original article

Clinical considerations for optimizing results in bone grafting: Part I

Abstract / Introduction: *Due to lack of an ideal bone substitute, which promotes reconstruction of different types of bone defects with high predictability, high success rates and preferably without the need for a donor site from the patient, it is known that obtaining results excellent results in bone grafting represents a real challenge to surgeons even nowadays.* Objective: *Thus, the aim of this study was to address some aspects that directly influence outcomes in bone grafting, namely: defect type, choice of bone substitute, biological limits of surgical techniques and the microarchitecture of grafts, particularly because properly approaching these factors enables clinicians to obtain excellent clinical results.* Keywords: *Alveolar ridge augmentation. Bone resorption. Dental implants.*

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INTRODUCTION

When placing an implant, the quantity and quality of bone in the recipient site are considered major factors for the success of dental implant treatments.[1,2] However, loss of one or more teeth results in an imbalance between bone formation and bone resorption in the alveolar process, often culminating in alveolar atrophy, which causes defects in bone height or thickness, or a combination of both.[2-5]

Thus, bone grafting prior to placing dental implants is considered a viable option. When well executed, it can help to readjust atrophic ridges, enabling implantation in these regions.[2,6-12]

Nevertheless, achieving good results when performing a bone graft, especially when it involves less predictable defects, remains a daunting challenge to surgeons,[8,10,12-19] which justifies the need to carry out studies capable of assisting professionals in seeking and obtaining better clinical outcomes.

In view of the above, the present study aimed to show clinicians some of the tasks and cares that need to be evaluated and taken into consideration when the diagnosis of bone defect is confirmed. These tasks range from diagnosing a bone defect to choosing a bone substitute and a surgical technique. This should ensure excellent results in reconstructive procedures.

CLINICAL CONSIDERATIONS REGARDING BONE GRAFTS

1) Diagnosing the type of bone defect and selecting a bone substitute

The choice of a bone substitute will depend on the type of defect, with no single recipe capable of ensuring success in all cases. Therefore, accurate diagnosis is paramount.

The literature shows that, in clinical practice, five types of alveolar ridge defects can be diagnosed: dehiscence, fenestration, thickness defects, height defects, and a combination of thickness and height defects.[3,4,10]

Also according to the literature,[4,10,20,21] dehiscence and fenestration defects are associated with implantation. These defects are the most predictable, and are often addressed with a combination of autogenous and heterogeneous/alloplastic graft or with heterogeneous/alloplastic material, only (Figs 1 and 2). Importantly, in most cases, the presence of these two types of bone defects does not directly influence the osseointegration process, in which case the use of bone substitutes is often related to the maintenance of the gingival framework.

Although thickness defects are considered to be more predictable than height defects which, in turn, are more predictable than a combined defect, the use of autograft is recommended for these three types of defects, either by itself or combined with other bone reconstruction techniques[7,9,10,12,13,15,22] (Fig 3A-I).

The only exceptions are cases of maxillary sinus pneumatization, which, at the discretion of the professional, can be addressed with heterogeneous/alloplastic material alone or in combination with autogenous bone[8,16,19] (Fig 3J-O).

Autogenous bone is indicated to treat less predictable alveolar ridge defects due to being the only type of graft that features all the ideal properties for proper bone formation (Fig 4), thereby yielding the best clinical results.[1,3,4,9,12,23]

2) Bone level adjacent to the defect

Whenever assessing imaging examination results, it is essential to carefully observe the vertical bone level of teeth adjacent to the defect. This is important because no matter how successful the reconstructive

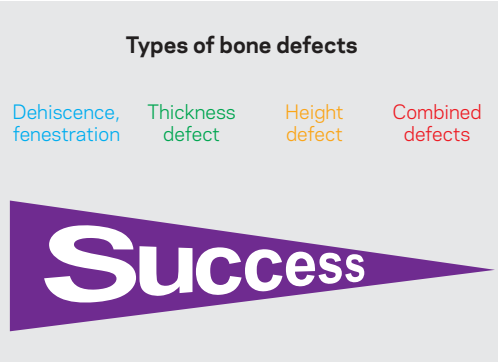

Figure 1. Relationship between the type of defect and expectation of success. Note that the less predictable the defect, the lower the expectation of success.

