# Implant Restoration 3 Months after One Stage Sinus Lift Surgery in Severely Resorbed Maxillae: 2-Year Results of a Multicenter Prospective Clinical Study

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## ABSTRACT

*Objectives:* This multicenter prospective study was aimed to clinically evaluate implant behavior inserted in severely resorbed maxillae and restored 3 months after sinus grafting.

*Materials and Methods:* In three clinical centers, 67 totally rough wide diameter implants were inserted during 30 consecutive sinus lifts. Computed tomography and panoramic analysis were preoperatively requested for each patient. Sinus grafting was performed using a nano-crystalline hydroxyapatite sole bone filler; no membrane was used to cover the buccal window. Preoperative residual bone height ranged between 1–4 mm (mean value: 2.70 mm, standard deviation [SD]: 0.9 mm). Uncovering procedure was carried out following 3 months of healing; 2 weeks later, a definitive restoration was seated using platform switching concept. To monitor stability changes, resonance frequency analysis was performed and implant stability quotient (ISQ) values were collected at the first surgery (baseline, $T_0$), at the abutment connection ($T_1$), and at 2-year follow-up ($T_2$). To measure bone changes, patients underwent panoramic analysis after 2-year follow-up. The image analysis software calculated the grafted bone height changes at level of implant site comparing preoperative and follow-up panoramic films; the software compensated for eventual radiographic distortion.

*Results:* Mean ISQ value was 35.7 (SD: 8.8) at baseline, 66.61 (SD: 4.76) at $T_1$, and 77.9 (SD: 4.7) at $T_2$. Statistically significant differences ($p \leq 0.005$) regarding ISQ mean values were found between $T_1$ and $T_0$, as well as between $T_1$ and $T_2$. After 24 months of functional loading, only two implants were lost (cumulative survival rate: 97%). During the same observation period, the mean value of radiographic vertical height of grafted sinus was 13.75 mm (SD = 1.3 mm), with a mean gain of 11 mm.

*Conclusions:* Within the limits of this study, despite preoperative residual bone height ranging 1 to 4 mm and absence of the membrane covering the buccal bone wall, maxillary sinus lift restoration 14 weeks after first surgery seems to be a reliable procedure using totally-rough surfaced implants restored using platform switching concept and nano-structured hydroxyapatite as sole bone filler.

KEY WORDS: early loading, nano-structured hydroxyapatite, platform switching, resonance frequency analysis, sinus lift

## INTRODUCTION

Sinus floor augmentation became a widely accepted surgical procedure to improve the amount of bone volume before implant placement. Although the use of autogenous bone seemed to be the gold standard,[1,2] much attention has been paid to the use of bone substitutes. In fact, after the harvesting procedure, donor site morbidity has to be taken into consideration.[3] Additional disadvantages for autografts are the limited availability and the tendency to resorption.[4]

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To overcome these limitations, several biomaterials have been evaluated in experimental and clinical study, such as demineralized freeze-dried bone allograft,[5] bovine bone matrix,[4] composite bone graft including platelet-rich plasma,[6] resorbable and non-resorbable hydroxyapatite,[7,8] and β-tricalcium phosphate.[9]

In particular, bio-ceramics based on calcium phosphate are widely used because of their biocompatibility and the absence of immunogenic factors and osteoconductivity, although the high temperature during the sintering process could negatively influence osteoconductivity and resorption time.[10]

NanoBone (Artoos, Rostock, Germany) is a recently developed grafting material consisting of nanocrystalline hydroxyapatite granules embedded in a silica gel matrix. Because of the open SiOH or SiO groups of polysilicic acid, this nano-structured biomaterial presents an extremely large internal surface (about 84 $m^2$/g). Furthermore, the very rough granule surface creates an interconnecting porous structure ranging from the µm to mm dimensions.

Clinical investigation demonstrated that Nanobone has osteoconductive and biomimetic properties and is integrated into the host's physiological bone turnover at a very early stage.[11]

Furthermore, a recently published study showed histologically significant new bone formation and remodeling of the grafted material even 3 months after sinus lift elevation.[12] Additionally, a case series study showed measured bone-to-implant contact (BIC) amounting to 17.75% of the case of micro-screw inserted in extremely resorbed maxilla grafted with Nanobone.[13]

According to these last papers, the present preliminary prospective multicenter study was designed to evaluate clinically implant restoration 3 months after one-stage sinus lift surgery in severely resorbed maxillae grafted using nano-crystalline hydroxyapatite.

An additional aim was to measure radiographically and clinically the longitudinal stability of the implants and grafted bone after 24 months of prosthetic loading.

