CASE REPORT

ALVEOLAR RIDGE AUGMENTATION WITH CUSTOM 3D-PRINTED BLOCK GRAFT: CASE REPORT

AUMENTO DO REBORDO ALVEOLAR COM ENXERTO EM BLOCO IMPRESSO PERSONALIZADO: RELATO DE CASO

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ABSTRACT

The use of the technology CAD/CAM (computer aided design/computer aided manufacturing) and 3D (three dimensional) to alveolar reconstructions in implant dentistry allows detailed preoperative planning, the design of the desired grafting result, and the virtual evaluation of the result in relation to the prosthetic reconstruction. This paper aims to details the synthetic bone graft made through this technology, followed by the installation of osseointegrated implants and prosthetic rehabilitation in a bone imperfection in the jaw. A 22-year-old man attended the clinic due to a tooth avulsion of the four lower incisors with significant vertical bone loss of alveolar ridge. Because of the extensive bone loss, it was made a prototyped printed block graft. The intraoral scan and the generated image files were sent to the virtual planning center. First, it was necessary a surgery to install the block graft. After the healing process, it was made a surgery to put two osseointegrated implants. Three months later, temporary fixed prostheses on implants were made to conditioning the peri-implant soft tissues and the progressive loading of the implants. The increase of the alveolar ridge using personalized printed block graft was presented as a technique with numerous advantages, since it does not require a donor site, reduces the surgical time and presents perfect adaptation of the block to the bone imperfection, resulting in a less postoperative morbidity. This technique is indicated to cases of severe bone imperfections, aims to optimize results, and provide less discomfort to the patient.

Keywords: bone graft; CAD/CAM; 3D print; hydroxyapatite; dental prosthesis; alveolar ridge augmentation.

RESUMO

A utilização da tecnologia CAD/CAM (*computer aided design/computer aided manufacturing*) e 3D (tridimensional) para reconstruções alveolares na implantodontia permite o planejamento pré-operatório detalhado, o design do resultado desejado do enxerto e a avaliação virtual do resultado em relação à reconstrução protética. Este trabalho objetiva detalhar a técnica cirúrgica de enxerto ósseo sintético confeccionado por meio dessa tecnologia, seguido da instalação de implantes osseointegráveis e reabilitação protética em um defeito ósseo na mandíbula. Paciente masculino, 22 anos, compareceu à clínica por avulsão dos elementos 32, 31, 41 e 42 com significativa perda óssea vertical de rebordo alveolar. Devido à extensa perda óssea, realizou-se enxerto em bloco prototipado impresso. O escaneamento intraoral e os arquivos de imagem gerados foram enviados ao centro de planejamento virtual. Primeiramente, foi realizada a cirurgia para instalação do enxerto em bloco. Após o período de cicatrização, foi realizada cirurgia para instalação de dois implantes osseointegráveis. Esperado o período de três meses a partir da instalação dos implantes, foi realizada a confecção de próteses provisórias fixas sobre implantes a fim de realizar o condicionamento dos tecidos moles peri-implantares e o carregamento progressivo dos implantes. O aumento do rebordo alveolar através do uso de enxerto em bloco impresso personalizado apresentou-se como uma técnica com inúmeras vantagens, por não necessitar de sítio doador, reduzir tempo cirúrgico e apresentar perfeita adaptação do bloco ao defeito ósseo, resultando em menor morbidade pós-operatória. Essa técnica é uma indicação para casos de defeitos ósseos severos, visando a otimizar o resultado e a propiciar menor desconforto ao paciente.

Palavras-chave: Enxerto ósseo; CAD/CAM; impressão em 3D; hidroxiapatita; implante dentário; aumento do rebordo alveolar.

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INTRODUCTION

Implant dentistry is a vast field within dentistry, which demands a great biological and anatomical knowledge from the dental surgeon. In tissue reconstruction, the use of autogenous graft is the gold standard due to its biocompatibility. On the other hand, it presents greater cases of postoperative morbidity, surgical time extended due to the need for two surgical areas, and a higher percentage of complications, such as, the presence of irreversible sequelae. In addition, the presence of limitations related to the bone volume available at the donor site has made the use of this technique increasingly smaller (1-3).

