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Prosthetically Driven Alveolar Reconstructions: A Retrospective Study

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This study aims to evaluate the post-extraction alveolar bone reconstruction amongst 12 patients exhibiting loss of buccal bone plate in a tooth of the anterior region of the maxilla using the prosthetically-driven alveolar reconstruction technique (PDAR). In PDAR, a partial fixed provisional prosthesis (PFPP [conventional or adhesive]) with a specially designed pontic maintains the clot in a mechanically stable position during alveolar regeneration. Moreover, the pontic design, in hourglass shape and located in the subgingival area, also prevents gingival margins from collapsing. Gingival recession was evaluated through the 6-month healing period. Cone beam computed tomography (CBCT) was performed 1 month before and 8 months after PDAR treatment. For the primary outcome, in the panoramic imaging, the central area of bone defect in each tooth was selected for linear measurements. Measurements of the vertical buccal bone gain and the gain in thickness in the alveolar bone crest were obtained 8 months after PDAR. Descriptive statistics and intraclass correlation coefficient analysis were conducted. After treatment, all patients showed bone formation (a mean vertical gain of 7.1±3.7 mm, associated with a horizontal mean gain of 4.5±1.4 mm in the alveolar bone crest). The intraclass correlation coefficient for the measurements performed using CBCT was 0.999. No gingival recession, greater than 1 mm, was observed. Lower-morbidity procedures without the use of biomaterials may be a useful in post-extraction alveolar ridge regeneration and/or preservation. PDAR promoted alveolar bone formation without flaps, grafts and membranes.

Key Words: alveolar ridge preservation, bone regeneration, extraction socket, coagulum, fixed provisional prosthesis.

Introduction

Conventional post-extraction alveolar regeneration results in quality (1) and dimensional alterations in the bone crest (2). Due to minimal thickness in the anterior region of the maxilla, the buccal bone plate is frequently affected, (3) possibly compromising the aesthetic result of treatment (4,5). Conventional surgical techniques have been used to prevent absorption of the alveolar bone that occurs after extraction. (6,7) A flapless alveolar ridge reconstruction technique could result in less morbidity and benefit bone formation. Prosthetically-driven alveolar reconstruction (PDAR) technique is a bone reconstruction technique (8), in which relaxing incisions, grafts and membranes are not used. In PDAR, a partial fixed provisional prosthesis (PFPP [conventional or adhesive]) with a specially designed pontic (with an hourglass shape extension located 3 mm in the subgingival area) provides mechanical stability to the clot, that probably stimulates the epigenetic memory of stem cells (9,10), during alveolar bone reconstruction healing phase, and also prevents the mucosal margin recession, due to its concave subgingival design (11).

Accordingly, this study aimed to evaluate alveolar post-extraction regeneration using the PDAR technique, of adult patients in areas exhibiting loss of the buccal bone plate in the anterior region of the maxilla, through clinical evaluation and cone beam computed tomography (CBCT).

Material and Methods

Sample Selection

In the present retrospective study, files of patients who had received PDAR technique were screened. The following inclusion criteria were adopted: having a tooth intended for extraction in the anterior region of the maxilla with neighbor teeth without proximal bone loss, exhibiting harmonious gingival architecture with neighboring teeth, and presenting buccal bone plate loss, needing an alveolar bone reconstruction procedure for dental implant treatment; good general health; good oral hygiene; and 18 years of age or older. The exclusion criteria adopted were: untreated periodontal disease; history of periodontal surgery; drug or alcohol use; any local or systemic condition contraindicating

the procedure, or interfering in bone metabolism; and pregnancy or lactation.

The protocol of this study was approved by the Platform Brazil Research Ethics Committee (no. 55765816.3.0000.5259). This study was conducted in full accordance with the declared ethical principles of the World Medical Association Declaration of Helsinki.

Image Analysis

All patients were evaluated using CBCT, which was performed before and after the bone regeneration treatment. Examinations were conducted using a tomography device (Prexion 3D CBCT, PreXion Inc, San Mateo, CA, USA) with a 90 kV, 4 mA acquisition protocol for 19 s. These examination data were exported in DICOM format, and displayed a 0.15 mm (voxel) thickness. When they were converted into DentalSlice files (DentalSlice converter®, Bioparts Prototipagem Biomédica, Brasília, Brasil), they generated 0.9 mm voxel files. In the CBCT panoramic image, the central region of the bone defect in the buccal aspect of each tooth was selected to obtain the sagittal cut. In the sagittal window, it was possible to observe the absence of the buccal bone of all teeth.