## MATERIALS AND METHODS

### Study Design and Patient Selection

Three dental centers consecutively recruited 30 patients scheduled for implant supported restoration in the posterior maxilla with sinus augmentation procedure. All patients were in general good health, they were informed about the procedure and were required to sign a consent form. They were followed during a period of 24 months after prosthetic rehabilitation.

**TABLE 1 Subject and Study Site Inclusion and Exclusion Criteria**

| |
|---|
| **Subject inclusion criteria** |
| Need for fixed implant-supported prosthesis in the posterior maxillae |
| Age >18 years |
| No relevant medical conditions |
| Non-smoking or smoking ≤10 cigarettes/day (all pipe or cigar smokers were excluded) |
| Full Mouth Plaque Score and Full Mouth Bleeding Score ≤25% |
| **Study site inclusion criteria** |
| Presence of native bone height of 1–4 mm in the sinus zone |
| **Specific subject and site exclusion criteria** |
| Schneiderian membrane acute infections or chronic sinusitis |
| Allergies involving the respiratory system |
| Patients with a history of Bisphophonate therapy |
| Patients with uncontrolled diabetes (HbA1c > 6%, glycemic level > 110 mg/dl) |

The only inclusion criteria was residual bone crest (distance between sinus floor and bone crest) ranging between 1 and 4 mm in height.

Exclusion criteria are summarized in Table 1.

All procedures and materials in the present prospective study were approved by the University of Greifswald ethical committee, and all patients provided informed consent.

The present study was performed following the principles outlined by the Declaration of Helsinki on experimentation involving human subjects.

### Preoperative and Postoperative Medication

Patients underwent a preoperative digital panoramic exam, subsequently used as baseline. Computed tomography scan was also required to investigate antral anatomy (Figure 1A and B).

One to seven days before surgical procedure, full mouth professional prophylaxis appointment was scheduled.

Patients were covered with 1 g penicillin clavulanate 1 day prior to surgery and continued with 2 g per day for

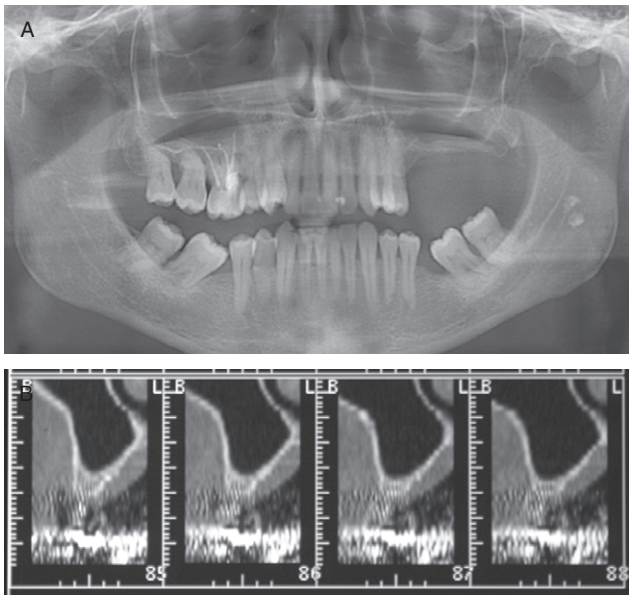


**Figure 1** (A) Preoperative digital panoramic exam. (B) Preoperative computed tomography scans.

6 days. Penicillin-allergic patients received 450 mg clindamycin. Immediately before surgery, patients underwent a 3-minute mouth rinse with 0.2% chlorhexidine gluconate.

## Surgical Technique

The sinus area was prepared under local anesthesia, as described by Boyne and James.[1] The bony window was left attached to the Schneiderian membrane. The sinus mucosa was elevated taking care not to lacerate.

Minimal perforations of sinus membrane occurred in four cases. They were repaired using a collagen membrane.

Implant sites were marked using a surgical template. In order to increase primary stability, osteotomies were performed using the narrower drill able to allow implant insertion avoiding buccal bone fractures. Residual bone height was assessed using a modified probe with a small hood. Then the graft material (Nanobone, Artoos, Rostock, Germany) was placed in the superior aspect of the sinus and against the medial aspect of the grafted compartment created in the sinus cavity. The graft material was meticulously condensed at every stage.

Then, one to three 13-mm long wide diameter (4.3, 4.8, and 5.5 mm in diameter) implants (Sweden & Martina, Padua, Italy) were placed with a torque value >10 N. The root-shaped implant used had full length sand-blasted and acid-etched surface. In the coronal zone, mini-threads are present to better distribute stress and achieve a better primary stability, while the apical portion presents with an oval design.

No membrane was used to cover the buccal window (Figure 2).

