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REVIEW

Postoperative Outcomes in the Surgical Rehabilitation of Alveolar Bone in Implant-Prosthetic Therapy: A Review

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Abstract. *Surgical rehabilitation of the muco-osseous support in edentulous patients with severe alveolar bone resorption is a challenging stage for the specialists in implant-prosthetics and oral surgery. Various biomaterials including autogenic, allogenic, xenografts, and synthetic biomaterials are considered on-the-board options for implant-prosthetic therapy. The selection of the bone graft must consider the systemic status, the osteogenic potential of the recipient site, and the available growth time of the new bone. A large range of alveolar bone reconstruction techniques is available to implantologist or oral surgeon: guided bone regeneration (GBR), vertical/horizontal augmentation by onlay blocks, distraction osteogenesis, alveolar ridge splitting techniques, bone expansion techniques) Various research groups reported the bone gain both in vertical and horizontal augmentation techniques by xenografts. Lateral bone augmentation techniques were recommended in post-extraction areas. The potential of the vertical augmentation procedures was highlighted but the long-term success depends on clinician' experience level. Various factors that can influence the implant success/failure rate when implants were placed in alveolar bone areas after reconstruction by grafting materials. The main factor responsible for the absence of graft integration, its migration, and the absence of implant integration in the grafted area is represented by the poor execution of the surgical technique and graft migration because of poor vascularization in the grafted area.*

Key words: alveolar bone, grafts, rehabilitation techniques, bone gain.

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Introduction

Implant-prosthetic treatment is a therapeutic approach associated with significant functional and aesthetic results for edentulous patients.

Specialists in implantology and prosthetics are challenged by high expectations of patients regarding aesthetics, in conditions where many of these patients have alveolar bone deficiency to various degrees. In these clinical

situations the insertion of short or low diameter dental implants, especially in implant sites with severe resorption does not allow proper long-term stability of the future implant-supported fixed partial dentures and increases the failure rate of implant therapy.

The reconstruction of the alveolar bone through various guided bone regeneration techniques will allow the placement of the future artificial teeth in the position that was occupied by the natural teeth as well as optimal restoration of the aesthetic parameters (Agop-Forna et al, 2021; Lee et al, 2017).

Surgical rehabilitation of the muco-osseous support in edentulous patients with severe alveolar bone resorption is a challenging stage for the specialists in implant-prosthetics and oral surgery.

Bone grafts and substitutes.

The selection of the bone graft must consider the systemic status, the osteogenic potential of the recipient site, and the available growth time of the new bone.

The properties of the ideal bone grafting material are as follows (Ricciardi et al, 2013):

- biocompatibility;
- absence of toxicity;
- mechanical stability;
- uniform porous structure;
- uniform bone resorption;
- stimulates the formation of bone tissue;
- low costs.

A recent classification of bone grafting materials is shown in figure 3.5.(Zhao et al, 2021) divide bone grafting materials into five categories:

1. Natural bone. Bone substitute materials:
• Autogenous bone;
• Allograft materials (demineralized bone matrix);
• Xenograft materials (bovine or porcine bone, chitosan);
• Phytogenic materials (materials based on corals or various species of algae).
2. Synthetic bone substitutes
• Hydroxyapatite;
• Ceramic beta-tricalcium phosphate;
• Calcium sulfate;
• Polymers;
• Calcium phosphate cements;
• Metals.
3. Composite bone substitutes:
• NanoBone;
• Fortoss Vital;
• SmartBone.

4. Bone substitutes with infusion of vital osteogenic cells:
• Dent osteotransplantation;
• Bioseed-Oral Bone.
5. Bone substitutes with growth factors:
• Osigraft;
• Augmentation;
• Infused.

Various biomaterials including autogenic, allogenic, xenografts, and synthetic biomaterials are considered on-the-board options for implant-prosthetic therapy (Kumar et al, 2013).

