Osteotome Sinus Floor Elevation and Simultaneous Implant Placement in Grafted Biomaterial Sockets: 3 Years of Follow-Up

Roberto Crespi,* Paolo Capparè,* and Enrico Gherlone*

Background: Immediate bone grafting procedures were proposed to preserve bone volume in residual damaged alveolar walls and to prevent the expansion of the sinus floor in the maxillary molar region. The use of an osteotome allows vertical bone augmentation and localized sinus elevation with minimal surgical trauma. The aim of this study is to evaluate the clinical outcome of implants placed in previously grafted alveoli that were expanded at a second-stage surgery by an osteotome technique.

Methods: Twenty patients requiring extraction of one or two upper molar teeth and/or a second premolar were selected. Thirty teeth were extracted, and their fresh sockets immediately received magnesium-enriched hydroxyapatite as a graft material. Three months after bone filling, osteotome sinus floor elevations were performed in grafted sites, and 30 titanium dental implants were placed. Three months after implant placement, temporary restorations were performed. Follow-up examinations and intraoral digital radiographs were taken at baseline and 6, 12, 24, and 36 months after implant placement to evaluate the alveolar bone gain for each implant. Comparisons among mean values of alveolar bone gain over time were performed by the Student two-tailed *t* test.

Results: At the 36-month follow-up, a survival rate of 100% was reported for all implants. The alveolar bone gain after 6 months of healing was 2.41 ± 1.23 mm. Successively, after 12 months, the bone gain increased (3.85 ± 1.37 mm). At 24 and 36 months after implant placement, the levels were stable (3.86 ± 1.50 mm and 3.82 ± 1.57 mm, respectively). Statistical analyses showed a significant difference ($P<0.05$) only between the 6- and 12-month values.

Conclusion: At the 36-month follow-up, the use of the osteotome technique for vertical expansion of the grafted tissue was considered a predictable procedure in the implant surgery. *J Periodontol 2010;81:344-349.*

KEY WORDS

Dental implants; maxillary sinus surgery; tooth socket.

* Department of Dentistry, Vita Salute University, San Raffaele Hospital, Milan, Italy.

Posterior maxillary tooth extraction causes an inferior expansion of the maxillary sinus in relation to fixed anatomic structures, thus proving the pneumatization phenomenon after tooth loss. The expansion of the sinus is larger after the extraction of teeth enveloped by a superiorly curving sinus floor, extraction of several adjacent posterior teeth, and extraction of second molars compared to first molars.[1] Furthermore, roots that protrude into the sinus have a thin cortical bone lining, and during the extraction procedure, this thin bone may break and dislocate, allowing the sinus to expand toward the empty socket.[2]

Molar extraction induces greater pneumatization than premolar extraction, probably due to a larger defect left in the alveolar cavity that allows the sinus to pneumatize.

To prevent the expansion of the sinus floor and to preserve the bone volume of fresh sockets after tooth extraction, immediate dental implant placement[3] and/or immediate bone grafting procedures are advocated. In an effort to increase the apical occlusal dimension of available bone for implant placement, the use of an osteotome allows for vertical bone augmentation and localized sinus elevation with minimal surgical trauma. The crestal bone is displaced toward the sinus floor, and the apical portion of the implant is placed in the

doi: 10.1902/jop.2010.090477

augmented space. In a study by Fugazzotto and De Paoli,[4] a modified trephine and osteotome procedure was performed at the time of a maxillary molar extraction to implode the interradicular bone after maxillary molar extraction. Particulate material and a membrane were then placed to increase the regeneration of alveolar bone.

In another clinical study,[5] implants were placed in fresh extraction sockets with simultaneous maxillary sinus floor elevations using the osteotome technique.[6,7] The graft materials used in both the sinus augmentation and peri-implant bone defects were a mixture of collagen gel and corticocancellous porcine bone particles.[5] No implants failed after a definitive prosthetic rehabilitation.[5]

However, when a fresh extraction socket is too wide or residual alveolar walls are damaged, immediate implant placement and the use of the osteotome technique must be avoided, especially in the posterior maxilla where bone volume is important for biologic processes.[8,9]

Consequently, surgical procedures, such as a bone allograft, bone autograft, and xenograft, are recommended to maintain the bone volume in fresh sockets before implant positioning.[10-12]

