

Hard Tissue Renegation Techniques

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Introduction

Bone is a unique structure of mineralized hard tissue, unlike any other part of the body. The ability of bone to continuously remodel itself has created different clinical approaches to the treatment of damaged bone. Large bone defects are rehabilitated with dental implants placement in the jaw after rehabilitation. Revolutionized the field of dentistry and improved patients' quality of life by rehabilitating edentulous patients with osseointegrated implants. Nevertheless, bone depletion or inadequacy resulting from diverse systemic and periodontal illnesses, injuries, and lesions persists as a significant hurdle for implant fabrication. To ensure a favorable long-term outlook for osseointegrated implants, ample and high-quality bone must be present at the sites of implantation.". Different techniques such as bone grafting techniques, alveolar distraction and guided bone regeneration (GBR) have been applied to replace lost bone to ensure that the implant is osseointegrated and maintained during functional loading (Chiapasco et al., 2006).

Following tooth loss, resorption of alveolar bone typically transpires within the initial 6 months, commencing horizontally and subsequently progressing vertically. Numerous methods exist to ameliorate deficiencies in alveolar bone, encompassing guided bone regeneration (GBR), onlay and inlay grafting, distraction osteogenesis, crest splitting, free vascularized autografts, and maxillary sinus grafting. The severity of bone depletion and the configuration of defects dictate the type, scope, and prognosis of bone grafting interventions. Despite clinical evidence indicating a high implant survival rate in augmented bone, extensive long-term clinical data for many techniques are lacking.(Aghaloo & Moy, 2007).

Although many techniques have been presented in the literature, there are basically five techniques. These are GBR, distraction osteogenesis, alveolar crest split, sinus floor elevation, and onlay block grafting. We present current literature data on surgical techniques for hard tissue regeneration.

1.Guided Bone Regenaration (GBR)

The GBR method involves isolating non-osteogenic cells, such as rapidly proliferating epithelial and connective tissue cells, from the grafted region using a barrier membrane. This setup enables osteoprogenitor cells to generate bone within the defective area. GBR is commonly employed in conjunction with bone grafting procedures. (Figure 1) (Dimitriou et al., 2012).

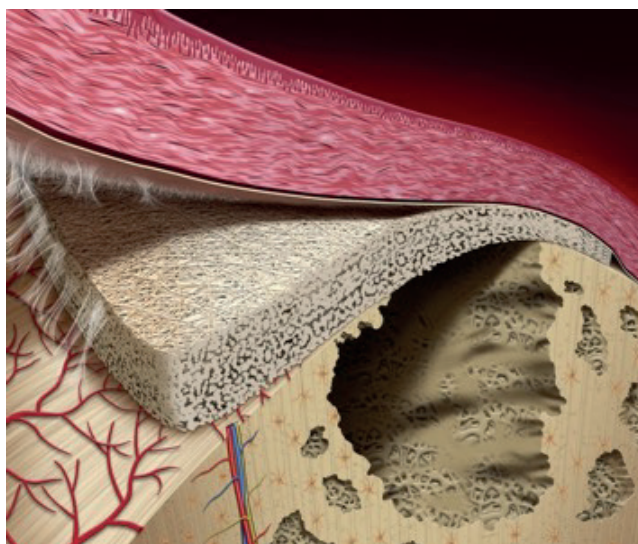


Figure 1. GBR procedure (Elgali et al., 2017)

The use of membranes in GBR technique is the most important component of the treatment. Desirable properties of membranes include biocompatibility, ease of application, adequate mechanical strength, and integration into the grafted area. If membranes are used in combination with bone grafts, they stabilize the graft materials. This reduces the resorption rate of the graft. There are resorbable and non-resorbable membranes used in periodontal tissue and bone regeneration (Bottino et al., 2012).

Membranes Used in GBR Technique

Non-Resorbable Barrier Membranes

They are biocompatible and have physical properties such as not disrupting their structural integrity, protecting the defect cavity better, not collapsing and shrinking towards the defect area compared to resorbable membranes. One of their disadvantages is that they cause bone resorption due to the exposure of the membrane due to its rigid structure. They do not have the ability to integrate with the tissue and their removal requires a second surgical intervention because they do not resorb. These membranes are divided into two groups (Rakhmatia et al., 2013).

Politetrafluoroetilen (PTFE) Membrane: The clinical efficacy of PTFE membranes depends on the surgical placement technique and the preservation of soft tissue coverage over the membrane. It is critical that the keratinized gingiva over the membrane is thick for optimal healing (Retzepi & Donos, 2010).

Expanded/e-PTFE membranes:

It has a porous structure and a flexible form. It is a chemically stable and inert polymer. It resists microbiological and enzymatic damage and does not cause immunological reactions. After placement of the membrane, bone formation on radiographs occurs after six months and can continue for a year. Clinical studies have shown that ePTFE membranes used in the GBR procedure are effective in correcting defects (Retzepi & Donos, 2010).

High density/ d-PTFE membranes:

Although e-PTFE is commonly used in dentistry, high-density teflon (d-PTFE) membranes have been used in recent years instead of e-PTFE depending on the patient and defect. The reason for this choice is that the high-density teflon membrane has a smaller pore size, which minimizes the risk of infection by minimizing bacterial infiltration. High-density PTFE membranes protect

the cavity and provide adequate stabilization of the incision, allowing sufficient time for bone regeneration. In addition, the fact that the membrane is not adhered to the tissue allows it to be removed using a mucosal flap without disrupting and traumatizing the mucosal tissue. The limited number of pores of dense PTFE membranes also limits blood flow to the area, so the blood flow required for bone regeneration is provided through holes created in the cortical bone (Soldatos et al., 2017).

Titanium Reinforced-PTFE :

Titanium-reinforced PTFE membranes are preferred when the defect morphology fails to create an adequate gap. Creation and maintenance of the gap have been recognized as important prerequisites for achieving the desired regeneration. Cavity formation also depends on the mechanical ability of the membrane to resist collapse. Titanium-supported PTFE membranes have been produced for situations where more space is needed to preserve the volume of the graft placed in the defect and for the desired regeneration. They are designed in configurations similar to conventional PTFE membranes. Several studies have shown that titanium-reinforced PTFE membranes have significant biological potential in alveolar bone regeneration. The cavity created is more predictable and more resistant to collapse due to mucosal overlying tissue than non-titanium-reinforced membranes (Soldatos et al., 2017).

Titanium Mesh Membran: It has good mechanical properties and biocompatibility. It provides a barrier for osteogenesis with its high strength and stiffness. The formable titanium mesh adapts to bone defects by flexion. These properties ensure that GBR with titanium mesh has a stable osteogenesis effect and bone augmentation in horizontal and vertical directions. Thickness and porosity are the main factors affecting its mechanical properties. Commonly used titanium mesh thicknesses range from 0.1 to 0.6 mm. Usually, titanium mesh with a thickness of 0.2 mm is used. Thick titanium mesh should be used in GBR to protect the bone regeneration area (Xie et al., 2020).

Resorbable Barrier Membranes

Resorbable barrier membranes have been developed to avoid the possibility of membrane exposure and a second surgical procedure. In the area where they are placed, they are resorbed by enzymatic reaction or hydrolysis. These membranes are biocompatible, flexible and formable. They are easier to shape clinically than non-resorbable membranes. The inadequate barrier of resorbable membranes due to their flexible structure may result in failure in preventing the migration of fibrous tissue forming cells to the area. Due to the low mechanical resistance of these membranes, they may be insufficient to protect the defect cavity, which must be protected for bone formation, against external forces. There is also a risk of triggering an immune response as they are resorbed by enzymatic reaction (Strietzel et al., 2006).

There are basically three types of resorbable membranes:

- polymeric centetic polyglycocytes (i.e., polylactic acite, polylactate/polygalactate copolymers);
- collagen
- calcium sulfate

The synthetic ones exist as polymers of glycolic acid and lactic acid. The ester bonds between these membranes dissolve between 30-60 days and an inflammatory reaction may occur due to the free acids released as a result of this dissolution (Duskova et al., 2006).

Collagen, acellular dermal matrix, fascia lata, pericardium and laminar bone are naturally resorbable membranes.