Autogenic grafts have the advantage of absent immunological responses, but they exhibit higher infection rates. Bovine-derived xenografts and porcine-derived xenografts are largely used due to their low content inflammatory reactions (Nistor, 2017). Alloplastic grafts (hydroxyapatite, tricalcium phosphate, bioactive glass) have the benefits of high availability, low residual graft and high new bone volume when compared to xenografts (Murphy, 2016). Most studies investigating Bio-Oss (xenograft) and β-TCP (alloplastic) consider these materials as the most predictable and sustainable in implant therapy of patients with severe resorptions of alveolar bone (Sawada et al, 2018; Shamsoddin et al, 2019).

The cycle of bone remodeling involves the activation of osteoclasts, resorption, and bone formation. Understanding these mechanisms allows the clinician to make the right selection for the optimal therapeutic alternative. The first condition for the success of the reconstruction treatment of the prosthetic field is the healing of the graft.

The factors that influence the speed and volume of post-grafting resorption are the following:

- the volume of the bone graft;
- the quality of the grafting material;
- the quality of the receptive bone bed;
- biomechanical properties;
- adhesion.

Surgical reconstruction techniques.

A large range of alveolar bone reconstruction techniques is available to implantologist or oral surgeon: guided bone regeneration (GBR), vertical/horizontal augmentation by onlay blocks, distraction osteogenesis, alveolar ridge splitting techniques, bone expansion techniques) (Tolstunov et al, 2019; Mittal et al, 2019).

Various research groups recommend in the alveolar bone reconstruction both vertical and horizontal augmentation techniques by xenografts (Bae et al, 2019;

Yaghobee et al, 2018; Lazaruc, 2018; Pang et al, 2017; Fala et al al, 2015; Torres et al, 2010; Pieri et al, 2008).

Data from the literature regarding traditional alveolar addition techniques, including those based on guided tissue regeneration, show variable results in relation to the range of investigated addition materials but also to the characteristics of the groups of patients investigated, the location of the implantation sites, the postoperative monitoring period. The research groups were concerned with the postoperative failure rate (postoperative infection, graft rejection, accelerated postoperative alveolar resorption) in classic addition techniques and in guided bone regeneration techniques, with or without barrier membrane exposure. Thus, the data on the average bone gain show average values between 2.6mm and 3.6mm (Jensen et al., 2009). Postoperative bone resorption can reach 40% at 6-12 months postoperatively (Chiapasco et al., 2009). The postoperative failure rate can reach 38% in clinical situations associated with barrier membrane exposure (Block et al, 2009), and classical alveolar bone addition techniques lead to postoperative bone resorption rates from 29% to 42% (Bernstein et al., 2006). Correlation of local bone status and preoperative loco-regional factors should be carried out in this type of study and would lead to the possibility of including these factors in recommending and optimizing surgical protocols (Chiapasco et al., 2009).

A systematic review performed by Elnayef et al (2018) reported a mean horizontal bone gain for all reconstruction techniques of 3.71 ± 0.24 mm, with 4.18 ± 0.56 mm for the block graft addition technique and 3.61 ± 0.27 mm for the alveolar sites reconstructed by guided bone regeneration techniques. The mean alveolar bone resorption at 6 months postoperative was 1.13 ± 0.25 mm, with 0.75 ± 0.59 mm for alveolar sites reconstructed by block graft augmentation techniques and 1.22 ± 0.28 mm for alveolar sites reconstructed by guided bone regeneration techniques. In the initial stages of healing, sites reconstructed by guided bone regeneration techniques showed higher degrees of resorption compared to block type grafts. In the case of using xenografts, alveolar resorption is at lower levels compared to sites rehabilitated by techniques that use mixed grafts (xenografts and autologous bone).

By using guided bone regeneration techniques with xenografts and titanium meshes in association with PRF, an average bone gain in the vertical plane of 3.3mm was obtained, respectively an average bone gain in the horizontal plane of 3.9mm (Torres et al, 2010). For the same type of guided bone regeneration techniques with xenograft addition materials, the average values of the vertical bone gain were 3.71 mm, respectively in the horizontal plane 4.16 mm (Pieri et al, 2008).

