Guided Bone Regeneration: 
Evidence & Limits

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INTRODUCTION

A variety of techniques and materials have been used to restore the necessary volume of bony tissue for supporting dental implants. The most commonly described methods in the dental literature are: Guided Bone Regeneration (GBR), onlay veneer grafting, interpositional inlay grafting, ridge splitting technique and distraction osteogenesis (Aghaloo et Moy 2007).

Guided bone regeneration is a frequently used procedure for hard tissue reconstruction (Esposito et al. 2006, Hämmerle et al. 2008, Buser et al. 2011). The treatment concept advocates that regeneration of osseous defects is predictably attainable via the application of occlusive membranes, which mechanically exclude non-osteogenic cell populations from the surrounding soft tissues, thereby allowing osteogenic cell populations originating from the parent bone to inhabit the osseous wound (Retzepi et Donos 2010, Donos et al. 2002a, 2002b, 2002c).

Indeed, successful results in the craniofacial region have been reported following the placement of mechanical barriers over jawbone defects in rabbits (Kahnberg 1979) and over cranial defects in rats (Melcher 1969). To the same extent, a well conducted split mouth design random controlled trial on sinus grafting indicated that a graft is not needed to obtain new bone in the sinus cavity, if it is possible to keep sufficient space using a resorbable rigid barrier. (Felice 2009). These studies suggest that bone regeneration is significantly enhanced when the invasion of soft tissue into osseous defects is mechanically impeded.

Thus, Guided bone regeneration (GBR) was introduced as a therapeutic modality aiming to achieve bone regeneration, via the use of barrier membranes (Dahlin et al. 1988).

Clinical applications and materials used in GBR

Various non-resorbable and resorbable membrane materials have been used in experimental and clinical studies in the context of GBR treatment. However, before choosing the membrane type, some prerequisites are essential. These include: (1) Biocompatibility, i.e. no interaction between material and tissue, (2) Cell occlusion properties, i.e. to prevent fibrous connective tissue invasion, (3) Integration by the host tissues, (4) Clinical managability and space making ability (Karring et al., 1993).

Expanded polytetrafluoroethylene (e-PTFE) has been the most frequently used material for periodontal and bone regeneration. e-PTFE is a chemically stable and biologically inert polymer, featuring a porous structure and flexible form. Their use has shown to lead to successful GBR treatments in many clinical reports. (Hämmerle & Jung 2003).

Titanium-reinforced e-PTFE membrane can also used in GBR (Urban et al. 2009, Simon et al. 1994, 2007). It consists of a double layer of e-PTFE and a titanium framework interposed, making of it a shapeable one.
with a stable form to allow the reconstruction of the geometry of the lost bone. Its main indications are for three dimensional bone reconstruction.

Non-resorbable membranes do not undergo the enzymatic degradation when placed in the living body as in the case of the resorbable membranes. Hence, they require a second surgical intervention in order to be removed. Moreover, the exposure of these membranes may lead to total failure of the regeneration process (Rochietta et al. 2008). These disadvantages led to the development of resorbable membrane devices.

Several resorbable membranes have been tested showing various degrees of successful bone regeneration, including collagen type I, polyurethane, polyglyactin 910, polylactic acid, polyglycolic acid, and different copolymers of polylactic and polygalactic acid (Sandberg et al. 1993, Zellin et al. 1995, Brunel et al. 1998).

Absorbable collagen membranes are used more and more frequently in dentistry for guided bone regeneration (GBR). The great advantage of using absorbable membranes is that a second procedure to remove the membrane is not necessary.

However, resorbable membranes have some drawbacks such as uncontrolled duration of barrier function (resorption time can ranges from four to sixteen weeks) and the need of membrane supporting material to minimize membrane collapse. In some cases, adding to the fact that the resorption process can interfere with wound healing and may also have a negative influence on the bone regeneration. That’s why a cross-linking of the resorbable membrane was proposed (Bronstein et al. 2009). Artificial cross-linking of collagen is an attempt to increase the barrier function of collagen membranes. However, recent results from clinical and pre-clinical studies have shown that this is unnecessary (Becker et al. 2009, Scwarzar et al. 2006).

