In the last decade, some investigations have reported that the resorbable blast media surface (also named CaPO$_4$ blasted implants [CaPO$_4$-BIs]) has achieved excellent results. However, no report regarding CaPO$_4$-BIs inserted into fresh frozen bone (FFB) is available. Thus, we planned a retrospective study on a series of CaPO$_4$-BIs inserted into FFB to evaluate their clinical outcome. In the period between December 2003 and December 2006, 16 patients (10 females and 6 males, median age of 55 years) were operated on, and 76 CaPO$_4$-BIs were inserted. The mean implant follow-up was 23 months. Implant diameter and length ranged from 3.25 to 4.5 mm and from 11.5 to 15 mm, respectively. Implants were inserted to replace 7 incisors, 11 cuspids, 31 premolars, and 27 molars. Only 1 out of 76 implants was lost (ie, survival rate [SVR] = 98.7%), and no differences were detected among the studied variables. When peri-implant crestal bone resorption was used as an indicator of clinical success (ie, success rate), it was possible to identify some variables that correlated with a better clinical outcome. Specifically, Cox regression showed that removable prosthetic restoration and longer implant length correlated with a statistically significant lower delta implant abutment junction (IAJ; ie, reduced crestal bone loss) and thus a better clinical outcome. In this study, CaPO$_4$-BIs had high survival and success rates, similar to those reported in previous reports of 2-stage procedures in nongrafted bone. CaPO$_4$-BIs inserted into FFB are reliable devices, although greater marginal bone loss occurs when fixed prosthetic restorations and short implants are used.

Key Words: iliac crest, allograft, homograft, dental implant

INTRODUCTION

Craniofacial “skeletal” defects ideally should be corrected with autologous bone or cartilage by replacement or augmentation. Although autografts are the standard procedure for bone grafting, it sometimes is not possible to harvest bone and collect an adequate amount of bone from other donor sites in the same patient.

Moreover, autologous bone grafts have the drawback of requiring secondary surgery for autograft retrieval, with increased operation time, anesthesia, and donor site morbidity. On the other hand, biomaterials are good but costly and may exfoliate at a later date. So, the use of allograft bone provides a reasonable alternative to meet the need for graft material.

Bone allograft has been used in humans for more than 100 years, and its use by orthopedic surgeons is increasing. Many forms of banked bone allografts are available to the surgeon, including fresh frozen bone (FFB), freeze-dried bone (FDB), and demineralized fresh dried bone (DFDB). Each of these grafts carries risks and has unique limitations and handling properties. To use these materials appropriately, the surgeon must be familiar with the properties of each and must feel confident that the bone bank providing the graft is supplying a safe and sterile graft.
The concept of osseointegration, that is, the direct anchorage of endosseous implants made of commercially pure or titanium alloy to the bone has caused a breakthrough in oral rehabilitation. The identification of factors that influence the number of total implants still in place at the end of the follow-up, also named survival rate (SVR), and the clinical and radiologic outcomes, also named success rate (SCR), are the main goals of implantologists. Several variables can influence the final result, but in general, these can be grouped as (1) surgical, (2) host, (3) implant, and (4) prosthetic-related factors.

The surface of the implant is one factor. The resorbable blast media (RBM) surface (also named CaPO$_4$ blasted implants (CaPO$_4$-BIs)) is roughened with the use of biocompatible calcium phosphate ceramic medium, which is fully resorbable, permitting its removal after manufacture. The result is a clean, textured, pure titanium surface. The roughening process does not involve acid etching; thus, the RBM implant surface is, by definition, free from acid etching residues. It also is not susceptible to the titanium grain boundary degradation that can occur during aggressive acid etching procedures. Previous studies on nongrafted jaws have reported a high survival rate after 50 months for 1077 implants placed in 348 patients: 950 in the mandible and 127 in the maxilla. Seven failures, all in the mandible, occurred before 50 months for 1077 implants placed in 348 patients: 950 in the mandible and 127 in the maxilla. Second-stage surgery was performed. FFB has an increasing number of clinical applications, and no studies on CaPO$_4$-BIs have been reported; therefore, this retrospective study was conducted.

**MATERIALS AND METHODS**

In the period between December 2003 and December 2006, 81 patients (52 women) with a median age of 52 years were operated on at the Civil Hospital, Castelfranco Veneto, Italy. A total of 16 patients (10 women) with a median age of 55 years were treated with CaPO$_4$-BIs. Informed written consent approved by the local Ethics Committee was obtained from patients to use their data for research purpose. The mean implant follow-up was 23 months.

Homologue FFB grafts were previously inserted into the patient’s jaws while he or she was under general anesthesia. The mean postgrafting period was 6 months before implant surgery, and the final prosthetic restoration was delivered 6 months later.

Subjects were screened according to the following inclusion criteria: controlled oral hygiene (overall plaque score <20%), absence of any pathologic lesions in the oral cavity (such as lichen, leukoplakia, and erythroplakia), and sufficient residual bone volume (autologous plus FFB graft) to receive implants of at least 3.25 mm in diameter and 11.5 mm in length; in addition, patients had to agree to participate in a postoperative follow-up program with bimonthly recall during oral rehabilitation and every 6 months thereafter.

