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The socket-shield technique: a proof-of-principle report

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Abstract

Aim: Clinical studies have suggested that retaining roots of hopeless teeth may avoid tissue alterations after tooth extraction. Therefore, the objective of this proof-of-principle experiment was to histologically assess a partial root retention (socket-shield technique) in combination with immediate implant placement.

Material and Methods: In one beagle dog, the third and fourth mandibular pre-molar were hemisected and the buccal fragment of the distal root was retained approximately 1 mm coronal to the buccal bone plate. Following application of enamel matrix derivate, a titanium implant was placed lingual to that tooth fragment either with or without contact to the buccal tooth fragment and a healing abutment was connected. Four months after implant placement, histological evaluation, and backscatter scanning electron microscopy were performed.

Results: All four implants were osseointegrated without any histologic inflammatory reaction and the tooth fragment was devoid of any resorptional processes. On the buccal side, the tooth fragment was attached to the buccal bone plate by a physiologic periodontal ligament. On the lingual side of the fragment, newly formed cementum could be detected. In the areas where the implant was placed into the fragment, newly formed cementum was demonstrated directly on the implant surface.

Conclusions: Retaining the buccal aspect of the root during implant placement does not appear to interfere with osseointegration and may be beneficial in preserving the buccal bone plate.

Key words: extraction socket; immediate implant placement; tooth-retention

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Numerous publications have verified that tooth extraction is followed by dimensional changes of the alveolar ridge contour (Amler et al. 1960, Pietrokovski & Massler 1967, Schropp et al. 2003, Araújo & Lindhe 2005, Fickl et al. 2008b). The resorption of the alveolar ridge is more pronounced on the buccal than on the lingual aspect of the extraction socket (Pietrokovski & Massler 1967, Araújo & Lindhe 2005). In particular in the aesthetic zone, the successive soft and hard tissue deficiencies can interfere with optimal implant positioning and hamper the overall aesthetic outcome of implant-supported prostheses.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest.
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In order to overcome the negative consequences of tooth extraction, various treatment approaches such as immediate implants (Botticelli et al. 2004, Araújo et al. 2005), graft materials (Carmagnola et al. 2003, Nevins et al. 2006, Araújo et al. 2008, Fickl et al. 2008a, Araújo et al. 2009) and/or barrier membranes (Lekovic et al. 1997, Lekovic et al. 1998) have been advocated and described in the literature. As a conclusion, the majority of the studies show that socket preservation is a suitable technique for socket augmentation with the ability to maintain the ridge dimension to a certain amount (Araújo et al. 2008, Fickl et al. 2008a, Araújo et al. 2009). However, a complete preservation and/or entire regeneration of the extraction socket have not been documented yet.

The marked alterations after tooth extraction appear to be attributable to the loss of periodontal ligament and the consecutive trauma in particular at the buccal bone plate (Araújo & Lindhe 2005). Thus, it can be assumed that root retention may have an influence on the occurring resorption process.

Clinical studies have tested the hypothesis that root retention, either of vital or pulpless teeth, may be able to avoid tissue alterations after tooth extraction. Filippi et al. (2001) showed in a case report that decoronation of an ankylosed tooth preserved the alveolar bone before implant placement. Few studies have demonstrated that the pre-

servation of decoronated roots in the alveolar process not only helps maintaining existing bone volume but also enables vertical bone growth, which can be observed coronally to the decoronated root (Malmgren et al. 1984, Malmgren et al. 1994, Andersson et al. 2003). Björn (1963) confirmed regeneration of alveolar bone around endodontically treated teeth that were submerged and covered by a surgical flap. Reames et al. (1975) demonstrated in an animal study that even though epithelium commonly occurred over the amputation sites of submerged teeth, bone formation coronal to the submerged roots was evident. O'Neal et al. (1978) showed histological and radiographic evidence that new cementum and connective tissue will form over the coronal surface of submerged roots separating the dentin from the new bone. Conclusively, histological and radiographic evidences suggest few inflammatory changes and bone apposition around roots that had been submerged for alveolar bone preservation. Bowers et al. (1989) submerged vital teeth with infrabony defects in nine patients and created notches at regions on the root that had been covered with dental calculus. After 6 months, no root resorption, ankylosis, or pulp death was observed.

