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Dimensional changes of the ridge contour after socket preservation and buccal overbuilding: an animal study

Stefan Fickl[1,2], David Schneider[3], Otto Zuhr[2], Marc Hinze[2], Andreas Ender[4], Ronald E. Jung[3] and Markus B. Hürzeler[2,5,6]

[1]Department of Periodontology and Implant Dentistry, New York University College of Dentistry, New York, NY, USA; [2]Private Institute for Periodontology and Implantology, Munich, Germany; [3]Department of Fixed and Removable Prosthodontics and Dental Material Science, Dental School, University of Zurich, Zurich, Switzerland; [4]Department of Preventive Dentistry, Cardiology, and Periodontology, Dental School, University of Zurich, Zurich, Switzerland; [5]Department of Operative Dentistry and Periodontology, Albert Ludwigs University, Freiburg, Germany; [6]University of Texas, Dental Branch, Houston, TX, USA

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Abstract

Objectives: The aim of the study was to volumetrically assess alterations of the ridge contour after socket preservation and buccal overbuilding.

Material and Methods: In five beagle dogs, four extraction sites were subjected to one of the following treatments:

Tx 1: The socket was filled with BioOss Collagen® and covered with a free gingival autograft from the palate (SP).

Tx 2: The buccal bone plate was forced into a buccal direction using a manual bone spreader and SP was performed.

Tx 3: The buccal bone plate was forced into a buccal direction using a manual bone spreader; SP was performed.

Tx 4: The socket was filled with BioOss Collagen and a combined free gingival/connective tissue graft was used to cover the socket and for buccal tissue augmentation.

Impressions were obtained at baseline, 2 weeks and 4 months post-operatively. Casts were optically scanned and superimposed in one common coordinate system. Using digital image analysis, the volumetric differences per area among the different treatment time points and among the treatment groups were calculated.

Results: Four months after tooth extraction, no statistically significant differences with regard to the buccal volume per area could be assessed among the treatment groups.

Conclusion: Overbuilding the buccal aspect in combination with socket preservation is not a suitable technique to compensate for the alterations after tooth extraction.

Key words: extraction socket; socket preservation; volumetric evaluation

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Introduction

Tooth extraction is followed by marked dimensional alterations of the alveolar ridge contour (Schropp et al. 2005, Fickl et al. 2008c). A previous clinical study reported that approximately 50% of the original alveolar bone width was reduced within the first 12 months after tooth removal (Schropp et al. 2005). Volumetric alterations of the alveolar ridge can be unfavourable for future endosseous implant placement and implant aesthetics. Therefore, socket preservation has been advocated at the time of tooth extraction to compensate for the postoperative volumetric alterations. Various methods have been described for socket preservation after tooth extraction. Besides techniques using occlusive membranes (Lekovic et al. 1997, 1998, Iasella et al. 2003) grafting extraction sockets with bone substitutes (Artzi & Nemcovsky 1998, Becker et al. 1998, Artzi et al. 2000, Carmagnola et al. 2003, Jung et al. 2004, Nevins et al. 2006) has been reported in the literature. It was recently

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reported in experimental studies that grafting extraction sockets with a deproteinized bovine bone mineral (DBBM)-preserved ridge dimensions to a certain extent (Araújo et al. 2008, Fickl et al. 2008c). These studies indicated that the placement of DBBM into the extraction socket failed to inhibit the process of modelling and remodelling after tooth extraction. Furthermore, a recent clinical study demonstrated that socket preservation with DBBM outperformed the control group, but loss of the buccal bone plate was reported in the majority of the cases (Nevins et al. 2006). At present, a complete preservation of the alveolar contour after tooth extraction with intra-socket grafts seems to be an unpredictable treatment goal. The aim of the following experimental trial was to evaluate whether an additional hard- or soft-tissue over-augmentation of the buccal bone plate in combination with socket preservation is able to entirely compensate for the dimensional alterations.

Material and Methods

The research protocol of this investigation was approved by the ethical committee of Biomatech (Namsa Company, Lyon, France).

