Stability of Implants Placed in Augmented Posterior Mandible after Alveolar Osteotomy Using Resorbable Nonceramic Hydroxyapatite or Intraoral Autogenous Bone: 12-Month Follow-Up

Alexandre M. Dottore, DDS;* Paulo Y. Kawakami, DDS, MS, PhD;* Karen Bechara, DDS;* Jose Augusto Rodrigues, DDS, MSc, PhD;[†] Alessandra Cassoni, DDS, MS, PhD;[†] Luciene C. Figueiredo, DDS, MS, PhD;[‡] Adriano Piattelli, DDS, MD;[§] Jamil Awad Shibli, DDS, MS, PhD[§]

ABSTRACT

Purpose: This prospective, controlled split-mouth study evaluated the stability of dental implants placed in the augmented mandibular areas with alveolar segmental "sandwich" osteotomies using nonceramic hydroxyapatite (ncHA) or autogenous bone.

Material and Methods: This study included 11 bilaterally partially edentulous mandibular patients in a split-mouth design. Alveolar augmentation osteotomies were performed bilaterally with interpositional ncHA graft (test group) or interpositional intraoral autogenous bone graft (control group). After 6 months of healing, four implants (two implants in each side) were placed in each patient. Forty-four implants were inserted and loaded after 6-month healing period. At 1-year follow-up, radiographic, prosthetic, and resonance frequency analysis parameters were assessed. Success criteria included absence of pain, sensitivity, suppuration, and implant mobility; absence of continuous peri-implant radiolucency; and distance between the implant shoulder and the first visible bone contact (DIB) < 2 mm.

Results: After a 1-year loading period, the overall implant survival rate was 95.45%, with two implant losses (one of each group). Among the surviving implants (42 out of 44), two did not fulfill the success criteria; therefore, the implant success was 90.90%. DIB was 0.71 ± 0.70 and 0.84 ± 0.72 mm for ncHA and autogenous bone grafts, respectively (p > .05). Implant stability measurements were similar between the groups during the 12-month follow-up (p > .05).

Conclusion: Within the limits of this study, the implants placed either in sites augmented with ncHA or autogenous bone seem to represent a safe and successful procedure, at least, after 12-month follow-up.

KEY WORDS: autogenous bone graft, dental implants, hydroxyapatite, implant success, inlay bone grafts, posterior mandible, resonance frequency analysis

*Graduated students, Department of Oral Implantology, Dental Research Division, University of Guarulhos, Guarulhos, SP, Brazil; [†]associate professors, Department of Restorative Dentistry, Dental Research Division, University of Guarulhos, Guarulhos, SP, Brazil; [‡]professor, Department of Periodontology, Dental Research Division, University of Guarulhos, Guarulhos, SP, Brazil; [§]professor, Department of Oral Medicine and Pathology, University of Chieti-Pescara, Chieti, Italy; [§]head of oral implantology clinic and professor, Department of Oral Implantology, Dental Research Division, University of Guarulhos, Guarulhos, SP, Brazil

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INTRODUCTION

In the last decade, the application of Guided Bone Regeneration to dental implant placement provided to the clinicians the ability to augment the width and the height deficient alveolar bone ridges with high predictability.¹ However, bone augmentation procedure in posterior mandible, due to the presence of the inferior alveolar nerve (IAN), is a challenge.

IAN constitutes an anatomic limitation that may be treated with different surgical techniques such as onlay bone graft, distraction osteogenesis, vertical guided bone regeneration, and short (<7 mm length) implant placement.² Earlier studies^{3–8} have shown that alveolar osteotomy associated with interpositional bone grafts

Reprint requests: Professor Jamil Awad Shibli, Centro de Pós-Graduação e Pesquisa – CEPPE, Universidade Guarulhos, Praça Tereza Cristina, 229 – Centro, 07023-070 Guarulhos, SP, Brazil; e-mail: jashibli@yahoo.com

could be a viable alternative to other surgical techniques to increase the vertical bone height in the posterior mandible. This technique is based on the concept that a bone graft is interposed between the osteotomized bony segments as a "sandwich," allowing a good vascular supply to the segment and the graft, and it may result in less bone resorption.^{4,5,7}