Salama et al. (2007) reported that the Root Submergence Technique (RST) maintains the natural attachment apparatus of the tooth in the pontic site, which in turn allows for complete preservation of the alveolar bone frame and assists in the creation of an aesthetic result in adjacent multiple-tooth-replacement cases.

Davarpanah & Szmukler-Moncler (2009) reported implant placement in contact with ankylosed root fragments in a five-case-report study without any specific pathological sign after a period of 12–42 months of loading.

No study yet has evaluated partial root retention around dental implants. Thus, the goal of this proof-of-principle experiment in conjunction with a case report was to histologically assess and clinically demonstrate the effect of buccal root retention (socket-shield technique) in combination with immediate implant placement.

Material and Methods

The research protocol was approved by the ethical committee of Biomatech – a NAMSA company. One beagle dog (1 year old and weighting 17.5 kg) was used for this experiment. Supragingival scaling was performed 5 days before tooth extraction and implant placement. Anaesthesia was induced by injecting atropine (Atropine®, Aguettant, Lyon, France; 0.05 mg/kg intramuscular) and tiletamine-zolazepam (Zoletil®100, Vorbac, Carros, France; 5–10 mg/kg intramuscular). Subsequently, an injection of thiopental sodium was given (NesdonalND, Merial, Lyon, France; 10–15 mg/kg intravenous) and the animal was placed on an O_2–N_2O isoflurane (1–4%) mixture. In both quadrants of the mandible, the third and fourth premolars ($_3P_3$ and $_4P_4$) were used as experimental sites.

The third and fourth mandibular premolars were hemisected using a fissure bur. Consecutively, a coarse-grained diamond bur was used to decoronate the distal aspect of the pre-molar. After performing the osteotomy drills for the dental implant on the lingual part of the root, residual tooth fragments were completely removed on the lingual, distal, and mesial region of the extraction socket (Fig. 1). Consecutively, enamel matrix derivate (Emdogain®, Straumann, Basel, Switzerland) was administered on the internal aspect of the fragment. The buccal fragment of the root was retained approximately 1 mm coronal to the buccal bone plate.

The implant (SPI®ELEMENT 4 × 11 mm, Thommen Medical, Waldenburg, Switzerland) was placed according to the manufacturer's recommendation and was situated at the height of the buccal root segment (Fig. 2). Randomly, two out of four implants were placed intentionally in direct contact with the buccal root fragment. Healing abutments of 4 mm in height were connected (Fig. 3).

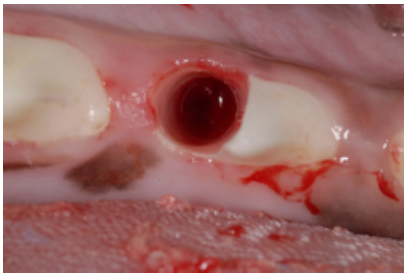

Fig. 1. Following hemisection, the buccal aspect of the root was retained approximately 1 mm apically to the coronal margin.

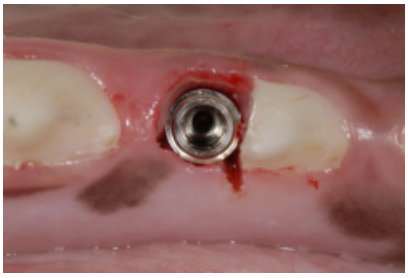

Fig. 2. The implant is placed lingually to retained root fragment. In two out of four implants the fixture is intentionally placed in direct contact with the root.

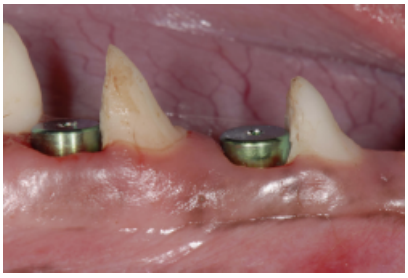

Fig. 3. Following implant placement, healing abutments were connected.

After surgery, the following regimen was administered:

- Antimicrobial prophylaxis: spiramycine 750,000 IU and metronidazole 125 mg/os/day for 7 days (Stomorgyl®, Merial).
- Anti-inflammatory drug: carprofene 50 mg/os/day for 6 days (Rimadyl®, Pfizer Santé Animale, Orsay, France).
- The 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% chlorhexidine was performed three times per week for 4 weeks.

