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Guided Bone Regeneration

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Introduction

Bone regeneration have a mechanical and biological function (Deliberador et al, 2006). Guided Bone Regeneration involves the use of barrier materials for healing a bone surface adjacent a defined bone area only by preventing the invasion of bone defect by competitive osteogenic tissue cells (Buser, 2009). Because of their physical and biological characteristics the barrier material most commonly used in implantology are membranes(Netter et al, 2005).

The use of non- reabsorbable membranes demonstrated an important therapeutic option in the treatment of peri-implant bone defects. However, this technique has the disadvantage of requiring a second surgery for removal of the membrane and fastening materials. Additionally, high frequency of complications associated with their use has produced in recent years, a decrease in the use and indications of this type of membrane, while an increase in the use of absorbable and non-reabsorbable membranes (Brighton & Hunt, 1997).

The development of guided bone regeneration membranes has proved useful to assist and help in bone (Spagnoli et al, 2001) grafts and has proved effective in protecting through a barrier effect filler oral means, preventing the rapid growth of soft tissue towards the graft. Documented problems with membranes include: dehiscence of soft tissue and exposure, displacement and collapse of the membrane (Arnsdorf et al, 2009). The membranes behave as foreign bodies can lead to infection and delayed healing, and if they had to be removed prematurely, bone regeneration would be less predictable.

The most contentious issue centers on whether to place a membrane when the periosteum of the mucoperiosteal flap is harmless. It seems clear that the membranes can be useful when used cortical grafts onlay block (Buser et al, 1996) or alloplastic materials when used solely (Spagnoli et al, 2001) because it allows the formation of new bone by osteoinduction mechanisms in the first case and the second osteoconduction.

The Effectiveness of Periosteum as a Barrier Membrane in Lateral and Vertical Alveolar Ridge Augmentation

The implantation of Periosteum in bone-tooth restoration has been a vital component of standard care in modern dentistry (Shapiro, 2008; Knothe. & Springfield, 2005; Schropp et al, 2003). The process of alveolar ridge augmentation in reconstruction surgery for deficient alveolar ridges implies Guided Bone Regeneration (GBR) and has become a predictable and well-practiced surgical approach in the field of dentistry (Buser, 2009). Moreover, the effectiveness of Periosteum in lateral and vertical alveolar ridge augmentation has been studied by Mardas et al., (2010, p. 688), who states that the use of barrier membranes as bone grafting materials avoid complex and expensive bone harvesting procedures and helps in re-modeling of newly periosteal tissues at augmented sites. In a study by Dimitriou et al. (2012, p. 81), the barrier membranes help in grafting of standardized defects in the mandibular angle by laying a collagen sponge, tricalcium phosphate granules, and harvesting a coral- hydroxyapetite granular epithelium. Furthermore, in periosteal implantation processes the mandible is opened and granular tissues are removed from the newly created alveolar ridges (Thabet et al, 2008). Ii allows the facilitation of fluid-tight and tension-free wound closure so that Periosteum can be released at its base (Mahajan, 2012).

The wound margins can them be aligned with horizontal mattress and interrupted sutures. This provides the augmented sites a consistent ridge expansion and new bone formation (Allen et al, 2004).. However, the use of barrier membrane does not seem to accelerate the remodeling of the cortical portion of the autograph. On the other hand, the contour of the alveolar ridges shows promising results in ridge profiles for the accommodation of rootform dental implants.

Conversely, bone to bone membrane contact process allows more opposition on the shaft or head of the fixation screw. Beitlitum et al., (2010, p. 1250) studied the effects of autografts and barrier membranes in lateral and horizontal augmentation process in alveolar ridges. Moreover, the use of barrier membranes likes Periosteum in yield membrane protection for efficient crestal contours and subsequent placement of rootform dental implants.

In contrast, the lateral and horizontal alignment of autograft placement shows a considerable crestal bone resorption in alveolar ridge augmentation process (Watzinger et al, 2000). However, there lie significant differences in barrier membrane allocations without the use of filler materials in bone regeneration and tranosseous bone defects located in the mandibular alveolar ridges. Beitlitum et al., (2010, p. 1250) signified the histologic evaluation, which shows a sequence of maturation of block grafts with membrane application and crestal and bone resorption. In a study by Dimitriou et al., (2012, p. 81), it is illustrated that particulate grafting materials like using a periosteal membrane in buccal bone defects of alveolar ridges helps in aligning cortical bones in sequential allogenic bone membrane regeneration.