The oral mucosa was sutured with interrupted sutures resorbable, 5.0 size.

## Postoperative Treatment

Patients were instructed to avoid blowing their noses for at least 7 days after surgery and to cough or sneeze with an open mouth to prevent increased pressure in the operated sinus.

Patients underwent a new digital panoramic exam for postoperative evaluation.

## Second Stage Procedure and Follow-Up Evaluation

Second-stage surgery to expose the implants was performed 3 months after implant placement. Performing a minimal crestal incision just over the area corresponding to the implant, cover screws were exposed and

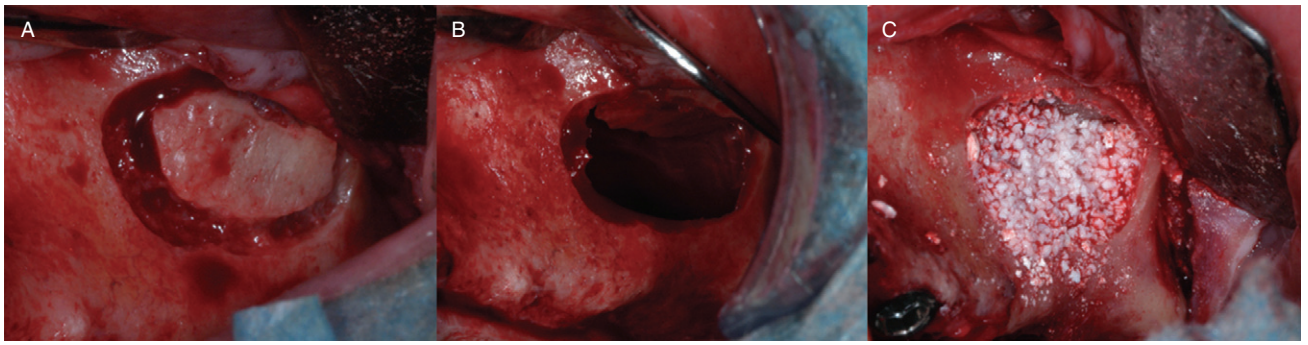


**Figure 2** Following the limits of the sinus, a bone window was outlined along the sinus edge with a round diamond bur (2000 rpm) under copious irrigation (A). Sinus mucosa elevated taking care not to lacerate. The bone in the center of the window was left attached to the Schneiderian membrane (B). Implants inserted and Nanobone graft material compacted in the sinus cavity (C).

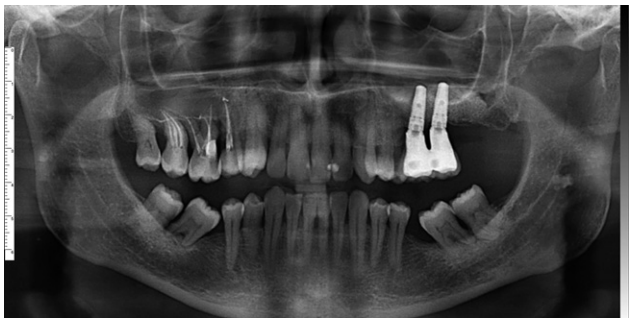

**Figure 3** Twenty-four months after prosthetic loading digital panoramic exam.

removed. Attached keratinized mucosa was left both on the palatal and buccal aspect around all implants.

An impression was taken using a standard (3.8 mm) coping transfer. Standard diameter (3.8 mm) healing abutments were screwed at 10 N.

Clinical evaluation criteria at the time of implant exposure included stability in all directions, eventual crestal bone resorption, and any reported pain or discomfort.

One week later, using platform switching prosthetic concept, standard (3.8 mm) titanium abutments were screwed at 32 N and provisional restoration were seated. Splinted crowns were adopted in order to allow better occlusal forces distribution. In case of multiple implant rehabilitation, implants inserted in residual neighboring bone without augmentation were not splinted to the ones inserted in augmented bone.

One week later, definitive crowns were cemented using provisional cement (Temp Bond, Kerr, Orange, CA, USA).

Twenty-four months after prosthetic loading, digital panoramic exam was obtained to assess the newly formed bone and its interface with the implant (Figure 3).

## Implant Stability Measurements

Immediately after implant insertion ($T_0$), resonance frequency analysis (RFA, Osstell, Mentor, Goteborg, Sweden) for each implant was carried out and values were used as baseline. The transducer (type 48; Osstell transducer, Goteborg, Sweden) was hand-screwed into the implant body as recommended by manufacturer. The RFA value is represented by a quantitative parameter called implant stability (ISQ). The ISQ ranges between 1 and 100. The measurements were repeated for each implant after 13 weeks ($T_1$) and 24 months after prosthetic loading ($T_2$) (Figure 4).

