Bilateral sinus floor augmentation using 100% alloplastic biomaterial for later rehabilitation of atrophic maxilla. A 5-year tomographic follow-up

Rodinei Luiz da Silva **BUCCO JUNIOR**[1], Tércio Pessoa **TABOSA E SILVA**[2], Caio César Leite **MIRANDA**[2], Márcia Helena Dutra **KOELSCH**[3], Antônio José Bittencourt da **ROSA**[2]

Abstract / Introduction: *Successful implant rehabilitation relies on previous planning that addresses the specific clinical variables of each case. Fixed-prosthesis rehabilitation of severely atrophic maxilla is a challenge, given that patients do not present with minimal posterior bone height required for implant placement at the site recommended by diagnostic wax-up.* ***Objective:*** *The present study aims at reporting a case of implant-supported complete denture oral rehabilitation performed by means of bilateral maxillary sinus lift with 100% alloplastic biomaterial for subsequent implant placement, with a 5-year clinical and tomographic follow-up.* ***Methods:*** *The use of synthetic bone substitutes (biphasic calcium phosphate) not only eliminates potential risks of contamination, but also reduces the number of surgical sites, given that it does not require autogenous bone to be harvested for grafting. Subantral residual bone height was less than 1 mm, therefore, bilateral maxillary sinus lift carried out by means of the lateral window approach was planned to be performed eight months before placement of eight implants. These implants would give support to a complete denture installed 60 days after implant placement surgery.* ***Conclusion:*** *Both scientific literature and the case reported herein evince that the use of 100% alloplastic biomaterial for vertical augmentation of atrophic maxilla by means of maxillary sinus lift is an efficient alternative to replace autograft due to presenting lower morbidity rates.* ***Keywords:*** *Dental prosthesis. Dental implants. Maxilla. Atrophy. Maxillary sinus lift.*

[1]MSc student in Implantology, São Leopoldo Mandic, Campinas, São Paulo, Brazil. Specialist in OMFST, Santa Casa de Misericórdia, Porto Alegre, Rio Grande do Sul, Brazil.
[2]MSc student in Implantology, São Leopoldo Mandic, Campinas, São Paulo, Brazil.
[3]Specialist in Dental prosthesis, Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS), Porto Alegre, Rio Grande do Sul, Brazil.

How to cite this article: Bucco Junior RLS, Tabosa e Silva TP, Miranda CCL, Koelsch MHD, Rosa AJB. Bilateral sinus floor augmentation using 100% alloplastic biomaterial for later rehabilitation of atrophic maxilla. A 5-year tomographic follow-up. Dental Press Implantol. 2015 Jan-Mar;9(1):42-56. doi: http://dx.doi.org/10.14436/2237-650X.9.1.042-056.oar

Submitted: 6/06/2014 - **Revised and accepted:** 4/02/2015

Contact address: Rodinei Luiz da Silva Bucco Junior - Rua Veríssimo do Amaral, 580 – apto 306 – Porto Alegre/RS - Brazil - CEP: 91360-470 – E-mail: rodineibucco@hotmail.com

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

INTRODUCTION

Successful implant rehabilitation with predictable functional and esthetic outcomes relies on determining the position and number of implants to be placed, based on a treatment planning that addresses the specific prosthetic features and difficulties of each case.[1,2]

Bone height is an aspect of diagnosis extremely important to treatment planning that includes implant placement in atrophic posterior maxilla. Maxillary sinus lift, whether by means of the lateral window approach or the transalveolar technique, proves an alternative for cases of pneumatization of maxillary sinus associated with insufficient subantral bone height without discrepancy between the maxilla and mandible. This finding has been well reported by evidence-based clinical studies that corroborate the use of a variety of graft material.[1,2,3]

For these cases, autograft has been considered as the gold standard for many years. This is not only due to its osteogenic cells, but also because of osteoinductive growth factors necessary for mesenchymal cell recruitment and differentiation, and because it provides an osteoconductive framework that offers immediate mechanical support, in addition to guiding bone formation at the desired site. Graft bone might be harvested from patient's iliac crest, symphysis, mandibular ramus, ribs, tibia or calvarium.[4,5]

Nevertheless, the procedure might be associated with patient's discomfort, postoperative morbidity, altered sensation, scars and infection of the donor site. Moreover, additional costs and the amount of bone harvested might be insufficient to cover the dimensions required for future implant placement, as planned.[6-11]

The use of graft material that does not imply harvesting autogenous bone is an alternative to overcome such clinical drawbacks. Allograft and xenograft, alloplastic material and different combinations between them have been investigated in the literature.[12]

A few years ago, 100% synthetic and bioinert biomaterial made 60% of HA (100% crystalline) and 40% of b-TCP, synthesized at 1,100 to 1,500 °C (Straumann BoneCeramic), was introduced into the market with promises of promoting periodontal and peri-implant regenerative bone therapy.[13]

This biomaterial has been investigated by immunohistochemical studies;[14,15] animal studies investigating alveolar defects;[14,16] and clinical studies on maxillary sinus lift,[12,17] lateral alveolar ridge augmentation[18] and periodontal defects;[19,20,21] all of which found it to be clinically feasible as an osteoconductive material.

The present study aims at reporting a case of bilateral maxillary sinus lift with 100% alloplastic biomaterial for subsequent implant rehabilitation, with a 5-year clinical and tomographic follow-up.

CASE REPORT

A female Caucasian 51-year-old patient, who could not adapt to a maxillary removable complete denture, sought restorative treatment at a private dental clinic. Her major complaint was about instability of the removable complete denture. After a thorough first interview and clinical examination, the patient did not report history of systemic disease or any risk factor that could hinder treatment with implants. Complementary examination, including digital panoramic radiograph and cone-beam computed tomography, were requested for the upper arch for full evaluation of the surgical site. Examinations revealed severe atrophy of the premaxilla, pneumatization of maxillary sinus and alveolar ridge resorption, which resulted in subantral bone height less than 1 mm, insufficient for dental implant placement (Figs 1 and 2). Diagnostic wax-up suggested acceptable relationship between the maxilla and mandible and acceptable alveolar ridge width. Thus, treatment option was to perform maxillary sinus lift alone, with no need for block graft to achieve tridimensional reconstruction of the jaws. Thus, the first phase of treatment included bilateral maxillary sinus grafting with alloplastic biomaterial, whereas the second surgical phase, carried out eight months after the grafting procedure, included placing eight implants that provided support to an implant-retained complete denture.