The animal was terminated 4 months after implant placement. After anaesthesia 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.

Histological evaluation

The specimens were cut longitudinally in the bucco-lingual direction through the centre axis of the implants 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). One half was analysed using a backscatter detector of a scanning electron microscope (B-SEM). The other half was processed for ground sections and evaluated with light microscopy (LM).

B-SEM

For the B-SEM evaluation, the specimen was glued on an aluminium holder. The surface to be examined was highly polished with diamond pastes and thoroughly cleaned in an ultrasonic cleaner. Thereafter, the polished surface was sputtered with a 6-nm-thick carbon layer using an SCD-500 sputter coater (Bal-Tec, Balzers, Liechtenstein). The specimen was examined with a Zeiss VPN-40 (Antwerp, Belgium) field cathode SEM using the backscatter detector.

LM

For LM evaluation, the samples were processed for the preparation of non-demineralized ground sections according to the technique of Donath & Breuner (1982). 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 30–40 µm. Sections were stained with toluidine blue/pyronine G and examined using both a Leica MZ16 stereomicroscope (Leica Microsystems, Leica, Wetzlar, Germany) and a Leica 6000DRB light microscope (Leica Microsystems).

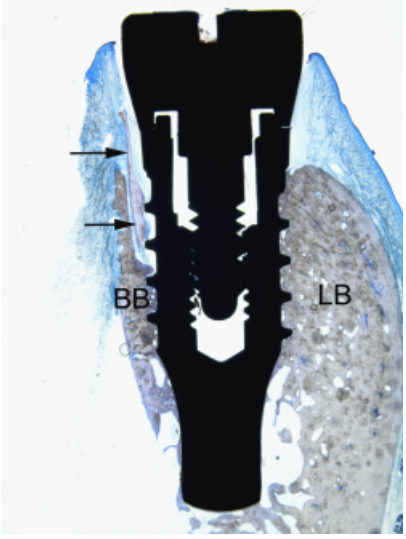

Fig. 4. Bucco-lingual ground section of a specimen showing an up to 0.5 mm wide gap between implant and the root fragment (arrows). Note the height of both, buccal bone plate (BB) and the lingual bone (LB). Also note the healthy peri-implant soft tissues. Toluidine blue/Pyronine G stain.

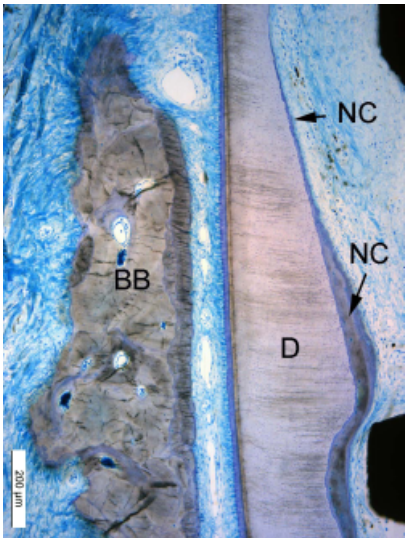

Fig. 5. Detailed view of Fig. 4 showing new cementum (NC) covering the treated dentin (D) surface. Note that the thickness of the new cementum layer gradually increase in the apical direction indicating its formation in the same direction. Also note the absence of any osteoclastic remodelling at the crest of the buccal alveolar crest (BB). Toluidine blue/Pyronine G stain. Scale bar = 200 m.

Results

Implants placed lingual to a tooth fragment

The bucco-lingual overview illustrated the presence of a tooth fragment located buccally from the implant (Fig. 4). The tooth fragment consisted of a small portion of enamel and an up to 0.5 mm-wide piece of root dentin. On its buccal side, the tooth fragment was still attached to the buccal bone plate by a physiologic periodontal ligament. Towards the implant, a small, up to 0.5 mm-wide gap, filled with connective tissue was interposed between the tooth fragment and the implant. The implant was osseointegrated into the alveolar bone on the lingual side. The height of the alveolar bone crest was identical on the buccal and on lingual side. The peri-implant soft tissue revealed a physiologic junctional epithelium and was free of any inflammatory reaction.