Collagen-based membranes produced from human skin, pig skin and bovine tendon have

started to be used instead of synthetic membranes due to their higher biocompatibility. Collagen membranes are resorbable without foreign body reaction, exhibit rapid vascularization and good tissue compatibility. The adhesion of connective tissue cells to the collagen membrane supports periodontal regeneration and provides hemostasis by helping to fill the defect with clot. Because of these properties, collagen membranes are an ideal choice for resorbable GBR barriers (Bunyaratavej & Wang, 2001).

GBR studies comparing the use of resorbable membranes with ePTFE membranes have shown that both membranes are equally effective. This has resulted in most clinicians using resorbable membranes in GBR procedures. In addition to collagen membranes, a wide variety of polyester-containing membranes such as polylactic acid (PLA) and its copolymers have been used. Many types of membranes combined with other polymers have been developed to improve their properties and clinical results are promising. The bio-resorbable GBR barrier membrane was constructed with PLA/poly(glycolide-co-lactide) copolymer (PLGA) membrane with polyglycolic acid network. PLGA is easy to handle and elastic at room or body temperature, but swells and hardens to prevent epithelial and gingival connective tissue displacement apically. Membrane destruction occurs over a period of 2-6 months. Furthermore, compared to PTFE membranes, polyester-containing membranes are bio-resorbable and easier to use. These membranes need to remain physically and mechanically intact for at least 4-6 weeks for regenerative therapy to be successful (Bottino et al., 2012).

Grafts Used in GBR Technique

Autogenous Grafts

Autogenous grafts; It is a type of graft that contains osteoprogenitor cells and live osteoblasts taken from a region of the same living creature and transplanted to the operated area. In the maxillofacial region, the mental region, mandibular ramus area, maxillary tuber area are considered intraoral autogenous graft sources, while iliac bone, rib and tibial bone are extraoral autogenous graft sources. Autogenous grafts are advantageous in terms of preference in GBR surgery due to early revascularization, no antigenic properties in the recipient site, high biocompatibility, osteoinductive effect and high osteogenic potential (Albrektsson & Tjellström, 2019).

Autogenous bone graft shows osteogenic effect in the first 2 weeks after placement. The osteoinductive effect starts 2-6 weeks after grafting and lasts up to 6 months. Finally, appositional bone formation occurs with osteoconductive effect. Collagen, the organic component of the graft, provides flexibility, strength and stability to the graft, while hydroxy apatite, the inorganic component, contributes to the rigidity of the graft (Albrektsson & Tjellström, 2019).

Allografts

It is a graft material that is transferred between individuals of the same species with different genotypes. Allografts do not contain osteogenic cells and their osteoinductive effect is considerably reduced as a result of demineralization. The fact that it does not require a donor site during sourcing and therefore does not require a secondary operation provides an advantage in terms of preference in maxillary GBR surgery (Albrektsson & Tjellström, 2019).

Freeze-dried bone allografts (FDBA) or demineralized freeze-dried bone allografts (DFDBA) can be categorized as cortical or trabecular. The benefits of using allografts include their ready-to-use nature, sparing patients from extensive autogenous graft harvesting, reducing surgical duration, and lowering complication risks. However, they are not as effective as autogenous bone grafts in promoting new bone formation. (Misch & Dietsh, 1993).

Xenografts

Xenografts, in which the donor type and recipient type are different for the graft source, have the ability to form a suitable scaffold for bone tissue. In cases where xenograft alone is used,

bone formation occurs from the source bone to the graft site. In surgical operations, deproteinized bovine bone is the most commonly used xenograft, either alone or mixed with autogenous bone or platelet rich plasma (PRP) (Rivara et al., 2017).

Alloplastics grafts

Hydroxyapatite is the most widely used alloplastic graft material that does not cause immune reactions, non-cytotoxic, resistant to masticatory forces, does not deteriorate by maintaining its stable structure before and after application, and meets the definition of ideal synthetic graft with its osteophilic and osteoconductive effects. Another alloplastic material approved for the regeneration of all bone tissue defects in the skeletal system is β -TCP. This graft material is completely absorbed at the site of implantation and is replaced by living and natural bone tissue after 3 months to 2 years. The blood vessels and collagen structure localized at the insertion site cover the porous particulate system of the material and form the matrix structure for new bone tissue formation. It has been reported to be a mechanically stable material without causing infection or immune reactions (Rivara et al., 2017).

Horizontal alveolar grafting typically yields a more predictable outcome compared to vertical alveolar grafting. However, studies in the literature have demonstrated successful results when vertical alveolar grafting is conducted in conjunction with non-resorbable PTFE membranes and bone grafts (Canullo & Malagnino, 2008). While non-resorbable membranes have traditionally been the go-to choice for vertical alveolar grafting, recent clinical studies suggest that the utilization of resorbable collagen membranes holds promise. The most important complication in the use of non-resorbable membranes is the opening of the flap and infection of the site. This is a common complication especially in vertical alveolar grafting applications due to the limiting effect of soft tissue (Canullo & Malagnino, 2008).

In cases where the defect is large, bioactive regenerative therapies such as the administration of recombinant growth factors in combination with GBR have been applied to achieve acceptable bone regeneration as a result of GBR application. In a clinical study, it was shown that when recombinant human platelet-derived growth factor (rhPDGF-BB) was applied by GBR technique with bone graft and resorbable membrane, the vertical dimension of the bone was preserved after implant treatment in the relevant region. However, further studies are required to clinically prove the mechanism of action of the growth factor (R. E. Jung et al., 2008).

Platelet concentrates such as platelet-rich plasma and platelet-rich fibrin have been proposed as additional stimulators for bone remodeling. Platelet concentrates were initially used as autologous scaffolds in GBR and maxillofacial surgery. Platelet concentrates contain wound healing promoting factors such as growth factors, platelets with the potential to secrete cytokines, leukocytes and are derived from the patient's own blood. Despite claims of platelet-rich fibrin being a bioactive membrane for guided bone regeneration (GBR), there have been relatively few published clinical reports in this area. (Chen et al., 2014). Concerns regarding the low mechanical strength and rapid resorption of this membrane have arisen in its application. Kawase et al. managed to mitigate these issues by employing a heat compression technique, which effectively reduced the biodegradation rate of the platelet-rich fibrin membrane without compromising its biocompatibility (Kawase et al., 2015).

2. Alveolar Crest Expansion

The alveolar crest-split procedure is the division and horizontal expansion of the existing narrow alveolar crest to accommodate the placement of implants. Since grafts and membranes are not used in this technique, treatment is less expensive, implant rehabilitation requires less time and complications, especially postoperative infections, occur less frequently. However, this procedure can also be performed as interpositional grafting by placing bone graft between the buccal and lingual bone walls of the surgically expanded alveolar crest. Systematic reviews and meta-analyses

in the literature have shown that horizontal reconstruction of the knife-edge alveolar crest with the crest-split technique is an effective surgical technique with a high implant success rate, low complication rate, increased horizontal alveolar crest width and an effective surgical technique (Figure 3) (Starch-Jensen & Becktor, 2019).

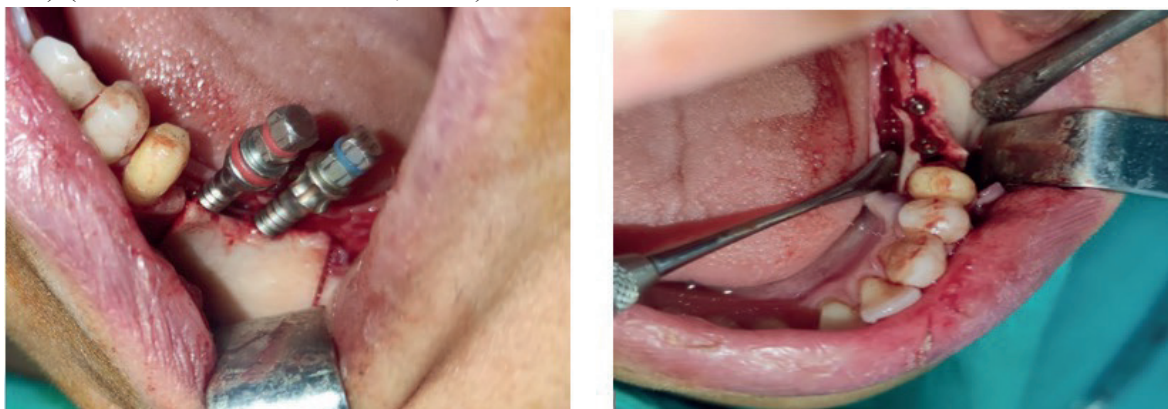


Figure 3. Crest split operation

In implant treatments, there should be 1 mm of bone around the implant in the buccal/lingual direction after implant treatment. Therefore, the average buccolingual width should be 6 mm. In the crest split technique, cortical and spongiose bone layers should be present in the buccal and lingual bone plates in the split of the knife-edge alveolar crest. Considering this available information, the alveolar crest should be 3-5 mm thick for crest split application. Preoperative clinical and radiologic evaluation of the patients is of great importance (Artzi, 2023).

