Implant-Guided Vertical Bone Augmentation Around Extra-Short Implants for the Management of Severe Bone Atrophy

Eduardo Anitua, MD, DDS, PhD1,2*  
Alia Murias-Freijo, DDS, MPhil1  
Mohammad H. Alkhraisat, DDS, PhD2  
Gorka Orive, PhD2

The purpose of this study is to describe the conservative treatment of severe vertical bone atrophy by combining the insertion of extra-short implants and implant-guided bone augmentation. For that, a low-speed drilling protocol was selected to facilitate the collection of bone particles and to maintain graft osteogenic properties. Extra-short implants were incompletely inserted because of the severe atrophy, and the denuded implant surface was covered by autologous bone particles held together by the adhesive properties of plasma rich in growth factors. The surgical site was then covered with resorbable fibrin membrane, and the flap was repositioned and sutured. Eight patients with a mean residual bone height of 4.19 ± 0.97 mm were treated according to the described treatment protocol. The distance between the implant shoulder and the bony crest was 1.77 ± 0.18, 2.16 ± 0.23, and 1.97 ± 0.26 mm at the mesial, central, and distal aspects, respectively. Vertical bone augmentation resulted in the coverage of 85% of exposed surface by stimulating 1.6 ± 0.5 mm of supra-alveolar bone growth. All 10 extra-short implants placed were successfully osseointegrated. After a mean of 5 ± 1.6 months, provisional screw-retained prostheses were placed. Within the limitations of this study, we conclude that the minimally invasive approach described may successfully rehabilitate extreme vertical bone atrophy in the posterior mandible.

Key Words: vertical bone augmentation, bone atrophy, autologous bone, low-speed drilling, short implants, extra-short implants

INTRODUCTION

Oral rehabilitation of severely resorbed edentulous ridges is a challenging problem because of the reduced residual height and usually requires advanced bone augmentation, such as the use of bone blocks harvested from extraoral or intraoral donor sites. Such surgical treatment is associated with significant risk of morbidity and increases the cost and time necessary for providing implant-supported prosthesis.1 For that, clinicians are seeking minimally invasive alternatives that permit the completion of implant therapy at lesser surgical morbidity, in a shorter time, and at a lower cost.1,2 This resulted in the design of reduced-length implants that lower the volume of bone necessary to support the implant fixture and, thus, limit the need for advanced bone augmentation surgery.1

Although initially the use of short implants was associated with higher risk of failure,3 recent studies have proven that short implants are as successful as standard implants even after long periods of function.4-7 This could be the result of optimized clinical protocols and improved implant design that help to overcome the consequences of unfavorable crown to implant ratio and off-axis loading.1,8 Extra-short implants (length ≤ 6.5 mm) are indicated when residual bone height is < 7 mm, and several studies are now available on their efficiency in the treatment of severely atrophied residual ridges. Anitua et al1 reported a survival rate of 98.2% for 114 extra-short implants with a mean follow-up time of 26 months after loading. In another study, 6.3-mm-long implants showed an average peri-implant bone loss of 1.24 mm, which is comparable to standard implants placed after vertical bone augmentation.2

However, clinicians may face challenging situations where the residual bone height is insufficient to support even extra-short implants. In such extreme situation, the usual solution is to correct the deficiency with bone augmentation surgery. This has encouraged us to develop a clinical technique to obtain vertical bone growth around extra-short implants and make feasible the option of conservative rehabilitation of severely resorbed mandible with implant-supported prosthesis.

Supra-alveolar bone formation around dental implants was first reported by Simion et al9 and then corroborated by Jovanovic et al.10 The technique resulted in a gain of 3–4 mm of vertical bone growth. Studies on the type of grafting material showed that the adjuvant use of autologous bone, demineralized freeze-dried bone allograft, and anorganic bovine bone
improved the outcome of vertical bone augmentation and enhanced the predictability of the technique.\textsuperscript{11–16}

Several studies have observed better postoperative recovery (less inflammation and pain) in surgeries where autologous plasma rich in growth factors (PRGF) was used.\textsuperscript{17,18} The use of PRGF in endodontic surgery significantly improved patients’ quality of life; functional activities were less impaired and pain was significantly lower during the first 6 days after surgery.\textsuperscript{19} During bone augmentation surgery, covering the titanium mesh with fibrin membrane proved an efficient way to prevent mesh exposure and thus minimize the risk of failure due to graft infection.\textsuperscript{20}

In this study we describe implant-guided bone augmentation around extra-short implants for the treatment of posterior mandibular sites with severe resorption. The grafting material was autologous bone particles harvested from the drilling procedure and stored in autologous platelet-rich plasma. A resorbable fibrin membrane was used to cover the surgical site. Thus, this study aimed to evaluate surgical complications that may occur after the described technique was performed and to evaluate the amount of vertical bone augmentation that is achieved around the dental implants.