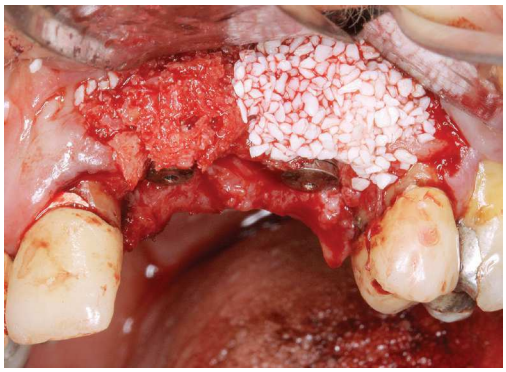

Figure 2. Dehiscence treated with autograft in the region of tooth #21 and heterogeneous graft in the region of tooth #22 (Lumina-Bone, Critéria). The purpose of using this type of material is to preserve the gingival architecture as well as prevent the contact of the gingiva with the implant threads, thereby averting gingival darkening in the long term.

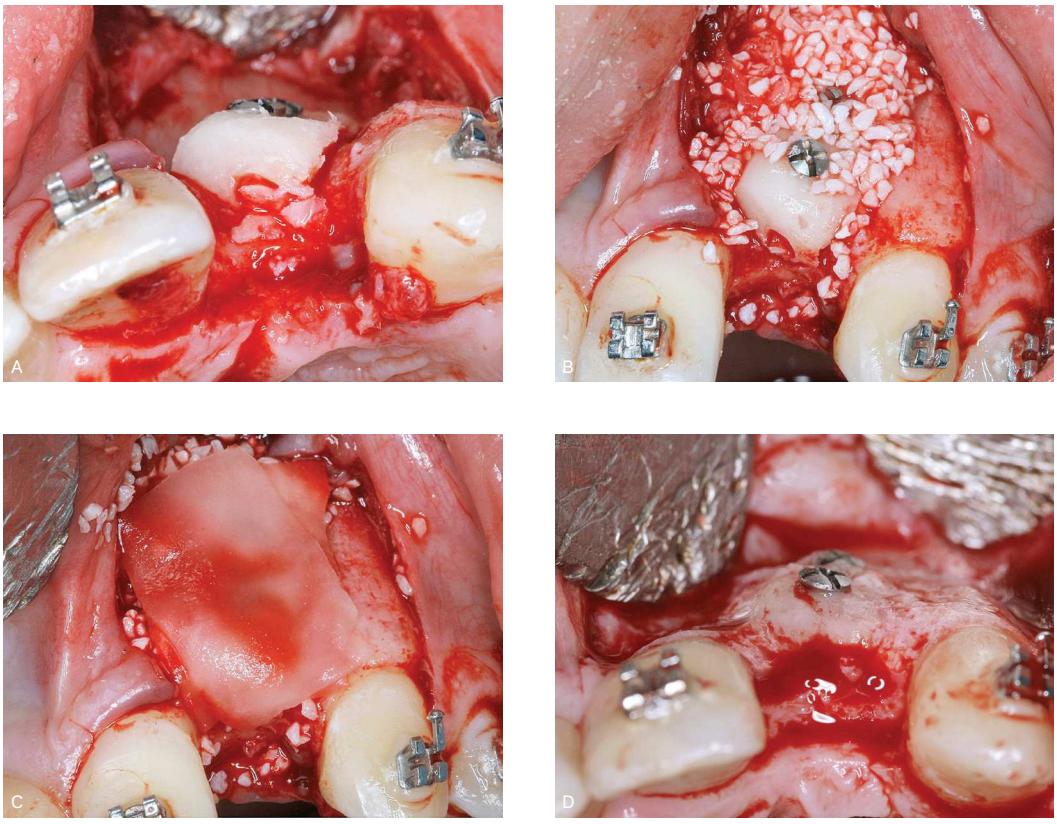

Figure 3A-3D. Thickness defect treated with block autograft removed from the mandibular ramus. Note that heterogeneous graft (Lumina-Bone, Critéria) and a collagen membrane (Lumina-Coat, Criteria) were added to the autogenous graft material. The objective of this combination of material was to decrease autograft resorption, thus achieving better reconstructive results.

