space maintenance, such as after the placement of immediate implants, there is evidence to suggest that the addition of bone grafting materials and membranes has no beneficial effect over no membrane/no graft control sites.[50,72,73] A consensus has yet to be formed regarding the need for the use of barrier materials and/or bone grafts around immediately placed implants.[74-78] It may be that assuming the critical jumping distance has not been exceeded, the space formed between the extraction socket and implant fixture provides an ideal environment for clot stabilization and subsequent osteogenesis.[79,80]

Various animal studies have proved that by excluding the epithelium and connective tissue, a secluded space is thereby created, allowing slowly migrating osteoblast cells to populate the wound, resulting in enhanced bone formation.[4,6,57] In a clinical and histomorphometric study in a canine model, Oh *et al*[31] used a beagle dog model to compare the effects of 2 collagen membranes (*i.e.,* BioGide; Osteohealth Co., Shirley, NY, and BioMend Extend; Zimmer Dental Inc., Carlsbad, CA) on GBR in surgically created buccal implant dehiscence defects. Membrane exposure occurred at 9 of 15 sites and was associated with poorer regenerative outcomes. In addition, a pattern of membrane collapse in most of the exposed sites (8 of 9) was associated with less regeneration. The investigators concluded that space maintenance and membrane coverage were the 2 most important factors affecting GBR using bioabsorbable collagen membranes.

Reinforced membranes allow space maintenance by preventing membrane collapse that may occur from pressure of overlying tissues. A titanium mesh incorporated into the membrane also improves the strength of the membrane and allows adaptability to the shape of the osseous defect. Jovanovic *et al*[81] used a canine model and compared 3 treatment groups in terms of bone regeneration. Group 1 had a titanium-reinforced membrane, group 2 had a standard expanded polytetrafluoroethylene membrane, and group 3 was a control and had no membrane. A marked gain of alveolar bone volume, resulting in complete supracrestal regeneration, was noted in both expanded polytetrafluoroethylene groups (1.82 and 1.9 mm) compared to only 0.53 mm achieved in the control group. Several other studies have compared the use of reinforced nonresorbable and absorbable membranes using various bone grafting materials.[22,43,82-84] From the available literature, it can be concluded that when a significant volume of bone is required for implant placement, the use of reinforced membranes or additional bone grafts is more beneficial.

When higher amounts of bone regeneration are required, space making with a barrier membrane is critical. As mentioned previously, absorbable membranes have various beneficial properties. However, a major challenge of using an absorbable membrane alone is membrane collapse that may be caused by the overlying soft tissue pressure. Various techniques have been developed to overcome this challenge. Using coronally advanced flaps, placing bone grafting materials under the membrane, or using other methods of mechanical support such as screws, pins, or internal membrane frameworks have all been evaluated with positive results.[85,86] Several case reports and clinical studies were performed in the early 1990s to develop a predictable surgical protocol that would enable the maintenance of a secluded space that could be occupied by cells with an osteogenic potential.[2,46,51,84,87]

Whether the use of bone graft material has any additional use other than space maintenance is debatable.[88] Mellonig *et al*[83] reported results from human cases in a delayed implant with simultaneous GBR technique. There were 3 treatment groups compared (*i.e.,* bioabsorbable membrane with decalcified freeze-dried bone allograft [DFDBA], expanded polytetrafluoroethylene with DFDBA, and bioabsorbable membrane alone) in nonspace making buccal dehiscence type defects. Comparable percent of bone-to-implant contact and amount of new bone volume, both in height and width, were observed in both groups using DFDBA. However, the control membrane-only group had a less favorable outcome, which the investigators attributed to lack of space making characteristics and subsequent membrane collapse.[83]

Similar results were shown using a bioabsorbable membrane alone in a monkey model,[89] or using a Teflon (DuPont Co., Wilmington, DE) membrane alone in a rat model.[90] In contrast, when a stiff, dome-shaped bioabsorbable membrane was used in a rabbit calvaria, no difference in the amount of regenerated bone was found between the membrane alone group and the membrane with bone graft group.[91] The literature seems to suggest that the major role of bone grafting material is space creation/maintenance. Osteogenic and/or osteoconductive properties of various bone grafts may also likely play a minor role.

