

# Effect of Single and Contiguous Teeth Extractions on Alveolar Bone Remodeling: A Study in Dogs

Mansour Al-Askar, MSc;\* Rory O'Neill, MS;† Paul C. Stark, ScD;‡ Terrence Griffin, DMD;§  
Fawad Javed, PhD;¶ Khalid Al-Hezaimi, MSc\*\*

---

## ABSTRACT

**Background:** Tooth extraction is associated with dimensional changes in the alveolar ridge. The aim was to examine the effect of single versus contiguous teeth extractions on the alveolar ridge remodeling.

**Material and Methods:** Five female beagle dogs were randomly divided into three groups on the basis of location (anterior or posterior) and number of teeth extracted – extraction socket classification: group 1 (one dog): single-tooth extraction; group 2 (two dogs): extraction of two teeth; and group 3 (two dogs): extraction of three teeth in four anterior sites and four posterior sites in both jaws. The dogs were sacrificed after 4 months. Sagittal sectioning of each extraction site was performed and evaluated using microcomputed tomography.

**Results:** Buccolingual or palatal bone loss was observed 4 months after extraction in all three groups. The mean of the alveolar ridge width loss in group 1 (single-tooth extraction) was significantly less than those in groups 2 and 3 ( $p < .001$ ) (multiple teeth extraction). Three-teeth extraction (group 3) had significantly more alveolar bone loss than two-teeth extraction (group 2) ( $p < .001$ ). The three-teeth extraction group in the upper and lower showed more obvious resorption on the palatal/lingual side especially in the lower group posterior locations.

**Conclusion:** Contiguous teeth extraction caused significantly more alveolar ridge bone loss as compared with when a single tooth is extracted.

**KEY WORDS:** alveolar, bone, dental, extraction, microcomputed tomography, ridge, tooth

---

\*Research associate, Eng. A.B. Research Chair for Growth Factors and Bone Regeneration, Department of Periodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia and Postgraduate student, Department of Periodontology, School of Dental Medicine, Tufts University, Boston, MA, USA; †Professor, Department of Periodontology, School of Dental Medicine, Tufts University, Boston, MA, USA; ‡associate professor, director of Advanced and Graduate Education, Department of Research Administration, Tufts School of Dental Medicine, Boston, MA, USA; §Professor, Department of Periodontology, School of Dental Medicine, Tufts University, Boston, MA, USA; ¶Research associate, Eng. A. B. Research Chair for Growth Factors and Bone Regeneration, College of Dentistry, King Saud University, Riyadh, Saudi Arabia; \*\*assistant professor and chairman, Eng. A.B. Research Chair for Growth Factors and Bone Regeneration, Department of Periodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Reprint requests: Dr. Khalid Al-Hezaimi, Eng. A. B. Research Chair for Growth Factors and Bone Regeneration, College of Dentistry, King Saud University, P.O. Box 60169, Riyadh 11545, Saudi Arabia; e-mail: hezaimik16@gmail.com

Conflict of interest and financial disclosure: The authors declare that they have no conflicts of interest and there was no external source of funding for the present study.

© 2011 Wiley Periodicals, Inc.

DOI 10.1111/j.1708-8208.2011.00403.x

## INTRODUCTION

The developing tooth influences the shape and volume of its surrounding alveolar socket. As a result, exodontia of the adult dentition may cause atrophy of the surrounding alveolar bone.<sup>1-5</sup> In their study, Cardaropoli and colleagues<sup>6</sup> investigated the events involved in the healing of the extraction socket. The results demonstrated that healing of the extraction socket involves several events including the formation of coagulum that was replaced by the following: (1) a provisional connective tissue matrix; (2) woven bone; and (3) lamellar bone and bone marrow.<sup>6</sup> This healing process has been associated with significantly more bone resorption on the buccal aspect of the alveolar plate as compared with the lingual or palatal.<sup>7</sup> Similar results were reported by a previous study.<sup>8</sup> The bony resorption of buccal wall has been reported to occur in two phases.<sup>1</sup> In the first phase, the bundle bone (which lines the internal walls of socket) is resorbed after tooth removal and is replaced with immature bone (woven bone). In the second phase,

resorption occurs from the outer surface of alveolar bone; however, the reasons of this resorption remain unclear.<sup>1</sup>