Bone fillers which can be Autogenous bone chips, allograft (same species), xenograft (another species), or alloplast (synthetic), are commonly used in the GBR process. Their aim is to promote osseous ingrowth and bone healing through osteoconduction, provide mechanical support of the membrane and stabilize the blood clot (Buser et al. 2008, Jensen et al. 2006).

**Guided bone regeneration (GBR) with simultaneous implant placement**

GBR with simultaneous implant placement is recommended only if the implant could be placed in an optimal three dimensional position with satisfactory primary stability from the existing natural bone (Chen et al. 2009). However, the success of the procedure does not rely only on implant’s stability, but also on the stability of the grafting material.

Park et al. (2008) in their random controlled trial which included 22 patients wanted to check the importance of using a barrier when GBR is carried to cover exposed threads of dental implants. Patients were divided into 3 groups; In group 1, the allograft was covered with a collagen membrane. In group 2, the allograft was protected with an acellular dermal matrix. In group 3, no membrane was used. Six months later, a 48 % loss of the graft was observed in group 1 in comparison with a 42 % loss in group 2 and a 66% loss in group 3. Based on this study as well as on others papers (Donos 2005 b, Chen et al. 2009), we can suggest that the application of an occlusive membrane minimizes the resorption rate of the graft.

The main indication of GBR use as simultaneous approach is to treat dehiscence- and fenestration-type defects. The majority of studies used combinations of bone grafts and barrier membranes to promote bone regeneration in peri-implant defects. The most commonly used augmentation material was deproteinized bovine bone mineral (DBBM), in conjunction with e-PTFE membranes or collagen membranes.(Zitzmann et al. 1999, Schropp et al. 2003, Nemcovsky et Artzi 2002, Covani et al. 2007, Nemcovsky et al. 2000, Chen 2005, 2007).

Many studies (Parma-Benfenati et al. 1999, Tinti et Parma-Benfenati 1998, Simion et al. 1994, 2007) had shown that GBR could be used for vertical bone augmentation in combination with implant placement. In this technique implants were inserted protruding 2 to 7mm from the bone level and the augmentation procedures is performed, mainly with non resorbable membrane with bone chips and/or bone substitutes. However, a significant rate of complications was observed. (Esposito et al. 2009).

**GBR use as a staged approach**

When the ridge anatomy does not allow for an ideal three-dimensional implant placement, a two-step procedure is recommended where the implant placement will be the second step after hard tissue reconstruction. Many studies (Seibert and Nyman 1990, Smukler 1995, Buser et al. 1995) had shown that GBR using membranes and bone substitutes could regenerate bone before implant placement. The implant placement could be planned for after five to nine months from performing GBR procedures. Thus, in classes III and IV of Cawood classification, GBR could achieve predictable results (Cawood 1988).

For vertical bone augmentation before implant placement, Jovanovic et al. (1995), Urban et al. (2009), Fontana et al. (2008) and Todisco (2010) described the use non resorbable e-PTFE membrane with DFDBA (deproteinized freeze-dried bone allograft) or DBBM (deproteinized bovine bone mineral) alone or mixed with autogeneous chips. The two main problems in this reconstruction are: membrane exposure and soft tissue collapse. That is why a tension free flap closure is a must, with appropriate sutting techniques. Also, the use of tenting screws have been found useful in minimize the soft tissue collapse. (Le et al. 2010).
Guided Bone Regeneration Using Nucleoss Dental Implants

(Fig 1) Hopeless upper left incisor due to failed root canal treatment, with a deep probing depth buccal.

(Fig 2) Panoramic X-ray one month after the extraction.

(Fig 3) Clinical situation one month after the extraction, the extension of the defect is obvious.

(Fig 4) Implant placement in an ideal 3 dimensional position, the whole implant threads are exposed.