Stability

The role of a barrier membrane is twofold. In addition to excluding unwanted cells, it also acts to stabilize the blood clot.[56,57,84,87,91,92] The importance of initial clot adhesion and wound stabilization is critical in wound healing.[84,87,93,94] It is understood that when the initial blood clot formation and wound stability, as well as initial implant stability, are achieved, a predictable wound healing sequence will occur. This sequence will ensure predictable bone formation. The initial blood clot is a rich source of cytokines (*e.g.,* interleukin-1, interleukin-8, tumor necrosis factor), growth factors (*e.g.,* platelet derived growth factor, insulin-like growth factor, fibroblast growth factor), and signaling molecules that recruit clearing cells to the wound site. Platelet derived growth factor in particular is a potent mitogen and chemoattractant for neutrophils and monocytes.[95] The blood clot serves as the precursor of initial highly vascular granulation tissue. The granulation tissue is then the site of initial intramembranous bone formation and remodeling.[51]

In addition to clot stabilization, primary stability of the implant fixture is a key to successful regeneration and long-term implant survival.[96-98] The lack of primary stability leads to micromotion at the bone to implant interface, which leads to fibrous encapsulation of the implant.[99] Some investigators have even advocated engaging 2 cortical layers whenever possible to enhance initial stability.[100,101] Resonance frequency analysis is a novel method that may be used to assess implant stability. In this technique, a transducer is attached to the implant fixture and excited over a defined frequency range. There are 2 factors that determine the resulting resonance frequency measurement: the degree of stability at the implant-bone interface and the level of the bone surrounding the transducer.[102-106] Using resonance frequency analysis, Meredith *et al*[102] examined 56 implants during their first year of insertion in 9 patients. The resonance frequency increased from 7473 to 7915 Hz on average after 8 months. There were 2 implant failures (failure to integrate) characterized by lower resonance frequency readings. However, its usage in detecting implant stability during or following GBR remains to be addressed.

Clinical Case and Technique

Fig. 2 illustrates the use of an absorbable collagen membrane with human mineralized bone allograft to augment a horizontal ridge defect in conjunction with implant placement.

Technique

- Baseline information analysis (Figs. 2A and 2B): A preoperative clinical and radiographic evaluation is needed to assess the need for bone augmentation during implant placement.
- Initial incision (Fig. 2C): An attempt is always made to locate the initial incision away from the defect site so that closure is not directly over the defect site. Vertical releasing incisions, either following the mucogingival junction or extending beyond mucogingival junction, are used whenever indicated. Mucogingival junction incision is a beveled vertical incision dropped toward the buccal aspect, with a wider base down to the mucogingival junction. This incision is continued along the mucogingival junction until adequate visualization of the surgical site is attained. The primary purpose of this flap is to provide a wide base of blood supply and minimize the scar tissue formation because the scar formed is likely to be hidden by the natural mucogingival junction. This effect is more predictable to achieve in patients with a wide band of keratinized gingiva.
- Reflection (Fig. 2D): A full thickness mucoperiosteal flap is reflected 2-3 mm beyond the margins of the defect. Traction is then placed on the flap, and an incision is made through the periosteum. The reflection is then continued by blunt dissection, creating a split thickness flap that can be repositioned tension free over the area to be treated, and primary closure be obtained. Several periosteal scorings within the buccal alveolar mucosa are also performed to allow easy segmental flap advancement, without placing excessive tension on the flap base. Usually, each periosteal scoring allows 2-3-mm flap advancement.
- Débridement (Fig. 2E): Granulation tissue is completely removed to help stop bleeding and allow careful inspection of the defect.