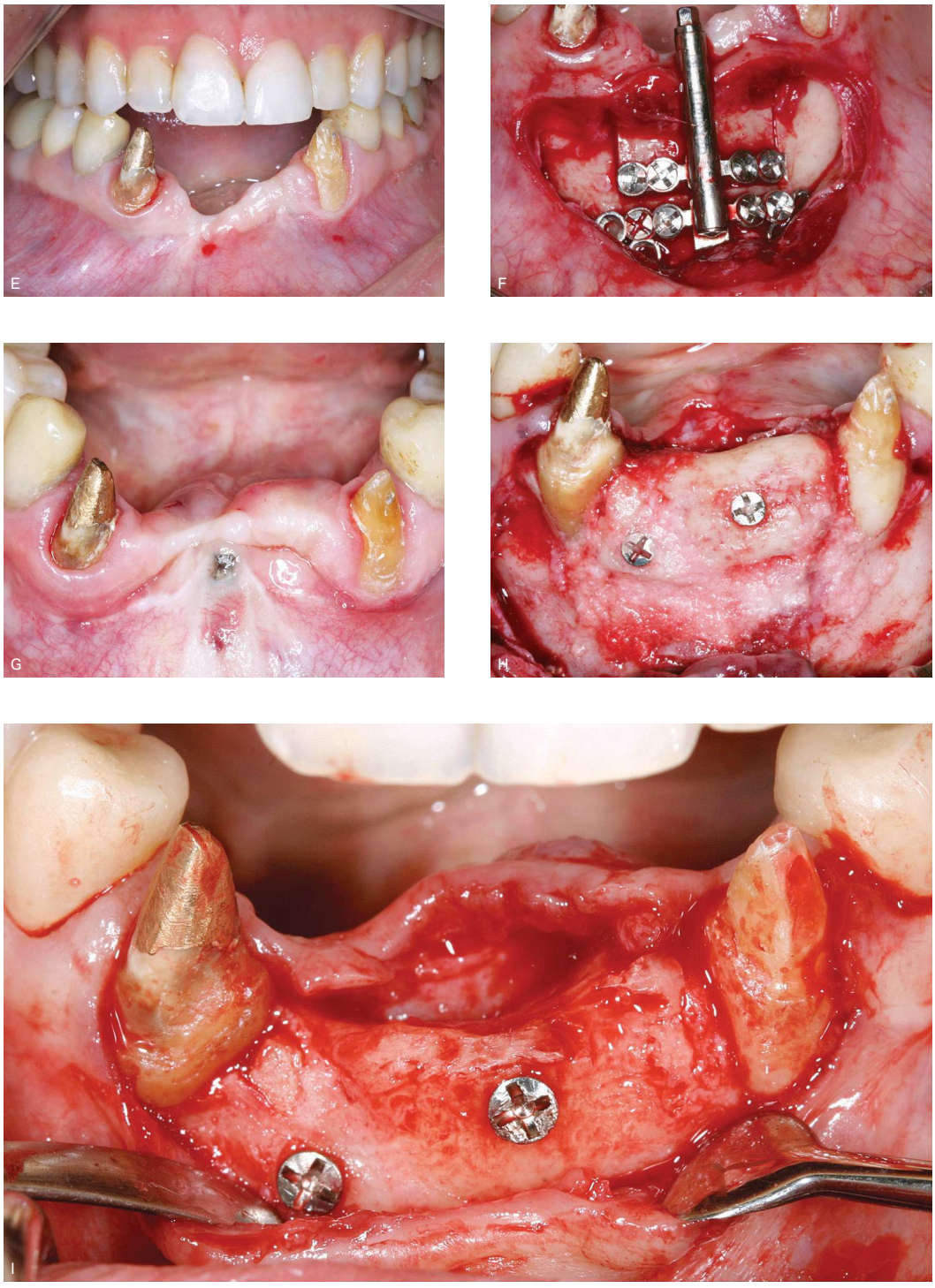

Figure 3E-3I. Combined bone defects (height and thickness) treated by performing alveolar distraction osteogenesis and autogenous graft in the chin. An accurate diagnosis, a combination of techniques and the fact that the procedures were performed in stages, enabled an excellent clinical outcomes.