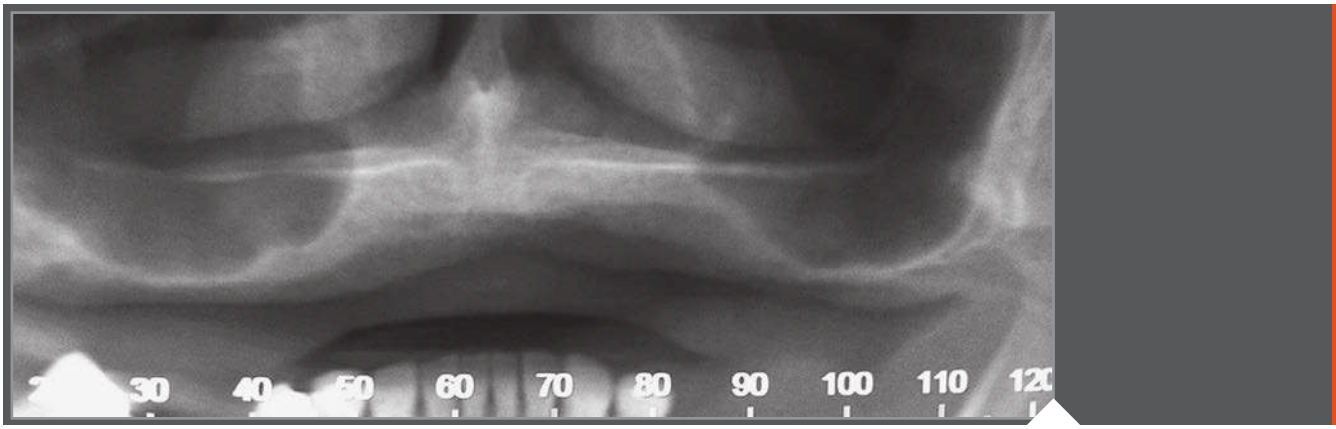

Figure 1. Panoramic radiograph revealing severely atrophic maxilla and pneumatization of maxillary sinus.

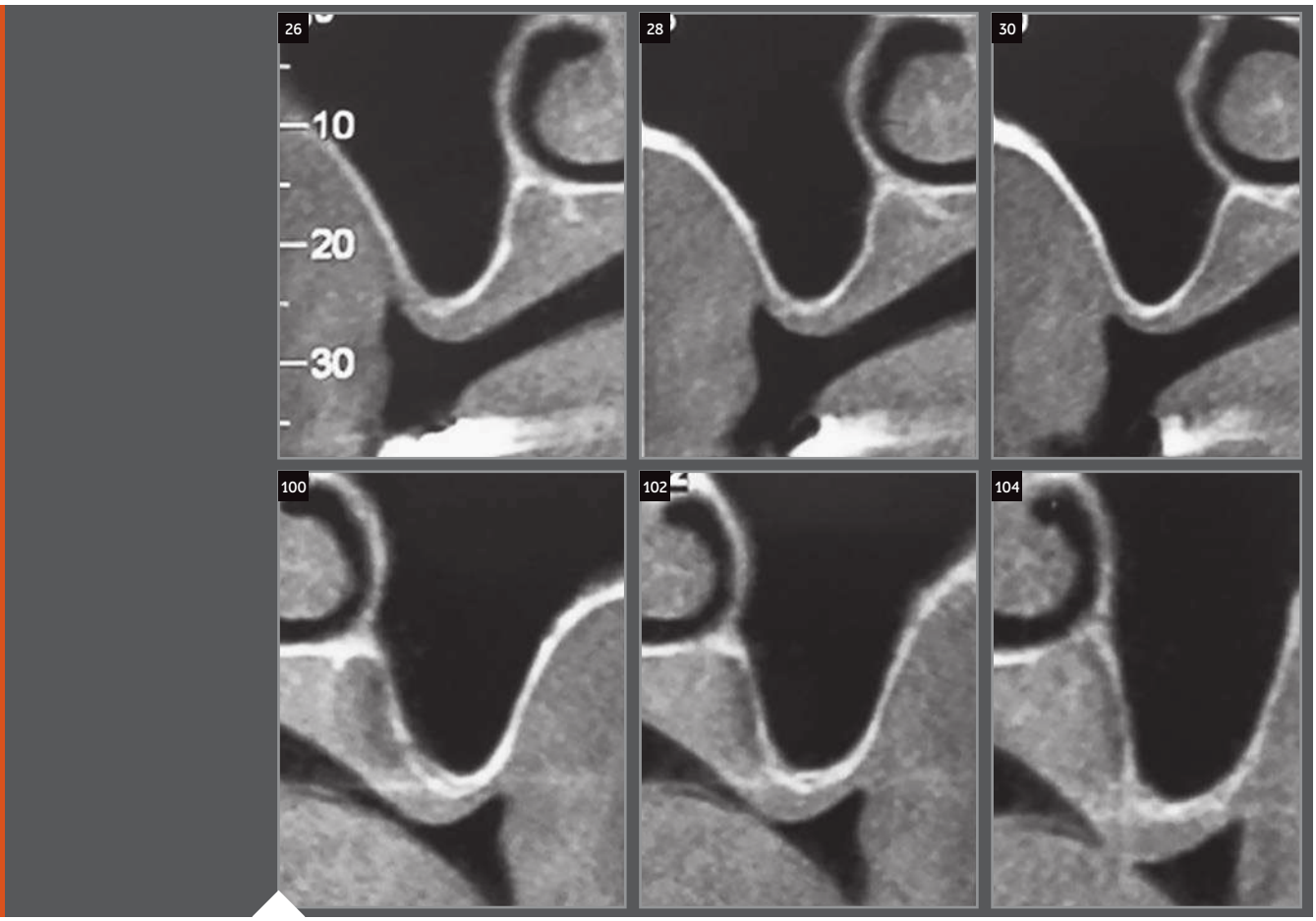

Figure 2. Transverse slices #26, 28 and 30 of right posterior maxilla. Transverse slices # 100, 102 and 104 of left posterior maxilla. Bone remnant not greater than 1 mm.

Preoperative radiographic examination was carefully assessed to evaluate the edges of maxillary sinus, in addition to sidewall thickness, the presence of blood vessels on the sidewall, the conditions of the mucosa (presence of cysts, sinusitis, etc.) and the presence of bone septa.