The importance of the role of membrane barriers for bone regeneration and the inability of the periosteum barrier material was demonstrated in one study (Dahlin et al, 1998) that bilateral fenestration was created lobby-palatal for 5mm diameter jaws of rat. At the test site, defects were covered with membranes expanded ethylene polytetrafluoride (GoreTex®) and the

flap is repositioned. In the control group, the flap is repositioned in position, making sure the periosteum was full. When it was observed few months later, the test group had produced a regeneration ad integrum of the change in default control group and lobby-palatal communication fenestrations remained open and the defect was with healed soft tissue.

This trial was failed to show periosteal is ineffective as a barrier to non-self-healing bone regeneration defects. Similar results were obtained by performing a similar protocol study in monkeys (Dahlin et al, 1990), which allowed insufficient confirmation of the role of the periosteum as a barrier to soft tissue colonization during bone regeneration. As for the regeneration of Peri-implant bone defects, many animal (Lundgren et al, 1997) and human studies (Lang et al, 1994) show higher bone regeneration when membranes are used, as compared to when they are not used, provided that certain requirements are met during surgery and the healing phase, the regeneration membrane will be completely predictable.

The Effectiveness of Resorbable in Comparison with Non-Resorbable Barrier Membranes in Alveolar Ridge Augmentation

Different situations may necessitate tooth extraction; advanced caries, trauma, endodontic lesions, developmental defects or advanced periodontitis. It should be that the extraction should be as aggressive as possible because after making the extraction it produces a bone resorption resulting in atrophy of the alveolar ridge and a collapse of soft tissue. This situation can cause aesthetic and functional problems such as impairment in a subsequent implant placement because of the lack of bone volume required (Cardaropoli et al, 2003).

The ultimate goal of treatment is to implant prosthesis function and suitable aesthetics. To do this, one must have sufficient bone volume in order to place the implant in an ideal position and to achieve technical alveolar preservation, which aims to reduce vertical and

horizontal dimensional changes in the socket after tooth extraction using bone substitute materials or without membrane so that after healing, is available the maximum possible bone volume. However, this does not prevent bone resorption, since, depending on the technique, yet it can produce a loss in width and height (Ten Heggeler et al, 2011).

The use of membranes to facilitate retention of the bone graft into the socket and isolation of alveolar soft tissue for a correct osteogenesis occurs without allowing invasion of soft tissues. We used a wide range of membranes, i.e. expanded polytetrafluoroethylene (ePTFE), collagen, and polyglycolic acid and poliláctivo. These can be divided into two categories; non-resorbable and resorbable ((Artzi et al, 2000; Tal, 1999):

- Absorbable membranes. It is animal collagen or synthetic membranes (from aliphatic, polylactic and polyglycolic acid) polyesters. They also have a halogen source (Bodies). If left exposed during healing but generally do not normally infect and will give lower bone regeneration. The advantage of these membranes is that one only needs a single surgery, the withdrawal will not be necessary. Unless a second surgery for implant placement is made, you will not know if it has produced new bone formation;
- Non-resorbable membranes: It includes polytetrafluoroethylene (ePTFE) and reinforced ePTFE titanium. These membranes have a greater risk of exposure during healing, with the bacterial colonization and subsequent risk of bone loss, which may be necessary remove them. The advantage of these membranes is that they will see the new bone formation that has occurred at the time of withdrawal. They can take the form and provide a desired defect in areas inaccessible space, they presented the need for a second surgical phase.

Jung et al. (2013, p. 1073) entailed that the process of bone regeneration in alveolar ridge augmentation involves biocompatibility, barrier ability, mechanical prevention and proliferation, integration of biological tissues, and preservation of the space sequence between the maxillary alignment. The use of barrier membrane against the masticatory forces and tissue tensions prevent the collapse of soft tissues and facilitate in reduction in wound spaces. The process of integration into the tissue through absorbable membrane allows wound stabilization and inhibits epithelial migration (von & Buser, 2006). In dependence to their biological environment, the alveolar tissue framework is divided into absorbable and non-absorbable membranes. The non-absorbable membranes maintains the structure and the shapes of alveolar tissues, therefore their removal required additional surgical interventions with a prolonged healing process (Jung et al., 2013, p. 1073). This also leads to the increased cost of therapeutic management of the patient and increase the susceptibility of trauma to the patient. However, the non-absorbable membranes predispose the alveolar ridge augmentation for secondary surgery, higher chances of infection, and greater risk of exposure.

