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Dimensional changes of the alveolar ridge contour after different socket preservation techniques

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Abstract

Objectives: The aim of the following study was to assess contour changes after socket preservation techniques.

Material and Methods: In five beagle dogs, the distal root of the third and fourth mandibular premolars was extracted. The following treatments (Tx) were randomly assigned for the extraction socket.

Tx 1: BioOss Collagen.

Tx 2: BioOss Collagen and a free soft tissue graft.

Tx 3: No treatment.

Tx 4: The internal buccal aspect was covered with an experimental collagen membrane, the extraction socket was filled with BioOss Collagen and the membrane folded on top of the graft.

Impressions were obtained at baseline, 2 and 4 months after surgery. Bucco-lingual measurements were performed using digital imaging analysis.

Results: All groups displayed contour shrinkage at the buccal aspect. Only the differences between the two test groups (Tx 1, Tx 2) and the control group (Tx 3) were significant at the buccal aspect ($p \leqslant 0.001$). No measurements of the Tx 4 group could be performed.

Conclusion: Socket preservation techniques, used in the present experiment, were not able to entirely compensate for the alterations after tooth extraction. Yet, incorporation of BioOss Collagen seems to have the potential to limit but not avoid the post-operative contour shrinkage.

Key words: dimensional alterations; extraction socket; socket preservation

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Morphologic and dimensional changes of the alveolar ridge after tooth extraction have been documented in the literature (Cardaropoli et al. 2003, Schropp et al. 2003, Araújo & Lindhe 2005). Schropp et al. (2003) demonstrated, in a clinical study, an average horizontal volume reduction of 5–7 mm within the first 12 months after tooth extraction. The authors reported that these values equalled a loss of approximately 50% of the original alveolar bone width. Araújo and Lindhe investigated, in an experimental animal study, bone resorption after tooth extraction and reported that the coronal part of the buccal bone plate was often comprised solely of bundle bone (Cardaropoli et al. 2003, Araújo & Lindhe 2005). This bundle bone lost its function after tooth removal and was resorbed due to osteoclastic activity. The authors considered the resorption of the bundle bone to be responsible for the substantial vertical and horizontal reduction of the buccal bone crest. Consequent to the partial or complete resorption of the buccal wall of the extraction socket, the collapse of the buccal soft tissue led – according to these authors – to the marked bucco-oral alterations. It can be speculated that similar procedures apply

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to the human extraction socket, although considerable variability seems to exist in humans with respect to hard tissue formation after tooth extraction (Trombelli et al. 2008).

Loss of hard and soft tissue after tooth removal is unfavourable for future implant supported (Barone et al. 1998) or conventional prosthetic restorations (Abrams 1980). Various methods have been described to maintain alveolar ridge dimensions after tooth extraction, focusing mainly on the preservation of the hard tissue (Lekovic et al. 1997, 1998, Artzi & Nemcovsky 1998, Artzi et al. 2000, Carmagnola et al. 2003, Iasella et al. 2003, Zubillaga et al. 2003). Ridge preservation using the Guided Bone Regeneration (GBR) technique has been shown to improve ridge height and width dimensions when compared with tooth extraction alone (Lekovic et al. 1997, 1998, Iasella et al. 2003). It was reported in these clinical studies that implants were placed into the augmented ridges successfully, mostly without additional bone grafting. Yet original ridge contours were not preserved since measurements indicated a horizontal buccal-oral tissue loss of 1.17–1.73 mm (Lekovic et al. 1997, 1998, Iasella et al. 2003). It was even reported that the treatment of extraction sockets with decalcified freeze-dried bone and bioabsorbable membranes failed to augment the extraction sites and did not preserve the alveolar ridges efficiently (Zubillaga et al. 2003).