As an attempt to mitigate this problem, the use of bone substitutes gained greater popularity and the adoption of guided bone regeneration (GBR), performed alongside bone particles associated with the use of a membrane as a physical barrier, became widely expanded and documented in the literature. The four main elements required for a successful GBR have been described as: primary wound closure, space maintenance, clot stability, and a correct angiogenesis to provide access to the necessary cells, nutrients, and oxygen for tissue regeneration (1-3). Space maintenance is associated with the proper management of soft tissues and membrane properties. On the other hand, angiogenesis and blood clotting formation depend mainly on the native alveolar bone architecture (4). Thus, for larger reconstruction areas, the difficulty of correct tissue management can lead to failure, so there is a need for an experienced surgeon due to limitations in the vertical increase of the alveolar ridge.

Given the evidence and with the breakthrough of digital dentistry, other solutions have been studied. The use of CAD/CAM and 3D printing for digital reconstruction and graft fabrication for procedures for increasing the alveolar ridge has significant benefits for the patient and the clinician. First, it allows detailed preoperative planning, the desired design graft outcome, and the virtual evaluation of the desired outcome in relation to the final prosthetic reconstruction. In addition, it has the potential to produce personalized grafts with optimal adaptation and stability, which are crucial factors for success in bone augmentation procedures. Additionally, it allows a significant reduction in operative time, usually resulting in a lower rate of complications and intercurrences during healing, less discomfort, and an improvement in the overall patient experience. Lastly, the CAD/CAM milling process can be applied to a wide range of graft materials, including alloplastic, and of allogeneic and xenogeneic origin. It allows the practitioner to use the material of their choice based on its properties for each clinical scenario. Finally, the 3D printing process, although currently limited to alloplastic materials, has the potential to optimize the surface topography and microporous architecture of these materials, significantly improving their regenerative potential and success. Thus, it is as a promising technology for better clinical results related to bone augmentation (5).

This work aims to expose a surgical technique of a synthetic bone graft made by CAD/CAM technology, followed by installation of osseointegrated implants and their prosthetic rehabilitation in a bone defect in the anterior region of the mandible.

CASE REPORT

The Ethics Committee in accordance with the National Health Council approved this present report under protocol number: 66073122.0.0000.5256.

A 22-year-old man attended the Implant Dentistry Department at the Navy Central Dentistry complaining of avulsion of the four lower incisors with significant vertical bone loss of alveolar ridge and need for rehabilitation in the anterior region of the mandible. Bone graft procedure was indicated for the installation of osseointegrated implants. At that point, the patient was using a temporary removable partial prosthesis to rehabilitate the region. All procedures were explained verbally and in writing to the participant, who signed an informed consent form, detailing the stages of the research. The patient underwent preoperative cone beam computed tomography (CBCT) with soft tissue clearance for evaluation of available bone volume and planning for tissue reconstruction surgery (Figure 1). Additionally, a complete scan of the arcades was performed to obtain the file in STL (Standard Triangle Language), along with DICOM images (Digital Imaging and Communications in Medicine), generated from the CBCT examination, which were sent to the company Plenum® (Jundiaí, Sao Paulo) to produce the personalized graft. From DICOM files, a trained professional performed in a specific software (Mimics and 3-Matic, Materialise, Belgium), the drawings (virtual planning) of the personalized grafts, which were previously approved, and then made by means of additive manufacturing in a 3D printer suitable for ceramic prints (CeraFab 7500, LITHOZ). The project of the graft was presented in a video call held along work team. Adjustments and considerations were made, and the block was approved for manufacture (Figure 2). The custom

piece was made using lithography-based ceramic manufacturing (LCM), its process consists in printing the virtual part (previously drawn and exported in STL file) in resin containing the desired bioceramic, in this case, hydroxyapatite (HA). After the printing process of the parts was done, a cleaning with solvent was performed to remove excess resin inside the pores. Then, the piece was sintered in a muffle furnace at 1000 °C. After dimensional measurement, it was packed with primary and secondary wrappers in blister and surgical paper, then sent for sterilization by gamma irradiation 25kGy (Sterigenics, Jarinu, Sao Paulo). Right after the arrival of the block graft at the Navy Central Dentistry, the surgery was scheduled. As a drug protocol, it was prescribed to the patient: amoxicillin 500mg every 8 hours for 7 days, with an initial dose of 1g, 1 hour before surgery; dexamethasone 4mg, single dose of 8mg, 1 hour before surgery; dipyrone 500mg every 4 hours, in case of pain; and mouthwash with 0.12% chlorhexidine twice a day for seven days.

