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Original Article

Tomographic assessment of bone volume changes following regeneration with titanium Mesh in the maxillary anterior region. A retrospective clinical study

Avaliação tomográfica das alterações ósseas volumétricas após regeneração com malha de titânio na região anterior da maxila. Estudo clínico retrospectivo

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Resumo

Introdução: Para o sucesso da reabilitação com implantes suportados e da manutenção dos resultados a longo prazo na região anterior da maxila, é imperativo que o paciente possua qualidade e quantidade óssea adequadas. **Objetivo:** O objetivo deste estudo foi avaliar o ganho e a estabilidade óssea após a reconstrução com malha de titânio na região anterior da maxila, independentemente do biomaterial utilizado para o aumento ósseo. **Material e método:** Utilizamos dados de pacientes oriundos do banco de dados da Faculdade, focando em indivíduos que haviam passado por reabilitação na maxila anterior previamente aumentada com enxertos ósseos e fatores de crescimento em conjunto com malha de titânio. Este estudo de coorte retrospectivo envolveu pelo menos 10 pacientes que atenderam aos critérios de inclusão. **Resultado:** De um total de 39 registros no banco de dados de pacientes que passaram por cirurgia de regeneração óssea guiada utilizando malha de titânio, doze atenderam aos critérios de inclusão, enquanto os demais foram excluídos. Assim, foram obtidos 17 sítios adequados para o estudo, envolvendo 12 pacientes e um total de 276 medições tomográficas. Houve um aumento notável na espessura óssea em todos os níveis de avaliação em relação ao ápice da crista óssea, tanto imediatamente (T1) quanto seis meses após a cirurgia (T2), em comparação com as medições iniciais (T0). Além disso, a espessura óssea tende a aumentar com a proximidade do nível apical. **Conclusão:** A utilização da malha de titânio combinada com vários biomateriais resultou em resultados favoráveis em termos de aumento do volume ósseo.

Descritores: Regeneração óssea; implantes dentais; biomateriais.

Abstract

Introduction: For a successful implant-supported rehabilitation and long-term maintenance in the anterior maxilla, it is imperative that the patient possesses adequate bone quality and quantity. **Objective:** The aim of this study was to assess bone gain and stability following reconstruction with titanium mesh in the anterior region of the maxilla, irrespective of the biomaterial used for bone augmentation. **Material and method:** Patient follow-up data were obtained from the Faculty's follow-up database. The focus was on individuals who had undergone rehabilitation in the anterior maxilla, previously augmented with bone grafts and growth factors in conjunction with titanium mesh. This retrospective cohort study involved at least 10 patients who met the inclusion criteria. Following an initial review of medical records, the eligible patients were invited for evaluation appointments. **Result:** Out of 39 patients who had undergone guided bone regeneration surgery using titanium mesh, 12 met the inclusion criteria. As such, 17 sites suitable for the

study were obtained, from which total of 276 tomographic measurements were then taken. There was a noticeable increase in thickness at all assessment levels relative to the bone crest apex, both immediately (T1) and six months post-surgery (T2), compared to baseline measurements (T0). Moreover, bone thickness tended to increase with the proximity to the apical level. **Conclusion:** The use of titanium mesh combined with various biomaterials has yielded favorable outcomes in terms of augmenting bone volume.

Descriptors: Bone regeneration; dental implants; biocompatible materials.

INTRODUCTION

With reference to reconstruction of the atrophic maxillary ridges, the scientific literature has demonstrated that there are numerous techniques available for alveolar ridge augmentation. Among these, guided bone regeneration using titanium meshes stands out for its ability to enhance the maintenance of a supportive scaffold. This technique is often coupled with bone grafting, with or without membranes, and can be performed either before or during dental implant placement procedures.

Alveolar bone resorption in the esthetic zone presents a significant challenge in contemporary clinical practice to dental surgeons. The imperative reconstruction of lost bone tissues aims to facilitate implant-supported rehabilitation, thereby driving technical enhancements and advances in biomaterial studies to replace or optimize grafting procedures[1-4]. However, to date there is not a single material which offers an ideal solution for guided bone regeneration, given that the material must be both biocompatible and possess an appropriate degradation time in vivo[4].