A higher magnification of the coronal part of the tooth fragment revealed buccally a physiologic junctional epithelium terminating at the cemento-enamel junction (supporting information Fig. S1). The uppermost end of the tooth fragment was in contact with the junctional epithelium tapering down along the implant. Initiating from this contact point, a thin layer of junctional epithelium was present on the internal surfaces of the tooth fragment and tapered down

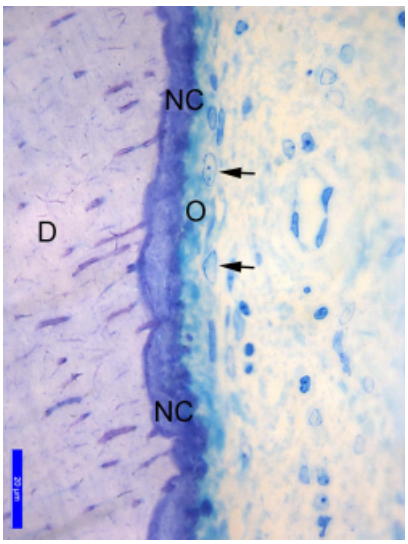

Fig. 6. High magnification of the internal part of the root fragment with new cementum (NC) formation on the treated dentin surface (D). Note the presence of an cementoid (O) and cementoblasts (arrows). Toluidineblue/Pyronine G stain. Scale bar = 20 µm.

in the apical direction (Fig. S2). Apically to the latter, the dentin surface was covered by a thin layer of newly formed cementum (Fig. S2) The thickness of the cementum layer increased continuously in the apical direction (Fig. 5). The most

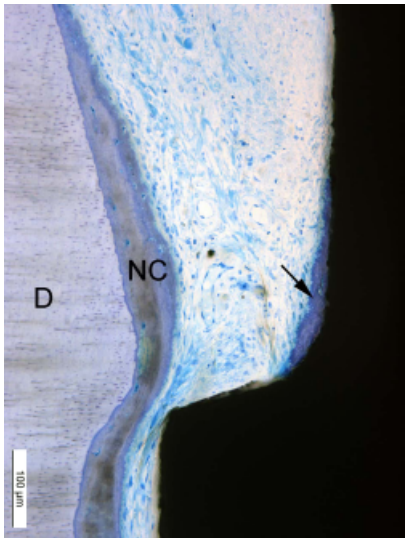

Fig. 7. Detailed view of Figure 1 demonstrating layers of new cementum (NC) as well as mineralized tissue (MT) on the implant surface. Toluidine blue/Pyronine G stain.

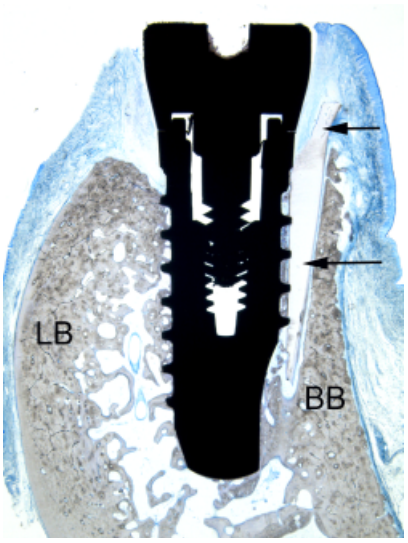

Fig. 9. Bucco-lingual ground section of a specimen placed without a gap between implant and the root fragment (arrows). Note the height of both, the intact buccal bone plate (BB) and the lingual bone (LB). Also note the healthy peri-implant soft tissues. Toluidine blue/Pyrodine G stain.

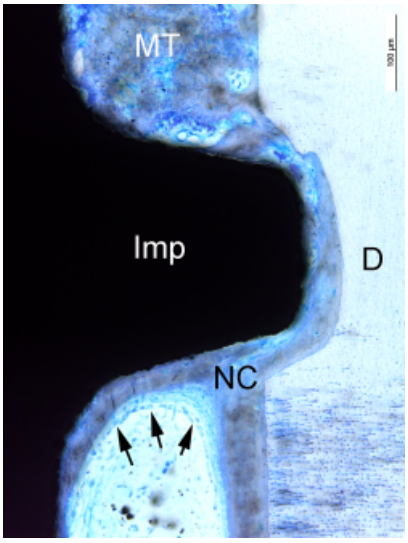

Fig. 11. Higher magnification of the tip of a thread integrated into newly formed cementum (NC) and amorphous mineralized tissue (MT). Toluidine blue/Pyronine G stain. Scale bar = 100 µm.