Other techniques such as grafting bone-substitute materials have also been used for ridge preservation (Artzi & Nemcovsky 1998, Becker et al. 1998, Artzi et al. 2000, Carmagnola et al. 2003, Jung et al. 2004, Nevins et al. 2006, Fickl et al. 2008). Artzi et al. (2000) placed de-proteinized bovine bone material (DBBM) in fresh extraction sockets of 15 patients and performed a histological examination of the grafted sites 9 months later. The investigators concluded that DBBM particles were a biocompatible bone derivative in fresh extraction sockets and an appropriate treatment option for ridge preservation. In contrast, Becker et al. (1998) and Carmagnola et al. (2003) reported that DBBM particles were mainly surrounded by connective tissue. Irrespective of these histological results, Nevins et al. (2006) demonstrated in a clinical study that augmenting extraction sockets with DBBM outperformed the control group. Yet a complete ridge preservation by the use of DBBM was not achieved either.

Techniques to achieve soft tissue closure of extraction sites have been developed, mainly related to immediate implant placement. Besides a coronally re-positioned buccal flap (Becker & Becker 1990), rotated buccal pediculated flaps (Gher et al. 1994, Rosenquist 1997) and a modified tunnel technique with subgingival pontics have been described (Zuhr et al. 2006). Jung et al. (2004) introduced a simplified surgical approach. The extraction socket was filled with DBBM integrated in a 10% collagen matrix and closure of the socket was achieved by a gingival autograft. Improved conditions of the healed soft tissue were reached about 6 weeks after tooth extraction.

To date, it is still uncertain as to which socket preservation technique is the most predictable. No study has compared dimensional changes after various socket preservation techniques under standardized conditions. It was the aim of the following experimental investigation in animals to evaluate socket preservation techniques regarding tissue contour alterations after tooth extraction.

Material and Methods

The research protocol of this investigation and a previously published study (Fickl et al. 2008) was approved by the ethical committee of Biomatech (Namsa Company, Lyon, France).

Surgical protocol

Five 1-year-old beagle dogs (weight 17–19 kg) were selected for this experiment. 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.

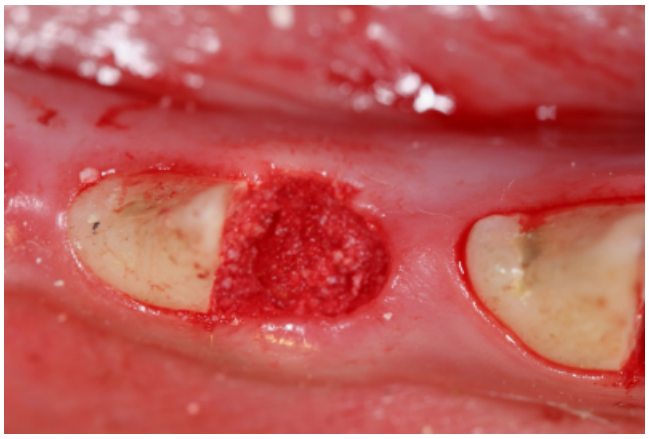

Fig. 1. Treatment group 1: BioOss Collagen® is applied into the extraction socket.

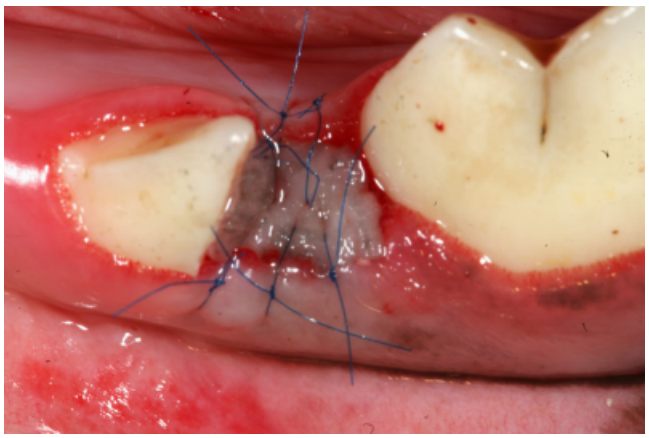

Fig. 2. Treatment group 2: BioOss Collagen® is applied into the extraction socket and a gingival autograft is sutured to the marginal soft tissue.

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 intra-muscular) 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.