However, to date, there are few controlled human studies that evaluated the long-term stability of dental implants placed in augmented sites by sandwich osteotomy. Therefore, the aim of this prospective, controlled study was to evaluate the 12-month follow-up of dental implants loaded in recipient alveolar sites augmented using either intraoral autogenous bone or resorbable nonceramic hydroxyapatite (ncHA).

MATERIAL AND METHODS

Patient Population

This prospective longitudinal study evaluated the stability of dental implants placed in augmented ridges treated with vertical augmentation on posterior mandible using alveolar osteotomy with interpositional bone graft between August 2009 and September 2010. The data about the augmentation technique were previously presented by Kawakami and colleagues.⁷ Briefly, 11 subjects (eight females and three males, mean age 54.2 years) presenting bilateral partial edentulism in the posterior mandible having a residual bone height between 4 and 5 mm and a thickness of at least 4 mm were enrolled in this study. The edentulous ridges, in a split-mouth design, were assigned in two groups: a control group consisting of n = 11 alveolar osteotomy that received an interpositional inlay autogenous bone graft from lateral oblique line and a test group consisting of n = 11 alveolar osteotomy that received an interpositional inlay resorbable nonceramic hydroxyapatite (ncHA) (OsteoGen® powder and pellets, Impladent Ltd., Holliswood, NY, USA). Tossing a coin was used to determine which side was assigned as control or test posterior mandible side.

The study protocol was explained to each subject and a signed informed consent was obtained according to The Institutional Clinical Research Ethics Committee of Guarulhos University.

Exclusion Criteria. Subjects were excluded if they were smokers and if they had residual mandible height after

segmental alveolar osteotomy insufficient to place regular implants (regular implants were defined as implant length with at least 8 mm), a chronic medical disease or condition that would contraindicate dental surgery (e.g., diabetes, uncontrolled hypertension, and history of head and neck radiation) and moderate to severe chronic periodontitis in the remaining teeth (i.e., suppuration, bleeding on probing in more than 30% of the subgingival sites or any site with probing depth >5 mm).

Alveolar Osteotomy. All subjects received oral prophylaxis treatment before surgery. Panoramic radiographs and dental volume tomography (ICat, KaVo Dental GmbH, Biberach, Germany) were taken of all patients. All patients received antibiotics (amoxicillin 875 mg and sulbactam 125 mg) and steroidal anti-inflammatory (dexamethasone 4 mg) prior to the surgery. The bilateral alveolar sandwich osteotomy was performed under local anesthesia on the same day. The surgical procedure involved an elliptical incision 10 to 12 mm from the ridge bone in the labiobuccal gingiva of the edentulous area. A full thickness flap was raised without detaching the lingual and the crestal mucoperiosteum to expose the labiobuccal cortical bone of the posterior atrophic mandible and the mental nerve. Two vertical and one horizontal osteotomy were made with a surgical bur and saws. The horizontal osteotomy was located at least 2 mm below the ridge bone and 2 mm above the mandibular canal. The final phase of the osteotomy was performed with chisels. The osteotomized segment was then carefully raised in the coronal direction, sparing the lingual periosteum to avoid the detachment of the segment. Based on this clinical feature, the maximum vertical gap was obtained. In the control group, the intraoral autogenous bone was shaped to fit between the mandible and the cranial fragment. Titanium osteosynthesis screws and plates were used to obtain stability. In the test group, the titanium plates were place before the ncHA to create an enough space. Then, a mix of ncHA powder and pellets was added between the osteotomized bony segments. Gaps in the vertical osteotomies were filled with particulate autogenous (control group) or ncHA (test group) (Figure 1). To allow flap apposition and closure after placement, incisions were made buccally after graft placement. Primary wound closure was achieved with horizontal mattress sutures alternated with interrupted sutures to ensure a submerged healing