An examiner (LCMSJ), previously calibrated and not involved in treatments, performed all measurements. To calibrate the measurements, the following protocol was adopted: bone thickness measures were obtained from the external cortical crest of the palatine bone to the most buccally located bone. Bone height measures were always made from the internal cortical of the nasal cavity floor/maxillary sinus, passing by the internal cortical of the buccal bone, and up to the bone crest. Twenty per cent of all sites were randomly measured 10 days later, for determining the intraclass correlation coefficient (ICC). The ICC for measurements performed using CBCT was 0.999.

Prosthesis Preparation

Before surgery, a PFPP was fabricated using a working cast. The compromised tooth (Fig. 1) was removed from the cast, and 3 mm of the 'subgingival' area was excavated (Fig. 2). The casts were scanned using the 3 series scanner (Dental Wings, Montreal, Canada). The PFPP was fabricated with acrylic resin (Vipi Block PMMA Trilux; VIPI Ind, Com, Exp e Imp de Produtos odontológicos Ltda, Pirassununga, Brazil), with the pontic extending to the subgingival area. Subsequently, a concavity was prepared in the intermediate subgingival millimetre using a 1 mm diameter spherical drill bur, giving the subgingival area an hourglass shape (Fig. 3). The concavity area of the pontic resulted in a height and depth of 1 mm, being situated 1 mm below the gingival margin, and 1 mm away from the provisional most apical area. The provisional was disinfected by immersing it in a 2% chlorhexidine solution, followed by extensive washing with saline solution.

Surgical Procedures

Before surgery, the patients were anesthetized

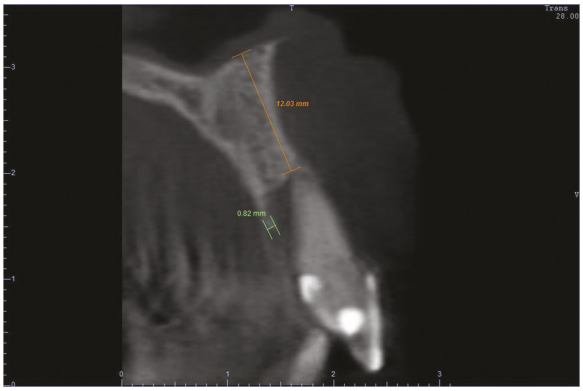

Figure 1. Initial cone beam computed tomography (CBCT) of central upper right with endoperiodontal lesion.

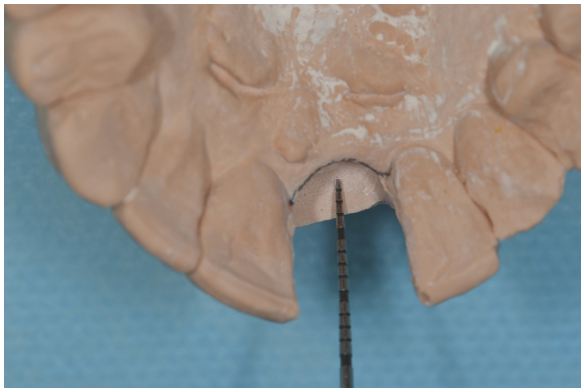

Figure 2. After removal of tooth in the cast , a 3 mm subgingival niche was excavated. The gingival margin was demarcated with a 0.5 mm mechanical pencil to be respected.

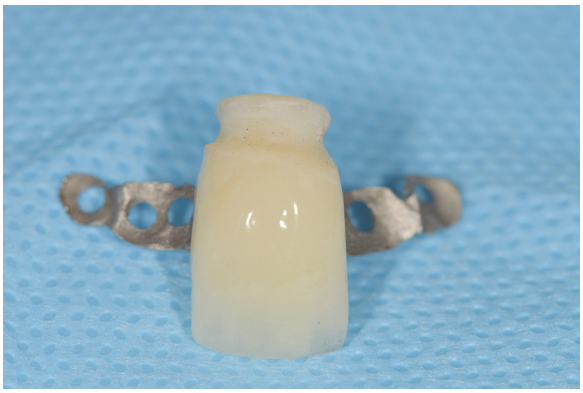

Figure 3. Adhesive fixed prosthesis made by CAD-CAM.