Surgical protocol

Five beagle dogs about 1 year old and weighing about 10–11.3 kg each were used for this experiment. The animals were housed under laboratory conditions. The recommended temperature range for the room was 15–21°C. The recommended humidity for the room was $>30\%$. The light cycle was controlled using an automatic timer (12 h light, 12 h dark). Before surgery, impressions of the lower jaws were obtained in a one-step/two-viscosity technique with polyether impression materials (Permadyne Garant 2:1/Permadyne Penta H, 3M Espe, St. Paul, MN, USA) and individualized impression trays.

Surgical procedure

Supragingival scaling was performed on all dogs 5 days before tooth extraction. Anaesthesia was induced by injecting atropine (Atropine®, Aguettant, Lyon, France – 0.05 mg/kg intramuscular) and tiletamine–zolazepam (Zoletil®100, Virbac, Carros, France – 5–10 mg/kg intramuscular). Subsequently, an injection of thiopenthal sodium was given (NesdonalND, Merial, Lyon, France – 10–15 mg/kg intravenous) and the animals were placed on an O_2–N_2O isoflurane (1–4%) mixture. Local anaesthesia was induced by a subcutaneous injection of articain (Ultracain®, Hoechst, Frankfurt, Germany – 1%).

In both quadrants of the mandible, the distal root of the third and fourth premolars (P_3, P_4) served as experimental sites. In order to mimic extraction sites of single-rooted teeth, the mandibular premolars were hemisected with the use of a fissure bur. The distal roots were removed using a forceps without elevation of a muco-periosteal flap or compromising the marginal gingiva. The pulp tissues of the mesial roots were extirpated and engaged with a Gates-Glidden bur. After filling the root canals with gutta-percha, the coronal part of the pulp chamber was sealed with an auto-polymerizing resin material (Clearfil Core®, Kuraray, Tokyo, Japan). One of the following treatment modalities was randomly assigned to each site:

Tx 1 ($n = 5$): The extraction socket was filled with deproteinized bovine bone material integrated in a 10% collagen matrix (BioOss Collagen®, Geistlich Biomaterials, Wolhusen, Switzerland). Consecutively, a free soft tissue punch according to the technique of Jung et al. (2004) and Landsberg & Bichacho (1994) was harvested from the palate with a thickness of approximately 3 mm. Several interrupted sutures (Seralene 7-0®, Serag Wiesner, Naila, Germany) were applied to fix the free soft tissue graft to the previously deepithelized marginal gingiva of the extraction socket (Fig. 1a and b).

Tx 2 ($n = 5$): Following intra-sulcular incision, a full-thickness preparation of the buccal bone plate of the distal root was performed without vertical releasing incisions. BioOss Collagen® was placed on the outer surface of the buccal bone plate and covered with an adsorbable collagen membrane (BioGide®, Geistlich Biomaterials), thus performing guided bone regeneration (GBR). Subsequently, the extraction socket was filled with DBBM (BioOss Collagen®) and closed with a free gingival autograft, according to Tx 1 (Fig. 2).

Tx 3 ($n = 5$): The buccal bone plate was forced into a buccal direction with a specially designed instrument mobilizing the buccal bone plate approximately 5 mm. DBBM (BioOss Collagen®) was packed into the socket to prevent the buccal bone plate from re-collapsing. Subsequently, the extraction socket was closed with a free gingival autograft (Fig. 3).

Tx 4 ($n = 5$): The extraction socket was filled with DBBM (BioOss Collagen®). Consecutively, an undermining split-thickness preparation of the buccal aspect was performed and a combined free gingival/connective tissue graft was obtained from the palate. The connective tissue portion of the graft was inserted into the undermined buccal pouch and sutured with several interrupted sutures (Seralene 7-0®, Serag Wiesner) (Fig. 4).

After surgery, the following regimen was administered:

- The animals were observed once daily for any clinical abnormality.

