The Socket-Shield Technique: First Histological, Clinical, and Volumetrical Observations after Separation of the Buccal Tooth Segment – A Pilot Study

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ABSTRACT

Background: The "socket-shield technique" has shown its potential in preserving buccal tissues. However, front teeth often have to be extracted due to vertical fractures in buccolingual direction. It has not yet been investigated if the socket-shield technique can only be used with intact roots or also works with a modified shield design referring to vertical fracture lines.

Purpose: The aim of this study was to assess histologically, clinically, and volumetrically the effect of separating the remaining buccal root segment in two pieces before immediate implant placement.

Material and Methods: Three beagle dogs were selected in the study. The third and fourth premolars on both sides of the upper jaw were hemisected and the clinical crown of the distal root was removed. Then, the implant bed preparation was performed into the distal root so that a buccal segment of healthy tooth structure remained. This segment was then separated in a vertical direction into two pieces and implants placed lingual to it. After 4 months of healing, the specimens were processed for histological diagnosis. In a clinical case, the same technique was applied and impressions taken for volumetric evaluation by digital superimposition.

Results: The tooth segments showed healthy periodontal ligament on the buccal side. New bone was visible between implant surface and shield as well as inside the vertical drill line. No osteoclastic remodeling of the coronal part of the buccal plate was observed. The clinical volumetric analysis showed a mean loss of 0.88 mm in labial direction with a maximum of 1.67 mm and a minimum of 0.15 mm.

Conclusion: The applied modification seems not to interfere with implant osseointegration and may still preserve the buccal plate. It may offer a feasible treatment option for vertically fractured teeth.

KEY WORDS: alveolar bone preservation, extraction socket, immediate implant placement, socket shield, tooth retention, volumetric tissue alterations

INTRODUCTION

The main expectation of patients regarding implants in the aesthetic zone besides a low cost-benefit ratio and time efficiency is the aesthetic outcome, especially regarding the long-term view. In addition to the white aesthetics of the prosthetic restoration, there is a strong focus on the red aesthetics,[1] which are made up by the color, shape, and character of the marginal gingiva. Following immediate implant placement in the aesthetic zone, these gingival tissues are subject to volumetric

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changes as they undergo a remodeling process. A major problem a clinician will encounter in this case is resorption mainly of the buccal tissues in horizontal dimension.[2,3] The amount of volumetric loss is hardly predictable. Small differences in the red–white aesthetics are visually perceived and therefore one must strive for complete long-term tissue preservation. The predictability of the hard and soft tissue appearance after reconstructive surgical interventions is limited because horizontal and vertical bone augmentations are frequently accompanied by subsequent tissue shrinkage.[4,5] Also soft tissue augmentation with a subepithelial connective tissue graft is accompanied by a volumetric reduction of about 30%.[6] In an animal study from the working group of the authors, it was shown that the resorption of the buccal plate could not be avoided completely by incorporation of biomaterials (in this case, Bio-Oss Collagen, Fa. Geistlich Biomaterials, Wolhusen, Schweiz).[7] Also, buccal overbuilding with guided tissue regeneration did not lead to satisfactory preservation of the alveolar ridge.[8] In contrast to studies that report on the implant survival rate, crestal bone resorption on radiographs, or aesthetic scores in two-dimensional view,[9] the mainly desired effect of the socket-shield technique – to maintain the buccal tissues – is investigated in a clinical case with a volumetric evaluation according to a method that was previously used in histological animal studies from our working group.[8,10]

Maintaining the volume after tooth extraction with preservation techniques in the sense of primary prevention is not yet possible with the available materials. Buccal overbuilding with bone grafting materials and a collagen barrier can only partly compensate but not avoid the resorption process and therefore a better solution is desirable. To meet the demand of more predictability of the postoperative gingival conditions, an innovative and less invasive method without the use of bone substitute material was developed to avoid the resorption process in horizontal and vertical dimensions. The idea was to leave a part of the root on the buccal side in the course of immediate implant placement. The desired effect is to remain the healthy periodontium, thereby maintaining the gingival tissues and keeping the crestal bone on its original level. This so-called "socket-shield technique" was examined in a subsequent investigation in beagle dogs.[11] Instead of bone grafting material, healthy tooth structure was left on the buccal part of the implant bed. The histological results of this proof-of-principle report showed clearly that there was no more remodeling happening on the buccal side and therefore no more resorption taking place. The conclusion was that partial root retention seems not to interfere with osseointegration and may be beneficial in preserving the buccal bone plate.

In that preceding study from the authors, an enamel matrix derivate (Emdogain®, Straumann, Basel, Switzerland) was applied to the inner surface of the tooth fragment before implant placement, which resulted in a layer of new cementum between implant and tooth segment. Yet it is not known if the use of emdogain leads to a favorable result and what would happen if it is omitted. Therefore, as an additional point of observation of this study, the reaction of the surrounding tissues without the use of Emdogain was evaluated.

The present study was performed to evaluate if the socket-shield technique also works when the buccal shield shows a vertical fracture line. There are concerns that the socket-shield technique can only be used when the buccal tooth structure is intact but in many cases a tooth that has to be replaced is vertically fractured. From the authors' experience, this fracture line cannot be left in the remaining root segment because it would form a recess for bacteria inaccessible by the immune system and will most probably lead to an infection. Therefore, a modification of the technique was examined where the buccal shield is separated in two pieces along the fracture line.