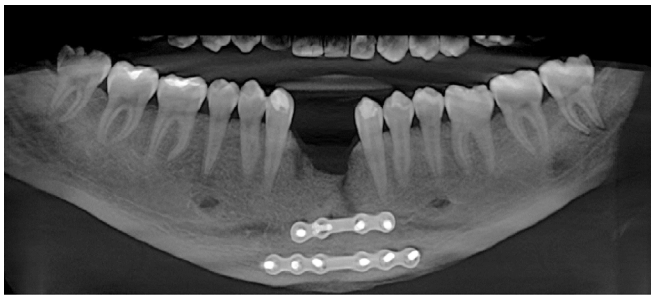

Figura 1: *Initial CBCT, panoramic reconstitution.*

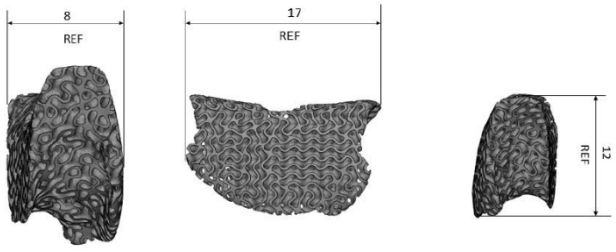

Figura 2 : *Digital planning with graft dimensions in millimeters.*

After preoperative planning procedures through CBCT and clinical examination, the patient was submitted to the three-dimensionally printed block bone graft surgery. At the beginning of surgery, he received a local anesthesia of lidocaine 2% with epinephrine 1:100,000, to block the mental and incisor nerves, associated with infiltrative anesthesia in the vestibular and lingual regions. An incision was made at the top of the remaining medial alveolar ridge from the left lower canine to the opposite side. Two incisions were made for vestibular relief in the distal portion of both canines, considering the position of the mental foramina. Then, a subperiosteal total detachment of the flap was performed and the relief of the vestibular flaps was made by means of superficial incisions (depth of 1 to 2 mm) with the scalpel blade 15C in the vestibular periosteum. This way, tissues disclosure could be made to obtain a relaxation of the mucosa until it exceeds the occlusal plane of the remaining teeth. Perforations were made in the cortical bone with fine burs until reaching the medulla. This step is essential to obtain the vascularization of the graft. Afterwards, a copy of the block graft was positioned to check its adaptation, once the template is checked and approved, there is no need to adjust the graft itself. This step was followed by preparation of the receptor site with a cylindrical bur. Also, blood was collected from the patient to produce plasma-rich fibrin (PRF) and, after being centrifuged, the i-PRF was added to the block graft, producing a membrane to be placed on the resorbable membrane. Once the adaptation was verified, the graft was fixed with the screw already in the previously planned position. The gaps between the block and the native bone were filled with a fine-grained particulate bone (Plenum®Osshp, Plenum®) and coated with the restorable membrane of xenogenic origin (BioGide®, Geistlisch®) to guarantee the coverage of the entire graft with an extension of 2 mm. Besides that, a PRF membrane was placed on this membrane to optimize the healing process. Finally, the suture was performed in two planes, firstly on a horizontal mattress to bring the flap closer to the surface, and then simple sutures with 4-0 polypropylene thread (Optilene Blue, Braun®) (Figures 3A-F).

Eleven months after the bone reconstruction surgery, digital planning was carried out for the preparation of a surgical guide through the CBCT and the STL scan file, so that osseointegrated implants could be installed (Figure 4). The participant underwent local anesthesia with lidocaine 2% alongside epinephrine 1:100,000. An incision was performed, without vertical relaxing incisions, and full thickness flap elevation. Guided surgical instrumentation was performed with external irrigation with sterile saline for the installation of two regular plenum implants 3.5x13mm lot 90413 (Plenum®, Jundiaí, SP). Torque installation was 30N.cm and the implant were closed with a cover (Figures 5A-D). At the end, a simple suture was performed as a first intention, without generating tension to soft tissues, with Nylon Soft Blue 5-0 (Techsuture®) thread. The patient continued to use temporary removable partial prosthesis, done after healing from bone reconstruction surgery.