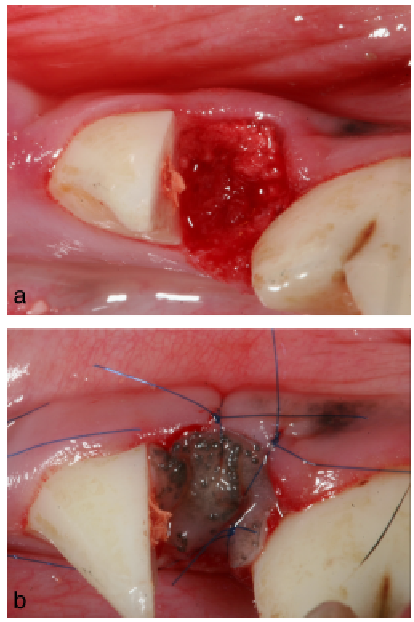

Fig. 1. Treatment group 1 (Tx 1): BioOss Collagen® is applied into the extraction socket and a free gingival autograft is sutured to close the extraction socket.

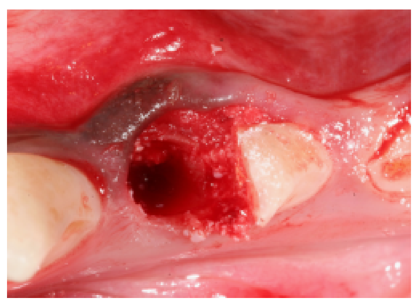

Fig. 2. Treatment group 2 (Tx 2): after elevation of a muco-periosteal flap, the buccal bone plate is augmented using the GBR-technique (BioOss Collagen®/BioGide®)

- Antimicrobial prophylaxis was performed with spiramycine 750,000 IU and metronidazole 125 mg/day per os for 13 days (Stomorgyl®, Merial).
- As an anti-inflammatory drug carprofene 50 mg per os and per day for 13 days (Rimadyl®, Pfizer Santé Animale, Orsay, France) was administred.
- Each animal received an injection of butorphanol (0.3 mg/kg) (Torbu Gesic®, Fort Dodge Animal Health, Southampton, UK) post-surgically and on the following day.
- The dogs were placed on a soft diet throughout the entire observation period.

Tooth cleaning with toothbrush and dentifrice and administration of 0.2% chlorhexidine solution were performed three times per week for 4 weeks.

The sutures were removed 2 weeks post-surgery. Healing presented uneventful. The soft tissue grafts were fully integrated without any sign of necrosis.

Polyether impressions were obtained 2 weeks and 4 months after tooth extraction.

Fig. 3. Treatment group 3 (Tx 3): the buccal bone plate is forced into a buccal direction with a specially designed instrument and stabilized with BioOss Collagen® and a free gingival autograft. Note the amount of buccal tissue enhancement.

Fig. 4. Treatment group 4 (Tx 4): after incorporation of BioOss Collagen® into the extraction socket a gingival autograft with a connective tissue portion is incorporated into a buccal pouch and sutured in place.

