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Tissue alterations after tooth extraction with and without surgical trauma: a volumetric study in the beagle dog

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Abstract

Objectives: The aim of this study is to evaluate whether tooth extraction without the elevation of a muco-periosteal flap has advantageous effects on the resorption rate after tooth extraction.

Material and Methods: In five beagle dogs polyether impressions were taken before the surgery. The roots of the first and second pre-molars (P_1 and P_2) were extracted and the sites were assigned to one of the following treatments: treatment group (Tx) 1, no treatment; Tx 2, surgical trauma (flap elevation and repositioning); Tx 3, the extraction socket was filled with BioOss Collagen® and closed with a free soft-tissue graft; Tx 4, after flap elevation and repositioning, the extraction socket was treated with BioOss Collagen® and a free soft-tissue graft. Impressions were taken 2 and 4 months after surgery. The casts were scanned, matched together with baseline casts and evaluated with digital image analysis.

Results: The ''flapless groups'' demonstrated significant lower resorption rates both when using socket-preservation techniques and without. Furthermore, socket-preservation techniques yielded better results compared with not treating the socket.

Conclusion: The results demonstrate that leaving the periosteum in place decreases the resorption rate of the extraction socket. Furthermore, the treatment of the extraction socket with BioOss Collagen® and a free gingival graft seems beneficial in limiting the resorption process after tooth extraction.

Key words: extraction socket; muco-periosteal flap; socket-preservation

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Tooth extraction will be followed by marked alterations of tissue volume. In a clinical study, Schropp et al. (2003) displayed that the loss of volume in the horizontal dimension amounts to 5–7 mm within the first 12 months . This corresponds to approximately 50% of the original width of the alveolar bone (Schropp et al. 2003). Two decisive reasons must be stated: It has been shown in experimental studies that the coronal part of the buccal bone wall of the extraction socket is often comprised solely of bundle bone (Araújo & Lindhe 2005). The bundle bone loses its function after tooth extraction and is resorbed due to osteoclastic activity, resulting in a substantial vertical and horizontal reduction of the buccal crest (Araújo & Lindhe 2005). As the buccal wall of the tooth socket is frequently partially or completely resorbed (Araújo & Lindhe 2005), the consequent collapse of the buccal soft tissue leads to marked bucco-oral alterations. It can be speculated that similar procedures occur in humans after tooth extraction, leading to these pronounced tissue alterations.

Additionally, as most of the experimental studies utilized muco-periosteal flaps in order to extract the teeth or obtain primary closure after tooth extraction (Cardaropoli et al. 2003, Araújo & Lindhe 2005), it must be assumed that denuding the buccal bone has further detrimental effects on the resorption process occurring after tooth extraction. Araújo et al. (2005) histologically studied the effect of the surgical trauma (sulcus incisions, rubber dam application, flap elevation) on soft- and hard-tissue remodelling and concluded

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The authors declare that they have no conflict of interests.

that all test teeth demonstrated signs of attachment loss and bone loss. With respect to the extraction socket Araújo and Lindhe (2005) stated that ''in specimens representing 1 and 2 weeks of healing, osteoclasts were indeed present in the exposed area of the alveolar ridge, which exhibited signs of surface resorption''. This may in part explain the marked dimensional alterations after tooth extraction demonstrated in the above-cited study. Some additional clinical information with particular respect to the volumetric alteration exists about the consequence of raising a muco-periosteal flap on the stability and the nutritional status of the underlying bone. So far, clinical studies have shown that following surgical exposure of the alveolar bone, resorption may be observed (Wilderman 1963, Tavtigian 1970, Wood et al. 1972, Brägger et al. 1988).

Several studies have proposed various ridge preservation techniques following tooth extraction, including the placement of graft materials and/or the use of occlusive membranes focusing on the preservation of the hard tissue (Lekovic et al. 1997, 1998, Artzi & Nemcovsky 1998, Artzi et al. 2000, Carmagnola et al. 2003, Cardaropoli et al. 2005). Carmagnola et al. (2003) grafted human extraction sockets with BioOss Collagen® (Geistlich Biomaterials, Wolhusen, Switzerland) and stated that 7 months after augmentation the sockets comprised mainly of connective tissue and small amounts of newly formed bone surrounding the graft particles. It must be assumed that the augmentation of the human extraction socket with the ultimate goal of bone regeneration and complete ridge preservation is hardly predictable.