In a study on mongrel dogs, Araújo and Lindhe<sup>1</sup> investigated the dimensional changes that occurred in the alveolar ridge after tooth extraction. The results showed that marked dimensional alterations in the alveolar ridge occurred during the first 8 weeks following exodontia of mandibular premolars.<sup>1</sup> In this study,<sup>1</sup> the authors suggested that the buccal bone wall (which entirely comprises of bundle bone) loses its function following tooth extraction, thereby resulting in its resorption. Similarly, a clinical study<sup>7</sup> reported a two-thirds reduction in the width of the alveolar ridge within the first 3 months after tooth extraction. Other studies have also demonstrated significant occluso-apical and buccolingual resorption following tooth extraction in sockets allowed to heal for 4 to 6 months in the absence of any treatment.<sup>9–11</sup> Besides buccal bone anatomy, another explanation in this regard may be derived from studies by Misch and colleagues<sup>12</sup> and Araújo and colleagues<sup>2</sup> in which the authors speculated that constriction of the blood clot within the alveolus (due to exodontia) may significantly contribute in bone-remodeling process following tooth extraction. In their histological study on baboons, Al-Hezaimi and colleagues<sup>13</sup> emphasized on the importance of the interdental bone blood supply to the buccal bone. This study<sup>13</sup> showed that trauma to the interdental bone blood supply is proportional to the number of teeth being extracted (single vs. contiguous teeth extraction). An extraction socket classification (ESC) was proposed – class I: extraction of a single tooth; class II: extraction of two adjacent teeth; and class III: extraction more than two adjacent teeth.<sup>13</sup> In the present study, it is hypothesized that extraction of contiguous teeth is associated with more severe alveolar bone resorption as compared with when a single tooth is extracted.

The aim of the present experimental study was to investigate the effects of single and contiguous teeth extractions according to the ESC on alveolar bone remodeling.

## MATERIALS AND METHODS

### Ethical Approvals

The study was approved by the Research Review Board and Animal Ethical Committee at the Engineer Abdullah

Bagshan Research Chair for Growth Factors and Bone Regeneration, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.

### Study Animals

Five female beagle dogs, with a mean age and weight of 15 months and 13.8 kg, respectively, were used. Animals with periodontal disease were excluded from the present study.

The animals were randomly divided into three groups (*group 1*: one dog; *group 2*: two dogs; and *group 3*: two dogs) by picking a paper marked “group 1,” “group 2,” or “group 3” from a brown bag.

### Surgical Protocol and Animal Subgroups

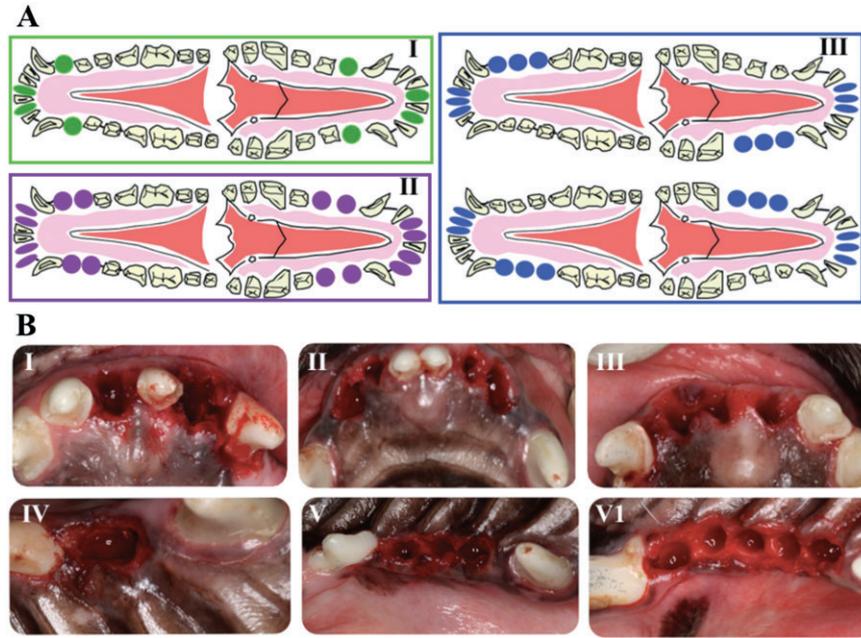
Prior to surgery, the dogs received supragingival scaling twice a week for 3 weeks using an ultrasonic scaler (Hu-Friedy, Chicago, IL, USA). The nonsurgical and surgical procedures were performed under general anesthesia using Ketalar (Pfizer Inc, New York, NY, USA) (10 mg/kg body weight) and local anesthesia with xylocaine (Astra, Westborough, MA, USA) (with epinephrine 5 mg/mL). Under general anesthesia (as described earlier), piezosurgery (Mectron, Piezosurgery®, Columbus, OH, USA) and forceps were used for bilateral extractions in both arches (without flap elevation).