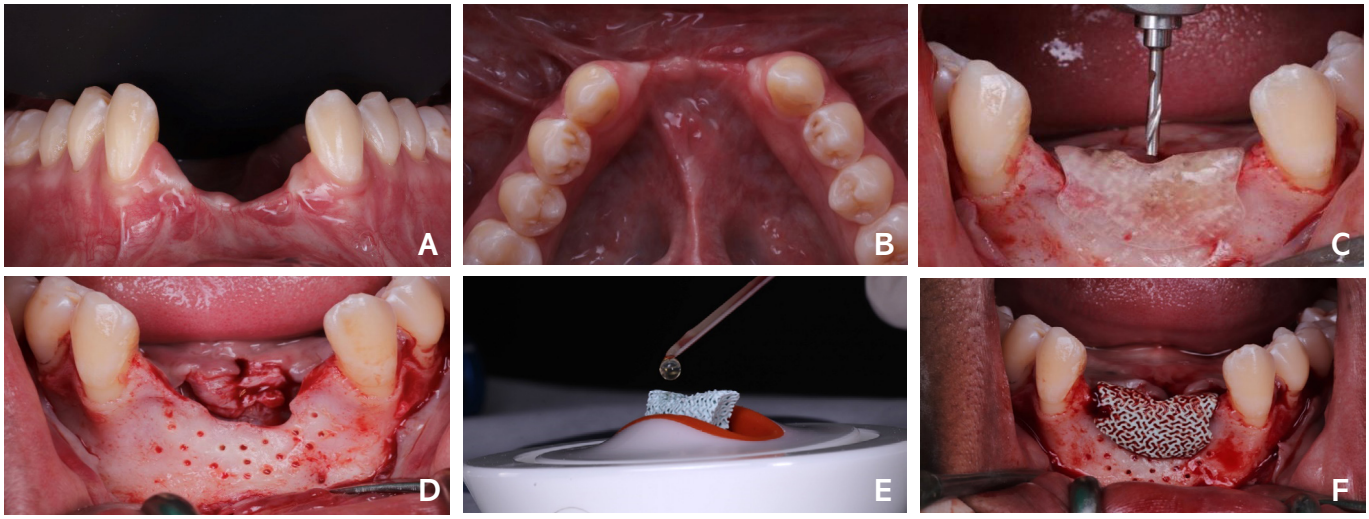

Figure 3: A – *Initial intraoral preoperative aspect - frontal view;* **B –** *Initial intraoral preoperative aspect- occlusal view;* **C –** *Test of template osteotomy;* **D –** *Bone aspect similar to Swiss cheese after perforations in the cortical;* **E –** *Addition of i-PRF in the block graft;* **F –** *Proof and fixation of the block graft on the bone defect.*