At the moment the main focus of treating the extraction socket must be to preserve the tissue volume to a certain extent and improve the soft tissue conditions for delayed implant placement. Various techniques have been published, including pedicle flap procedures (Becker & Becker 1990), coronally displaced flaps (Gher et al. 1994) and a modified tunnelling technique in combination with sealing the extraction socket with subgingival pontics (Zuhr et al. 2006). However, from a clinical standpoint it seems that the described techniques are highly time consuming and technique sensitive. Jung et al. (2004) published a simplified approach containing of a soft tissue punch technique in combination with the incorporation of BioOss Collagen® (Geistlich Biomaterials) into the extraction socket. Improved conditions of the healed soft tissue were reached about 6 weeks after tooth extraction (Jung et al. 2004). It was concluded that delayed implant placement combined with augmentative procedures could thus occur under optimized soft tissue conditions. To date no study has volumetrically assessed the benefit of a soft tissue punch technique at the time of tooth extraction.

The aim of the following investigation was to evaluate how much of the volumetric alteration occurring after tooth extraction is due to the surgical trauma applied when elevating a muco-periosteal flap. Furthermore, the effect of socket-preservation techniques with and without flap elevation was investigated.

Material and Methods

The experiment was approved by the ethical committee of BIOMATECH – a NAMSA company with protocol number 43344.

Surgical procedure

Five beagle dogs about 1 year old and weighing about 17–19 kg each were used for this experiment. In order to fabricate individualized impressions trays, a silicone impression (Optosil plus, Kulzer, Hanau, Germany) was taken from each dog 2 weeks before the surgical intervention. Before the surgery, impressions of the lower jaws were obtained in the one-step/two-viscosity technique with polyether materials (Permadyne Garant 2:1/Permadyne Penta H, 3M Espe, St Paul, MN, USA) and used as baseline reference.

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.

In both quadrants of the mandible the first and second pre-molars (P_2 and P_1) were used as experimental sites. After an intrasulcular incision, the roots were carefully extracted using a forceps without elevation of a muco-periosteal flap or compromising the marginal gingiva. The following treatment groups were created:

Treatment group (Tx) 1: The extraction socket was left with its blood clot (Fig. 1).

Tx 2: Surgical trauma was applied with a muco-periosteal flap being elevated into the vestibule using a crestal incision and two vertical releasing incisions (Fig. 2). After 10 min., the flap was repositioned into its original position and fixed with macrosurgical interrupted sutures (Gore-Tex® CV5, W.L. Gore & Associates, Putzbrunn, Germany). The extraction socket was left with its blood clot (Fig. 3).

Tx 3: After tooth extraction, BioOss Collagen® (Geistlich Biomaterials) was shaped to the size of the extraction

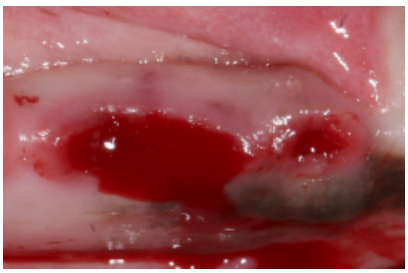

Fig. 1. Treatment group 1: the extraction socket is left with its blood clot.

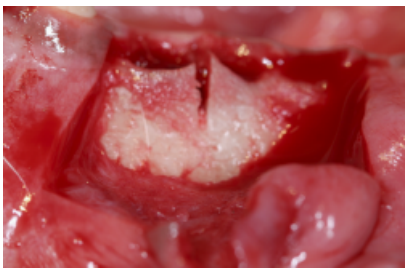

Fig. 2. Treatment group 2: a muco-periosteal flap is raised on the buccal aspect.

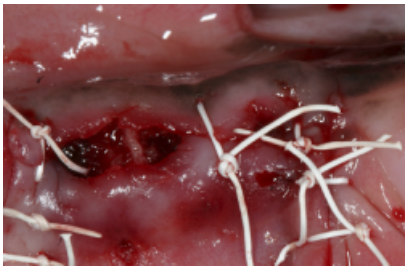

Fig. 3. Treatment group 2: After repositioning of the flap, the socket is left with its blood clot.

socket and applied into the socket without any hydration. Consequently, the extraction socket was filled to the buccal and lingual bone crest with BioOss Collagen® (Geistlich Biomaterials) and a free soft tissue graft was sutured to cover the socket. The free soft tissue punch according to the technique of Jung et al. (2004) and Landsberg and Bichacho (1994) was harvested with a scalpel 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 transplant to the marginal gingiva of the extraction socket (Fig. 4).

Tx 4: Surgical trauma was applied with a muco-periosteal flap being elevated into the vestibule using a crestal incision and two vertical releasing incisions. After 10 min., the flap was repositioned into its original position and fixed with macrosurgical interrupted sutures (Gore-Tex® CV5, W.L. Gore & Associates). Consequently, the extraction socket was filled with BioOss Collagen® (Geistlich Biomaterials) according to the principles mentioned in Tx 3 and a free soft tissue graft harvested from the palate was superficially applied to the socket with several interrupted sutures (Seralene 7-0®, Serag Wiesner) (Fig. 5).