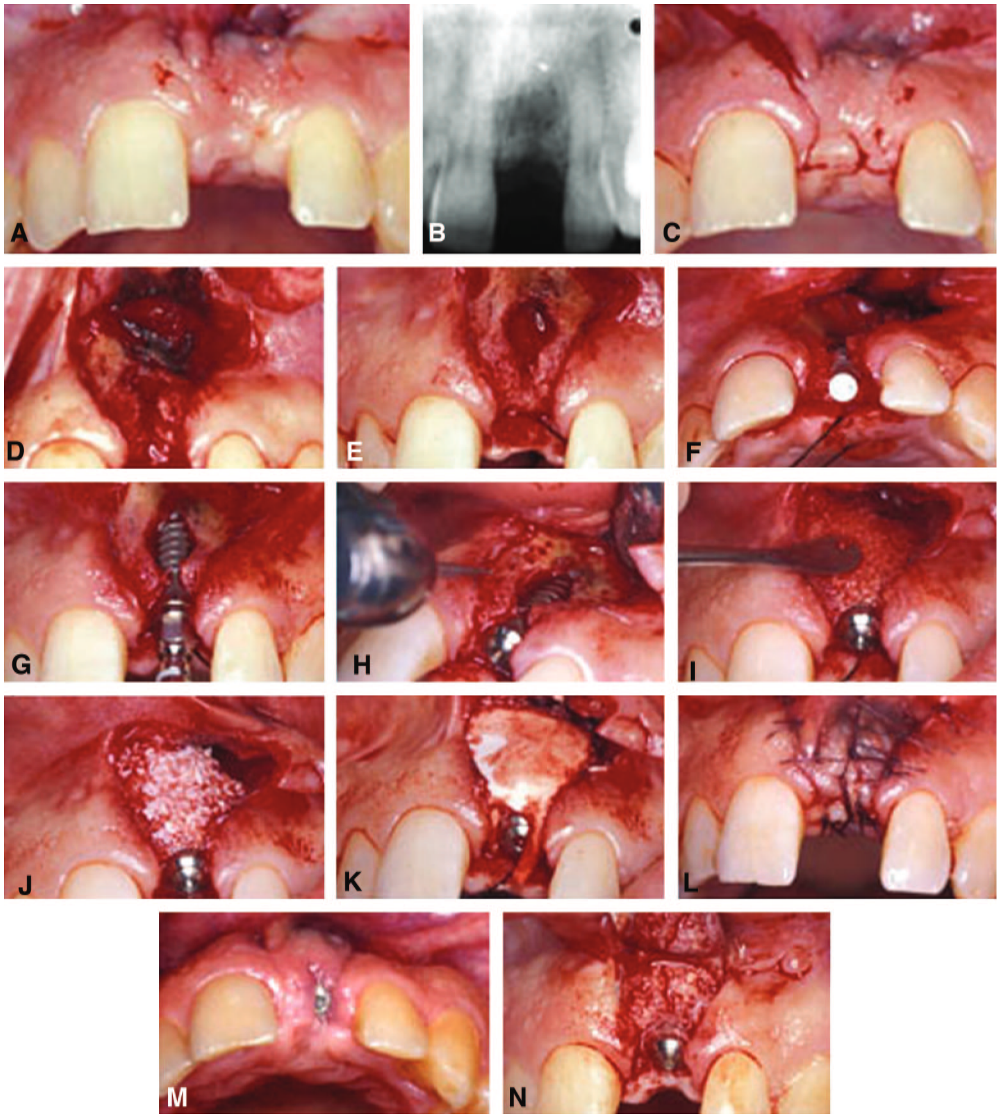

Fig 2 Case No. 2. Augmentation of horizontal ridge defect in conjunction with implant placement. A, Preoperative view showing inadequate ridge width and height. B, Presurgical radiograph illustrated potential apical lesion. C, Initial incisions depict 2 divergent vertical releasing incisions. D, Surgical view showing ridge defects with granulomatous tissues. E, Area was débrided to the bare bone. F, Initial implant drill following the surgical guide to indicate ideal buccolingual location. G, Implant placement with horizontal ridge deficiency. H, Intra-bone marrow penetration using half-round bur. I, Sandwich bone augmentation. First layer of bone graft aimed at promoting better bone to implant contact (human mineralized cancellous bone allograft, Puros; Zimmer Dental Inc.). J, Sandwich bone augmentation. Second layer of bone graft aimed at creating/maintaining space (human mineralized bone cortical allograft, Puros) was used for barrier support and space creation, both horizontally and vertically. K, Sandwich bone augmentation. Outer layer used for barrier support and space creation, both horizontally and vertically (collagen membrane, BioMend Extend). L, Suture with 4-0 and 5-0 Vicryl suture (primary coverage with passive flap tension). M, Four-week healing indicated uneventful healing. N, Reentry at 6 months showing new bone formation.