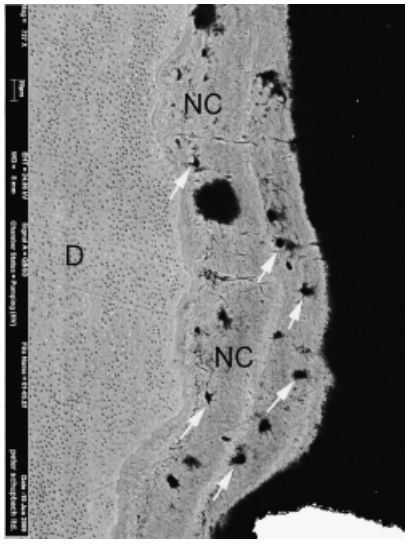

Fig. 8. B-SEM micrograph illustrating newly formed cementum (NC) on dentin (D) and the presence of cementocyte lacunae (white arrows).

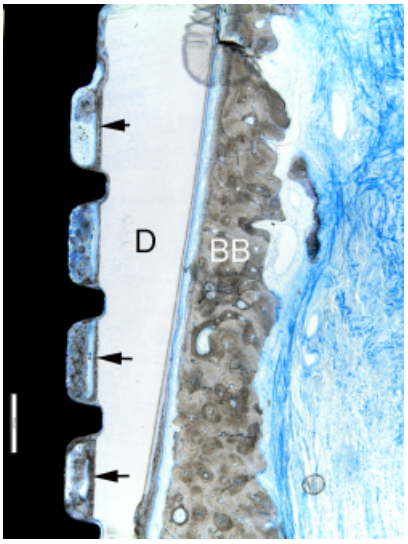

Fig. 10. Detailed view of Figure 9 showing the tooth fragment in contact with the tips of the implant threads. Note that treated dentin (D) is covered by newly formed cementum (arrows) and that the space between the threads is partially filled with an amorphous mineralized tissue. BB = buccal bone. Toluidine blue/Pyronine G stain. Scale bar = 200 µm.

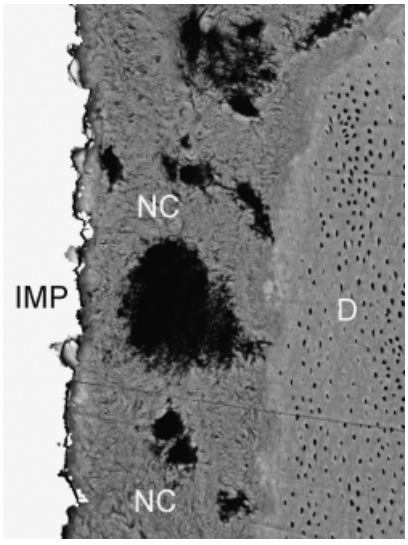

Fig. 12. B-SEM micrograph demonstrating the integration of the implant surface (IMP) into newly formed cementum (NC). Note the continuity between dentin (D) and cementum and the intimate contact between cementum and implant.

coronal part of the new cementum was an acellular type of cementum, which was apically continuous with cellular cementum (Fig. 5). At a higher magnification, the acellular cementum showed ongoing formation of cementum by the presence of a cementoid and cementoblasts (Fig. 6) and was characterized by the insertion of collagen fibre bundles anchored in cementum (Fig. S3). Cellular cementum was deposited in multiple layers (Fig. 7). The connective tissue interposed between the newly formed cementum and the implant surface was healthy and was adherent to the implant surface (Fig. 7). Occasionally, new formation of woven bone was observed on the latter (Fig. 7). Backscatter SEM micrographs of the newly formed cementum demonstrated its firm attachment towards the dentin (Fig. 8). The apical end of the tooth fragment showed no resorption processes. The surface also was partially covered by a thin layer of newly formed cementum (Fig. S4).

