A Randomized Clinical Trial to Evaluate and Compare Implants Placed in Augmented Versus Non-Augmented Extraction Sockets: 3-Year Results

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Background: The alveolar ridge undergoes reabsorption and atrophy subsequent to tooth removal and thus exhibits a wide range of dimensional changes. Preservation of the alveolar crest after tooth extraction is essential to enhance the surgical site before implant fixture placement. The aim of this randomized clinical study is to investigate and compare the need for additional augmentation procedures at implant insertion, as well as the success rate and marginal bone loss for implants placed in the grafted sites versus those placed in naturally healed sites.

Methods: Forty patients with ≥1 hopeless tooth were randomly allocated to: 1) a test group, receiving extraction and grafting corticocancellous porcine bone; and 2) a control group, receiving extraction without any graft. After 7 months of healing, implants were inserted in each of the sites. The implants were submerged and loaded after 4 months with metal–ceramic rehabilitation. The follow-up included evaluation of implant diameter and length, the need for additional augmentation procedures at implant placement, implant failure, and marginal bone level changes. All patients were followed over a 3-year period.

Results: One implant failed in the control group at the second stage of surgery (6 months after placement); one implant failed in the test group after 2 years of loading. The cumulative implant success rate at the 3-year follow-up visit reached 95% for both groups. No statistically significant differences were detected for marginal bone changes between the two groups.

Conclusions: It was concluded that implants placed into grafted extraction sockets exhibited a clinical performance similar to implants placed into non-grafted sites in terms of implant survival and marginal bone loss. However, grafted sites allowed placement of larger implants and required less augmentation procedures at implant placement when compared to naturally healed sites. *J Periodontol 2012;83:836-846.*

KEY WORDS

Alveolar bone loss; bone substitutes; dental implants; survival rate.

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The range of indications for implant dentistry has broadened from fully- to partially-edentulous jaws. The replacement of a missing single tooth has become a frequent procedure with predictable outcomes.[1] The long-term stability of implants depends on the quality and quantity of the available alveolar bone. Limiting loss of alveolar ridge height and width to a minimum provides a better site for placing dental implants. Moreover, the outcome of implant therapy is no longer evaluated in terms of implant survival alone but by favorable esthetic and functional results as well.[2] Such issues depend not only on the correct positioning of the implant to ensure an appropriate alignment of the restoration and an adequate emergence profile,[2] but also on the amount of bone available at the implant site to allow maximal support and stability of surrounding hard and soft tissue.[3,4]

It is well documented[5,6] that alveolar ridges exhibit resorptive changes after tooth removal. Alveolar bone loss can occur as a result of iatrogenic trauma while extracting teeth or natural postextraction socket healing. The alveolar process is a tooth-dependent tissue that develops in conjunction with tooth eruption. Subsequent to tooth extraction, the alveolar ridge undergoes reabsorption and atrophy, exhibiting a wide range of

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dimensional changes.[5,6] Although bone fill in the socket will continue for several months, it does not reach the level of adjacent teeth.[5-7] The reabsorbed ridges do not allow for appropriate pontic fabrication when conventional fixed prostheses are considered, nor do they permit the placement of endosseous implants in a favorable prosthetic position. Because ridge dimensions are so critical, preservation of the alveolar crest after tooth extraction is essential to maintain the vertical and horizontal dimensions of the alveolar ridge. Several studies have proposed various ridge-preservation approaches, including placement of different grafting materials and/or use of occlusive membranes to avoid the tendency for soft-tissue invagination and the formation of fibrous tissue in the coronal portion of the alveolus.[8-12] Site preservation through socket grafting is a predictable procedure to enhance the surgical site before implant fixture placement. Different bone substitutes have been used in attempts to avoid alveolar ridge resorption after tooth removal.[13,14] Although the use of autogenous bone is, in nearly all cases, the gold standard in bone augmentation,[8] it may be considered unreasonable to harvest autogenous bone to fill the above limited bone deficiency. Many authors have assessed the reliability of using either allografts or xenografts for such purposes, which prevent the need for an additional surgical site for bone collection.[10,13-15]

A comprehensive systematic review found that implants placed in augmented edentulous sites had a survival rate similar to implants placed in native bone.[16] In a retrospective analysis, Urban et al.[17] reported a 100% cumulative survival rate 6 years after loading, in 36 sites regenerated with titanium-reinforced membranes and particulated autogenous bone graft. They reported an overall mean crestal bone remodeling of 1.01 mm measured from the implant abutment junction. Similarly, a 1.32-mm marginal bone remodeling was reported in a previous study[18] on 32 vertically augmented sites with autogenous bone chips and titanium-reinforced membranes. The authors concluded that vertically augmented bone using guided bone regeneration (GBR) techniques responds to implant placement in the same way as native, non-regenerated bone.[18] In a retrospective study by Benić et al.,[19] the GBR procedure involved grafting with a xenogenic bone substitute covered with a bio-resorbable collagen. The level of the marginal bone below the shoulder of the implant at the 5-year follow-up examination was 1.3 mm for the GBR group and 1.6 mm for the control group. These results demonstrated that bone regenerated by GBR in peri-implant bone defects remains as stable over time as pristine peri-implant bone. Although the cumulative survival rate was lower for the implants placed into native bone (94.1% versus 100% for the GBR group), this difference was not statistically significant.

In a recent literature review,[20] several grafting techniques were evaluated to ascertain their capability to support implant placement and survival. The socket preservation technique resulted in a cumulative implant survival rate of 90.3% based on the comprehensive analysis of two studies in which 65 of the 72 placed implants survived .[21,22] The authors[20] concluded that there was insufficient data to draw any conclusions about the potential benefits of this approach because of the lack of peri-implant tissue evaluation, the small sample size, and data heterogeneity within and across studies.

The aim of this randomized clinical study is to test the hypothesis that there is no difference in success rate, bone tissue remodeling, and need for augmentation procedures for implants placed in grafted sites versus implants placed in naturally healed sites. This is a 3-year report of an ongoing prospective study. In the first part of the present ongoing investigation[15] a xenogenic bone substitute consisting of corticocancellous porcine bone was used. In that preliminary report,[15] the ridge-preservation approach using porcine bone in combination with a collagen membrane significantly limited the reabsorption of hard-tissue ridge after tooth extraction compared to extraction alone. Furthermore, the histologic and ultrastructural analysis on bone biopsies showed significantly higher percentages of trabecular bone and total mineralized tissue in ridge-preservation sites when compared to extraction-alone sites 7 months after tooth removal.