In both quadrants of the mandible, the third and fourth premolars served as experimental sites. In order to mimic extraction sites of single-rooted teeth, the mandibular premolars were hemisected. The distal roots were removed without elevation of a muco-periosteal flap or without 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 (Guttapercha Points; Obtura Spartan, Fenton, MO, USA), the coronal part of the pulp chamber was sealed with an auto-polymerizing resin material (Clearfil Core®; Kuraray, Tokyo, Japan). The extraction sites were randomly assigned to one of the following extraction socket treatments (Tx).

Treatment 1 (Tx 1): The extraction socket was filled with DBBM integrated in a 10% collagen matrix (BioOss Collagen®; Geistlich Biomaterials) (Fig. 1). In order to protect the graft, two interrupted sutures were applied to the marginal area of the extraction socket (Gore-Tex® CV5; W. L. Gore & Associates, Putzbrunn, Germany).

Treatment 2 (Tx 2): The extraction socket was filled with BioOss Collagen® and a free gingival graft was sutured into the orifice of the extraction socket. A gingival autograft of approximately 3 mm thickness was harvested from the palate using a scalpel according to the technique of Jung et al. (2004) and Landsberg et al. (1994). Several interrupted sutures (Seralene 7-0®; Serag Wiesner, Naila, Germany) were applied to fix the transplant to the marginal gingiva of the extraction socket (Fig. 2).

Treatment 3 (Tx 3) (control group): The extraction socket remained with the blood clot only. To protect the blood clot, two interrupted sutures were applied to the marginal segment of the extraction socket (Gore-Tex® CV5; W. L. Gore & Associates) (Fig. 3).

Treatment 4 (Tx 4): The internal buccal aspect of the extraction socket was

Fig. 3. Treatment group 3: After tooth extraction, the socket is left with its blood clot and two superficial interrupted sutures.

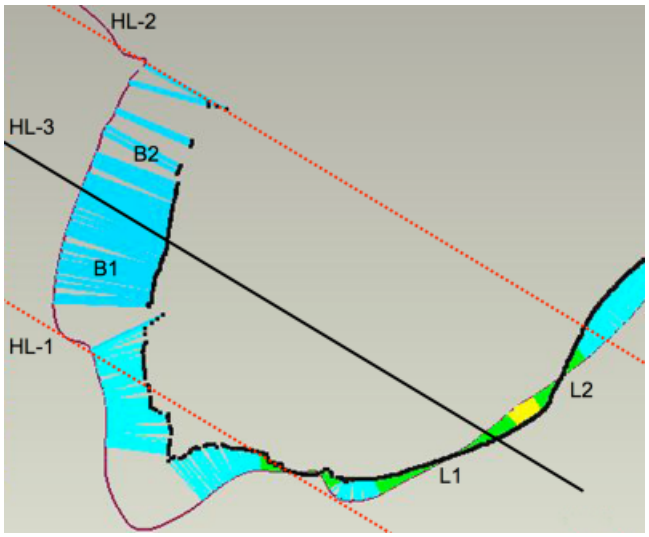

Fig. 4. Schematic drawing of the different compartments for the measurements.
HL-1 = Horizontal line connecting the buccal and lingual margo gingivae
HL-2 = Parallel line to HL-1 through the deepest point of the vestibule
HL-3 = Central horizontal line separating the coronal and apical compartment
B1: coronal buccal compartment
B2: apical buccal compartment
L1: coronal lingual compartment
L2: apical lingual compartment.

Table 1. Mean measurements in different compartments comparing baseline and 4-month cast

Treatment	B1	B2	L1	L2
1 ($n = 10$)	− 1.5 (0.2)	− 1.3 (0.3)	− 0.4 (0.1)	− 0.4 (0.1)
2 ($n = 10$)	− 1.6 (0.2)	− 1.3 (0.3)	− 0.4 (0.1)	− 0.4 (0.1)
3 ($n = 10$)	− 2.2 (0.2)	− 1.8 (0.3)	− 0.6 (0.1)	− 0.5 (0.1)

B1, bucco-coronal section; B2, bucco-apical section; L1, lingual-coronal section; L2, lingual-apical section.