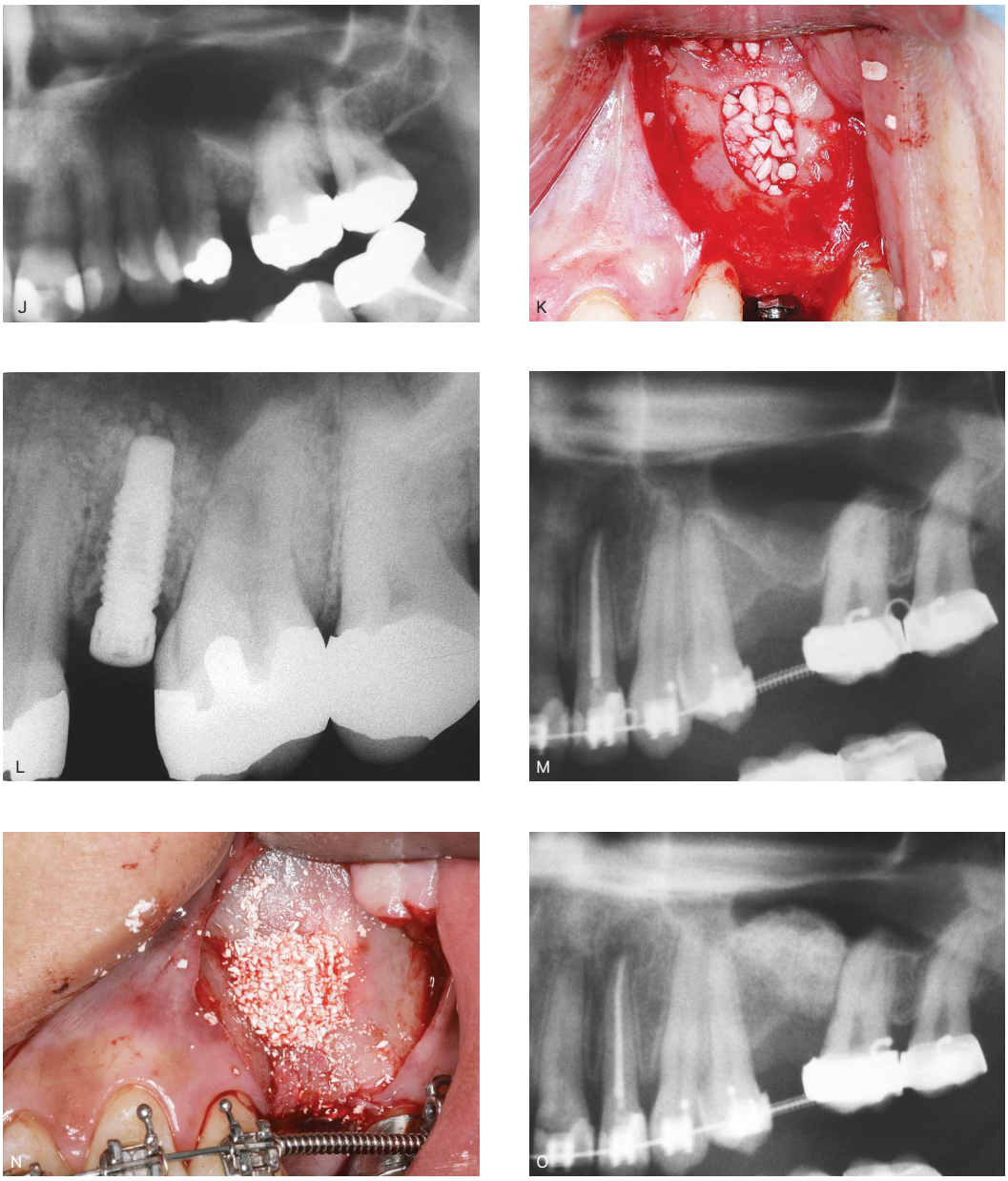

Figure 3J-30. Maxillary sinus pneumatization treated with heterogeneous graft (Lumina-Bone, Crit[eria) only. Given that the sinus is a closed cavity where nutrition is readily available, maxillary sinus defects are considered predictable, which enables them to be treated with heterogeneous material only.

Type of graft	Osteoconduction	Osteoinduction	Osteogenesis
Autogenous	Yes	Yes	Yes
Homogeneous	Yes	No	No
Heterogeneous	Yes	No	No
Alloplastic	Yes	No	No

Figure 4. Types of bone grafts and their respective properties. In cases of less predictable ridge defects, it is essential that treatment makes use of a material with ideal bone formation properties, in which case autogenous graft is the material of choice. (Source: Mazzonetto et al,[4] 2012).

procedure might be, bone gain is only possible when it reaches the bone height of teeth adjacent to the defect (Fig 5).[4,11,24]

It should be understood that placing bone graft beyond the level of adjacent teeth increases the risk of exposing the graft to the oral environment. In addition, nutrition will not occur since most of it comes through contact with the bone surrounding the teeth adjacent to the defect.[3,4,10,12,22,23] Therefore, it is much more predictable and safe to adjust the bone level of adjacent teeth during surgery.

If bone gain were possible beyond the level of teeth adjacent to the defect, the cure for periodontal disease would have been found.

Figure 5A. Adequate bone level of teeth adjacent to the defect. In this case, one or more than one well performed surgical procedures should yield satisfactory clinical outcomes. (Source: Mazzonetto et al,[4] 2012).