MATERIALS AND METHODS

Study Population and Design

Patients requiring one single tooth extraction and subsequently an implant-supported restoration, who were ≥18 years old and able to sign an informed consent form were eligible for inclusion in this trial. The criteria for exclusion were: 1) history of systemic diseases that would contraindicate oral surgical treatment; 2) long-term non-steroidal anti-inflammatory drug therapy; 3) require antibiotic prophylaxis; 4) lack of opposite occluding dentition in the area intended for extraction and subsequent implant placement; 5) presence of molar sites that required extraction; 6) absence of adjacent teeth; 7) absence of an alveolar bone wall; 8) unwillingness to return for the follow-up examination; and 9) smoking >10 cigarettes per day. Participants smoking <10 cigarettes per day were requested to stop smoking before and after surgery; however, their compliance could not be monitored.

Patients were recruited from the consultation clinic at the Dentistry Department of Versilia Hospital, from July 2006 to August 2007. All patients received thorough explanations and completed a written informed consent form before enrollment. The study was approved by the Ethics Committee of the Versilia General Hospital, Lido

di Camaiore, Italy. Patients included in the study were evaluated by examining diagnostic casts and periapical/panoramic radiographs; data were collected for each patient, such as age, sex, smoking habits, indications for tooth extraction based on both clinical and radiographic examination, location of tooth, and presence/absence of adjacent teeth. All patients underwent ≥1 session of oral hygiene before the extraction procedures to provide a more favorable oral environment for wound healing. Extraction sockets were allocated to either a test (graft material) or control (spontaneous healing) group using a computerized random allocation process (Fig. 1). A computer-generated restricted randomization list was created. Only one of the investigators (BO), not involved in the selection and treatment of the patients, was aware of the randomization sequence and had access to the randomization list. The randomized codes were enclosed in sequentially numbered, identical, opaque, and sealed envelopes.

All patients received prophylactic antibiotic therapy (2 g amoxicillin or 600 mg clindamycin if allergic to penicillin) 1 hour before the extraction procedure and continued to take the antibiotic postoperatively (1 g amoxicillin or 300 mg clindamycin) twice daily for 4 days. All patients rinsed for 1 minute with 0.2% chlorhexidine mouthwash before the surgery (and twice daily for the following 3 weeks) and were treated under local anesthesia using lidocaine with adrenaline at 1:50,000. All surgical procedures, at this stage, were performed by the same clinician (AB). All the patients were treated with the same surgical technique, consisting of tooth extraction as previously described.[15] Briefly, a full-thickness mucoperiosteal flap was elevated, and one or two releasing incisions were performed so that the socket could be examined and primary closure achieved. Great care was taken to reduce the trauma on the buccal bone plate and to keep the integrity of a four-wall bone morphology (Figs. 2 and 3). The extraction sockets were thoroughly debrided to remove all soft tissues. Subsequently, the randomization envelope was opened informing the surgeon if the socket would be treated as a test or control site according to the randomization list.

Extraction sockets in the test group were grafted with corticocancellous porcine bone,‖ and a collagen membrane¶ was used to completely cover the socket. In the control group, no biomaterial was grafted. The mucosal flaps were closed with resorbable sutures, achieving complete soft-tissue closure. Patients were instructed to continue with prophylactic antibiotic therapy, and 550-mg naproxen sodium tablets were prescribed as an anti-inflammatory to be taken twice daily for as long as required. Removable prostheses, if present, were not permitted until they had been adjusted and refitted no sooner than 3 weeks after surgery.

After 7 months of healing, the surgical reentry procedure was performed and implants# were inserted in grafted (Figs. 4 and 5) and naturally healed (Figs. 6 and 7) sites by the same operator (UC). The treatment allocation was masked to the investigator involved in treating the patients. After 4 months, implants were manually tested for stability and impressions were taken using polyvinylsiloxane impression material** and customized resin impression trays. Final prosthetic restorations were cemented and patients were enrolled in an oral hygiene program with a recall visit every 3 months (Figs. 8 and 9).

The following outcome evaluations were considered: 1) diameter and length of implants placed; 2) augmentation procedure required at implant placement for peri-implant bone defects; 3) implant success, including implant mobility, removal of stable implants as a result of progressive bone loss and implant fracture (stability of individual implant was measured at delivery of final crown at 1, 2, and 3 years after prosthetic rehabilitation); 4) any biologic or prosthetic complication; and 5) peri-implant marginal bone levels evaluated on intraoral radiographs.

Digital intraoral periapical radiographs were taken (70 kVp, 7 mA) using a parallel cone technique with digital sensor.†† A paralleling device and individualized bite blocks made of polyvinylsiloxane impression material‡‡ were used for the standardization of the x-ray geometry. Bone loss was measured by comparing the radiographs taken at the baseline (immediately after prosthesis delivery) to those taken 12, 24, and 36 months after functional loading. The marginal bone height was set as the distance between the reference point and the most apical point of the marginal bone level. The reference point was the fixture–abutment interface. Calibration was performed using the known thread-pitch distance (1.0 mm) of the implants. Previous known values, such as fixture diameter and length, were used for calibration when the threads were not clearly visible on the radiographs. Measurements were taken to the nearest 0.01 mm using computer software.§§ Bone loss was measured at the mesial and distal peri-implant sites, and their average values were used. All measurements were taken by one examiner (LC) who was not involved in the surgical treatment (Figs. 10 through 13).

Statistical Analyses

A data analysis was performed with descriptive statistics and an independent sample *t* test was used for the

‖ mp3, OsteoBiol, Coazze, Italy.
¶ Evolution, OsteoBiol.
# Premium, Sweden & Martina, Due Carrare, Italy.lexitime, Heraeus Kulzer, Hanu, Germany.
†† Schick Technologies, Long Island City, NY.
‡‡ Flexitime, Heraeus Kulzer.
§§ UTHSCSA Image Tool, v.3.0, University of Texas Health Science Center, San Antonio, TX.