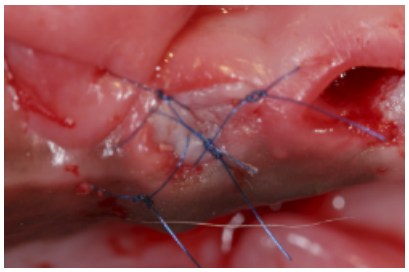

Fig. 4. Treatment group 3: After incorporation of BioOss Collagen® the socket is superficially closed with a free gingival graft, harvested from the palate.

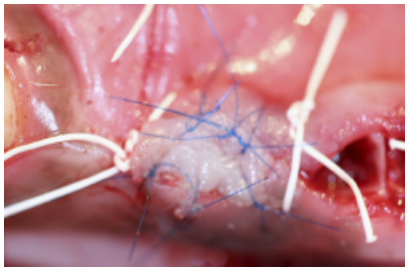

Fig. 5. Treatment group 4: After repositioning of the muco-periosteal flap, the socket is filled with BioOss Collagen® and superficially closed with a free gingival graft.

In each dog, the extraction socket of the first mandibular pre-molar was assigned to Tx 3 and Tx 4 and the second mandibular pre-molar to Tx 1 and Tx 2, respectively. Flap elevation was randomized to either the left or the right side of the jaw, creating four different treatment groups.

Following surgery, the following regimen was administered:

- Antimicrobial prophylaxis: spiramycine 750.000 IU and metronidazole 125 mg per day per os for 7 days (Stomorgyl®, Merial, Lyon, France).
- Anti-inflammatory drug: carprofene 50 mg per os and per day for 6 days (Rimadyl®, Pfizer Santè Animale, Orsay, France).
- Each animal received an injection of butorphanol (0.3 mg/kg) (TorbuGesic®, Fort Dodge Animal Health, Southampton, UK) post-surgically and on the following day. Tooth cleaning with toothbrush and dentifrice and administration of 0.2% chlorhexidindigluconat was performed three times per week for 4 weeks.

The sutures were removed 2 weeks after surgery. Healing presented uneventful. The soft tissue grafts were fully integrated without any sign of necrosis. Polyether impressions were obtained 2 and 4 months after tooth extraction.

Volumetric evaluation

Dental casts were fabricated for each dog and time point. The casts were scanned by a laser beam and the lateral displacement of the laser beam's reflection on the cast was detected by a charge-coupled device chip. The scanned baseline casts were matched with the corresponding 2- and 4-month casts with digital image software (Match3D, Wolfram Gloger, Munich, Germany). When superimposing the different casts, the canine and the molar were used as a reference object. The matched and superimposed images were converted using the Dentvisual3D program (Dentvisual3D, Albert Mehl, Munich, Germany) and analysed by a digital image software (Geomagic Qualify, Raindrop Geomagic, Research Triangle Park, NC, USA) allowing measurements with an accuracy of 10 μm (Mehl et al. 1997). For each superimposed model, bucco-oral sections were obtained in the area of the extraction socket using the tooth axis of the baseline cast as a reference (Figs 6 and 7).

One horizontal line (HL-1) was placed from the buccal Margo gingivae to the lingual Margo gingivae of the baseline cast. A corresponding parallel line (HL-2) was placed through the deepest point of the vestibule. This corridor was now separated into two equal parts by a horizontal line (HL-3). For each area [buccal–coronal (B1), buccal–apical (B2), lingual–coronal (L1), lingual–apical (L2)] differences between the baseline cast and the

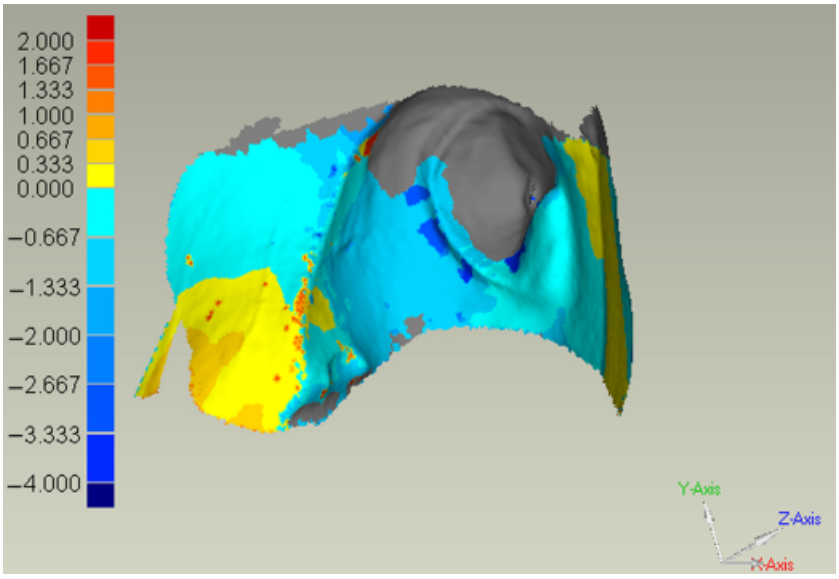

Fig. 6. Baseline cast and 4-months cast are matched and superimposed. Note the volumetric alterations which are displayed in the different colours.