The aim of this animal study was to histologically asses the effect of separating the buccal shield in the extraction socket in two pieces before immediate implant placement. Additionally, the effect of renouncing Emdogain should be evaluated. In conjunction with a case report, it was demonstrated in clinical application if this method is also suitable for teeth vertically fractured in buccolingual direction.

MATERIAL AND METHODS

The animal study was performed according to a previous experiment from this working group.[11] The study protocol was approved by the ethical committee of Biomatech (BIOMATECH NAMSA, Lyon, France). Three beagle dogs (1 year old and weighing between 17 and 18 kg) were selected for the experiment. Supragingival scaling was performed 5 days before immediate implant placement using the socket-shield technique. Anesthesia was induced by injecting atropine

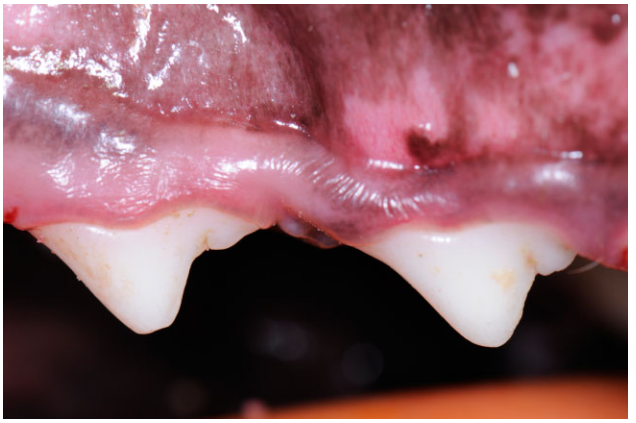

Figure 1 The third and fourth premolars were used as experimental sites.

Figure 3 The distal aspects were decoronated and osteotomy drills were performed.

(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 10 to 15 mg/kg thiopental sodium was given intravenous (Nesdonal®, Merial, Lyon, France) and the animal was placed on a 1 to 4% O_2–N_2O isoflurane mixture. In both quadrants of the maxilla, the third and fourth premolars ($_3P_3$ and $_4P_4$) were used as experimental sites (Figure 1).

In order to mimic the extraction sites of single-rooted teeth, the third and fourth maxillary premolars were hemisected using a fissure bur (Figure 2). Consecutively, the distal aspects of the premolars were decoronated with the use of a coarse-grained diamond bur (Figure 3). After performing the osteotomy drills for the dental implant bed on the lingual part of the root, residual tooth fragments were completely removed on the lingual, distal, and mesial region of the extraction socket without elevation of a mucoperiosteal flap.

To separate the shields in two pieces before implant placement, a fissure bur was used to drill a vertical separation line (Figures 4 and 5). The buccal fragment of the root was retained approximately 1 mm coronal to the buccal bone plate. In contrast to the previous study,[11] no Emdogain was applied.

A total of 12 implants (SPI® ELEMENT 4×8.5 mm, Thommen Medical, Waldenburg, Switzerland) were placed according to the manufacturer's recommendations and were situated at the height of the buccal root segments in direct contact with the buccal root segments (Figure 6). Healing abutments of 4 mm in height were inserted (Figure 7).

After surgery, the following regimen was administered:

1 Antimicrobial prophylaxis: spiramycine 750,000 IU and metronidazole 125 mg/day per os for 7 days (Stomorgyl®, Merial, Lyon, France).

Figure 2 The teeth were hemisected using a fissure bur.

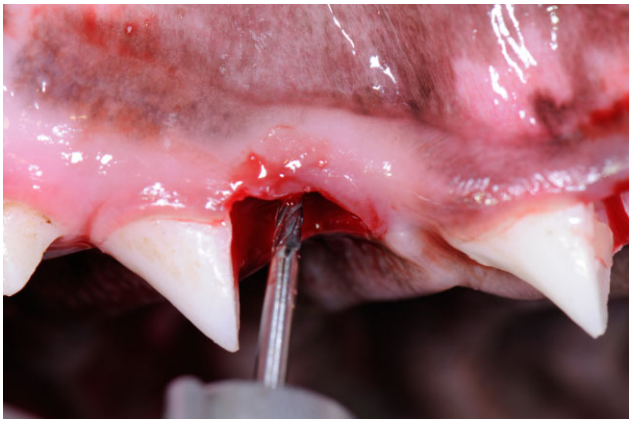

Figure 4 A fissure bur was used to drill a vertical separation line.

Figure 5 The shields were separated in two pieces before implant placement.

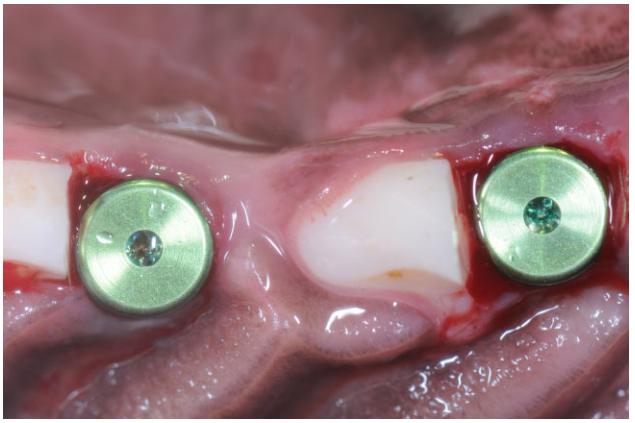

Figure 7 After implant placement healing abutments were inserted.