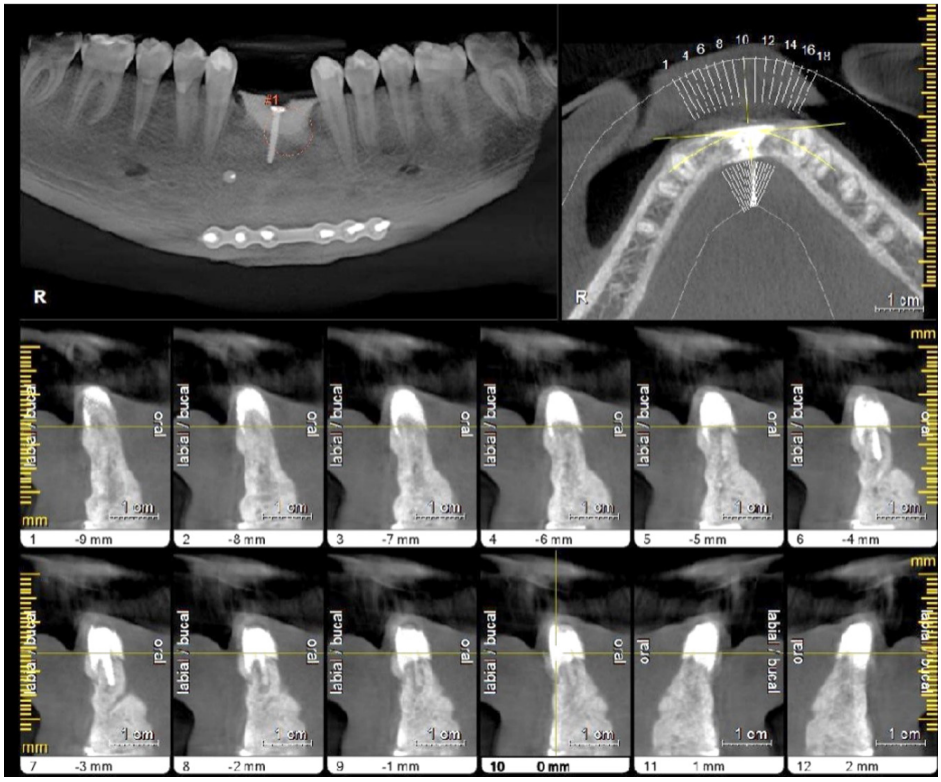

Figure 4: *CBCT after eleven months of graft healing, showing the juxtaposition of the graft to the native bone; panoramic, axial and transaxial reconstitution.*

Two months after the installation of the implants, due to the need of increasing keratinized gum band in the region, it was decided to perform a free epithelial graft surgery. A strip of epithelial tissue was removed from the palate. Then, an incision was made dividing the flap and the free epithelial graft was fixed in the region. The Nylon Soft Blue 5-0 (Techsuture®) thread was used (Figure 6).

After four months of healing, a reopening surgery was performed, in which was possible to confirm the osteointegration of the implants. Two transmucosal minipillars of 2mm high with their respective provisional cylinders (Plenum®, Jundiaí, SP) were installed. After occlusal adjustment and polishing were done, a fixed provisional prosthesis was performed directly in the mouth, for minipillars fixation. The patient is using the provisional fixed partial prosthesis to perform the progressive loading of these implants (Figure 7A-D).