Figure 1 Clinical view of (A) segmented osteotomized block fixed with titanium miniplates; (B) a mix of powder and pellets of nonceramic hydroxyapatite (ncHA) was added into the gap; and (C) 6-month healing of test group. Note the complete integration of the ncHA graft; (D) implants placed on the site grafted with ncHA. Note that some pellets of ncHA (*) are completely integrated with the bone and are quite difficult to observe the limits between pristine bone and the graft.

procedure in segmented alveolar bone. The windows were closed with 4.0 nylon sutures in one layer.

Postoperative Care. Postoperative care consisted of a 0.12% chlorhexidine mouthrinse twice a day for 14 days without mechanical cleaning at the surgical areas. Antiinflammatory medication (dexamethasone 4 mg) was administered once a day and appropriate analgesia (paracetamol 750 mg) for 3 days following surgery in order to reduce postoperative swelling and pain. A postoperative antibiotic regimen with amoxicillin and sulbactam was prescribed during 7 days. Nylon sutures were removed 14 days after surgery. No removable prosthesis was allowed for 6 months. Professional plaque control supplemented this healing phase every month during 6 months. *Removal of Miniplates and Implant Placement.* Six months after augmentation, under local anesthesia, titanium miniplates and screws were removed; knife-edge ridges were flatted to allow a thickness of at least 4 mm. Screw-shaped implants with sandblasted acid-etched surface, 3.75 to 4.1 mm–diameter and 8 to 11 mm length, were used in this study. The preparation of implant sites was carried out with twist drills of increasing diameter under constant irrigation. Implants were positioned at the bone crest level.

Care was taken to assess the position of the mental foramen. Implant sites were marked using a surgical template. The templates were based on the diagnostic waxing with perforations on the longitudinal axis, on the premolar and molar regions, according to ideal position of final implant-supported restorations. Primary wound closure was achieved with horizontal mattress sutures alternated with interrupted sutures to ensure a submerged healing procedure in dental implants. After 6-month healing period, the implants were exposed and restored with screw-retained implant-supported restoration.

Clinical, Radiographic, and Prosthetic Evaluation

The following clinical parameters⁹ were investigated, after 1 year of functional loading (i.e., 18 months after alveolar osteotomy), for each implant as the presence or absence of pain/sensitivity, suppuration/exudation, and implant mobility. The latter was tested manually using the handles of two dental mirrors.

Moreover, intraoral periapical radiographs were taken for each implant at the baseline (immediately after implant insertion – 6 months after augmentation procedure) and at 1 year of loading (18 months after augmentation procedure). Radiographs were taken using a Rinn alignment system with a rigid film-object x-ray source coupled to a beam-aiming device in order to achieve reproducible exposure geometry. The distance between the implant shoulder and the first visible bone contact (DIB) in millimeter measured by means of an ocular grid was obtained.

With the latter value, crestal bone level changes at 1 year were registered as modifications in the distance from the implant shoulder to the bone level on the mesial and distal implant side. To correct dimensional distortion, the apparent dimension of each implant was measured on the radiograph and then compared with the actual implant length. Finally, at the 1-year follow-up session, prosthesis function was tested. Static and dynamic occlusion was evaluated using standard occluding papers. Careful attention was dedicated to the analysis of prosthetic complications, such as abutment screw loosening, ceramic fractures.

Implant Survival and Implant Success Criteria

The evaluation of implant survival and implant success was performed according to the following clinical and radiographic parameters.¹⁰ Implants were basically divided into two categories: "survived" and "failed" implants. An implant was classified as a "survived implant" when it was still in function at the end of the study, after 1 year of functional loading. Implant losses were categorized as failures; implants presenting pain upon function, suppuration, or clinical mobility were removed and were all failure categories. The conditions for which implant removal could be indicated included failure of osseointegration or infection, recurrent periimplantitis, or implant loss due to mechanical overload.