On the basis of the location (anterior vs. posterior teeth) and the number of teeth extracted, the animals in each group were divided into two subgroups as follows: *group 1* (one dog): (1A) four single anterior teeth and (1B) four single posterior extracted; *group 2*: (2A) two adjacent anterior teeth and (2B) two adjacent posterior teeth; and *group 3*: (3A) three adjacent anterior teeth and (3B) three adjacent posterior teeth (Figure 1, A and B).

Eight samples were obtained from each group and the samples were pooled.

### Postoperative Management

All animals received intramuscular injections of Medicycline Vet (Norbrook Lab Ltd, County Down, Northern Ireland) (5 mg/kg body weight once a day for 3 days) and were placed on a soft diet for 10 days. Plaque control procedures, which included topical application of a 0.2% chlorhexidine digluconate solution (GUM, Chicago, IL, USA), were performed twice weekly for 4 months after surgery.



**Figure 1** A, Study designs for (I) groups 1 (green), (II) 2 (purple), and (III) 3 (blue). B, Clinical view of the experiment. (I) Two single anterior teeth extraction of group 1. (II) Two anterior teeth extraction of group 2 in two sites. (III) Three anterior teeth extraction of group 3. (IV) Single posterior tooth (two-rooted) extraction of group 1. (V) Two posterior teeth (two-rooted second premolars) extraction of group 2. (VI) Three anterior teeth extraction of group 3. In (VI), a total of five roots were extracted.

### Hard Tissue Sectioning and Microcomputed Tomography Analysis

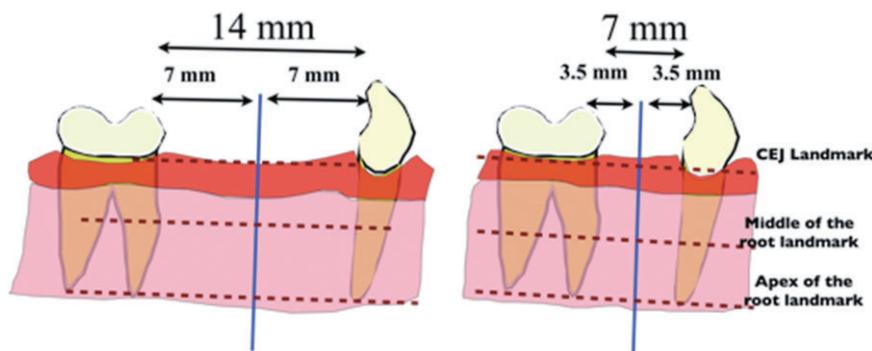
Each extraction site was sagittally sectioned using an electrical saw microtome (Leica SP 1600, Bannockburn, IL, USA). A situation where a tooth was associated with two extraction sites was sectioned in the midline in order to use its cementoenamel junction (CEJ) as a landmark for measurements in both extraction sites. The blocks were fixed in 10% neutral formalin solution.

The jaw segments containing the extraction site/s, the adjacent teeth and alveolar bone, were analyzed in

the buccolingual and apico-coronal directions using microcomputed tomography (micro-CT) scan (1172 Skyscan®, Kontich, Belgium). The reference points for the linear measurements (in millimeters) were taken from the following locations: (1) 2 mm below the CEJ; (2) the middle of the distance between the CEJs; and (3) root apex of the adjacent teeth (Figure 2).

### Data Analysis

Data were analyzed using SPSS, version 18.00 (IBM, Somers, NY, USA). One-way analysis of variance was performed to assess the differences among the three



**Figure 2** Reference points for the linear measurements. The crest of the bone (2 mm from cementoenamel junction), the middle of the root, and the apex of the adjacent teeth. The measurement point was taken at the center of the edentulous area.

groups in the mean alveolar bone thickness at three landmarks (crest of the bone, middle, and apex of the root). Box plots were constructed to show the differences in the mean alveolar bone thickness among the groups.

## RESULTS

All extraction sockets healed uneventfully and bone remodeling was observed in all groups 4 months after extraction.