The first surgery was performed in a policlinic, with the patient under local anesthesia with 2% mepivacaine associated with epinephrine (norepinephrine 1:100.000) initially aspirated, followed by intravenous sedation monitored by an anesthesiologist. Initially, a linear incision was made on the

bone crest of the left posterior maxilla, supplemented by a distal releasing incision. The mucoperiosteal flap was then detached to give access to the site where the lateral window was created. Lateral window circumference was established by a round diamond bur used under copious irrigation with sterile saline solution; while its height was determined based on implant length added to 2 mm of gap. Schneiderian membrane was teared and elevated along with the bone wall into the sinus cavity. The grafting procedure was carried out with biphasic calcium phosphate (BoneCeramic, Straumann). The flap was then repositioned over a membrane barrier and stabilized with interrupted suture. Subsequently, all the aforementioned procedures were also carried out in the right posterior maxilla. Postoperative examination was performed and sutures were removed two weeks after the procedure.

Dental implant placement surgery was planned to be carried out eight months after bilateral maxillary sinus lift. A cone-beam computed tomography for full evaluation of the maxilla was requested, particularly to assess the stage of graft bone repair (Figs 3 and 4). Surgery was performed in a policlinic, with the patient under local anesthesia with 2% mepivacaine associated with epinephrine (norepinephrine 1:100.000) initially aspirated, followed by intravenous sedation monitored by an anesthesiologist. An incision was made on the bone crest of the maxilla, from the distal surface of second molar to the distal surface of second molar on the contralateral side, followed by releasing incisions made to facilitate full-thickness flap elevation. The elevated flap was stabilized with two simple sutures using 4-0 nylon. Subsequently, the bone sites that would later receive the eight implants (SLActive, Straumann AG, Basel, Switzerland)

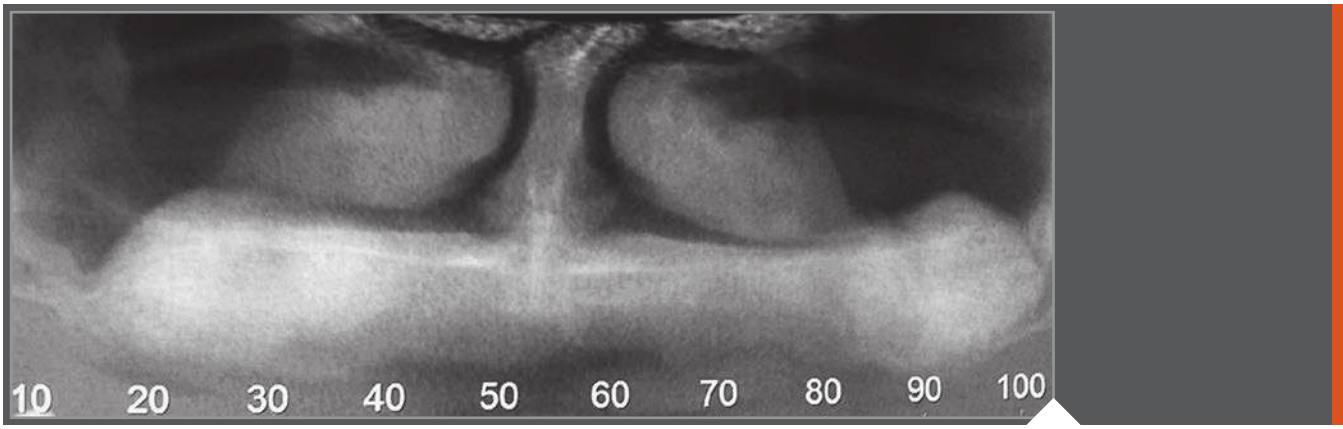

Figure 3. Panoramic radiograph eight months after maxillary sinus lift surgery.

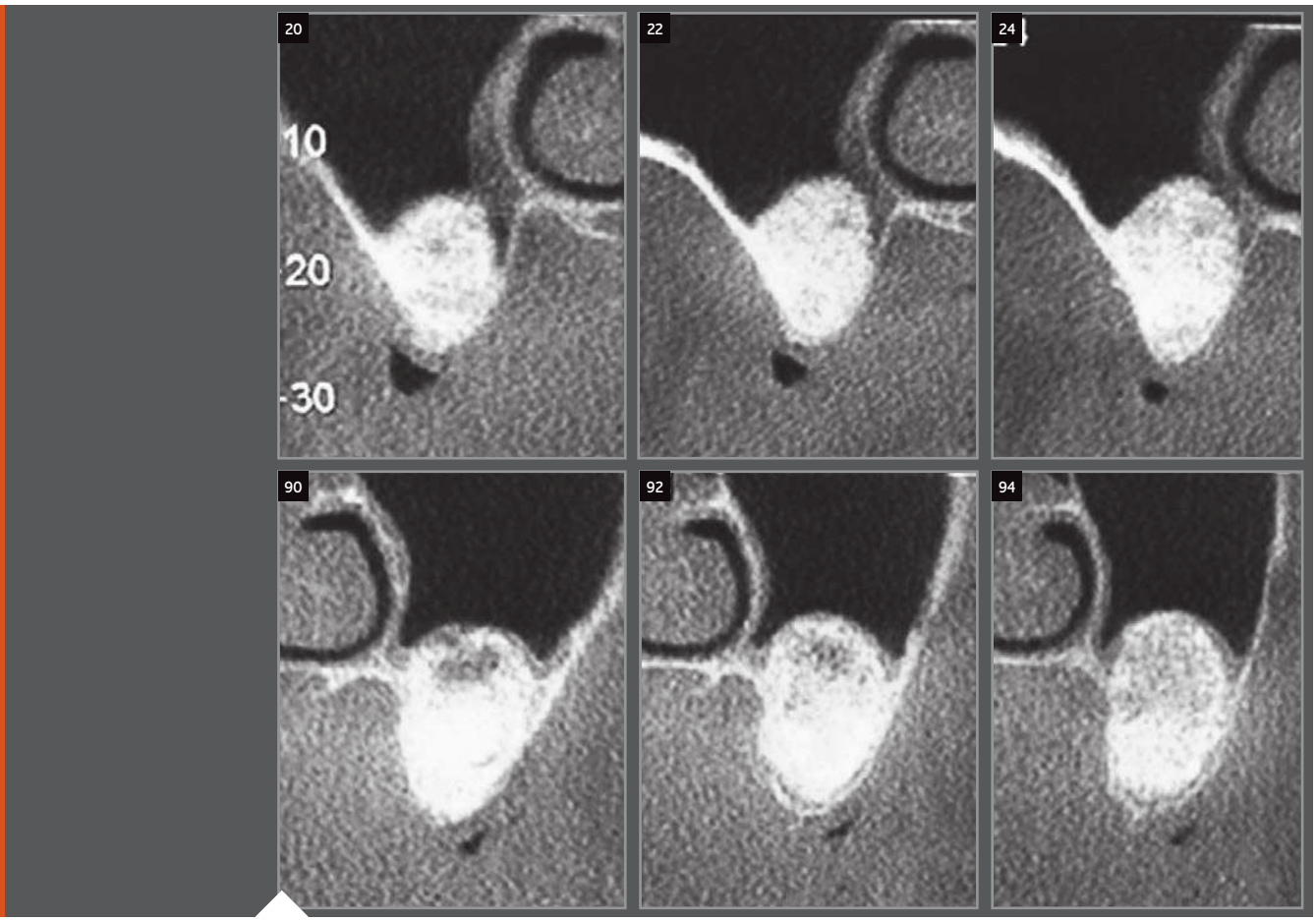

Figure 4. Transverse tomographic slices of right and left posterior maxilla.