\section*{MATERIALS AND METHODS}

The patient database from a private clinic was analyzed retrospectively to identify patients with severe jaw atrophy, which was defined as the presence of a residual height $<7$ mm. Patients were enrolled in the study if they met the following criteria: residual height $<7$ mm; incomplete insertion of the extra-short implants, which was indicated by the presence of a vertical gap between the bone crest and the implant shoulder; and performance of implant-guided vertical bone growth. Patients who failed to meet any of these criteria were excluded from the study. The principal outcomes were the bone coverage of the denuded implant surface and dental implant osseointegration.

Preoperatively, residual bone height was determined by analyzing a cone-beam computerized tomography scan (Galileos 3D scanner (Bensheim, Hesse, Germany) and BTI scan), and the treatment plan was set to include the provision of an implant-supported prosthesis, insertion of at least one extra-short implant, and implant-guided bone augmentation. After the treatment plan was discussed with the patients, they gave informed consent.

\section*{Surgical procedure}

Patients received 1 g of acetaminophen 30 minutes before surgery and 2 g of amoxicillin (600 mg of clindamycin for patients allergic to amoxicillin) 60 minutes before surgery. Local anesthesia was achieved by inferior alveolar nerve block anesthesia and buccal infiltration anesthesia using articaine hydrochloride with epinephrine (1:100 000). A crestal incision was made to elevate a full-thickness flap and expose the surgical site. The implant site was prepared using a biological low-speed (150 rpm) drilling without irrigation.\textsuperscript{21} The bone type, determined according to Lekholm and Zarb classification,\textsuperscript{22} was used to select the sequence of bone drills and the final drill diameter, as described elsewhere.\textsuperscript{1}

The drilling procedure of the residual bone was divided in 2 phases: the first phase used conventional drills, and the working length was set 1 mm shorter than the height of the residual alveolar bone (in all cases the residual bone height was shorter than the length of the implant). The second phase used a special drill with a frontal cutting surface to prepare the last 1 mm of the implant site. The dental implant was inserted with a surgical motor at an insertion torque of 25 Ncm and implant placement was finished manually. The final insertion torque was registered in the patient’s record.

The severe bone atrophy did not permit the complete insertion of the extra-short implant, so a periodontal probe was used to measure the distance between the implant shoulder and the crest of alveolar bone at the mesial, central, and distal aspects. The mean distance between the implant shoulder and the crest of the alveolar bone was $1.77 \pm 0.18$ mm, $2.16 \pm 0.23$ mm, and $1.97 \pm 0.26$ mm at the mesial, central, and distal aspects, respectively (range $= 1.1–2.6$ mm at the mesial aspect, $1.2–2.9$ mm at the central aspect, and $1.1–3.1$ mm at the distal aspect).

Autologous bone and fibrin graft was used to cover the exposed implant’s threads (Figure 1). The low-speed drilling and the design of the bone drills permitted the collection of bone particles during the preparation of implant site. The harvested autologous bone was stored in fraction 2 of the PRGF-Endoret (BTI, Vitoria, Spain) until use. This resulted in the formation of a fibrin clot that glued together the autologous graft particles (Figure 1). To stimulate supra-alveolar bone augmentation, fibrin-glued bone graft was applied on the denuded implant surface (Figure 1). Fibrin membrane, prepared from fraction 1 of PRGF, was compressed to provide thin and consistent membrane, which was then applied to cover the surgical site (Figure 1) before flap reposition and suturing (interrupted suture) with monofilament 5/0 nylon suture. Postoperatively, patients were instructed to perform light and gentle brushing of the tooth/structures close to the surgical area after 24 hours and to avoid chewing on the operated site.

After at least 4 months, a second surgery was then performed to connect transepithelial abutments (Multi-Im, BTI). The residual distance between the implant shoulder and the bone crest was measured again. As extra-short implants were placed, a progressive loading protocol was followed with screw-retained acrylic resin provisional prosthesis.

