During tooth eruption in a facial direction and toward the occlusion, a functional alveolar bone, bundle bone, develops. Following tooth extraction, this functional bundle bone undergoes fast remodeling, resulting in a diminished alveolar ridge.1 Knowing that up to 50% of the ridge width will be resorbed and that this resorption is mostly limited to the buccal bone, there is an obvious need for bone grafting after tooth extraction.2 A new concept, “socket shield,” was introduced, aiming to maintain the esthetics and function of the marginal periodontium by preserving the buccal bone when tooth extraction is indicated.3 A healthy, intact marginal periodontium is a prerequisite for the socket-shield procedure.4 The procedure involves the retention of the facial root fragment while the rest of the root is extracted. A retained root fragment, a socket shield, is attached to the buccal bundle bone by a healthy periodontal ligament and by fibers and cells of the marginal gingiva,5,6 allowing the preservation of normal blood supply and physiologic strain. Routinely, an implant is inserted immediately into the extraction site lingual/palatal to the retained root fragment7, 8 and allowed to heal in a nonsubmerged manner. Glocker et al suggested the performance of a two-stage socket-shield procedure.9 After socket-shield preparation, a collagen cone is placed into the socket. Then, after 4 to 6 months, an implant is inserted into the healed socket. This is an alternative approach for cases where implants cannot be placed immediately due to an inflammatory process, a tooth with gingiva recession, or where primary implant stability cannot be attained.10

Effectiveness of Autologous Tissue Grafts on Soft Tissue Ingrowth in Patients Following Partial Root Extraction with Socket Shield: A Retrospective Analysis of a Case Series

Snježana Pohl, MD, DMD1/Itzhak Binderman, DMD2/Darko Božić, DMD3/Lior Shapira, DMD4/
Narayan Tondikulam Venkataraman, MDS5

Purpose: There is little knowledge about healing patterns for the socket with an intentionally retained root fragment: a socket shield. The clinical observation is soft tissue ingrowth next to the socket shield. The aim of this study was to evaluate the effectiveness of autologous grafting matrices in preventing soft tissue ingrowth. Materials and Methods: Patient data from a private clinic were searched for sockets with a socket shield left to heal with blood clot or grafted with autologous materials: autologous platelet-rich fibrin (PRF), scraped particulate bone, cortical tuberosity bone plate, or particulate dentin and covered with PRF membranes. The included sites were exposed by the flap 4 months after the first surgery, and soft tissue ingrowth depth and width next to the root fragment were measured by a scaled probe and documented. Results: Evaluation of 34 sites showed the greatest depth of soft tissue ingrowth in the nongrafted sockets (6.0 ± 0.0 mm). Grafting with PRF plugs (depth of 2.3 ± 0.2 mm) or particulate bone (depth of 2.7 ± 0.6 mm) decreased soft tissue ingrowth. Grafting with particulate dentin or cortical tuberosity bone plate resulted in a soft tissue ingrowth depth of only 1 mm, yielding the best clinical outcome. Radiography confirmed those findings. Conclusion: Autologous dentin particulate or tuberosity cortical bone plate is most effective for preventing soft tissue ingrowth. Int J Oral Maxillofac Implants 2021;36:362–370. doi: 10.11607/jomi.8581

Keywords: bone graft, case report/series, dentin graft, platelet-rich plasma, socket shield, soft tissue ingrowth

1Department of Oral Medicine and Periodontology, University of Rijeka, Private Clinic Rident, Rijeka, Croatia.
2Department of Oral Biology, School of Dental Medicine and Department of Biomedical Engineering, Tel Aviv University, Tel Aviv, Israel.
3Department of Periodontology, School of Dental Medicine, University of Zagreb, Zagreb, Croatia.
4Department of Periodontology, The Hebrew University-Hadassah, Faculty of Dental Medicine, Jerusalem, Israel.
5Private Practice, Bangalore, India.

Correspondence to: Dr Dr Snježana Pohl, Clinic Rident, Franje Čandeka 39, Rijeka 51000, Croatia. Email: snjezana.pohl@rident.hr

extraction socket. At present, it is unknown whether soft tissue ingrowth along the inner part of the root fragment can be prevented by the utilization of bone substitute material.

The present retrospective case series reports on the amount of soft tissue ingrowth next to the dentin surface of the root fragment following socket-shield preparation and the residual socket grafting with autologous dentin particulate compared with autologous platelet-rich fibrin (PRF), particulate autologous bone, and cortical tuberosity bone plate.