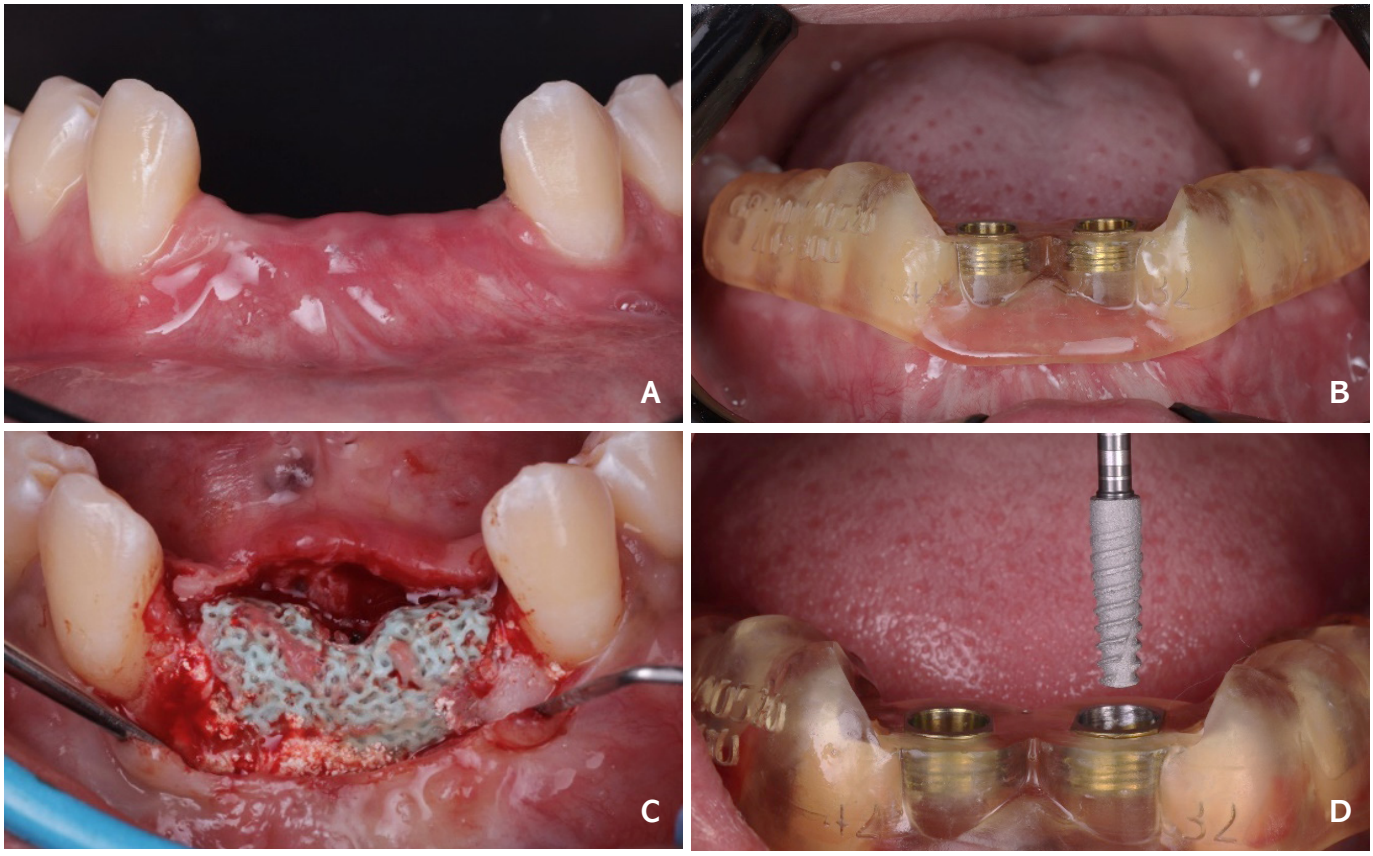

Figure 5: A - *Intraoral appearance before implant installation;* **B -** *Proof of surgical guide;* **C -** *Graft appearance after flap opening;* **D -** *Installation of Regular Plenum implant 3.5x13mm.*

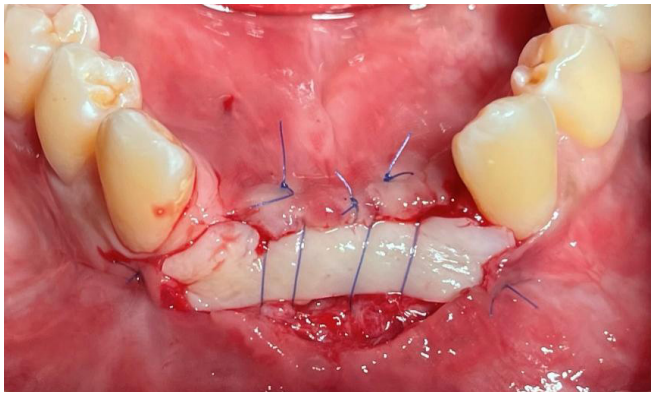

Figure 6: *Intraoral aspect during surgery for grafting free epithelial tissue.*

DISCUSSION

Several techniques are described in the literature for bone augmentation in atrophic jaws, such as onlay/inlay bone grafting, GBR, edge expansion and osteogenic distraction (6-10). Although it has already been shown that in all these techniques there is an edge increase, each of them present risks of complications and potential dimensional loss of the graft (11). In addition, all these techniques require perioperative manual adjustments of graft. This process is challenging and time-consuming and can lead to an unsatisfactory adaptation of the graft to the bone defect (12). This maladaptation of the graft to the receptor site is a major problem for the increase of the alveolar border since the mechanical instability of the graft can compromise the biological response and consequently the treatment outcome (12).

Currently, 3D scanning technology and new bone substitutes, with excellent osteoconductive characteristics, are promising to open new alternatives in relation to alveolar ridge augmentation techniques. It is possible to produce a precise 3D format calculated by the computer, creating a synthetic bone substitute in the exactly required format (13). This technology was used in this case report inspired by a described technique made for anterior alveolar ridge of the mandible reconstruction. The Plenum® Oss 3Dβ fit was used, a patient-specific bone graft with customized dimensions, produced from the additive manufacturing process (3D printing), and composed of hydroxyapatite, with complex geometry and faithful to the anatomy of the bone tissue to be reconstructed. In the bone graft planning process, an STL file was obtained, which associated with additive manufacturing technology, resulted in the production of these parts that integrate personalized medical devices, sub-classified as “patient-specific” according to RDC Nº 305/2019 (14).

