A narrative review of surgical techniques in mandibular regions and the use of bone grafts in implant dentistry

Luciano Bonatelli Bispo

DDS, M.Sc., Ph.D. by Department of Dentistry, University of São Paulo, Brazil

KEYWORDS

- Bone substitutes
- Immediate dental implant loading
- Jaw, edentulous
- Alveolar bone loss

ABSTRACT

Aim: Bone quantity and quality are indispensable for obtaining primary stability and for prosthesis planning in implantology. Both the maxilla and the mandible undergo continuous, intermittent and progressive bone resorption over time. In order to circumvent this loss, bone grafts and substitutes are used to increase the thickness and height of the alveolar ridge. Particularly the mandible, provides important donor areas for cortical and medullary bone. The aim of this work was to review grafting techniques and the successful use of mandibular grafts for bone reconstructions in height and width, for immediate and posterior osseointegrated implant rehabilitation.

Methods: The selection of articles was made by searching the electronic databases PubMed (National Library of Medicine - National Center for Biotechnology Information) and BBO (Bibliography Brazilian Dentistry). The indexed terms searched, between 2010 and 2021, were: Bone substitutes; Immediate Dental Implant Loading; Jaw, Edentulous; and, Alveolar Bone Loss (DeCS / MeSH - Health Sciences Descriptors).

Results: Autogenous grafts are still considered the gold standard. Despite the existence of numerous bone substitutes, none of them has all the biological properties when compared to patient’s autografts.

Conclusion: The region of the oblique line and the mandibular symphysis are preferable for harvesting autologous grafts because they present a low risk of infection, do not have a high cost, are in proximity to the receiving bed, and surgical techniques can be used in the dental office under local anesthesia, presenting high rates of clinical success and acceptance by patients.

Introduction

The technical and scientific evolution of dentistry and a better understanding of the basic sciences of physiology, pathology and microbiology increased the possibilities of rehabilitation of edentulous patients. The emergence of implantology combined with improved scientific knowledge from evidence-based dentistry has made the reconstruction of the jaw bones and implant placement a predictable and resolutive current reality.

The phenomenon of osseointegration can be defined, in a simplistic way, as: a direct, structural and functional connection between living, mature, organized, vascularized bone and the surface of an endosseous titanium alloy implant, with surface treatment, that can undergo the functional loads for a long period of time (1). However, for osseointegration to occur, it is necessary to have availability in quantity and quality of bone tissue in order to achieve primary stability (2). In fact, one of the prerequisites for achieving success in osseointegration is implant primary stability (3). The immobility of the implant, during the healing period, prevents the formation of fibrous tissue at the bone / implant interface. In low-quality bone, lower rates of success, highly variable, between 50 and 94%, are to be expected owing to the lack of primary stability (4).

During the first year after tooth extraction about 25% of bone tissue volume is lost in the anterior region of
the maxilla; in terms of thickness, about 40 to 60% of its volume is lost after the third year. Three years after dental extractions, the loss of alveolar volume is 50% in the posterior maxillary region, which contains up to twice as much bone mass when compared to the anterior region (5).

The mandibular alveolar bone undergoes a loss about four times higher than in the maxilla, due to chewing forces and resulting compressive forces exerted by head movements. However, it is important to note that the maxillary area is almost twice as large as that of the mandible (6). In addition to dental extractions, periodontal diseases, traumas, tumors, cysts, use of mucosa-supported prostheses, among others, lead to more accelerated resorption of the maxillary bone. The resorption process is chronic, irreversible, progressive and inexorable (7). Therefore, the reestablishment of patients’ aesthetics and function starts with a correct diagnosis, and is followed by planning, restoration of the lost bone ridge, implant primary stability and adequate design of the implant-supported prosthesis (8).

Bone reconstructions are possible through the use of autografts, homografts, xenografts, alloplastic synthetic materials, or growth factors. Despite this wide variety of bone substitutes and possible mixtures of their components, even today, autogenous bone is considered the “gold standard” due to its osteogenic, osteoinductive and osteoconductive properties (9).

Several regions of the human body can provide donor areas for graft harvesting. Extra-buccal sites are recommended in case of major reconstructions and extensive bone defects. However, this results in postoperative discomfort, as well as need for general anesthesia, hospitalization and collaboration by a multidisciplinary staff. Intraoral areas, are recommended when minor rehabilitation in terms of bone volumes in height and thickness, are required. In this case guided bone regeneration techniques result in low morbidity, high predictability, low resorption potential, minimal complications, low cost, absence of immunogenic problems, with low risk of infections. Moreover, the desirable standard properties are maintained for both en block and in particle grafts. Furthermore, donor sites are located close to the receiving area (10).