In classical crest splitting procedures, osteotomes, hammers, rotating instruments and bone saws are used. Osteotome operations require more careful and atraumatic work during osteotomy, which prolongs the operation time. Rotating instruments work faster, but soft tissues may be damaged and bone loss may occur depending on the thickness of the burs used. In addition, when working with rotating instruments, neighboring teeth may prevent access to the area. The piezosurgery method, on the other hand, causes less damage to the soft tissue, minimal bone loss and less risk of damage to neighboring tissues. In addition, piezosurgery provides a more comfortable field of vision in the operation compared to other methods. In addition, piezosurgery is superior to conventional rotary devices in cases where the area to be operated is close to the nerves, such as cutting in mineralized tissue, impacted wisdom teeth very close to the inferior alveolar nerve, osteotomies to be applied close to the mental foramen and nerve repositions (Blus & Szmukler-Moncler, 2006).

Autogenous block bone grafting from the mandibular ramus or iliac crest to the knife-edge alveolar crest is generally considered the treatment of choice for horizontal reconstruction of the alveolar crest. The high survival rate of implants placed at the grafted site has been documented in systematic reviews and meta-analyses (Waechter et al., 2017). However, the use of block bone graft has disadvantages such as donor site morbidity, unexpected resorption of the grafting material, and long healing time of the grafted area. Therefore, alveolar crest split treatment technique has been proposed for horizontal reconstruction of the alveolar crest in patients with knife-edge alveolar crest due to less surgical morbidity and short treatment time (Waechter et al., 2017).

Since the preparation of the bone cavity for implant placement in the crest split procedure differs from routine implant treatment, it is important to evaluate the neck resorption of the implant after the application of this technique. In a retrospective study of 22 patients, a mean crestal bone loss of 0.8 mm was observed after 6 months. The mean crestal bone loss at 6 months after function was 1.0 mm. However, the authors noted that implant neck resorption increased as the compact bone ratio increased. Therefore, bone quality seems to be a determining factor in cases with indication for crest split (Strietzel et al., 2002).

In contrast, Bruschi et al. evaluated crestal bone loss in 71 cases of crest split with 137 implants with a mean radiographic follow-up of 6.5 years. While an average of 1.1 mm of crestal bone loss was recorded after the first year, an average of 0.89 mm of bone gain was observed after 3 years and remained stable after that (Bruschi et al., 2017).

In a recent short-term evaluation of 13 crest split and 42 implant-treated patients, crestal bone loss was measured by periapical radiography. For both jaws, a mean bone loss of 1.26 mm was observed after a 6-month healing period, which was significantly reduced to 0.5 mm at the end of the first year (Sharaf et al., 2022).

In the meta-analysis of Chiapasco et al. 374 articles were reviewed and 392 crest split operations and 733 implant treatments were followed up for 6-68 months and the surgical success rate was found to be 98%-100%. Implant survival rates were found to be between 91% and 97.3%. Fracture of the buccal plate during crest split was reported as the most important complication, although rare (Chiapasco et al., 2006).

Donos et al. performed a similar systematic clinical evaluation on 435 articles they reviewed. They placed 1090 implants in a total of 279 patients who underwent crest split treatment and reported implant survival rates ranging from 86.2% to 100% during the 18-60 month follow-up period. Again, fracture of the buccal bone plate during crest split was the most common complication, while loss of osseointegration was rare (Donos et al., 2008).

Milinkovic and Cordaro's systematic review included six studies, two prospective and four retrospective. The mean increase in bone width ranged from 3.37-6.33 mm, with a mean gain of 2.96 mm and a mean implant survival rate of 97.4%. Reported complications included infection, non-integration of the implant and buccal bone plate fractures, with a mean complication rate of 6.8% (Milinkovic & Cordaro, 2014).

Bassetti et al. used two databases, Medline and EMBASE, to further expand their systematic review of the crest split procedure. Their data included 18 human and 6 animal studies followed by histologic interpretation, with implant survival ranging from 91.7% to 100% and surgical success ranging from 88.2% to 100% after an average follow-up of 1-10 years. They observed crestal bone loss after the first year of loading, especially in the buccal bone plate, and these authors suggested that additional horizontal grafting of the alveolar crest with directed bone regeneration would reduce buccal crestal bone loss (Bassetti et al., 2016).

Santagata et al. reported 13 cases of combined subepithelial connective tissue grafting to improve soft tissue management in crest split procedures. These authors measured a mean alveolar crest width gain of 3.5 mm and an implant survival rate of 97% (Santagata et al., 2015).

In conclusion, the alveolar crest split method allows the implant to be placed in the same session in cases of insufficient bone width. By applying bone graft materials to the cavity obtained in the same operation, support for the separated bone layers is created and relapse is prevented.

3. Distraction Osteogenesis

Distraction osteogenesis is the process of forming new bone in the space between two separated bone fragments by applying a graded and controlled stretching force to the new bone. Alveolar distraction osteogenesis is a method used to elevate or widen the mandible and maxilla and its success depends on the appropriate mechanical tensile force applied to the osteotomy site (Figure 4) (Mohanty et al., 2015).

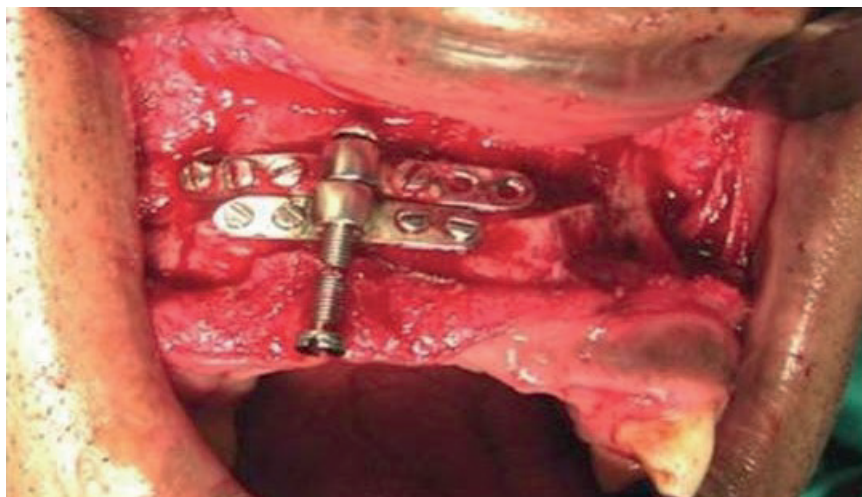


Figure 4. Alveolar distraction osteogenesis (Mohanty et al., 2015)

Alveolar distraction osteogenesis was first applied on dogs by Block et al. in 1996. In the same year, the investigators made the first application in humans using an alveolar distractor in alveolar defects caused by traumatic tooth loss. Since then, promising results have increased its popularity, but this treatment modality is still in the early stages of development (Mohanty et al., 2015).

Severe atrophy of the edentulous crest (insufficiencies greater than 4 mm), segmental alveolar crest insufficiencies that aesthetically and functionally compromise implant placement (inappropriate crown-implant relationship), narrow alveolar crests where horizontal distraction can be applied, Alveolar distraction osteogenesis can be used in cases where orthodontic displacement is not feasible or fails, such as the gradual vertical movement of ankylosed teeth and the gradual vertical displacement of an osseointegrated implant with the surrounding alveolar bone, edentulous spaces between 2-4 teeth, tissue loss due to traumatic injuries, restoration of teeth lost as a result of periodontal disease, congenital malformations, after grafting. Alveolar distraction osteogenesis is contraindicated in patients who have undergone radiotherapy, in patients with osteoporosis and in patients with general systemic diseases (Garcia-Garcia et al., 2004).