Vertical and/or horizontal bone loss in the anterior maxilla compromises an ideal tridimensional position of the implant, and consequentially impairs the patient's implant-supported rehabilitation and worsens their masticatory function and/or aesthetics[5,6]. Various techniques for bone augmentation exist, but the predictability of success remains uncertain, with no clear indications for any preferred procedures[6,7]. Nonetheless, favorable outcomes are achievable with the available options, i.e., autogenous, xenogenous or alloplastic bone grafts combined or not with scaffolds. Autogenous grafting has emerged as an excellent choice due to its osteoinductive, osteoconductive, and osteogenic properties. Nevertheless, intraoral donor sites have a limited availability, and resorting to additional surgical procedures to harvest bone from extraoral sites heightens morbidity and potential donor area complications[1]. Several alternatives, such as osteoconductive biomaterials (xenogenous and alloplastic bones) and/or the placement of growth factors like human bone morphogenetic protein (BMP), offer promising alternatives[8] when compared to the "gold standard" autogenous bone.

The clinical use of rhBMP-2 (recombinant human BMP, subtype 2) in conjunction with an absorbable collagen sponge (ACS) has been researched extensively, alongside its practical application by various medical and dental professionals[9-11]. RhBMP-2 are currently used in maxillary signus augmentation procedures, socket preservation and augmentation of maxillary ridges[11]. The concentration and the carrier of this protein remain subjects of debate in the literature, as is the case with its clinical application and potential complications[12].

A limitation of the clinical application of rhBMP-2/ACS is the necessity for a supportive framework. Titanium mesh is the most commonly used material for bone grafts in terms of thickness and height, due to its flexibility and adequate rigidity for adaptation and stabilization in the grafted area[13,14]. Titanium mesh has also been employed in conjunction with biomaterials, and has yielded favorable outcomes when combined with particulate autogenous bone grafts[15,16]. However, guided bone regeneration procedures associated with titanium mesh use have drawbacks, such as the risk of titanium mesh exposure and subsequent infection of the area[15]. In these situations, removal of the titanium mesh is indicated.

During the regenerative procedures for augmentation of the alveolar ridge, monitoring not only the quality and quantity of regenerated bone tissue, but also the clinical and radiographic

parameters related to implants placed in the grafted region is essential. Additionally, the stability of the regenerated bone tissue can be adversely affected by the chosen regenerative procedure and biomaterial used. Many cases are rehabilitated using titanium mesh associated with biomaterials for bone regeneration and concurrent or subsequent implant installation and prosthetic fabrication. Nonetheless, few studies include follow-ups to assess the survival and success rates of implants placed on grafted areas[15]. The dissemination this technique's results are crucial for expanding its clinical applicability. Therefore, the aim of this study was to assess bone gain and stability, following reconstruction with titanium mesh in the maxilla anterior region, regardless of the biomaterial used for bone augmentation.

MATERIAL AND METHOD

Study design

The protocol for this retrospective cohort study was reviewed by a Human Research Ethics Committee established by the Plataforma Brazil (Brazil Platform) (Approval No.: #2.512.815). The study aimed to evaluate bone gain and stability in the anterior maxillary region, following guided bone regeneration techniques in conjunction with titanium mesh.

The sample was selected from the patient follow-up database of the Latin American Institute of Dental Research and Education - ILAPEO, Curitiba, PR, Brazil. A preliminary survey identified bone graft procedures associated with the use of titanium mesh at the Institute. Clinical records were then analyzed to determine eligibility based on the following criteria: 1) age between 18 and 75 years; 2) previous guided bone regeneration surgery in the premaxilla using titanium mesh; 3) complete tomographic documentation pre-surgery, immediately post-surgery, and at least 6 months post-surgery; and 4) availability for follow-up consultations.

The number of surgical sites was determined based on a retrospective evaluation of potential participants' health background and attendance records, following the indicator approved by the Human Research Ethics Committee, with a minimum of n=10. Patients who did not meet the inclusion criteria and/or could not be clinically and radiographically evaluated were excluded. Given that this study assessed follow-ups on previously operated and potentially rehabilitated patients, systemic conditions were not initially considered unless they were found to influence the results during data evaluation. In such cases, the patients were advised to seek a medical follow-up and reevaluate the previously performed dental treatment.