Table 2. Mean measurements in different compartments comparing baseline and 4-month cast

Treatment	B1	B2	L1	L2
1 ($n = 10$)	− 1.4 (0.2)	− 1.3 (0.3)	− 0.4 (0.1)	− 0.4 (0.1)
2 ($n = 10$)	− 1.5 (0.2)	− 1.2 (0.3)	− 0.4 (0.1)	− 0.4 (0.1)
3 ($n = 10$)	− 2.2 (0.2)	− 1.8 (0.3)	− 0.6 (0.1)	− 0.5 (0.1)

B1, bucco-coronal section; B2, bucco-apical section; L1, lingual-coronal section; L2, lingual apical section.

covered with an experimental porcine cross-linked collagen membrane and later the extraction socket was filled with BioOss Collagen® and then the membrane was folded on top of the graft according to the technique of Elian et al. (2007). Consecutively, a pre-fabricated resin-bonded bridge with subgingival pontic design was bonded to the adjacent teeth with an auto-polymerizing resin material (Clearfil Core®; Kuraray).

After surgery, the following protocol was applied.

- Antimicrobial prophylaxis: Spiramycine 750,000 IU and metronidazole 125 mg per os, per day, for 7 days (Stomorgyl®; Merial).
- Anti-inflammatory drug: Carprofene 50 mg per os, per day, for 6 days (Rimadyl®; Pfizer Santé Animale, Orsay, France).
- 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. Tooth cleaning with a toothbrush and dentifrice as well as mouth rinsing with 0.2% chlorhexidine solution was performed three times per week for 4 weeks.

Sutures were removed 2 weeks post-surgery. Healing of treatment groups Tx 1, Tx 2 and Tx 3 was uneventful. The soft tissue grafts of group Tx 2 were fully integrated without any sign of necrosis. Polyether impressions were obtained 2 and 4 months after tooth extraction.

The majority of surgical sites of group Tx 4 demonstrated severe tissue infections with membrane exposure, dehiscence and pus expression during the first post-operative weeks. Because of the unpredictable amount of tissue recession, no qualitative or quantitative evaluation of tissue contour alterations could be performed in this group.

Evaluation of tissue contour changes

Master casts of each dog were made with dental stone (GC Fujirock type 4; GC Corp., Tokyo, Japan) utilizing the pre-extraction and follow-up impressions after 2 and 4 months. To obtain the volumetric dimensions of the extraction sites, computer-aided design software and an optical scanner were used to take optical impressions of the casts. The Cerec 3 system used (Sirona Dental Systems GmbH, Bensheim, Germany) was established in operative dentistry to capture three-dimensional information about the shape of tooth preparations and the adjacent soft tissue contours (Mörmann & Brandestini 1996, Mormann & Bindl 2002). A grid of parallel light beams was projected onto each specimen under a parallax angle according to the principles of active triangulation. The depth-dependent deviation of the light beams was detected with an area sensor (CCD video chip; resolution 25 μm in all three-dimensional axes). The scanning of the baseline model was matched with the corresponding scanning of the 2 and 4 months post-surgery casts using digital imaging software (Match3D; Wolfram Gloger, Munich, Germany).