Distraction osteogenesis is used in maxilla and midface deformities, hypoplastic mandible, mandibular defects after temporomandibular joint ankylosis and pre-implant alveolar bone correction. This method is based on the tension-stress principle described by Dr. Ilizarov. The principle of operation is that after corticotomy is performed on the bone segments to be separated, the distraction apparatus is placed. The gradual removal of bone segments (0.5-1 mm per day) by the distraction apparatus creates a tension that stimulates bone formation and induces a biological response. Subsequently, pluripotent cell differentiation, angiogenesis, osteogenesis and bone mineralization occur. Compared to augmentation with autogenous bone grafts, the advantage of this technique is that new bone is formed in the intervening space as a result of the gradual removal of bone, the movement of bone segments can be controlled and the amount of soft tissue increases in adaptation to this situation. There is no donor site morbidity because grafting is not performed (Tolstunov et al., 2019).

Alveolar distraction osteogenesis no morbidity at the donor site, simultaneous changes in both hard and soft tissues, less likelihood of exposure of hard tissues and less likelihood of resorption of grafts, more predictable volume of hard and soft tissue gained, teeth or implants can be present in the transferred fragment and thus occlusal or aesthetic defects can be corrected, consolidation time and total treatment time are short, It has advantages such as allowing the use of complementary regeneration techniques in cases where the results are insufficient, minimal

bone resorption following distraction, the new bone to be formed as a result of distraction in the maxilla and mandible is predictable and stable, it is the technique that provides the most vertical gain among the techniques of crest elevation or expansion, the possibility of infection is low, the transferred part is always fed from the original sources of the body (M.Miloro GEG, P.E.Larsen, P.D. Waite. Peterson's Principles of Oral and Maxillofacial Surgery. Second Edition Ed. London: BC Decker Inc; 2004., n.d.).

In addition to the advantages of alveolar distraction osteogenesis; The disadvantages of alveolar distraction osteogenesis include the need for daily activation of the distractor, intraoral appliances making speech and eating difficult, inability to apply in highly atrophied mandibles, risk of losing the position of the distracted part, risk of bleeding at the osteotomy site, fracture of the part during large movements of the thin alveolus, difficult adaptation of microplates, need for patient cooperation, high number of controls, expensive application, difficulties in cooperation with the patient or family members for activation of the appliance (McAllister & Gaffaney, 2003).

In a meta-analysis study, all authors agreed that the frequency of distraction should not exceed 1 mm per day, and since 2007, almost all authors have used a distraction force of 1 mm per day. In addition, the mean bone gain with alveolar distraction osteogenesis was 7.55 mm, while extraosseous distraction devices reported higher bone gains ranging from 8.13-6.97 mm (Pérez-Sayáns et al., 2018). Researchers agree that alveolar distraction osteogenesis is the technique with the greatest potential for bone gain in the vertical direction (Pérez-Sayáns et al., 2018).

Milinkovic and Cordaro revised 351 implants placed after alveolar distraction osteogenesis and found success rates of 98.8% and 92.3%, respectively (Milinkovic & Cordaro, 2014). The longest follow-up period after implant placement was developed by Kim et al. who observed a 92.7% success rate and 97.3% survival rate in implants followed for 85 months (Kim et al., 2013).

Perez-Sayans et al. compared 50 implants placed in a group of patients undergoing alveolar distraction osteogenesis with 50 patients without alveolar distraction osteogenesis. They analyzed peri-implant loss at the time of loading and after 1 and 3 years. They found that there were significant differences in loading time, more resorption in the alveolar distraction osteogenesis group (0.5 mm in the alveolar distraction osteogenesis group and 0.25 mm in the control group), and no difference in peri-implant bone after one year of follow-up (loss 0.66 mm in both groups). However, at 3-year follow-up, bone loss was significantly higher in the alveolar distraction osteogenesis group (1.03 mm vs. 0.68 mm) (Perez-Sayans et al., 2013). According to Saulacic et al., the effect of previous bone defects in the alveolar distraction osteogenesis group on these results corresponded to 51% and 58% of cases (Saulacic et al., 2008).

Chiapasco et al. conducted an analysis of 138 implants subsequent to alveolar distraction osteogenesis over a four-year period. Their findings indicated an initial loss of 0.8 mm during the first year post-functional loading. Subsequently, resorption rates were recorded at 0.1 mm in the second and third years, and 0.2 mm in the fourth year. Impressively, they achieved a survival rate of 100% and a success rate of 94.2% for the implants. (Chiapasco et al., 2004).

Polo et al. observed a 1.9 mm resorption one year after loading in a total of 34 implants inserted following alveolar distraction osteogenesis in the posterior maxillary region. (Polo et al., 2005). In a subsequent study, Chiapasco et al. compared the outcomes of 19 implants inserted following alveolar distraction osteogenesis with 21 implants placed after augmenting the graft with autogenous block. They reported comparable results between the two techniques regarding success and survival rates, as well as surgical and postoperative complications (Polo et al., 2005).

Alveolar Distraction Osteogenesis Protocol

Latent Phase: This is the period from the time the osteotomy is performed until the start of traction. During this period, soft new bone is formed. The latent period applied in maxillofacial

distraction varies between 4-10 days. Adequate blood supply in the maxillofacial region reduces or eliminates the latent period. In the studies, no significant difference was observed between those with and without a latent period. In clinical alveolar distraction, a latent period of 4-7 days is indicated to prevent premature exposure of the bone (Saulacic et al., 2004).

Distraction Phase: It is the period when the tensile force is applied to the transferred bone fragment and new immature tissue is formed. During the distraction phase, the values of three variables must be determined. These are: the rate and rhythm of distraction and the total time required for distraction. In alveolar distraction, this period usually ends in 1-2 weeks. A daily distraction rate of less than 0.3 mm is insufficient for cell proliferation and premature union may occur. A daily distraction rate of 0.3-0.7 mm increases cell proliferation. A daily rate of 0.8-1 mm is optimal for cell proliferation. Distractions performed too fast cause fibrous nonunion. It has been reported that distraction can be applied 3 times a day at 0.3 mm or 2 times a day at 0.4 mm. (McAllister & Gaffaney, 2003).

Consolidation Phase: This is the period that allows the newly formed bone to mature. After the end of distraction, the central fibrous and osteoid areas of the facial bones begin to ossify and mineralize largely intramembranously. After this period, implants can be placed in the area. If implants are placed after 4 weeks, the displacement of the cortical bone and deformation of the callus will be above physiologic limits. After eight weeks, the distribution of forces becomes more homogeneous and the displacement of the distracted cortical fragment decreases. Studies show that 16 weeks is optimal for consolidation; however, values obtained after 8 weeks are sufficient for implant placement. After 8 weeks is considered to be the appropriate time for implant placement, earlier applications may result in failure (Enislidis et al., 2005).

Since the beginning of distraction applications, problems related to the activation of distraction devices have caused interruptions and delays in the treatment. Failure to achieve the intended success in treatments where the activation of the device is not performed by the physician causes the treatment to last longer than the targeted time. Accordingly, researchers are trying to make improvements on automatic distractors. The conclusion drawn from a study comparing automatic distractors is that although automatic distractors have advantages, studies need to continue before they can be put into general use, especially due to their size and problems with their systems (Huang et al., 1999).

In another study on distractors, especially external distractors were organized by calculating the comfort of use of external distractors on the patient and sleep patterns, and distractors that can provide bilateral distraction and whose external extension is unilateral were used (Shang et al., 2012).

The use of distraction osteogenesis in the early treatment of children with the syndrome is increasing in several western countries, especially in patients with Pierre Robin syndrome, early distraction can be used to treat patients without the need for tracheostomy (Hönig et al., 2002).

Bone lengthening procedures have started to be performed by taking autogenous grafts from the patient (tibia, etc.) and distracting this graft after callus formation in the recipient area in the latent period, especially in cases with excessive hard tissue loss and requiring reconstructive surgery (Block et al., 1996).