### Group 1: Single-Tooth Extraction

The micro-CT analysis displayed a slightly higher remodeling on the buccal side compared with the palatal/lingual side (Figure 3, AI and BI).

In the anterior sites, the maxillary and mandibular widths of the alveolar ridge were 4.0 and 4.67 mm, respectively, whereas in the posterior sites, the maxillary and mandibular widths of the alveolar ridge were 4.07 and 4.47 mm, respectively. The width of the buccolingual/palatal bone at three different points was as follows: (1) at the crest,  $4.3 \pm 0.347$  mm; (2) at the middle,  $5.09 \pm 0.637$  mm; and (3) at the apex level of the adjacent tooth,  $8.27 \pm 0.499$  mm (Figure 4A).

### Group 2: Extraction of Two Adjacent Teeth

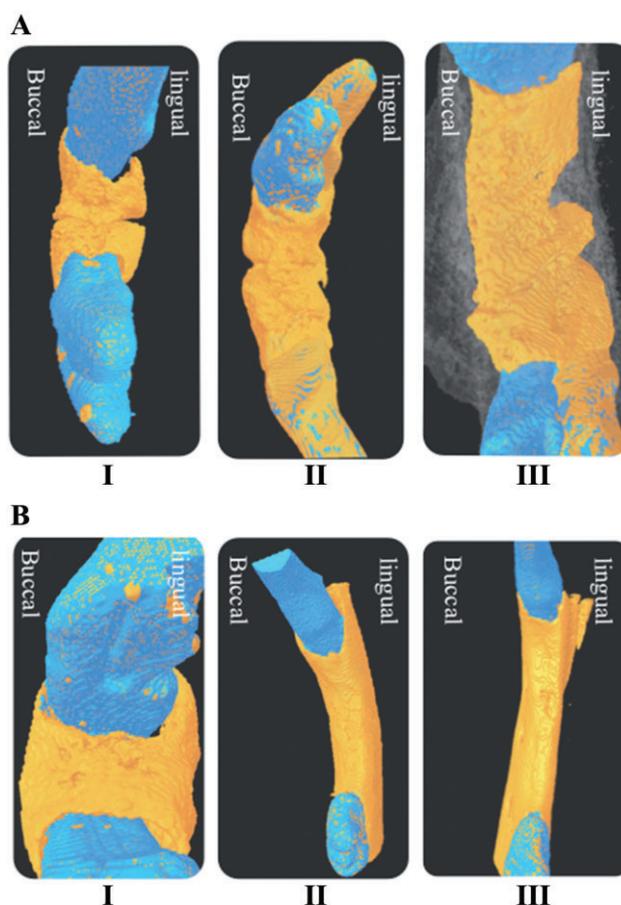
The micro-CT analysis showed an equivocal bone remodeling on buccal and lingual/palatal sides (Figure 3, AII and BII).

In the anterior sites, the width of the alveolar ridge was 3.65 and 3.77 mm for the mandible and maxilla, respectively. In the posterior sites, the width of the alveolar ridge for the mandible and maxilla was 3.33 and 3.66 mm, respectively. The width of the buccolingual/palatal bone at three different points was as follows: (1) at the crest,  $3.6 \pm 0.203$  mm; (2) at the middle,  $3.85 \pm 0.292$  mm; and (3) at the apex level of the adjacent tooth,  $6.77 \pm 0.332$  mm (Figure 4B).

### Group 3: Extraction of Three Adjacent Teeth

Micro-CT analysis demonstrated a more significantly pronounced remodeling on the lingual/palatal side compared with the buccal side (Figure 3, AIII and BIII).