with a solution of mepivacaine 2% with 1:100.000 noradrenaline (Nova DFL, Rio de Janeiro, Brasil). For tooth extraction a root elevator (model 17.045.00; Helmut Zepf Medizintechnik, Germany) was used in flapless extraction of the compromised tooth. The root elevator was introduced into the periodontal ligament space sectioning the connective tissue fibers in an apical direction. After tooth extraction, only the bone walls of the alveolus were meticulously debrided, and a North Carolina periodontal probe (Hu-Friedy MFG. Co., Chicago, IL, USA) was used to verify bone defect dimensions in the buccal wall. No tooth presented the buccal bone wall confirming the CBCT examinations. All surgeries were performed with no relaxing incisions. Eight teeth presented root fracture, 2 teeth showed endodontic failure and 2 teeth presented with endoperiodontal lesions. Systemic antibiotic amoxicillin 500 mg TID for 7 days (Amoxicilina; Medley Indústria Farmacêutica Ltda, Sumaré, Brazil), and anti-inflammatory ibuprofen 600 mg TID for 3 days (Alivium; Mantecorp Indústria Química e Farmacêutica S.A., Rio de Janeiro, RJ, Brazil) were prescribed in association with chlorhexidine mouthwash 0.12% for 14 days (Perioxidin; Laboratório Gross, Rio de Janeiro, RJ, Brazil).

Restorative Procedures

Immediately after extraction, PFPP settling was tested and, when needed, adjustments were made to allow for complete seating. This procedure was performed with extreme care so that the prosthesis in the subgingival area was round, with no sharp angles, and well-polished for it to be cemented. All PFPP were cemented using dual-cured resin cement (RelyX TM ARC, 3M do Brasil Ltda., Campinas, Brazil). The cement was manipulated and inserted into the resin-bonded retainer of the PFPP, on each side, which were bonded to the inner edge of the adjacent teeth, that were acid etched during 30 s, washed and then the coupling agent was applied (Fig. 4). The resin-bonded retainer had holes, and the cement excess filled these spaces and was light cured for 40 s using a halogen light source. After, the occlusion was checked and adjusted, and the resin was polished. In approximately 60-day intervals, to evaluate the healing process, the PFPP were removed during the control consultations, and were then recemented.

Clinical Evaluation

For evaluating the secondary outcome, during the 6-month healing period, using a North Carolina probe (Hu-Friedy Mfg. Co., LLC), the level of the mucosal margin at the FPP pontic was clinically evaluated measuring the distance of the mucosal margin to the submucosal concavity area of the pontic - located 1 mm below the mucosal margin. The measurements were rounded to the nearest millimeter.

Statistical Analysis

Descriptive statistical analysis of the results involved calculating mean and standard deviation for differences in alveolar ridge initial and final bone height and thickness. Concordance of intra-examiner measurements was assessed using the intraclass correlation coefficient. Statistical analysis was performed using SPSS version 20 (IBM Corporation, Chicago, IL, USA).

Results and Discussion

Mechanical complications were observed in two cases. In one case (11), the PFPP had to be re-cemented within 48 h, and one PFPP fractured and had to be redone (Case 2). After a mean 8-month healing period, depending on the patient's availability, a new CBCT (Fig. 5) was performed. During control consultations, in

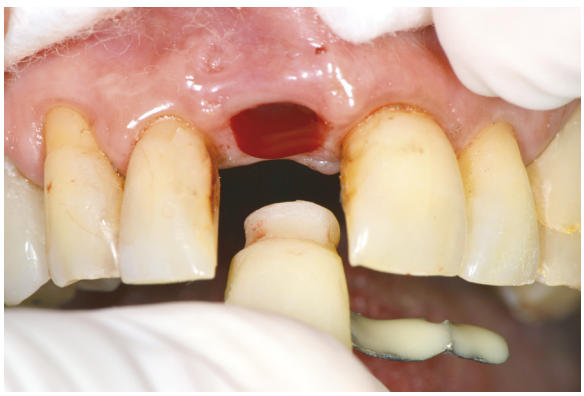

Figure 4. Cementation of provisional adhesive prosthesis immediately after extraction.

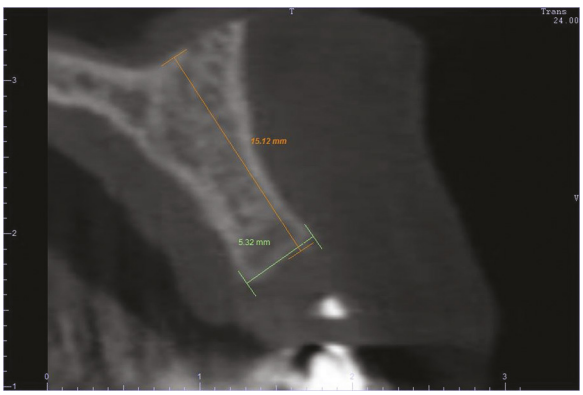

Figure 5. CBCT sagittal image showing bone reconstruction, after 6-month period, with graftless bone reconstruction technique.

approximately 60-day intervals, the PFPP was removed and gradual epithelization of mucosa was observed (Figs. 6-10).