Due to their excellent biocompatibility and bioactivity, bioceramics are widely used in bone grafting and dental devices as bone substitutes because hydroxyapatite (HA) ceramics have the ability to induce mesenchymal cells to differentiate toward osteoblasts rendering HA as a potential scaffold material for bone-tissue engineering.[13-16]

The present study considered damaged fresh extraction sockets unable to support immediate implant placements and/or vertical expansions. At a first-stage surgery, the sites were filled with magnesium-enriched HA (MHA). At a second-stage surgery, 3 months later, implants were placed using an osteotome technique for vertical expansion of MHA-grafted sites. This technique was different from previous studies in which osteotomes were used for native bone expansion.[6,7] The aim of the study is to evaluate the clinical outcome of implants placed in previously grafted alveoli that were expanded at a second-stage surgery by the osteotome technique.

MATERIALS AND METHODS

Patient Selection

Between January 2006 and April 2009, 20 patients (12 women and eight men; mean age: 55.2 years; age range: 37 to 69 years) were included in this prospective study. Each patient required the extraction of one or two molar teeth and/or a second premolar. The inclusion criteria for the fresh sockets were a loss of bone plates and the impossibility of having an immediate implant placement. All patients were in good health, were non-smokers, had no chronic systemic disease, and had an absence of acute or chronic sinus problems. Exclusion criteria were coagulation disorders, the presence of signs of acute infection around alveolar bone at the surgical site, and alcohol or drug abuse. The local ethical committee at the San Raffaele Scientific Institute approved the study, and all patients signed an informed consent form. The diagnosis was made clinically and radiographically. The patients were treated by one oral surgeon (RC) and one prosthodontist (EG) at the Department of Dentistry, Vita Salute University, San Raffaele Hospital.

Table 1.

Implant Positions and Dimensions (diameter × length) (N = 30 implants)

Implant Position	5 × 13 mm	5 × 10 mm	Total
3	7	1	8
14	5	1	6
4	3	1	4
13	2	2	4
31	3	1	4
18	3	1	4
Total	23	7	30

Surgical Protocol

One hour prior to surgery, the patients received 1 g amoxicillin and 1 g twice a day for a week after the surgical procedure. Surgery was performed under local anesthesia (octocaine,† 20 mg/ml, with adrenaline, 1:80.000). Thirty teeth were extracted, and the majority of the surgical sites were in the upper first molar region followed by second premolar and second molar regions (Table 1). The teeth were extracted, avoiding flap elevation, and a periodontal probe was used to verify the wall assessment of the fresh sockets, which were debrided before receiving graft materials. Thirty fresh sockets received MHA Ca10-xMgx(PO4)6(OH)2 as a graft material, which was available in a granule form.‡

All graft materials were hydrated with a sterile solution for 3 minutes prior to insertion in the sockets and packed into the alveolus. A collagen sheet was used to cover the inner denuded biomaterial. The collagen was placed under the detached palatal tissue and secured with silk sutures[17] (Fig. 1).

Three months after tooth extraction and graft-material[17] placement, titanium plasma-spray implants

† Molteni Dental, Scandicci, Italy.
‡ SINTlife, Finceramica, Faenza, Italy.

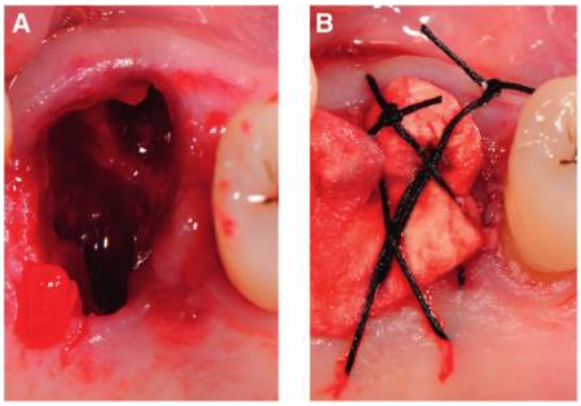

Figure 1.
A) *Clinical photograph of a fresh socket with damaged walls and the absence of the buccal and palatal plates.* ***B)*** *MHA was compressed into the socket, and a collagen sheet covered the inner denuded biomaterial and was secured with silk sutures.*

with a machined neck of 0.8 mm and a rough surface body with a progressive thread design[§] with an external hexagon as implant–abutment junctions were positioned in each site (Fig. 2).