2 Anti-inflammatory drug: carprofene 50 mg/day per os for 6 days (Rimadyl® Pfizer Santé Animale, Orsay, France).
3 The animal received an injection of butorphanol (0.3 mg/kg) (TorbuGesic®, Fort Dodge Animal Health, Southampton, UK) postsurgically and on the following day.
4 Tooth cleaning with toothbrush and dentifrice and administration of 0.2% chlorhexidine was performed three times weekly for 4 weeks.

Four months after implant placement, the animals were sacrificed. After anesthesia with an intramuscular injection of Zoletil® (50 mg/kg), heparin was administered by intravenous injection (100 IU/kg). The animal was euthanized by a lethal dose injection of Dolethal® (pentobarbital sodique, Vetoquinol, Paris, France) before formalin injection. Tissue fixation was achieved by injecting approximately 300 mL of 10% formalin in the common carotid artery. Following this initial fixation, the mandible was dissected behind the first molar and resected. Each ramus was separated by a frontal section and fixed in 10% buffered formalin solution.

Figure 6 The implants were placed in direct contact to the buccal root segments.

Histological Evaluation

The specimens were cut longitudinally in the buccolingual direction next to the separation line and in some horizontal sections using an Exakt cutting unit (Exakt®, Norderstedt, Germany) equipped with a diamond-coated bandsaw. The two resulting halves of the original specimen were embedded following complete dehydration in ascending grades of ethanol in a light-curing one-component resin (Technovit 7200 VLC, Kulzers, Friedrichsdorf, Germany).

Light Microscopy

For light microscopy evaluation, the samples were processed for the preparation of nondemineralized ground sections according to the technique of Donath and Breuner.[12] Polymerized blocks were sliced longitudinally on an Exakt cutting unit (Exakt). The slices were reduced by microgrinding and polishing using an Exakt grinding unit to an even thickness of 30 to 40 mm. Sections were stained with Sanderson's Rapid Bone Stain (methylene blue and potassium permanganate) and acid fuchsin counterstain and then examined using both a Leica MZ16 stereomicroscope (Leica Microsystems, Leica, Wetzlar, Germany) and a Leica 6000DRB light microscope (Leica Microsystems), as well as a digital imaging software (Image Access, Imagic, Glattbrugg, Switzerland).

Volumetric Analysis

Volumetric analysis was performed in one patient, which is presented in the following case report. Polyether impressions were taken with Permadyne® (3 M, St. Paul, MN, USA) before implant bed preparation, 5 months later before removal of the healing abutment, and 2 weeks later after insertion of the final restoration. Plaster models were made with a type IV die stone (esthetic base gold®, dentona AG, Dortmund, Germany) and optically scanned with a structured light 3D scanner (D104®, Imetric 3D, Courgenay, Switzerland). The obtained Standard Triangulation Language data were compared regarding volume alterations of the buccal soft tissues by digital superimposition in a matching software (SMOP Volume Compare®, Swissmeda, Zurich, Switzerland). The volume alterations were measured as the mean loss in distance (Δd [mm] = Δvol [mm^3]/area [mm^2]) in labial direction according to animal studies by Fickl et al.[8,10] and a clinical study by Schneider et al.[13]

RESULTS

Histological Findings

Clinically, healing of all experimental sites proceeded without adverse events and without signs of inflammation.

The bucco-oral overview illustrates the presence of a tooth fragment apically in contact with the threads of the implant (Figure 8). The tooth fragment consisted of a small portion of enamel and an up to 1.5-mm-wide piece of root dentin (Figures 9 and 10). On its buccal side, the tooth fragment was still attached to the buccal bone plate by a physiologic periodontal ligament (Figure 11). On the buccal alveolar crest, which was very thin, no osteoclastic remodeling was found (Figure 12). A higher magnification of the coronal part on the buccal revealed a physiologic junctional epithelium ending at the cemento-enamel junction (see Figure 10). Beginning from this contact point, a thin layer of junctional epithelium was present on the internal surfaces of the tooth fragment and tapered down in the apical direction (Figure 13). Beginning slightly above the implant shoulder, a small, up to 0.5-mm-wide gap filled with new bone was interposed between the dentin and the implant by means of ancylosis (Figure 14). This bone was free of resorption processes. On the lingual side, the implant was osseointegrated into the alveolar bone.