were prepared following the sequence of milling procedures recommended by the manufacturer. Two RN SP SLActive 4.1 x 6 mm implants were installed in the anterior region, whereas six RN SP SLActive 4.1 x 8 mm implants were installed in the posterior region. Implants were placed in prosthetic position, as previously planned, and the flap was ultimately repositioned and stabilized with interrupted suture, so as to allow submerged healing of implants. A removable complete denture was relined with resilient acrylic material (Trusoft, Bosworth) and temporarily used during implant osseointegration. The patient was advised to avoid excess load at the surgical site, so as to prevent early load during repair and osseointegration.

For the first surgery (bone graft), the following medications were prescribed: 4 mg dexamethasone one hour before surgery; 100 mg nimesulide every

12 hours for four days; amoxicillin associated with 875 mg clavulanic acid every 12 hours for ten days. For analgesia, 750 mg paracetamol was prescribed to be taken every six hours (in case of pain), while 0.12% chlorhexidine digluconate mouthwash was prescribed to be used twice a day for local antisepsis until suture removal.

For the second surgery (implant placement), the following medications were prescribed: 4 mg dexamethasone one hour before surgery and 100 mg nimesulide every 12 hours for four days. For analgesia, 750 mg paracetamol was prescribed to be taken every six hours (in case of pain), while 0.12% chlorhexidine digluconate mouthwash was prescribed to be used twice a day until suture removal. A prophylactic dose of 500 mg amoxicillin was prescribed: four capsules one hour before surgery.

Implants remained submerged for 60 days, after which transmucosal abutments were placed for subsequent prosthetic procedures. For the case reported herein, straight abutments (Synocta 1.5 mm, Straumann AG) screwed to copings for bridges (smooth) were used. After 20 days, a period dedicated to the adjustment of prosthetic and laboratory phases of treatment, the implant-supported complete denture was installed, followed by minor occlusal adjustments.

During the first year, the patient returned to the office for follow-up appointments every three months. In the next four years, appointments were spread out to six months.

During the 5-year follow-up, suppuration, mobility, radiolucency around implants or prosthetic complications were absent (Figs 5 to 10).

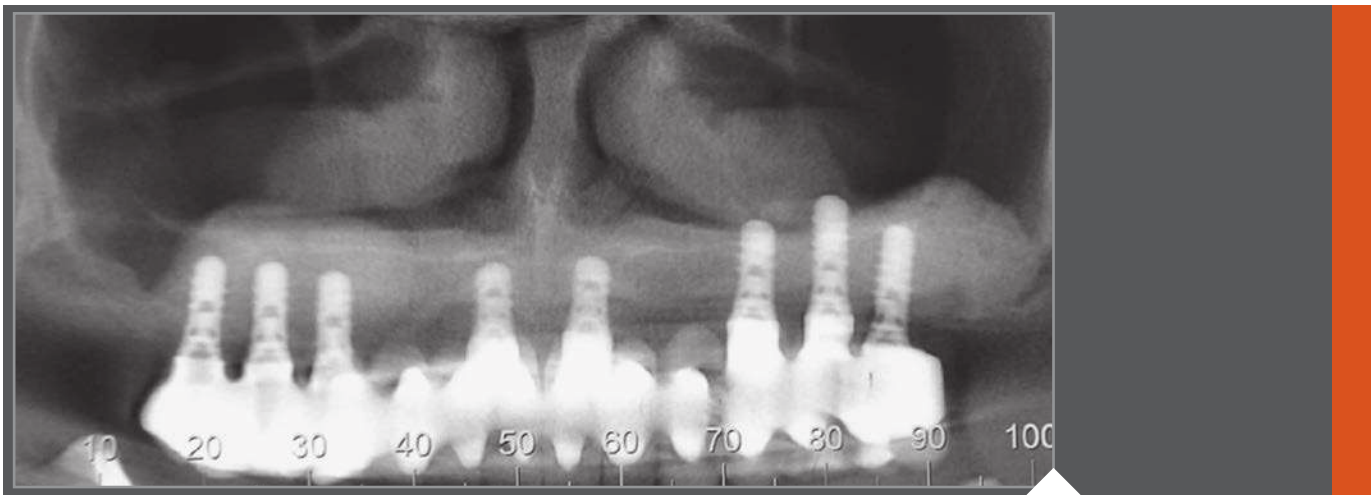

Figure 5. Panoramic radiograph. Five-year radiographic follow-up.