Each measurement was taken twice and the mean value was used. The measurements were calibrated using a calibration block because each transducer has a unique fundamental resonance frequency.

## Radiographic Evaluation

The patients' grafted volume was evaluated with a computerized measuring technique applied to digital panoramic radiographs. In each case, the surface of grafted sinus was marked with a virtual marking instrument. An image analysis software application (Autocad 2006, version Z 54.10, Autodesk, San Rafael, CA, USA) calculated the grafted bone height changes at level of implant site comparing pre-operative and follow-up panoramic films; the software had the ability to compensate for eventual radiographic distortion.[14,15]

All measurements were conducted and collected by the same trained independent examiner, without input from the implant surgeon.

## Statistical Analysis

Descriptive statistics including mean values and standard deviation (SD) were used to describe changes of implant stability over the time.

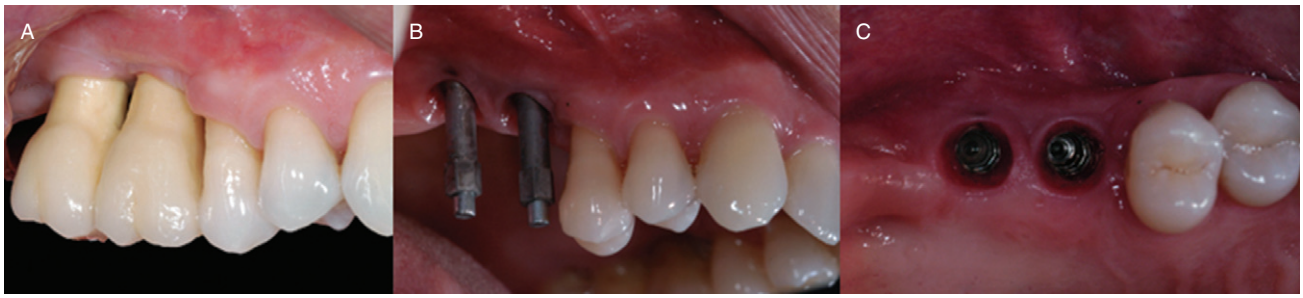


**Figure 4** Buccal clinical overview (A). Implant stability quotient measurement after 24 months of prosthetic loading using Osstell smart-pegs (B). Clinical aspect of peri-implant soft tissues around implants restored using platform switching concept: no inflammatory signs could be detected in the so called "walling off function tissues" overlaying implant platform not covered by the abutment (C).

Two-tailed Pearson tests were used to detect any correlation between ISQ values and preoperative height, postoperative height, and implant diameter.

Pearson's correlation test is used to test the relationships between variables. The hypotheses for this test are: $H_0$: rho = 0 versus $H_1$: rho <> 0. A low *p*-value for this test means that there is evidence to reject the null hypothesis in favor of the alternative hypothesis, or that there is a statistically significant relationship between the two variables.

One-way analysis of variance with repeated measures was performed to test the significant difference between ISQ values at at $T_0$, $T_1$ and $T_2$. The test assumes the sphericity (that is, repeated measures are uncorrelated and have equal variance). Sphericity can be tested using the Mauchly test in SAS; in this case the violation of the sphericity assumption is verified so *F*-test is not valid. Wilks lambda is recommended; the null hypothesis is that means are equal versus the alternative hypothesis that at least two of the means differ from each other.

## RESULTS

A total of 30 patients (16 female and 14 male) were treated. The mean age was 58.3 years (SD: 11.05). No patient dropped out during the study.

Preoperative residual bone level ranged between 1 and 4 mm (mean value of 2.70 mm, SD: 0.93). The healing period following sinus augmentation was without complication for every patient. Minor nosebleeds occurred in one case. No clinical symptoms of maxillary sinusitis occurred in any patient.

Nine patients referred to be light smokers (<10 cig/day). Although they were informed about the negative effects of smoking on bone regeneration, none stopped their habit.

A total of 67 totally rough-surfaced wide-diameter implants were inserted in extremely resorbed posterior maxillae in this study. Two implants were mobilized during the uncovering procedure in two different patients, both mild smokers. For the failed implant, preoperative height was respectively 2 and 3 mm, implant diameter was 4.3 mm for both and ISQ values at $T_0$ was 29 and 22. Both patients did not refer any symptom during the healing period.

Implants were substituted using 4.8 m in diameter implants at the same surgical stage, restored after additional 3 months of healing.