Regarding the results regarding the postoperative changes in height and width parameters, one study reported bone gain on prosthetic fields with mean values of

alveolar bone height of 5.5 ± 0.30 mm, respectively mean values immediately post augmentation 14.51 ± 0 .27 mm, respectively 6 months post-augmentation of 13.77 ± 0.32 mm, with a degree of bone resorption, during the 6-month period, of 0.74 ± 0.05 mm (Fala, 2015). Pang et al (2017) evaluated the bone gain in the vertical plane obtained with the Bio-Oss xenograft material of bovine origin, in alveolar addition techniques in post-extraction sites, in a study comparing this material with a graft material from human dental tissue (AutoBT). The evaluation performed on CBCT images was performed immediately post addition and 6 months post addition. Bone gain in the vertical plane was 6.56 ± 3.54 mm for the Bio-Oss® group, respectively 5.38 ± 2.65 mm for the AutoBT group at 6 months post-extraction. The histomorphometry analysis regarding the rate of non-bone tissue showed that at the level of the alveoli rehabilitated with Bio-Oss® the percentage of non-bone tissue was 35.00 ± 19.33%. Both groups showed similar success rates, similar levels of implant stability and similar histological structures at the level of regenerated bone tissue, but bone gain in the vertical plane was significantly higher in the case of implant sites rehabilitated with the Bio-Oss bovine xenograft.

A review of studies focusing on the effectiveness of bone grafting techniques in relation to the types of bone grafting materials evaluated the rate of new bone formation, the postoperative follow-up period, the success rate in the rehabilitation of bone defects, the degree of bone gain in the horizontal plane and vertically, the degree of postoperative bone density increase in the grafted areas, the postoperative resorption rate (the percentage of resorbed bone volume compared to the augmented bone volume), the rate of postoperative complications (Troeltzch et al., 2016). The conclusions were as follows: regardless of the technique used, the use of xenograft materials leads to a volume of new bone formed (85.8%) higher than the average value recorded for all types of investigational addition materials (74%); regardless of the technique used, the use of xenograft materials leads to an average value of bone gain in the horizontal plane of 4.5mm (+/- 1.0mm).

Bone alveolar areas with severe S-shaped resorption where autogenous bone addition techniques were used, show higher values of bone gain in the plane (5.7mm) and vertical (12.4mm) (Miyamoto et al., 2012). Alveolar bone areas with severe V-shaped resorption where autogenous bone augmentation techniques were used are associated with lower values of vertical (5.4 mm) or horizontal (3.7 mm) bone gain (Miyamoto et al., 2012). Alveolar bone areas with severe H-shaped resorption where autogenous bone addition techniques were used are associated with higher values of bone gain in the horizontal plane (3.9mm) (Miyamoto et al., 2012). Another limitation of research focused on evaluating the success rate of augmentation materials and surgical techniques is the absence of long-term

studies that aim to compare a wide range of augmentation materials (Esposito et al., 2009).

The limits and disadvantages in guided tissue regeneration techniques using alloplastic bone grafts are as follows (Liu, 2014):

-Longer period of formation of new bone tissue;
-Reduction of bone regeneration rate;
-Higher resorption rate compared to autogenous bone grafts;
-Allow proteins and growth factors to adhere to the surface of the graft;
-Mechanical stability;
-Sufficient volume available;
-Dimensional stability;
-Absence of immunological reactions.

Based on a systematic review of studies with a follow-up period of at least 3-5 years, Ellakia et al. (2017) recommended the replacement of the allografts and xenografts with autologous bone in alveolar bone areas with moderate and severe bone resorption. Xenografts can delay the new bone formation when compared to pristine bone but can maintain alveolar ridge volume and stimulate bone regeneration processes to allow high success rate in mandibular fixed implant-prosthetic restorations (Li et al., 2013). The use of alloplastic grafts allows the preservation of 90% of the width of the post-extraction sites compared to the pre-extraction width (Horowitz et al., 2009).