On the other hand, the Resorbable membrane does not require removal after implantation that reduces patient discomfort immediately after surgery, reduces the cost of treatment and complications after surgery. Moreover, the duration of resorption of these membranes cannot be estimated due to their varying nature. Since, the process of resorption begins as soon as they are implanted into the tissue, the expected membrane persistence and durability range from 4 weeks to several months (Mardas et al., 2010, p. 688). On the other hand, collagen has the ability to adhere to non-Resorbable barriers, mostly made of expanded polytetrafluoroethylene (e-PTFE) and is termed highly successful in guided tissue replastic surgery and bone regeneration procedures.

Conversely, the non-Resorbable membranes need to be detached from the existing material in order to avoid bacterial growth and disease causation. Moreover, the barrier membranes need to be separated from bacterial contamination and colonization and the subsequent risk of chronic reinfection. When collagen membranes are applied, wounds do not get infected. However, there is a chance for the premature degradation of collagen frameworks, in non-Resorbable barrier membranes. Primary stabilization is achieved by applying Resorbable barrier membranes to prevent premature degradation of newly laid periosteal tissues in alveolar ridges.

The non-Resorbable membrane can lead to method of new bone generation and maturation, and sustaining contamination-free environment in closed compartments beneath the barrier membranes. Thus, the soft tissue component throughout the healing and regeneration process in Resorbable membranes improves functional integrity for successful bone augmentation. In Resorbable barrier membrane, the space maintenance of primary soft tissues is essential factor for Guided Bone Regeneration with the use of collagen barriers.

Mardas et al., (2010, p. 688) in their study, indicated that only partial bone generation is achieved if barrier membranes are exposed to oral surroundings after surgery. Non-Resorbable and Resorbable membranes are the most important type of barriers utilized for Guided Bone Regeneration (GBR). When these implants are exposed to oral biological environment, they rapidly become infected because of their layered sequences, biological arrangements, cellular integration, and must be retrieved because of bacterial contamination and subsequent reinfections. Moreover, newly developed bone is seen in patients who were exposed during their first 3 months post surgery compared with those patients exposed after 3 to 6 months until 2ndstage of implantation surgery.

Effectiveness of Barrier Membranes in Maxillary Sinus Augmentation

As the new surgical technology has evolved, various grafting materials have been in use for implanting maxillary sinus with varying macro- or micro-morphologies. Successful outcomes have been in practice with ever-highest survival rates for implantations in implanted maxillary sinuses. Esposito et al., (2010, p. 26) studied the justification of barrier membrane for successful implantation of maxillary sinus augmentation. De Vicente et al., (2010, p. 430) studied the favourable bone formation and higher implant survival rates when a membrane is utilized over the maxillary sinus and lateral window. It has also been known that the vital bone formation in the maxillary sinus with barrier membrane is on average twice as stable in comparison to sinuses not covered by membranes at all. Furthermore, the implant survival rates have been amplified in Guided Bone Regeneration procedures. It is noteworthy to know that the presence of non-osteogenic connective tissue from the grafted maxillary sinus can increase in vital bone formation and an increase rate of bone regeneration.

It has further been demonstrated by De Vicente et al., (2010, p. 430), that the phenomenon called “caging effect” shows that when a barrier membrane is placed over a maxillary grafted bone, it completely seals the defects from the external environment, corticalization of the wound surface, and increases the vascularity of the grafted material. The alignment of barrier membrane allows the histologic wound healing possible at a faster rate and bone formation is initiated from the walls and floor of the maxillary sinus. This arrangement can initiate the vascular supply to lateral walls and surrounding perivascular osteoblasts. The barrier membrane allows the development of new vessels along with the formation of new bone tissues. In alveolar augmentation, bone formation appears with the help of exclusion of Periosteum from

the regenerating maxillary sinus graft. Once, lifted and replaced, the Periosteum loses its osteogenic ability and becomes embedded by fibrous tissues.

It is considered as proceeding vertical augmentation, any technique that aims to create greater alveolar ridge height in a vertical dimension, with the aim to place dental implants of a suitable length (usually of 9 mm or more) (Esposito et al, 2009). The advent of osseointegration and advances in biomaterials and techniques has contributed to increased utilization and dental implants in the rehabilitation of patients, either partially or totally toothless. An important prerequisite to predict the long-term success of osseointegrated implants is a sufficient volume of healthy bone in the receptor sites (Rocchietta et al, 2008).