The aim of this work was to review the intra-oral donor areas, such as the mentonian symphysis and the mandibular branch, as well as the surgical techniques for bone augmentation in height and thickness in the alveolar ridge for subsequent implant-supported rehabilitations.

Materials and methods
The articles were searched in the following electronic databases: PubMed (National Library of Medicine - National Center for Biotechnology Information) and BBO (Bibliography Brazilian Dentistry). The following terms were searched: Bone substitutes; Immediate Dental Implant Loading; Jaw, Edentulous; and, Alveolar Bone Loss (DeCS / MeSH - Health Sciences Descriptors).

Systematic or narrative review articles, retrospective clinical follow-ups, case reports, books and laboratory researches were included, published in the period from 2010 to 2021 January, with easy access on line, preferably in English language.

As inclusion criteria, studies on bone grafts of intraoral origin, harvested from the mandibular branch and symphysis, and surgical procedures were selected, as well as articles that related bone grafts of autogenous origin to implant-supported rehabilitations.

As exclusion criteria, articles from extensive craniofacial reconstructions with different rehabilitations were not considered, even when osseointegrated implants were used.

Of the 75 articles found, 27 were excluded because they were not relevant to the aims of the review. Of the 48 articles that remained, 4 were books and 44 scientific articles.

Results
Brief historical report
According to the historical evolution presented by Mazzonetto et al. (11), the techniques of reconstruction of the alveolar process date back to the pre-Incan era (3,000 B.C); heterografts were attempted in 1680 and at the beginning of the 19th Century, bone defects were treated with calcium sulfate: in 1820 the first allograft was proposed. In 1940, storage of bone tissue was attempted and in 1950 osteogenic distractions were developed. In the same period, studies on osseointegration were started. In the 1970s, clinical use of PRP (platelet-rich plasma) was started and ceramic materials were tested. In the 1980s, tissue engineering began its evolution. In the 90s, autogenous grafting was consecrated in literature and at the end of the same decade, works on BMPs (Bone Morphogenetic Proteins) became more and more common.

Surgical techniques
- Mentonian symphysis. Bilaterally, the inferior alveolar nerve must be anesthetized regionally and complementary infiltrative vestibulo-lingual punctures must be performed. The incision must be made in the crest of the alveolar ridge from the papilla or mucosa to the periosteum. A full thickness flap is lifted up to the mandibular base, with consequent bone exposure. Osteotomies are performed, according to the defect, with saws,
discs or drills. As a safety limit, an area 5 mm below the apexes of the lower incisors and 5 mm above the basal bone and 5 mm laterally to the mental foramina should be preserved, in order to preserve innervation and nutrition. Therefore, only the block inside that area should be removed. Depth depends on the thickness of the cortex. However, chisels can be used to remove medullary bone particles. Hemostatic agents or bone wax can be rubbed to contain bleeding (8).

- Oblique line or mandibular branch. Clinical palpation is necessary to identify the oblique line. The incision can be intrasulcular, distally from the second premolar with extension to the retromolar triangle and medially to the oblique line. An extensive incision is not necessary in the posterior areas, so as to avoid injuring the buccal artery. A mucoperiosteal flap is raised with bone exposure on the lateral side of the branch. A retractor is pushed and pulled laterally to the base of the mandibular coronoid process. A 4 mm thick rectangular cortical block can be removed. The block commonly has a height of up to 10 mm and a length of 35 mm. The basis of the coronoid process serves as a reference for osteotomy. Initially, 4 mm medial to the oblique line extending to the distal side of the first molar. Vertical anterior and posterior sections are perpendicular to the 10 mm long horizontal osteotomy. Osteotomies can be demarcated with small holes in the bone, spaced every 2 mm, by means of spherical drills, which are later joined with disc or drill under irrigation. Attention must be paid to the depth of the cuts to prevent damage to the nervous bundle. The surgeon should be careful while cutting with a disc mounted on a straight surgical piece with a deepening of only half a diameter. A fracture line is created and tested at the angles with chisels for mobility before performing abrupt removal movements. In fact, unwanted fractures of the block can occur if smooth movements are not applied. Also, hemostatics are necessary for bleeding control. Passive placement of the flap without tension and suture with good technique are also important (8).

- Graft. Cortical blocks or particulate bone can be obtained from different donor areas. Blocks can be used in onlay techniques and particles in inlay techniques. With the recipient area exposed, measurements are taken to plan graft adaptation and stability. The receptor area must be drilled with drills promoting bone decorticalization and bleeding. The graft must have its medullary face turned to the receiving bed. An adaptation is made to the block by smoothing its angles, removing its excesses, helping its placement. One or two titanium screws are used to fix the block, a thin layer of clot must be kept to prevent mobility and avoiding the interposition of fibrous tissue, which may jeopardize the union between the graft and the receiving bed (8).