Horizontal and vertical incisions were performed to raise a partial-thickness flap. The implant site was prepared using a calibrated bur, 2 mm in diameter, to a depth of 1 mm below the sinus floor, determined radiographically. Subsequently, a standardized sequence of osteotomes was used. The elevation of the maxillary sinus was performed using the last osteotome to achieve a sinus floor fracture. No additional graft material was introduced into the recipient site. The implant was placed into the bone site to the planned depth. Subsequently, the soft tissues were sutured.

Prosthetic Protocol

Three months after the implant placement, temporary restorations were performed. Transfer copings were inserted into the external hex of the implant with a seating instrument and secured with abutment screws. Impressions were taken with a silicon material using an individual impression. Prepared final metal abutments were screwed onto the dental implants. All temporary crowns were in full contact in centric occlusion. Two months later, final metal ceramic restorations were cemented on abutments. The occlusion was checked using an 8-μm foil,[‖] which resisted withdrawal only under maximal clenching.

Radiographic Assessments

Intraoral digital radiographs[¶] were made at baseline and 6, 12, 24, and 36 months after implant placement. Periapical radiographs were taken perpendicular to the long axis of the implant with a long-cone parallel technique using an occlusal template. A masked radiologist (PC) measured the changes in marginal bone height over time.

The following parameters were assessed from the periapical radiograph: the presurgical distance from the alveolar crest to the floor of the maxillary sinus 3 months after placement of the graft material (Fig. 2B); the amount of new radiopacity between the sinus floor and alveolar crest measured from the mesial and distal surfaces of each dental-implant surface (Fig. 3); and the mean for the initial and gained alveolar bone height, obtained from these readings by a specific software[#] and evaluated at 6, 12, 24, and 36 months of healing from implant placement.

Follow-Up Evaluation

The following clinical parameters were checked: pain, occlusion, and prosthesis mobility. The success criteria for implant survival were accepted as the presence of implant stability, absence of radiolucent zone around the implants, no mucosal suppuration, and no pain.[18]

Probing depths (PDs) were determined on the mesial, distal, buccal, and palatal surfaces of the implants with a periodontal probe.[19]**

Follow-up examinations were performed at baseline and 6, 12, 24, and 36 months after implant placement.

Statistical Analyses

Data are presented as the mean ± SD. Comparisons among mean values of bone height at different time points (6, 12, 24, and 36 months) were performed by the Student two-tailed t test. $P < 0.05$ was considered the threshold for statistical significance.

RESULTS

Surgical and Prosthetic Procedures

After 36 months of follow-up, a survival rate of 100% was reported for all implants. No sinus membrane perforation was performed. No pain or final prosthesis mobility was recorded. There was suitable wound healing around temporary abutments with a fine adaptation to the temporary crown. Minor swelling of the gingival mucosa was present in the first days after surgical procedures, but no mucositis or flap dehiscence with suppuration was found.

Clinical Parameters

The mean PD was obtained from averaging PD measurements on the mesial, distal, buccal, and palatal surfaces of the implants; the mean values were 1.39 ± 0.42 mm and 2.05 ± 0.31 mm at baseline and 36 months, respectively.[19]

§ Sweden & Martina, Due Carrare, Italy.
‖ Shimstock, Hanel, Germany.
¶ Schick Technologies, Long Island City, NY.
# Schick CDR, Schick Technologies.
** Hu-Friedy PGF-GFS, Hu-Friedy, Chicago, IL.