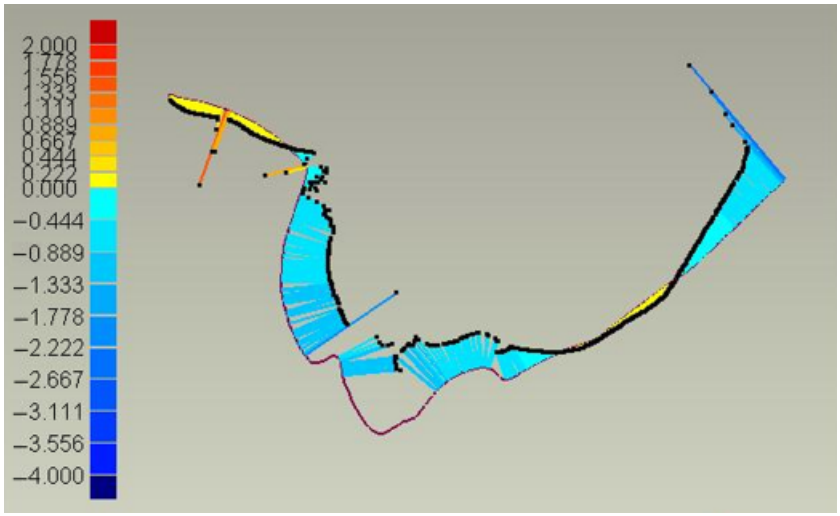

Fig. 7. Bucco-oral sections are obtained using the tooth axis from the baseline cast as a reference.

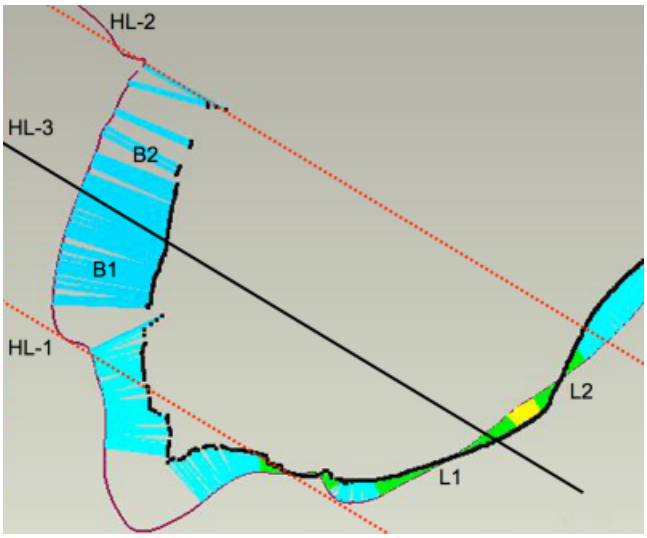

Fig. 8. Schematic drawing of the different compartments for the measurements.
HL-1 = Horizontal line connecting the buccal and lingual margo gingivae.
HL-2 = Parallel line to HL-1 through the deepest point of the vestibule.
HL-3 = central horizontal line separating the coronal and apical compartment.
Bl: 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 2-months cast

Treatment groups	B1	B2	L1	L2
1	1.8 (0.2)	1.5 (0.3)	0.6 (0.1)	0.5 (0.1)
2	2.5 (0.2)	1.9 (0.3)	0.6 (0.1)	0.6 (0.1)
3	1.3 (0.2)	1.4 (0.3)	0.4 (0.1)	0.3 (0.1)
4	1.9 (0.2)	2.0 (0.3)	0.4 (0.1)	0.4 (0.1)

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

Treatment groups	B1	B2	L1	L2
1	2.1 (0.2)	1.5 (0.3)	0.6 (0.1)	0.5 (0.1)
2	2.5 (0.2)	2.0 (0.3)	0.6 (0.1)	0.6 (0.1)
3	1.4 (0.2)	1.2 (0.3)	0.4 (0.1)	0.3 (0.1)
4	2.0 (0.2)	1.7 (0.3)	0.4 (0.1)	0.4 (0.1)

2- and 4-month cast, respectively, were calculated using digital image software (Geomagic Qualify, Raindrop Geomagic) (Fig. 8). Mean values for each area were assessed.

Statistical analysis

For the measurements, the analysis of variance (ANOVA) with the two factors ''dog'' and ''treatment group'' were 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.

Results

Volumetric results

The results from the volumetric evaluation are displayed in Tables 1 and 2.