MATERIALS AND METHODS

Study Design and Patient Population
All patient records from June 2016 to January 2019 in the first author’s clinic were screened, and all participants with a socket shield and delayed implant placement were identified.

Patients with data fulfilling the following requirements were included: (1) sockets with socket shield with 1.5- to 2-mm thickness and length of approximately two-thirds of the initial root length grafted with autologous materials or nongrafted and (2) documented soft tissue ingrowth measurements during reentry for implant placement 4 months after the first surgery. For all sites, preoperative and CBCT scans prior to implant placement were available. The procedure was performed for teeth that were indicated for extraction due to deep carious lesions, subgingival crown fractures, and failed endodontic treatments, which were fit for a socket-shield procedure, but immediate implant placement was less predictable due to unavailability of adequate bone to achieve primary stability. The procedure was not done for teeth with periodontal pockets, mobility, buccal bone dehiscence, decay, or resorption of the buccal root part. Further conditions for exclusion were systemic contraindications for implant therapy, including recent myocardial infarction and cerebrovascular accident, immunosuppression, bleeding issues, active treatment of malignancy, drug abuse, psychiatric illness, lack of treatment for periodontal disease, radiographs showing a loss of alveolar bone on the adjacent teeth, current treatment with chemotherapy or radiation therapy to the head and neck, pregnant or breastfeeding women, as well as intravenous bisphosphonate use.

All surgical procedures were performed by one experienced specialist (S.P.). The procedures were undertaken in accordance with the ethical principles of the World Medical Association Declaration of Helsinki. The patients’ specific files and data were kept confidential. The extracted data were assigned random case numbers. The patients signed a written consent form, and the ethical committee approved data collection. This retrospective study is reported according to the STROBE statement.

Socket-Shield Preparation and Socket Grafting
Following local anesthesia, the tooth crown was cut off, and vertical sectioning of the tooth was performed in a mesiodistal direction to extract the palatal part and the apex, whereas the buccal root fragment was retained with its attachment to the bundle bone. The root canal content was removed completely without elevating a mucoperiosteal flap. After apex removal and root fragment shaping, the socket shield length amounted to two-thirds of the initial root length. The coronal part of the root fragment was reduced to the level of the alveolar bone. A gingival retractor was used to protect the gingiva during root fragment preparation. The shield thickness varied from 1.5 to 2.0 mm, while the coronal part of the root fragment was thinned out and shaped into a concave form (Fig 1). Following the socket-shield procedure, sockets were grafted, depending on the easy and minimally invasive availability of autologous graft material.

This resulted in the following groups: (A) No graft, (Control) n = 6; and (B) Autologous graft, (Test) n = 28.

Group B was further divided into the following, depending on the easy and minimally invasive availability of autologous graft material:

- (B1) Socket grafted with PRF plugs, n = 7
- (B2) Socket grafted with particulate autologous bone, n = 7
- (B3) Socket grafted with autologous particulate dentin, n = 7
- (B4) Socket grafted with tuberosity cortical bone plates, n = 7

Fig 1 A typical clinical presentation of a prepared socket shield showing a buccal root fragment thinned to 1.5- to 2-mm thickness with a concave shape in the coronal aspect.
The socket openings of all grafted sockets were covered with a PRF membrane, whereas the nongrafted sockets were left uncovered. The PRF membranes were prepared according to the slow centrifugation protocol. Briefly, PRF membranes and plugs were pressed in a PRF box after blood centrifugation at 1,300 rpm for 8 minutes in a Choukroun PRF DUO centrifuge (Process for PRF). Autologous particulate bone was harvested utilizing a bone scraper (Safescraper TWIST, META). Bone particles harvested by a bone scraper are swirly shaped with an average size of 1.4 mm. When dentin grafts were employed, extracted teeth were thoroughly mechanically cleaned and ground using a Smart Dentin Grinder (SDG) unit (KometaBio) in accordance with the manufacturer’s recommendations. The dentin particulate was sieved to ensure a grain size of 300 to 1,200 μm and immersed in an alkaline-alcohol cleanser to dissolve organic debris and bacteria. This was followed by washing in sterile saline buffer solution. Analogous to the procedure with particulate autologous bone, sockets were filled with particulate dentin and covered with a PRF membrane (Fig 2a). Cortical tuberosity bone plates were harvested utilizing the Piezo device (Mectron) and bone chisels (Devemed). The pieces of cortical tuberosity bone plates were shaped to fit into the socket along the lingual part of the socket-shield surface, and they were bent to completely cover the socket opening (Fig 2b).