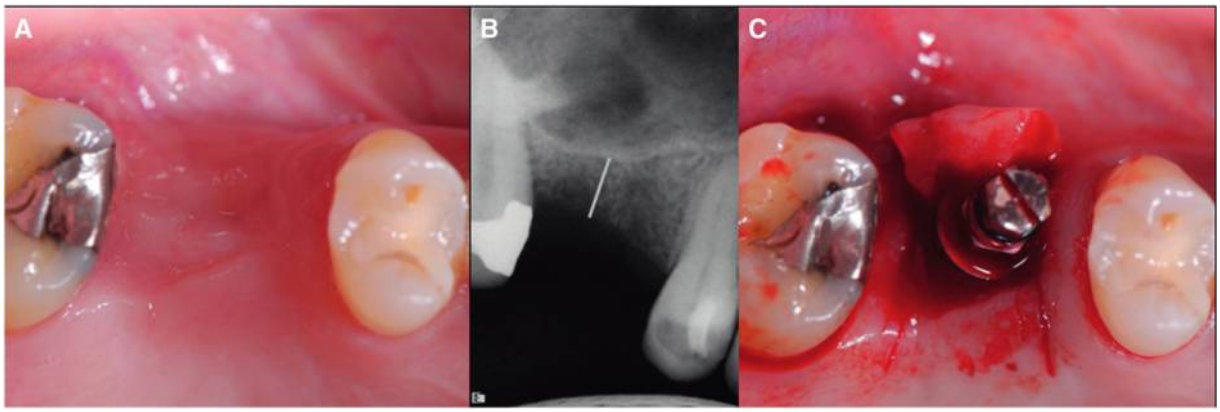

Figure 2.
A) *Clinical photograph of soft tissue healing prior to the second-stage surgery.* ***B)*** *Clinical x-ray of the presurgical distance from the alveolar crest to the floor of the maxillary sinus 3 months after positioning of the graft material.* ***C)*** *Clinical photograph of implant placement.*

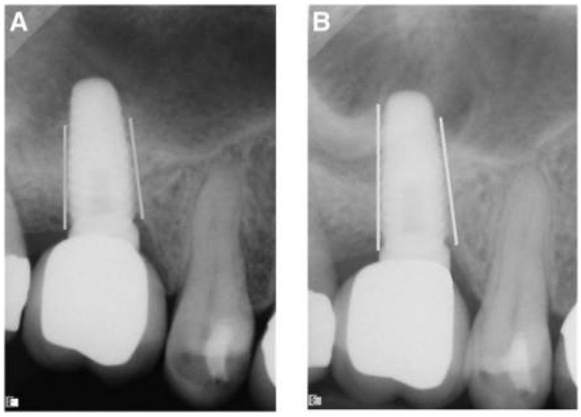

Figure 3.
A) *Measurements (lines) of the distance from the alveolar crest to the most apical part of the radiopacity along the distal and mesial surfaces of the dental implant 6 months after implant placement.* ***B)*** *Measurements (lines) of the distance from the alveolar crest to the most apical part of the radiopacity along the distal and mesial surfaces of the dental implant 36 months after implant placement.*

Radiographic Evaluation

Radiographic results were reported at 6, 12, 24, and 36 months after implant placement (Table 2).

Three months after tooth extraction and placement of the graft material, the initial alveolar bone height was 6.62 ± 1.89 mm. The alveolar bone gain after 6 months of healing, evaluated as the presence of radiopacity around exposed mesial and distal implant surfaces within the created space at the floor of the maxillary sinus, resulted in a mean value of 2.41 ± 1.23 mm.

Successively, after 12 months, the radiopacity around exposed surfaces of mesial and distal implants increased, resulting in a mean value of 3.85 ± 1.37 mm.

Table 2.

Radiographic Results for Gain in Alveolar Bone Height (mean ± SD) (N = 30 implants)

Time From Implant Placement (months)	Mesial Bone Height (mm)	Distal Bone Height (mm)	Mean Bone Height (mm)
6	2.59 ± 1.01	2.22 ± 1.45	2.41 ± 1.23
12	4.26 ± 1.21	3.44 ± 1.53	3.85 ± 1.37
24	4.31 ± 1.35	3.42 ± 1.66	3.86 ± 1.50
36	4.25 ± 1.42	3.40 ± 1.72	3.82 ± 1.57

At 24 and 36 months after implant placement, the mean bone-height measurements were stable (3.86 ± 1.50 mm and 3.82 ± 1.57 mm, respectively) (Table 2). Statistical analyses showed a significant difference ($P<0.05$) between the 6- and 12-month values, whereas no statistically significant differences were found among the 12-, 24-, and 36-month values.

These results demonstrate a significant increase in bone height between 6 and 12 months and stable bone levels at the 3-year follow-up. The implants stayed in function for the 36 months of the study.