The buccal side of the tooth fragment showed the intact periodontal ligament

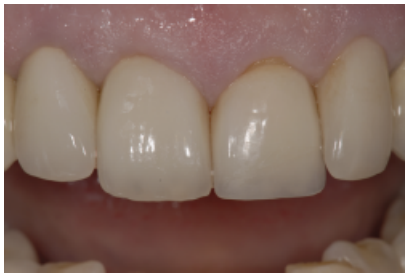

Fig. 13. The patient presented with a vertical root fracture in the left central incisor.

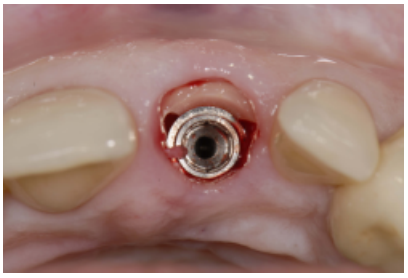

Fig. 15. Occlusal view showing the root fragment in direct contact with the implant.

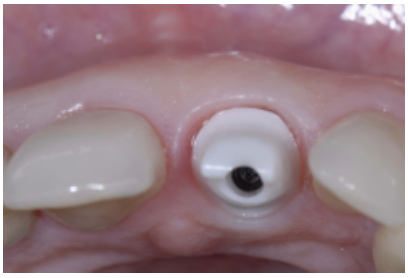

Fig. 17. Final restoration with all-ceramic abutment.

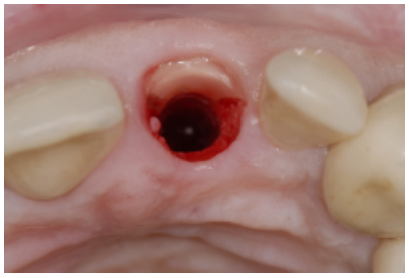

Fig. 14. Occlusal view of the retained root fragment on the buccal aspect.

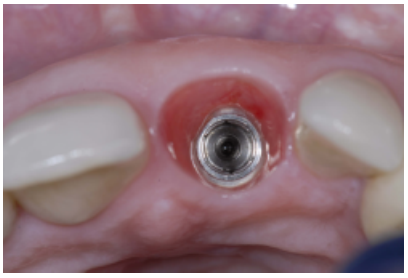

Fig. 16. Five months after implant placement tissue loss on the buccal aspect could be avoided.

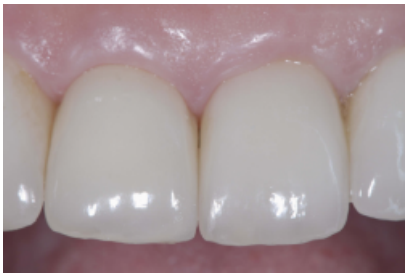

Fig. 18. Harmonic gingival conditions with the final prosthetic reconstruction.

(Fig. S2). The alveolar bone crest was free of any resorption processes. In contrary, new formation of woven bone was observed (Fig. S2).

Implants placed in contact to a tooth fragment

The bucco-lingual overview illustrates the presence of a tooth fragment apically in contact with threads of the implant (Fig. 9). The coronal part of the tooth fragment was separated by connective tissue interposed between tooth fragment and implant (Fig. 9). Along this portion of the tooth fragment, a junctional epithelium and the formation of new cementum was observed as described above. Again, the border between the apical end of junctional epithelium and the newly formed acellular cementum was clearly visible (Fig. S5). The more apical portion of the tooth fragment was in direct contact with the tips of the implant threads and covered by a cellular type of cementum (Figs 10, 11; Fig S6). The areas between the threads were partially filled with an amorphous mineralized tissue and connective tissue (Figs 10, S6). Higher magnifications of the tips of the implant threads demonstrated their integration in the newly formed cementum interposed between dentin and the implant (Fig. 11). In some areas, formation of new cementum via cementoblasts and a cementoid occurred directly on and along the implant surface (Fig. 11). Backscatter SEM micrographs demonstrated newly formed cementum bridging the space between the dentin and the implant surface (Fig. S7). Higher magnifications showed the intimate contact, without any fibrous tissues interposed, between the new cementum and the implant surface (Fig. 12).

The buccal side of the tooth fragment revealed a normal and intact periodontal ligament (Fig. S6). No signs of bone resorption were observed at the alveolar bone crest (Fig. S8).