Clinical Assessment
After 4 months (15 to 17 weeks), CBCT scans were done for implant planning.

Mucoperiosteal flaps were elevated in order to ascertain proper bone fill of the socket and to prepare the site for implant placement. A 15-mm periodontal probe from the University of North Carolina (UNC; Hu-Friedy) with markings at each millimeter was utilized to measure the amount of soft tissue ingrowth along the root fragment inside the socket, similar to bone sounding in periodontal pocket probing. Tissue sounding of the entire socket surface was performed utilizing firm pressure, and penetration of the tissue by the probe was observed by tactile and visual means. The probe showed minimal to no penetration into hard tissue, whereas the probe penetrated into the soft tissue to a significant depth.

The depth and width of soft tissue ingrowth were measured. Distances were measured to the nearest millimeter and rounded up to the next number if the measurement was past or equal to the halfway point between readings. The depth of soft tissue ingrowth was measured from the most coronal part of the root fragment toward the apical part until hard tissue was reached, as shown in the schematic drawing (Fig 3a). The width of the soft tissue was also measured from the most coronal, central part of the socket shield in a buccal-palatal direction until hard tissue was reached, which represents the widest diameter of soft tissue ingrowth (Fig 3b). Given that soft tissue ingrowth volume depends on depth and width measurements, its volume was estimated using the cone volume equation given that the socket resembles a cone more than a cylinder. The depth was considered to be the height (h) of the cone, and the width was considered to be the diameter (2r). The estimated volumes of the different
The estimated volume was computed as the following:

\[ V = \frac{r^2 \pi h}{3} \]

**RESULTS**

Twenty-three patients with 34 sites fulfilled the inclusion criteria. All identified teeth were single-rooted teeth in the anterior maxilla: 14 central incisors, 12 lateral incisors, 5 canines, and 3 first premolars. The results of the five different treatment modalities with the estimated volumes are presented in Table 1. In the group where no graft was utilized \((n = 6)\), the mean width measurement of soft tissue was 4.0 ± 0.0 mm, whereas the depth was 6.0 ± 0.0 mm. The estimated soft tissue ingrowth volume was maximal \((25.1 \text{ mm}^3)\). Sockets grafted with PRF plugs and covered with a PRF membrane \((n = 7)\) showed significantly less soft tissue ingrowth \((3.5 \text{ mm}^3)\), with an average width and depth of 2.3 ± 0.49 mm and 2.3 ± 0.2 mm, respectively. Similar amounts of soft tissue ingrowth volume were found in the particulate bone graft \((n = 7)\) group covered with a PRF membrane, which amounted to 4.8 mm\(^3\) with an average width of 2.1 ± 0.9 mm and depth of 2.7 ± 0.6 mm. In contrast, autologous particulate dentin processed from extracted teeth and cortical bone pieces removed from the tuberosity were most effective for preventing soft tissue ingrowth, allowing bone deposition on the dentin surface of the root fragment. The measurements of the depth and width in both dentin \((n = 7)\) and cortical bone \((n = 7)\) groups never exceeded 1 mm, giving an estimated soft tissue volume ingrowth of only 0.26 mm\(^3\). Statistically independent Student \(t\) tests revealed that all grafting materials significantly reduced the soft tissue invagination \((P < .001)\). Particulate dentin or cortical tuberosity significantly reduced soft tissue invagination in comparison with particulate bone \((P = .003)\) and in comparison with the PRF graft \((P < .001)\). The same significant changes were found for the width or height. Figure 4 presents representative images for all treatment groups at the time of reentry.

**Table 1** Measurements of Soft Tissue Ingrowth 4 Months After Grafting of Autologous PRF, Autologous Particulate Bone, Autologous Particulate Dentin, and Cortical Tuberosity Bone Plate and Its Estimated Volume (in mm\(^3\))