Tx 1 (Fig. 9)

The mean differences between baseline and the 2-month cast were -1.8 ± 0.2 mm for B1 and -1.5 ± 0.3 mm for B2. The corresponding values for the lingual aspect were -0.6 ± 0.1 mm for L1 and -0.5 ± 0.1 mm for L2. Four months after tooth extraction, the buccal aspect showed alterations of -2.1 ± 0.2 and -1.5 ± 0.3 mm, respectively. At the lingual side, no change compared with the 2-month cast could be assessed for L2. The mean volumetric alteration for L1 after 4 months was -0.6 ± 0.1 mm.

Tx 2 (Fig. 10)

Two months after tooth extraction the following values could be assessed for the buccal aspect: -2.5 ± 0.2 mm for B1 and -1.9 ± 0.3 mm for B2. The corresponding values for the lingual aspect were 0.6 ± 0.1 mm in both areas.

Four months after tooth extraction the buccal side showed -2.5 ± 0.2 mm at B1 and -2.0 ± 0.3 mm at B2. At the lingual side, no change compared with the 2-month cast could be assessed.

Tx 3 (Fig. 11)

The mean differences between baseline and the 2-month cast were -1.3 ± 0.2 mm for B1 and -1.4 ± 0.3 mm for B2. The corresponding values for the lingual aspect amounted to -0.4 ± 0.1 mm at L1 and -0.3 ± 0.1 mm at L2.

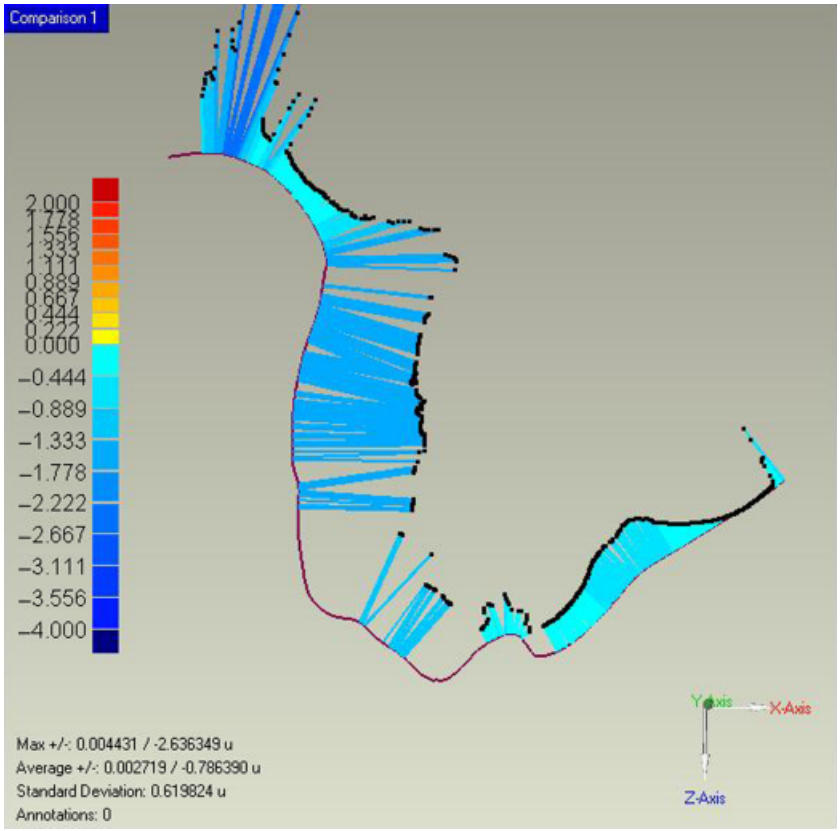

Fig. 9. Bucco-oral section of treatment group1 comparing baseline and 4-months cast. Note the pronounced loss of tissue especially on the buccal aspect.