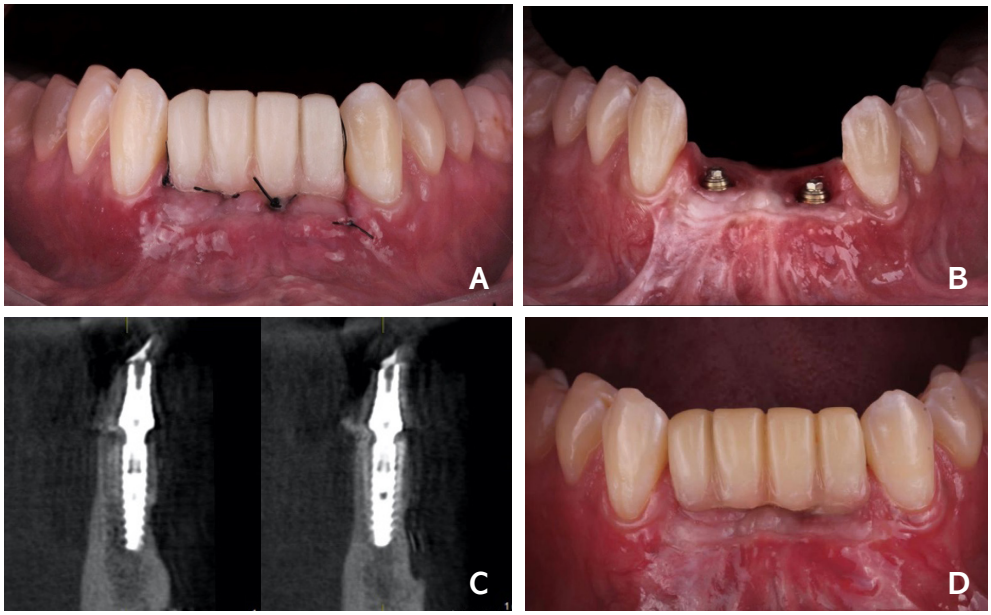

Figure 7: A - *Intraoral aspect at the end of the surgery reopening and preparation of direct fixed provisional prosthesis;* **B -** *Front view of the minipillars after soft tissue healing;* **C -** *Axial sections of the tomography examination in the center of the osteointegrated implants.* **D -** *Final image of the current gingival aspect, after 12 months with progressive loading of the implants, notice the presence of adequate keratinized tissue. (Sequence from left to right).*

The digital approach has many benefits, such as avoiding the need for a donor site and ensuring the perfect adaptation of the block to the bone defect. In our case, because it is a defect greater than 6mm in height and depth, the block graft was anchored with a screw to allow adequate fixation at the receptor site and three-dimensional stabilization to support muscle forces. That is the reason why the block graft onlay technique was chosen (15).

Although autologous bone, extracted from intraoral or extraoral sites, is currently the most reliable material for alveolar ridge augmentation, with the highest success rate, the use of these block grafts has many disadvantages, such as the need for multiple interventions, limited bone availability, the risk of morbidity at the donor site, and the high rate of graft resorption (16). Because of this, it is common for patients to prefer a bone substitute block over an autograft block, collected from an intra or extraoral site. It was no different in this case, since the patient had other mandibular fractures, which required the surgical approach of rigid fixation with plate and screw, a scarce donor area for performing an autologous graft, considering also the patient's preference.

There is a variety of bone substitute materials available as allogeneic, xenogeneic, or synthetic/alloplastic (16-19). An ideal bone substitute should be able to three-dimensionally regenerate complex anatomical defects (16,20). It must be biocompatible, osteoconductive, and osteoinductive, stimulating appropriate cell differentiation through signaling factors, so that the arrival of pluripotent cell types can be allowed (16,19). It should also be structurally similar to bone, performing mechanical activity similar to native structures, and allowing adequate function and dissipation of loads (16,19), besides being synthetic and not from human or animal origin (21,22). Finally, it should be easily made into various shapes. For this reason, materials with three-dimensionally made pores are currently used as bone substitutes (16,19). The 3D structure of the pores provides space for a new bone formation, supports cell proliferation and maintains its differentiation function, acting similarly to the extracellular matrix, and its architecture defines the final shape of the new bone (16,19). The graft used was made with macrogeometry in such a way to facilitate angiogenesis in the area, making it cell proliferation easier.

Synthetic grafts are usually made of calcium phosphate bioceramics, such as hydroxyapatite, β-TCP (β-tricalcium phosphate), or the combination of both (23). β-TCP was evidenced as a bone substitute due to its cell's reabsorption, usually osteoclasts, which cause acidification of the medium, dissolving β-TCP (24-26). This process makes β-TCP a restorable compound, allowing a fast bone neoformation (24,27,28). Hydroxyapatite, on the other hand, is not a restorable material, and its use is suitable to extensive regions that need to remain as a framework for bone neoformation. Moreover, both materials can be obtained from

various production methods. One of them is 3D printing, which has several advantages. The use of this manufacturing process has been described since 1994 in medicine, which led to the development of personalized grafts for bone reconstruction in rehabilitation with implants (29,30). The present study used this 3D printing technology to produce a hydroxyapatite block graft, a technique that reduces material waste, as it is additive. In addition, as there is a need for structural support to the implants installed in the area, due to the large extension of it, the use of a graft such as the one composed of β-TCP would not be indicated because of its resorption, therefore, in theory, it would not work as a structure for a future implant.