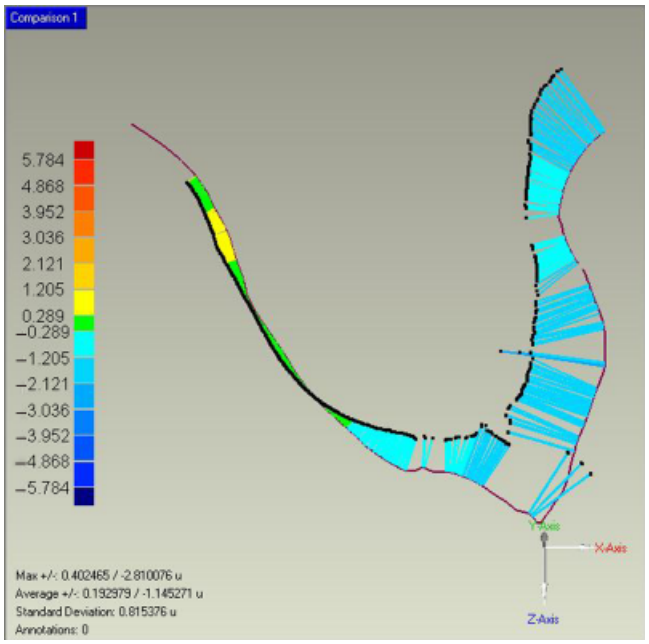

Fig. 5. Bucco-oral section of Tx 1 comparing baseline and 2-months cast.

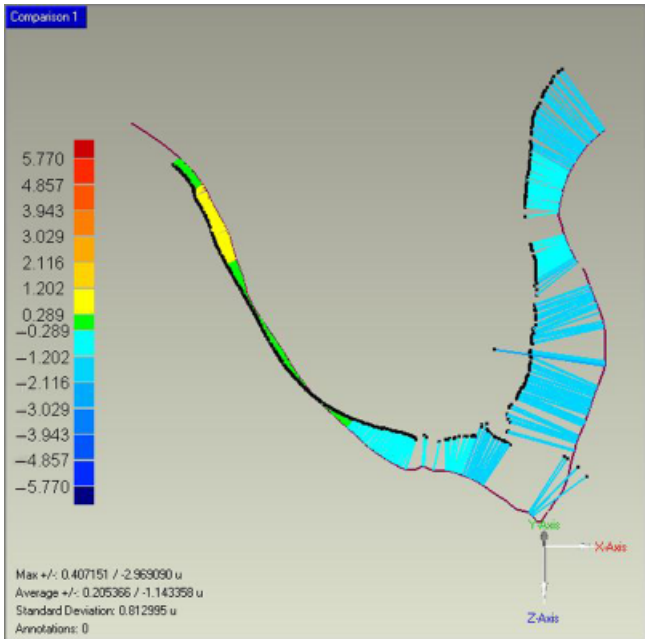

Fig. 6. Bucco-oral section of Tx 1 comparing baseline and 4-months cast.

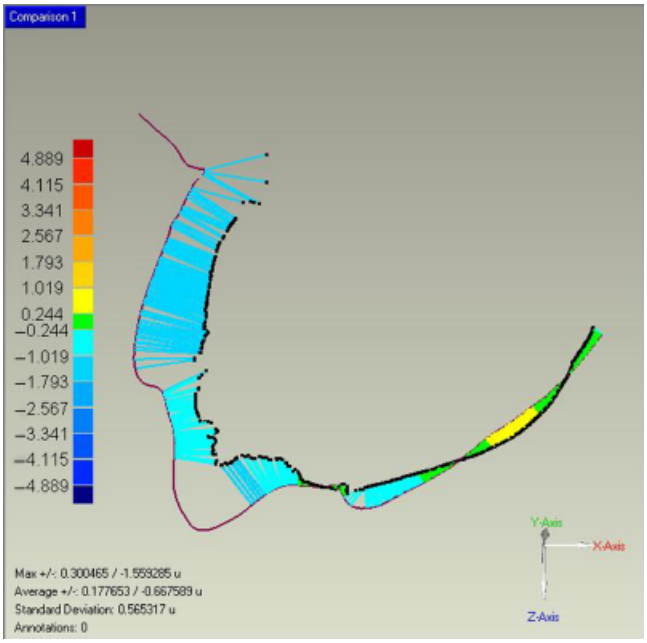

Fig. 7. Bucco-oral section of Tx 2 comparing baseline and 2-months cast.