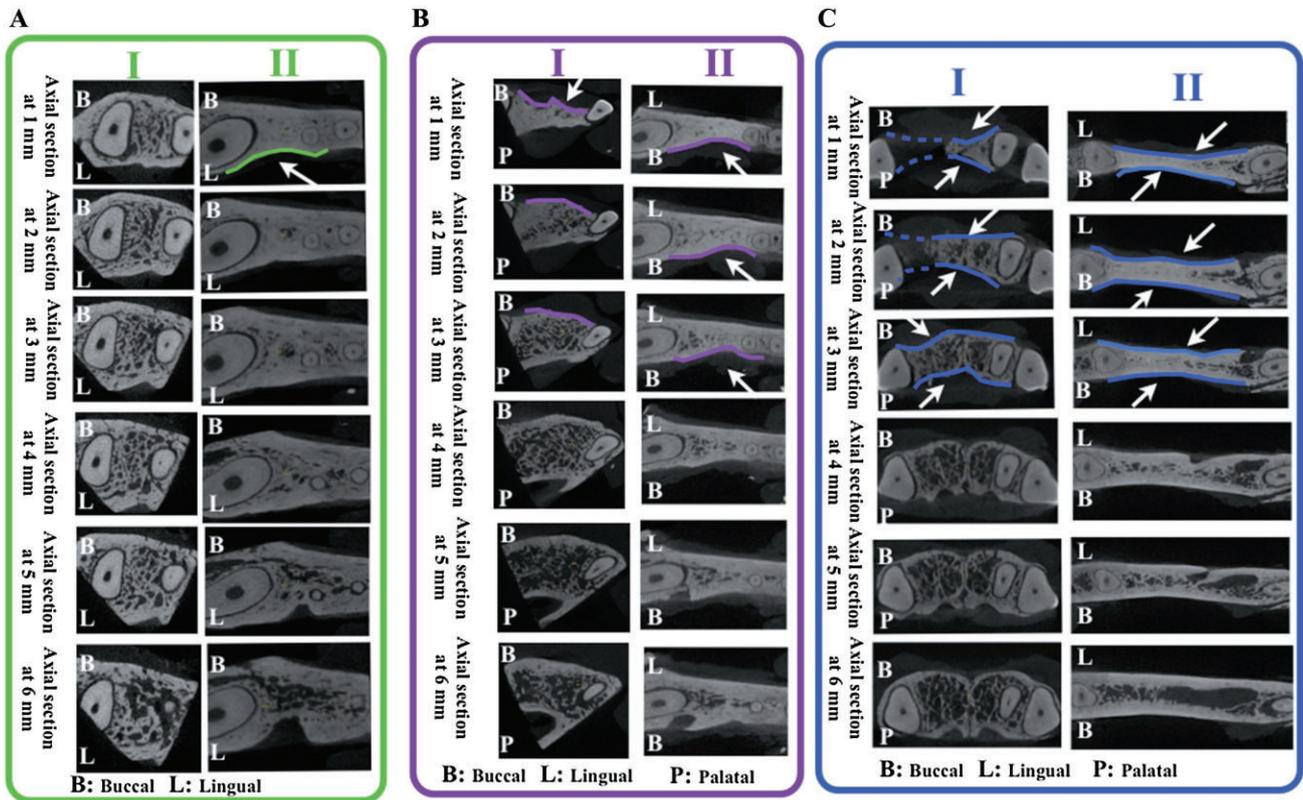
This group showed more bone resorption compared with groups 1 and 2. In the anterior sites, the maxillary and mandibular widths of the alveolar ridge were 1.95 and 1.75 mm, respectively. In the posterior sites, the maxillary and mandibular widths of the alveo-



**Figure 3** A, A three-dimensional reconstructed photomicrograph of the 1172 micro-CT showing an occlusal view of healed extraction sites: (I) Cl-I anterior shows slight crestal and more buccal bone resorption in the form of depression, (II) Cl-II anterior shows equivocal buccal and lingual bone resorption and more alveolar bone alteration than Cl-I, and (III) Cl-III anterior shows more lingual than buccal bone resorption and the alveolar ridge alteration is more in severity than Cl-I and II. B, (I) Cl-I posterior shows slight crestal and buccal bone resorption, (II) Cl-II posterior shows more alveolar bone alteration and more lingual bone resorption, and (III) Cl-III posterior shows more alveolar ridge alteration and resorption both in buccal and lingual aspects. The lingual resorption was more pronounced than the buccal side.

lar ridges were 1.53 and 2.06 mm, respectively. The width of the buccolingual/palatal bone at three different points was as follows: (1) at the crest,  $1.8 \pm 0.234$  mm; (2) at the middle,  $2.85 \pm 0.217$  mm; and (3) at the apex level of the adjacent tooth,  $4.25 \pm 0.360$  mm (Figure 4C).