Case Report

A 45-year-old patient presented with a non-contributory medical history, requesting replacement of tooth #21 due to a vertical root fracture (Fig. 13). The patient gave his informed consent to the root-retention technique in conjunction with immediate implant placement. Tooth #21 was decoronated with a coarse-grained diamond approximately 1 mm apical to the gingival margin (Fig. S9). Consecutively, the osteotomy drills were performed through the lingual aspect of the root. Then, all root fragments were removed on the lingual, mesial and distal aspect, retaining only the buccal portion of the root (Fig. 14). Following application of enamel matrix derivate (Emdogain®, Straumann), the implant (SPI®ELEMENT, Thommen Medical 4×13 mm) was inserted and positioned slightly apical to the preserved root fragment (Fig. 15). A screw-retained provisional was fabricated and hand tightened onto the implant (Fig. S10). Care was taken to remove all centric and eccentric functional contacts from the provisional crown. A soft diet was recommended for the duration of the implant-healing phase. The patient was advised against functioning or activities to the implant site.

The gingival architecture around the implant was well preserved after 6 months (Fig. 16). The final impressions were made and the definitive restoration consisted of a full-ceramic abutment and a full-ceramic crown (Figs 17, 18).

Discussion

This proof-of-principle experiment confirms that buccal root retention in conjunction with immediate implant placement is able to achieve osseointegration without any inflammatory or resorptional response. Within the limits of that preliminary trial, the histological analysis suggests that the buccal bone plate was preserved. Therefore, it may be speculated that this technique may have the potential to avoid the marked resorption of the buccal bone plate after tooth extraction.

Tooth extraction and its trauma to the hard tissues are followed by pronounced resorptions in particular of the buccal bone plate (Schropp et al. 2003, Araújo & Lindhe 2005). This is also true for tooth extraction in combination with immediate implant placement. Scientific evidence has shown that immediate implant placement is able to predictably achieve osseointegration (den Hartog et al. 2008), but does not appear to have an influence on the biological response of the extraction socket (Botticelli et al. 2004, Araújo et al. 2005, Vignoletti et al. 2009a, b).

Preserving the periodontal ligament and the supra-crestal attachment of the tooth on the buccal aspect in conjunction with immediate implant placement appears to have the potential to avoid buccal bone remodelling. The technique of retaining roots to avoid alveolar bone remodelling was adopted from dental traumatology, where Malmgren et al. (1984) suggested the decoronation technique of ankylosed teeth. Decoronation may be considered a type of guided bone regeneration due to the fact that the remaining residual root will undergo a resorptive process by osteoclasts from the adjacent bone marrow and gradually be replaced by bone. Multiple experimental and clinical studies have shown, that the decoronation of ankylosed teeth predictably preserves the alveolar ridge contour (Malmgren 2000, Filippi et al. 2001, Malmgren & Malmgren 2002, Cohenca & Stabholz 2007, Sapir & Shapira 2008). However, the results of the present study illustrate that a non-ankylosed tooth fragment does not appear to undergo resorptional processes. Furthermore, the retained root portion appears to preserve its characteristics with particular respect to its periodontal ligament and the supra-periosteal attachment. This can be seen in accordance with studies assessing the use of submerged roots to improve the retention of overdentures. O'Neal et al. (1978) reported on a study of 16 submerged endodontically treated mandibular pre-molar roots in four dogs. Results after 1–4 months depicted coronal overgrowth of bone, no periapical and limited pericoronal inflammation (O'Neal et al. 1978). Reviews conclude that submerging teeth appear to be a viable and safe technique to preserve alveolar bone (Casey & Lauciello 1980, Dugan et al. 1981).