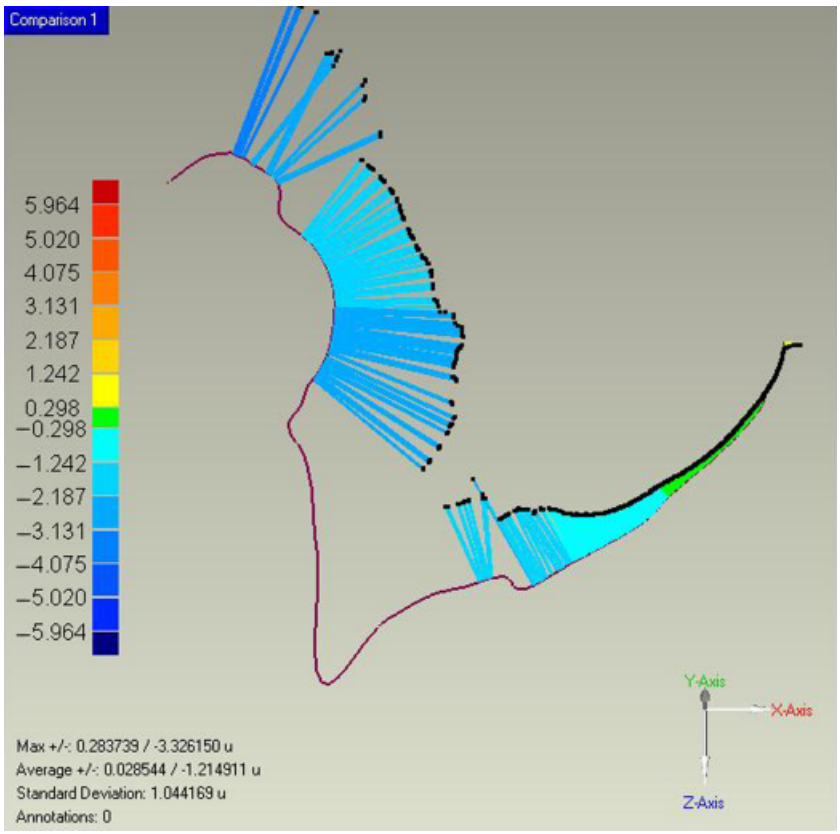

Fig. 10. Bucco-oral section of treatment group 2 comparing baseline and 4-months cast. Note that the shrinkage is even more pronounced on the buccal side.

Four months after tooth extraction, differences of -1.4 ± 0.3 mm at the B1 area and of -1.2 ± 0.3 mm at the B2 area could be assessed. At the lingual side, no change compared with the 2-month cast could be assessed.

Tx 4 (Fig. 12)

The Tx 4 group depicted the following values 2 months after tooth extraction: B1, -1.9 ± 0.2 mm; B2, -2.0 ± 0.3 mm; L1, -0.4 ± 0.1 mm; L2, -0.4 ± 0.1 mm. Four months after tooth extraction the following values could be assessed: B1, -2.0 ± 0.2 mm; B2, -1.7 ± 0.3 mm; L1, -0.4 ± 0.1 mm; L2, -0.4 ± 0.1 mm.

The values from the buccal aspect are schematically displayed in Figs 13 and 14.

Statistical results

When tested with an ANOVA, the ''flapless group'' demonstrated significant lower resorption rates: a statistically significant difference when comparing Tx 1 with Tx 2 ($p<0.001$) and a statistically significant difference when comparing Tx 3 with Tx 4 ($p<0.001$). No statistically significant differences could be assessed for each group at the lingual side and when comparing 2- and 4-month casts. The Tx 3 group depicted statistically significant lower resorption rates when comparing with Tx 1 ($p<0.001$).

Discussion

The findings from the present volumetric analysis disclose that the application of surgical trauma (vertical incisions, flap elevation, suturing) in order to extract a tooth is followed by significantly more bucco-oral shrinkage than without the periosteum being detached. Yet, the results should be analysed with great caution due to the limitations of this present study. The second pre-molar in the beagle dog consists of two roots and is bigger than the first pre-molar: this may lead to a higher resorption tendency per se because of the two roots being located adjacent to each other, and additional surgical trauma had to be applied to the tooth and the underlying bone when separating the two roots. Furthermore, the use of two vertical releasing incisions and a macrosurgical suture material may inadequately represent the clinical procedure of tooth extraction,