The vertical Alveolar bone loss, particularly in edentulous patients, remains a challenge due to anatomical limitations and technical difficulties involved in planning implants. The presence of the nasal cavity, maxillary sinus and inferior alveolar nerve, limit the height of bone available for proper implant placement. Moreover, a large inter-maxillary height may alter the length and shape of the crown and produce unfavourable crown-root ratio of the final prosthetic reconstruction. The latter may result in a prosthetic restoration with an unacceptable aesthetic and / or could cause difficulties for proper oral hygiene, potentially jeopardizing the long-term prognosis (Rocchietta et al, 2008). There are two specific indications for vertical bone regeneration techniques, the first is when there is not enough to install and maintain an implant that will ensure success and long-term stability of the prosthetic bone element; and the other is for aesthetic reasons (Merli et al, 2010).

The augmentation procedures can be performed sometimes before implant placement (two-stage procedure), or in the act in which the implant is placed (one-step process), using various materials and techniques. When performed before placing the implant needed a second

surgery, which implies that a prudent period of time to allow the repair area before implants are placed (Esposito et al, 2009).

These techniques utilize barrier membranes in order to protect the bone defects of the invasion by the growth of soft tissue cells, such that the osteoprogenitor cells to develop bone without being inhibited. Invagination or growth of soft tissues into the defect may prevent bone formation in the defect area or regenerate. The membranes can be resorbable or non-resorbable (Esposito et al, 2009). Resorbable membranes generally allow greater bone regeneration membranes and non- resorbable PTFE. However, if the soft tissue dehiscence can be avoided, the ePTFE membranes allow bone slightly larger than the resorbable regeneration.

Zitzmann et al (1997) and Simion et al (2001) reported that the incidence of dehiscence exposure of a barrier membrane is from 8-40% and that in the case of barrier membranes exposed, the risk of infection increases, while the decreased amount of regenerated bone.

Langer et al. (2010) presented the results of eight patients receiving particulate dehydrated frozen allograft demineralized bone (DFDBA) and barrier membranes, both non-resorbable (ePTFE reinforced with titanium), as bioresorbable (Resolut), using either mini-screws (two step procedure), or implants (one-step process), or only the graft material, for supporting the membrane or support. A vertical gain ranging between 2-8 mm was obtained. In patients in whom bioresorbable membrane was used, the requirement for regeneration of vertical height was much lower. The use of allograft eliminated the need for additional surgery at the site to be treated and therefore minimized morbidity. In all patients, the amount of vertical bone regeneration enabled placement of one or more implants in graft sites, followed by the making of the definitive prosthesis, at least 5.5 months after implant placement. The height of marginal bone around the implants remained stable over 4-13 years of follow-up.

Merli et al. (2010), in a randomized controlled trial they compared the efficacy of two different techniques for vertical bone regeneration and implant placement, using autogenous bone particulate intraoral, adjacent to the implant sites areas and bone collected with a "trap" or filter, sites prepared to place implants; bioresorbable membrane covered with collagen barrier (Bio-Gide), supported by osteosynthesis plates, versus non-resorbable barrier membranes of e-PTFE reinforced with titanium, with follow-up time of three years from the burden of the implants. 22 partially edentulous patients, requiring vertical augmentation of bone, were randomized into two groups, each consisting of 11 patients. The failure of the implant and the prosthesis complications, the amount of bone regenerated vertically and the levels of marginal peri-implant bone were recorded "blind" by independent consultants. No patient was excluded out of the study or within 3 years of follow-up. The vertical bone gain was similar for both groups; 2.5 mm average for the group of non-absorbable membrane and 2.2 mm for the group of resorbable membrane, with no significant differences between groups. No prosthetic failures occurred, or dental implants or complications after implant loading. There was no statistically significant difference in bone loss between the two groups in the first year or third year. After three years, patients treated with bio-resorbable membranes had a mean bone loss of 0.55 mm; whereas patients treated with non-resorbable membranes, bone showed an average loss of 0.53 mm. Due to the results, it was concluded that three years after implant loading no failures or complications and marginal bone loss showed peri-implant was minimal; therefore, both techniques are effective in bone augmentation, although both were associated with a significant number of pre-load functional complications. Therefore, they presented evidence that bone can be successfully regenerated vertically maintained over time after the implant the functional load