In this study, the PDAR technique resulted in a gain of alveolar bone height (7.1±3.7 mm) associated with a horizontal gain in the alveolar bone crest (4.5±1.4 mm) (Table 1) (Figs. 11A-L, 12A-L).

After the healing period, it was observed that no PFPP pontic concavity at the submucosal area was exposed. This confirmed that soft tissue margins remained stable or recession did not exceed 1 mm at the end of the treatment. Although, soft tissue margin recession in the first week was observed in two cases (2 and 8), after the pontic subgingival portion was ground in the facio-palatal direction, preserving the pontic subgingival concavity area, in the following control session, after one week, the gingival margin returned to the original position.

The findings of the present study show that PDAR promotes bone formation. Neiva et al. (6) observed a mean vertical bone gain of 10.9 mm and a mean horizontal gain 3 mm from the crest of 7.7 mm, after 3 months, using GBR with Ossix Plus membranes. Coomes et al. (7) observed a mean vertical bone gain of 4.8±2.7 mm and a mean horizontal gain 3 mm from the crest of 6.0±1.6 mm, after 5 months, using human bone morphogenetic protein 2. Due to methodological differences between this study and previous studies, it is difficult to compare

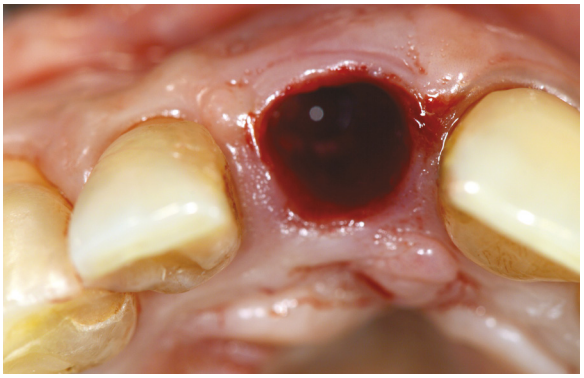

Figure 6. Occlusal view of the ridge crest during the healing period: day 1.

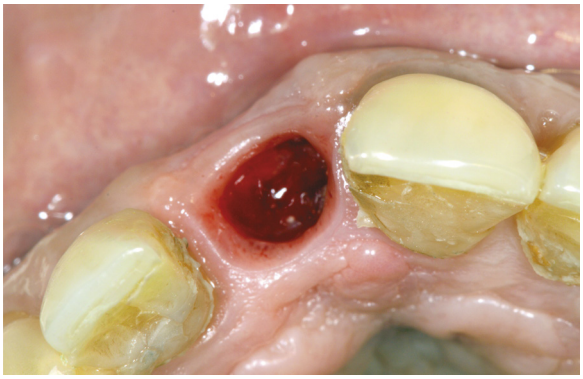

Figure 7. Occlusal view of the ridge crest during the healing period: day 110.

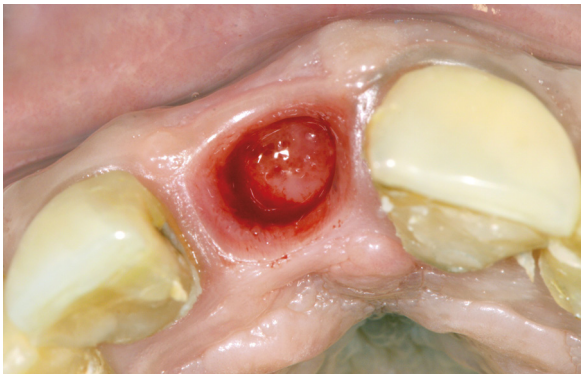

Figure 8. Occlusal view of the ridge crest during the healing period: day 165.