Figure 5B. Note that the bone level of teeth adjacent to the defect is located at a much lower position. In this case, no matter how successful the reconstructive surgical procedures might be, maximum bone gain can only be achieved up to such bone level. (Source: Mazzonetto et al,[4] 2012).

3) Choice of reconstructive surgical technique

Once the type of alveolar bone defect has been accurately diagnosed, it is necessary to choose a technique (or more than one) to reconstruct the defect. It is worth noting that there is no recipe (or a single technique) that ensures success in all cases. The surgeon must know different techniques as well as their indications, advantages, disadvantages and other peculiarities, so that he/she can offer the patient the most appropriate treatment for each case[2,3,4,9,22,25] (Fig 6).

It should also be emphasized that should a particular surgical technique be wrongly recommended, treatment is bound to fail, thereby causing the patient to incur financial losses and, even worse, biological costs, as treatment time and morbidity are increased.

Another important factor is the surgeon's mastery of the technique to be used, since it is known that no matter how well planned the case might be, it is not totally exempt from potential complications. Thus, the professional should have sufficient knowledge and experience to address potential complications.

4) Biological Limitations

Adherence to biological principles is essential for successful bone grafting. The surgeon should always be aware of the dimension of the defect to be treated as well as the quantity and quality of soft tissue present in the region.[2,3,8,19,22]

Treatment of large defects becomes more predictable and safe when treatment planning involves more than one surgical

Surgical techniques	Type of defect
Block graft	Thickness defect Height defects up to 3 mm
Particulate graft	Thickness defect* Height defects up to 3 mm* Maxillary sinus defects Dehiscence and fenestrations
Segmental osteotomy	Height defects between 4 and 8 mm
Alveolar distraction osteogenesis	Height defects greater than 8 mm Defects with the need for soft tissues gain
Ridge expansion (split crest)	Thickness defects, with sufficient bone remnant for expansion without fracture
Inferior alveolar nerve (IAN) lateralization	IAN superficialization that impairs other reconstruction techniques

Figure 6. Major reconstructive techniques and their indications. Note that there is a direct relationship between surgical technique and the type of defect for which it is indicated, which once again underscores the importance of an accurate diagnosis of the defect.

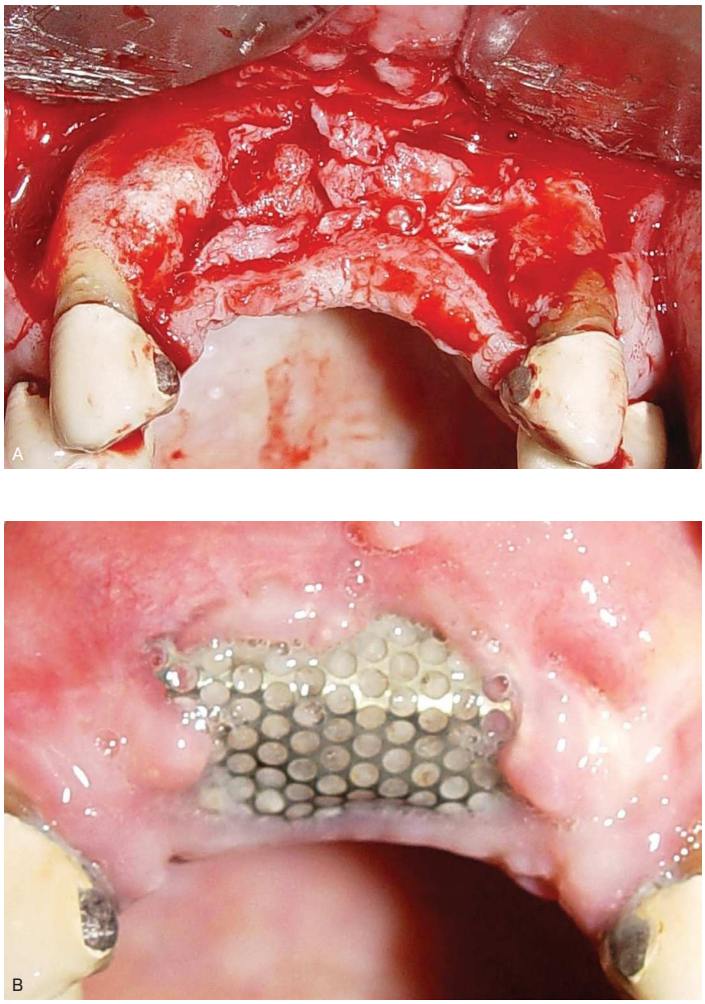

Figure 7A, 7B. A height defect of approximately 11 mm caused by an automobile accident. In this case, treatment was planned in a single surgical procedure carried out with particulate autogenous graft associated with a titanium mesh. Postoperatively, the graft was exposed to the oral environment and underwent an intense resorption process. The reconstruction was, therefore, totally lost.