Owing to the above mentioned scenario, the efficiency of xenograft as a sinus bone replacement may be the outcome of several factors (Esposito et al., 2010, p. 26). The osteo-conductive power of cancellous grafts in maxillary sinus is markedly dependent on the pore sizes of the barrier membrane. Therefore, the density and polarity of the osteogenic cells are highly essential for the stability of the graft and the long lasting bone implantation. In every specimen, the process of sinus augmentation in maxillary bone appears to be the most successful type of graft used in orthodentistry. Moreover, the main problem may arise in using barrier membranes in maxillary sinus graft lead to the mineralization of the implanted alveolar cells with osteogenic lamellae.

Effectiveness of Autogenous Blood Harvested Barrier Membranes in Alveolar Ridge Augmentation

One of the biggest challenges today in oral and maxillofacial surgery is the reconstruction materials filling cavities and bone defects of the jaw. Aesthetic and functional possibilities representing osseointegrated implants has led to bone filling procedures more used each time, and bone regeneration techniques and the use of various osteoinductive material interest arise every day (Knothe et al, 2007)..Different materials may act by at least one of three mechanisms well described in the literature (Ripamonti et al, 2001; Wikesjo et al, 2001; Anitua, 1999; Marx et al, 1998). Bone grafts have been the target of studies for more than four decades (Fontana et al, 2004).

The biomaterial induced, bone formation irrespective of the mechanism that causes, mainly reflecting a modification in the cellular microenvironment (Rohrich & Mickel, 1995).. In general, after the establishment of an immature and well-vascularized connective tissue, bone

formation continues with recruitment, proliferation and differentiation of osteoblast cells secreting collagen, matrix proteins and subsequent mineralization (Cooper, 1998).

Only autogenous bone has osteogenic property, that is, the ability to include osteoblasts osteocompetent graft or undifferentiated cells, capable of creating bone (Becker et al, 1996). But not all autologous bone has the same osteogenic capacity; the foam is one that provides the greatest amount of osteogenic cells (Blay et al, 2003).

The use of reconstruction of alveolar ridges by Autogenous blood harvested barrier membranes are generally reported as being performed to increase bone volume in horizontal and vertical dimensions. Moreover, dental alveolar implants fulfill aesthetic demands of conventional barrier membranes. It has further been emphasized by Sittitavornwong & Gutta, (2010, p. 330), that in order to regenerate new bone and to restore wound space, the blood harvested barrier membrane mediates in the formation of bone-forming cells retained within the graft and promote wound healing process. The use of blood harvesting barrier membrane in the bone grafting method is still a gold standard in the current Autogenous bone framework. In addition, the viable bone formation cells help in retaining the integrity of graft and the release of cytokines during the healing process (Mardas et al., 2010, p. 688). In order to cope with the larger graft defects, the intraoral sites such as the mandibular symphisis, the barrier membrane helps in laying down cancellous blocks as well as effective graft material.

On the other hand, the allografts are an alternative source of grafting material, however, the use of blood harvesting membrane allows the graft bone regeneration in combination to xenograft or alloplast' implantation. In addition to the above mentioned comments, Retzepi & Donos, (2010, p. 567) suggested that large volume of materials, have low antigenic potential and the osteoconductive capability of the mandible and maxilla is improved by the use of blood

harvesting membranes. It has further been implicated that the use of blood harvesting barrier membranes provides augmentation in the endogenous implant and their maximum activity.

Additionally, the use of barrier membranes in minimizing the development of disease process or when the jaw bone areas lack sufficient bone mass has found to be improved. Recently achieved graft cells tend to rest on the barrier membrane in order to extract clinging and basement support. Sittitavornwong & Gutta, (2010, p. 330) addressed the issue by studying the documentation of effectiveness of procedures in utilizing the barrier membranes in conjunction with endosseous implants.

It was found that the cells which have access to blood harvesting barrier membrane and they migrate to a given wound space determine the survival rate of the graft development and predicts the outcome of the implant process. The blood harvesting membrane allows the newly developed cells that can regenerate their potential to grow from the organic component of the membrane and through which metabolites can be transferred through ion channels.