Tonetti et al (2008) presented data regarding the reconstruction alveolar bone techniques in pro-implant stage. The improvement in clinical performance regarding alveolar bone volume gain and quality of new bone was reported. Lateral bone augmentation techniques were recommended in post-extraction areas. The potential of the vertical augmentation procedures was highlighted but the long-term success depends on clinician' experience level. Regarding the augmentation of the maxillary posterior area, special attention must be paid to the adverse events associated with sinus lifting procedures (sinus membrane perforation, postoperative grafted bone infection, bone graft migration and loss) associated in some cases to the impossibility of implant insertion. For alveolar bone with less 6 mm of residual bone height, it was reported a 17% implant loss rate at 3 years post-implantation when lateral window sinus procedures were used for the reconstruction of posterior maxillary areas. In sinus lifting with trans-alveolar interventions, the rate of implant failure was 11% at 3 years post-implantation (Tonetti et al, 2008).

Barone et al (2012) found similar long-term performance between implant-prosthetic restorations applied in implant sites without bone grafting compared to sites undergoing guided tissue regeneration procedures. Jenssen et al (2009) conducted a review of studies evaluating the performance of different alveolar augmentation techniques, for a follow-up of at least 12 months. The investigated

parameters were as follows: dehiscence and fenestration categories, horizontal augmentation techniques, vertical augmentation techniques, sinus lift with lateral window or trans alveolar approach. The research group concluded that the heterogeneity of the available data did not allow the identification of an augmentation protocol with significantly better results compared to other techniques, for any of the types of bone defects investigated. The research group points out that the use of some bone addition materials has been well documented, being indicated for use in current practice (for example, the Bio-Oss xenograft material). The most important conclusion was that similar survival rates were recorded both to implants placed in augmented bone and implants placed in pristine bone.

A systematic review performed by Aghaloo et al. (2007) consider alveolar reconstruction techniques as follows: guided bone regeneration (GBR), onlay block vertical augmentation (OVG), combinations of guided bone regeneration techniques and onlay bone blocks (COG), distraction osteogenesis (DO), the bone splitting technique (RS), vascularized autografts in bone discontinuity defects (DD), mandibular interposition grafting (MI), post extraction socket preservation (SP). The implant survival rate was 92% for implants placed in alveolar areas reconstructed with autogenous bone and mixed grafts (autogenous bone / composite grafts), 93.3% for implants placed in alveolar areas reconstructed with allogeneic/non-allogenous composite grafts, 81% for implants placed in alveolar areas reconstructed with allografts and mixed grafts (allografts / xenografts), respectively 95.6% for implants placed in alveolar areas reconstructed with xenografts. The implant survival rate for follow-up between 5-74 months was 95.5% for alveolar reconstruction with guided bone regeneration (GBR) techniques, 90.4% for alveolar reconstruction with vertical augmentation techniques using onlay bone blocks, 94.7% for alveolar reconstruction by distraction osteogenesis (DO) and 83.8% for alveolar reconstruction by using a combination of guided bone regeneration techniques and onlay bone blocks (COG). The long-term clinical implant success/survival at follow-up over 5 years, regardless of the grafting material(s) used, is comparable to that of implants placed in pristine bone. The success of implant-prosthetic therapy in patients that required alveolar bone augmentation is more sensitive to the operator's experience when compared with type of technique and grafting biomaterial (Aghaloo et al, 2007). This systematic review also investigated the studies evaluating various factors that can influence the implant success/failure rate when implants were placed in alveolar bone areas after reconstruction by grafting materials. Factors that affect the healing of bone grafts are as follows: the type of grafting biomaterial; quality of blood supply; infectious factors; stability and biomechanical loading; systemic factors such as nutrition, medication, systemic diseases, smoking. Regarding the postoperative evolution, there are numerous

factors that influence the speed and volume of post-grafting resorption: the volume of the bone graft; the quality of the grafting material; the quality of the receiving bone bed; biomechanical properties; adhesion. Bone graft's structure and membranes are one of the influencing factors of the outcome of implant-prosthetic therapy. Implant survival rate is significantly higher in implant sites reconstructed with granule-type grafts compared to bone-type grafts. Also, the survival rate of dental implants is higher in maxillary implant sites where collagen membranes were used at the level of the lateral sinus window compared to sinus lifting procedures that did not used membranes at the level of the lateral sinus window. However, autogenous bone grafts do not influence the survival rate of dental implants, when compared to alloplastic grafts or xenografts (Aghaloo et al, 2007).