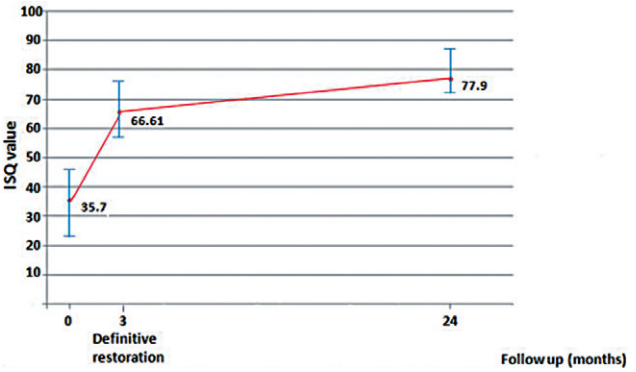


**Figure 5** Graph of mean implant stability quotient values at $T_0$ (time of surgery), $T_1$ (reopening procedure), and $T_2$ (24 months after prosthetic loading). Statistically significant differences were found between groups. ISQ = implant stability quotient.

All other implants resulted to be osseointegrated after 24 months of prosthetic loading (cumulative survival rate: 97.01%).

The mean value of radiographic vertical height of grafted sinus floor was 13.75 (SD: 1.3 mm) after 24 months of prosthetic loading.

At baseline ($T_0$), ISQ mean value was 35.7 (SD: 8.8). ISQ $T_1$ mean value was 66.6 (SD: 4.7). ISQ $T_2$ mean value was 75.9 (SD: 4.7) (Figure 5).

Statistically significant differences ($p \leq 0.05$) regarding ISQ mean values were found between $T_1$ and baseline as well as between $T_1$ and $T_2$.

About correlation between ISQ values and preoperative height, postoperative height and implant diameter, results are as follows:

For 2 years ISQ and preoperative height, the test allows to accept $H_0$ hypothesis, that is, there is no significant relationship from the two variables (rho = 0.021, *p*-value = 0.32).

For 2 years ISQ and postoperative height, the test allows to reject $H_0$ hypothesis, that is, there is significant relationship between the two variables (rho = –0.396, *p*-value = 0.045) and the relationship between the two variables is inverse.

For 2 years ISQ and implant diameter, the test allow to accept $H_0$ hypothesis, that is there is no significant relationship between the two variables (rho = 0.296, *p*-value = 0.142).

About the difference between ISQ values at $T_0$, $T_1$ and, $T_2$, Wilks lambda test allow to reject the null hypothesis in favor of the alternative hypothesis (Wilks' lambda [2.63] = 0.05; $F = 593.81$; $p < 0.0001$) that is a

statistically significant difference exists between ISQ values in different times.

## DISCUSSION

This prospective multicenter study demonstrated the possibility of achieving osseointegration and stability of completely rough-surfaced implants when placed in maxillary sinuses previously grafted with a nano-crystalline hydroxyapatite even in critical conditions.

The graft material investigated in this study is a nano-sized hydroxyapatite embedded in a highly porous matrix of silica gel. The nano-structure produces a large, bioactive surface (84 $m^2/g$), and presents a microporosity size ranging from 10 to 20 nm. This configuration seems to be able to induce migration, adhesion, and proliferation of osteblasts inside the pore network, and to promote angiogenesis inside.[11]

Nano-crystalline hydroxyapatite bone substitution material has been successfully introduced for augmentation treatment in recently published studies in humans and animals.[11–13,16–18]

Although most authors admit that the interpretation of results reported in literature regarding sinus lift are difficult, Del Fabbro et al.[19] showed the residual bone crestal height as one of most critical factors influencing implant survival rate.

Dental implant placement associated with augmentation of the sinus floor in an atrophic maxilla can be performed in one or two surgical stages, depending on the height of the residual alveolar bone. In a one-stage procedure, a minimum base height of 4 to 5 mm is recommended for adequate implant stabilization and parallelism. A two-stage approach is performed when there is insufficient residual bone. This allows healing of the graft material for future implant sites.

However, according to Peleg et al.,[20] despite of a severely resorbed maxilla, a one-stage surgical technique has been adopted in the present study.

Despite the bone crest being 1 to 4 mm in height, only two implants failed at the time of the second surgery. In fact, implant survival rate was 97.01% after 24 months of loading, according to the results obtained by Fugazzoto[21] in his retrospective report, and according to Wallace[22] and Del Fabbro[19] in their review.

The fixture macro- and micro-topography maybe considered as a co-factor in this high implant survival rate, as they have been associated to the formation of a superficial fibrin network, which could theoretically enhance the initial stability of the bone/implant interface.[23,24]

According to Hermann,[25] moreover, micro-rough titanium surface extending to the implant shoulder, in conjunction with platform switching, concept provides osseous integration along the entire length of the implant.