\section*{PRGF preparation}

The PRGF was prepared using an Endoret kit (BTI). Briefly, citrated venous blood was centrifuged at 580g for 8 minutes to separate blood components according to the gravity density. Then, plasma column was fractioned into fraction 2, which was defined as the 2 mL of plasma above the buffy coat, and fraction 1, which was defined as the plasma column above fraction 2. Activated fraction 1 was used to prepare a fibrin membrane that covered the surgical area before flap closure, and activated fraction 2 was used to store bone particulate harvested during the drilling procedure and to wet and inject surfaces between implants and before insertion.

\section*{Implant-Guided Bone Augmentation}
FIGURES 1 AND 2. FIGURE 1. After the extra-short implants were inserted (a), the exposed implant surface was covered by the clot of plasma rich in growth factors containing autologous bone particles (b, c). Fibrin membrane was then placed to cover the surgical site before closure (d). FIGURE 2. Severe bone atrophy in the posterior mandible, where a residual height of 5.05 mm was available.
Postoperative phase

Follow-up visits were scheduled to remove sutures and to detect any surgical complications. Clinical evaluation and implants status were also monitored. It is important to mention that during the period of implant osseointegration, no provisional prosthesis was delivered to avoid moving the graft.

Data collection and statistical analysis

Measurement of the distance between the implant shoulder and the bone crest was realized by the same clinician (M.F.A.). A normality test (Shapiro-Wilk) was applied to verify if data followed a normal distribution. A paired Student t test was applied to analyze the statistical significance of the difference between both measurements. The level of statistical significance was set at $P < .05$. Vertical bone coverage of the denuded implant surface was calculated by subtracting the distances measured before and after surgery. Data analysis was performed with SPSS v15.0 for Windows statistical software package (SPSS Inc, Chicago, Ill).

RESULTS

Eight patients fulfilled the inclusion criteria and were enrolled in this retrospective study. Two patients received 2 extra-short implants, so a total of 10 extra-short implants were included in the study. Average age of the patients was $63 \pm 10.8$ years (range = 51–79 years), and there were 7 women and 3 men. Patients’ medical history indicated the presence of osteoporosis (2 patients), hyperthyroidism (1 patient), hypertension (1 patient), hypercholesterolemia (1 patient), and renal calculus (1 patient). Two patients were allergic to penicillin.

Preoperative cone-beam computerized tomography showed extreme bone atrophy and a mean residual bone height of $4.19 \pm 0.97$ mm (range = 2.92–5.38 mm) (Figure 2). Bone type III was found at the sites of 9 implants and bone type II at only 1 implant site. The drilling protocol successfully enabled the insertion of extra-short implants at an initial torque of $48 \pm 11.1$ Ncm (range = 20–60 Ncm).

The anatomic location of the extra-short implants is shown in Figure 3, where 80% of the implants were inserted at the position of second mandibular molar. The length of 8 implants was 5.5 mm, and the diameter of these implants was 5.5 mm, with the exception of 2 implants that had a diameter of 4.5 mm and 5.0 mm. The other 2 implants were 6.5 mm in length and had a diameter of 4.5 mm and 5.5 mm.

After implant insertion, the distance between the implant shoulder and the crest of the alveolar bone was $1.77 \pm 0.18$ mm, $2.16 \pm 0.23$ mm, and $1.97 \pm 0.26$ mm at the mesial, central, and distal aspects, respectively (Figures 4 through 7). The denuded implant surface (Figures 1 and 6) was then covered with a composite of autologous bone particles and PRGF-Endoret. The latter prevented the migration of bone particles, and the adhesive properties of the fibrin helped stabilize them at the implant surface.

During the healing period, patients’ recovery was uneventful, and pain was efficiently treated with ibuprofen or acetaminophen. Paresthesia was not reported or observed in the mandible, which suggests that the procedure was safe.

Exposure of surgical sites was not observed in any patient, and incision closure was uneventful (Figure 5). The use of fibrin membrane instead of nonresorbable membrane simplified flap closure and prevented graft/implant exposure, thus avoiding undesirable outcomes.