In general, the alveolar bone alteration was proportional to the number of teeth extracted. In the three-dimensional image reconstruction, the second and third groups in the upper and lower anterior and posterior extraction sites had more severe alveolar ridge



**Figure 4** A, (Class I): 1-mm level axial cross sections of group 1: (I) lower anterior. (II) Lower left posterior. Buccal bone resorption in first 1 to 2 mm (arrow). B (Class II): 1-mm level axial cross sections of group 2: (I) upper right anterior. Buccal and lingual resorption in first 1 mm (arrow). (II) Lower left posterior. Buccal bone resorption in first 3 mm (arrow). C, (Class III): 1-mm level axial cross sections of group 3: (I) upper right anterior. Marked buccal and lingual resorption in first 3 mm (arrow). (II) Lower right posterior. Marked buccal and lingual resorption in first 3 mm (arrow).

resorption on the palatal/lingual side compared with the buccal side (Figure 4).

The buccal-lingual bone remodeling in the anterior and posterior sites was significantly higher in group 3 as compared with group 1 and group 2 ( $p < .001$ ), as shown in Table 1.

**DISCUSSION**

The ESC by Al-Hezaimi and colleagues<sup>13</sup> suggested that single-tooth versus contiguous teeth extractions have a

significant impact on the buccolingual bone remodeling. This is an important observation especially in cases of immediate implant placement. The ESC provided histological evidence regarding the significance of interdental blood supply to the buccal bone and its impact on the bone remodeling. Although in the present study, there was no implant placement, however, the results clearly demonstrate that there was a significant difference between ESC classes in regard to the buccolingual bone remodeling and vertical bone loss.

| TABLE 1 Alveolar Bone Thickness within the Groups with Reference to Anatomical Location of the Extraction Sites |                           |                     |                           |
|---|---------------------------|---------------------|---------------------------|
| Alveolar Bone Thickness   | Group 1 (Mean ± SD)       | Group 2 (Mean ± SD) | Group 3 (Mean ± SD)       |
| Anterior  | 5.97 ± 0.61 <sup>†</sup>  | 4.84 ± 0.17         | 2.98 ± 0.16 <sup>†</sup>  |
| Posterior   | 5.81 ± 0.35 <sup>  </sup> | 4.64 ± 0.27         | 2.97 ± 0.27 <sup>  </sup> |

<sup>†</sup> $p < .001$ ; <sup>‡</sup> $p < .01$ ; <sup>||</sup> $p < .001$ ; <sup>§</sup> $p < .001$ . SD, standard deviation.

The alveolar bone is a specialized part of maxillary and mandibular bone that forms the primary support for teeth. Previous studies<sup>3,6-8</sup> have reported that exodontia is directly associated with modifications in the morphology of alveolar bone. For example, in the clinical study by Schropp and colleagues,<sup>7</sup> alveolar bone remodeling following tooth extraction was investigated in 46 patients using radiographs and study casts. The results showed that the total loss of bone volume (in the horizontal plane) accounted for 50% of the original width of the alveolar bone. Similarly, Tallgren study<sup>14</sup> also found that the greatest reduction of the residual ridge occurs within the first 2 years of postextraction healing. From these results, it may be claimed that following extraction, major dimensional changes in the alveolar bone (associated with the extraction site) are expected to occur. It should, however, be noted that the former results were extracted from studies based merely on a single-tooth extraction.

It is known that the alveolar blood supply plays a significant role in maintaining the integrity of the alveolus.<sup>15</sup> An animal study reported that the blood supply to the alveolus is considerably greater than that to other parts of the jaw.<sup>15</sup> As tooth extraction compromises the blood supply to the extraction socket, the probability of bone resorption in the extraction socket may also increase compared with sockets where teeth remain intact with bone.<sup>16</sup> It has been suggested that following the elevation of a mucoperiosteal flap and tooth extraction, the vascular supply to the alveolus may be severed.<sup>1</sup> This diminished blood supply to the alveolus may cause death of the osteocytes and ultimately lead to necrosis of the alveolar bone walls.<sup>17</sup> A marked osteoclastic activity has also been reported in the walls of the socket by the eighth week of tooth extraction.<sup>1</sup> Hence, it may be postulated that in the 16th-week specimens of the present experiment, a large number of osteoclasts could be present on the walls of the extraction socket. As the buccal bone has been suggested to be composed completely of bundle bone,<sup>1</sup> a significantly higher osteoclastic activity may occur on this surface of the extraction socket as compared with the lingual or palatal surface. Moreover, contiguous extractions of teeth may cause an enhanced osteoclastic activity and tissue necrosis as compared with when a single tooth is extracted; however, it is notable that contiguous extractions may compromise the socket vascular supply from the periodontal ligament vessels as well as from the interdental

region, thereby diminishing the vascular supply to the alveolar process to a much greater extent as compared with when a single tooth is extracted. This may elucidate our results where extraction of two or more teeth exerted a significantly more alveolar bone remodeling as compared with when a single tooth was extracted. From a clinical perspective, this may be an important implication for clinicians considering placement of dental implants, particularly in the aesthetic zone. Besides exodontia, contributions of other factors (such as disuse atrophy, pressure from prosthesis, trauma, and inflammation) that have also been associated with alveolar bone remodeling following extraction cannot be disregarded.