<table>
<thead>
<tr>
<th>Sample group</th>
<th>Width of soft tissue ingrowth (mm)</th>
<th>Mean width ((2r)) of soft tissue ingrowth (mm)</th>
<th>Depth of soft tissue ingrowth (mm)</th>
<th>Mean depth ((h)) of soft tissue ingrowth (mm)</th>
<th>Volume (mm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) No graft ((n = 6))</td>
<td>4,4,4,4,4,4</td>
<td>4.0 ± 0.0</td>
<td>6,6,6,6,6,6</td>
<td>6.0 ± 0.0</td>
<td>25.1</td>
</tr>
<tr>
<td>B1) PRF graft ((n = 7))</td>
<td>2,3,2,2,2,3,2</td>
<td>2.3 ± 0.49</td>
<td>2,3,2,2,2,3,2</td>
<td>2.3 ± 0.2</td>
<td>3.5</td>
</tr>
<tr>
<td>B2) Particulate bone graft ((n = 7))</td>
<td>2,2,1,3,3,3,1</td>
<td>2.1 ± 0.9</td>
<td>2,2,2,3,3,6,1</td>
<td>2.7 ± 0.6</td>
<td>4.8</td>
</tr>
<tr>
<td>B3) Dentin graft ((n = 7))</td>
<td>1,1,1,1,1,1,1</td>
<td>1.0 ± 0.0</td>
<td>1,1,1,1,1,1</td>
<td>1.0 ± 0.0</td>
<td>0.26</td>
</tr>
<tr>
<td>B4) Cortical tuberosity bone ((n = 7))</td>
<td>1,1,1,1,1,1,1</td>
<td>1.0 ± 0.0</td>
<td>1,1,1,1,1,1</td>
<td>1.0 ± 0.0</td>
<td>0.26</td>
</tr>
</tbody>
</table>

\(n = \) number of tested extraction sites with PET procedure. Values are presented as mean ± SD in mm.

Independent \(t\) test: no graft vs PRF, \(P < .0001\); no graft vs particulate autologous bone, \(P < .0004\); PRF/particulate dentin and cortical tuberosity bone plate, \(P < .0001\). Particulate bone vs particulate dentin, \(P = .003\).
Although CBCT scans were not suitable for accurate soft tissue dimension measurements, differences in translucency between the grafting groups were observed. Figure 5 shows representative CBCT scans 4 months after socket-shield procedures for all treatment groups. It can be observed in Fig 5a that a non-grafted socket revealed a radiolucency within the socket next to the lingual surface of the retained root fragment. In Fig 5b, where the PRF plug was utilized, radiolucency can still be seen but to a smaller degree. In Fig 5c, where the particulate autologous bone was used, there is similar radiolucency as in the CBCT scan of the PRF plugs, while in Figs 5d and 5e, where cortical tuberosity bone plates and particulate dentin were used, there is almost no radiolucency next to the root fragment.

Table 2 shows the amount of soft tissue ingrowth per extraction site type. This was done in order to determine whether different sites exhibit a substantially different amount of ingrowth to require a more site-specific analysis. However, there were no significant differences across all sites for a specific procedure (group). Based on clinical appearance, the patient’s gingiva phenotype was determined as thick-flat (12 patients) or thin-scalloped (11 patients).

In Table 3, the amount of soft tissue ingrowth per extraction site for specific procedures related to gingiva biotype is shown. There were no significant differences.

**DISCUSSION**

The socket-shield procedure involves the retention of the facial root fragment while the rest of the root is extracted, and an implant is placed palatal/lingual to the retained root fragment in the same session or following a delay. A 5-year follow-up study showed that the use of the socket-shield procedure with simultaneous implant placement preserved the buccal alveolar ridge contour. A recent animal study confirmed the ability of the socket-shield procedure to maintain the alveolar ridge dimensions and the buccal profile with only minimal labial bone loss. Furthermore, in the aforementioned animal study, the nongrafted socket-shield sockets exhibited almost completely new bone formation along the root surface. Glockler et al described a technique of ridge preservation by creating a socket shield without immediate implant placement, using a collagen sponge in the socket. In clinical observations of socket-shield cases, there was often varying degrees of soft tissue downgrowth. The present human study was carried out to investigate the effect of different autologous materials in ridge preservation for delayed implant placement after the socket-shield procedure. The present study found that when the sockets with a socket shield were left to heal naturally, there was significant soft tissue ingrowth, leading to insufficient
Fig 5 Representative CBCT scan images:
(a) nongrafted socket, (b) PRF plug, (c) particulate autologous bone, (d) cortical tuberosity bone plate, and (e) particulate dentin.