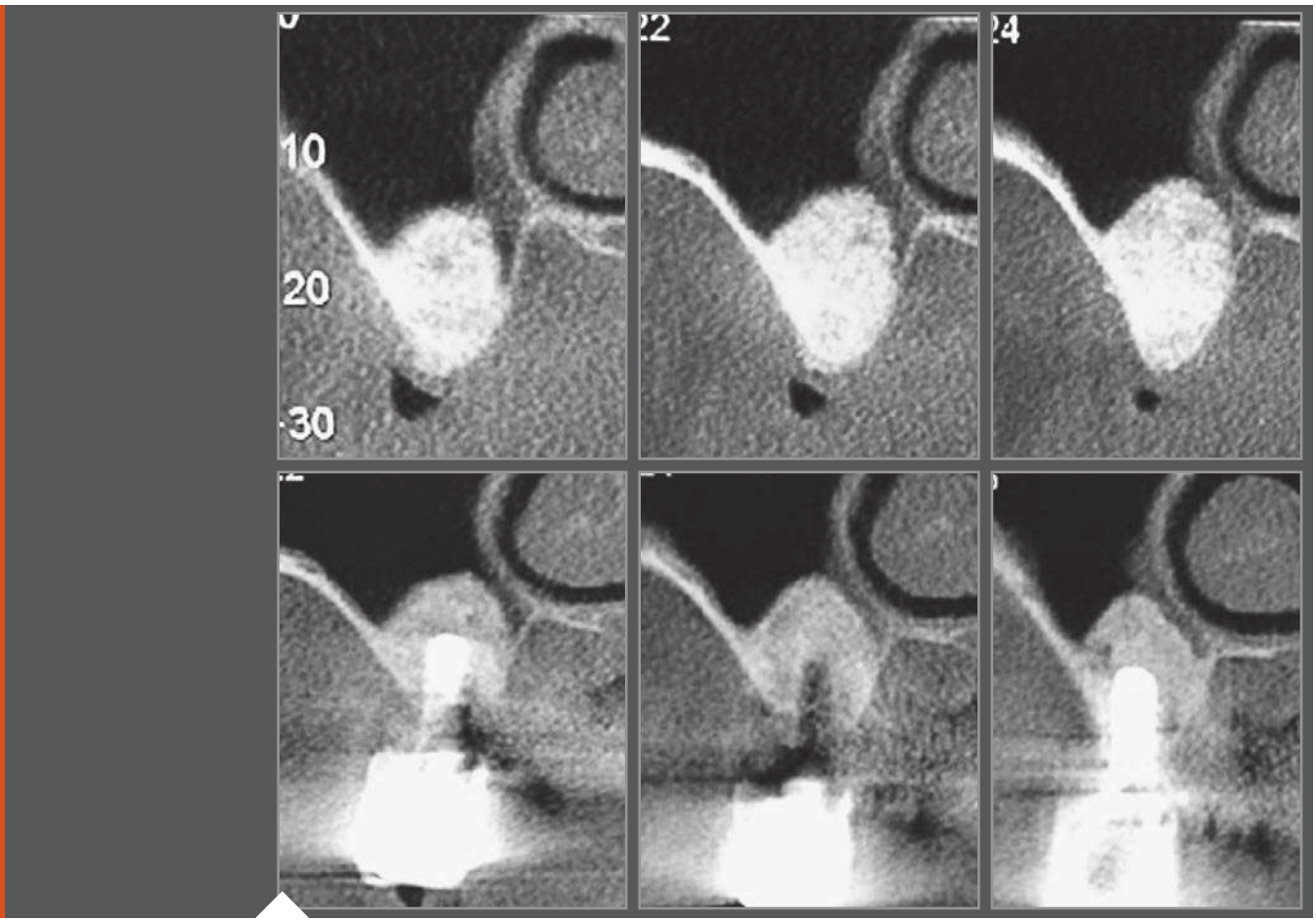

Figure 6. Transverse slices comparing right posterior maxilla. On the top: before implant placement. On the bottom: five years after implant placement. Note preservation of vertical bone gain.

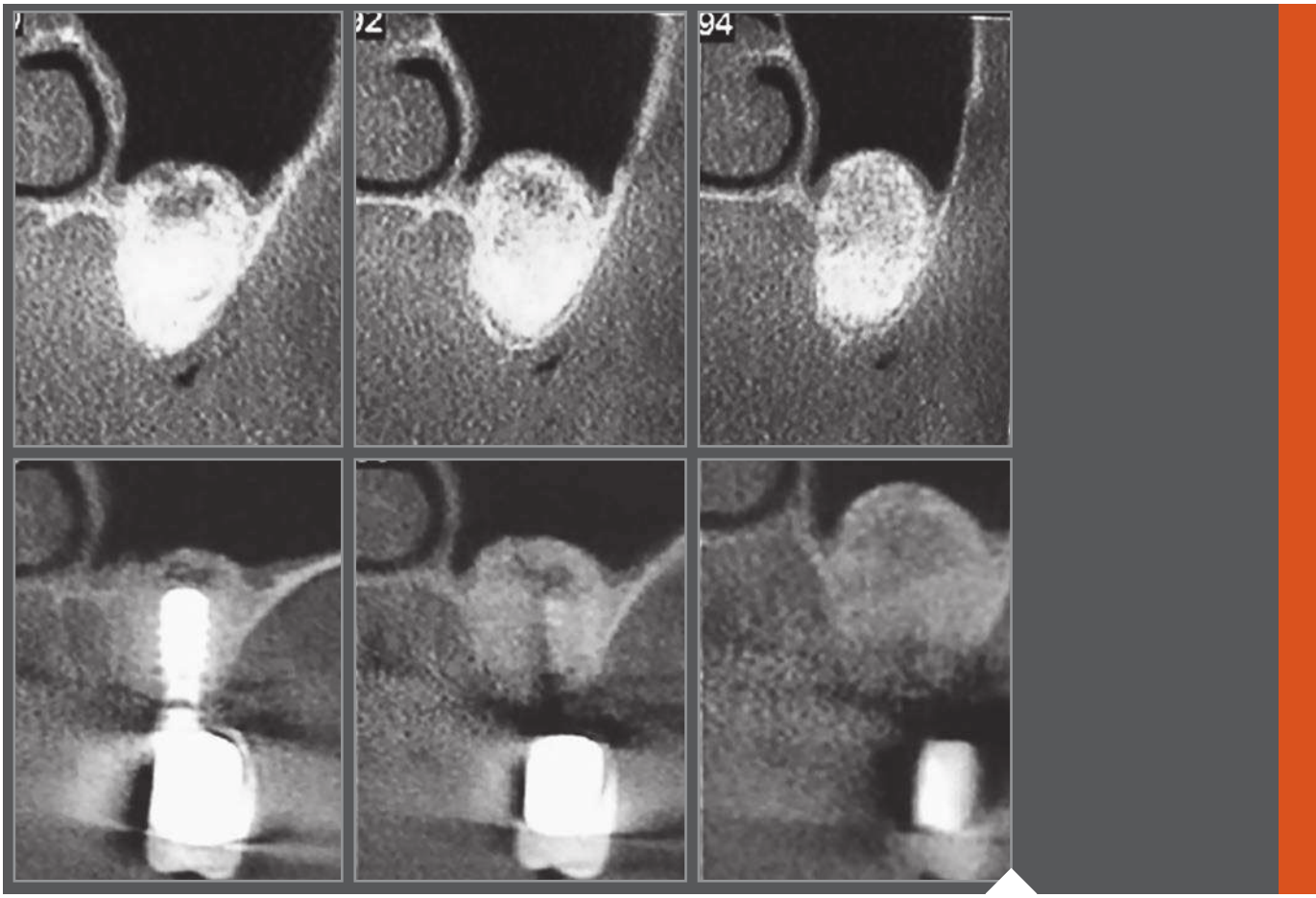

Figure 7. Transverse slices comparing left posterior maxilla. On the top: before implant placement. On the bottom: five years after implant placement.