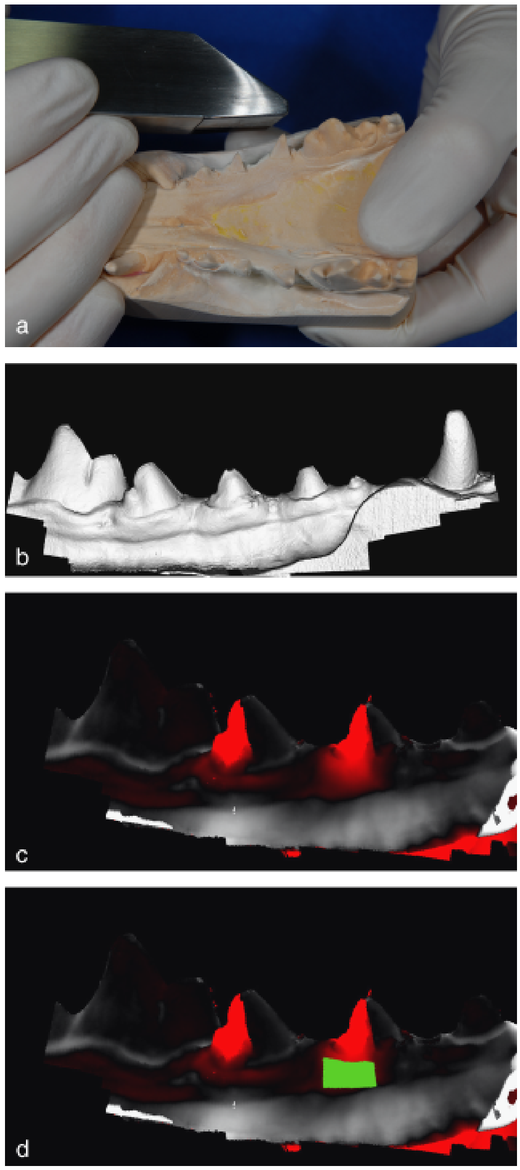

Fig. 5. (a) Optical scan of the casts using the Cerec 3D camera. (b) Digital image of cast (baseline), after import in Match3D software. (c) Volume changes after superposition of optical impressions representing baseline and two-month follow-up. Red areas represent loss, white areas gain of volume. (d) Example of measured area.

Evaluation of tissue contour changes

Master casts of each dog were made out of dental stone (GC Fujirock type 4, GC Corp., Tokyo, Japan) utilizing the pre-extraction and follow-up impressions after 2 weeks and 4 months.

For the evaluation of the dimensional changes at the extraction sites, the casts were optically scanned with a 3D camera (Cerec 3, Sirona Dental Systems GmbH, Bensheim, Germany) (Fig. 5a). This camera was developed to digitally capture the three-dimensional shape of prepared teeth and the adjacent soft tissue contours applying the principle of active triangulation (Mörmann & Brandestini 1996, Mormann & Bindl 2002, Windisch et al. 2007). The accessible area for the optical scanner is limited to a field of 17×14 mm at a time. Therefore, several overlapping optical impressions from the buccal and the bucco-occlusal direction were taken, including the canine and the first molar. These two structures were considered reliable reference points. The data acquired were then composed into one digital image, encompassing the jaw segments from the canine to the first molar by a CAD/CAM software (Cerec 3, Sirona Dental Systems GmbH).

The obtained digital images of the casts reflecting the different treatment time points (baseline, 2 weeks post-surgically and 4 months post-surgically) were then transferred into another digital imaging software (Match3D, University of Munich, Munich, Germany) (Fig. 5b). In the next step, it was used to superimpose and match the images in one common coordinate system. The buccal surfaces of the canine and the first molar were used as reference points for the superposition of the different images. Subsequently, a defined area of interest at the buccal aspect of each extraction site was measured and the volume difference between the time points was calculated (Fig. 5c and d). Because of an individually variable anatomic situation the measured area varied between the sites, but was constant at one site over time. It roughly exhibited a trapezoid shape and reached from the muco-gingival line to the line of hemisection, followed the gingival margin at a distance of around 0.5 mm and the perpendicular at the former distal end of the premolar.

In order to allow a direct comparison between the different sites and the different treatment methods, respectively, the calculated variable Δd was the measured volume difference per measured area [Δd (μm) = Δvol (μm^3)/area (μm^2)]. The data obtained were then analysed regarding volume alterations in terms of different treatment modalities and time points using pairwise comparisons of unpaired *t*-tests (between groups) and paired *t*-tests (between stages).