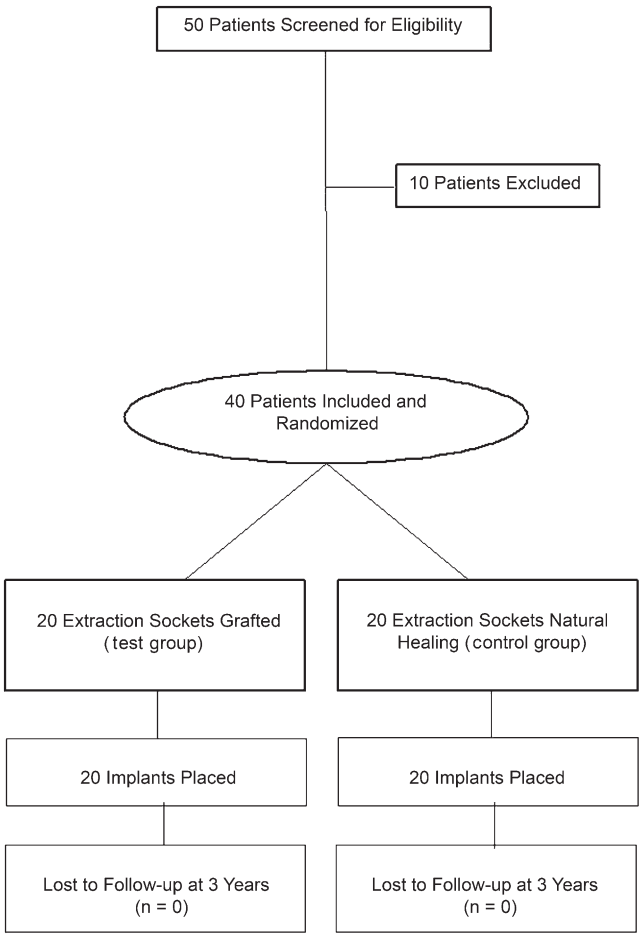

Figure 1.
A flow diagram representing the several phases of the trial.

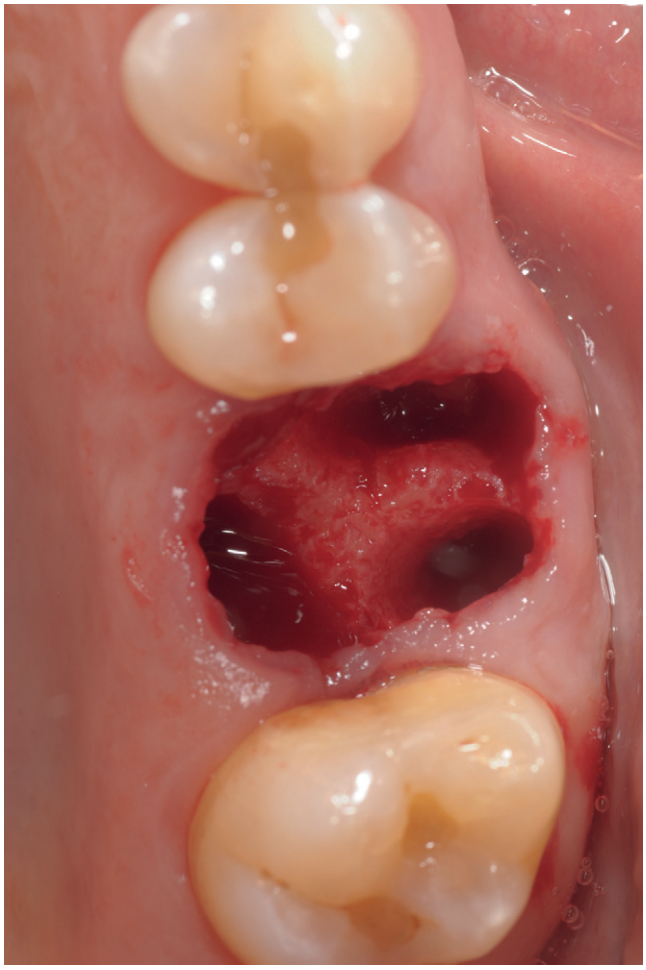

Figure 2.
Postextractive alveolar socket (test group).

comparison of mean values between groups to evaluate the significant differences between the two treatment groups. The Pearson χ^2 test was used to test for relationships between variables. A P value <0.05 was selected as the level of statistical significance. The estimation of the implant survival rate and cumulative implant survival over time was assessed using the Kaplan-Meier analysis. The cumulative survival rate is the probability that the implant will survive at least to a specified time within the study observation period. The failure time for each implant was defined as the elapsed time from placement to the date of failure. In cases in which the terminal event (implant failure) was not reached, the elapsed time between implant insertion and the last visit was assumed as the survival time. All evaluations were performed using statistical software.‖

RESULTS

A flow diagram showing the several phases of the trial is shown in Figure 1.

Fifty patients were considered eligible for the study, but 10 were not included for the following reasons: three patients refused to receive an augmentation procedure at the extraction socket, although they initially agreed when they enrolled, and seven patients had damaged alveoli and suppuration of the fresh extraction sockets. Therefore, 40 patients were enrolled in the trial. All patients were treated according to the allocated interventions. There were no dropouts or exclusions ≤3 years after implant prosthetic rehabilitation and the data of all patients were used in the statistical analysis. Dental fracture was the most common reason for extraction accounting for 20 teeth, severe dental caries occurred in 11 cases, and endodontic failure occurred in nine cases.

Each of the 40 participants (16 males and 24 females, aged 26 to 69 years) contributed one extraction site. The extracted teeth are reported in Table 1 according to their position and treatment group. Twelve participants (30%) were smokers (six in

‖ SPSS software v.6.1.2 for Windows, IBM, Armonk, NY.