For any surgical technique, the implant survival rate of the implants placed into reconstructed alveolar sites ranged from 91.7% to 100%, while the survival rates for implants inserted into pristine bone varied between 93.2% and 100%, at follow-up periods of 1-5 years (Donos et al, 2008).

The implants inserted in alveolar bone augmented by bone-guided regeneration techniques had a mean survival rate of 95.5% at 5–74 months post loading (Aghaloo et al, 2007). Urban et al (2009) reported a 5.45mm mean vertical bone gain when alveolar bone areas were reconstructed by GBR techniques using the combination of autogenous bone and xenograft with d-PTFE membranes. A systematic review of studies with 1-3-years follow-up did not find significant changes in clinical peri-implant soft tissue parameters and the degree of peri-implant marginal bone lysis when lateral bone augmentation techniques were used (Schwarz et al., 2018). The survival rate of implants for alveolar bone subjected to horizontal reconstruction techniques was from 97% to 100% at 6-12 months of follow-up (Elnayef et al, 2018). The average total bone gain in the horizontal plane estimated at the time of completion of the bone regeneration processes was 3.71 ± 0.24 mm, with 4.18 ± 0.56 mm for the block graft addition technique and 3.61 ± 0.27 mm for alveolar sites reconstructed by guided bone regeneration techniques. Estimated global net bone gain at final reassessment (11.9 ± 7.8) was 2.86 ± 0.23 mm. The mean estimated resorption at 6 months was 1.13 ± 0.25 mm, with 0.75 ± 0.59 mm for alveolar sites reconstructed by block graft augmentation techniques and 1.22 ± 0.28 mm for alveolar sites reconstructed by guided bone regeneration techniques. The survival rate of dental implants has been 97% to 100%. The degrees of graft resorption are very different between grafting materials used in guided bone regeneration techniques. Block type grafts maintain the volume of alveolar sites at higher levels compared to sites rehabilitated by guided bone regeneration techniques. In the initial stages of healing, sites reconstructed by guided bone regeneration techniques show higher degrees of resorption compared to block type grafts. In the case of using

xenografts, alveolar resorption is at lower levels compared to sites rehabilitated by techniques that use mixed grafts (xenografts and autologous bone). Elnayef et al (2018) point out that overcorrection of horizontal defects is necessary to compensate for the resorption of the grafting materials.

Increased success rates in guided bone regeneration techniques using autogenous grafts were demonstrated by Liu (2014) and Stern et al. (2015). In the selection of the donor site, the advantages of grafts from intraoral sites compared to grafts from extraoral sites must be considered (Friedmann et al. 2011): less resorption, improved revascularization, superior integration. In patients who underwent sinus lifting for maxillary posterior edentulous areas with severe alveolar resorption, this intervention increases the implant-prosthetic success rate, in patients with ridge height below 8mm, respectively ridge thickness below 3 mm, bone parameters frequently encountered in patients with sinus with increased volume or lowered sinus floor.

