Regenerative Needs Following Alveolar Ridge Preservation Procedures in Compromised and Noncompromised Extraction Sockets: A Cone Beam Computed Tomography Study

Theofilos Koutouzis, DDS, MS[1]/David Lipton, DDS[2]

Purpose: *The aim of this study was to evaluate the necessity for additional regenerative procedures following healing of compromised and noncompromised extraction sockets with alveolar ridge preservation procedures through the use of virtual implant imaging software.* ***Materials and Methods:*** *The cohort was comprised of 87 consecutive patients subjected to a single maxillary tooth extraction with an alveolar ridge preservation procedure for subsequent implant placement. Patients were divided into two main groups based on the integrity of the buccal bone plate following teeth extraction. Patients in the compromised socket (CS) group (n = 52) had partial or complete buccal bone plate loss, and patients in the noncompromised socket (NCS) group (n = 35) exhibited no bone loss of their socket walls following tooth extraction. Following 4 to 6 months of healing, all patients had a cone beam computed tomography (CBCT) study. Root-formed implants were placed virtually in an ideal prosthetic position. The number of implants per group and location (anterior, premolar, molar) exhibiting exposed buccal implant surface was calculated.* ***Results:*** *In the CS group, 5 out of 19 anterior implants (26.3%), 4 out of 14 premolar implants (28.5%), and 7 out of 19 molar implants (36.8%) had exposed buccal surfaces. In the NCS group, 4 out of 9 anterior implants (44.4%), 2 out of 9 premolar implants (22.2%), and 4 out of 17 molar implants (23.5%) had exposed buccal surfaces. There were no statistically significant differences for intragroup and intergroup comparisons (χ^2 test, $P > .05$).* ***Conclusion:*** *This study failed to find statistically significant differences in the frequency of implants with exposed buccal surfaces placed virtually, following treatment of compromised and noncompromised sockets. A high proportion (22% to 44%) of sites had implants that potentially needed additional regenerative procedures.* Int J Oral Maxillofac Implants 2016;31:849–854. doi: 10.11607/jomi.4437

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Following tooth extraction, bone modeling and remodeling characterize the healing of the extraction socket,[1,2] exhibiting a reduction in both the height and the width of the alveolar ridge.[3–5] Bone dehiscences or fenestrations that are present at the time of extraction are most likely to further compromise the healing of the extraction socket. Dehiscences and fenestrations may result from periapical pathology, tooth position in the alveolus, cracking or fracture of endodontically treated teeth, removal of the facial bone during extraction, removal of teeth with curved roots or multiple roots, ankylosis, and root fractures.

In an attempt to preserve alveolar ridge dimensions and to optimize subsequent prosthetic rehabilitation of the edentulous site, several materials and techniques have been utilized.[6–8] Those methods have focused mainly on the management of noncompromised extraction sockets without necessarily addressing the needs of sockets with compromised bony walls. Even though barrier membrane placement and complete primary wound closure are fundamental principals of guided bone regeneration,[9] successful outcomes without primary wound closure and without barrier membranes have been reported in the literature for alveolar ridge preservation procedures.[10–12]

[1]Associate Professor, Department of Periodontology, College of Dental Medicine, Nova Southeastern University, Fort Lauderdale, Florida, USA.
[2]Resident, Department of Periodontology, College of Dentistry, University of Florida, Gainesville, Florida, USA.

Correspondence to: Dr Theofilos Koutouzis, Department of Periodontology, College of Dental Medicine, Nova Southeastern University, Fort Lauderdale, Florida, 3200 South University Drive, Fort Lauderdale, FL 33328, USA. Fax: +19542621782. Email: tkoutouzis@nova.edu

In addition, primary wound closure at the time of the extraction may influence the location of the mucogingival junction and the amount of keratinized mucosa at the healed site.[13]

Linear and volumetric changes have been mainly used to evaluate alveolar ridge preservation techniques, with few studies including adequate controls and several studies combining data from heterogeneous clinical conditions such as management of single and multirooted teeth.[14] Implant position is one of the most important determinants for long-term maintenance of implant esthetics and function.[15] Thus, the efficacy of alveolar ridge preservation procedures can also be evaluated in terms of the ability to position implants in a restoratively driven ideal position without any of the implant surface exposed. There is limited information in the literature for the efficacy of alveolar ridge preservation procedures on noncompromised and compromised extraction sockets in terms of ideal implant positioning following healing, without any additional regenerative needs.