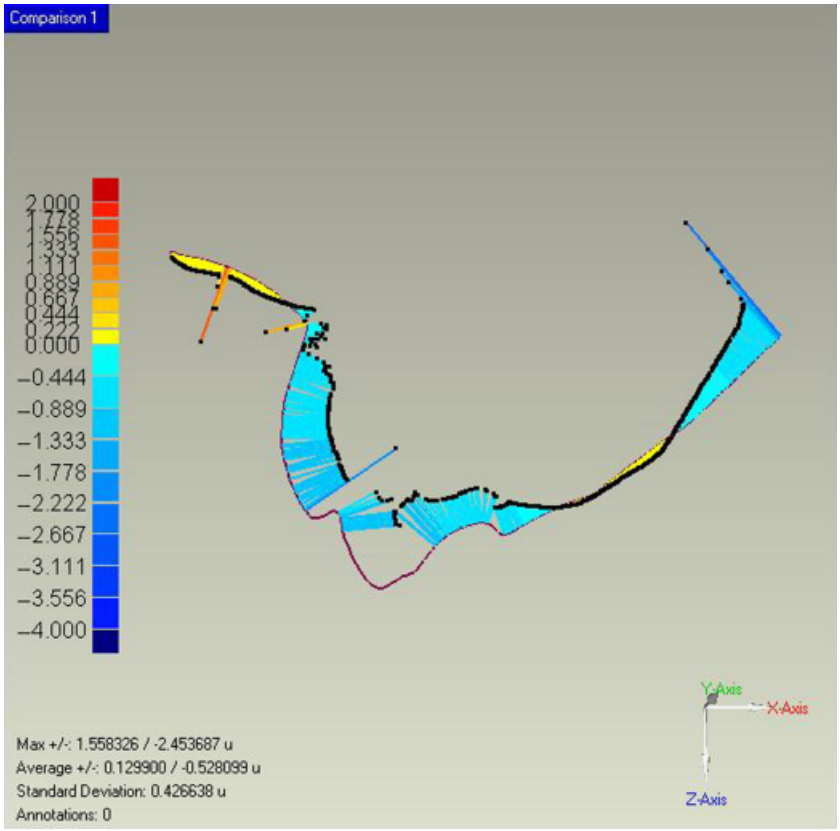

Fig. 11. Bucco-oral section of treatment group 3 comparing baseline and 4-months cast.

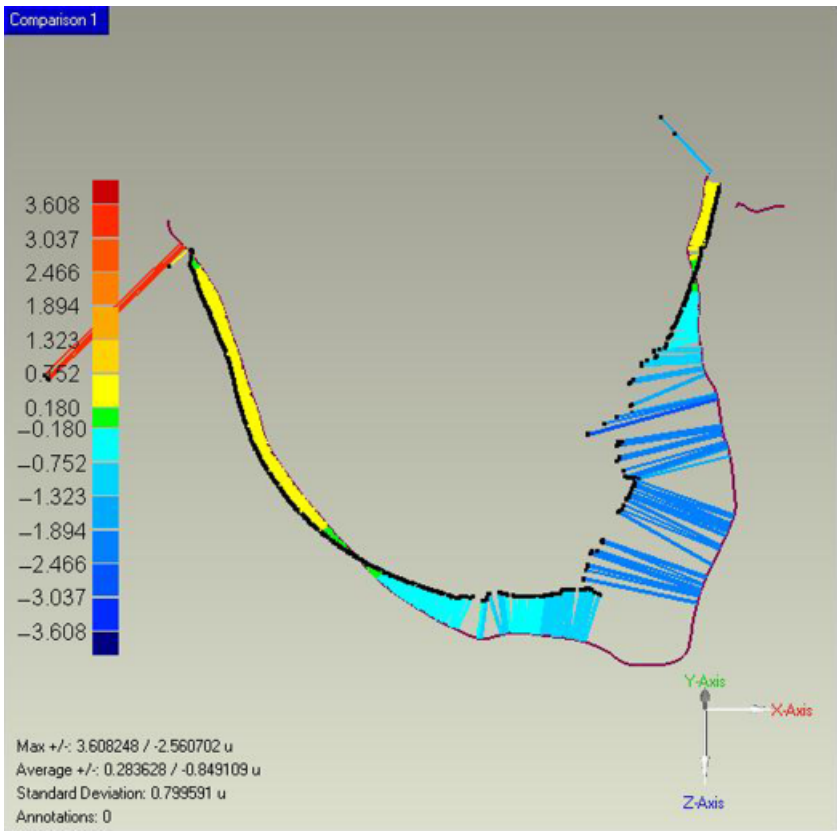

Fig. 12. Bucco-oral section of treatment group 4 comparing baseline and 4-months cast.

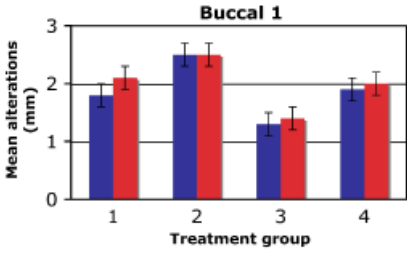

Fig. 13. Histogram describing the mean alterations in the different treatment groups for coronal aspect of the buccal side.

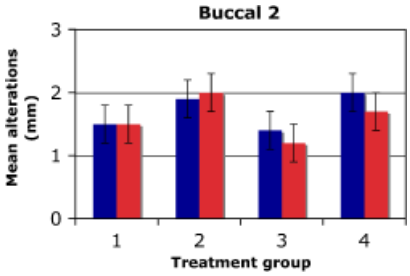

Fig. 14. Histogram describing the mean alterations in the different treatment groups for apical aspect of the buccal side.

leading to a more pronounced alteration in these Tx. Therefore, the results should be regarded as a trend. The values were consistent when comparing flap-elevation *versus* no-flap-elevation in the different Tx. It can be stated that, when the values of the coronal aspects on the buccal side were being combined, the additional flap elevation led to 0.7 mm more shrinkage of the buccal aspect compared with a flapless procedure. The results from this experimental trial should be evaluated with caution due to the limited amount of experimental sites, but the findings can be seen in concordance with the studies of Wood et al. (1972) and Donnenfeld et al. (1964). They reported a mean crestal bone loss after a full-thickness flap elevation of 0.6 mm. In a clinical re-entry study, Tavtigian (1970) showed a mean loss of 0.47 mm of the facial radicular alveolar crest after full-thickness flap procedures. More recently, Brägger and colleagues compared the bone density after modified Widman flaps, aesthetical crown lengthening and scaling and root planing procedures. They concluded that in 69% of the test groups and 34% of the control groups a loss of density was evident, indicating bone-remodelling procedures (Brägger et al. 1988).