Exclusion criteria were as follows: insufficient bone volume, patients with bruxism, smoking more than 20 cigarettes/day or drinking more than a liter of wine per day, localized radiation therapy of the oral cavity, antitumor chemotherapy, liver, blood, and kidney diseases, immunosuppressed patients, patients taking corticosteroids, pregnant women, inflammatory and autoimmune diseases of the oral cavity, and poor oral hygiene.

The FFB, which was obtained from the Veneto Tissue Bank in Treviso, Italy, is a mineralized, nonirradiated, disinfected, and frozen homologous bone. The bone was harvested from the anterior and posterior iliac crest, within the first 12 hours postmortem. The bone then was disinfected for 72 hours at $-4^\circ$C, in a polychemotherapeutic solution of vancomycin, polymyxin, glazidine, and lincomycin, after which the sample was irrigated with a sterile saline solution. The sample then was divided into cortico-medullary blocks, packed in double sterile casing, and frozen at $-80^\circ$C.

The requirements for homologous bone donors are more stringent with respect to those of organ donors. The presence of risk factors such as contagious disease, neoplasm, rheumatic and/or degenerative disease, and sepsis disqualifies donors. To detect infectious agents, the following tests were performed on donor blood samples taken within 8 hours of death: anti–human immunodeficiency virus (HIV)-I/II antibody (Ab), anti–hepatitis C virus (HCV) Ab, hepatitis B surface antigen (HbsAg), antibody to hepatitis B core antigen (anti-HBc) Ab, anti–hepatitis B surface antigen (HbsAb) Ab, anti–human T-lymphotropic virus (HTLV)-I/II Ab, anti-Ag Treponemal Ab, anti-cytomegalovirus (CMV) immunglobulin G (IgG) Ab, anti-CMV IgM Ab, anti-Toxoplasma IgG Ab, and anti-Toxoplasma IgM Ab. A culture is also performed to detect aerobic and anaerobic bacteria, mycobacteria, and mycotic agents. As a further safety method, serologic follow-up is conducted with the use of polymerase chain reaction techniques to detect any viral RNA or DNA of HIV, HCV, and hepatitis B virus (HBV). This method reduces the “diagnostic window period” to 7 days for HIV, HCV, and HBV.

Prior to surgery, radiographic examinations were performed with the use of orthopantomograph and...
computed tomography (CT) scans. In each patient, peri-implant crestal bone levels were evaluated through calibrated examination of ortopantomograph x-rays. Measurements were recorded before surgery, after surgery, and at the end of the follow-up period. Measurements were carried out mesially and distally to each implant, and the distance between the edge of the implant and the most coronal point of contact between the bone and the implant was calculated. The bone level recorded just after surgical insertion of the implant was the reference point for the following measurements. The measurement was rounded off to the nearest 0.1 mm. A peak scale loupe with a magnifying factor of 7 times and a scale graduated in 0.1 mm was used. Peri-implant probing was not performed because controversy still exists regarding the correlation between probing depth and implant success rates.\(^\text{10,11}\) The implant success rate (SCR) was evaluated according to the following criteria: (1) absence of persisting pain or dysesthesia; (2) absence of peri-implant infection with suppuration; (3) absence of mobility; and (4) absence of persisting peri-implant bone resorption greater than 1.5 mm during the first year of loading and 0.2 mm/yr during the following years.\(^\text{12}\)

A total of 76 RBM implants were inserted into 16 patients: 15 in the mandible and 61 in the maxilla. Implant diameter and length ranged from 3.25 to 4.5 mm and from 11.5 to 15 mm, respectively. Implants were inserted to replace 7 incisors, 11 cuspids, 31 premolars, and 27 molars.

All patients underwent the same surgical protocol. An antimicrobial prophylaxis was administered with 500 mg amoxicillin twice a day for 5 days starting 1 hour before surgery. Local anesthesia was induced by infiltration with articaine/epinephrine (1:100.000), and postsurgical analgesic treatment was performed with 100 mg Nimesulid twice daily for 3 days. Oral hygiene instructions were provided.

After a crestal incision was made, a mucoperiosteal flap was elevated. Implants were inserted according to the procedures recommended. The implant platform was positioned at the alveolar crest level. Sutures were removed 14 days after surgery. After 24 weeks from the time of implant insertion, the provisional prosthesis was provided, and the final restoration usually was delivered within an additional 8 weeks. The number of prosthetic units (ie, the implant/crown ratio) was about 0.6. All patients were included in a monthly hygiene recall.