However, in this study – contrary to the above-cited studies – only the buccal part of the root and its supra-periosteal attachment were preserved and furthermore no primary closure was obtained. The major findings of the histological analysis were that the internal aspect of the root was covered with new cementum and new periodontal attachment. In addition, in areas where the implant has been placed into the root fragment, cementum could be detected on the implant surface. This can be seen in accordance with the study conducted by Buser et al. (1990) concluding that in areas where the implant has been placed in close relationship to the root fragment, the examination of the undecalcified sections revealed a cementum layer on the implant surface with inserting collagen fibres. The fact that a new periodontal attachment could be detected on the inside of the root fragment may be explanative by the use of enamel matrix derivate, which plays a major role in the development of periodontal tissues and show effectiveness in the regeneration of the periodontium (Hammarstrom 1997, Heijl et al. 1997, Sculean et al. 2000). Enamel matrix derivative have also been documented to prevent epithelial proliferation and to have an antimirobial capacity (Bosshardt 2008). In order, to prevent epithelial down-growth along the retained root and to preserve the characteristics of the root fragment, enamel matrix derivative was used as an adjunct to immediate implant placement.

On the other hand, Nyman et al. (1982) has shown that exclusion of epithelial cells leads to periodontal regeneration due to cells from the periodontal ligament. Within the limits of this experiment, it may be speculated that the blood clot between implant and root may have prevented the epithelium from colonizing the root surface. Amler et al. (1960) and Cardaropoli et al. (2003) have histologically demonstrated that it takes approximately 4 weeks after tooth extraction to cover the extraction socket with epithelium. It may be assumed that the same process occurs between the implant and the retained tooth fragment. As the blood clot prevents the epithelium from growing along the internal root surface, it appears that cells from the remaining periodontal ligament are capable of colonizing the root surface and regenerate new periodontal attachment.

It may be concluded that retaining the buccal aspect of the root in conjunction with immediate implant placement is a viable technique to achieve osseointegration without any inflammatory or resorptive response. Yet, as this is a proof-of-principle experiment, further histological evidence and long-term follow up has to be conducted to recommend the socket-shield technique on a general basis.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Figure S1. Detailed view showing the coronal part of the tooth fragment. Note the apical end of the natural junctional epithelium (aJEP). Junctional epithelial cells also cover the root fragment (small arrows) in the apical direction. E = enamel; D = dentin. Toluidine blue/Pyronone G stain. Scale bar = 100 μm.
Figure S2. Detailed view of the tooth fragment showing on the left side the periodontal attachment and cementum (C) and on the right side the border between downgrowing junctional epithelium (arrows) and new cementum (NC) covering the dentin surface (D). Toluidine blue/Pyronine G stain. Scale bar = 100 μm.
Figure S3. High magnification of the internal part of the root fragment demonstrating new attachment by fiber bundles (arrows) inserting into newly formed cementum (NC). Toluidine blue/Pyronine G stain. Scale bar = 100 μm.
Figure S4. Detailed view demonstrating the apical end of the tooth fragment. Note the periodontal ligament (PL) on the untreated left side and the thick layer of new cementum (NC) on the treated dentin (D) side. Also note the absence of root resorption and new formation of cementum on the apical wall (arrows).
Figure S5. Detailed view of Figure 13 showing the border between the downgrowing junctional epithelium (arrows) and the most coronal layer of newly formed cementum (NC). D = dentin. Toluidine blue/Pyronine G stain. Scale bar = 100 μm.
Figure S6. Ground section demonstrating new cementum (arrows) on the treated dentin (D) surface and mineralized tissue (MT) partially filling the space between the threads. Toluidine blue/Pyronine G stain. Scale bar = 100 μm.
Figure S7. B-SEM micrograph illustrating newly formed cementum (NC) bridging the space between implant surface (Imp) and dentin (D).
Figure S8. Detailed view of Figure 10 showing the alveolar crest of the buccal bone (BB). Note the absence of any resorption processes. Toluidine blue/Pyronine G stain. Scale bar = 100 μm.
Figure S9. The tooth was decoronated and separated and the buccal aspect of the root retained. A diamond bur was used to reduce the root fragment approximately 1 mm apical to the gingival margin.
Figure S10. Occlusal view with a provisional hand tightened on the implant.

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Clinical Relevance

Scientific rationale for this study: The goal of this proof-of-principle experiment was to histologically assess the biological response following partial tooth retention in combination with immediate implant placement.

Principal findings: The retained root was devoid of any inflammatory or resorptive reactions. A newly formed root cementum could be detected on the internal part of the root fragment and on top of the implant surface, when placed in direct contact to it.

Practical implications: Retaining parts of the root is a viable technique to achieve osseointegration. It may also have the potential to preserve the buccal bone plate.