step (Fig 3E-I), thus allowing implant placement in appropriate proportions.[11,19,22,23,25]

In cases of extensive defects, which are less predictable by nature, performing a single surgical treatment procedure becomes very risky, since soft tissues might not be sufficient to tightly cover the graft, thereby risking exposure of the graft to the oral environment. Moreover, the risk of not having enough nutrition for the graft cannot be ruled out, as the graft eventually undergoes an intense resorption process[3,4,22,23,25] (Fig 7A-B).

5) Bone graft microarchitecture

Preservation of bone graft volume is largely influenced by graft microarchitecture (cortical, medullary or cortico-medullary), and not by its embryological origin, as previously believed.[4,5,9,26,27]

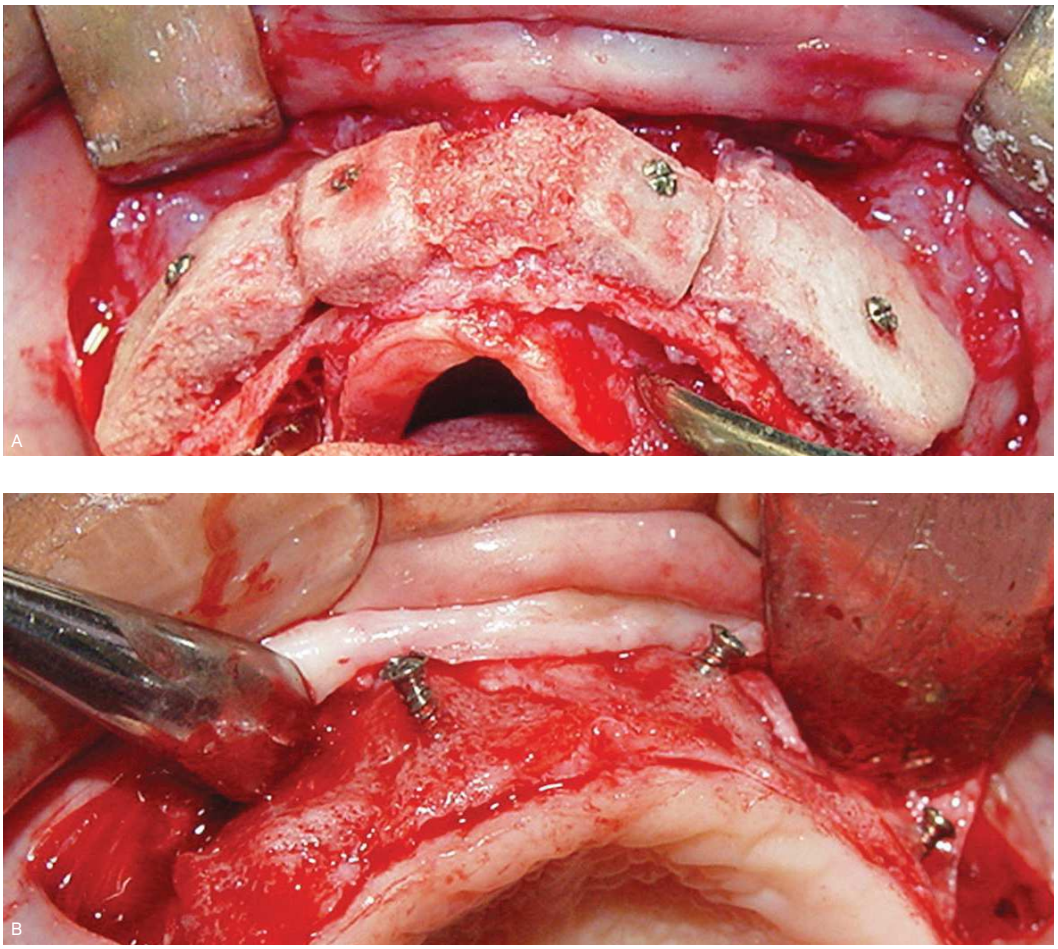

Figure 8A, 8B. Reopening of an iliac crest bone graft five months after it was performed. Note that it underwent intense resorption, which caused it to lose much of its volume. However, whatever remained of the graft has been fully incorporated into the patient's body.