Discussion
According to Cawood & Howell (12), in 1988, the region located between the mental foramina in the mandible exhibits a horizontal resorptive pattern, whereas in the regions outside these foramina, it follows a vertical pattern. In the maxilla, resorption is horizontal throughout its extension. Also, the vestibular face of the maxilla is very thin, showing a cortex with horizontal resorption. Therefore, the alveolar process undergoes a very significant and very predictable reabsorptive pattern (12).

The alveolar process has as main objective the support of the teeth: after tooth loss, there is a gradual chronic, progressive, inexorable, irreversible and cumulative resorption of this process (13). This bone loss is more intense in the first 6 months after extraction and successively during the patient’s life (14, 15).

Beside the premature loss of teeth, also malocclusions, infections, trauma resulting from uneven forces, diseases, among others, lead to bone resorption, which leads patients to functional changes in masticatory incapacity, phonetic problems, malnutrition, anti-aesthetic forces, in addition to the consequences of social interaction and psychological disorders (16-19). This stimulated literature on the aesthetic-functional rehabilitation of edentulous patients with the use of osseointegrated implants.

Bone grafts and substitutes are studies and researched in order to solve these problems. According to Potter & Ellis III (20), in 2004, an ideal material for bone grafting should have the following properties: chemically inert, non-allergic, affordable, biocompatible, possibility to be fixed with screws, easy to handle, radiopaque, easily adaptable, that can be shaped, that can be sterilized, non carcinogenic, bactericidal or bacteriostatic, totally resorbable, replaceable by neoformed bone and dimensionally stable. As for the biological properties of bone substitutes (21), they are: osteopromotion, osteoconduction, osteoinduction and osteogenicity. Osteopromotion is associated with the use of membranes in the guided bone regeneration technique, selectively preventing unwanted cells that hinder regeneration with inhibitory competitors. Osteoconduction requires adjacent bone to supply osteoblasts or differentiated mesenchymal cells for resorption and apposition. The biomaterial provides a support matrix or framework for the new bone formation. Osteoinduction is the process
of inducing osteogenesis by recruiting immature cells and consequent differentiation into cells with osteoprogenitoring capacity. Osteogenesis refers to "living" bone cells, remaining in the graft, that can form a new matrix (21).

Among the types of grafts, we can highlight: autografts (autogenous or autologous), homogenous (homologous), heterogeneous (xenogeneic), synthetic (alloplastic) and growth factors (9). Autografts have osteoconductive potential, favor osteogenesis, promote angiogenesis, have high compatibility, have vital and functional osteogenic cells, do not have undesirable immune reactions and release growth factors. They are considered the gold standard according to several authors (22-24). Allografts are of human origin, but the donor is not the recipient itself. As the greatest representative, we have the lyophilized demineralized human graft or demineralized bone matrix. Xenografts are of a different animal species, usually of bovine or porcine origin, and are used to maintain space in order to prevent the growth of fibrosis, helping osteogenesis and healing (25).

Synthetic or alloplastic materials have the function of providing bone growth and healing through a physical structure. Hydroxyapatite is the major representative with osteoconductive properties and favorable long-term results (26). Growth promoters minimize the amount of graft needed, accelerate maturation and bone growth. Bone Morphogenetic Proteins (BMPs), have the ability to recruit mesenchymal cells with consequent differentiation into bone-forming cells (27). PRP platelet-rich plasma, initially discovered in the 1970s, has a high concentration of platelets, being an adhesive compound of autologous fibrin, obtained by double centrifugation of 450 mL of blood, with activation by bovine thrombin (9). Plasma rich in PRGF growth factors require a blood volume of 50 mL and the activator is calcium chloride with only one centrifugation step (9). Despite the enormous controversy and confusion in studies on PRP and PRGF (28), there is no agreement in the literature about their effectiveness (29). Not all types of graft have properties in relation to most neoformation mechanisms. The literature is unanimous in presenting the autogenous graft as the one that combines the properties of osteogenesis, osteoconduction and osteoinduction. Both homogeneous grafts, such as heterogeneous and alloplastic grafts are only osteoconductive (8, 11, 16, 20 27). In view of the above, there is no substitute grafting material considered ideal or that meets all desirable properties. Autogenous bone has been consecrated in the literature, as it aggregates the largest number of desirable characteristics. However, it still has disadvantages due to the need for a donor area. In addition to the discomfort and morbidity associated with the patient, there is still the potential for resorption and great difficulty in adapting the graft to the receiving area (30).