The aim of orthodontic treatments is the manipulation of teeth and bone. Distraction osteogenesis method, which is used in the treatment of dentofacial deformities, can be used for many orthodontic treatments. In addition to its use for palatal expansion for many years, its use for distalization of the canine tooth has become widespread in recent years. The time required for this treatment is considerably reduced (Kisnisci & Iseri, 2011).

In an animal study investigating the effect of hyperbaric oxygen therapy on consolidation time, the effects of hyperbaric oxygen on the blood supply of tissues, which is also an important part

of Ilizarov principles, were investigated. In this study, it was also observed in histological sections that oxygen accelerated healing and it was demonstrated that the treatment could be completed with less consolidation time than normal (Ilizarov, 1990).

In an animal study investigating the latent period, new bone density and quality were compared in the group that started distraction immediately after the surgical phase and in the group that started treatment after the latent period. The results of this study showed that the latent period had little or no effect on bone quality and quantity (Okcu et al., 2009).

4. Sinus Floor Elevation

The maxillary bone is atrophied at the level of the second premolar in more than half of the patients and at the level of the molars in 80-90% of the patients. In this region, advanced surgical techniques are needed to place dental implants due to the proximity to the maxillary sinus and decreased bone height. One of these techniques is sinus floor elevation. The first prosthetic filling of the maxillary sinus with bone graft was performed by Boyne in 1960. With the development of titanium implants in root form, alveolar crest augmentation for implant placement in the maxillary posterior region with insufficient vertical bone height was sometimes sufficient to overcome this deficiency, but it became necessary to place a graft in the sinus floor in most cases. Boyne and James first reported sinus floor grafting for metallic implant placement in 1980. Before this report, Tatum presented the clinical application of this procedure but did not publish the results in the literature (J.-H. Jung et al., 2007).

Today, sinus floor elevation can be performed in two ways: open (lateral window method) and crestal technique (osteotome). In the lateral technique, a bone window is opened in the maxillary sinus wall and the bone height is increased by applying graft material under the exposed sinus floor. This technique requires a large working area. The lateral sinus lift technique is shown in Figure 5. The crestal technique is less invasive than the lateral technique because it can be performed with osteotomes over the crest. Crestal sinus lift technique is shown in Figure 6 (J.-H. Jung et al., 2007). Another method applied in the crestal sinus lift technique is the antral membrane balloon elevation (AMBE) technique. The minimally invasive antral membrane balloon elevation technique is based on the elimination of the Schneiderian membrane by means of a latex mini balloon. The AMBE technique allows the operation to be performed with a limited mucosal incision and a small entry window in the residual bone (Soltan & Smiler, 2005).

Both techniques are known to be an effective and safe method for dental implant placement in the posterior maxilla. During or after sinus floor elevation, complications such as patient-related complications, perforation of Schneider's membrane, bleeding, pushing the implants into the sinus and infection may occur. Depending on the source of the complication, the treatment may vary from palliative treatment to surgical intervention (J.-H. Jung et al., 2007).



Figure 5. Lateral sinus lift technique

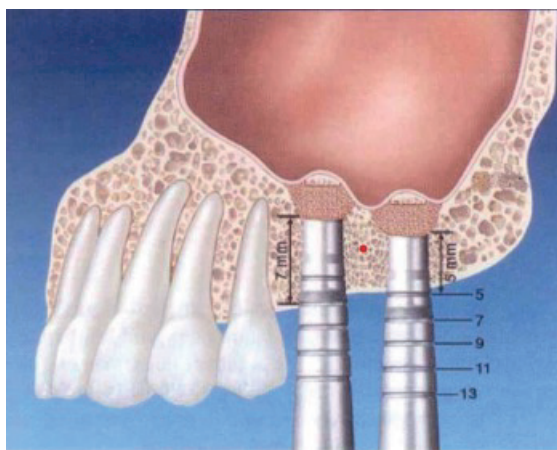


Figure 6. Crestal sinus lift technique (Dergisi & Cilt, 2009)

For many years, the use of autogenous allogeneic bone grafts and alloplasts in sinus augmentation in single or combined single or double stage has been mentioned. However, there is still no definitive conclusion as to which material is superior. Although autogenous grafts with osteogenic, osteoconductive and osteoinductive properties are considered the gold standard for sinus augmentation, their use in sinus augmentation has been questioned due to disadvantages such as the need for extra donor site and general anesthesia, high cost and rapid resorption of the graft. It has been reported that successful results have been obtained in maxillary sinus elevation with allografts, which are preferred because of their advantages over autografts, such as ease of application, no need for a second operation site, and no need for quantity limitation as in autografts (FINDIK & ŞENTÜRK, 2015).

Schneider's membrane is a 0.13-0.5 mm thick mucous membrane containing multilayered cylindrical epithelium lining the maxillary sinus. Perforation of the membrane is the most common complication during sinus floor elevation with a rate of 12% to 44%. Infection, chronic sinusitis, graft and implant loss may occur as a result of direct contact between the graft material and the sinus cavity due to perforation of the membrane during the operation. Factors that may cause membrane perforation include thin membrane, presence of septum in the sinus, sharp protrusion of the bone, and malpractice during osteotomy or membrane elevation. Vlassis and Fugazzotto reported that perforation occurred during osteotomy rather than membrane elevation (Vlassis & Fugazzotto, 1999).

Thick membranes are membranes with a thickness of 1.5 mm or more and thin membranes are membranes with a thickness of less than 1.5 mm. The rate of perforation in thick membranes is 16.6%, while this rate increases to 41.0% in thin membranes. In the literature review, it was found that the most commonly used perforation repair method was the use of resorbable membranes. However, there are also studies in which fibrin glue and cyanoacrylate adhesive were used (Choi et al., 2006).

Becker et al. In their study of 41 patients in which they evaluated the prognosis of sinus membrane perforation, defects smaller than 5 mm were repaired with resorbable collagen membrane and defects larger than 5 mm were repaired with 6.0 resorbable suture material. For defects larger than 1 cm, the operation was stopped. Based on the findings of the study, it was reported that membrane perforations did not show adverse effects as long as they were repaired during the operation (Becker et al., 2008).

There is no consensus on the effect of membrane perforations on implant success. Proussaefs et al. reported implant success of 69.5% in sinus floor elevation procedures in which perforation occurred and 100% in sinus floor elevation procedures in which the membrane remained intact; based on these results, they revealed that sinus membrane perforation decreases implant success.

(Proussaefs et al., 2004).

The maxillary sinus is supplied by the posterior superior alveolar, infraorbital and posterior lateral nasal arteries, which are branches of the maxillary arteries. Although these arteries are relatively small, serious bleeding may occur if they are damaged during surgery. However, bleeding has not been reported to be life-threatening. The most common arteries that can be exposed in the lateral window technique are the posterior superior alveolar artery and the infraorbital arteries. Elian et al. performed CT examination to determine the presence of the maxillary artery in the lateral sinus wall and detected the artery in 52.9% of cases. The average distance of 80% of the arteries to the alveolar crest was found to be 16 mm. Since this distance is sufficient for the preparation of the osteotomy and implant application, the risk of encountering the artery during the operation was reported to be 20%, and it was recommended to determine the localization of the artery with CT examination before the operation. In case of intraoperative bleeding, it has been reported that elevating the patient's head to an upright position reduces nasal mucosal blood flow by 38%. Other precautions include tampon compression, use of electrocautery, suturing, and placement of particulate bone graft into the artery (Katranji et al., 2008).

In studies, Schneiderian membrane perforation was measured as 6.76% in sinus lift operations performed using the AMBE technique. Sinus elevation and bone gain success rates were observed between 91.6% and 71.4%. Approximately 6.96 mm bone gain was achieved with the AMBE technique (Asmael, 2018).

Implant thrust into the sinus is caused by a lack of primary stabilization when the crest thickness is minimal. In this case, the implants are removed by Caldwell Luc technique or endoscopic approach. Although both methods are effective, the endoscopic approach is known to be more advantageous in terms of postoperative comfort (Felisati et al., 2007).