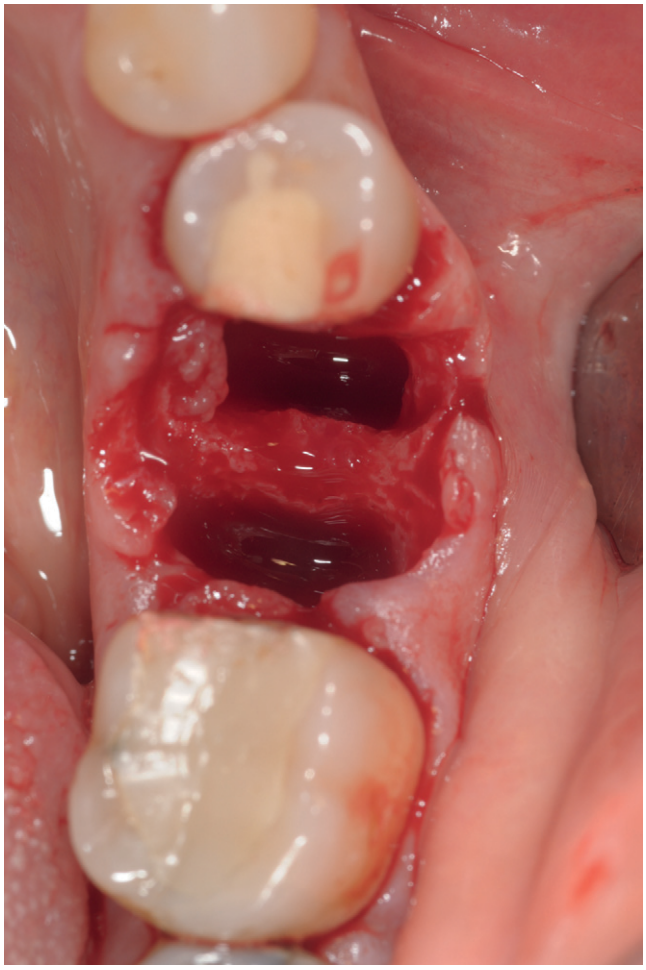

Figure 3.
Postextractive alveolar socket (control group).

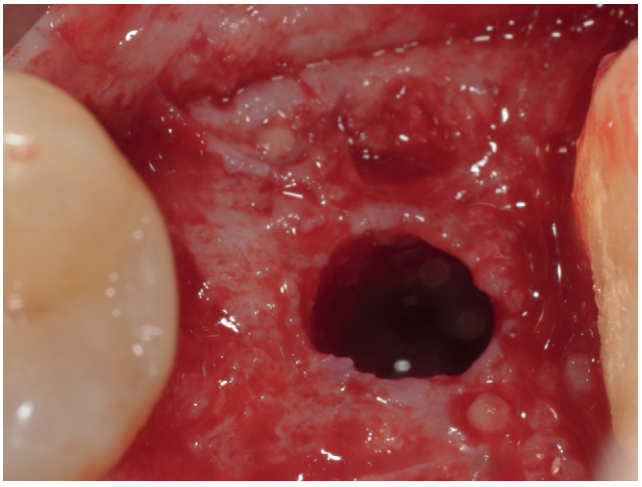

Figure 4.
Grafted site healing 7 months after tooth extraction (test group).

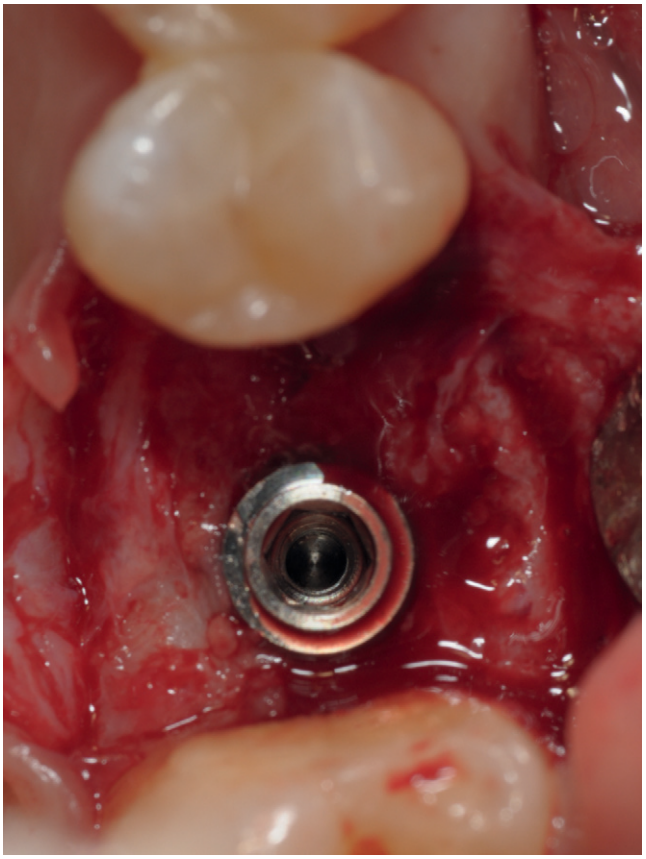

Figure 5.
Implant inserted in the grafted site (test group).

each group); the rest never smoked or were former smokers who quit >10 years earlier. During the reentry procedures for implant placement, 13 implants (three in the grafted group and 10 in the natural healing group) required additional bone augmentation, which was performed with corticocancellous porcine bone¶¶ and a collagen membrane.## This difference was statistically significant ($P = 0.02$). Implant length ranged from 10 to 13 mm in both groups, and implant diameter ranged from 3.3 to 5 mm in both groups (Tables 2 and 3). The implant length and diameter were higher in the ridge-preservation group when compared to naturally healed sites. A significant relationship was found between implant length ($P = 0.03$), implant diameter ($P = 0.03$) and treatment group according to the χ^2 analysis. In one patient, one control implant was not osseointegrated at the time of the abutment connection, 6 months after implantation. In all patients the healing time until loading was equal for the test and the control implants and prosthesis

¶¶ mp3, OsteoBiol.
Evolution, OsteoBiol.

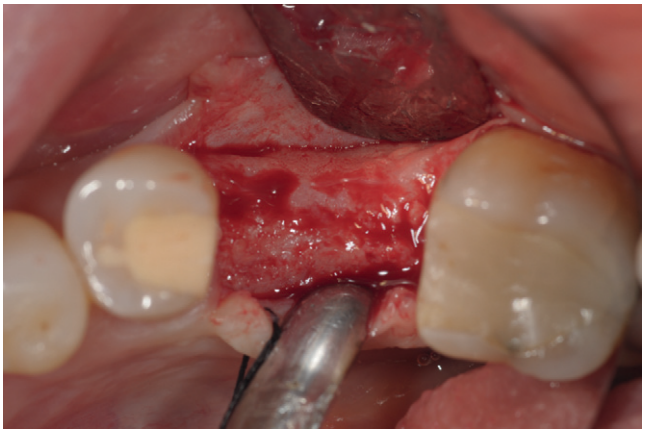

Figure 6.
Naturally healed socket (7 months after tooth extraction).