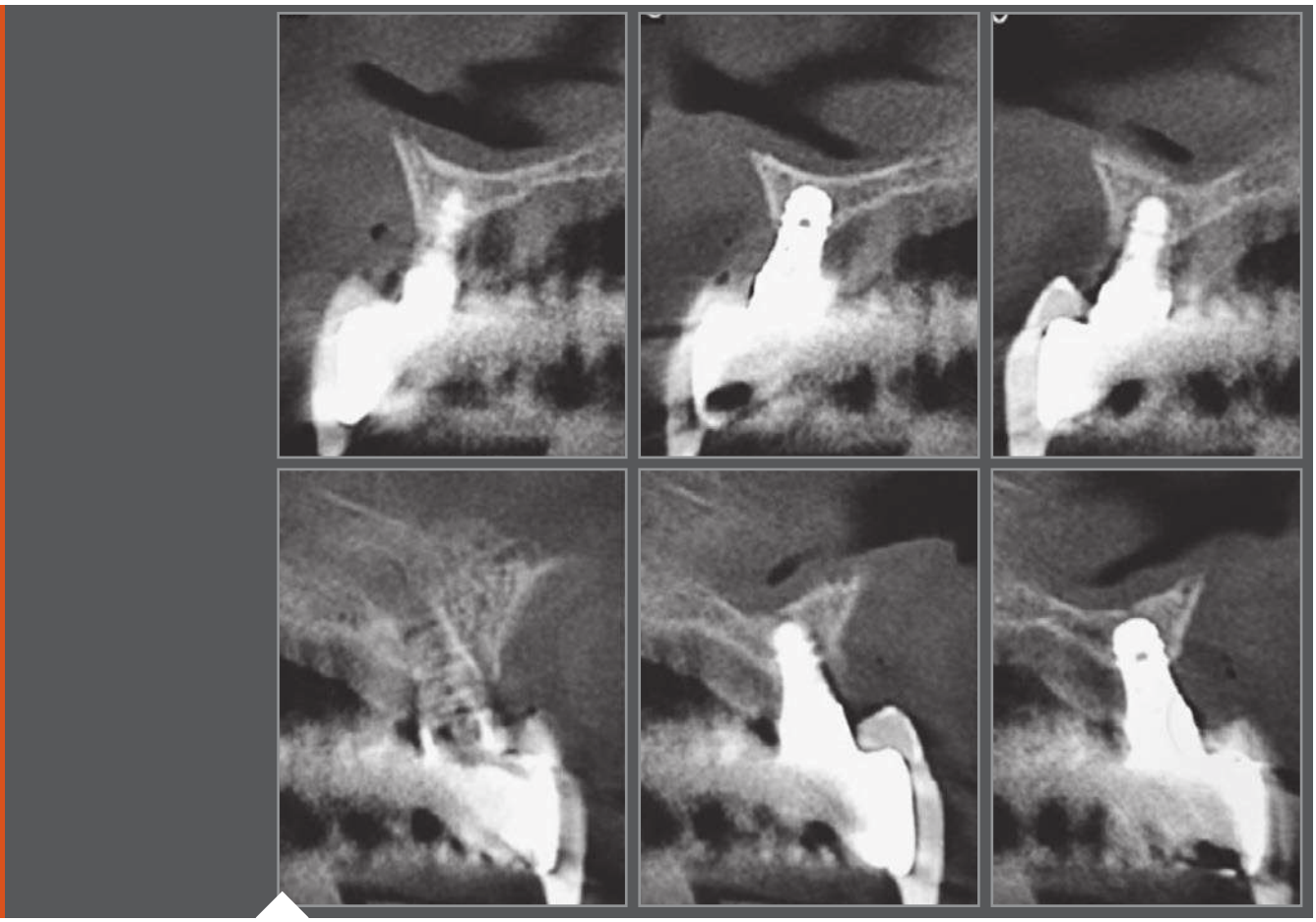

Figure 8. Implants placed in the anterior maxilla. Five-year tomographic follow-up.

Figure 9. Hygiene of maxillary fixed complete denture. Anterior and occlusal view.

Figure 10. Five-year clinical follow-up.

DISCUSSION

There are two different maxillary sinus lift approaches, each one with their own advantages and disadvantages. It is up to the dentist to make the correct decision, that is, he will choose the technique to be employed based on bone height and maxillary sinus anatomical traits.[1]

The lateral window approach allows significant bone volume augmentation, regardless of maxillary sinus anatomical traits; whereas the transalveolar technique allows bone gain limited to 2 to 3 mm.[23] A systematic literature review concluded that implant survival rates after transalveolar sinus lift technique are drastically lower when initial bone height is less than or equal to 5 mm.[24] Moreover, this technique should be restricted to cases of nearly horizontal maxillary sinus floor.[1,24]

Whenever implant primary stability can be achieved, immediate implant placement is preferable, as it reduces the number of surgical interventions and, as a result, morbidity associated with the procedure.[1] However, in the case reported herein, subantral bone height was less than 1 mm, which made it impossible to achieve primary stability. For this reason, the two-stage lateral window approach was the technique of choice.

The biomaterial (biphasic calcium phosphate) used in the case reported herein is made of hydroxyapatite (HA) and beta-tricalcium phosphate (b-TCP). It is a bioinert, 100% synthetic material that eliminates potential risks of contamination. It has been suggested that both substances (HA and b-TCP) yield better bone repair results when used together rather than when they are used alone, especially when a greater amount of HA is added to the mixture.[25]

This hypothesis is due to the fact that b-TCP has high resorption rates, while HA has low degradation rates. Thus, the ceramic is gradually resorbed, and the graft material is replaced by vital bone without losing osteoconductive and space preservation properties, thereby avoiding soft tissue collapse and invagination.[25,26]

The ratios of HA and b-TCP in BoneCeramic (Straumann) are 60% and 40%, respectively. In addition, the compound presents 90% porosity, with interconnected pores 100 to 500 µm in diameter. Such level of porosity provides adequate space for vascular neoformation, which is indispensable to supply the ideal amount of oxygen necessary for mesenchymal cells differentiation, osteoblasts activity and ultimate bone neoformation inside the graft.[13]

An observational clinical trial,[17] conducted based on descriptive statistical data, assessed the quality and quantity of bone formation after a sinus lift procedure was carried out with biphasic calcium phosphate (Straumann BoneCeramic). The unilateral procedure was performed in six patients

using 100% synthetic material, as in the case reported herein. After six months of repair, biopsies were carried out for histological and histomorphometric analyses. Samples were collected with the aid of a trephine bur (3.5 mm of outer diameter) at bone sites previously intended for implant placement. After this period, it could be seen that biphasic calcium phosphate had completely attached to maxillary sinus floor bone and was relatively stable, thereby ensuring successful implant placement. Implants 4.1 mm in diameter and 10 or 12 mm in length were placed. Radiographic examination revealed that vertical height achieved immediately after graft surgery remained unchanged after six months of follow-up.