Salmen et al. (2017) reported a survival rate of dental implants of 93.5%, with failures present in 4.5% of patients with dental implants inserted in alveolar sites that were reconstructed by alveolar augmentation procedures, respectively 2.6% of patients with dental implants inserted in sites augmented by augmentation procedures sinus lifting. Hansen et al. (2017) reported a survival rate of dental implants of 97% in the case of insertion in alveolar sites reconstructed by alveolar augmentation interventions, respectively 91% in the case of insertion of dental implants in alveolar sites augmented by sinus lifting. Peñarrocha et al. (2013) reported, at 12 months post-loading (immediate loading), survival rates of 100% in patients who required alveolar augmentation at the level of the maxillary posterior group and survival rates of 96.9% in the case of patients with delayed prosthetic loading. Onisor-Gligor et al. (2015) evaluated, at 24-months postoperatively, the quality and stability of alloplastic biomaterials and autologous bone used for sub antral bone augmentation in patients with posterior maxillary edentulousness. The research group found failure rates of dental implants placed in alveolar bone augmented with autologous bone of 1.89% (0.036 ± 9.398), while the failure rate for implants inserted in alveolar bone augmented with allografts was 7.69 % (1,960 ± 19,194). Bone resorption was significantly higher at 12 months follow-up for the alveolar areas reconstructed with alloplastic grafts (9.87 ± 3.76%) and those reconstructed with autologous bone (18.87 ± 3.25%). Implants placed in sites reconstructed with autologous bone have lower failure rate when compared to those placed in sites reconstructed with alloplastic grafts; the resorption rate of the alloplastic grafts was significantly lower when compared to the resorption rate of the autologous bone (Onisor-Gligor et al., 2015).

The post-operative early complications due to exposure or poor stabilization of the grafted bone or post-operatory infection will compromise the success of the implant-prosthetic therapy. The absence of risk factors due to strict selection criteria could contribute significantly in maximizing the success rate of the alveolar reconstruction procedures (Moy et al, 2019). Implant survival rate is not influenced by status of the

implant site (alveolar bone augmentation vs. pristine bone), but higher complications rate was reported for implants placed in sites with vertical and horizontal resorption (Dastaran et al, 2019). For alveolar bone reconstruction with xenografts, a delay in new bone formation was reported (when compared to pristine bone), but xenografts also stimulate the new bone formation and enable high success rate in mandibular implant-prosthetic restorations (Ellakia et al, 2017). Salmen et al. (2017) found a failure rate of 6.5% in bone grafting procedures, higher in the maxillary areas when compared to the mandible areas. 65% of pro-implant procedures were alveolar augmentation. The failure rate in implant survival was 4.5% in alveolar augmentation procedures, respectively 2.6% in sinus lifting procedures. 77% of bone graft failures and 80% of dental implant failures were recorded in patients over 40 years of age. Hansen et al. (2011) investigated the success rate of implant therapy associated with alveolar augmentation or sinus lift procedures at 12 months postoperatively. The survival rate of implant-prosthetic restorations was 90%-100%, after a period of one year postoperatively. In relation to the type of pre-implantation procedures, the success rates were 97% in situations that involved alveolar augmentation, 91% in situations that involved sinus lifting, respectively 100% in combined procedures. The association of alveolar augmentation interventions leads to a reduction in the rate of implant success compared to groups where implants are applied in sites where no bone grafting has been performed (Barone et al, 2012; Esposito et al, 2010). The rate of postoperative complications, in GBR at mandibular level, was between 15.8% (PTFE barrier membranes) and 21.1% (titanium meshes associated with resorbable barrier membranes of collagen) (Cucchi et al.,2017). Miyamoto et al. (2012) reported among the most frequent postoperative complications, in GBR with autogenous bone, the exposure of titanium meshes or barrier membranes, postoperative infections, partial/total bone resorption, respectively neurological disorders (in mandibular interventions).

Conclusions.

- The most common used techniques in the alveolar bone reconstructions are horizontal and vertical augmentation as well as guided bone regeneration techniques performed with xenografts/alloplastic grafts with or without autologous bone.
- Each of the techniques and grafting material presents advantages and limits regarding the postoperative evolution, the rate of postoperative complications, the rate of post-grafting resorption.
- The main factor responsible for the absence of graft integration, its migration, and the absence of implant integration in the grafted area is represented by the poor execution of the surgical technique and graft migration because of poor vascularization in the grafted area.

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