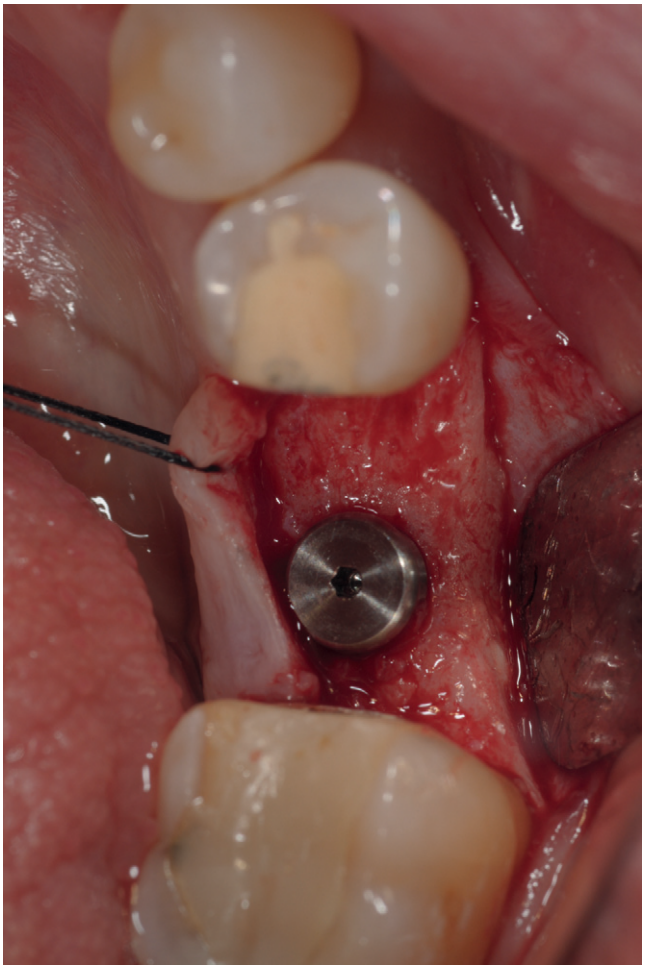

Figure 7.
Implant insertion in the naturally healed site (control group).

incorporation was performed 6 months after implantation. All patients were provided with implant-supported single crowns. One implant failed and was consequently removed as a result of mobility after 24 months of loading in the test group. The cumulative implant survival rate at the 3-year examination reached 95% for both groups; the difference in implant failures between groups was not significant.

Radiographic evaluation indicated that all remaining implants were successfully osseointegrated. There were no significant differences in mean marginal bone loss between the two groups at any of the three evaluation periods: 1 year, $P = 0.82$; 2 years, $P = 0.66$; 3 years, $P = 0.52$. (Figs. 7 through 10). (Figs. 11 through 13, Table 4).

DISCUSSION

The preservation of the alveolar bone volume seems to be fundamental for proper esthetic rehabilitation and for placement of longer and wider implants. In the present study, 40 implants were inserted to replace hopeless teeth in the esthetic area. The height and the thickness of the buccal bone and the level of the alveolar peaks in the interproximal aspects play a critical role in this area, because the papilla size, the embrasure shape, and the emergence profile strictly depend on the anatomy of the underlying bone. After tooth extraction, the alveolar process is markedly reduced with respect to both height and width; the dimensional changes are more pronounced at the buccal than at lingual/palatal bone walls. This is not surprising because the buccal bone plate of the alveolar ridge is commonly thin and fragile.[7] Moreover, the space previously occupied by the tooth and its periodontal ligament will be replaced mainly by the trabecular bone and bone marrow.[23,24]

In the esthetic zone, where the buccal plate is often <1.5 to 2 mm thick, the pattern of bone reabsorption makes the placing of implants more difficult in a favorable prosthetic position without producing buccal bone defects. A patient with high esthetic demands, such as a high lip line or a thin biotype, which is prone to additional recession, represents a specific indication for ridge preservation.[25] In our previous study,[15] the ridge-preservation procedures using corticocancellous porcine bone*** and collagen membrane††† reduced the bone dimensional changes after tooth extraction, thus allowing a more favorable implant position. This ridge-preservation approach significantly limited the resorption of the hard-tissue ridge after tooth extraction compared to extraction alone. Furthermore, the histologic analysis showed a significantly higher percentage of trabecular bone and total mineralized tissue in

*** mp3, OsteoBiol.
††† Evolution, OsteoBiol.

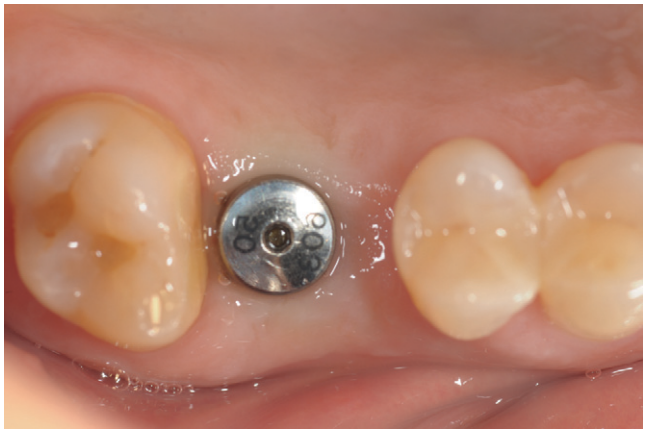

Figure 8.
Healthy gingival tissue around implant (test group).

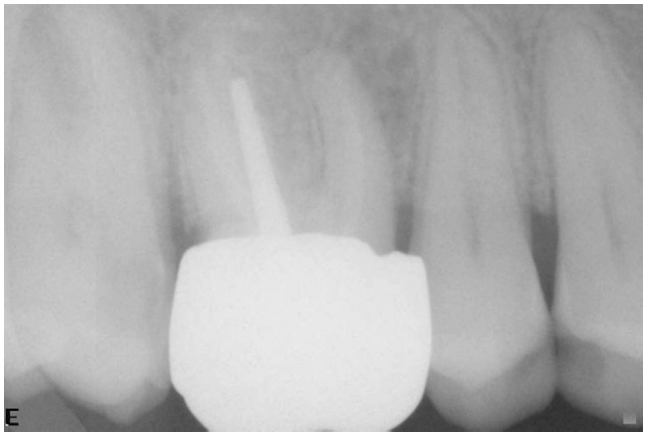

Figure 10.
Initial radiograph (test group).