Clinical trials using 3D ceramic structure for bone regeneration have already been developed and have obtained satisfactory results (,), which confirm its clinical applicability (31,32). In the present study, a hydroxyapatite graft was used as the scaffold. This material has already been widely used for repair and augmentation of hard tissues in preclinical and clinical studies (19,33-36). It is biocompatible, osteoconductive and has osteoinductive properties, has appropriate porosity for the diffusion of nutrients, and the invasion of vascularization of the surrounding tissue. In addition, its surface chemistry allows the cells to adhere and express the osteogenic phenotype (33-36), presenting adequate mechanical properties. Moreover, it is synthetic and economical, and capable of easily forming an adequate anatomy (33,36). All these features have been observed so far, in this case. The patient did not present biological alteration compatible with any type of reaction to a foreign body or allergy. When the implant installation surgery was performed, the biological integration of the graft to the patient's bone tissue was stated due to the feasibility of surgical instrumentation without graft displacement. Only the fact of being economical is debatable, because as it is a material yet to be marketed, there is no final value of the product for analysis.

In this report, we had the opportunity to use a framework made from the CAD/CAM system of anatomical format custom-made, which adapted perfectly to the recipient site, without the need for any changes during surgery. This precision may have contributed to the biological integration of the graft, culminating in excellent clinical results. The treatment time was considerably reduced, with clear benefits for the patient. Indeed, the perioperative time is not consumed by the repeated conformation of the graft to the native bone as in conventional procedures (13,37,38). The procedure allows a faster closure of the surgical wound, avoiding possible sources of graft contamination and reducing postoperative discomforts, such as swelling and pain, resulting from long and difficult surgical procedures (37). Another advantage is that the graft is completely reproducible, so if there are any complications during surgery, it is possible to have an extra graft available on the operating table. Therefore, the entire procedure is simplified and more accessible even to less experienced surgeons (37,38).

In this study, PRF was added to the operative site, since this technique allows a the delivery of an aggregate of proteins and growth factors that can promote wound healing and tissue regeneration at the site of surgery. As reported in previous studies PRF can be effective in the administration of many growth factors, such as: platelet-derived, endothelial, vascular endothelial, fibroblast, among others (39,40). All these factors can promote tissue healing and regeneration (41,42).

As potential limitations of the present technique, there are motion artifacts during CT scans and the presence of restored teeth or metal restorations near the toothless area (38). The CT scan data set may be quite imprecise, and the presence of metallic artifacts may complicate the CAD process and the personalized design of the graft, in addition to the calibration of the professional who will operate the tomograph being fundamental for the success of the technique, as it can be considered technologically dependent.

Finally, the time between the tomographic images and the time of surgery is another limitation of this technique. The entire procedure must be done within a few weeks, to prevent bone remodeling processes from altering the patient's anatomy. In fact, changing the residual anatomy can result in inaccuracy of the custom-made graft during surgery. Beyond that, the timesaving with the use of the CAD/CAM approach is still controversial, even though the surgical time is considerably reduced, more time is required during the virtual planning, design and manufacture of the custom-made graft (43).

Long-term follow-up of this report is necessary because, up to this point, there has been twenty months of follow-up since the installation of the implants, and thirteen months since the provisional loading. To the best of our knowledge, there is only one ongoing clinical trial described in the literature (44), which warns of the importance of developing randomized clinical trials involving the above theme to enable the formation of more

robust scientific evidence and increase the safety of professionals when using this technique.

CONCLUSION

The increase of the alveolar ridge with personalized patient-specific block graft was presented as a technique with numerous advantages, such as the absence of the need for a donor site, reduction of surgical time, and excellent block adaptation to the bone defect, resulting in lower postoperative morbidity. Therefore, this technique is an alternative to be generally used by dentists in cases of severe bone defects, to optimize the result and provide less discomfort to the patient.

The authors declare no conflicts of interest.

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