It must be assumed that the detachment of the periosteum is even more crucial with respect to the extraction socket. It has been demonstrated that

one of the reasons for the marked bucco-oral alterations is the loss of the bundle bone occurring from the inside of the socket (Cardaropoli et al. 2003, Araújo & Lindhe 2005). If a muco-periosteal flap is raised, an additional osteoclastic resorption will occur on the external aspect of the buccal bone plate. Pfeifer (1965) observed histologically an increased osteoclastic activity 7, 14 and 21 days after apically repositioned flaps and split thickness flaps. Costich & Ramfjord (1968) found signs of resorption in histological sections up to 6 weeks after gingivectomy and up to 4 weeks after split thickness flaps. With partial respect to the extraction socket, Araújo demonstrated that osteoclasts were present in the exposed area of the outer alveolar ridge 1 and 2 weeks after tooth extraction (Araújo & Lindhe 2005). It must be assumed that especially when dealing with thin periodontal biotypes, the osteoclastic activities occurring at the internal and external side will merge together and lead to a more pronounced loss of the buccal bone plate. Consequently, when the buccal bone plate is resorbed, the soft tissue complex can no longer be stabilized and will collapse into the newly formed space. As the buccal soft tissue occupies the place of the former buccal bone plate, the room for bone regeneration is reduced, leading to the observed major bucco-oral shrinkage.

Furthermore, the results of the presented study depict that incorporation of BioOss Collagen® (Geistlich Biomaterials) and superficial closure with a free gingival graft seem to have the potential to limit the post-operative volumetric shrinkage to a certain extent. Within the limitations the results are in accordance with a recently published histological study by Fickl et al. (2007), who demonstrated that the application of BioOss Collagen® (Geistlich Biomaterials) into the extraction socket does not modify the biological procedures occurring after tooth extraction, particularly with respect to the buccal bone plate. However, it was shown that when filling the extraction socket with BioOss Collagen® (Geistlich Biomaterials), the bucco-oral dimension of the alveolar process 4 months after tooth extraction was significantly greater compared with the group without socket preservation (Fickl et al. 2007).

Socket-preservation techniques seem to limit the bucco-oral shrinkage. Yet, a complete preservation even without elevation of a muco-periosteal flap could not be shown. On the other hand, when a muco-periosteal flap was raised on the buccal aspect, the effect of the socket-preservation technique was nullified. For aesthetic reasons, bucco-oral shrinkage should be completely avoided. In this context the presented socket-preservation techniques even without elevating the periosteum do not seem to be sufficient to reach that particular goal. Further investigations with the ultimate goal of avoiding or compensating the resorption process after tooth extraction should be conducted.

It can be concluded that the exposure of the buccal bone has a detrimental effect on the resorption process occurring after tooth extraction. Further investigations have to be performed to assess the effect of denudation of the alveolar bone before tooth extraction in a clinical setup. Yet, in the presented animal model, 0.7 mm additional volumetric shrinkage could be observed. Furthermore, within the limitations of this study, socket-preservation techniques seem to be able to limit the resorption processes to a certain extent. So far, they are not able to preserve the entire volume.

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Clinical Relevance

Scientific rationale for the study: The goal of the present study was to determine the detrimental effect of an additional surgical trauma (vertical incisions, flap elevation, suturing) with respect to the extraction socket and socket-preservation techniques.
Principal findings: Within the limitations of this study it was demonstrated that the elevation of a muco-periosteal flap will induce 0.7 mm more volumetric alteration, particularly at the buccal side. Socket-preservation techniques seem to be able to limit the volumetric shrinkage to a certain extent, but are not able to compensate for the entire alterations.
Practical implications: Tooth extraction should be performed without elevation of a muco-periosteal flap so as not to enhance the volumetric tissue alteration occurring particularly on the buccal aspect. Socket-preservation techniques are only able to limit the post-extraction shrinkage of the extraction socket. However, particularly in the aesthetic zone, no loss of tissue can be accepted. Within the limitations of this study it can be concluded that soft- or hard-tissue augmentative procedures will be needed at implant placement or second-stage surgery in order to compensate for the volumetric alteration occurring after tooth extraction.