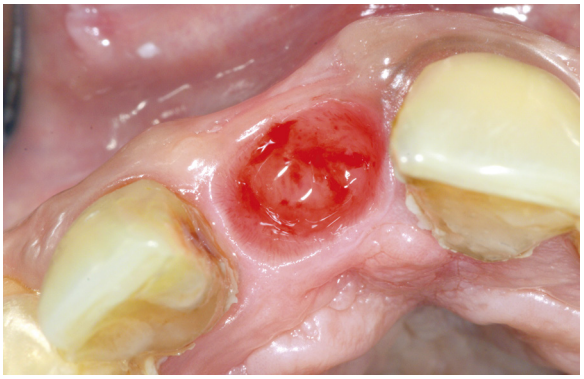

Figure 9. Occlusal view of the ridge crest during the healing period: day 210.

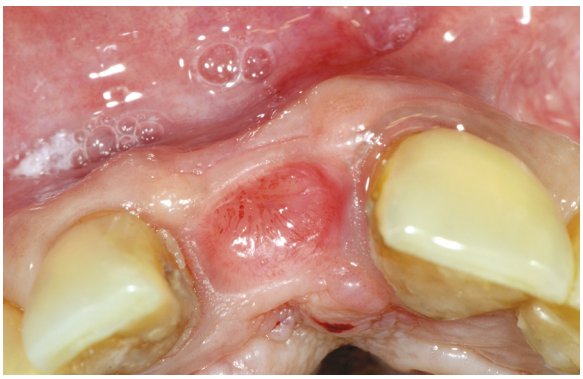

Figure 10. Occlusal view of the ridge crest during the healing period: day 250.

their results.

Regarding the mucosal margin, soft tissue stability was maintained. In the PDAR technique, the concave area of the pontic favors the mucosal inward growth (Fig. 13), resulting in marginal stability, and avoids recession and soft tissues collapse. Furthermore, the flat disc design of the most apical part of the PFPP pontic aims to seal access to the residual alveoli after extraction, and provide the mechanical stability to the clot. A hypothesis is that the mechanical stabilized clot probably acts as an epigenetic memory scaffold, which may induce an osteogenic capacity of local stem cells (9,10). The blood clot stability may not be easy to achieve in a traditional extraction with single sutures, because frequently a gap is observed between the mucosal margins. After some days the coagulum is not present fulfilling the alveolus. Additionally, the sutures diminish the dimensions of the original alveolus/mucosal margins complex.

Different post-extraction dimensional alteration evaluation methods have been used including: measurements based on bone scans using stent (6); measurements obtained from models (12); or trans-surgical measurements (13). In this study, CBCT measurements were chosen because they enable precise and accurate facio-palatal bone measurements (14). Some studies have performed these measurements by overlapping standardized tomographies before and after treatment with the aid of specialized software. In this study, tomographic measurements were performed separately. For this reason, the methodology proposed by Zekry et al. (3) was used to minimize potential bias (i.e., in cases in which a precise measurement was not possible, it was decided to underestimate it).

Comparing results from different studies is difficult due to the use of different methodologies. This also applies to strict consideration of tomographic studies that evaluate the results of different alveolar ridge preservation techniques after dental extraction. Consequently, comparison of results may not truly reflect bone formation. Most bone substitute biomaterials are radiopaque, and absorption time is typically greater than study monitoring time (15). Consequently, because of radiopacity, it is unclear whether the tissue in the regenerated area is formed only by bone. In this study, the only reason for the tomographic image to have been radiopaque was bone formation. After the CBCT obtained after bone regeneration treatment, all sites received an implant (this phase of treatment was not included in this study). In the implant surgery, a crestal incision was done and the bone formation was clinically observed in all sites.

The limitations of the present study were: the small number of patients, probably related to the specificity of the bone defect, the lack of the buccal bone wall;

Table 1. Sample characteristics and results*

Patient	Age, years	Cause of dental loss	Region	BHi	BHf	Gain	BTi	BTf	Gain
1	58	EP	14	2.8	7.9	5.1	1	7.1	6.1
2	42	E	11	15.5	22.9	7.4	2	5.8	3.8
3	55	EP	11	12	15.1	3.1	0.8	5.3	4.5
4	54	RF	12	13.4	21	7.6	1.5	4.5	3
5	49	E	12	7.7	17.2	9.5	1.6	5.5	3.9
6	20	RF	21	2.5	19	16.5	1.3	5.1	3.8
7	38	RF	24	3.3	7	3.7	1.3	4.4	3.1
8	58	RF	21	9.3	16.8	7.5	2.3	8.9	6.5
9	57	RF	14	5.4	14.6	9.2	3.5	8	4.5
10	72	RF	16	4.7	8.6	3.9	1.4	6	4.6
11	40	RF	24	4.5	8.3	3.8	4.1	7	2.9
12	25	RF	24	2.1	10.1	8	1.6	8.6	7
Mean	47	-	-	7.7	14.9	7.1	2	6.4	4.5
SD	15	-	-	5.1	6.4	3.7	1.4	1.7	1.4