Implant drills were performed according to manufacturer's recommended protocol. In addition, drilling was based upon the prefabricated surgical guides that consider proper esthetic profile (Fig. 2F). Fig. 2G shows implant placement in a proper position with an obvious horizontal ridge deficiency.

- Removal of epithelium: Where appropriate, as in treatment of defects associated with existing implants, epithelium should be removed from the inner surface of the flap using a sharp curette or diamond bur. The implant surface should then be detoxified with appropriate agents (*e.g.,* 50 mg/mL tetracycline for 3 minutes).
- Fitting the membrane: Collagen membrane is trimmed and fitted so that it extends 2-3 mm beyond the margins of the defect in all directions. Usually, the collagen membrane is hydrated in sterile saline or sterile water for 5-10 minutes before use, to improve handling (malleability), however, this is not mandatory.
- Fitting the flap: The flap is checked and trimmed if necessary to ensure that primary tension-free closure is possible.

- Cortical perforations (Fig. 2H): Cortical perforations are made with a half-round bur to create bleeding at the defect site and allow egress of progenitor cells.
- Bone replacement graft placement (Figs. 2I and 2J): Graft material (*e.g.,* mineralized bone allograft) is placed at the defect site to support the tented membrane. Tenting screw(s) can also be used for this purpose, either alone or in conjunction with graft material(s).
- Membrane placement (Fig. 2K): The membrane is then adapted at the defect site. If the membrane is stable, no attempt is made to fix it. However, if the membrane is not stable, then pins, bone screws, or tacks may be needed to assist the membrane stability.
- Closing (Fig. 2L): The surgical site is closed with Vicryl (Ethicon, Inc., Johnson & Johnson, Somerville, NJ), Teflon, or silk suture with passive tension.

Postoperative Care

Antibiotic (*e.g.,* Amoxicillin 2 g/day for 10 days) can be prescribed for the patient. The patient is placed on warm saltwater rinses for the first 2-3 weeks to encourage normal flap healing without disturbing migrating cells. Chlorhexidine gluconate 0.12 (*i.e.,* Peridex ; Zila Pharmaceuticals, Inc., Phoenix, AZ)or Periogard (Colgate-Palmolive, New York, NY) mouthrinse will then be used for the next 3 weeks to facilitate plaque control. Sutures are removed at 10-14 days. The surgical site should be checked every 2 weeks for a period of 2 months (Fig. 2M). Final result is usually assessed at the implant uncovering, typically 4-6 months after initial surgery (Fig. 2N).

Conclusions

GBR can be a very predictable treatment modality in the partially or fully edentulous implant patient. The success of the technique is based on several biologically supported principles, such as PASS: primary wound closure to ensure undisturbed and uninterrupted wound healing, angiogenesis to provide necessary blood supply and undifferentiated mesenchymal cells, space maintenance/creation to facilitate adequate space for bone ingrowth, and stability of wound and implant to induce blood clot formation and uneventful healing events. This article has reviewed the biologic foundation that is essential for successful GBR. In addition, the technique involved in this principle was clearly illustrated.

Disclosure

The authors do not have any financial interests, either directly or indirectly, in the products listed in the study.