(Fig 5) DBBM mixed with autogenous bone chips collected from the site, covering the defect.

(Fig 6) Double layer collagen membrane: well adapted and extended 3-4mm apically beyond the defect.
Enhancing our GBR practice (Tips and hints to achieve optimal results)

Some tips and hints can be useful to the GBR success. They are a sum-up of many publications as well as from the authors personal experience.

In the following surgical procedures, (1) Flap designing, (2) Membrane stabilization, and (3) Flap closure, some key techniques are essential to achieve success in GBR:

1. **Flap designing**

   Due to an avascular zone located over the edentulous ridge about 1 to 2mm wide, (Kleinheinz 2005), midline incisions with vertical discharge at the anterior border of the alveolar ridge are favorable for healing. (Norton et al. 2007).

   Whether an overlapped flap design, a coronally positioned flap, or a pedicle flap technique is used, an effective primary closure during the regenerative period is a must (Langer and Langer 1990, Buser et al. 1995, Tinti and Parma-Benfenati 1995, Fugazzotto 1999, 2006).

2. **Membrane fixation**

   The membrane should overlap the defect by 3-4mm, be protected by the flap and achieve good stability (Hämmerle et Jung 2008).

   Two main procedures can be implemented for membrane stabilisation:
   1. Adapting the membrane to the defect. It is noted that collagen membranes possess an inherent adaptation capacity. (Buser, 2011)
   2. Fixation of the membrane by using:
      a. Resorbable and non resorbable mini screws
      b. Cover screw or healing abutment

3. **Flap closure**

   Periosteal fenestrations allow some flap elasticity. If vertical incisions do not facilitate optimal tissue advancement, hold the flap under tension with a tissue forceps (e.g. Adson tissue forceps), and score the periosteum close to the base of the flap from the distal to mesial aspect across the whole flap. To attain further tissue advancement, insert a closed blunted scissor or...
Guided Bone Regeneration
Case 2

(Fig 12) Pre-operative clinical photo: Metal-ceramic bridge from upper right central incisor or to upper left lateral incisor. The patient consults for bridge mobility and fistula apical to the lateral incisor.

(Fig 13) Panoramic X-ray: Wide-diameter post, weak dental structure and periapical radiolucency.

(Fig 14) Clinical situation 3 weeks after the extraction of the 2 incisors. Intact buccal plate on the central incisor, and no buccal wall on the lateral incisor.

(Fig 15) Implant placement. On the lateral incisor, almost half of the implant threads were exposed.

(Fig 16) DBBM covering the implant threads and the pontic area.

(Fig 17) Collagen membrane covering the defect. On the lateral incisor area, three layers of this membrane were used.

(Fig 18) X-rays 2 months after implant placement.
The past two decades of clinical and scientific investigation have established the use of guided bone regeneration (GBR) as a proven method to regain a diminished alveolar ridge (Zitzmann et al. 1999) or for socket preservation (Wang et al. 2004). The dental literature is full of systematic reviews, clinical trials and consensus statements supporting the use of GBR a reliable procedure in treating dehiscence and fenestration-type defects (Chen et al. 2009, Esposito 2008).

With respect to horizontal bone augmentation before implant placement, in cases of extreme horizontal bone resorption, we are still unable to confirm that GBR is a reliable procedure. In 2009, the ITI consensus statement (Chen et al. 2009) clarified that “horizontal ridge augmentation often requires the use of autogenous bone block, which may be combined with a membrane and/or a particulate autograft, allograft, or xenograft”. However, for other authors, GBR seems to give comparable results to autogenous bone block which, up till now, is considered the gold standard in bone reconstruction (Meijndert 2007).