Most patients presented a slight decrease in height of grafted areas one year after implant placement. Histological analysis revealed that all samples had bone neoformation that respected the framework provided by the bone substitute. Remnant trabecular bone gradually occupied the area taken up by the graft in cranial direction, which allowed bone substitute particles to strongly connect to the neoformed trabecular bone network. Bone maturation was made obvious with the presence of lamellar bone. Bone formation occurred simultaneously to partial degradation of graft. Nevertheless, histological analysis revealed that, after six months, bone cells had not ceased to actively replace bone substitute by new vital bone. Clinically, tissues were stable enough so as to allow implant placement, whereas, at the cellular level, the whole process remained active.[17] Unlike the study cited, in which bone height varied between 4 and 8 mm, the case reported herein presented with severe atrophic maxilla in the posterior region, with bone remnant not greater than 1 mm. For this reason, a longer period of bone maturation was necessary (eight months) before implant placement was carried out, so as to ensure greater stability and safety.

Lyophilized bovine bone (Bio-Oss, Geistlich Pharma, Germany) is another biomaterial widely used in sinus lift procedures. It has been compared to biphasic calcium phosphate by previous studies which concluded that both types of biomaterial are adequate to be used in sinus lift procedures.[27,28]

The 60-day waiting period before transmucosal abutments were placed was necessary because the implants used for the case reported herein were launched into the market with promises of speeding up bone repair and reducing the waiting period for load to be applied. This fact is justified by the hydrophilic features of implants responsible for providing greater wettability and, as a result, stronger interaction between implant surface and the biological environment.[29-32]

In order achieve hydrophilic features, surfaces undergo blasting and acid etching with hydrochloric and sulfuric acids (HCl/H_2SO_4). After the initial

procedures, the hydrophilization technique is employed by preparing implants protected by nitrogen gas (N_2) and stored in sodium chloride (NaCl) isotonic solution.[29] This technique is associated with the high amount of free energy kept on the surface of titanium dioxide (TiO_2), which prevents contaminants, such as hydrocarbons and carbonates present in the air, from being absorbed.[30]

Experimental trials report significant bone apposition and anchorage to implant surfaces at the initial stages of bone repair in animal models.[29] These experimental outcomes were confirmed not only by prospective clinical studies in which implants were loaded after 21 days of bone repair,[33,34] but also by studies measuring implant stability with the aid of resonance frequency analysis (RFA),[35] genetic expression profile and histological analysis of human models.[36,37]

As regards the use of antibiotics, a recent systematic review concluded that scientific evidence suggests that, in general, this type of drug is advantageous, as it aids reducing failure rates of implants placed under normal conditions.[38]

CONCLUSION

Based on histological and radiographic evidence found in the literature as well as in the case reported herein, it is reasonable to conclude that biphasic calcium phosphate, used as bone substitute for vertical augmentation of atrophic posterior maxilla by means of sinus lift, followed by implant placement, is a safe and predictable alternative, whether used in association or not with autogenous bone.

REFERENCES:

1. Katsuyama H, Jensen SS. ITI Treatment guide, sinus floor elevation procedures. Berlim: Quintessence; 2011.
2. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants. 2009;24 Suppl:237-59. Review.
3. Chiapasco M, Zaniboni M, Rimondini L. Dental implants placed in grafted maxillary sinuses: a retrospective analysis of clinical outcome according to the initial clinical situation and a proposal of defect classification. Clin Oral Implants Res. 2008;19(4):416-28.
4. Rawashdeh MA, Telfah H. Secondary alveolar bone grafting: the dilemma of donor site selection and morbidity. Br J Oral Maxillofac Surg. 2008;46(8):665-70.
5. van Hout WM, Mink van der Molen AB, Breugem CC, Koole R, Van Cann EM. Reconstruction of the alveolar cleft: can growth factor-aided tissue engineering replace autologous bone grafting? A literature review and systematic review of results obtained with bone morphogenetic protein-2. Clin Oral Investig. 2011;15(3):297-303.
6. Raghoebar GM, Louwerse C, Kalk WW, Vissink A. Morbidity of chin bone harvesting. Clin Oral Implants Res. 2001;12(5):503-7.
7. Cricchio G, Lundgren S. Donor site morbidity in two different approaches to anterior iliac crest bone harvesting. Clin Implant Dent Relat Res. 2003;5(3):161-9.
8. Silva FM, Cortez AL, Moreira RW, Mazzonetto R. Complications of intraoral donor site for bone grafting prior to implant placement. Implant Dent. 2006;15(4):420-6.