Table 2 Soft Tissue Ingrowth Volume Measurements by Tooth Site

<table>
<thead>
<tr>
<th>Sample group</th>
<th>Average soft tissue ingrowth volume in mm³ +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central incisor (no. of sites)</td>
</tr>
<tr>
<td>A) No graft (n = 6)</td>
<td>25.1 (2)</td>
</tr>
<tr>
<td>B1) PRF graft (n = 7)</td>
<td>3.8 (3)</td>
</tr>
<tr>
<td>B2) Particulate bone graft (n = 7)</td>
<td>3.7 (2)</td>
</tr>
<tr>
<td>B3) Dentin graft (n = 7)</td>
<td>0.26 (3)</td>
</tr>
<tr>
<td>B4) Cortical tuberosity plate (n = 7)</td>
<td>0.26 (4)</td>
</tr>
</tbody>
</table>

(+ ) Average ingrowth was calculated based on the formula described and shown in Table 1. The calculation was applied to each site and for each procedure (group) separately.

Table 3 Soft Tissue Ingrowth Volume Measurements by Soft Tissue Biotype

<table>
<thead>
<tr>
<th>Sample group</th>
<th>Average soft tissue ingrowth volume in mm³ +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thick soft tissue biotype (no. of sites)</td>
</tr>
<tr>
<td>A) No graft (n = 6)</td>
<td>25.1 (3)</td>
</tr>
<tr>
<td>B1) PRF graft (n = 7)</td>
<td>3.4 (4)</td>
</tr>
<tr>
<td>B2) Particulate bone graft (n = 7)</td>
<td>5.9 (4)</td>
</tr>
<tr>
<td>B3) Dentin graft (n = 7)</td>
<td>0.26 (3)</td>
</tr>
<tr>
<td>B4) Cortical tuberosity plate (n = 7)</td>
<td>0.26 (4)</td>
</tr>
<tr>
<td>Average soft tissue ingrowth in mm³</td>
<td>6.33 (18)</td>
</tr>
</tbody>
</table>

(+ ) Average ingrowth was calculated based on the formula described and shown in Table 1. The calculation was applied to each site and for each procedure (group) separately.
bone formation in the socket. One of the potential biologic reasons for this reduced bone fill could be the lack of migration of Wnt-responsive osteoprogenitor cells, which reside in the periodontal ligament, into the extraction socket. A significant part of the tooth root is maintained in the socket-shield concept, thus preventing these inherently osteogenic cells from contributing to new bone formation.18

In the present study, dentin particulate or cortical tuberosity bone plate best prevented soft tissue ingrowth. PRF plugs or particulate bone graft both covered with PRF membrane were less effective in preventing this soft tissue downgrowth. In a recent systematic review, the effect of PRF on bone regeneration was found to be inconclusive.19 This is in agreement with the observations of the present study that PRF plugs or cancellous bone decreases soft tissue ingrowth but does not prevent it, leaving clinically relevant defects that require additional grafting at implant placement.

Recently, dentin has been proposed as a grafting material for bone regeneration. Root dentin blocks for horizontal bone augmentation have been shown to be highly biocompatible and safe for use in humans.20 Animal immunohistochemistry of implants inserted into such augmented sites showed that root dentin blocks supported the early stages of osseointegration similarly to the cortical autologous bone blocks.21 Others have investigated autologous dentin particulate as a bone grafting material and have shown that this material is highly bioactive and able to generate bone formation in extraction sockets.22,23 Furthermore, in cementoblasts and dentin, bone morphogenetic proteins 2, 4, and 7 continue to be expressed after birth, indicating the potential of the tooth as a grafting material for bone induction.24,25 Indeed, in a dog socket-shield study, Hürzeler et al showed that cementoblasts migrated from the buccal part of the shield to the inner part and contributed to the formation of new cementum and mineralized tissue that was in intimate contact with the implant surface.3

Furthermore, it was recently shown in a human biopsy after socket grafting with particulate dentin that the newly formed bone had evident intimate contact with both dentin and cementum.26–28 Two recently published studies assessed healing dynamics after autologous particulate dentin grafting.26,27 Mazor et al showed that 3 and 5 months after dentin grafting, the majority of graft particles were replaced by the new vital bone. Andrade et al found a relative proportion of dentin graft of 10.4% at 4 months after socket grafting.