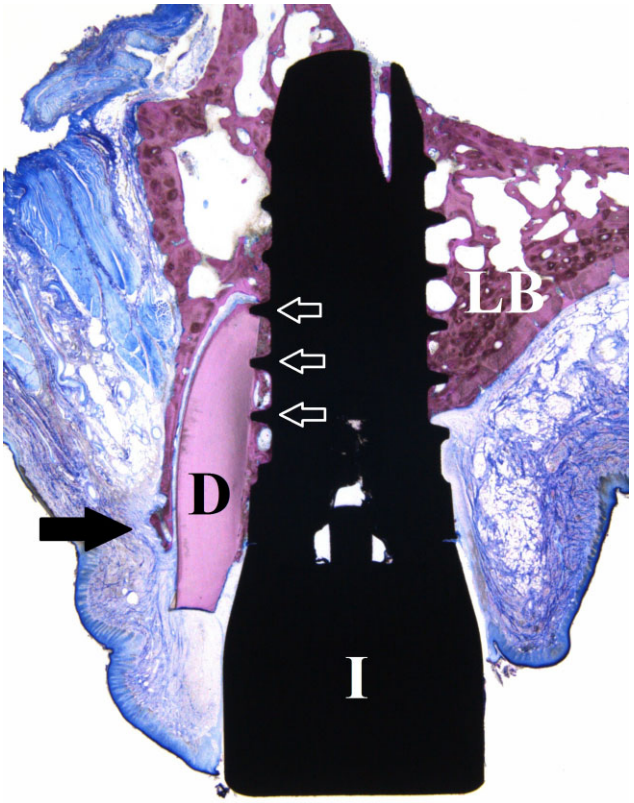

Figure 8 Bucco-oral ground section of a specimen showing the implant threads in contact with the tooth fragment (white arrows). Note the healthy peri-implant tissues and the height of the buccal bone plate (black arrow) compared with the lingual bone (LB). Sanderson's Rapid Bone Stain (methylene blue and potassium permanganate) and acid fuchsin counterstain. D = dentin; I = implant.

The height of the alveolar bone crest was higher on the buccal than on the lingual side (see Figure 8). The peri-implant soft tissue revealed a physiologic junctional epithelium and was free of any inflammatory reaction. Also the apical end of the tooth fragment showed no resorption. The horizontal sections also showed the implant in contact to the tooth fragment with a small gap filled with new bone between them (Figures 15 and 16). The vertically drilled outline also appeared filled with new bone with no signs of resorption.

Case Report

A 69-year-old female patient presented with a vertical fracture on the right canine. The neighboring lateral and central incisor were already missing and replaced by a fixed partial denture from tooth #6 to #8. A conservative extraction of tooth #6 with the anticipated subsequent resorption of the buccal tissues would have meant a far-reaching change of the aesthetics. Due to previous intravenous administration of bisphosphonates,

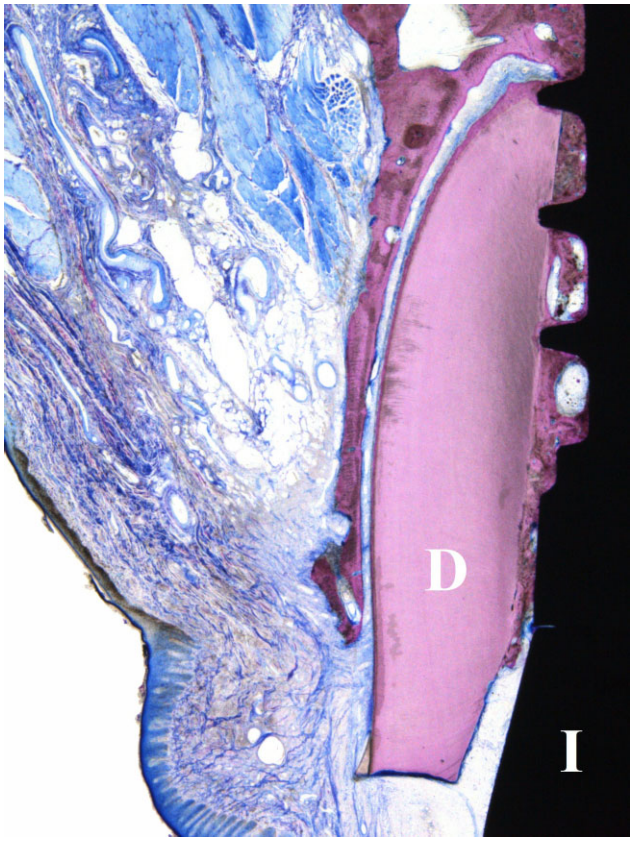

Figure 9 Magnification of the coronal part. Note the healthy periodontium and the new bone between implant (I) and dentin (D).

extensive surgical procedures were not possible. Therefore, the treatment plan implicated an immediate implant placement within the meaning of the socket-shield technique and flapless implant placement at the site of tooth #8. The preoperative pocket probing depth in the area of the vertical root fracture on the buccal aspect was 15 mm (Figure 17). Tooth #6 was decoronated with a coarse-grained diamond bur and the fracture line on the buccal became visible (Figure 18). The shield was prepared by osteotomy drills for the dental implant on the lingual part of the root (Figure 19). After preparation of the implant bed, all remaining tooth segments except for the buccal shield were removed. By drilling out the fracture line, a gap was created and the shield was separated into two pieces in order to enable blood clot formation in this specific area and to not leave a recess for bacteria inaccessible to the immune system (Figure 20). A Thommen Medical implant (4.0×14 mm SPI) was placed according to the manufacturers recommendations on the palatal aspect of the extraction socket without contact to the shield. The implant shoulder was situated 1 mm apically to the maintained root segment (Figure 21). An open healing was chosen and no sutures were necessary. As immediate loading was not indicated due to low primary stability, a gingiva former of 4.0 mm in height was connected and a removable partial denture was placed. In the same intervention, a Thommen Medical implant (4.5×12.5 mm SPI) was placed in region #8 with a flapless approach and supplied with a healing abutment 2 mm in height. After 6 months, the gingival tissues around the implants appeared very voluminous and harmonic (Figure 22). Following good healing, the implants were well osseointegrated and could now be loaded. The final impressions were taken and the implants in the regions of #6 and #8 were supplied with a screw-retained ceramic-to-metal fixed partial denture (Figures 23 and 24).