9. Schwartz CE, Martha JF, Kowalski P, Wang DA, Bode R, Li L, Kim DH. Prospective evaluation of chronic pain associated with posterior autologous iliac crest bone graft harvest and its effect on postoperative outcome. Health Qual Life Outcomes. 2009 May 29;7:49
10. Dimitriou R, Mataliotakis GI, Angoules AG, Kanakaris NK, Giannoudis PV. Complications following autologous bone graft harvesting from the iliac crest and using the RIA: a systematic review. Injury. 2011 Sep;42 Suppl 2:S3-15.
11. Deppe H, Mücke T, Wagenpfeil S, Hölzle F. Sinus augmentation with intra- vs extraorally harvested bone grafts for the provision of dental implants: clinical long-term results. Quintessence Int. 2012;43(6):469-81.
12. Cordaro L, Bosshardt DD, Palattella P, Rao W, Serino G, Chiapasco M. Maxillary sinus grafting with Bio-Oss or Straumann Bone Ceramic: histomorphometric results from a randomized controlled multicenter clinical trial. Clin Oral Implants Res. 2008;19(8):796-803.
13. Dietze S, Bayerlein T, Proff P, Hoffmann A, Gedrange T. The ultrastructure and processing properties of Straumann Bone Ceramic and NanoBone. Folia Morphol (Warsz). 2006;65(1):63-5.
14. Schwarz F, Herten M, Ferrari D, Wieland M, Schmitz L, Engelhardt E, Becker J. Guided bone regeneration at dehiscence-type defects using biphasic hydroxyapatite + beta tricalcium phosphate (Bone Ceramic) or a collagen-coated natural bone mineral (BioOss Collagen): an immunohistochemical study in dogs. Int J Oral Maxillofac Surg. 2007;36(12):1198-206.
15. Sager M, Ferrari D, Wieland M, Dard M, Becker J, Schwarz F. Immunohistochemical characterization of wound healing at two different bone graft substitutes. Int J Oral Maxillofac Surg. 2012;41(5):657-66.
16. Antunes AA, Oliveira Neto P, Santis E, Caneva M, Botticelli D, Salata LA. Comparisons between Bio-Oss(®) and Straumann(®) Bone Ceramic in immediate and staged implant placement in dogs mandible bone defects. Clin Oral Implants Res. 2013;24(2):135-42.
17. Frenken JW, Bouwman WF, Bravenboer N, Zijderveld SA, Schulten EA, ten Bruggenkate CM. The use of Straumann Bone Ceramic in a maxillary sinus floor elevation procedure: a clinical, radiological, histological and histomorphometric evaluation with a 6-month healing period. Clin Oral Implants Res. 2010;21(2):201-8.
18. Friedmann A, Dard M, Kleber BM, Bernimoulin JP, Bosshardt DD. Ridge augmentation and maxillary sinus grafting with a biphasic calcium phosphate: histologic and histomorphometric observations. Clin Oral Implants Res. 2009;20(7):708-14.
19. Zafiropoulos GG, Hoffmann O, Kasaj A, Willershausen B, Weiss O, Van Dyke TE. Treatment of intrabony defects using guided tissue regeneration and autogenous spongiosa alone or combined with hydroxyapatite/beta-tricalcium phosphate bone substitute or bovine-derived xenograft. J Periodontol. 2007;78(11):2216-25.
20. De Leonardis D, Paolantonio M. Enamel matrix derivative, alone or associated with a synthetic bone substitute, in the treatment of 1- to 2-wall periodontal defects. J Periodontol. 2013;84(4):444-55.
21. Peres MF, Ribeiro ED, Casarin RC, Ruiz KG, Nociti Junior FH, Sallum EA, et al. Hydroxyapatite/β-tricalcium phosphate and enamel matrix derivative for treatment of proximal class II furcation defects: a randomized clinical trial. J Clin Periodontol. 2013;40(3):252-9.
22. Zafiropoulos GG, Hoffmann O, Kasaj A, Willershausen B, Weiss O, Van Dyke TE. Treatment of intrabony defects using guided tissue regeneration and autogenous spongiosa alone or combined with hydroxyapatite/beta-tricalcium phosphate bone substitute or bovine-derived xenograft. J Periodontol. 2007;78(11):2216-25.
23. Pjetursson BE, Ignjatovic D, Matuliene G, Brägger U, Schmidlin K, Lang NP. Transalveolar maxillary sinus floor elevation using osteotomes with or without graft material. Part II: Radiographic tissue remodeling. Clin Oral Implants Res. 2009;20(7):677-83.
24. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. J Clin Periodontol. 2008;35(8 Suppl):241-54.
25. Nery EB, LeGeros RZ, Lynch KL, Lee K. Tissue response to biphasic calcium phosphate ceramic with different ratios of HA/beta TCP in periodontal osseous defects. J Periodontol. 1992;63(9):729-35.
26. LeGeros RZ, Lin S, Rohanizadeh R, Mijares D, LeGeros JP. Biphasic calcium phosphate bioceramics: preparation, properties and applications. J Mater Sci Mater Med. 2003;14:201-9.
27. Cordaro L, Bosshardt DD, Palattella P, Rao W, Serino G, Chiapasco M. Maxillary sinus grafting with bio-oss or straumann bone ceramic: histomorphometric results from a randomized controlled multicenter clinical trial. Clin Oral Implants Res. 2008;19(8):796-803.
28. Iezzi G, Degidi M, Piattelli A, Mangano C, Scarano A, Shibli JA, et al. Comparative histological results of different biomaterials used in sinus augmentation procedures: a human study at 6 months. Clin Oral Implants Res. 2012;23(12):1369-76.
29. Buser D, Broggini N, Wieland M, Schenk RK, Denzer AJ, Cochran DL, et al. Enhanced bone apposition to a chemically modified SLA titanium surface. J Dent Res. 2004;83(7):529-33.
30. Zhao G, Schwartz Z, Wieland M, Rupp F, Geis Gerstorfer J, Cochran DL, et al. High surface energy enhances cell response to titanium substrate microstructure. J Biomed Mater Res A. 2005;74(1):49-58.
31. Rupp F, Scheideler L, Olshanska N, de Wild M, Wieland M, GeisGerstorfer J.Enhancing surface free energy and hydrophilicity through chemical modification of microstructured titanium implant surfaces. J Biomed Mater Res A. 2006;76(2):323-34.
32. Rupp F, Scheideler L, Eichler M, Geis-Gerstorfer J. Wetting behavior of dental implants. Int J Oral Maxillofac Implants. 2011;26(6):1256-66.
33. Bornstein MM, Wittneben JG, Brägger U, Buser D. Early loading at 21 days of nonsubmerged titanium implants with a chemically modified sandblasted and acidetched surface: 3year results of a prospective study in the posterior mandible. J Periodontol. 2010;81(6):809-18.
34. Morton D, Bornstein MM, Wittneben JG, Martin WC, Ruskin JD, Hart CN, et al. Early loading after 21 days of healing of nonsubmerged titanium implants with a chemically modified sandblasted and acidetched surface: two year results of a prospective two center study. J Periodontol. 2010;81(6):809-18.
35. Bornstein MM, Hart CN, Halbritter SA, Morton D, Buser D. Early loading of nonsubmerged titanium implants with a chemically modified sandblasted and acidetched surface: 6month results of a prospective case series study in the posterior mandible focusing on periimplant crestal bone changes and implant stability quotient (ISQ) values. Clin Implant Dent Relat Res. 2009;11(4):338-47.
36. Lang NP, Salvi GE, HuynhBa G, Ivanovski S, Donos N, Bosshardt DD. Early osseointegration to hydrophilic and hydrophobic implant surfaces in humans. Clin Oral Implants Res. 2011;22(4):349-56.
37. Ivanovski S, Hamlet S, Salvi GE, HuynhBa G, Bosshardt DD, Lang NP, et al. Transcriptional profiling of osseointegration in humans. Clin Oral Implants Res. 2011;22(4):373-81.
38. Esposito M, Grusovin MG, Worthington HV. Interventions for replacing missing teeth: antibiotics at dental implant placement to prevent complications. Cochrane Database Syst Rev. 2013 Jul 31;7:CD004152