*Data presented as millimeters (mm), where applicable. BHi: initial bone height of buccal wall; BHf: final bone height of buccal wall; BTi: initial bone thickness in ridge crest; BTf: final bone thickness in ridge crest; EP: endoperiodontal lesion; E: endodontic failure; RF: root fracture; SD: standard deviation

and the lack of a control group with patients treated with conventional extractions, that is justified for ethical reasons. Giannobile et al. suggested that the healing of an injured tissue that leads to the formation of a tissue that differs in morphology or function, from the original tissue, is termed repair; and regeneration is a term used to describe a healing that leads to the complete restoration of morphology and function (16). Although the results of the present study showed satisfactory bone formation, considering the actual definition of the healing processes, the bone formation should be considered a repair, since there are differences between the new formed bone and the pristine bone. The pristine bone, named bundle bone (17), has characteristic fibers embedded, different from the new bone. This dichotomized healing classification may consider the new bone formation as a repair, like what occurs when no treatment is performed, leading an ingrowth of non-osseous tissue or a fibrous tissue with high proliferative activity. But both healing situations were quite different. A new class of healing may contemplate a third healing process. We suggest, in these cases, that the new bone formation should be termed neoregeneration, i.e., a healing that leads to the formation of a desired tissue different from the pristine tissue and from the tissue that repair the injured tissue if no treatment procedure is performed.

PDAR proved to be effective in promoting alveolar regeneration after extraction, as well as in other alveolar ridge preservation procedures (18). Traditional alveolar ridge preservation techniques involve more invasive procedures including relaxing incisions and flaps. They are time-consuming and are associated with higher morbidity. Regardless, to achieve optimum aesthetic results, there are risks, including formation of scars in relaxing incision areas, change of mucogingival line position, and reduction in vestibular depth, when flaps are coronally displaced.