The present study showed that by combining the socket-shield concept and simultaneous grafting with dentin particulate, maximal hard tissue deposition could be achieved in the socket, the same as with the cortical tuberosity bone graft. It was assumed that pieces of cortical bone or dentin particulate may have a dual effect: first, by blocking soft tissue ingrowth due to their solid surfaces, and second, in parallel, they may attract osteogenic cells to deposit bone directly on the dentin or cortical bone plate surfaces, in this manner bridging the socket-shield dentin surface and the grafted material. Interestingly, the particulate bone that was collected by scraping cortical bone from other sites of the jaws was much less effective for preventing soft tissue ingrowth compared with the cortical bone plate. It seems that such small particles of bone undergo fast resorption that is not fully compensated by new bone formation.29

Socket healing is an open wound system, which results in bone fill and a soft tissue covering. Socket healing dynamics are altered by the root fragment, with greater and varying depths of soft tissue downgrowth along the dentinal surface and the exclusion of one bony wall probably altering the overall healing process. The extent of soft tissue downgrowth can affect the implant placement procedure itself, often needing the soft tissue to be curetted out. While the buccolingual dimensions may be intact, the internal bone fill is often unsatisfactory.

An animal study demonstrated a newly formed bone directly on the implant surface 12 weeks after implant placement in a fresh postextraction socket with a socket shield.30 In a recent human histologic case report of an implant with a socket shield 5 years after implant insertion, the occurrence of soft tissue ingrowth was reported.31 In the coronal portion, where the implant was not in contact with the socket shield, connective tissue without inflammatory infiltrate was observed between the root and the implant, whereas trabecular mature bone at the interface of the implant and the root was observed toward the apical portion. The root fragment and the buccal bone plate appeared to be intact. In another human case report, using histology, Schwimer et al demonstrated that bone filled the space between root dentin and an osseointegrated implant surface in a patient 2 years after a socket-shield procedure.32 The sagittal section showed that the implant was placed in contact with the socket shield both apically and coronally. The histologic sections revealed that the space between the implant threads and the root fragment dentin was filled with mature bone in the apical portion and toward the coronal portion. It seems that contact osteogenesis occurred on the dentin surface (ankylosis), whereas distance osteogenesis occurred more frequently on the implant surface (osseointegration).33

The presence of an implant and particularly occlusal marginal gingiva supporting an individual healing abutment or a provisional crown may result in a different socket healing pattern compared with that of a socket-shield socket without an implant. This should be an area for further research.
The present retrospective case series reports, for the first time, the healing patterns of hard and soft tissues in a socket-shield socket either without grafting or following the use of four autologous grafts. It should be noted that the selection of graft method and biomaterials or the use of no grafting was dependent on biomaterial availability, with care taken to perform the procedure in a minimally invasive manner. Measurements utilizing a scaled probe were accurate, since the soft tissue did not show the resistance of dense connective tissue; in contrast, the soft tissue was loosely and clearly distinguishable from the hard tissue, in terms of both visual and tactile characteristics.

The soft tissue ingrowth was independent of the socket dimensions. The buccolingual gap distance between the lingual socket-shield surface and the palatal socket dimensions. The buccolingual gap distance between the lingual socket-shield surface and the palatal bone wall and the baseline socket depth were tooth site-specific. Regardless of the differences in root surface area and consequently the socket dimension, the amount of soft tissue ingrowth was not greater for premolar and canine sites. The same can be concluded for the socket-shield dimension, since the retained root fragment length amounted to two-thirds of the initial root length.

The soft tissue phenotype does not seem to have an influence on soft tissue ingrowth. With this being a retrospective study, these observations were made based on clinical records distinguishing between thick-flat and thin-scalloped gingiva biotype based on clinical appearance. Future prospective studies may include precise gingiva thickness measurements.

The limitations of this study are the small number of examined sockets, the utilization of autologous grafting materials only, and the retrospective study characteristic. Future prospective studies should include a greater number of sites, evaluate the influence of nonautologous grafting materials, and exactly evaluate baseline socket and socket-shield dimensions on the healing pattern of the sockets with an intentionally retained buccal root fragment. Histologic assessment should determine the nature of the tissue formed in the socket-shield sockets.

CONCLUSIONS

The findings of this study suggest that socket grafting with a slow resorbable and highly osteoinductive autologous cortical tuberosity bone plate and particulate dentin most effectively regenerate the extraction site, thus preventing soft tissue invagination adjacent to root fragments during the socket-shield procedure.

ACKNOWLEDGMENTS

The authors wish to acknowledge Anton Sculean and Georgious Kotsakis for critical reading and valuable suggestions. Apart from the support of the authors’ institution, no external funding was available for this study. S.P., D.B., L.S., and N.T.V. declare no conflicts of interest in this study. I.B. declares that he is a co-founder of a Smart Dentin Grinder (SDG) autologous dentin particulate process owned by Kometabio Inc., and he owns shares in the company.

REFERENCES