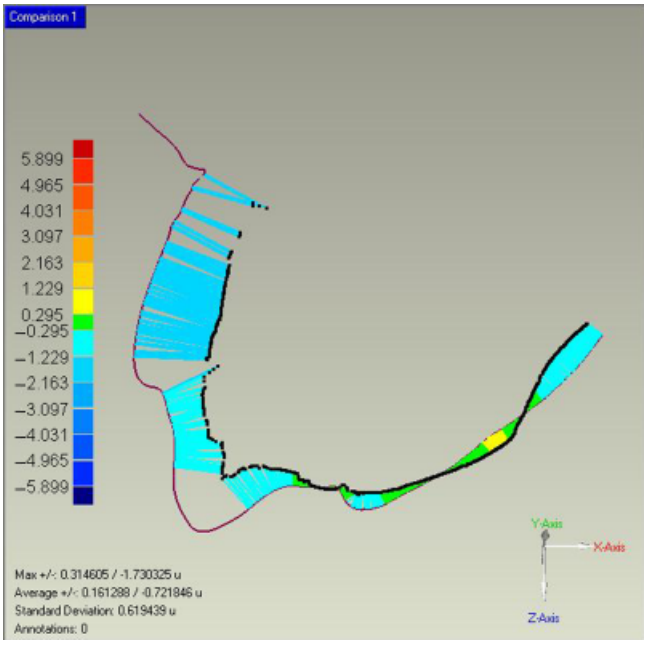

Fig. 8. Bucco-oral section of Tx 2 comparing baseline and 4-months cast.

While superimposing the different scans, the adjacent canine and molar were used as reference points to ensure a precise mapping of the experimental sites. Following data conversion (Dentvisual3D; Albert Mehl, Munich, Germany), the scans of investigated sites were analysed with an additional digital imaging software (Geomagic Qualify; Raindrop Geomagic, Research Triangle Park, NC, USA). The software allowed measurements of 10 μm accuracy (Mehl et al. 1997).

For each superimposed pair of cast images (baseline to 2 months and baseline to 4 months), a buccal-lingual cross-section was generated at the area of the experimental site. In order to perform standardized measurements, the bucco-lingual cross-section was always performed through the distal tip of the tooth crown, which was detectable in the baseline image.

The buccal and lingual crest of the marginal gingiva (margo gingivae) was identified in the buccal-lingual cross-sections before tooth extraction. A tangential horizontal line (HL-1) was drawn from the buccal margo gingivae to the lingual margo gingivae. A second line (HL-2) was placed parallel to HL-1 crossing the deepest point of the buccal vestibule. The space between these lines was divided into two equal segments by another parallel horizontal line (HL-3).

The segmentation of the horizontal cross-section of the alveolar ridge by these lines resulted in four defined measurement divisions. Dimensional measurements were performed every 100 μm in the buccal-coronal (B1), the buccal-apical (B2), the lingual-coronal (L1) and the lingual-apical (L2) divisions. Dimensional differences between the outline of the baseline scan and the outline of the 2-month scan and 4-month scan, respectively, were acquired using digital imaging software (Geomagic Qualify) (Fig. 4). Mean values for each area were calculated.

Statistical analysis

For the horizontal and vertical measurements, analysis of variance (ANOVA) with the two factors ''dog'' and ''treatment group'' was applied. Because the interactions between the factors treatment and dog were low and the mean differences between dogs were not significant, the factor ''dog'' was deleted. To achieve a global level of significance ($\alpha = 0.05$), the *p*-values resulting from pair-wise comparisons of unpaired *t*-tests (between groups) and paired *t*-tests (between stages) were calculated.

Results

The results of the dimensional evaluation are displayed in Tables 1 and 2. The following dimensional changes occurred according to the treatment option (descriptive data between stages).