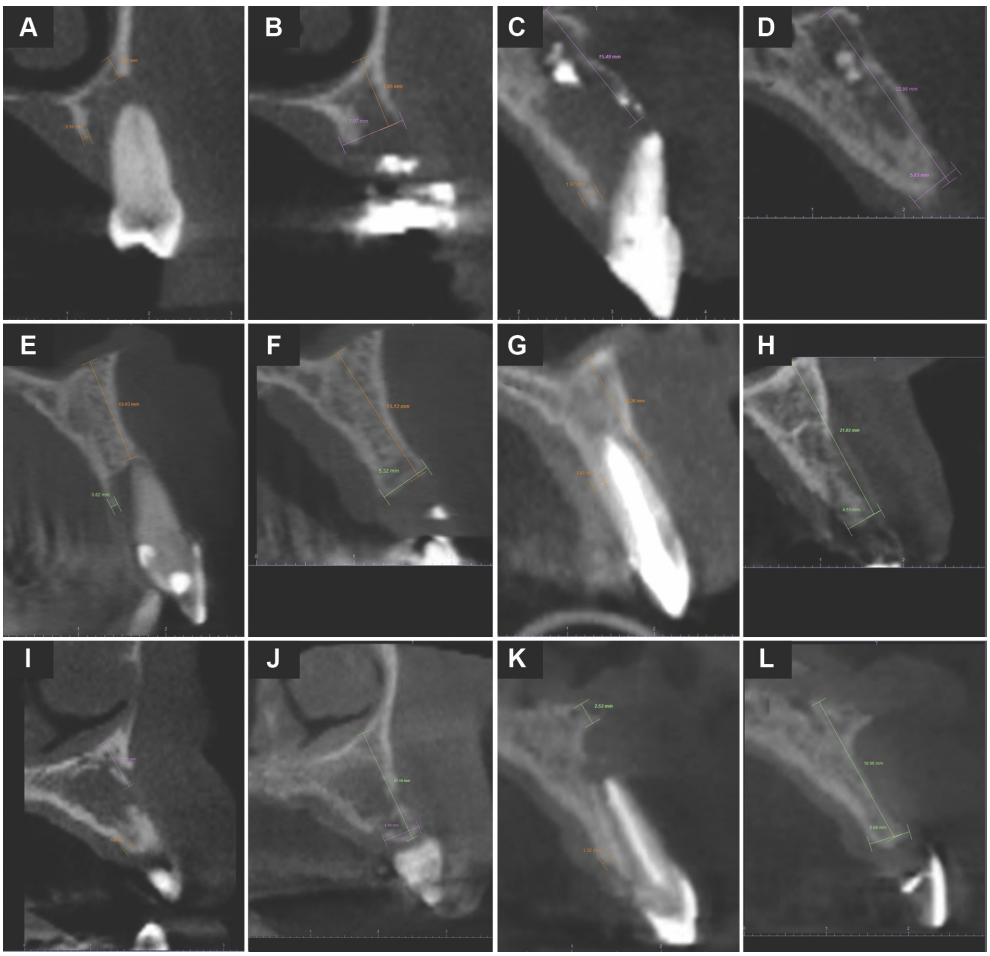

Figure 11. A: Initial CBCT of patient 1; B: Patient 1 CBCT sagittal image showing bone reconstruction with PDAR technique; C: Initial CBCT of patient 2; D: Patient 2 CBCT sagittal image showing bone reconstruction with PDAR technique; E: Initial CBCT of patient 3; F: Patient 3 CBCT sagittal image showing bone reconstruction with PDAR technique; G: Initial CBCT of patient 4; H: Patient 4 CBCT sagittal image showing bone reconstruction with PDAR technique; I: Initial CBCT of patient 5; J: Patient 5 CBCT sagittal image showing bone reconstruction with PDAR technique. K: Initial CBCT of patient 6; L: Patient 6 CBCT sagittal image showing bone reconstruction with PDAR technique.

Thus, PDAR is a less-invasive alternative, with no need for grafts or membranes, resulting in successful regeneration of the alveolar ridge. Future researches of the PDAR should focus on the biological mechanisms involved in the healing process regarding the importance of the blood clot stability maintenance, the regeneration of the periosteum after the inflammation cause removal, and the real effect of the relaxing incisions in the periosteal bone regeneration. Clinically multicenter studies were necessary to develop the potential benefits of this technique. Lower-morbidity procedures without the use of biomaterials may be a useful in post-extraction alveolar ridge regeneration and/or preservation. PDAR promoted alveolar bone formation without flaps, grafts and membranes.

Resumo

Este estudo teve como objetivo avaliar a reconstrução do osso alveolar após extração em 12 pacientes com perda da tábua óssea vestibular em dentes na região anterior da maxila usando a técnica da reconstrução alveolar proteticamente guiada (RAPG). Na RAPG, uma prótese parcial

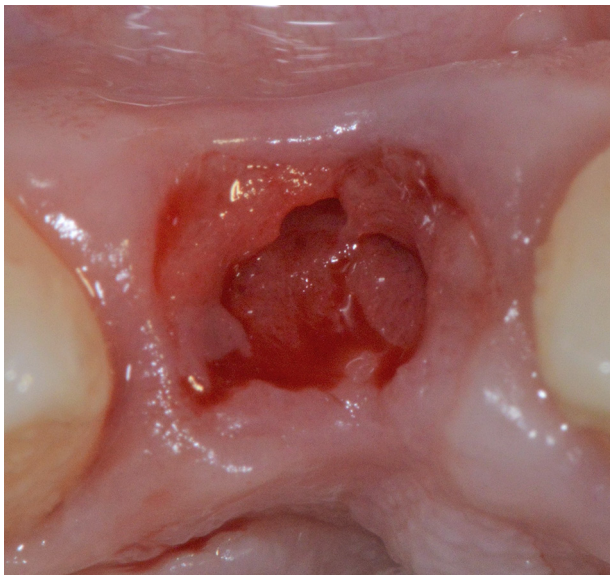

Figure 13. Immediately after the prosthesis removal it is possible to observe the mucosal inward growth, resulting in a mucosal o'ring.