The aim of this study was to evaluate the necessity for additional regenerative procedures following healing of compromised and noncompromised extraction sockets with alveolar ridge preservation procedures through the use of virtual implant imaging software.

MATERIALS AND METHODS

Subjects who had extraction of a single maxillary tooth with an alveolar ridge preservation procedure and a cone beam computed tomography (CBCT) survey for implant therapy treatment planning 4 to 6 months following the procedure were included in the study. All included patients had extractions performed for nonperiodontal reasons. The subjects were grouped according to the integrity of the extraction socket and type of alveolar ridge preservation procedure performed. Patients in the compromised socket (CS) group had partial or complete buccal bone plate loss, and patients in the noncompromised socket (NCS) group exhibited no bone loss of their socket walls following tooth extraction.

For all patients in both groups, a careful periodontal examination including assessment of plaque, gingivitis, probing depth, and radiographic bone loss at all remaining teeth was performed. This was followed by oral hygiene instructions and periodontal therapy if indicated.

All extractions and grafting procedures in this study were carried out under local anesthesia. For patients in the CS group, vertical releasing incisions were placed at the proximal line angles of the teeth adjacent to the extracted tooth, and a full-thickness flap was elevated beyond the mucogingival junction. Following careful debridement of the extraction socket, freeze-dried bone allograft (FDBA; Mineralized Ground Cancellous, 250 to 1,000 μm, Straumann) was placed, and a resorbable collagen membrane (Cytoplast RTM, Osteogenics) covered the graft material. For all the sockets with compromised buccal bone wall, there was an attempt to overfill the defect to increase the buccolingual dimension of the site. For all the cases, there was no attempt to stabilize the collagen membranes by means of tacks or sutures. Following periosteal releasing incisions, the flap was advanced and secured with nonresorbable sutures (PTFE monofilament, Osteogenics) to achieve primary closure. For patients of the NCS group, tooth extraction was followed by graft placement (Mineralized Ground Cancellous, 250 to 1,000 μm, Straumann) in the socket, and a collagen dressing material (CollaPlug, Zimmer Dental) was placed to cover the grafting material. Lastly, the site was secured with nonresorbable sutures without any intention to achieve primary closure (PTFE monofilament, Osteogenics). Each patient received 500 mg of amoxicillin three times per day for 7 days from the time of the alveolar ridge preservation procedure.[16]

CBCT Image Acquisition and Virtual Implant Placement

Four to six months following tooth extraction and alveolar ridge preservation, a CBCT study was performed on each patient, using the 9000 CBCT (Carestream Dental). The exposure settings selected were 74 kV and 10 mA. The scanning parameters selected were 76-μm voxel size, 10.68-second acquisition time, and a field of view that varied based on the scanned region. The CBCT scans of each individual were transferred to a desktop computer equipped with an implant planning software program (InVivo5, Anatomage).

Parallel root-form implants were placed virtually in the selected edentulous sites. The diameter of the selected implants corresponded to the edentulous site and the system utilized at the private practice (Straumann Bone Level Implants, Straumann). Thus, for edentulous spaces of central incisors, canines, and premolars, implants with a diameter of 4.1 mm were selected. For edentulous spaces of lateral incisors and molars, implants with diameters of 3.3 and 4.8 mm were selected, respectively. The length of the implants was selected based on the anatomical limitations provided by the inferior wall of the maxillary sinus. Shorter implants were selected to avoid anatomical bony concavities in maxillary areas and maintain the apical portion of the implant within the bony housing. Implant lengths varied from 8 to 12 mm. Implant crowns were virtually designed based on the dimensions of the edentulous spaces and the adjacent teeth. The