Tomographic Analysis

Measurements of the surgical sites in all tomographic images were taken by a blinded and calibrated examiner using specific imaging analysis software Sidexis (Sirona, Bensheim, Germany). The measurements were taken in horizontal sections at 2, 6, and 8 mm from the alveolar crest surface, and in vertical sections at 4 and 8 mm from the bilateral midline, at three time points: pre-surgery (T0), immediately post-surgery (T1), and at least 6 months post-surgery (T2). All patients were informed about the research and signed an Informed Consent Form.

Statistical Analysis

The program GraphPad Prism 6 (San Diego, CA, USA) was used for statistical analysis in this study, with a significance level of 5% for all tests. A normal distribution of the analyzed data was confirmed by the D'Agostino & Pearson test. Comparisons between different evaluation times and between each analysis point with respect to the top of the alveolar ridge were performed using ANOVA, supplemented by Tukey's post-hoc test.

RESULT

Out of 39 records in the ILAPEO database of patients who had undergone guided bone regeneration surgery using titanium mesh, only 12 met the inclusion criteria. The remainder was excluded based on the exclusion criteria. Thus, 17 sites suitable for the study were obtained, and a total of 276 measurements were taken. The thickness of the alveolar ridge was measured at 2, 6, and 8 mm from the top of the bone crest.

An increase in thickness was observed at all evaluation levels relative to the top of the bone crest at both the immediate (T1) and 6-month periods (T2), compared to baseline (T0). These results indicate the effectiveness of the guided bone regeneration technique in increasing bone availability for implant placement. The more apical the evaluation level, the greater the bone thickness, regardless of the evaluation period, except for T1, where no differences were observed between the 6 and 8 mm levels. This confirms a pattern of bone loss that occurs in alveolar ridges after tooth loss. Table 1 and Figures 1 and 2 present the means and standard deviations of alveolar ridge thickness at all levels with regard to the top of the bone crest for all evaluation periods.

Table 1. Mean and standard deviation of alveolar ridge thickness at all levels in relation to the top of the bone crest and in all evaluation periods

Period	2mm	6mm	8mm
T0	1.23 ± 0.54^{Cb}	3.68 ± 1.04^{Bb}	5.86 ± 1.57^{Ab}
T1	6.82 ± 0.78^{Ba}	9.54 ± 0.82^{Aa}	10.67 ± 1.28^{Aa}
T2	6.46 ± 0.70^{Ca}	8.72 ± 1.05^{Ba}	9.95 ± 1.46^{Aa}

Capital letters represent analyses varying levels of bone in relation to the top of the bone crest, while lowercase letters represent analyses across different evaluation periods. Different letters indicate statistically significant differences. Analysis was performed using ANOVA for repeated samples, complemented by Tukey's post-hoc test.

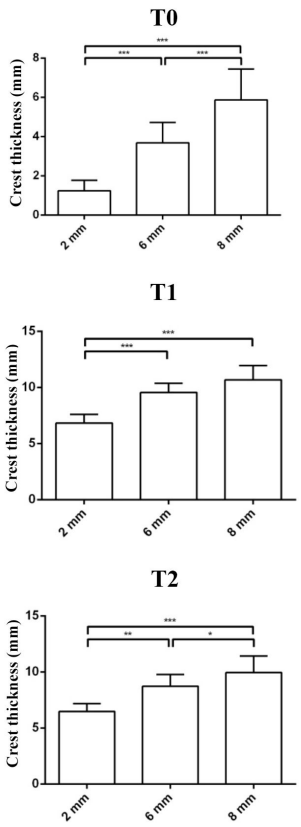

Figure 1. Representative image of intergroup results, illustrating the thickness of the ridge at three stages: pre-surgery (T0), immediately post-surgery (T1), and at least six months post-surgery (T2). At each stage, three measurements of thickness are presented: 2mm, 6mm, and 8mm, respectively. These measurements correspond with the calibrated values used for evaluation in this study. * p<0.05; ** p<0.01; *** p<0.001.