Volumetric Evaluation

The area of the selected surface of measurement amounted to 28.68 mm^2 (Figure 25). Between the original situation before implant bed preparation and

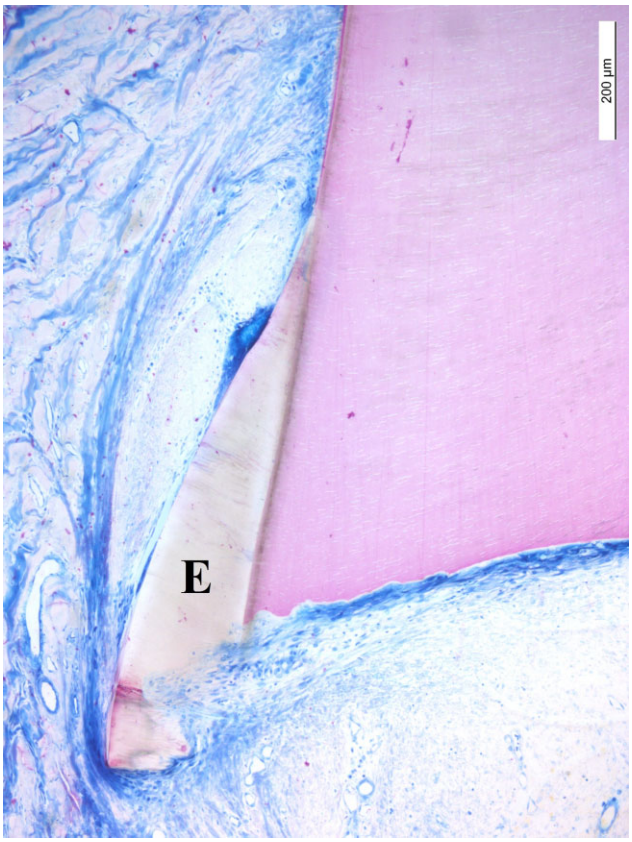

Figure 10 Coronal part of the tooth fragment with a small portion of enamel (E). Note the physiologic junctional epithelium. Bar = 200 µm.

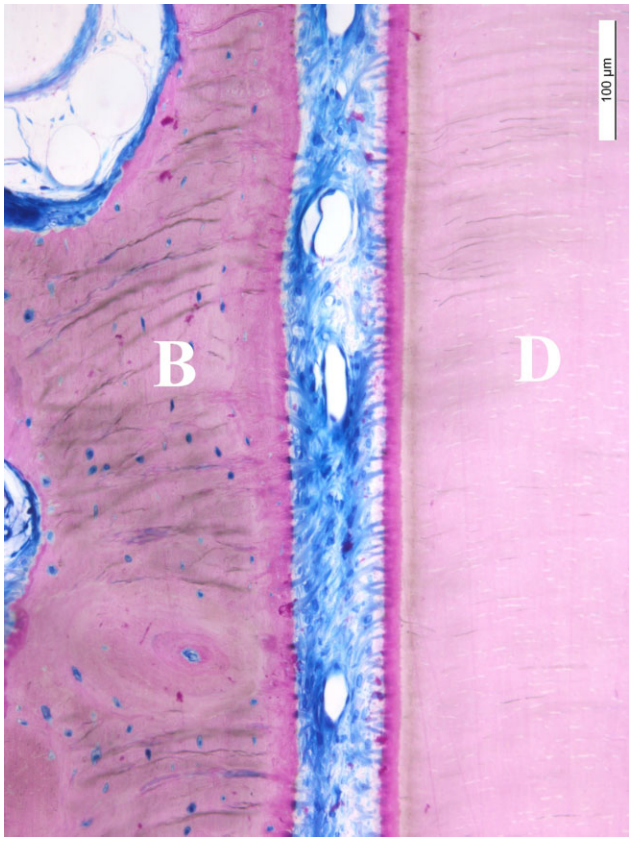

Figure 11 Higher magnification of the tooth fragment in contact to the buccal plate. Note the healthy periodontal tissue. Bar = 100 µm. B = new bone; D = dentin.

5 months later before removal of the healing abutment, a mean loss of 0.66 mm in labial direction was found. As the outline of the amount of loss was not homogenous within the defined area, a maximum value of 1.16 mm and a minimum of 0.01 mm could be identified. A more pronounced loss was detected in the middle of the area, decreasing toward the mesial and distal (Figure 26). The same values were calculated to compare the original situation with the condition after placement of the final restoration within the equivalent area. The mean distance of loss was 0.88 mm with a maximum of 1.67 mm and a minimum of 0.15 mm, meaning an additional mean loss of 0.22 mm between removal of the healing abutment and placement of the final restoration (Figure 27).

DISCUSSION

The specific objective of this investigation was to histologically asses the effect of separating the buccal shield in the extraction socket in two pieces before immediate implant placement. The major finding of this study is that there was no remodeling in the most coronal part of the crestal bone on the buccal side, which is in accordance with the results of the preceding study by this working group.[11] By way of derogation to that study, new bone formation could be observed between the implant and the tooth segments, as well as in the artificially created gap between the two remaining tooth segments. In the previous study, new cementum was observed in this area. A possible explanation for this deviation could be that no enamel matrix derivate was applied. If the presence of cementum between implant and tooth segment is desired, it might be necessary to apply Emdogain. To make sure which role enamel matrix derivates play in this context, a comparative study with and without the use of it would be meaningful.