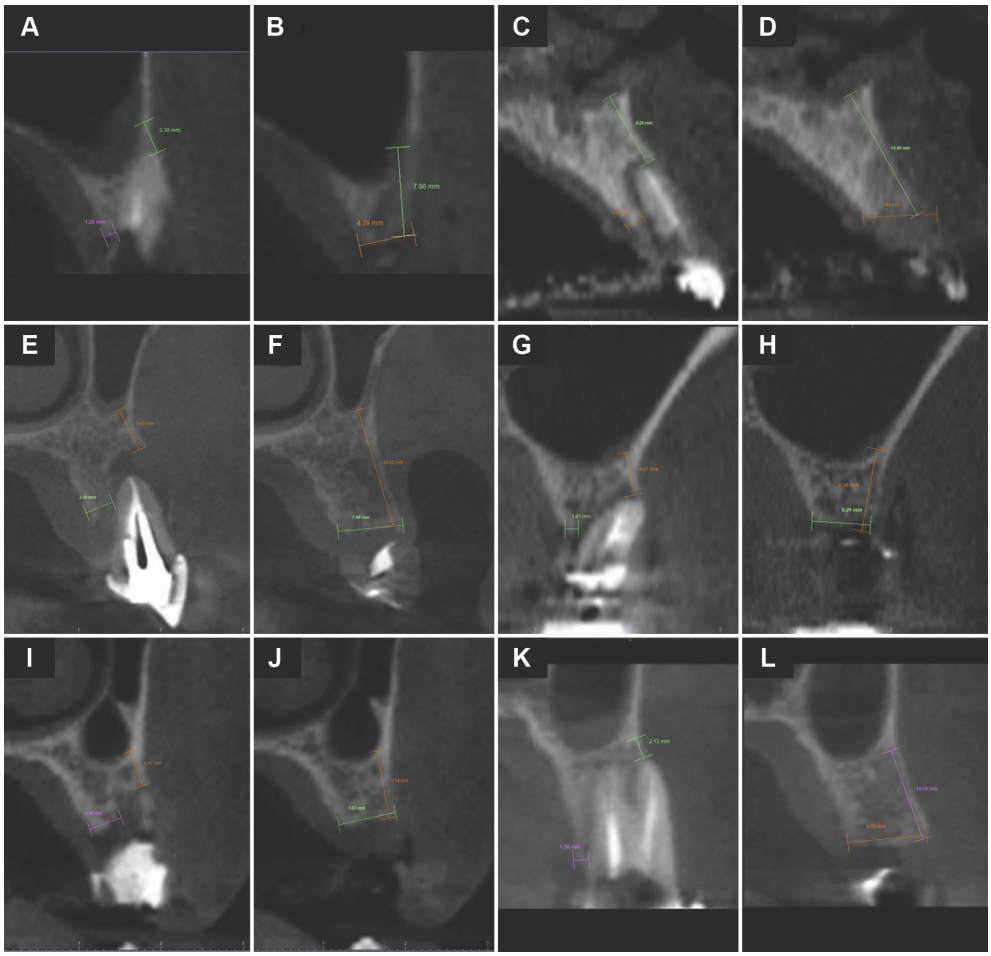

Figure 12. A: Initial CBCT of patient 7; B: Patient 7 CBCT sagittal image showing bone reconstruction with PDAR technique. C: Initial CBCT of patient 8; D: Patient 8 CBCT sagittal image showing bone reconstruction with PDAR technique. E: Initial CBCT of patient 9; F: Patient 9 CBCT sagittal image showing bone reconstruction with PDAR technique. G: Initial CBCT of patient 10; H: Patient 10 CBCT sagittal image showing bone reconstruction with PDAR technique. I: Initial CBCT of patient 11; J: Patient 11 CBCT sagittal image showing bone reconstruction with PDAR technique. K: Initial CBCT of patient 12; L: Patient 12 CBCT sagittal image showing bone reconstruction with PDAR technique.

fixa provisória (PPFP [convencional ou adesiva]) com um pôntico com design específico mantém o coágulo numa posição mecanicamente estável. Além disso, o design do pôntico, com formato de ampulheta e localizado na área subgengival, também previne o colapso das margens gengivais. A recessão gengival foi avaliada durante o período de cicatrização de 6 meses. Tomografias computadorizadas cone beam (TCCB) foram feitas 1 mês antes e 8 meses após o tratamento com a RAPG. Para o desfecho primário, nas imagens panorâmicas, a área central do defeito ósseo em cada dente foi selecionada para as medições lineares. As medições do ganho vertical ósseo vestibular e do ganho em espessura na crista óssea alveolar foram realizadas. A análise estística descritiva e a análise do coeficiente de correlação intraclasse forma realizados. Após o tratamento, todos os pacientes apresentaram formação óssea (ganho vertical médio de 7,1±3,7 mm, associado a ganho horizontal médio de 4,5±1,4 mm na crista óssea alveolar). O coeficiente de correlação intraclasse foi de 0,999. Nenhuma retração gengival acima de 1 mm foi observada. Procedimentos com baixa morbidade sem o uso de biomateriais podem ser úteis na regeneração/preservação do rebordo após as extrações. A RAPG promove a formação do osso alveolar sem o uso de retalhos, enxertos e membranas.

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