DISCUSSION

Osteotome-mediated sinus floor elevation was associated with an implant survival rate directly related to the height of the remaining subsinus bone because the initial stability of implants was only provided by the residual alveolar ridge.[20] This justifies the use of a biomaterial graft to avoid bone collapse after tooth

extraction by providing a residual bone height to allow a vertical bone expansion. In clinical studies,[5,21] after tooth extraction in a one-stage surgery, the implant site was immediately prepared using standardized sequence of osteotomes for vertical expansion of native bone, and immediately, a mixture of collagen gel and corticocancellous porcine bone particles was introduced into the receptor site and pressed into the fractured sinus floor area; subsequently, the implant was placed into the bone site to the planned depth.

In another clinical study,[4] after molar extraction, the osteotome imploded both the interradicular native bone and the underlying sinus membrane; then, the prepared alveolus was filled with anorganic bovine bone material and covered by membranes. At the second-stage surgery, after 4 months, the implants were placed using a traditional surgical procedure. A total of 97.8% of the implants were functioning successfully for up to 3 years. In all reported cases, the osteotome procedure was used for the expansion of native bone to create a vertical and horizontal space for implant placement.

In the present study, damaged alveolar walls of the fresh sockets prevented both immediate implant placement and the use of osteotomes; consequently, the alveoli were filled with MHA without expansion procedures.

Three months later, at second-stage surgery, the implant site was prepared by using osteotomes[22-26] that compressed and expanded grafted tissues and not a native bone as reported by literature, for vertical bone expansion and cortical sinus floor elevation, thereby obtaining a survival rate of 100% for all placed implants at 36 months of follow-up.

The same clinical outcome was reported for implants placed 3 months later in sockets grafted with different biomaterials using a conventional surgical protocol.[27]

From the previous article[27] and the present study, the same defects of fresh sockets were filled by the same graft material, MHA, and after 3 months, implant sites were prepared by different surgical procedures, one using traditional drilling[27] and the other using an osteotome, and a survival rate of 100% was reported for all implants.

It is probable that, within the grafted area, increasing amounts of bone might grow during the osseointegration process, providing drilling or expansion procedures for implant site preparation and allowing appropriate functional loading periods.

The alveolar bone gain reported in the present study after 6 months of healing, expressed as the presence of radiopacity around exposed implant surfaces within the created space at the floor of the maxillary sinus and increased radiopacity after 12 months, may be due to the graft material and osteotome procedure.

The MHA grafted in the maxillary sinus lift[16] was analyzed by histomorphometry and ex vivo osteoblast expansion followed by highly sensitive gene-expression profiling by quantitative real-time reverse transcription-polymerase chain reaction (RT-PCR).

Biopsies presented a bone volume of 76.72% ± 11.47%, and real-time RT-PCR analyses showed a significantly high expression of the osteoblast differentiation factor, cure-binding factor α1 (Cbfα1) and the matrix formation marker osteocalcin.

Other clinical studies[28,29] evaluated bone formation histologically and biomechanically in extraction sites after implantation of bioceramics, and all sites revealed good primary stability at implant insertion and proper implant rigidity at abutment placement, indicating that early implant osseointegration was not influenced by the application of bone biomaterials.

CONCLUSION

Although these are promising clinical results, further studies are needed to better understand the healing process of grafted biomaterials in relationship with dental implants.

ACKNOWLEDGMENT

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

REFERENCES

1. Sharan A, Madjar D. Maxillary sinus pneumatization following extractions: A radiographic study. *Int J Oral Maxillofac Implants* 2008;23:48-56.
2. Wehrbein H, Diedrich P. Progressive pneumatization of the basal maxillary sinus after extraction and space closure (in German). *Fortschr Kieferorthop* 1992;53: 77-83.
3. Schwartz-Arad D, Grossman Y, Chaushu G. The clinical effectiveness of implants placed immediately into fresh extraction sites of molar teeth. *J Periodontol* 2000;71:839-844.
4. Fugazzotto PA, De Paoli S. Sinus floor augmentation at the time of maxillary molar extraction: Success and failure rates of 137 implants in function for up to 3 years. *J Periodontol* 2002;73:39-44.
5. Barone A, Cornelini R, Ciaglia R, Covani U. Implant placement in fresh extraction sockets and simultaneous osteotome sinus floor elevation: A case series. *Int J Periodontics Restorative Dent* 2008;28:283-289.
6. Summers RB. The osteotome technique: Part 3–Less invasive methods of elevating the sinus floor. *Compendium* 1994;15:698, 700, 702-704.
7. Summers RB. A new concept in maxillary implant surgery: The osteotome technique. *Compendium* 1994; 15:152, 154-6, 158 passim; quiz 162.
8. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005;32:212-218.
9. Okamoto T, Onofre Da Silva A. Histological study on the healing of rat dental sockets after partial removal