Intrabuccal bone grafts from both the maxilla and the mandible have been described for the convenience of surgical access, for the reduction of the operative time due to the proximity between the donor and receiving areas, for the low cost, for the need of local anesthesia only, for the minimization of the morbidity, for the reduction of the discomfort and because it is a widespread alternative to bone augmentation before placing osseointegrated implants (31). The mandibular bone has been widely used in the reconstruction of alveolar processes to allow the placement of implants with favorable results (31). Block grafts can be collected from the mental symphysis with a corticomedullar microarchitecture. The mandibular branch, on the other hand, provides a more cortical bone morphology (8).

The removal of the graft from the mandibular ramus offers a bone quantity in volume for an area equivalent to 3 or 4 teeth. A bone block of 3 to 5 mm (thickness), 40 mm long and up to 15 mm (height) can be obtained. Consequently, 2.36 mL volumes with horizontal 5-7 mm ridge increases are also common (32). The mandibular body has an embryological origin from intramembranous ossification. Intramembranous grafts have lower rates of resorption (20-30%) when compared to endochondral grafts (75%). In addition to rapid revascularization, it is still speculated that its maximum potential as a graft lies in the similarity of the protocollagen between the receiving and donor areas. Also, there is the hypothesis of its three-dimensional configuration, having a thicker cortex, which would explain these low rates of resorption. The main reason for rapid healing, small dimensional loss, low resorption rate and easy incorporation of intramembranous bones lies in its architecture, as well as the immediate installation of the implants (when possible) which would stimulate the maintenance of this microstructural configuration, better primary stability of the implants and better distribution of forces (32).

The mandibular symphysis has an average thickness of 4-8 mm from the removed block, with consequent bone gain of 6 mm. This block allows for extensive maxillary reconstructions of the atrophic ridge in an area of approximately 3 teeth. The achieved bone volume is 4.84 mL, with dimensions of approximately 20.9 mm (thickness), 9.9 mm (length) and 6.9 mm (height). One of the great advantages of symphysis is the availability of growth factors, with the potential for healing due to the greater presence of medullary bone (32). The volume obtained from the chin bone corresponds to 50% compared to that obtained from the oblique line. Despite having medullary bone that favors revascularization and the potential supply of
osseoprogenitor cells, the donor area of the symphysis is associated with more frequent complications, such as: alteration of skin sensitivity, temporary or permanent paresthesia of the mental nerve and interference in pulp vitality of the teeth adjacent to the surgical site (33).

According to Silva et al. (34), in a total of 103 intraoral surgeries for graft harvesting: 31.2% was from the maxillary tuberosity, 28.5% from the mandibular ramus and 40% from the symphysis. These authors noticed lower rates of morbidity and postoperative complications when the graft was harvested from the maxillary tuberosity. However, the limited quantity and bone quality of this region cannot be adequate to all the needs and volumes required in any clinical situation. Naert et al. (35) reported that the association between bone grafts and implants must be performed with caution and that they do not necessarily always have a successful follow-up. However, Rocha et al. (32) did not associate implant loss with the type of graft, as success or failure resulting from a series of variables that are almost impossible to quantify. They also reported that the eventual failure is related to attempts to match the amount of bone necessary with that harvested from the mandibular ramus, as the limit of tissue that can be harvested is lower; moreover, this site is connected to a higher risk of fracture of the mandible, paresthesia of the lower alveolar nerve which is in intimate proximity (32). For Rabelo et al. (36), 6.6% of reconstructions of alveolar crest using autografts alone could not allow the placement of as many osseointegrated implants as initially planned. For Jensen & Sindet-Pedersen (31), out of 107 implants placed after autograft harvested from the mandibular symphysis only 7 were lost, corresponding to a 6.5% failure rate. This is in agreement with Rocha et al. (32), who found 95% average success, and with Levin et al. (37), who evaluated 129 implants installed after grafts from the mandible, with an average success rate of 96.9%.