Various treatment regimes including use of bone grafts and immediate placement of dental implants in fresh extraction sockets have been suggested in order to preserve the integrity of the alveolar ridge;<sup>18-21</sup> however, the results remain debatable.<sup>3,22</sup> Froum and colleagues<sup>22</sup> conducted a study to investigate the effect of various bone graft and bone replacement materials on extraction socket healing. This study<sup>22</sup> also compared healing extraction sockets 6- to 8-month postimplantation of a bioactive glass or freeze-dried bone allograft with an unfilled socket (control). According to the results, there were no significant differences in percentage of vital bone formation among the three treatment groups (59.5% for bioglass, 34.7% for freeze-dried bone, and 32.4% for control sites).

In conclusion, extraction of contiguous teeth causes a more extensive bone remodeling compared with extraction of a single tooth.

## REFERENCES

1. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005; 32:212-218.
2. Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol* 2005; 32:645-652.
3. Fickl S, Zuhr O, Wachtel H, Bolz W, Huerzeler MB. Hard tissue alterations after socket preservation: an experimental study in the beagle dog. *Clin Oral Implants Res* 2008; 19:1111-1118.
4. Ashman A. Ridge preservation: important buzzwords in dentistry. *Gen Dent* 2000; 48:304-312.
5. Amler MH. The time sequence of tissue regeneration in human extraction wounds. *Oral Surg Oral Med Oral Pathol* 1969; 27:309-318.

6. 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.
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. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. *J Prosthet Dent* 1967; 17:21–27.
9. 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.
10. Lekovic V, Camargo PM, Klokkevold PR, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. *J Periodontol* 1998; 69:1044–1049.
11. 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.
12. Misch CE, Dietsh-Misch F, Misch CM. A modified socket seal surgery with composite graft approach. *J Oral Implantol* 1999; 25:244–250.
13. Al-Hezaimi K, Levi P, Rudy R, Al-Jandan B. Bone type and blood supply to the buccal bone in monkeys and an extraction socket classification (ESC). *Int J Periodontics Restorative Dent* 2011; 31:3–8.
14. Tallgren A. Positional changes of complete dentures: a 7-year longitudinal study. *Acta Odontol Scand* 1969; 27:539–561.
15. Indresano AT, Lundell MI. Measurement of regional bone blood flow in the rabbit mandible using the hydrogen washout technique. *J Dent Res* 1981; 60:1365–1370.
16. Atwood DA. Postextraction changes in the adult mandible illustrated by microradiographs of midsagittal sections and serial cephalometric roentgenograms. *J Prosthet Dent* 1963; 13:810–824.
17. Schenk RK, Hunziker EB. Histologic and ultrastructural features of fracture healing. In: Brighton CT, Friedlaender G, Lane JM, eds. *Bone formation and repair*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 1994:117–146.
18. Kim DM, Nevins M, Camelo M, et al. The feasibility of demineralized bone matrix and cancellous bone chips in conjunction with an extracellular matrix membrane for alveolar ridge preservation: a case series. *Int J Periodontics Restorative Dent* 2011; 31:39–47.
19. Becker W, Becker BE, Caffesse R. A comparison of demineralized freeze-dried bone and autologous bone to induce bone formation in human extraction sockets. *J Periodontol* 1994; 65:1128–1133.
20. Barone A, Rispoli L, Voza I, Quaranta A, Covani U. Immediate restoration of single implants placed immediately after tooth extraction. *J Periodontol* 2006; 77:1914–1920.
21. Artzi Z, Kohen J, Carmeli G, Karmon B, Lor A, Ormianer Z. The efficacy of full-arch immediately restored implant-supported reconstructions in extraction and healed sites: a 36-month retrospective evaluation. *Int J Oral Maxillofac Implants* 2010; 25:329–335.
22. 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.

Copyright of Clinical Implant Dentistry & Related Research is the property of Wiley-Blackwell and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.