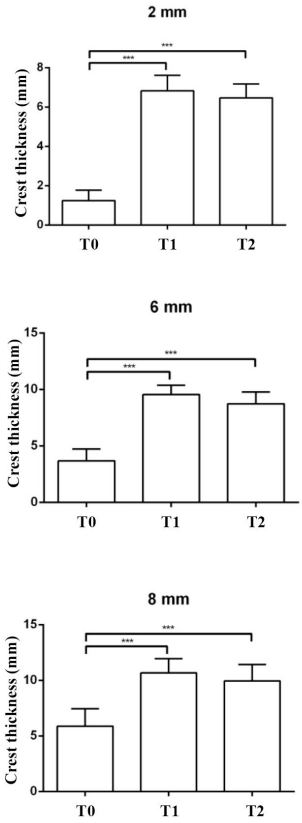

Figure 2. Representative image of the intra-group results, showing the thickness of the ridge at three heights from the bone crest: 2mm, 6mm, and 8mm. These measurements were taken at three surgical stages: pre-surgery (T0), immediately post-surgery (T1), and at least six months post-surgery (T2). $p<0.05$; ** $p<0.01$; *** $p<0.001$.

DISCUSSION

The present study has assessed the effect of guided bone regeneration, associated with titanium mesh, on increasing bone tissue availability for implant placement on edentulous ridges in the anterior maxillary region. The results of this study underscore the achievement of bone gain and maintenance for primarily horizontal ridge augmentation in the premaxilla region. Increasing bone volume in oral rehabilitation remains a formidable challenge. The literature offers a wide range of methods to this end, including osteoinduction through growth factors like rhBMP2, osteoconduction using graft materials as scaffolds for new bone growth, distraction osteogenesis, guided bone regeneration, and autogenous bone grafting[17,18].

Successful osseointegration depends on placing implants in bone of a sufficient quantity and quality to ensure implant stabilization[19]. Adequate bone height and thickness are pivotal factors in rehabilitative implantology. Implants must be surrounded by bone tissue along their entire length to ensure long-term success[15,16]. No biomaterial has yet emerged as a perfect solution for guided bone regeneration, since it should be both biocompatible and capable of an adequate in vivo biodegradation[4]. Titanium mesh, often employed in combination with other biomaterials and particulate autogenous bone grafts, considered the gold standard, has shown efficacy irrespective of the biomaterial type. This statement parallel observation made in our study in which the type of biomaterial used (xenogenous bone or growth factor, rhBMP-2) was irrelevant with reference to clinical horizontal bone gain when associated with titanium mesh[15,16].

The success and survival rate of implants in horizontal ridge augmentation were found to be 96.8%, with significant average bone gains[20]. An important study by Buser et al.[21] evaluated the

success and survival rate of titanium implants installed in previously regenerated bone with autogenous graft and non-resorbable membrane over a 5-year period. The authors concluded that regenerated bone, when combined with membrane barriers, exhibits an osseointegration capacity and load-bearing capacity similar to non-regenerated bone. In turn, this leads to favorable long-term results.

Non-resorbable e-PTFE membranes, with or without titanium reinforcement, have shown promising results regarding bone gains in the literature. Notwithstanding, a significant number of complications, notably exposure to the oral environment, have been reported[22]. Mesh exposure is the most common complication, necessitating extensive further studies to enhance this technique's reliability[23]. Although early detection and monitoring of mesh exposure in the intraoral environment do not compromise the treatment, they do require proactive prevention measures for the patient's post-surgical perceptions and sensations[24-26]. These findings are consistent with the use of titanium mesh, which is even more rigid than e-PTFE - a major limitation of its use. Therefore, clinicians should be careful when indicating the use of titanium mesh for oral rehabilitation. It The achievement of a primary and stable wound closure to avoid flap dehiscence and, consequently, mesh exposure, is essential to the long-term success of bone regeneration with the use of titanium mesh and biomaterials.

The results of this study have demonstrated a significant increase in bone thickness at all evaluation levels relative to the top of the bone crest at both T1 and T2, compared to baseline, as shown in Figures 1 and 2. These findings demonstrate the effectiveness of the guided bone regeneration technique in increasing bone availability for implant placement, irrespective of the biomaterial used. The more apical the evaluation level, the greater the bone thickness, regardless of the evaluation period, except for T1, where no differences were observed between the 6 and 8 mm levels, as demonstrated in Table 1. These data confirm the pattern of bone loss that occurs in alveolar ridges after tooth loss.

CONCLUSION

Our findings have demonstrated that the use of titanium mesh in conjunction with biomaterials and growth factors enhanced bone volume in the anterior maxilla in the follow-up period.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Methodology: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Validation: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Formal analysis: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Investigation: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Data curation: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Writing—original draft preparation: RSM and RMF: Writing—review and editing: CPR, ADZ, EMJr, FNGKF, RSM, RMF; Supervision: RMF. All authors have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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