Furthermore, in their systematic review, Wallace and Froum[22] indicated membrane placement over the lateral window as an important factor to improve regenerated bone quality. An absorbable collagen membrane placed on the buccal sinus wall seemed to prevent the graft from soft tissue invasion, which would reduce the amount and the quality of the *de novo* formed mineralized tissue.[26,27] This data was also confirmed by a very recently published systematic review.[28] In this study, Pjetursson showed, in fact, an annual implant failure rate significantly higher (4.0% versus 0.7%) when no membrane was used to cover the lateral window after the grafting procedure.

However, our results showed that, if using the nano-structured hydroxyapatite, a membrane might not be a critical factor for implant survival rate.

This study on sinus lift implant loading was scheduled 3 months after the first surgery because of the proven high osteoconductive surface of the bone filler.

Regarding the correct healing time, reviews suggested that an acceptable healing period for grafted sinus procedures ranged between 6 to 9 months.[29,30]

In a clinical retrospective long term study, Mardinger et al.[31] showed that for sinus lift procedures carried out in severely resorbed maxillae, using bovine bone matrix as only graft material and rough-surfaced implants, the healing period ranged from 5 to 11 months (mean value 6.6 months, SD: 1.4). The implant survival rate was 95.1%.

Similar results were found by Peleg et al.[20] The authors showed that the survival rate in severely atrophic maxillae was 94.6% for implants in residual bone with heights of 1 to 2 mm after 6 to 10 months of healing time.

On the other hand, Hallman et al.[32] concluded that, after meanly 6 months of healing, a mixture of Bio-Oss (80%) and bone chips (20%) grafted in severely resorbed maxillae gave a cumulative survival rate lower than 90%.

Gotz et al.[11] showed that Nanobone is integrated by the host's physiological bone turnover after 3 months; furthermore this study demonstrated that prosthetic loading after early healing is a reliable option in association with sinus lift procedures, even in critical conditions. In fact, although early loading, minimal residual bone crest height and absence of membrane placement to occlude lateral, only two implants resulted lost at the end of our study.

Furthermore, a mean value of 13.75 mm (SD: 1.3 mm) in postoperative vertical height was detected with a gain of 11.05 mm.

A study by Schwartz et al.[15] used digital panoramic radiographs in a similar manner to our protocol; in fact, maintaining the same exposure set, augmented sinus heights were measured preoperatively and 24 months after prosthetic loading, and using software that is able to compensate for eventual distortions, baseline was compared to follow-up assessment.

Despite of largely resorbed maxillas, no complications from a surgical point of view occurred when the implants were inserted simultaneously with the graft material. Conversely, Mardinger et al.[31] described problems during the surgical phase in sinus augmentation in patients with a 1- to 4-mm residual bone height; this variation might be explained by the use of wide diameter implants that allowed for sufficient primary stability[33] in our study.

An additional reason for the selection of wider implants is the reduction of peri-implant bone resorption at the time of restoration. In fact, the use of the platform switching prosthetic concept might have preserved peri-implant bone from further resorption during the first months of loading.[34] This should theoretically allow the graft material to mature for a longer period. Platform switching is a prosthetic concept accepted in literature that minimizes the post-restorative peri-implant bone remodeling.[35] Bone resorption is supposed to be strictly correlated to the so-called "biologic width re-establishment," following bacterial invasion of the implant/abutment interface.[36] This biologic process is altered when a wider implant is restored using a narrower abutment; the horizontal gap resulting from this mismatching seems to move the infection away from the vital bone, minimizing the effect of "biologic width re-establishment."[37]

Resonance frequency analysis, with a baseline ISQ mean value of (35.7, SD: 8.8), demonstrated a poor primary stability. However, a correlation between implant diameter, preoperative bone height, and ISQ was not found. This, might probably be explained by the different bone qualities found at the implant insertion stage.

Although the mean value at $T_0$ was very low, data reported at $T_1$ (ISQ: 66.6, SD: 4.7) is in line with previously reported figures. In fact, Lai et al.[38] reported, for rough-surfaced implants installed after minor sinus floor elevation, ISQ values ranging between 66.8 and 69.2 12–16 weeks after surgery.

The statistically significant increase of ISQ values between $T_0$ and $T_1$ could evidence fast maturation of the graft in within a 3-month period.

Additional increase between $T_1$ and $T_2$ could highlight, after 24 months of prosthetic loading, a further maturation of the material.

The RFA results seem to confirm histological outcomes reported in the above-mentioned publications regarding the material adopted in this study.