Table 1. Results of the volumetric measurements

Tx	Area (μm^2)	Δvolume/area t0 – t2 (μm)	Δvolume/area t2 – t4 (μm)	Δvolume/area t0 – t4 (μm)
1	1181.00	– 683.57	– 941.64	– 1625.20
	1608.00	– 474.69	– 398.28	– 872.97
	1440.00	– 278.94	– 185.58	– 464.52
	4750.00	– 758.83	– 768.71	– 1527.54
	2188.00	– 540.75	– 561.08	– 1101.82
Mean	2233.40	– 547.35	– 571.06	– 1118.41
SD	1454.60	187.51	297.88	477.57
2	2226.00	– 1021.51	– 1041.07	– 2062.58
	2723.00	– 459.59	– 1445.18	– 1904.76
	385.00	– 715.89	– 302.14	– 1018.03
	1975.00	– 416.78	– 486.51	– 903.29
	3493.00	– 28.75	– 925.36	– 954.10
Mean	2160.40	– 528.50	– 840.05	– 1368.55
SD	1149.25	369.17	455.03	565.75
3	2396.00	244.94	– 2311.02	– 2066.08
	3366.00	– 314.34	– 1198.55	– 1512.89
	2791.00	645.13	– 1473.72	– 828.58
	2519.00	197.40	– 1238.93	– 1041.53
	4005.00	– 5.25	– 1034.29	– 1039.54
Mean	3015.40	153.58	– 1451.30	– 1297.72
SD	667.58	352.16	505.60	497.26
4	2987.00	– 721.97	– 786.68	– 1508.65
	2400.00	– 611.37	– 561.05	– 1172.42
	4634.00	85.56	– 701.27	– 615.71
	3235.00	– 646.03	– 781.65	– 1427.68
	3612.00	– 795.29	– 1069.31	– 1864.61
Mean	3373.60	– 537.82	– 779.99	– 1317.82
SD	830.96	355.64	185.67	464.10

SD, standard deviation. Tx 1, DBBM + FGG; Tx 2, DBBM + Membrane + FGG; Tx 3, Bone mobilization + DBBM + FGG; Tx 4, DBBM + FGG/CTG. For details see text. t0, Baseline, before extraction; t2, 2 weeks after extraction; t4, 4 months after extraction.

Results

The results of the volumetric measurements are summarized in Table 1 and are shown in Fig. 6a–d.

Two weeks (t2) following extraction, the treatment group 3 (Tx 3) showed a slight increase in the mean buccal volume per area ($\Delta d_{Tx\ 3} = 153.58\,\mu$m), while all other treatment groups lost buccal changes. The difference to Tx 3 was statistically significant ($\Delta d_{Tx\ 1} = -547.35\,\mu$m, $p = 0.011$, $\Delta d_{Tx\ 2} = -528.50\,\mu$m, $p = 0.069$, $\Delta d_{Tx\ 4} = -537.82\,\mu$m and $p = 0.004$), except for group 2 ($p = 0.069$). However, in group 3 the behaviour of the buccal volume was very variable (Fig. 6c). The changes ranged from a loss of volume of $\Delta d_{Tx\ 3} = -314.34\,\mu$m to a gain of $\Delta d_{Tx\ 3} = 645.13\,\mu$m. There were no statistically significant differences among the other groups Tx 1, 2 and 4.

Four months (t4) after extraction, there were no statistically significant differences regarding the amount of buccal volume among the treatment groups. All groups had lost between $\Delta d = -1118.41$ and $\Delta d = -1368.55\,\mu$m. In the period t2 (2 weeks post-surgically) to t4 (4 months post-surgically), the loss in buccal volume was most pronounced in treatment group 3 ($\Delta d_{Tx\ 3} = -1451.30\,\mu$m). In summary, all treatment groups lost between 1.12 mm and 1.45 mm in volume per area.

Discussion

The volumetric measurements of the present investigation demonstrate that all tested treatment groups exhibited a loss of buccal tissue contour 4 months after tooth extraction. No statistical significance could be found between the various socket preservation procedures after 4 months. These results reveal that overbuilding the buccal aspect in combination with socket preservation may not be a suitable technique to compensate for the resorptional alterations occurring after tooth extraction.

In a previously published study it was shown that socket preservation limits the buccal resorption process after tooth extraction (Fickl et al. 2008c). When compared with tooth extraction alone (2.2 mm), a loss of buccal dimension between 1.5 and 1.4 mm could be demonstrated (Fickl et al. 2008c). This is in agreement with other clinical and experimental studies concerning socket preservation: a complete preservation of the alveolar contour has not been documented (Lekovic et al. 1997, 1998, Nevins et al. 2006, Araújo et al. 2008). In conclusion, intra-socket grafts seem to be unsuitable to reach the ultimate goal of complete ridge preservation, but were able to reduce the amount of resorption compared with spontaneous healing.