To achieve implant success, the following clinical and radiographic success criteria should be fulfilled: absence of pain or sensitivity upon function, suppuration or exudation, clinically detectable implant mobility, continuous peri-implant radiolucency, and DIB < 2.0 mm after 12 months of functional loading.

Implant Stability

Immediately after the implant placement – at baseline (6 months after alveolar osteotomy), at 6 months at second-stage surgery (12 months after alveolar osteotomy), and at 12 months after loading (18 months after alveolar osteotomy) – the resonance frequency analysis (RFA) (Osstell implant stability quotient [ISQ], Integration Diagnostics, Savadaled, Sweden) was used to measure the primary stability of the implants. The transducer (smartpeg type 1) was hand screwed into the implant body. For every series of RFA measurements, the ISQ values (unit of RFA) were recorded. An ISQ value between 1 and 100 was given where 1 is the lowest and 100 is the highest. A mean of ISQ value was calculated for each implant based on two measurements of each implant and then of each group.

Statistical Analysis

The mean and standard deviation of the value of RFA and radiographic data were calculated for each implant and then for each group. Paired nonparametric Wilcoxon rank test was used to calculate the differences between groups for the radiographic and RFA variables, as well as to evaluate the intragroup differences between RFA values at baseline, 6 months, and 12 months posttherapy. The unit of analysis was the patient and the level of significance was 5%.

RESULTS

Vertical Bone Gain and Implants Distribution

The radiographic vertical bone gain after alveolar osteotomy ranging between 6.5 ± 1.6 and 7.0 ± 2.6 mm for control and test groups (p > .05). A total of 44 implants were placed: 22 implants in each group. The



Figure 2 (A) Radiographic view of 12-month follow-up implant-supported restoration in the grafted area showed in Figure 1; (B) radiographic view of the contralateral side of the implants placed in augmented area with autogenous bone; and (C) clinical view of the worst case showing 3-mm crestal bone loss.

mean length of the implants placed into control and test groups was 9.3 ± 1.44 mm and 9.8 ± 1.56 mm, respectively (*p* = .94).

Implant Survival

There were no patients who dropped out from this study and all implants were examined at the 1-year recall. At the end of the study, the overall implant survival rate was 95.45%, with 42 implants still in function. Two implants (one in each group) failed and had to be removed at the second-stage surgery.

Implant Success

Forty-two implants were still in function at the end of the study. Among these implants, 40 out of 42 implants (90.90%) were classified in the implant success group. Two implants showed a DIB between 2 and 4 mm. The 40 remaining implants did not show pain or clinical mobility, suppuration, or exudation, with a DIB < 2.0 mm (Figure 2). The overall radiographic evaluation of the implants revealed a similar range DIB between 0.78 ± 0.82 and 1.02 ± 0.93 mm for ncHA and autogenous bone grafts, respectively, at the 1-year examination (p = .38) (Figure 3).

Prosthetic Complications and Maintenance

Prosthetic complications included loosening of abutment screw (one patient, 2.5% in a control group).

RFA. ISQ is presented in Figure 4. Implant stability measurements at 6 months after osteotomy showed a mean of ISQ value of 76 for implants placed at HA augmented sites. After healing of 6 months, i.e., 12 months after osteotomy, the ISQ mean value was around 75 in both groups (p > .90). Finally, at 12-month follow-up (18 months after bone augmentation), ISQ values ranged around 76 for both groups (p > .90).



Figure 3 Scatter dot plot with mean \pm standard deviation of crestal bone remodeling after 1-year loading of all implants in each group (n = 21 implants per group). Wilcoxon rank test (p > .05). HA = hydroxyapatite; ns = nonsignificant.

DISCUSSION

The present data showed that the implants placed and loaded in sites augmented by "sandwich" osteotomy technique using either autogenous bone or nonceramic resorbable HA in the posterior mandible presented good results after 12-month follow-up.