Excessive filling of the sinus cavity with graft material during sinus floor elevation may cause sinusitis by obstructing the ostium and a second surgical procedure may be required to remove the excess material. During the operation, contamination of the surgical field or graft material with saliva and lack of aseptic conditions may cause infection. Entry of the graft into the sinus as a result of membrane perforation during the operation is also an important factor. The incidence of infection is between 10% and 20%. This rate can be reduced with careful surgical practice and antibiotic prophylaxis. It is also recommended to add antibiotics to the graft during the operation (Katranji et al., 2008).

Lundgren et al. In 2004, Lundgren et al. described the graftless lifting procedure by stating that the space to be left between the antral wall and the schneiderian membrane would result in new bone formation around the implants in the maxillary sinus, even without the use of bone graft, and applied 19 implants in 10 patients with maxillary sinus elevation in a single stage. The reason for the formation of new bone obtained with this method is still not fully understood, it is thought that mesenchymal cells originating from the bone walls of the sinus and the osteogenic capacity of the membrane are effective in new bone formation. (Lundgren et al., 2004).

Altıntaş et al. reported that the new bone formed in the sinus lifting procedure performed without graft was denser than the bone formed in the procedure performed with graft. (Altintas et al., 2013).

The PRF clot developed by Choukrun et al. consists of platelets, leukocytes, cytokines and stem cells surrounded by a fibrin matrix network. Ali et al. stated that PRF can be used in combination with bone grafts or alone to fill the sinus cavity and reported that immediate implant placement following PRF application yielded successful results. (Ali et al., 2015).

5. Onlay Block Grafting

Onlay block bone grafts enable the acquisition of sufficient bone volume and appropriate morphology, facilitating the correction of abnormal intermaxillary relationships and the secure fixation of implants for both aesthetic and functional purposes. However, a significant challenge associated with alveolar reconstruction using appositional block grafts (onlay grafts) is the elevated occurrence of superficial resorption over the medium to long term. This resorption is particularly pronounced during vertical augmentation, as the forces exerted on the graft can lead to increased surface resorption when the soft tissue is vertically expanded (Chiapasco et al., 2006).

The process of neovascularization following bone placement in the recipient site is crucial for the long-term viability of the graft. This revascularization, which needs to be both rapid and thorough, can be challenging to achieve completely in bone blocks with a significant cortical component, such as onlay grafts. The infiltration of macrophage cells before the newly formed vessels penetrate the interior of the graft has been documented to induce necrosis in central areas, ultimately leading to resorption. The prognosis of the graft is determined by the quality and intensity of revascularization. The faster the revascularization, the more favorable the regeneration and graft survival. Graft revascularization does not normally start in the first hours after surgery. Osteoblasts and osteocytes can be nourished by fluid in their reserves and by diffusion for up to 4 days. They can survive longer if blood supply is available in the early period. Grafts from the iliac crest are one of the best graft types in terms of regeneration due to their morphologic structure containing a large proportion of cancellous bone. Bone marrow contains a large number of bone cells and has a high capacity for revascularization. Although excellent in terms of regeneration, the same cannot be said for the osseointegration quality of the dental implant. Biopsies taken from the bone 6 months after surgery showed bone of poor quality in terms of density. On the other hand, mandibular bone grafts, consisting mainly of cortical bone and a low proportion of cancellous bone, are resistant to revascularization and have poor regeneration potential. However, they have excellent bone quality for osseointegration (Figure 7) (Khoury, F., Antoun, H., & Missika, 2007).

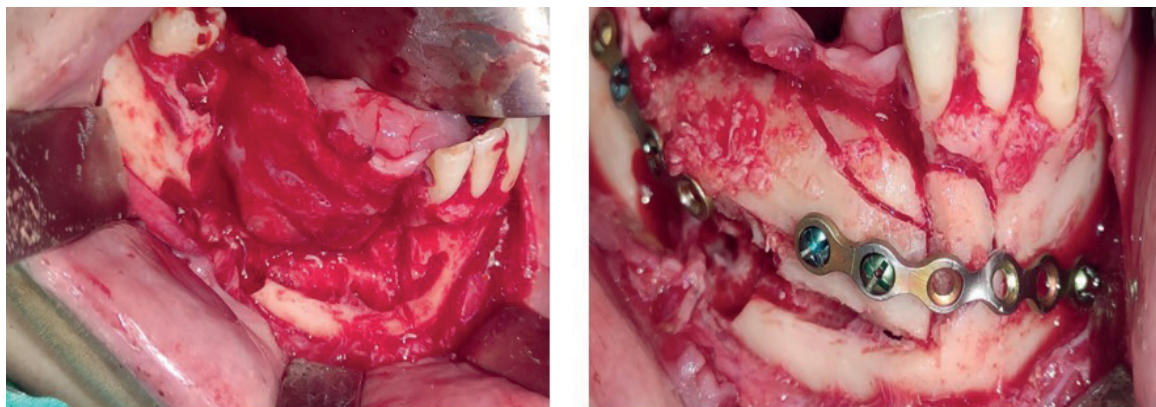


Figure 7. Iliac bone graft

To combine the advantages of the low resorption rate of cortical bone with the osteoconductive properties of cancellous bone, Khoury developed a bone block grafting method in which a thin block of cortical bone is fixed to the alveolar crest at a distance with osteosynthesis screws. The space between the crest and the graft is then filled with bone particles (Khoury & Hanser, 2015).



Figure 8. Khoury Technique

Autogenous bone block grafting has been associated with a high survival rate of superstructures and implants, minimal marginal bone loss, adequate width gain in alveolar bone, and few complications. However, harvesting an autogenous bone block graft presents drawbacks such as donor site morbidity, unpredictable graft resorption, and the risk of injury to adjacent vital structures. Consequently, various allogeneic, xenogeneic, and alloplastic bone block materials have been utilized for reconstructing alveolar crest deficiencies, aiming to simplify the surgical procedure and avoid the need for a second operative field required for harvesting autogenous bone block grafts. Nevertheless, these materials are linked to a significantly higher incidence of complications, including infection due to immunologic reactions, wound dehiscence, implant loss, and partial or complete loss of graft material, when compared to autogenous bone block grafts.

The use of autogenous tooth grafts in the reconstruction of alveolar deficiencies has also been proposed. In addition to their high biocompatibility and convenient acquisition, they do not require high temperature or other processing procedures to alter their internal structure; therefore, they retain a large amount of organic matter to enhance bone regeneration. They have osteoinductive effects and dental tissue can serve as a scaffold for bone repair. Therefore, autogenous dental materials are classified as a new type of bone substitute that can be used as bone grafts and are expected to have broad development prospects. However, the difficulty in obtaining them from each patient as needed is one of their major disadvantages (Zhang et al., 2018).

Obtaining the Graft

Extraoral and intraoral sites are utilized to obtain autogenous bone in areas where the amount of bone is insufficient. The techniques used to obtain bone extraorally require hospitalization under general anesthesia. This increases the risk of complications and cost. Since the graft material obtained will show endochondral healing, the possibility of resorption was also found to be higher. Iliac, costochondral, calvarium, proximal tibia and vascularized fibula grafts are commonly used extraoral autogenous graft sources (Saruhan, N., Ertaş, 2012).

In the mouth, block grafts can be obtained from the ramus, symphysis, tuber and zygoma. The most commonly used intraoral sites are the ramus and symphysis. A cone beam computed tomography scan is recommended before graft harvesting. One of the advantages of using a mandibular donor site for bone grafting is that the recipient site improves bone quality and volume. When the dense symphysis or ramus with a denser structure is preferred for graft harvesting, it has been found that bone resorption is less than in other regions and the amount of densities in the recipient area is higher (Alfaro, 2006).

The symphysis is a suitable donor site that can be easily accessed and bone blocks can be obtained without weakening the mandible. Although the morbidity of the donor site is much lower than extraoral sites, it has been reported to have disadvantages such as pain, functional limitations, swelling and paresthesia in the mental and lower lip region. In one study, transient paresthesia

was observed between 10% and 50%. During graft harvesting from the symphysis, a vestibular incision is made 5 mm below the gingival line to expose the mental muscle. Then the muscle and periosteum are passed and the bone is reached. The graft is obtained by maintaining a distance of 5 mm from the mental nerve, 5 mm from the apical teeth and 5 mm from the lower border of the jaw (Hunt & Jovanovic, 1999).