Short observation period, limited number of patients, meticulous surgical technique, prosthetic monitoring, and strict periodontal care at the follow-up appointments could be indicated as the most important co-factors of the high success rate observed in this study. However, within the limits of this prospective study, the clinical outcomes obtained might allow to state that, when using totally rough implants, the observed nanocrystalline hydroxyapatite could be effective also in critical condition such as: early loading, absence of membrane on the buccal wall and low residual bone height in maxillary sinus lift procedures. Nevertheless, the results obtained are to be confirmed by histological and clinical studies using a split-mouth design or clinical randomized controlled trials comparing nanocrystalline hydroxyapatite to autogenous bone.

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## REFERENCES

1. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980; 38:613–616.

2. Cordaro L. Bilateral simultaneous augmentation of the maxillary sinus floor with particulated mandible. Report of a technique and preliminary results. Clin Oral Implants Res 2003; 14:201–206.
3. Kalk WW, Raghoebar GM, Jansma J, Boering G. Morbidity from iliac crest bone harvesting. Int J Oral Maxillofac Implants 2007; 22:359–365.
4. Maiorana C, Redemagni M, Rabagliati M, Salina S. Treatment of maxillary ridge resorption by sinus augmentation with iliac cancellous bone, anorganic bovine bone, and endosseous implants: a clinical and histologic report. Int J Oral Maxillofac Implants 2000; 15:873–878.
5. Cammack GV, Nevins M, Clem DS, Hatch JP, Mellonig JT. Histologic evaluation of mineralized and demineralized freeze-dried bone allograft for ridge and sinus augmentations. Int J Periodontics Restorative Dent 2005; 25:231–237.
6. Galindo-Moreno P, Avila G, Fernández-Barbero JE, et al. Evaluation of sinus floor elevation using a composite bone graft mixture. Clin Oral Implants Res 2007; 18:376–382.
7. Karabuda C, Ozdemir O, Tosun T, Anil A, Olgaç V. Histological and clinical evaluation of 3 different grafting materials for sinus lifting procedure based on 8 cases. J Periodontol 2001; 72:1436–1442.
8. Ewers R, Goriwoda W, Schopper C, Moser D, Spassova E. Histologic findings at augmented bone areas supplied with two different bone substitute materials combined with sinus floor lifting. Report of one case. Clin Oral Implants Res 2004; 15:96–100.
9. Zerbo IR, Zijderveld SA, de Boer A, et al. Histomorphometry of human sinus floor augmentation using a porous beta-tricalcium phosphate: a prospective study. Clin Oral Implants Res 2004; 15:724–732.
10. Vikram D, Nather A, Kalid KA. Role of ceramics as bone graft substitutes. In: Nather A, ed. Bone graft and bone substitutes. Basic science and clinical applications. Hackensack, NJ: World Scientific, 2005:445–458.
11. Gotz W, Gerber T, Michel B, Lossdorfer S, Henkel K-O, Heinemann F. Immunohistochemical characterization of nanocrystalline hydroxyapatite silica gel (NanoBones) osteogenesis: a study on biopsies from human jaws. Clin Oral Impl Res 2008; 19:1016–1026.
12. Canullo L, Dellavia C. Sinus lift using a nanocrystalline hydroxyapatite silica gel in severely resorbed maxillae: histological preliminary study. Clin Implant Dent Relat Res 2009. [Epub ahead of print]
13. Canullo L, Vozza I, Dellavia C. Maxillary sinus floor augmentation using a nano-crystalline hydroxyapatite silica gel a prospective study – histological results after 3 months of healing. Implants 2009; 2:272–277.
14. Hatano N, Shimizu Y, Ooya K. A clinical long-term radiographic evaluation of graft height changes after maxillary sinus floor augmentation with a 2:1 autogenous bone/xenograft mixture and simultaneous placement of dental implants. Clin Oral Implants Res 2004; 15:339–345.
15. Schwartz Z, Goldstein M, Raviv E, Hirsch A, Ranly DM, Boyan BD. Clinical evaluation of demineralized bone allograft in a hyaluronic acid carrier for sinus lift augmentation in humans: a computed tomography and histomorphometric study. Clin Oral Implants Res 2007; 18:204–211.
16. Artzi Z, Nemcovsky CE, Dayan D. Nonceramic hydroxyapatite bone derivative in sinus augmentation procedures: clinical and histomorphometric observations in 10 consecutive cases. Int J Periodontics Restorative Dent 2003; 23:381–389.
17. Thorwarth M, Schultze-Mosgau S, Kessler P, Wiltfang J, Schlegel KA. Bone regeneration in osseous defects using a resorbable nanoparticular hydroxyapatite. Int J Oral Maxillofac Implants 2005; 63:1626–1633.
18. Strietzel FP, Reichart PA, Graf HL. Lateral alveolar ridge augmentation using a synthetic nano-crystalline hydroxyapatite bone substitution material (Ostim): preliminary clinical and histological results. Clin Oral Implants Res 2007; 18:743–751.
19. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in the grafted maxillary sinus. Int J Periodontics Restorative Dent 2004; 24:565–577.
20. Peleg M, Garg AK, Mazor Z. Predictability of simultaneous implant placement in the severely atrophic posterior maxilla: a 9-year longitudinal experience study of 2132 implants placed into 731 human sinus grafts. Int J Oral Maxillofac Implants 2006; 21:94–102.
21. Fugazzotto PA, Vlassis J. Report of 1633 implants in 814 augmented sinus areas in function for up to 180 months. Implant Dent 2007; 16:369–378.
22. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. Ann Periodontol 2003; 8:328–343.
23. Shalabi MM, Gortemaker A, Van't Hof MA, Jansen JA, Creugers NH. Implant surface roughness and bone healing: a systematic review. J Dent Res 2006; 85:496–500.
24. Rompen E, Domken O, Degidi M, Farias Pontes AE, Piattelli A. The effect of material characteristics, of surface topography and of implant components and connections on soft tissue integration: a literature review. Clin Oral Implants Res 2006; 17:55–67.
25. Hermann F, Lerner H, Palti A. Factors influencing the preservation of the periimplant marginal bone. Implant Dent 2007; 16:165–175.
26. Tawil G, Mawla M. Sinus floor elevation using a bovine bone mineral (Bio-Oss) with or without the concomitant use of a bilayered collagen barrier (Bio-Gide): a clinical report of immediate and delayed implant placement. Int J Oral Maxillofac Implants 2001; 16:713–721.