Our data agree with previous studies in humans^{3–5,8,11} who also obtained, in a varied range, new bone formation in the atrophic mandibles after sandwich osteotomy with implant success rates higher than 90%.

It has been suggested that dental implants placed in posterior mandible presented lower success index



Figure 4 Box plots of mean (+) and outliers (dark circles) of ISQ values of implants placed in control (autogenous) and test (nonceramic HA) groups at baseline (6 months after alveolar osteotomy), at 6 months in second-stage surgery (12 months after osteotomy), and at 12-month follow-up (18 months after alveolar osteotomy). Wilcoxon rank test (p > .05). HA = hydroxyapatite; ISQ = implant stability quotient; ns = nonsignificant.

comparable with those inserted in posterior maxilla or grafted areas.¹² This idea is based on blood supply in the mandible: as the main source of blood supply in the posterior mandible originates from inferior alveolar artery and periosteal source, according to the surgical procedure, a relative ischemia of this area could jeopardize the soft and bone tissue healing, contributing with the dental implant failure. In the present investigation, the alveolar segmental osteotomy with interposed graft material maintained the vascularization in the bone ridge throughout the intact lingual pedicle of the soft tissue. This vascular supply was important to allow the viability of the coronal segment, allowing for rapid remodeling of the interpositional bone graft.^{3,7}

In addition, our data showed that implants inserted on augmented sites in posterior mandible presented stable crestal bone remodeling. The marginal bone loss ranged between 0.71 and 0.84 mm for ncHA and autogenous groups, respectively. These peri-implant marginal bone loss data are comparable with the data obtained from studies that evaluated implants in pristine bone^{13,14} and segmented mandibular sites.⁵ Conversely, our marginal bone loss means were lower than those obtained by previous study¹⁵ that used the vertical ridge augmentation using barriers associate with bone graft. We can speculate that this difference is mainly due to surgical technique employed in both studies. The interpositional or inlay grafts as a "sandwich" involve the placement of graft material within a three- to five-walled cancellous compartment. This technique allows that the recipient site contains and stabilizes the graft material and the circulating of blood flow between the osteotomized bony blocks providing cells, soluble regulators, and nourishment. In the sandwich graft approach, a section of the cortical bone is removed and placed within the cancellous compartment, and the plug of cortical bone is repositioned on top of the graft material and stabilized with monocortical bone screws.⁷

Complementary, the satisfactory success rate obtained with dental implants in the treatment of edentulous subjects depends on the volume and quality of the bone. The primary stability of these implants is fundamental for achieving osseointegration.¹⁶ According to the mean values of ISQ obtained in both groups (around 75 ISQ), we could suggest that the bone density in those augmented areas allowed a good anchorage for the dental implants after 6 months of augmentation procedures. In this present study, we also focused on identifying possible related factors that could influence the dental implant success rate. The stability of marginal peri-implant bone as well as the RFA data evaluated over 1-year follow-up could support the concept that interpositional bone augmentation technique, independently of the graft material (ncHA or autogenous bone), can provide a stable substrate for implantsupported restoration.

Finally, it is reported that RFA can provide objective evaluation of implant stability, possibly demonstrating evidence for extending of implant osseointegration. Therefore, the present data demonstrated that the use of ISQ values ranged between 55 and 80 (mean of 77) to implants placed in test and control sites. Some of these values are compatible with immediate loading protocol ISQ values, suggesting that there was bone integration or remodeling between graft and recipient mandibular site, with both grafts (autogenous and ncHA). At 1-year follow-up, the ISQ values were stable, suggesting that the bone remodeling and adaptation at the bone-implant interface around the grafted areas allowed a direct bone anchorage around the implants.

Within the limits of this study, it could be concluded that implants placed either in sites augmented with ncHA or autogenous bone seem to represent a safe and successful procedure, at least, after 12-month follow-up.

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