Treatment Tx 1: Mean dimensional differences (SD) between baseline and the 2-month scan were -1.4 ± 0.2 mm for B1 and -1.3 ± 0.3 mm for B2 buccally. The corresponding values for the lingual aspect were (L1 and L2) -0.4 ± 0.1 mm in both areas. Four

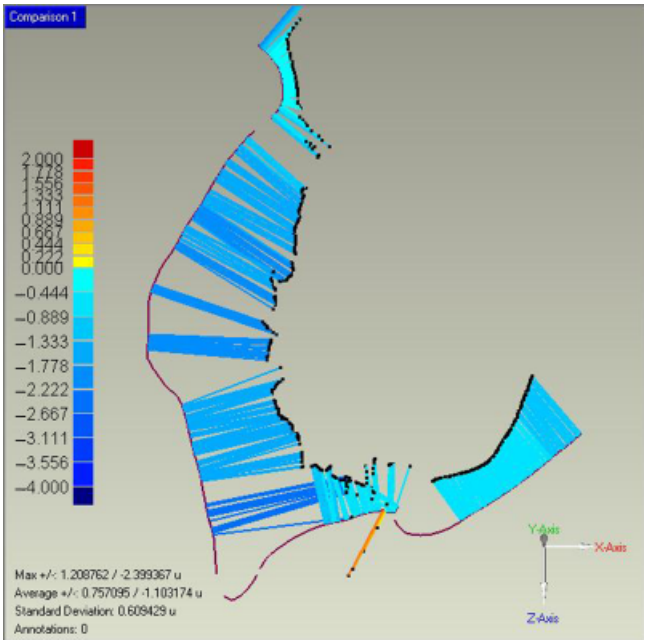

Fig. 9. Bucco-oral section of Tx 3 comparing baseline and 2-months cast.

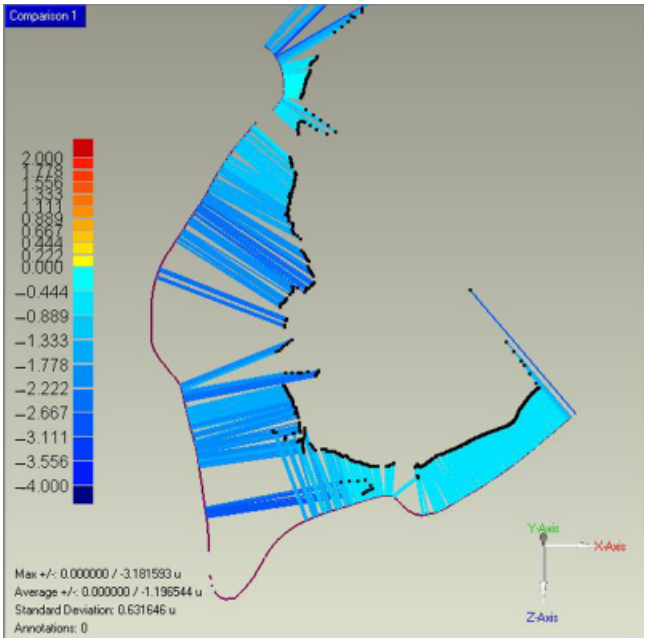

Fig. 10. Bucco-oral section of Tx 3 comparing baseline and 2-months cast.

months after tooth extraction, the buccal aspect showed a decrease of -1.5 ± 0.2 mm (B1) and -1.3 ± 0.3 mm (B2), respectively. The lingual aspect demonstrated no further changes in comparison with the 2-month results (Figs 5 and 6).

Treatment Tx 2: Two months after tooth extraction, the following volumetric changes were recorded for the buccal aspect: -1.5 ± 0.2 mm (B1) and -1.2 ± 0.3 mm (B2). The corresponding values for the lingual side were -0.4 ± 0.1 mm in both areas (L1 and L2).

Four months after tooth extraction, the buccal aspect showed a decrease of -1.6 ± 0.2 mm (B1) and -1.3 ± 0.3 mm (B2). The lingual measurements revealed no further dimensional changes when compared with the 2-month results (Figs 7 and 8).

Treatment Tx 3 (control): The mean differences between baseline and the 2-month scans were -2.2 ± 0.2 mm (B1) and -1.8 ± 0.3 mm (B2). The corresponding values for the lingual aspect were -0.6 ± 0.1 mm (L1) and -0.5 ± 0.1 mm (L2).

The analysis of the 4-month scans did not show a further decrease of volume buccally and lingually when compared with the 2-month results (Figs 9 and 10).