27. Carmagnola D, Adriaens P, Berglundh T. Healing of human extraction sockets filled with Bio-Oss. Clin Oral Implants Res 2003; 14:137–143.
28. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. J Clin Periodontol 2008; 35(8 Suppl):216–240.
29. Yildirim M, Spiekermann H, Biesterfeld S, Edelhoff D. Maxillary sinus augmentation using xenogenic bone substitute material Bio-Oss in combination with venous blood. A histologic and histomorphometric study in humans. Clin Oral Implants Res 2000; 11:217–229.
30. Yildirim M, Spiekermann H, Handt S, Edelhoff D. Maxillary sinus augmentation with the xenograft Bio-Oss and autogenous intraoral bone for qualitative improvement of the implant site: a histologic and histomorphometric clinical study in humans. Int J Oral Maxillofac Implants 2001; 16:23–33.
31. Mardinger O, Nissan J, Chaushu G. Sinus floor augmentation with simultaneous implant placement in the severely atrophic maxilla: technical problems and complications. J Periodont 2007; 78:1872–1877.
32. Hallman M, Sennerby L, Zetterqvist L, Lundgren S. A 3-year prospective follow-up study of implant-supported fixed prostheses in patients subjected to maxillary sinus floor augmentation with a 80:20 mixture of deproteinized bovine bone and autogenous bone clinical, radiographic and resonance frequency analysis. Int J Oral Maxillofac Implants 2005; 34:273–280.
33. Turkyilmaz I, Aksoy U, McGlumphy EA. Two alternative surgical techniques for enhancing primary implant stability in the posterior maxilla: a clinical study including bone density, insertion torque, and resonance frequency analysis data. Clin Implant Dent Relat Res 2008; 10:231–237.
34. Vigolo P, Givani A. Platform-switched restorations on wide-diameter implants: a 5-year clinical prospective study. Int J Oral Maxillofac Implants 2009; 24:103–109.
35. Cappiello M, Luongo R, Di Iorio D, Bugea C, Cocchetto R, Celletti R. Evaluation of peri-implant bone loss around platform-switched implants. Int J Periodontics Restorative Dent 2008; 28:347–355.
36. Broggini N, McManus LM, Hermann JS, et al. Peri-implant inflammation defined by the implant-abutment interface. J Dent Res 2006; 85:473–478.
37. Rodríguez-Ciurana X, Vela-Nebot X, Segalà-Torres M, et al. The effect of interimplant distance on the height of the interimplant bone crest when using platform-switched implants. Int J Periodontics Restorative Dent 2009; 29:141–151.
38. Lai H, Zhang Z-Y, Wang F, Zhuang L-F, Liu X. Resonance frequency analysis of stability on ITI implants with osteotome sinus floor elevation technique without grafting: a 5-month prospective study. Clin Oral Impl Res 2008; 19:469–475.