of the buccal bony plate. *J Nihon Univ Sch Dent* 1983;25:202-213.
10. Rosenquist B, Ahmed M. The immediate replacement of teeth by dental implants using homologous bone membranes to seal the sockets: Clinical and radiographic findings. *Clin Oral Implants Res* 2000;11:572-582.
11. Schwartz-Arad D, Chaushu G. Placement of implants into fresh extraction sites: 4 to 7 years retrospective evaluation of 95 immediate implants. *J Periodontol* 1997;68:1110-1116.
12. Araújo M, Linder E, Lindhe J. Effect of a xenograft on early bone formation in extraction sockets: An experimental study in dog. *Clin Oral Implants Res* 2009; 20:1-6.
13. Cammack GV II, Nevins M, Clem DS III, 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.
14. 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.
15. Okumura M, Ohgushi H, Dohi Y, et al. Osteoblastic phenotype expression on the surface of hydroxyapatite ceramics. *J Biomed Mater Res* 1997;37:122-129.
16. Crespi R, Mariani E, Benasciutti E, Capparè E, Cenci S, Gherlone E. Magnesium-enriched hydroxyapatite versus autologous bone in maxillary sinus grafting: Combining histomorphometry with osteoblast gene expression profiles ex vivo. *J Periodontol* 2009;80:586-593.
17. Crespi R, Capparè P, Gherlone E. Magnesium-enriched hydroxyapatite compared to calcium sulfate in healing of human extraction sockets: Radiographic and histomorphometric evaluation at 3 months. *J Periodontol* 2009;80:210-218.
18. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11-25.
19. Mombelli A, Lang NP. Clinical parameters for the evaluation of dental implants. *Periodontol 2000* 1994;4: 81-88.
20. Toffler M. Osteotome-mediated sinus floor elevation: A clinical report. *Int J Oral Maxillofac Implants* 2004; 19:266-273.
21. Fugazzotto PA. Implant placement at the time of maxillary molar extraction: Treatment protocols and report of results. *J Periodontol* 2008;79:216-223.
22. Rosen PS, Summers R, Mellado JR, Salkin LM, Shanaman RH, Marks MH. The bone-added osteotome sinus floor elevation technique: Multicenter retrospective report of consecutively treated patients. *Int J Oral Maxillofac Implants* 1999;14:853-858.
23. Summers RB. Sinus floor elevation with osteotomes. *J Esthet Dent* 1998;10:164-171.
24. Leonetti JA, Rambo HM, Throndson RR. Osteotome sinus elevation and implant placement with narrow size bioactive glass. *Implant Dent* 2000;9:177-182.
25. Bruschi GB, Scipioni A, Calesini G, Bruschi E. Localized management of sinus floor with simultaneous implant placement: A clinical report. *Int J Oral Maxillofac Implants* 1998;13:219-226.
26. Brägger U, Gerber C, Joss A, et al. Patterns of tissue remodeling after placement of ITI dental implants using an osteotome technique: A longitudinal radiographic case cohort study. *Clin Oral Implants Res* 2004;15:158-166.
27. 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.
28. Molly L, Vandromme H, Quirynen M, Schepers E, Adams JL, van Steenberghe D. Bone formation following implantation of bone biomaterials into extraction sites. *J Periodontol* 2008;79:1108-1115.
29. 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.

Correspondence: Dr. Roberto Crespi, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Via Olgettina N. 48, 20123, Milan, Italy. E-mail: robcresp@libero.it.

Submitted August 14, 2009; accepted for publication October 8, 2009.