The design of the present study is limiting because only three dogs have been included and no control was implemented. Regarding histological analysis, histomorphometric data could have provided more information and the follow-up time of 4 months may be too short to

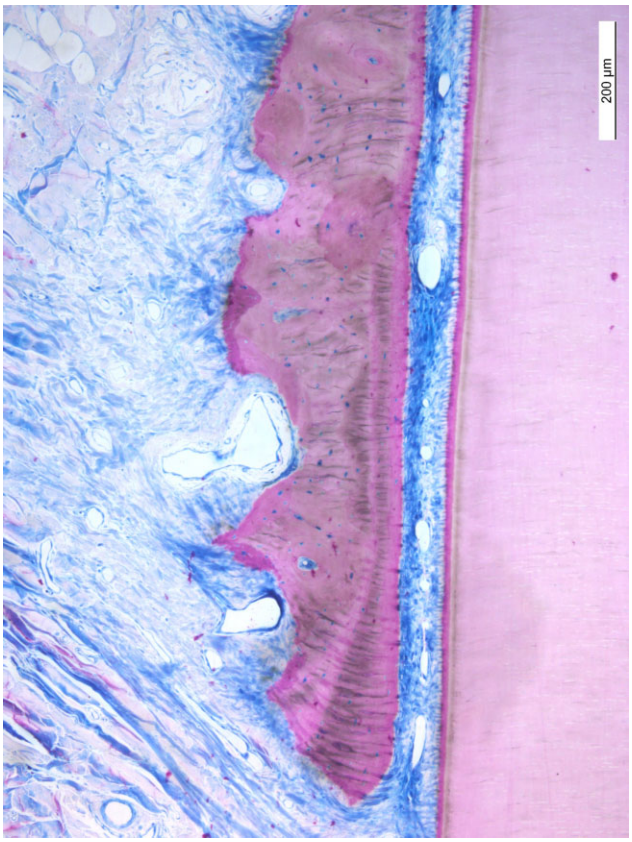

Figure 12 Detailed view showing the buccal alveolar crest. Note the absence of osteoclastic remodeling. Toluidine blue/pyronin G stain. Bar = 200 µm.

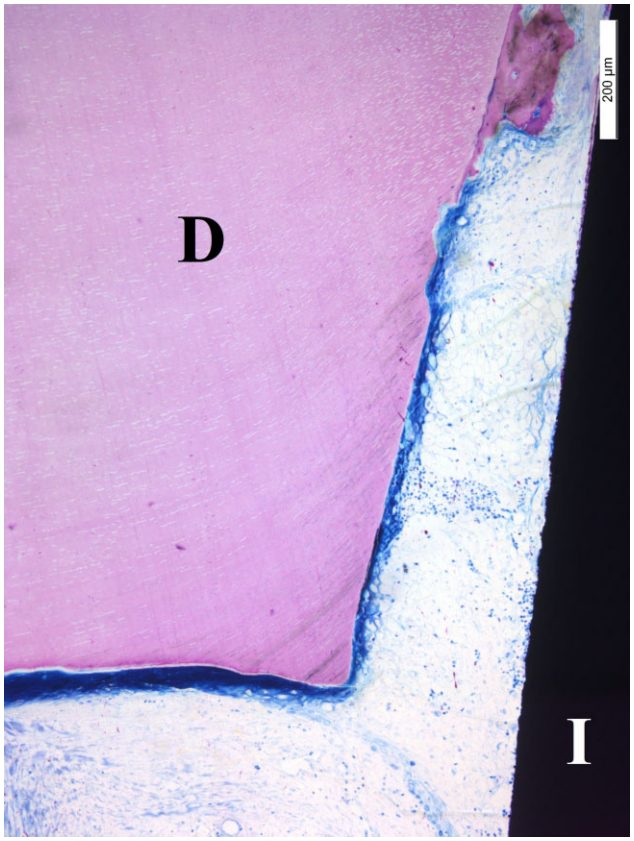

Figure 13 Junctional epithelium tapering down between dentin (D) and implant (I). Bar = 200 µm.

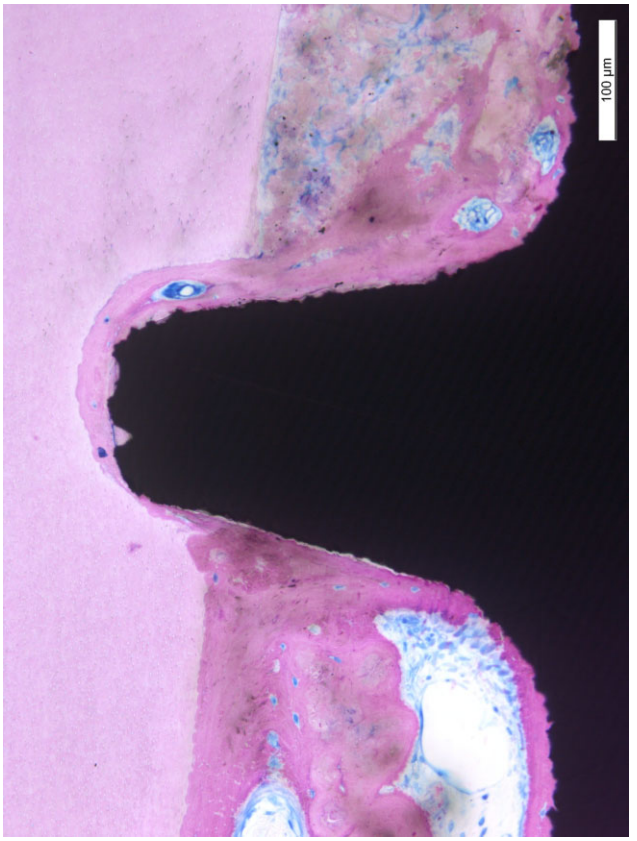

Figure 14 High magnification of an implant thread in contact to the dentin integrated into new bone on its surface. Bar = 100 µm.

make a reliable prediction about the future course of the buccal bone plate and the root remnants. Also the clinical case should be followed up for a longer time.