The comparison of the groups by unpaired *t*-tests (ANOVA) resulted in significant differences in dimensional change between the test groups Tx 1 and Tx 2 and the control group Tx 3 at the buccal aspects (B1/B2) for both time intervals (2 and 4 months) ($p \leqslant 0.001$). No significant differences were found between Tx 1 and Tx 2 at the buccal aspects in both stages ($p \geqslant 0.10$). The lingual measurements did not demonstrate significant differences between all groups and time intervals ($p \geqslant 0.10$).

Discussion

The present study in animals evaluated the use of DBBM integrated in a 10% collagen matrix with and without an additional free gingival graft for socket preservation following tooth extraction. The outcome of the investigation indicates that the tested socket preservation techniques result in less contour reduction, in particular, at the buccal aspect when compared with non-treated extraction sockets. The application of DBBM seems to have the potential to limit the post-operative tissue shrinkage to a certain extent. The findings indicate, on the other hand, that the investigated socket preservation techniques were not able to prevent tissue alterations entirely after tooth extraction.

A limitation of this study is that only buccal-lingual cross-sections of the experimental sites could be analysed. Because measurements were based on master models, no statements can be made as to whether the documented horizontal volume resorption was caused by loss of soft tissue or underlying bone. However, no complete preservation of the outline of the alveolar crest could be assessed in particular at the buccal aspect. This was in accordance with the clinical study of Nevins et al. (2006), demonstrating that filling the extraction socket with DBBM outperformed the control group but could not entirely maintain the baseline height of the bone crest. In addition, socket preservation using the GBR technique has been shown to improve ridge height

and width dimensions when compared with tooth extraction alone (Lekovic et al. 1997, 1998, Iasella et al. 2003). Yet a complete ridge preservation was never reported. Original contours were only preserved, however, and even slightly augmented when an additional GBR was performed on the buccal and coronal portions of the alveolus (Simon et al. 2000). This indicates that an additional overlay graft may be essential to secure the tissue contour in the esthetic zone if original aesthetic contours are to be preserved.

The results of the present study indicate, furthermore, that the supplementary use of a free gingival graft to seal the grafted socket had no beneficial effect with respect to the contour alteration of the ridge. Yet the biologic integration of the soft tissue punch was successful as no complication regarding complete graft necrosis could be observed. This is in accordance with the clinical study of Jung et al. (2004), who reported that 3 weeks after surgery, 99.7% of the soft tissue grafts were fully integrated. Landsberg and Bichacho (1994) stated that due to primary wound closure and the additional mechanical stability of the free autograft, the soft tissue collapse might be avoided to a certain extent. However, in the present study, no statistically significant effect of the gingival autograft with respect to the maintenance of the tissue contours, particularly at the buccal aspect, could be found. Within the limits of this study, the additional use of a free gingival graft to seal the orifice of the extraction socket might be questioned. This is in accordance with several clinical trials reporting successful treatment outcomes with secondary wound healing over alien materials placed in the extraction sockets (Carmagnola et al. 2003, Serino et al. 2003, Elian et al. 2007, Serino et al. 2008). Further clinical investigations should be conducted to evaluate the purpose of an additional soft tissue graft over grafted extraction sites.

In conclusion, the present paper demonstrates that socket preservation techniques are able to limit – but not avoid – the contour changes after tooth extraction. It appears that complete ridge preservation is not possible with the socket preservation techniques evaluated.

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Clinical Relevance

Scientific rationale for the study: The goal of the present study was to determine the effect of socket preservation techniques on the preservation of the alveolar contour after tooth extraction.

Principal findings: It was demonstrated that socket preservation techniques were able to limit the shrinkage process, occurring after tooth extraction. A complete preservation of the ridge contour could not be shown.

Practical implications: Socket preservation limits the tissue alterations occurring after tooth extraction. Yet, with respect to the aesthetic zone, any loss of contour is unacceptable. Therefore, it could be concluded that in the aesthetically demanding zone, intra-socket grafts might not be suitable to reach that specific goal.