Velasco et al. (38) compared the healing of donor areas, in particular they observed the recovery of the mental area in terms of regeneration and local healing. The main purpose was to assess the possibility of reopening the areas where the grafts were harvested after a 190-day postoperative follow-up. The region of harvesting of the autogenous bone greatly influences the final results of the graft in terms of quality of the new formed bone. Thus, they stated that the region that presents the best characteristics for bone harvesting is the mandibular region. They also observed that healing and regenerative response of the sites was very similar after 190 days. In sites below the mandibular canines, the depth was lower, even without a cortical coating on the ceiling. In an upper portion of the sites, there was a clear corticalization of the ceiling, and also an invagination of the vestibular cortex towards the base of the defect. Sites just below the central and lateral mandibular incisors were found drastically reduced. The entire ceiling of the defect was covered by a cortex with a swelling at the center of the donor area. There were diffuse areas of bone rarefaction in the internal portions of the sites. According to these results, the authors were able to conclude that a complete recovery of the donor areas in the chin region, mainly occurred just below the mandibular incisors. Regions closer to the mandibular symphysis enjoy improved healing. Mesial portions of the defects resulting from the donor sites are closer to the symphysis in a deeper and more cortical area. This contact and proximity help bone neoformation and rapid recovery, as in that area the defect is surrounded with bone of greater density. In contrast, near the mandibular canines there is a very thick vestibular cortex. Unfortunately, the site is located in a lower density region without the same potential for mineralization than the more central defects of the mandible. The authors report a new graft harvesting after 190 days from the mesial areas that present greater and better regeneration. Unfortunately, in the most distal defects, located closer to the canines, regeneration was not complete.

In 1965 a study (39) on mandibular arteriographs found that partial arterial obstruction occurs with age: these obstructions were present in 79% of the patients selected in the study, and started from the age of 40 and presented total occlusion after the age of 60. In young patients, blood nutrition in the jaw has multicentric and centrifugal characteristics. Nutrition is provided by the lower alveolar artery and in a secondary way by the branches of the buccal, lingual and facial arteries. Also, in 33% of the same sample, arterial flow was not found. There is also a directly proportional correlation of this absence or arterial decrease with the absence of teeth. This inversion of the flow makes the plexus of the buccal, lingual and facial arteries fulfill the main function of supplying blood perfusion and nutrition to the mandibular region over time. Thus, bone resorption, vestibuloplasty, tooth loss, prosthesis load per unit area and unbalanced occlusal forces decrease the bone area available for harvesting of mandibular grafts from the symphysis. This would be the main cause of the non-viability of the mandibular region as a donor site for bone grafts (40). In patients without these dysfunctions, there is no reason to discard the mandible as the region of first choice for the harvesting of autografts.

Medullary grafts are interposed within the recipient bed by a thin clot. There is a vascular invasion promoted by capillaries and their anastomoses between the graft and the recipient site. Osteoblasts from the graft and the recipient bed initiate the production
of bone matrix (41). The precursor and osteogenic cells initiate the secretion of growth factors and, through osteoinduction, favor bone neoformation. The remodeling phase begins with resorption of non-living bone and consequent complementary bone neoformation. In contrast, cortical bone has a delay in revascularization because it does not have pores that allow capillary invasion and its anastomoses. There is a need for an initial osteoclastic resorption that will pave the way for the vessels. Neoformation only begins with the colonization of the cortical bone by osteoblasts that will start the new bone apposition. For an indefinite time, there will be a coexistence of newly formed bone with non-viable bone. The real repair begins at the periiphery and advances into the graft (41).

The cortico-spongy block from the mandibular symphysis passes through all these phases. Thus, it passes through the rapid repair of its medullary content and the innate density of its cortical part that favors the achievement of primary stability of osseointegrated implants. Therefore, we cannot say, in terms of implantology, that the cortical tissue is superior to the medullary one or vice versa, when referring to grafts (41).

According to Misch (42), the criteria that directly affect the prognosis of bone grafts are: closure of tension-free surgical flaps, adequate asepsis of the operative field, healing period, intrinsic growth factors, regional metabolism, receiving bed conditions, immobility and graft stabilization, soft tissue situation adjacent to the defect, extent and degree of bone defect, presence of calcium phosphate and use of autogenous bone. It is clear that, at the same time, the presence of autogenous bone is indicative of excellent surgical graft harvesting, especially in the mandibular branch, with a lower rate of paresthesias and postoperative complications, according to several authors (43-48).

Conclusion

The region of the oblique line or branch of the mandible as a donor site for autografts, despite the smaller amount of bone tissue offered and the predominantly cortical microstructure, shows biocompatibility, is used in bone regenerative techniques, has a low risk of infection, is not expensive, can be performed in the dental office under local anesthesia, has a high success rate and excellent aesthetic acceptability by the patient. However, it is difficult to harvest, needs manipulation to remove excess, needs to be established for stability in the receiving bed, needs components (such as screws) for fixation, increased morbidity due to two surgical sites and demands training/experience from the surgeon. Further studies are necessary to find an ideal bone substitute or one that has the same properties of autogenous bone.

References

17. Gassen HT, Filho RM, Siqueira BM, Oliveira SB, Junior ANS. Reconstrução óssea de maxila atrofica utilizando