It is further studied that the graft bone regeneration is a process that requires a refined clinical protocols and understanding the mechanism of undesired cells in the wound area and the formation of a wound space in the regeneration of desired tissues (Dimitriou et al., 2012, p. 81). Some of the other factors also play their role in weakening and strengthening the relation between bioresorbable materials, ideal size of membrane proliferation, the stability of membrane, and the ionic concentration across membranes. Furthermore, after the period of 5 months post-implant surgery, the cells start to lose integrity, and some of them resorp in the surrounding. This process of resorption allows the bone regeneration, and bone formation in the next 4 months.

The main advantage of blood harvesting membrane is the stiff and solid formation of root base for the new laid ells to grow and establish their framework (Dimitriou et al., 2012, p. 81). It

has been studied that the necessity of barrier membrane lies in the fact that the patients are either treated with the blood harvest barrier membrane so that the width of the ridges can be adjusted in accordance with the size of the bone defects. The presence of bone defects allow the time of removal of membrane after 6 months, and thus allow the grafts to be removed by implant placement and collagen membrane. The treatment modalities like clinical deproteinization of new bone cells and using bovine bone material is the first conjunction procedure for successful graft implantation.

Most studies focus on breast stuffed maxilar (Velich et al, 2004) which would be indicated for those situations where there is little amount of autogenous bone available or minor defects. Thus, less supply of autologous bone is needed. One drawback is the risk of transmitting diseases and increased cost.

Conclusion

A wide range of biomaterials on the market is essential to analyse the clinical and experimental studies that scientifically endorse the behaviour and mechanism of action of these materials highlighting the importance of the concept of biocompatibility.

Although many materials are available to fill bone cavities, yet to be described which can replace or corticocancellous autogenous bone particulate. There are also no conclusive studies on the usefulness, translated into real and satisfactory clinical results, the placement of membranes, which makes today its indications are limited. The controversy associated with the combination of autologous grafts with other filling materials has led to multiple studies, some in favour of the association and others against, no definitive conclusions can be established (Gosain & Persing, 1999).

References

Allen, M.R., Hock, J.M. &, Burr, D. B. (2004). Periosteum: Biology, regulation, and response to osteoporosis therapies. *Bone*, 35:1003–1012

Anitua, E. (1999). Plasma rich in growth factors: Preliminary results of use in the preparation of future sites for implants. *Int J Oral Maxillofac Implants,* 14: 529-35.

Arnsdorf, E.J., Jones, L.M. & Carter, D.R. (2009). The periosteum as a cellular source for functional tissue engineering. *Tissue Eng Part A*, 5:2637–2642

Artzi, Z., Tal, H. & Dayan, D. (2000). Porous bovine bone mineral in healing of human extraction sockets. Part 1: histomorphometric evaluations at 9 months. *J Periodontol*, 71:1015-23.

Becker, W., Urist, M. & Becker, B. (1996). Clinical and histological observations of sites implanted with intraoral autologous bone grafts or allogafts: 15 human reports. *J Periodontol,* 67:1025-33

Beitlitum, I., Artzi, Z., & Nemcovsky, C. E. (2010). Clinical evaluation of particulate allogeneic with and without autogenous bone grafts and resorbable collagen membranes for bone augmentation of atrophic alveolar ridges. *Clinical oral implants research*, *21*(11), 1242-1250.

Blay, A., Tunchel, S. & Sendyk, W.R. (2003). Viability of autogenous bone grafts obtained by using bone collectors: histological and microbiological study. *Pesqui Odontol Bras,* 17:234-40.

Brighton, Carl, T. & Hunt, Robert, M. (1997). Early histologic and ultra-structural changes in micro-vessels of periosteal callus. *Journal of Orthopaedic Trauma*, **11 (4)**: 244-253

Buser, D. (2009). *Twenty years of guided bone regeneration in implant dentistry*. 2nd ed. Chicago, IL: Quintessence.

Buser, D., Dula, K. & Hirt, H.P. (1996). Lateral ridge augmentation using autografts and barrier membranes: A clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg,* 54:420-24

Cardaropoli, G., Araujo, M. & Lindhe, J. (2003). Dynamics of bone tissue formation in tooth extraction sites: An experimental study in dogs. *J Clin Periodontol*, 30:809-18.

Carlson, E.R. & Marx, R.E. (1996). Mandibular reconstruction using cancellous cellular bone grafts. *J Oral Maxillofac Surg,*54: 889-97.

Cooper, L. (1998). Biologic Determinants of bone formation for oseointegration: Clues for future clinical improvements. *The Journal of Prosthetic Dentistry*, 80: 439-449.