The mandibular symphysis contains cortical and cancellous bone, so that a corticocancellous block graft of approximately 1.5 x 6 cm² can be taken from the midline. This amount is usually sufficient to place 4 implants. However, in cases where more height and width gain is required, this amount is insufficient. The limited amount of bone available for reconstruction is the biggest disadvantage of intraoral donor sites. The symphysis shows more bone resorption than the ramus, but less resorption is observed in intraoral grafts compared to grafts obtained from the iliac crest, proximal tibia and costa. Disadvantages include sensory disturbances to the teeth, mucosa or skin and altered jaw profile. To avoid neurologic problems or to reduce the risk of damage, it is recommended that the donor site be 5 mm more apical to the tooth roots (Herford & Nguyen, 2015).

The mandibular ramus is a dense, cortical structure used for the reconstruction of small and medium alveolar defects of the maxilla and mandible. With autogenous grafts prepared from the ramus, sufficient bone volume and sufficient stability for implant placement can be obtained. It shows minimal resorption, postoperative graft failure has been reported at low rates. The close proximity of the recipient and donor sites shortens the duration of surgery and anesthesia. It has disadvantages such as the risk of damage to the inferior alveolar and lingual nerve, hematoma, infection and fracture risk. If more graft is needed, it can also be taken bilaterally. Evaluation of the ramus as a donor site is done by panoramic radiography and clinical examination of the external oblique margin. Attention should be paid if there is an impacted 3rd molar in the area (Yates et al., 2013).

Inferior alveolar block anesthesia or local infiltrative anesthesia can be used to obtain a block graft from the ramus. Local infiltrative anesthesia is recommended because the complete loss of sensation alerts the operating physician when the canal is approached. A trapezoidal incision is made and the ascending ramus is exposed. A graft 2-3 cm in length and width can be obtained from the external oblique ridge. Khoury divided this graft into two thin laminae with disks, fixed it with screws and filled the gaps with autogenous bone particles (Fouad Khoury et al., 2007). The mandibular ramus donor site shows fewer postoperative complications than the symphysis site. However, patients may experience swelling and difficulty opening the mouth and chewing. Sensory change is lower (in the range of 0% to 5%) and usually not permanent compared to the symphysis (Brugnami et al., 2009).

The zygomatic region has good bone quality (D1-D2) and is relatively easy to access. The amount of bone that can be obtained from the zygomatic arch is limited. It can usually only be used to obtain sufficient bone for the repair of a few edentulous defects. In the operations performed to obtain bone from the donor area, care should be taken to avoid perforation of the sinus membrane and damage to the infraorbital nerve adjacent to the relevant area. There are disadvantages such as bleeding and trismus as postoperative complications (Sittitavornwong & Gutta, 2010).

Calvarial bone grafts are taken from the parietal bone, the thickest part of the outer layer of the skull. Due to its dense cortical structure, it can be rigidly fixed as a block. Osseointegration and blood supply are successful and resorption rate is low. Postoperative morbidity is minimal when a drain is placed to prevent hematoma formation. Low complication rate, painless healing process compared to other donor sites and scar tissue remains under the scalp are among its advantages (Smolka et al., 2005).

Costochondral grafts, which contain both bone and cartilage tissue, are used as an ideal graft in pediatric patients and in temporomandibular joint reconstruction. The fact that costochondral bone

is covered with cartilage and has a rounded surface makes it histologically and morphologically similar to the normal mandibular condyle. In surgery, the right side is generally preferred because of the location of the heart and the 5th to 8th costae are chosen as donors. It has a low morbidity rate. Pain, postoperative pulmonary complications and scar tissue are among its disadvantages (Thapliyal, 2006).

A large amount of cancellous graft can be obtained from the proximal part of the tibia by medial or lateral approach. It is used for alveolar crest and maxillary sinus augmentation. The advantages of this donor site are that general anesthesia and hospitalization are not required, the patient can walk immediately after the operation, pain complaints are less common and the risk of complications is low. However, tibial bone graft should not be used in young and growing patients because of the risk of damage to the growth centers (Thapliyal, 2006).

The iliac bone is an easily accessible site with rapid revascularization and integration, partially abundant (approximately 50 cm³ corticocancellous) and high quality bone. The presence of a second surgical site (donor site) in the patient may lead to increased morbidity, which is a disadvantage, but studies have reported low complication rates and high long-term success rates. However, there is a risk of morbidity at the donor site and some surgical complications in autogenous graft harvest from the anterior iliac crest.

The iliac crest is the most commonly preferred extraoral donor site for augmentation of large bone defects. It contains a higher volume of cancellous bone than other donor sites and has the highest cancellous/cortical bone ratio. The graft can be harvested from anterior or posterior iliac crest sites (Nguyen et al., 2019).

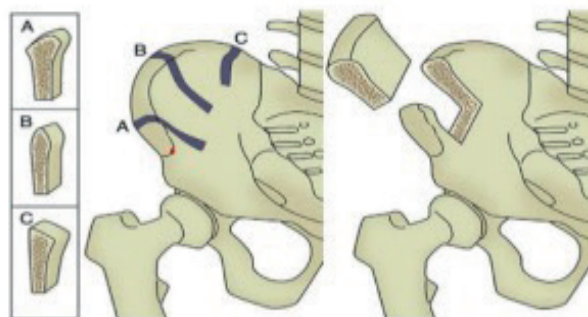


Figure 9. A. anterior iliac crest B. Middle iliac crest C. Posterior iliac crest (Misch, 2007)

From the posterior iliac crest, 2-2.5 times more grafts can be obtained than from the anterior iliac crest; therefore, it is preferred when larger graft volumes are required. It has advantages such as less postoperative morbidity, pain and gait disturbance. However, it has disadvantages such as additional intraoperative time for patient positioning, risk of displacement of the endotracheal tube, and inability to perform graft harvesting and grafting procedures simultaneously. Infection, hematoma, nerve injury, persistent pain, gait disturbance, iliac crest fracture, ileus, sacroiliac instability, abdominal hernia and cosmetic deformity are some of the complications seen after iliac crest grafting (Joshi & Kostakis, 2004).

Although studies have shown that autogenous grafts are the best graft material, an additional surgical field is required to obtain the bone. The optimal donor site should be chosen depending on the volume and type of bone required. The largest volume of bone graft is obtained from the posterior iliac crest (~140 mL), followed by the anterior iliac crest (~70 mL), calvarium (~40 mL) and tibia (~20-40 mL). However, graft preparation from extraoral donor sites has the disadvantages of higher cost, the need for general anesthesia and hospitalization. Another disadvantage is the increased resorption potential of the graft if simultaneous dental implant placement cannot be

performed. The limited amount of bone available for reconstruction is the biggest disadvantage of intraoral donor sites. Up to 5-10 mL of bone can be obtained from the ascending ramus and up to 5 mL from the symphysis. The advantages of intraoral grafts are the proximity of the donor and recipient sites, practical surgical access to the site, prevention of a surgical scar and short duration of surgery and anesthesia (Herford & Nguyen, 2015).

In the period immediately after autogenous bone graft placement, healing begins with remodeling and resorption stages. This loss of autogenous graft volume in the future depends on the size and quality of the bone graft, bone quality at the recipient site, biomechanical properties and the degree of fixation of the graft to the surrounding bone. During the first phase of bone regeneration, the transplanted cells in the graft proliferate and form new osteoid for several weeks. The cells within the graft are nourished by plasmatic diffusion for the first 3-5 days. From the fifth day onwards, capillary growth from the surrounding soft tissue and bone into the graft occurs (Thapliyal, 2006).