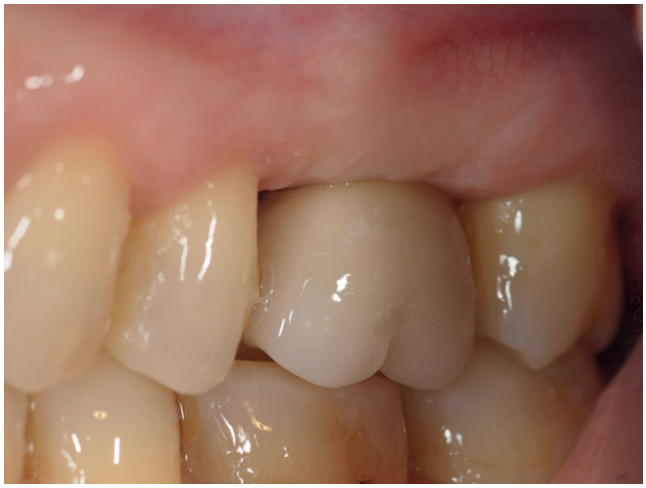

Figure 9.
Healthy gingival tissues at 3-year follow up (test group).

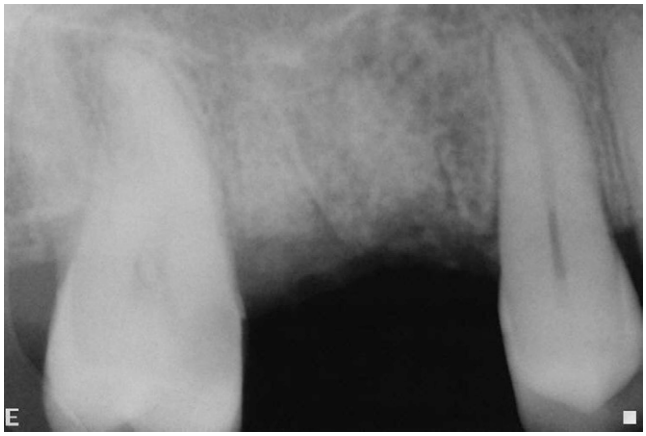

Figure 11.
X-Ray examination showing the grafting material put in the alveolar socket (test group).

ridge-preservation sites compared to extraction-alone sites 7 months after tooth removal.[15]

It is well documented[26-28] that porcine bone is a safe and biocompatible biomaterial. It has a microscopic structure similar to human bone, and in a human study, was reported to be osteoconductive well integrated in the host site after 5 months.[26] It was also found to promote bone formation and did not interfere with bone regeneration.[27] Barone et al.[26] and Nannmark and Sennerby[28] did not detect any sign of inflammatory infiltrate, necrosis, foreign-body reaction, or evidence of adverse reaction with the use of corticocancellous porcine bone. The resorption rate of this biomaterial represents another important feature that should be taken into account. Barone et al.[26] observed partial resorption of porcine bone in a study on maxillary sinus augmentation. Xenografts do not completely reabsorb, and they maintain their density over long periods, thus acting as a mineral reservoir necessary for new bone formation.[29] The incorporation of the corticocancellous particles in host bone creates a dense and hard-tissue network, in which the graft particles, completely embedded in mineralized bone, provide support to dental implants.[30]

The results of the present study show that there were no differences in the survival rates between implants placed into augmented and non-augmented sites. These survival rates compare well with findings reported in previous studies including implants in pristine as well as regenerated bone.[31] According to a systematic review,[32] the survival rate of implants placed into sites with regenerated/augmented bone using barrier membranes varied from 79% to 100% with the majority of studies indicating >90% after ≥1 year of function.[32] The survival rates obtained in such

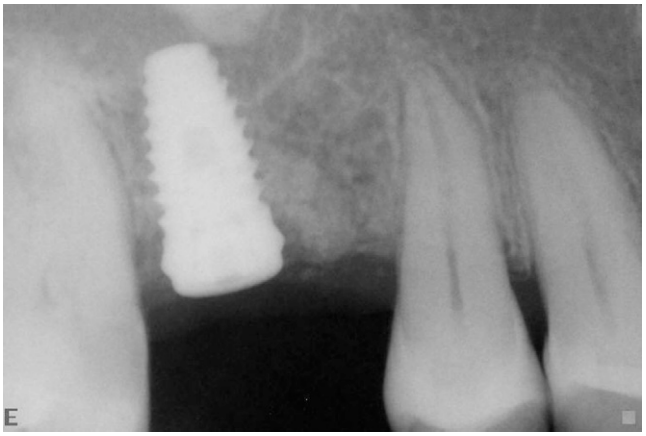

Figure 12.
x-Ray examination after implant insertion (test group).

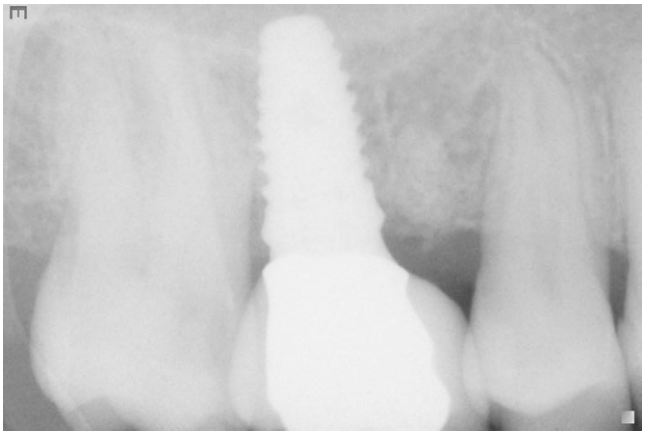

Figure 13.
Final radiograph (3-year follow up) of test group.

a systematic review are similar to those generally reported for implants placed conventionally into sites without the need for bone augmentation. Survival rates of implants placed in vertically augmented bone with the GBR technique appeared similar to implants placed in native bone in a less recent clinical trial.[18] Benić et al.[19] showed that implants placed with bone regeneration did not perform differently from implants placed into native bone in terms of implant survival: cumulative survival rates reached 100% for the GBR group and 94.1% for the control group without statistical significant difference. The 24-month follow-up showed 100% implant survival for implants placed in extraction sockets grafted with three different materials in a study by Crespi et al.[33] These results suggested that the early prognosis of such a treatment modality is not negatively influenced by grafting materials of different composition.

Table 1.

Tooth Position According to Treatment Performed

Group	Incisor	Canine	Premolar	Total
Maxilla control	3	2	8	13
Mandible control	0	2	5	7
Maxilla test	4	1	7	12
Mandible test	0	3	5	8
Total	7	8	25	40

Table 2.

Distribution of Implant Lengths Presented as Absolute and Relative Numbers

Group	10 mm	11.5 mm	13 mm	Total
Control	8	5	7	20
Test	1	8	11	20
Total	9	13	18	40

Table 3.