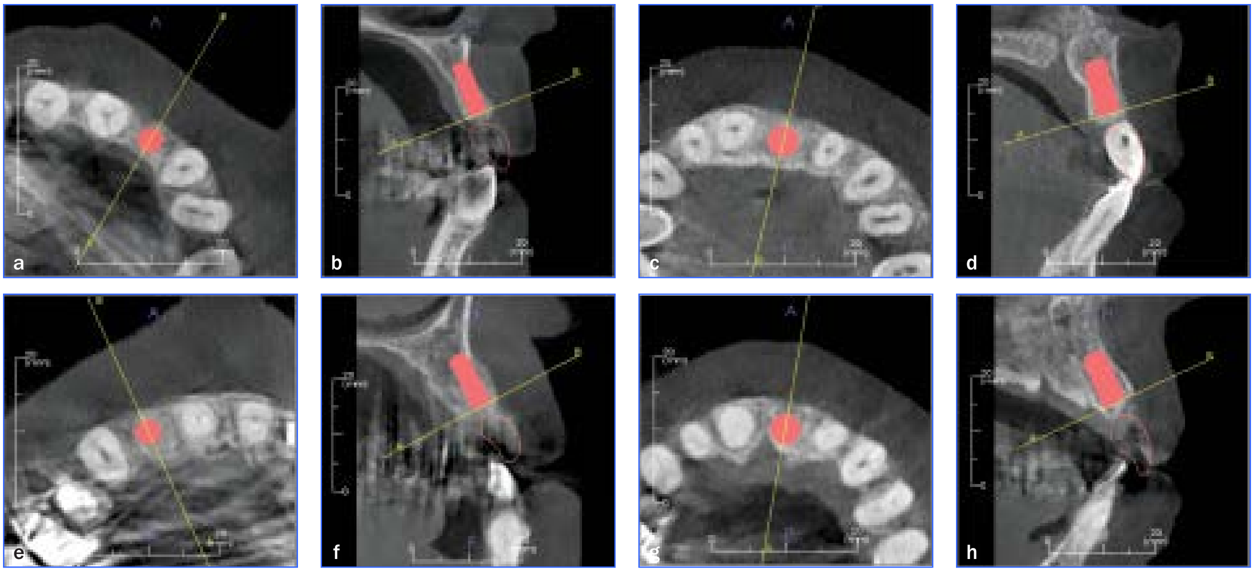

Fig 1 CBCT images with virtually positioned implants. *(a)* Axial image of left lateral incisor of NCS group. *(b)* Transaxial image of left lateral incisor of NCS group showing exposure of the implant surface. *(c)* Axial image of left central incisor of NCS group. *(d)* Transaxial image of left central incisor of NCS group. *(e)* Axial image of right lateral incisor of CS group. *(f)* Transaxial image of right lateral incisor of CS group. *(g)* Axial image of left central incisor of CS group. *(h)* Transaxial image of left central incisor of CS group.

three-dimensional ideal implant position was based on the characteristics and position of the designed crowns and principles described by Buser et al.[15] Thus, mesiodistally, implants were positioned in the center of the edentulous span. Buccolingually, the buccal periphery of the implant was positioned at least 1 mm and no more than 2 mm palatal to the point of emergence of the adjacent teeth. Apicocoronally, the implant platform was positioned at least 3 mm and no more than 4 mm apically to the cervical margin of the designed implant crown. Once the implant was positioned, any exposure of the implant surface was recorded (Fig 1). All virtual implant placement and recording of the exposed surfaces was performed by a periodontist (D.L.) not involved in the patient treatment.

Statistical Analysis

Implant sites of the CS and NCS groups were further divided into anterior, premolar, and molar sites. The total number of implants per group (CS, NCS) and site (anterior, premolar, molar) exhibiting exposed surfaces was calculated. The χ^2 test was applied to evaluate differences in the number of implants with exposed surfaces within and between groups. A P value $< .05$ was considered significant.

RESULTS

The records from 87 consecutive patients treated with alveolar ridge preservation procedures for subsequent, single-tooth, implant replacement were reviewed. The subject sample consisted of 54 men and 33 women with a mean age of 58.9 years (range, 26 to 80 years) treated at a private practice setting during 2012 to 2014 by one periodontist (T.K.). Fifty-two patients comprised the CS group (n = 52), and thirty-five patients comprised the NCS group (n = 35).

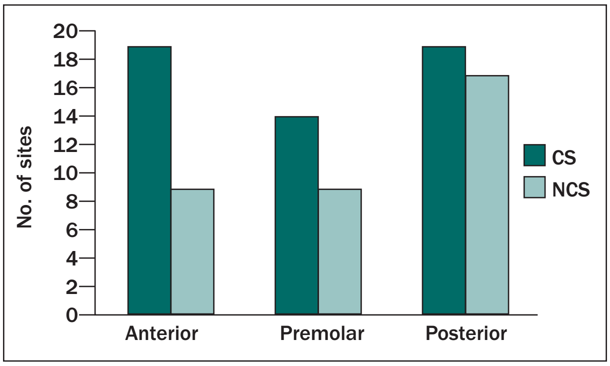

Fig 2 Distribution of sites according to positions and groups.