The Kaplan-Meier algorithm\(^\text{13}\) and Cox regression analysis\(^\text{14}\) were applied on the global number of implants still in place at the end of the observation period (ie, survival rate [SVR]). In addition, the same statistical analyses were applied to an indicator of clinical success (ie, SCR) that was the peri-implant crestal bone resorption. Specifically, the difference between the implant abutment junction and the crestal bone level was defined as the implant abutment junction (IAJ) and was calculated at the time of operation and during follow-up. The delta IAJ is the difference between the IAJ at the last checkup and the IAJ recorded just after the operation. The delta IAJ medians were stratified according to the variables of interest.

Disease-specific survival curves were calculated according to the product-limit method (Kaplan-Meier algorithm).\(^\text{13}\) Time zero was defined as the date of insertion of the implants that were still in place and were included in the total number at risk for loss only up to the time of last follow-up. The calculated survival rate was the maximum estimate of the true survival curve. Log rank testing was used to compare survival curves, generated by stratifications for a variable of interest. Cox regression analysis then was applied to determine the single contribution of covariates to survival rate.\(^\text{14}\) Stepwise Cox analysis allowed us to detect the variables most often associated with implant survival and/or success.

### RESULTS

Because only 1 out of 76 implants was lost (SVR = 98.7%), no statistical differences were detected among the studied variables when the survival rate was used. Consequently, the degree of crestal bone resorption was considered an indicator of SCR and was used to explore the effect of several host-, implant-, and occlusion-related factors on clinical outcome.

Tables 1 to 5 report the median delta IAJ according to the studied variables. Graft site (Table 1) did not show any difference between mandible and maxilla and between implant site and diameter (Tables 2 and 4). Crestal bone resorption ranged from 1.6 to 1.9 mm. Implant length (Table 3) demonstrated a worse outcome for short implants, whereas fixed restoration...
demonstrated a better outcome compared with removable dentures (Table 5).

One implant was lost during the postoperative period (within 6 months): it was 3.75 wide and 13 mm long; it was placed to restore an upper left first molar and was never loaded.

Table 6 shows that removable prostheses and 13-mm-long implants correlated with a statistically significant lower delta IAJ and thus better clinical outcomes.

**DISCUSSION**

In the present study, several variables that may influence the SVR and SCR of CaPO₄-BIs were analyzed. Because only 1 out of 76 implants was lost, no statistical differences were detected among studied variables with the use of “failed implants.” When peri-implant crestal bone resorption was used as an indicator of clinical success, it was possible to identify some variables that have an impact on crestal bone remodeling. Table 6 summarizes the outcomes of multivariate analysis. Cox regression analysis compared success data while taking into account the statistical value of independent variables, such as age and sex, for whether or not an event (ie, the overcoming of a conventional cut-off of crestal bone resorption around the implant neck, normalized for a number of years of follow-up) is likely to occur. Variables associated with a P value lower than .05 were considered statistically significant.

In general, length (Table 3) and diameter (Table 4) are considered to be relevant fixture-related factors. In the present study, we obtained statistically significant lower crestal bone resorption for 13-mm-long implants (Table 6). Worse outcomes detected for shorter implants could be due to the smaller surfaces onto which the load was distributed, whereas additional studies are needed to verify the poorer outcomes for longer fixtures.

Previous studies on RBM implants in nongrafted jaws have reported an SVR of about 99% at 50 months, showing that CaPO₄-BIs achieve a superior clinical outcome in standard conditions. In this study, similar results are reported for grafted jaws.

Bone quality, a host-related factor, is believed to be one of the strongest predictors of outcome. It is well known that the mandible has better bone quality than the maxilla, and this fact is probably the reason why several reports are available regarding immediately loaded implants inserted into the mandible with a high SVR. Our data demonstrate that FFB is a reliable grating material, as only 1 implant was lost. In addition, no differences were detected regarding graft and implant site.

Among occlusion-related factors, better results can be obtained with fixed prosthetic restorations (Table 6). This datum could be explained by the reduction of micromovement in fixed restoration compared with removable dentures. In fact, in immediate loading, one of the critical points is the reduction of micromovement in implants caused by splitting them with specific devices. In addition, implants without prosthetic restoration have significant crestal bone resorption. This fact could be due to the tendency of unloaded crestal bone to resorb. Additional studies on...
appropriate loading time for avoiding graft resorption are needed.

FFB is a reliable grating material for grafting jaws. RBM implants inserted into FFB have high survival and success rates, similar to those obtained in nongrafted alveolar crest. CaPO₄-BIs inserted into FFB can be considered reliable, although a higher marginal bone loss can be attained when removable dentures and short implants are used.

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**REFERENCES**


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**Table 6**

Output of the Cox regression reporting the variables associated statistically with delta IAJ (ie, success rate)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Significance (P &lt; .05)</th>
<th>95% Confidence Interval</th>
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<tr>
<td>Age</td>
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</tr>
<tr>
<td>Gender</td>
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</tr>
<tr>
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<td>Implant site</td>
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<tr>
<td>Implant length</td>
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<tr>
<td>Implant diameter</td>
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<tr>
<td>Type of restoration</td>
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<td>0.0288 0.4554</td>
</tr>
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</table>

IAJ, implant abutment junction.