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"PASS"-Prinzipien für eine vorhersagbar erfolgreiche Knochengewebsregeneration

ABSTRACT: Die geleitete Knochengewebswiederherstellung stellt eine eingeführte Methode zur Anreicherung unzureichender Alveolarleisten dar. Eine vorhersagbare gute Regeneration bedarf sowohl der gro en technischen Fähigkeiten wie auch eines profunden Kenntnisstandes bezüglich der einer erfolgreichen Wundheilung zu Grunde liegenden Prinzipien. Die vorliegende Arbeit beschreibt die vier wesentlichen biologischen Prinzipien (d.h. PASS), die für eine vorhersagbar gute Knochenregeneration erforderlich sind. Hierzu gehören: der primäre Wundverschluss zur Gewährleistung einer ungestörten und ununterbrochenen Wundheilung; Gefä bildung zur Bereitstellung eines ausreichenden Blutzuflusses sowie unveränderte Mesenchymalzellen; Raumerhaltung oder -schaffung, um den entsprechenden Platz für Neuknochenbildung bereit zu stellen; und Wund- sowie Implantatstabilität zur Vermeidung von Blutgerinnselbildung und unerwünschten Begleiterscheinungen bei der Heilung. Au erdem werden in der Abhandlung eine neuartige Lappenkonstruktion sowie klinische Fälle, die dieses Prinzip praktisch zur Anwendung gebracht haben, vorgestellt.

SCHLÜSSELWÖRTER: Geleitete Knochengewebswiederherstellung, Knochentransplantat, horizontale Knochengewebsanreicherung, Implantate

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Los principios "PASS" para la regeneración pronosticable del hueso

ABSTRACTO: La regeneración guiada del hueso es una técnica bien establecida para aumentar crestas alveolares deficientes. La regeneración pronosticable requiere un alto nivel de aptitud técnica y un completo entendimiento de los principios de curación de una herida. Esta manuscrito describe los cuatro principios biológicos principales (PASS) necesarios para la regeneración pronosticable del hueso; cierre de la herida principal para asegurar una curación de la herida sin problemas y sin interrupciones; angiogénesis para proporcionar el suministro necesario de sangre y células mesenquimales indiferenciadas; mantenimiento/creación del espacio para facilitar un espacio adecuado para el crecimiento del hueso; y estabilidad para la herida y el implante para inducir la formación de un coágulo sanguíneo y una curación sin dificultades. Además, se presentan un diseño nuevo de la aleta y casos clínicos que utilizan este principio.

PALABRAS CLAVES: GBR; regeneración guiada del hueso; injertos de hueso; aumento horizontal del hueso, implantes.

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Princípios "PASS" para Regeneração Óssea Previsível

RESUMO: A Regeneração Óssea Guiada é uma técnica consagrada usada para aumento de rebordos alveolares deficientes. A regeneração previsível exige tanto um alto nível de habilidade técnica quanto um entendimento completo dos princípios subjacentes da cura de feridas. Este manuscrito descreve os quatro princípios biológicos principais (i.e., PASS) necessários para a regeneração óssea previsível: Fechamento primário da ferida para assegurar a cura tranqüila e ininterrupta de feridas; Angiogênese para fornecer suprimento necessário de sangue e células mesenquimais indiferenciadas; Manutenção/criação de espaço para facilitar espaço adequado para crescimento para dentro do osso; e estabilidade de ferida e implante para induzir a formação de coágulo sangüíneo e eventos de cura tranqüilos. Além disso, um original design de borda e casos clínicos que utilizam este princípio são apresentados.

PALAVRAS-CHAVE: GBR; Regeneração óssea guiada; enxertos ósseos; aumento horizontal do osso; implantes.

Predictableな骨再生のための"PASS" Principle

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要約：誘導骨再生は、歯槽堤欠陥増大法として定着した方法である。Predictableな再生には、高い技術水準と損傷治癒の原理的で完全な理解がともに必要とされる。本論文は、predictableな骨再生に必要な4つの生物学的に重要な原理（"PASS"）：妨害のない継続的な損傷治癒を確保するための「Primary wound closure」；必要な血行とundifferentiated mesenchymal cellsを提供する「Angiogenesis」；骨のingrowthのための空間を確保する「Space maintenance/creation」；血栓形成を起こし良好な治癒を可能にする「wound and implant Stability」について解説する。加えて、この原理を適用した新しいflapデザインとその臨床例も紹介する。

キーワード：GBR、誘導骨再生、骨移植、水平方向骨増大、インプラント

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