On the other hand, Meijndert et al. performed an RCT study in 2007 which had a large sample size of 93 patients divided into 3 equal groups. They used three different techniques to horizontally augment local ridge maxillary defects (from 1st to 1st premolars) for allowing placement of single implants: (1) bone blocks from the chin, combined to particulate autogeneous chips; (2) bone graft from the chin with a resorbable barrier; and (3) 100% bovine anorganic bone with a resorbable barrier. Implants were placed 3 months after autogenous bone grafting and 6 months after augmenting sites with DBBM. Patients in the first 2 groups were treated according to the first 2 techniques respectively, i.e. with blocks of bone, whereas in the third group, the defects were reconstructed with 100% bone substitute and a resorbable barrier. Despite these relatively high numbers, the authors confirmed that no complication occurred. Only two implants failed early in the bone substitute group. However, they were successfully replaced. It is true that the healing period for the bone substitute group was three months longer, but on the other hand, no autogenous bone was needed to complete the procedure.

Esposito’s systematic review in 2009 concluded that there is early evidence that GBR can be used as a staged approach to allow for vertical bone augmentation. While the random controlled trials included in his Cochrane review confirmed this proposition. The evaluated techniques, however, were associated with high complication rates ranging from 60% (Bianchi 2008) to 20% (Felice 2008).

The ITI fourth consensus (Chen et al. 2009) concerning the predictability of vertical bone augmentation declared that “Vertical ridge augmentation procedures most
In the case of horizontal type defects around dental implants, as for using GBR in a staged approach for horizontal and/or vertical bone augmentation, some of the studies reveal a high percentage of success. However, many of them had a short-term follow-up. Moreover, complications arise with vertical reconstructions, while in the case of horizontal augmentation, studies have shown less complications.

**CONCLUSION**

Within the limits of this mini-review which aimed to analyze the outcome of the use of GBR for hard tissue reconstruction, it is concluded that GBR can be successful treatment modality for dehiscence-and fenestration-type defects around dental implants. As for using GBR in a staged approach for horizontal and/or vertical bone augmentation, some of the studies reveal a high percentage of success. However, many of them had a short-term follow-up. Moreover, complications arise with vertical reconstructions, while in the case of horizontal augmentation, studies have shown less complications.

Thus, a moderate level of evidence in the staged approach is found and more clinical trials are required to test the validity of GBR in vertical and horizontal bone augmentation.

With extreme bone resorption (Cawood class VI), and with bone regeneration involving maxillo–facial surgeries, the use of GBR is not well documented. Thus, a low level of evidence can be attributed in these clinical situations.

**REFERENCES**


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**Table 2** Advantages and disadvantages of different membrane types. (+ favorable point; - unfavorable point)

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>ePTFE</th>
<th>Collagen</th>
<th>PLA/PGA</th>
</tr>
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<tbody>
<tr>
<td>Handling, Adaptation</td>
<td>-</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Exposure, Site Infection</td>
<td>-</td>
<td>++</td>
<td>?</td>
</tr>
<tr>
<td>Collapse</td>
<td>+</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>Barrier Function</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Breakdown, Bone Resorption</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Re-entry</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

**Table 3** Levels of evidence upon using GBR

<table>
<thead>
<tr>
<th>GBR used for dehiscence and fenestration type defects</th>
<th>High level</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBR used for socket preservation</td>
<td>High level</td>
</tr>
<tr>
<td>GBR used as a staged approach for horizontal bone augmentation</td>
<td>Moderate level, Low risk of complications</td>
</tr>
<tr>
<td>GBR used as a staged approach for vertical bone augmentation</td>
<td>Moderate level, Significant risk of complications</td>
</tr>
<tr>
<td>GBR used for severe vertical bone reconstruction</td>
<td>Low level</td>
</tr>
</tbody>
</table>

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Often required the use of autogenous block graft, which may be combined with a membrane and/or a particulate autograft, allograft, or xenograft. Despite the use of an autogenous block graft, elevated rate of complications and a need for additional grafting have to be anticipated. The common point between Esposito’s review and the ITI consensus statement is the high percentage of complications with vertical bone augmentation.

**Table 1** Classification of the edentulous jaws, according to Cawood (edentulous jaws, according to Cawood JI & Howell RA (Int J Oral Maxillofac Surg 1988 Aug;17(4):232-6)