Distribution of Implant Diameters Presented as Absolute and Relative Numbers

Group	3.3 mm	4 mm	5 mm	Total
Control	4	13	3	20
Test	0	11	9	20
Total	4	24	12	40

In the present investigation, the level of the marginal bone loss amounts to 1.02 ± 0.3 mm for the control group and to 1.00 ± 0.2 mm for the test group at the 3-year follow-up examination (Table 4). These results demonstrated that ridges regenerated with the use of porcine bone in postextraction sockets remain as stable over time as native bone. The marginal bone levels in the present investigation were within the range of values reported previously in long-term studies documenting the outcome of implants placed in native bone.[34-36] In a study by Nickenig et al.,[37] bone loss for machined implants progressed from 0.5 mm

Table 4.

Mean Radiographic Peri-Implant Marginal Bone Loss (mm) Between Groups and Time Periods

	1 Year After Loading			2 Years After Loading			3 Years After Loading		
Group	n	Mean	SD	n	Mean	SD	n	Mean	SD
Control	19	0.76	0.3	19	0.84	0.2	19	1.02	0.3
Test	20	0.75	0.3	20	0.83	0.2	19	1.00	0.2
Difference		0.01			0.01			0.02	

in the healing period to 0.8 and 1.1 mm at the 6- and 24-month follow-ups. Conversely, bone loss for the microthreaded implants progressed from 0.1 mm in the healing period to 0.4 and 0.5 mm in the 6- and 24-month follow-ups. In a study by Peñarrocha et al.,[38] the marginal bone loss was 0.95 mm using digital radiography. All the implants displayed some extent of bone loss throughout the follow-up period in a study by Bratu et al.[39] At 12 months after loading, the microthreaded implants and the polished neck implants displayed 0.9 versus 1.5 mm marginal bone loss, respectively.

It is difficult to compare the results of the present study with those of other studies because, to our knowledge, this is the first study to assess marginal bone loss associated with implants placed in native bone and in sites subjected to socket preservation. The marginal bone height values for the control and the test groups in the present study are in accordance with the ones observed in previous studies[19,40,41] documenting the outcome of implants placed in native bone as well as regenerated bone. A bone level change of 0.8 to 1.3 mm was reported at the 5-year follow-up examination by Buser et al.[40] In that study, as well as in our investigation, the staged approach was chosen, in which the bone is first regenerated and the implant subsequently placed into a ridge exhibiting sufficient bone volume. The level of the marginal bone was 1.3 to 1.6 mm below the shoulder of the implant at 5 years after implant insertion in a study by Benić et al.[19] Values of 1.73 mm for the control group and 1.83 mm for the test group were reported in another study at the 5-year follow-up examination.[41]

The increased height and width of bone available for implant placement, after tooth extraction, allowed wider and longer implants to be placed in preserved ridges (Tables 2 and 3). Indeed, a significant relationship was found between implant size and treatment group. Furthermore, advantages of socket preservation seemed to include a reduced number of surgical procedures at the time of implant insertion, because 10 implants in the naturally healed sites required an additional bone augmentation procedure.

One limitation of the present study is that the surgical technique could be perceived as too aggressive because a number of studies[42-45] have shown full bone preservation and formation of vital bone without the need for bone replacement graft materials and with no need for obtaining primary closure over the surgical site.[2] It must be pointed out that this study was performed from 2006 to 2007 using the best available procedure at that time. We first published the results in 2008,[15] and this article represents the follow-up over a 3-year time period.

CONCLUSIONS

Based on the results of the present investigation, it can be concluded that implants placed into sites subjected to ridge preservation exhibited a clinical performance similar to implants placed into non-grafted sites with respect to implant survival and marginal bone loss. However, it seems from these findings that extraction alone may lead to unpredictable healing patterns in which the remaining ridge does not often allow for an esthetic and functional solution without the aid of an additional bone augmentation procedure simultaneously with implant placement. Furthermore, the height and width preservation of the ridge allowed for the placement of large-diameter implants, and this could optimize the emergence profile of the implant supported rehabilitation. Thus, the ridge-preservation approach could attain a satisfying clinical outcome for the patients.

ACKNOWLEDGMENT

The authors report no conflicts of interest related to this study.

REFERENCES

1. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP. A systematic review of the 5-year survival and complication rates of implant-supported single crowns. *Clin Oral Implants Res* 2008; 19:119-130.