The distribution of sites according to positions and groups is illustrated in Fig 2. The number of implants per group (CS, NCS), location (anterior, premolar, molar), and exposure of surface are illustrated in Table 1. The intragroup comparisons for the CS group revealed no statistically significant difference in the number of implants exhibiting exposed surfaces for anterior versus premolar implant sites ($\chi^2 = 0.33$; $P > .05$), anterior versus molar implant sites ($\chi^2 = 0.48$; $P > .05$), and premolar versus molar implant sites ($\chi^2 = 0.04$; $P > .05$). Similarly, for the NCS group, no statistically significant differences were found in the number of implants

Table 1 Number and Frequency (%) of Implant With and Without Exposed Surfaces According to Groups (CS, NCS) and Site (Anterior, Premolar, Molar)

	CS group (n = 52)			NCS group (n = 35)		
Implant placement	Anterior (n = 19)	Premolar (n = 14)	Molar (n = 19)	Anterior (n = 9)	Premolar (n = 9)	Molar (n = 17)
With exposure	5 (26.3%)	4 (28.5%)	7 (36.8%)	4 (44.4%)	2 (22.2%)	4 (23.5%)
Without exposure	14 (73.7%)	10 (71.5%)	12 (63.2%)	5 (55.6%)	7 (77.8%)	13 (76.5%)

χ^2 test for intragroup and intergroup comparisons; $P > .05$.

exhibiting exposed surfaces for anterior versus premolar implant sites ($\chi^2 = 1.00$; $P > .05$), anterior versus molar implant sites ($\chi^2 = 1.20$; $P > .05$), and premolar versus molar implant sites ($\chi^2 = 0.06$; $P > .05$). In regard to intergroup comparisons, there was no statistically significant difference in the number of implants exhibiting exposed surfaces between CS and NCS groups for anterior implant sites ($\chi^2 = 0.92$; $P > .05$). Similarly, there were no statistically significant differences in the number of implants with exposed surfaces between CS and NCS groups for premolar ($\chi^2 = 0.41$; $P > .05$) and molar implant sites ($\chi^2 = 0.74$; $P > .05$).

DISCUSSION

The present study evaluated the frequency of virtual implant exposure when aligned in an ideal prosthetic position following alveolar ridge preservation procedures. The primary outcome variable for evaluation of alveolar ridge preservation procedures has been changes in alveolar ridge dimensions evaluated clinically,[17] on study casts,[18] or with CBCT.[19] Changes in alveolar ridge dimensions can provide valuable information for the efficacy of different alveolar ridge preservation procedures, assuming that adequate standardization is ensured when measuring the dimensions of the alveolar ridge. Standardization and interpretation of measurements following alveolar ridge preservation procedures can be challenging, especially when it involves treatment of compromised sockets. In that case, the outcome of the procedure is related to the regeneration of the lost structures, rather than the mere preservation of the dimensions of the existing alveolar ridge. Thus, for treatment of compromised sockets, a different term other than alveolar ridge preservation procedure may need to be considered. It is not always obvious if the effect of alveolar ridge preservation procedures is adequate for placement of a dental implant in a prosthetically driven position without any surface of the implant exposed and subsequently in need of additional regenerative procedures. The present study did not evaluate the efficacy of the alveolar ridge preservation procedures in terms of alteration of the dimensions of the alveolar ridge, mainly due to the retrospective nature of the study and the lack of information of the alveolar ridge dimensions immediately following tooth extraction. However, the efficacy of the alveolar ridge preservation techniques were evaluated in terms of providing a ridge adequate for implant placement without any exposure of the implant surface, which is highly clinically relevant.

In the present study, no statistically significant differences were found for the intragroup and intergroup comparisons. However, the anterior NCS group exhibited the highest proportion of implants (4/9, 44.4%) having exposed surfaces following alveolar ridge preservation procedures. All four exposed implant sites were noted at the lateral incisor area, with four out of five lateral incisors exhibiting implant exposure mainly at the apical portion of the implant. A relatively high proportion of implants in the maxillary incisor area with fenestrations (approximately 20%) following virtual implant placement in healed ridges has also been described.[20] In this study, it was not clear what type of alveolar ridge management was performed following tooth extraction. It demonstrates, however, that the physiologic anatomical features of the maxillary incisor area, such as the depth of the buccal concavity, can be predisposed to fenestration of the implants, especially at the apical part. In comparison to the other regions of the maxilla (premolar, molar), the higher proportion of implants with exposed surfaces in the anterior region can also be attributed to the thickness of the buccal plate following extraction. A decrease in the thickness of the buccal plate from the premolar to the incisor region with a thin or missing buccal plate in the anterior maxillary area has been reported in 90% of the patients.[21] Regardless of the region of treatment, exposure of the implant surface and additional regenerative needs should be anticipated following management of intact sockets. This demonstrates that some dimensional alterations should be expected even following an alveolar ridge preservation procedure in a noncompromised socket.