After 5 ± 1.6 months (range = 4–8 months) a second surgery was performed to connect the transepithelial abutment (Multi-Im, BTI). The distance between the implant shoulder and the crest of the bone was reevaluated and scored in the patient’s record (Figures 5 through 8). The new distance was $0.31 \pm 0.13$ mm at the mesial aspect, $0.43 \pm 0.16$ mm at the central aspect, and $0.43 \pm 0.16$ mm at the distal aspect (range =
FIGURES 5 AND 6. **FIGURE 5.** A radiograph (the same patient in Figure 1) showing the presence of residual bone height of 4.3 mm (a) that was treated by extra-short implant and vertical bone augmentation (b). At the second surgery, uneventful healing and no exposure of the implant could be observed (c), and the implant was covered by vertical bone augmentation (d). **FIGURE 6.** The denuded implant surface was covered by the clot of plasma rich in growth factors autologous bone particles. Five months after surgery, vertical bone augmentation was observed to cover the exposed implant threads and permitted the conservative rehabilitation of extreme atrophy.
0–1.1 mm at the mesial aspect, 0–1.3 mm at the central aspect, and 0–1.1 mm at the distal aspect), indicating vertical bone coverage of almost 85% of the denuded implant surface. The gained vertical bone regeneration was $1.46 \pm 0.22$ mm at the mesial aspect, $1.73 \pm 0.28$ mm at the central aspect, and $1.54 \pm 0.31$ at the distal aspect. Statistical analysis revealed significant differences between the measurements of exposed area at implant insertion before and after bone augmentation ($P < .05$). Clinical examination of the implants indicated successful osseointegration of the extra-short implants, which permitted the delivery of a screw-retained provisional prosthesis.

**DISCUSSION**

Different clinical protocols have been developed to promote vertical bone augmentation around dental implants. Guided bone regeneration using nonresorbable membrane with or without the use of bone graft has been reported to have different degrees of success. Recombinant human bone morphogenetic protein (rh-BMP2, rh-BMP7) has been found to stimulate upward bone growth. However, membrane/graft exposure is not unusual and has a significant negative effect on the outcomes. It is also technique sensitive as both fixation of the membrane and tension-free flap closure are technically demanding.

In this study, the low-speed drilling permitted the collection of bone particles during bone cutting and avoided the need for additional surgery to harvest autologous bone graft. The volume of autologous bone was sufficient to cover the vertical defect around the extra-short implants. Graft stability is particularly important in inducing vertical bone augmentation. Accordingly, the graft mixture with autologous platelet rich preparation is motivated by the adhesive properties of the fibrin, which would prevent particle migration from the wound site and increase graft volume. The use of fibrin membrane instead of nonresorbable membrane has also simplified the procedure and prevented graft/implant exposure and undesirable outcomes.

The results of this study showed that the described technique induced supra-alveolar bone growth of about 2 mm and enabled rehabilitation of a severely atrophied mandible (residual height $4.19 \pm 0.97$ mm) with implant-supported prosthesis. The amount of generated bone was comparable with that achieved in the study of Freilich et al, where a combination of demineralized bone matrix (DBM) and rh-BMP-2 was used.

The success of this approach could also be related to the avoidance of provisional prosthesis during the healing period, thus protecting the graft from mechanical stresses that might have affected graft stabilization. Additionally, the prevention of surgical site exposure and the osteogenic properties of the autologous bone enhanced the success of the described technique.

This study was limited because of the retrospective design and the limited number of patients. Further prospective clinical studies are necessary to validate the conclusions, and animal studies are needed that permit the harvesting of biopsies and the histologic analysis of regenerated bone quality, bone quantity, and bone to implant interface. This is important as Simion et al, in a canine model, showed that the new bone was generally not in direct contact with the implants because of the presence of connective tissue between the implants and the newly formed bone. Similarly, Cornelini et al observed

**FIGURE 8.** Residual exposed implant surface measured at the time of the second surgery to connect the transepithelial abutment. The lower and upper border of the box corresponds to the first and third quartiles, and the line inside the box is the median. The ends of the whiskers represent the lowest value within the 1.5 interquartile range of the lower quartile and the highest value within the 1.5 interquartile range of the upper quartile.
mineralized tissue growth around the dental implants that was covered on the outside by a thick layer of connective tissue.

The use of guided bone regeneration with tenting screws/pins/implants to prevent membrane collapse is another clinical procedure for vertical bone augmentation. This procedure has been shown to achieve an increase of 3.5–7.0 mm and, thus, could be indicated in patients where higher bone augmentation is required. However, screw exposure has been reported and is a problem that is associated with gingival thickness and the tension in the flap.

CONCLUSIONS

Within the limitations of this study, implant guided bone augmentation around extra-short implants permitted the conservative treatment of mandibular alveolar ridge atrophy with implant-supported prostheses and provided an alternative to more invasive surgical techniques. Further studies with more patients are needed to confirm the results of this research.

ABBREVIATIONS

PRGF: plasma rich in growth factors
rhBMP: recombinant human bone morphogenetic protein

ACKNOWLEDGMENT

M.H.A. acknowledges the support from the Program of Torres Quevedo, Ministry of Economy and Competitivity, cofounded by the European Social Fund (PTQ-11-04711).

REFERENCES