2. Darby I, Chen ST, Buser D. Ridge preservation techniques for implant therapy. *Int J Oral Maxillofac Implants* 2009;24(Suppl.):260-271.
3. Buser D, Dula K, Belser U, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. 1. Surgical procedure in the maxilla. *Int J Periodontics Restorative Dent* 1993;13:29-45.
4. Buser D, Chen ST, Weber HP, Belser UC. Early implant placement following single-tooth extraction in the esthetic zone: Biologic rationale and surgical procedures. *Int J Periodontics Restorative Dent* 2008;28:441-451.
5. Lekovic V, Kenney EB, Weinlaender M, et al. A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. *J Periodontol* 1997;68:563-570.
6. Lekovic V, Camargo PM, Klokkevold PR, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. *J Periodontol* 1998;69: 1044-1049.
7. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: A clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent* 2003;23:313-323.
8. Nemcovsky CE, Serfaty V. Alveolar ridge preservation following extraction of maxillary anterior teeth. Report on 23 consecutive cases. *J Periodontol* 1996;67:390-395.
9. Artzi Z, Tal H, Dayan D. Porous bovine bone mineral in healing of human extraction sockets. Part 1: Histomorphometric evaluations at 9 months. *J Periodontol* 2000;71:1015-1023.
10. Artzi Z, Tal H, Dayan D. Porous bovine bone mineral in healing of human extraction sockets: 2. Histochemical observations at 9 months. *J Periodontol* 2001;72:152-159.
11. Froum S, Cho SC, Rosenberg E, Rohrer M, Tarnow D. Histological comparison of healing extraction sockets implanted with bioactive glass or demineralized freeze-dried bone allograft: A pilot study. *J Periodontol* 2002;73:94-102.
12. Froum S, Cho SC, Elian N, Rosenberg E, Rohrer M, Tarnow D. Extraction sockets and implantation of hydroxyapatites with membrane barriers: A histologic study. *Implant Dent* 2004;13:153-164.
13. Carmagnola D, Adriaens P, Berglundh T. Healing of human extraction sockets filled with Bio-Oss. *Clin Oral Implants Res* 2003;14:137-143.
14. Iasella JM, Greenwell H, Miller RL, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: A clinical and histologic study in humans. *J Periodontol* 2003;74:990-999.
15. Barone A, Aldini NN, Fini M, Giardino R, Calvo Guirado JL, Covani U. Xenograft versus extraction alone for ridge preservation after tooth removal: A clinical and histomorphometric study. *J Periodontol* 2008;79:1370-1377.
16. Fiorellini JP, Nevins ML. Localized ridge augmentation/preservation. A systematic review. *Ann Periodontol* 2003;8:321-327.
17. Urban IA, Jovanovic SA, Lozada JL. Vertical ridge augmentation using guided bone regeneration (GBR) in three clinical scenarios prior to implant placement: A retrospective study of 35 patients 12 to 72 months after loading. *Int J Oral Maxillofac Implants* 2009;24: 502-510.
18. Simion M, Jovanovic SA, Tinti C, Benfenati SP. Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. A retrospective study on 123 implants with 1-5 year follow-up. *Clin Oral Implants Res* 2001;12:35-45.
19. Benić GI, Jung RE, Siegenthaler DW, Hämmerle CH. Clinical and radiographic comparison of implants in regenerated or native bone: 5-year results. *Clin Oral Implants Res* 2009;20:507-513.
20. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int J Oral Maxillofac Implants* 2007;22(Suppl.):49-70.
21. Norton MR, Wilson J. Dental implants placed in extraction sites implanted with bioactive glass: Human histology and clinical outcome. *Int J Oral Maxillofac Implants* 2002;17:249-257.
22. Sàndor GK, Kainulainen VT, Queiroz JO, Carmichael RP, Oikarinen KS. Preservation of ridge dimensions following grafting with coral granules of 48 post-traumatic and post-extraction dento-alveolar defects. *Dent Traumatol* 2003;19:221-227.
23. Cardaropoli G, Araújo MG, Lindhe J. Dynamics of bone tissue formation in tooth extraction sites. An experimental study in dogs. *J Clin Periodontol* 2003; 30:809-818.
24. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005;32:212-218.
25. Darby I, Chen S, De Poi R. Ridge preservation: What is it and when should it be considered. *Aust Dent J* 2008; 53:11-21.
26. Barone A, Crespi R, Aldini NN, Fini M, Giardino R, Covani U. Maxillary sinus augmentation: Histologic and histomorphometric analysis. *Int J Oral Maxillofac Implants* 2005;20:519-525.
27. Orsini G, Scarano A, Piattelli M, Piccirilli M, Caputi S, Piattelli A. Histologic and ultrastructural analysis of regenerated bone in maxillary sinus augmentation using a porcine bone-derived biomaterial. *J Periodontol* 2006;77:1984-1990.
28. Nannmark U, Sennerby L. The bone tissue responses to prehydrated and collagenated cortico-cancellous porcine bone grafts: A study in rabbit maxillary defects. *Clin Implant Dent Relat Res* 2008;10:264-270.
29. Scarano A, Pecora G, Piattelli M, Piattelli A. Osseointegration in a sinus augmented with bovine porous bone mineral: Histological results in an implant retrieved 4 years after insertion. A case report. *J Periodontol* 2004;75:1161-1166.
30. Iezzi G, Scarano A, Mangano C, Cirotti B, Piattelli A. Histologic results from a human implant retrieved due to fracture 5 years after insertion in a sinus augmented with anorganic bovine bone. *J Periodontol* 2008;79:192-198.
31. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2002;29(Suppl. 3):197-212, discussion 232-233.
32. Hämmerle CHF, Jung RE, Feloutzis A. A systematic review of the survival of implants in bone sites augmented with barrier membranes (guided bone regeneration) in partially edentulous patients. *J Clin Periodontol* 2002;29(Suppl. 3):226-231, discussion 232-233.
33. Crespi R, Capparè P, Gherlone E. Dental implants placed in extraction sites grafted with different bone

substitutes: Radiographic evaluation at 24 months. *J Periodontol* 2009;80:1616-1621.
34. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: A 5-year follow-up report. *Int J Oral Maxillofac Implants* 1993;8:635-640.
35. Lekholm U, van Steenberghe D, Hermann I, et al. Osseointegrated implants in the treatment of partially edentulous jaws: A prospective 5-year multicenter study. *Int J Oral Maxillofac Implants* 1994;9:627-635.
36. Weber HP, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clin Oral Implants Res* 2000; 11:144-153.
37. Nickenig HJ, Wichmann M, Schlegel KA, Nkenke E, Eitner S. Radiographic evaluation of marginal bone levels adjacent to parallel-screw cylinder machined-neck implants and rough-surfaced microthreaded implants using digitized panoramic radiographs. *Clin Oral Implants Res* 2009;20:550-554.
38. Peñarrocha M, Palomar M, Sanchis JM, Guarinos J, Balaguer J. Radiologic study of marginal bone loss around 108 dental implants and its relationship to smoking, implant location, and morphology. *Int J Oral Maxillofac Implants* 2004;19:861-867.
39. Bratu EA, Tandlich M, Shapira L. A rough surface implant neck with microthreads reduces the amount of marginal bone loss: A prospective clinical study. *Clin Oral Implants Res* 2009;20:827-832.
40. Buser D, Dula K, Lang NP, Nyman S. Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. 5-year results of a prospective study with 12 implants. *Clin Oral Implants Res* 1996;7:175-183.
41. Zitzmann NU, Schärer P, Marinello CP, Schüpbach P, Berglundh T. Alveolar ridge augmentation with Bio-Oss: A histologic study in humans. *Int J Periodontics Restorative Dent* 2001;21:288-295.
42. Serino G, Biancu S, Iezzi G, Piattelli A. Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: A clinical and histological study in humans. *Clin Oral Implants Res* 2003;14:651-658.
43. Serino G, Rao W, Iezzi G, Piattelli A. Polylactide and polyglycolide sponge used in human extraction sockets: Bone formation following 3 months after its application. *Clin Oral Implants Res* 2008;19:26-31.
44. Shotwell J, Billy E, Wang HL. Effects of a putty-form hydroxyapatite matrix combined with the synthetic cell-binding peptide P-15 on alveolar ridge preservation. *J Periodontol* 2008;79:291-299.
45. Howell TH, Fiorellini J, Jones A, et al. A feasibility study evaluating rhBMP-2/absorbable collagen sponge device for local alveolar ridge preservation or augmentation. *Int J Periodontics Restorative Dent* 1997;17: 124-139.

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