Tooth extraction is accompanied by an inevitable subsequent remodeling process of the alveolar ridge. Several studies[3,14–17] have shown that implant placement in fresh extraction sockets does not counteract postextractive tissue alterations like it was expected in first studies by Barzilay et al. in 1991.[18] Vignoletti et al.[19,20] as well as other groups[21–23] have shown in animal models that bone resorption takes places after tooth extraction to a vertical amount of about 2 mm, even with immediate implant placement. In this study, no histomorphometric measurements were performed but neither the crestal nor the more apical bone showed signs of resorption. Therefore, one could assume that no or only very slow resorption is taking place which corresponds to the desired effect of maintaining the periodontal tissues on the buccal side.

When it comes to implant therapy in the aesthetic zone, it is fundamental to maintain the buccal bone plate. Although it is also essential to keep a high soft tissue volume on the buccal side to achieve a most ideal appearance of the gingival tissues, there are few studies evaluating volumetric changes of the oral tissues. In 2009, Fickl et al. used an optical method to evaluate the three-dimensional changes of the ridge contour after

Figure 15 Horizontal section showing the implant (I) in contact to the tooth fragment (dentin [D]) and new bone where the dentin was drilled out (arrow).

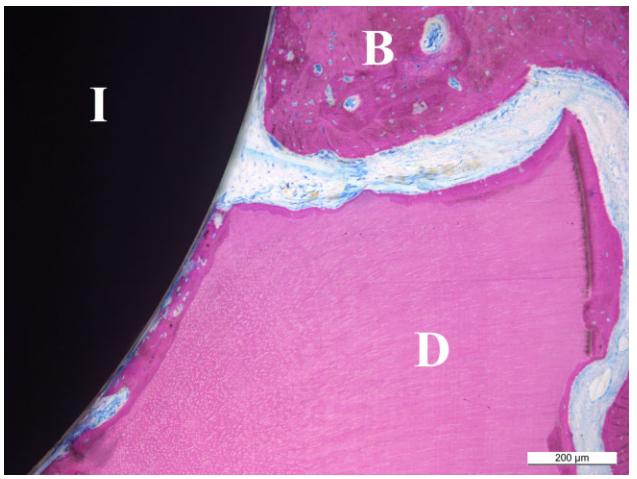

Figure 16 Detailed view of the horizontal section showing the implant (I) in contact to the dentin (D) and the new bone (B). Bar = 200 µm.

buccal overbuilding.[8] In 2010, Thoma et al.[24] evaluated the use of collagen-based matrices for soft tissue augmentation. Both were preclinical studies in the dog and can therefore not be used as references regarding the measured values. In fact, there is only one clinical study assessing volume alterations around implants by Schneider et al. from 2011.[13] In this study, 15 patients were followed up after implant placement with guided bone regeneration with a mean loss of 0.04 ± 0.31 mm 1 year after crown insertion. One major finding was that the degree of tissue change was highly variable between the individuals. Despite this individual variability and lack of clinical data for comparison, one can say that the loss of 0.88 mm in the presented case can be considered as acceptable. A major point that has to be taken care of in the future is the perfect shape of the healing abutment

Figure 17 The pocket probing depth on #6 along the vertical fracture line was 15 mm.

Figure 18 After decoronation the vertical fracture line became visible.

and final restoration to support the marginal soft tissues. To document the safety of the therapy, it has to be pursued in long-term view if leaving root remnants adjacent to implants possesses a risk potential, for

Figure 19 The remaining root segment formed the "socket shield."

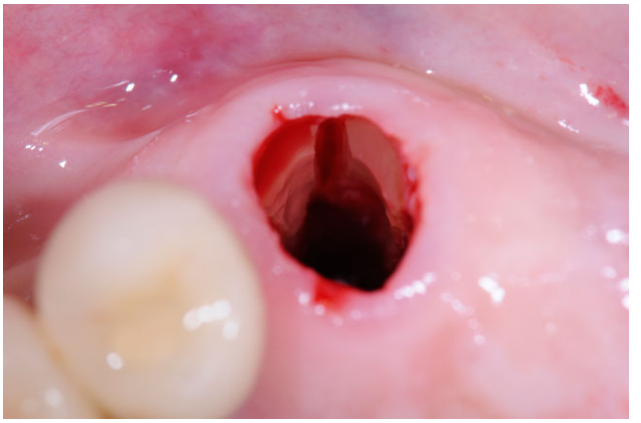

Figure 20 A furrow was drilled into the segment to remove the fracture line.