Unlike noncompromised sockets, little data are currently available for management of extraction sockets with compromised buccal bone walls. Furthermore, reconstruction protocols treating sockets with compromised buccal bone walls have not been validated with experimental data. Implants placed into sites with compromised buccal walls tend to lead to higher early failure,[22] more mucosal recession,[23] fewer sites with bone fill,[24] and greater peri-implant horizontal bone resorption.[25] Evidence therefore suggests that it may be clinically important to reconstruct the missing facial plate prior to implant placement.

The anterior sites of the CS group exhibited a lower proportion of implants with exposed surfaces (5/19, 26.3%) compared with the anterior sites of the NCS group. The management of the sites for the CS involved periosteal flap elevation, placement of the grafting material, barrier membrane, and primary wound closure according to the "PASS" principles for bone regeneration.[26] This way of compromised socket management is providing the opportunity to reconstruct the region beyond the anatomical borders of the socket, and altering the depth of the buccal concavity. This was accomplished by overfilling the defect with grafting material. Obviously, it was not possible for this to be accomplished in the NCS group since no flap elevation was performed. It is generally accepted that flap elevation can have a detrimental effect on bone remodeling[27] due to interruption of the periosteal vascular supply and an increase in postsurgical local inflammation. However, recent preclinical evidence indicates that flap elevation does not necessarily promote alveolar bone loss.[28] Flap elevation for management of compromised sockets provides access for proper debridement of the defect, biomaterial placement, and primary wound closure. A drawback of this approach is the alteration of the mucogingival junction and reduction of the vestibular depth. Several aspects in the management of the compromised sockets, such as the beneficial effects of flap elevation, barrier membrane placement, and primary wound closure, have not been fully understood. The results of the present study point out that similar outcomes may be expected when managing compromised sockets in different regions of the mouth.

Few studies have evaluated the proportion of implants with exposed implant surfaces when placed following alveolar ridge preservation techniques.[29,30] In a study of alveolar ridge preservation of noncompromised sockets of maxillary premolar teeth, it has been reported that none of the sockets in the alveolar ridge preservation group needed additional bone grafting at the time of implant placement.[29] On the contrary, 33% of the control sites required additional bone grafting procedures at the time of implant placement. These findings are difficult to interpret because a nonsignificant 0.12 mm difference in horizontal ridge dimension change was reported between the test and control groups. The findings of this study are in contrast with the findings of the present study that reports 22.2% of the noncompromised sockets of maxillary premolar sites have implants with exposed surfaces. Differences in the biomaterial properties used and definitions of ideal implant position may explain differences in findings between the studies. A more recent study[30] evaluated the flapless management of compromised sockets with recombinant human bone morphogenetic protein 2/absorbable collagen carrier (rhBMP-2/ACS) and reported on the proportion of sites in need of additional grafting procedures 5 months following treatment. It was reported that 33.3% of nonmolar sites treated with rhBMP-2/ACS needed additional grafting procedures. This is close with the findings of the present study showing that 26.3% of anterior sites and 28.5% of premolar sites had implants with exposed surfaces.

The present study has several limitations, such as the retrospective nature, the lack of standardization of overfilling the defects with grafting material, the small sample size, the lack of ridge dimensions immediately following extraction, the lack of evaluation of dimensional changes over time, and the lack of evaluating factors that may contribute to the outcome of alveolar ridge preservation. Most importantly, the major limitation of this study is the lack of an appropriate control group that is treated without any biomaterials. However, to the authors' knowledge, this is one of the few studies evaluating the outcome of compromised socket management in comparison to noncompromised sockets.

CONCLUSIONS

The aim of this study was to evaluate the necessity for additional regenerative procedures following healing of compromised and noncompromised extraction sockets with alveolar ridge preservation procedures through the use of virtual implant imaging software.

Within the limits of this study, it failed to identify statistically significant differences in the frequency of implants with exposed buccal surfaces placed virtually, following treatment of compromised and noncompromised sockets. In addition, the study failed to find significant differences in the frequency of implants with exposed surfaces for different regions of the maxilla for both compromised and noncompromised sockets. A relatively high proportion (22% to 44%) of sites had implants that potentially need additional regenerative procedures.

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