Dahlin, C., Linde, A., Gottlow, J. & Nyman, S. (1998). Healing of bone defects by guided tissue regeneration. *Plastic Reconstruct Surg*, 81:672.

Dahlin, C., Gottlow, J., Linde, A. & Nyman, S. (1990). Healing of maxillary and mandibular bone defects using a membrane technique: An experimental study in monkeys. *Scand J Plastic Reconstructive Surg*, 24:13-19.

Deliberador, T., Nagata, M., Furlaneto, F., Melo, O., Sundefeld, M. & Fucini, S. (2006). Auto-

genous Bone Graft With or without a Calcium Sulphate Barrier in treatment of class II Furcation Defects: A Histologic and Histometric Study in Dogs. *J Periodontology*, 77(5):780-8.

De Vicente, J. C., Hernández-Vallejo, G., Braña-Abascal, P., & Peña, I. (2010). Maxillary sinus augmentation with autologous bone harvested from the lateral maxillary wall combined with bovine-derived hydroxyapatite: clinical and histologic observations. *Clinical oral implants research*, *21*(4), 430-438.

Dimitriou, R., Mataliotakis, G. I., Calori, G. M., & Giannoudis, P. V. (2012). The role of barrier membranes for guided bone regeneration and restoration of large bone defects: current experimental and clinical evidence. *BMC medicine*, *10*(1), 81.

Esposito, M., Grusovin, M.G., Felice, P., Karatzopoulos, G., Worthington, H.V. & Coulthard, P. (2009). The efficacy of horizontal and vertical bone augmentation procedures for dental implants: A Cochrane systematic review. *Cochrane Review*, 4: 195-218.

Esposito, M., Grusovin, M. G., Rees, J., Karasoulos, D., Felice, P., Alissa, R., ... & Coulthard, P. (2010). Effectiveness of sinus lift procedures for dental implant rehabilitation: a Cochrane systematic. *Eur J Oral Implantol*, *3*(1), 7-26.

Fontana, S., Olmedo, D. & Crosa, M.E. (2004). Effect of Platelet Rich Plasma on the Peri-implant Bone Response: An Experimental Study. *Implant Dent*, 13:73-8.

Gosain, A.K. & Persing, J.A. (1999). Biomaterials in the face: benefits and risks. *J Craniofac Surg,*10: 404-14.

Jung, R. E., Fenner, N., Hämmerle, C. H., & Zitzmann, N. U. (2013). Long-term outcome of implants placed with guided bone regeneration (GBR) using resorbable and non-resorbable membranes after 12–14 years. *Clinical oral implants research*, *24*(10), 1065-1073.

Knothe, U.R. & Springfield, D.S. (2005). A novel surgical procedure for bridging of massive bone defects. *World J Surg Oncol*, 3:7.

Knothe, Tate, M.L., Ritzman, T.F. & Schneider, E. (2007). Testing of a new one-stage bone-transport surgical procedure exploiting the periosteum for the repair of long-bone defects. *J Bone Joint Surg Am*, 89:307–316.

Lang, N., Brägger, U., Hammerle, C. & Sutter, F. (1994). Immediate transmucosal implants using the principle of guided tissue regeneration: Rationale, clinical procedures and 30-month results. *Clin Oral Impl Res*, 5:154-163.

Langer, B., Langer, L. & Sullivan, R.M. (2010). Vertical ridge augmentation procedure using guided bone regeneration demineralized freeze-dried bone allograft, and miniscrews: 4- to 13- year observations on loaded implants. *Int J Periodontics Restorative Dent*, 30: 227-235

Lundgren, A., Sennerby, L., Lundgren, D., Taylor, A., Gottlow, J. & Nyman, S. (1997). Bone

augmentation at titanium implants using autologous bone grafts and a bio-reabsorbable barrier: An experimental study in the rabbit tibia. *Clin Oral Impl Res,*;8: 82- 89.

Mahajan, A. (2012). Periosteum: A highly underrated tool in dentistry. *Int J Dent*, 717816.

Mardas, N., Chadha, V., & Donos, N. (2010). Alveolar ridge preservation with guided bone regeneration and a synthetic bone substitute or a bovine-derived xenograft: a randomized, controlled clinical trial. *Clinical oral implants research*, *21*(7), 688-698.