For this reason, the principles of GBR, soft tissue augmentation and ridge splitting were applied to the extraction socket in order to overbuild the buccal aspect. GBR techniques using occlusive membranes (Esposito et al. 2006,

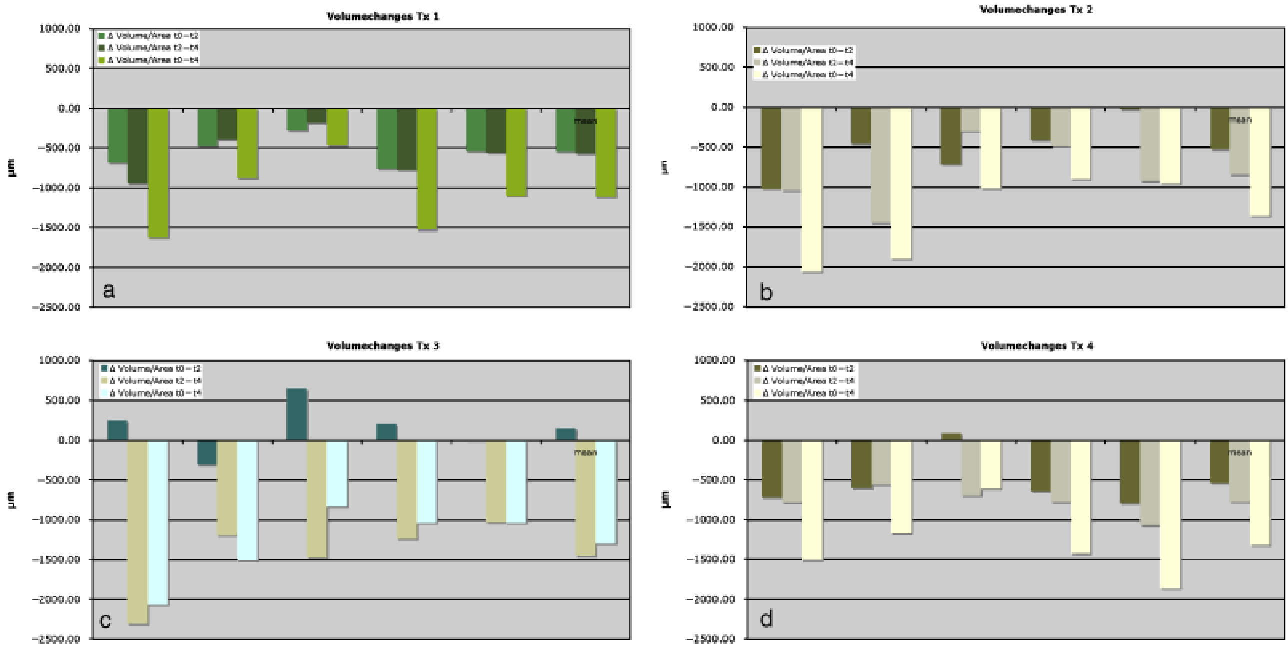

Fig. 6. Volumetric alterations at five measured sites and mean change for the different treatment groups.

Aghaloo & Moy 2007) and soft tissue augmentation using connective tissue grafts (Studer et al. 1997a, 2000) have been documented to be efficacious and clinically successful.

In the present investigation, bone and soft tissue augmentation techniques failed to compensate for the volumetric alterations after tooth extraction. No statistically significant difference could be demonstrated among the treatment groups 4 months post-surgically. It can be speculated that the ridge enhancement effect obtained was nullified by the additional volume shrinkage due to traumatic injury of the fragile buccal bone plate. This can be seen in accordance with an experimental study of Fickl et al. (2008b). It was demonstrated that supplementary surgical trauma during tooth extraction – i.e. incisions, flap elevation and suturing – is followed by significantly more volumetric alteration in particular at the buccal aspect compared with a ''flapless'' extraction procedure (Fickl et al. 2008b). The results indicate that the achieved bone augmentation was levelled by the additional dimensional alteration due to the surgical trauma.