The healing of grafts differs according to the type of graft (cancellous, corticocancellous or cortical). Following surgical trauma, hemorrhage occurs in and around the graft. Various mediators released from the tissue and cellular components of the blood stimulate the migration of inflammatory cells, phagocytes and mesenchymal pluripotent cells by chemotaxis. Depending on the type of stimulus, mesenchymal cells differentiate into endothelial cells, fibroblasts and osteoblasts and proliferate to form new blood vessels and connective tissues. As a result of anastomosis of the vessels in the graft and the recipient bed, revascularization begins within a few hours after grafting. Completion of revascularization of the cancellous bone graft occurs within a few weeks. Unlike cortical bone graft, bone formation occurs without resorption caused by osteoclasts. Osteoblasts line up on the surface of the old trabeculae and initiate osteoid formation. This tissue is then mineralized and immature bone is formed. During the final remodeling stage, osteoclasts resorb newly formed immature bone and necrotic bone, which are then replaced by mature lamellar bone (Thapliyal, 2006).

Interpositional (Inlay) Grafting

Inlay grafting is the process of increasing bone volume by applying graft between bone osteotomy incisions. Inlay grafting is applied especially in the reconstruction of vertical deficiencies of the maxilla and mandible. This method, which is mostly indicated in the maxillary anterior region, can be used in most regions of the maxilla and mandibular arch. It is preferred in cases where vertical bone is required in moderately atrophic areas such as 3-8 mm. The alveolar segment is moved and fixed in the required vertical dimension. Since the periosteal blood supply of the separated part continues, its dimensional stability will be preserved. A maximum vertical movement of 5 mm can be made in the anterior region of the maxilla. In more than 5 mm movement, blood support will decrease and slippage of the segment and aesthetic problems will occur. The interpositional graft technique is a simpler technique compared to block graft methods due to the need for less flap lifting. In order to be applied in the posterior areas of the mandible, there must be a minimum of 4 mm of bone tissue above the nerve. Otherwise, there is a risk of iatrogenic nerve injury. Successful results have been obtained in cases of moderate atrophy in the posterior mandible. The inlay technique is also used synonymously with the sandwich technique. In the inlay technique, there are also cases where Le Fort I osteotomy should be performed in the maxilla (Figure 10) (T., 2007).

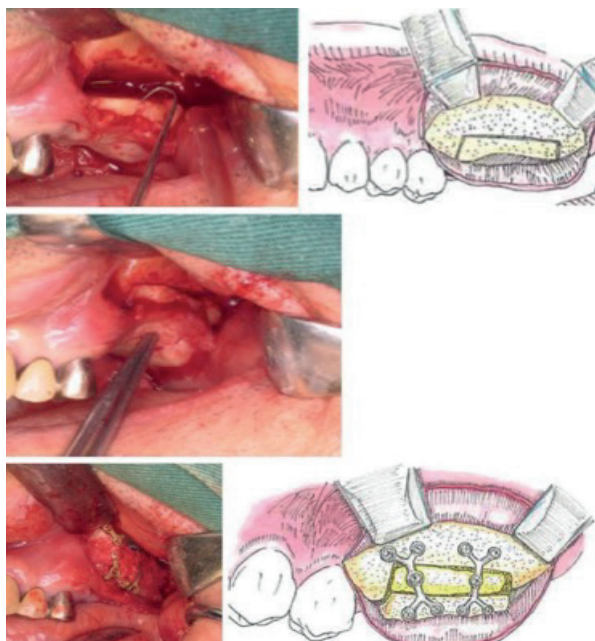


Figure 10. Interpositional (Inlay) Grafting (Tanaka et al., 2017)

Le fort I osteotomy used in interpositional grafting is an effective technique for positioning the maxilla inferiorly and anteriorly in patients with severe maxillary resorption and block graft from the iliac crest is preferred because of its corticocancellous structure.

The interpositional grafting procedure is based on the theory that biomaterial placed between cancellous bone in 2 pieces of pedicled bone will provide rapid and complete healing and fuse with the graft with a lower percentage of resorption. The sandwich osteotomy allows the graft to be positioned in a well-demarcated area as well as providing adequate blood supply to sustain new bone growth (Figure 10). This procedure allows simultaneous correction of the sagittal intermaxillary relationship and vertical dimension. This technique has been applied to both the mandible and maxilla. In the case of performing a sandwich osteotomy in the posterior mandible, significant surgical precision is essential to prevent injury to the inferior alveolar nerve. Given these considerations and the limited available data in the literature, further research is necessary to validate the predictability of this regenerative technique (Figure 11) (Laino et al., 2014).

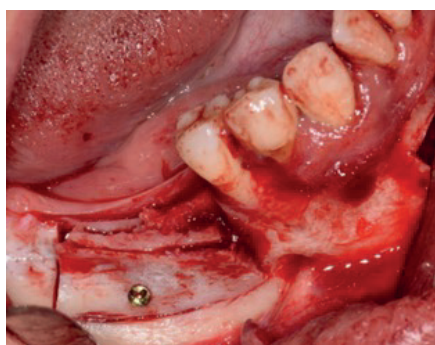


Figure 11. Sandwich osteotomy (Atef et al., 2019)

In 1976, Epker and Wolford reported that grafting should be performed in all cases of maxillary advancement if more than 10 mm of posterior maxillary grafting was to be performed. This guideline stated by Epker and Wolford was later revised and it was reported that grafting must be performed if more than 0.5 cm advancement is to be performed. In surgeries where the maxilla is positioned downward, the use of interpositional bone graft serves to prevent soft tissue migration into the osteotomy gaps, accelerate bone healing, and create a physical barrier against

occlusal forces (Epker et al., 1976).

Rosen et al. 1989 and 1991 reported that the use of autogenous bone (iliac graft) as an interpositional bone graft is the gold standard. The main reason why iliac bone graft is the gold standard is that it has a high osteogenic potential and no immunologic reaction is observed. However, it also has disadvantages such as the need to create a second surgical field for iliac bone grafting and lower extremity limitation (Rosen, 1989).

In their study, Egbert and Waite reported that while a relapse rate of 10-26% was observed in maxillary advancement surgery without interpositional graft placement, this rate decreased to 6-7% with graft use (Waite et al., 1996).

Araujo et al. In their 1978 study, they found a great difference between the two groups in terms of the potential for relapse after maxillary advancement surgery in a study between two study groups with and without graft application. The mean amount of advancement of the study groups was determined as 6 mm. The amount of relapse observed in the study group using grafts was between 0-5%, while the amount of relapse observed in the study group not using grafts was between 31% and 68%. In addition, as a result of the study, it was stated that the routine use of interpositional bone grafts after maxillary advancement surgeries is not indicated if surgical stability and plate fixation are adequate, skeletal maxillomandibular fixation can be achieved, ideal occlusion is achieved postoperatively and the amount of movement is less than 5 mm. If one or more of these parameters cannot be achieved, the use of interpositional bone grafts has been reported to be necessary to achieve postoperative stability (Araujo et al., 1978).

Yang et al. In their 2012 article, they reported a modified Le Fort I osteotomy study in which inferior positioning of the maxilla was known to be the minimum stable movement in terms of stability and therefore they aimed to increase postoperative stability by increasing the bone contact points. In the study, the maxilla should be positioned inferiorly in cases with vertical insufficiency, but as Proffit et al. 2007, they mentioned that inferior positioning is the least stable movement known. Some of the factors that are effective in decreasing stability are increased masticatory forces, the presence of inadequately applied or never applied bone grafts, and inadequate stabilization. In the article, the use of plates to increase mouth opening before surgery for the adaptation of the muscular system, bilateral coronoidotomy or pterigomasseteric myotomy applications during the operation were mentioned and it was mentioned that these applications facilitate adaptation to the increased facial height after the operation. In addition, rigid fixation of the maxilla with a miniplate, the use of interpositional bone grafts and simultaneous mandibular surgery will help to increase stability by reducing occlusal forces (Wardrop & Wolford, 1989).

Interpositional grafts are grafts placed in the 3, 4 or 5-walled cancellous bone compartment. These grafts are placed in defects where the borders are alveol, sinus membrane and medial wall as in the sinus floor elevation technique. Thus, the graft is stabilized and blood supply is provided. Another interpositional graft application is the cortical split technique applied in alveolar bone. The cortical bone is separated vertically and the cancellous bone compartment is exposed. The graft is then inserted into the cavity. A similar technique is the sandwich graft technique applied in the mandible. In this technique, the cortical bone is removed, the graft is placed in the cancellous compartment and the removed cortical bone is placed on the graft with the help of screws and stabilized (Smiler & Soltan, 2006).

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