Thus, grafts obtained from iliac crest regions are more likely to undergo bone resorption. However, revascularization process and subsequent incorporation of these grafts are sped up[3,26-30] (Fig 8).

The opposite can be observed in grafts obtained from cortical regions, such as the mandibular ramus, which tend to exhibit lower resorption potential, but are revascularized and ultimately incorporated at a lower pace[4,26-30] (Fig 9).

Thus, it is reasonable to assert that from the standpoint of microarchitecture, the best type of graft is the cortical-medullaryone, as it comprises the advantages of both aforementioned modalities (Fig 10). The mandibular symphysis is an example of such donor site[3,4,26-30] (Fig 11).

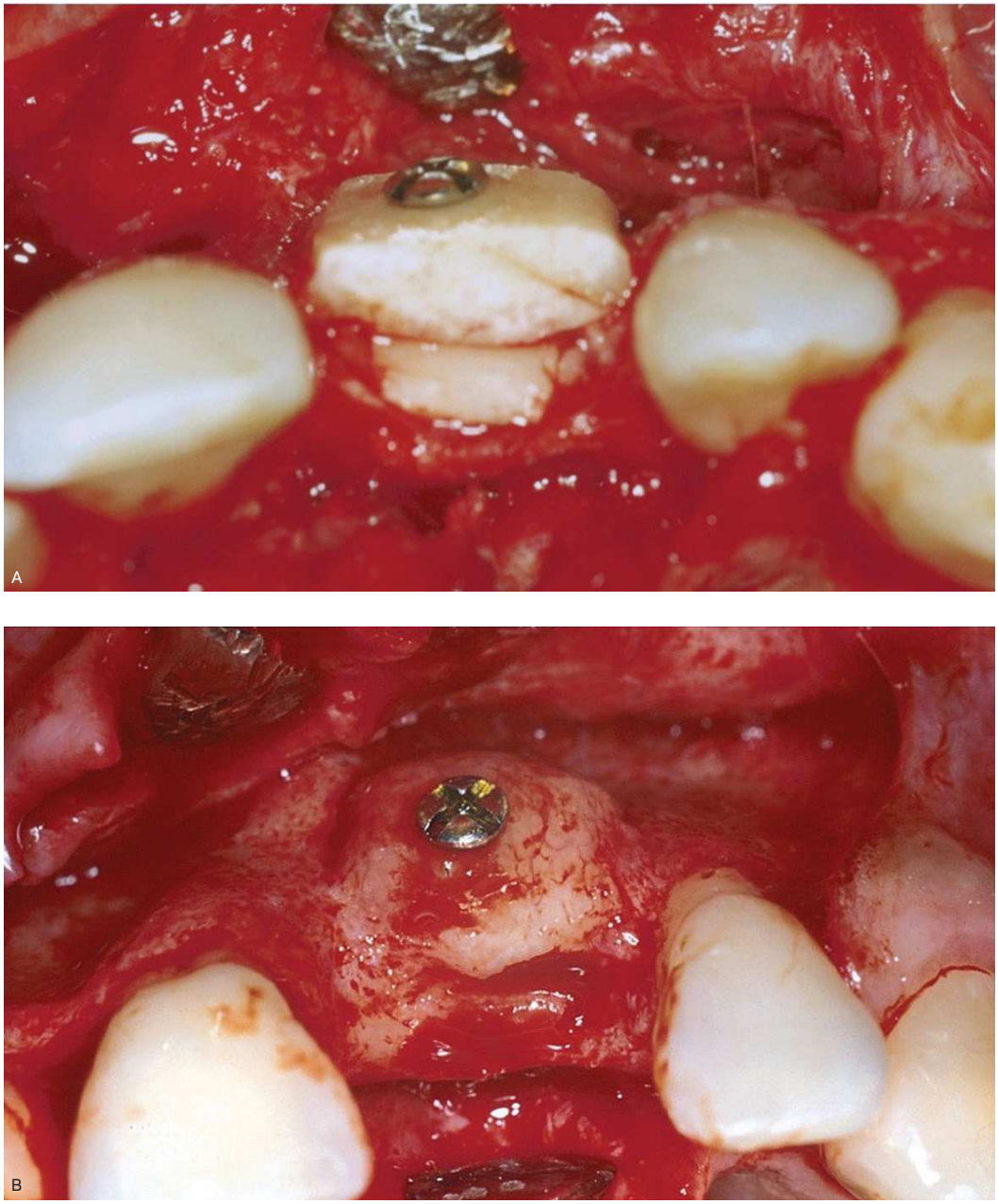

Figure 9A, 9B. Reopening of a mandibular ramus bone graft five months after it was performed. Note that the graft was minimally resorbed and that its original volume was, therefore, preserved. However, since it is still being incorporated into the body, one should take extreme care so as to prevent it from coming loose during implantation.