Marx, R.E., Carlson, E.R. & Eichstaedt, R.M. (1998). Platelet-rich plasma: Growth factor enhancement for bone graft. *Oral Surg Oral Med Oral Patho Oral Radiol Endod*, 85: 638-46.

Merli, M., Lombardini, F. & Esposito, M. (2010). Vertical ridge augmentation with autogenous bone grafts 3 years after loading: Resorbable barriers versus titanium reinforced barriers. A randomized controlled clinical trial. *Int J Oral Maxillofac Implants*, 25: 801-807

Molly, L., Vandromme, H. & Quirynen, M. (2008). Bone formation following implantation of bone biomaterials into extraction sites. *J Periodontol*, 79:1108-15

Netter, Frank, H., Dingle, Regina, V. & Mankin, Henry J. (2005). *Musculoskeletal system: anatomy, physiology, and metabolic disorders*. Summit, New Jersey: Ciba-Geigy Corporation.

Retzepi, M., & Donos, N. (2010). Guided bone regeneration: biological principle and therapeutic applications. *Clinical oral implants research*, *21*(6), 567-576.

Ripamonti, U., Ramoshebi, L. & Maatsaba, T. (2001). Bone induction by BMPs/OPs and related family members in primates. *The Journal of Bone and Joint Surgery,* Vol. 83-A, Supplement 1 part 2: 116-27.

Rocchietta, I., Fontana, F. & Simion, M. (2008). Clinical outcomes of vertical bone augmentation to enable dental implant placement: A systematic review. *J Clin Periodontol*, 35 (Suppl. 8): 203-215.

Rohrich, R.J. & Mickel, T.J. (1995). Frontal sinus obliteration: in search of the ideal autogenous material. *Plast Reconstr Surg*; 95:580-5

Schropp, L., Wenzel, A., Kostopoulos, L. & Karring, T. (2003). Bone healing and soft tissue contour changes following single tooth extraction: a clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent,* 23(4): 313-23

Shapiro, F. (2008). Bone development and its relation to fracture repair: The role of mesenchymal osteoblasts and surface osteoblasts. *Eur Cell Mater*, 15:53–76.

Simion, M., Jovanovic, S.A. & Tini, C. (2001). Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. *Clin Oral Implant Res*, 12: 35-45

Sittitavornwong, S., & Gutta, R. (2010). Bone graft harvesting from regional sites. *Oral and maxillofacial surgery clinics of North America*, *22*(3), 317-330.

Spagnoli, D.B., Mazzonetto, R. & Marchena, J. M. (2001). Clinical procedures currently using bone grafting with guided tissue regeneration techniques. *Oral Maxillofac Surg Clin North Am,*13:423-36.

Tal, H. (1999). Autogenous masticatory mucosal grafts in extraction socket seal procedures: a comparison between sockets grafted with demineralized freeze-dried bone and deproteinized bovine bone mineral. *Clin Oral Implants Res*, 10:289-96.

Ten Heggeler, J.M., Slot, D.E. & Van, der, Weijden, G. A. (2011). Effect of socket preservation therapies following tooth extraction in non-molar regions in humans: a systematic review. *Clin Oral Implants Res*, 22:779-88.

Thabet, A.M., Paley, D. & Kocaoglu, M. (2008). Periosteal grafting for congenital pseudarthrosis of the tibia: A preliminary report. *Clin Orthop Relat Res,* 466:2981–2994

Velich, N., Nemeth, Z., Toth, C. & Szabo, G. (2004). Long-term results with different bone substitutes used for sinus for elevation. *J Craniofac Surg,* 15: 38-41

von, A.T. & Buser, D. (2006). Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: a clinical study with 42 patients. *Clin Oral Implants Res,* 17(4): 359-66.

Watzinger, F., Luksch, J., Millesi, W., Schopper, C., Neugebauer, J. & Moser, D. (2000). Guided bone regeneration with titanium membranes: a clinical study. *Br J Oral Maxillofac Surg,* 38(4): 312-5.

Wikesjo, U., Sorensen, R. & Wozney, J. (2001). Augmentation of alveolar bone and dental implant osseointegration: Clinical implications of Studies with RH BMP-2. *The Journal of Bone and Joint Surgery*, 83-A, Supplement 1 part 2: 116-27.

Zitzmann, N.U., Naef, R. & Scharer, P. (1997). Resorbable versus non-resorbable membranes in combination with Bio-oss for guided bone regeneration. *Int J Oral Maxillofac Implants*, 12: 844-852.