Specific instruments were constructed to achieve a horizontal spreading of the buccal bone aspect. Intra-operatively, a buccal tissue enlargement of approximately 5 mm could be reported. The volumetric results obtained 2 weeks after tooth extraction demonstrate that the ridge contour could successfully be preserved and even slightly augmented. Yet the measurements after 4 months imply that the traumatic injury of the buccal bone plate in particular due to bone spreading leads to marked alterations, thus compensating the effect of this augmentation technique. It has to be concluded that squeezing and mobilizing the buccal bone plate at the time of tooth extraction is not effective in minimizing post-operative dimensional alterations.

Furthermore, the integration of a connective tissue graft into a supraperiosteal buccal pouch did not demonstrate any resorption-protective effect. No significant difference was reported when compared with socket preservation alone and the other treatment groups. It might be assumed that the trauma due to partial-thickness flap elevation also enhanced the resorptive process of the buccal bone plate. This can be seen in concordance with Pfeifer, who observed histologically an increased osteoclastic activity 7, 14 and 21 days after split-thickness flaps (Pfeifer 1965). Costich & Ramfjord (1968) found signs of resorption up to 4 weeks after split-thickness flaps.

Various methods have been described for the measurement of soft and hard tissue volume including optical projection (Moire method: Studer et al. 1997b, 2000), optical scanning (Jemt & Lekholm 2003, 2005, Thomason et al. 2005), conventional X-rays (Alpiste-Illueca 2004) and gravimetry (Proussaefs et al. 2002). Other possibilities are the use of computer tomography (Chen et al. 2008), direct measurements extraorally (casts) or intra-orally (Cardaropoli et al. 2006, Chen et al. 2008), measurements on photographs (Ricci 2007) and bone mapping by sounding (Wilson 1989, Chen et al. 2008).

Limited data are available on the accuracy and reproducibility of these techniques. In addition, some of these techniques might be regarded as critical due to their invasiveness and the need for radiation exposure. These disadvantages can be eliminated by the use of optical scans or photographs. However, a major problem with techniques using images is the superimposition of the images and their matching in one coordinate system to allow exact measurements.

In a recent in vitro study, a high level of accuracy and reproducibility using an optical 3D method (Cerec system, Sirona Dental Systems GmbH) on cuboid and geometrically complex specimens was attained (Windisch et al. 2007). In the present study, the same optical scanning technique was used to obtain a digital, three-dimensional image (Ender et al. 2003). An additional software allowing manual determination of reference surfaces for the matching and transformation in one coordinate system was used. This software was originally designed to measure occlusal wear. It is able to reach an accuracy of 10 μm (Mehl et al. 1997).

A similar approach was chosen in a previous dog study evaluating alterations after tooth extraction (Fickl et al. 2008a). However, two-dimensional digital sections through the models were used for the measurements of volume alterations. In the present study not only one section, but an area of interest was captured, allowing a more representative three-dimensional volume measurement.

The accuracy of the measurements might be impaired by artefacts and dimensional changes of the impression and cast materials. Direct optical impressions in the mouth might overcome this source of error. However, limited access and the presence of saliva can compromise the quality of the scans.

As a conclusion, surgical techniques to overbuild the extraction socket at the time of tooth extraction might be regarded as an additional trauma, which enhances the resorptive alterations. From the results of this study, it might be stated that any manipulation of the buccal bone plate at the time of tooth extraction seems to be contraindicated.

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Address:
Stefan Fickl
Department of Periodontology and Implant Dentistry
New York University College of Dentistry
345 East 24th Street
New York,
10010 NY
USA
E-mail: fickl@nyu.edu

Clinical Relevance

Scientific rationale for the study: The goal of the present study was to volumetrically assess the effect of an additional extra-socket graft on the ridge dimension during socket preservation techniques.

Principal findings: No difference could be found among the different treatment groups concerning post-surgical ridge dimensions.

Practical implications: An additional extra-socket graft seems to be contra-productive at the time of tooth extraction. The additional surgical trauma seems to aggravate the bone resorption, thus nullifying the augmentative effect.