Bone graft architecture	Revascularization	Resorption
Cortical	Mild	Mild
Medullary	Intense	Intense
Cortical-medullary	Moderate	Moderate

Figure 10. Bone graft microarchitecture and its influence over the revascularization and resorption process. Note that the cortical-medullary graft is more advantageous than the other two groups, thus being considered the ideal graft (Source: Mazzonetto et al,4 2012).

Bone graft architecture	Donor site
Cortical	Mandibular ramus, coronoid process, skull
Medullary	Maxillary tuberosity, posterior iliac crest, anterior iliac crest
Cortical-medullary	Mandibular symphysis

Figure 11. Bone graft microarchitecture and donor sites. Note that the mandibular symphysis is the region that allows removal of a cortical-medullary graft (Source: Mazzonetto et al,4 2012).

DISCUSSION

Dental implant placement demands adequate quantity and quality of bone tissue, since bone will be the key support factor determining the survival of this type of rehabilitation over the years.[1,2]

Clinical findings demonstrate a low success rate for implants when bone volume and quality are inadequate.[10-13] However, several studies, such as those by Keller et al,[6] Becktor et al,[7] and Nóia et al,[1] show that readjusting the alveolar ridge with grafts of excellence raises the success rate to a level similar to what is attained with non-reconstructed jaw bones. This underscores the importance of correct diagnosis and appropriate reconstructive procedures.

The difficulties encountered in performing reconstructive procedures of excellence involve correct diagnosis of the defect, choosing the appropriate bone substitute for the case, and a correct application of the proposed surgical technique. Moreover, factors such as bone level of adjacent teeth, adherence to biological limitations, and bone graft microarchitecture are also important and, if taken into account, will help in attaining good clinical results.

Likewise, the study published by Ortega-Lopes et al[28] suggests that in order to optimize the results of grafts harvested from medullary areas, such as the iliac crest, one can modify its structure by compressing the medullary surface, thereby diminishing existing marrow spaces, while the resorption potential of the graft will eventually decrease. Another important aspect pointed

out by the authors is the possibility of shortening the interval between grafting and reopening the graft for implant placement. This is made possible due to the rapid incorporation of graft harvested from medullary areas. The author of this study, therefore, suggests that reopening be performed after approximately 4 months.

Much of postoperative exposure of grafts to the oral environment is due to long-lasting procedures in which the defect is being treated by a single reconstructive surgical procedure. As a result, the amount of soft tissue is insufficient to cover the site.[3,4,14,26,30] Thus, clinicians need to understand that when bone is gained in stages, involving more than one surgical procedure, it is often more predictable and safe, requiring lower financial and biological costs.

Another important factor to be considered is the possibility of graft resorption. In addressing this issue, one should note that combining autogenous material with heterogeneous/alloplastic material and a resorbable collagen membrane makes significant difference in the final outcomes. Recent studies suggest that this association benefits reconstructive procedures. Furthermore, it allows the reduction, control and even prevention of the bone resorption process.[13-19] Monje et al[14] conducted a study by means of computed tomography to assess the gain in thickness of 19 graft blocks harvested from the iliac crest or the mandibular ramus, combined with heterogeneous graft. The authors concluded that this combination is predictable and allows real gain of implant placement.

Likewise, Maiorana et al,[15] after conducting a histomorphometric analysis of the effectiveness of combining autograft with anorganic bovine bone, assert that the proposed technique is capable of preserving the volume of graft blocks, especially those containing a substantial amount of cancellous bone, as it is the case of the iliac crest.

The time factor also deserves attention, since most patients wish to complete their rehabilitation as soon as possible, and are therefore reluctant to undergo more than one reconstructive surgical procedure. These patients need to be informed that when it comes to extensive, hard-to-predict defects, bone gain occurs in stages presents a much greater chance of success. Additionally, it reduces treatment time, since the risk of losing the graft, either by exposure or intense resorption, is substantially lower.

FINAL CONSIDERATIONS

A combination of factors, such as accurate diagnosis of defect, the choice of a suitable bone substitute for treating the type of defect, as well as adherence to surgical and biological principles, should be taken into account to ensure excellent results in bone grafting and the long-term success of dental implant rehabilitation.

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