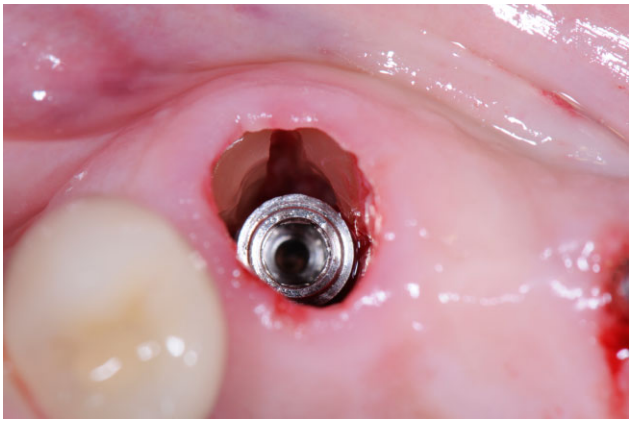

Figure 21 The implant is placed 1 mm apically and without contact to the segment.

Figure 24 The buccal tissues appeared very voluminous and free of inflammation.

example, if the dentin is replaced over time by tissue other than bone.

Because of its technique sensitivity and the need for more scientific data, the "socket-shield technique" can still not be generally recommended for clinicians in daily practice. One has to keep in mind that this is a new technique that is still in development and experiences a stepwise refinement. It is also very demanding to prepare the original root to the form of a shield and to place an implant in the aesthetic zone flapless; the implant shoulder has to be placed perfectly in the three-dimensional view.

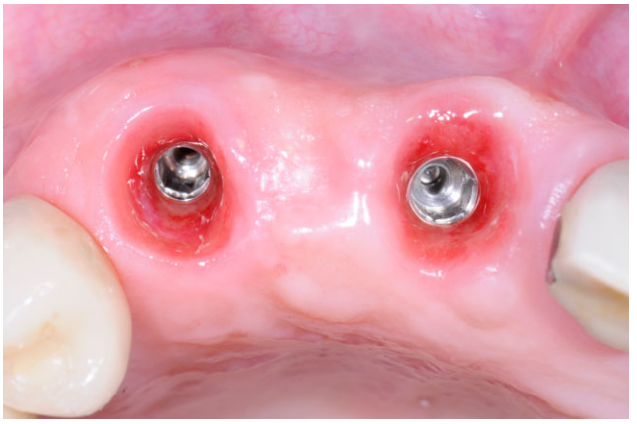

Figure 22 Occlusal view of region #6 and #8. Situation following implant uncovery 6 months after implant placement.

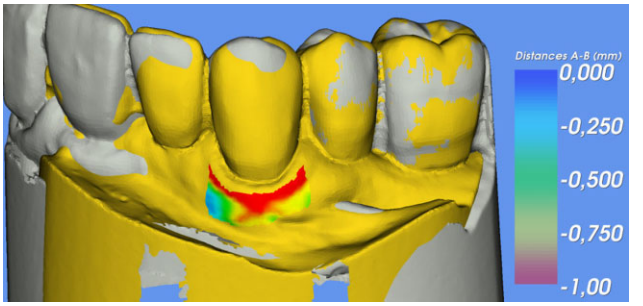

Figure 25 The superimposed digital models and the selected surface showing the volume loss in a color scale.

Figure 23 Frontal view after insertion of the final restoration.

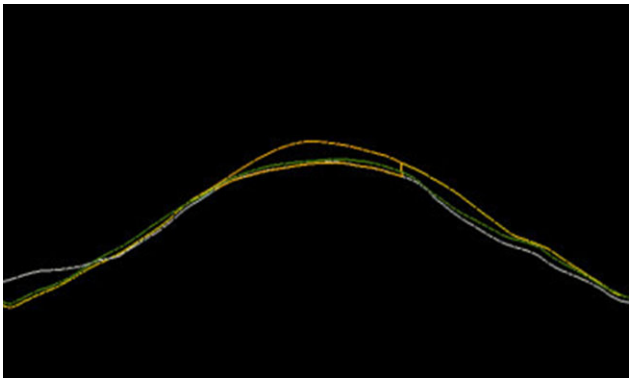

Figure 26 Horizontal section of the three models in the region of tooth #6. Yellow line = before implant placement. Green line = 5 months later. Gray line = after insertion of the final restoration.

Figure 27 Vertical section of tooth #6 showing the measured field of volume alterations in yellow (arrow). The dimension of the original clinical crown appears to have a larger diameter in buccal direction than the healing abutment and the prosthetic restoration.

Yet the observed results are very promising and seem to offer an option to better fulfill the patient's demands regarding red aesthetics. The known alternatives are on the one hand common immediate implant placement, which leads in most cases to buccal resorption with only moderate aesthetic results, or on the other hand delayed implant placement with the need of subsequent reconstruction. Particular indications where the technique's superiority is obvious consist of patients with a high smile line and when two implants beside each other have to be placed in the aesthetic zone. Besides the aesthetic advantages, the technique is also more economic because no grafting and membrane material are needed. Also the comorbidity is reduced because a second surgery site to gain a connective tissue graft is not necessary, which results in less postoperational pain. Therefore, this operation method may also be a good solution for patients with contraindications for major surgery due to their medical history.

CONCLUSION

To completely judge the reaction of the tissues in humans, a long-term clinical study and a human histological dissection are needed. Within the limitations of an animal pilot study, we can conclude that the applied modification may offer a feasible treatment option to proceed the socket-shield technique in vertically fractured teeth. The presented case report indicates that it may also be used without severe adverse events and that the aspired effect of buccal maintaining might also be achieved in human tissues.

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