Autogenous Particulate Dentin in Socket Site Preservation Procedures: Histologic and Histomorphometric Observations

Zvi Artzi, DMD, Prof[1]/Erez Netanely, BSc, DMD[1]/Uri Renert, MSc, DMD[1]

Purpose: To evaluate the efficacy of autogenous particulate dentin as a bone substitute to maintain dimensional volume in human socket preservation procedures. ***Materials and Methods:*** Particulate dentin was used in socket site preservation procedures. The extracted natural tooth was ground to particles 250 to 1,200 µm in size to fill the socket site. At 6 months, during the implant placement stage, hard tissue biopsy specimens were harvested by a 2.5-mm cylindrical trephine bur for the histologic analysis. Histomorphometry was carried out with ImageJ software to calculate direct bone to grafted dentin particles contact, newly formed bone, and particulate dentin area fractions. ***Results:*** Fifteen patients went through the socket preservation procedure using particulate dentin as the grafted bone substitute. De novo bone formation filled the entire grafted area. Newly formed bone was observed throughout the entire grafted area, particularly around the grafted dentin particles. The majority of particles were surrounded by direct contact with newly formed osseous tissue enriched by osteocytes. Newly formed bone ankylosed to particulate dentin and became a solid matrix preserving the ridge dimension. Histomorphometric measurements showed that the new bone formation area fraction was on average 38.4% ± 16.5%, while the residual particulate dentin showed an average of 29.9% ± 14.4%, and 31.7% ± 14.2% was captured by the connective tissue component. Particulate dentin was in direct contact with newly formed bone at an average rate of 69.1% ± 22.8%. ***Conclusion:*** Particulate dentin showed complete biocompatibility and high osteoconduction. Thus, it can be used as an appropriate grafting biomaterial to maintain socket site volume dimensionally for subsequent implant placement procedures. *Int J Oral Maxillofac Implants 2022;37:XXX–XXX. doi: 10.11607/jomi.9216*

Keywords: autogenous dentin particles, bone graft substitute, ridge augmentation, socket site preservation

The residual alveolus is extensively resorbed, primarily in its labial aspect, during immediate postextraction,[1,2] shifting the residual alveolus lingually. Clinical and radiographic reports[3,4] demonstrated significant resorption of the buccal bony plate due to its thickness and complete resorption of the bundle bone.[2] A systematic review[5] that included 20 clinical studies concluded that a 3.79-mm reduction in the horizontal dimension and 1.24 mm in the vertical dimension should be expected at 6 months postextraction. This marked ridge reduction and lingual shifting might alter an ideal implant placement position followed by a flawed prosthetic superstructure profile.

Preservation of the extraction/socket site is considered to be a superior alternative approach for minimizing those ridge alterations. It was defined in a systematic review by Vignoletti et al[6] as: "Any therapeutic approach carried out immediately after tooth extraction aimed to preserve the alveolar socket architecture and to provide the maximum bone availability for implant placement." In a recent systematic review,[7] it was shown that less alveolar bone resorption (specifically 1.99 mm and 1.72 mm in the horizontal and vertical direction, respectively) can be expected following socket site grafting, thus promoting ridge preservation.

In recent years, an autogenous tooth, whether as a solid mass or following grinding, has been proposed as a potential grafting material in bone augmentation and/or socket preservation procedures.[8–11] Dentin has much in common with bone structure. It comprises up to 85% of the tooth's mass and is made up of 70% hydroxyapatite (HA), 20% organic material, and 10% water, whereas bone is made up of 60% HA mineral, 30% organic material, and 10% water. Ninety percent of its organic content is made of collagen type I and 10% of noncollagenous

[1]Department of Periodontology and Oral Implantology, School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel.

The first two authors contributed equally to this study.

Correspondence to: Prof Zvi Artzi, Department of Periodontology and Oral Implantology, School of Dental Medicine, Tel Aviv University, Tel Aviv, 69978 Israel. Fax: +972-36409250. Email: zviartzi@tauex.tau.ac.il

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proteins, with water residing mainly within the dentinal tubules.[12] Yeomans and Urist[13] showed that dentin contains osteoinductive properties. Those authors implanted decalcified and nondecalcified dentin, as well as decalcified bone, tendon, and muscle tissue into three sites, a pouch in the rectus abdominis muscle, a drill-hole defect in the mandible, and an empty tooth socket, and tested its ability to induce bone in rabbits. Both dentin and bone were shown to induce bone formation calcification in all those selected sites.

Controversial opinions on the most efficacious form of dentin to be used as a proper grafting biomaterial were reported. In an early pioneering report,[14] demineralized dentin induced higher levels of bony matrix formation compared with calcified dentin and in a shorter period of time. In addition, calcified dentin particles have induced a small amount of bone formation after a period of 8 to 12 weeks. Recently, Koga et al reported in an in vitro study that large particles (1,000 µm) of partially demineralized dentin showed higher regenerative activity than mineralized dentin.[15] On the other hand, others[8,9] have shown excellent bone regeneration using mineralized dentin. This delayed bone-inductive property of calcified dentin may be related to the inhibition of bone morphogenetic protein (BMP) release by apatite crystals. The process of demineralization enhances the osteoinduction activity of the dentin by exposing organic substances from within the teeth to the surface, by increasing porosity and surface area, and by decreasing its crystallinity.[16] Furthermore, the process of dentin decalcification is more time-consuming, whereas mineralized dentin remodeling would be prolonged in time[13,17,18] and thus would preserve the volume of the grafting site and its contour for a longer period of time.

The rationale for using an extracted tooth and to "recycle" it as biomaterial for various augmentative procedures is based upon the principle of replacement resorption. This phenomenon was first reported in the setting of reimplantation of avulsed teeth, where the root of the implanted tooth had undergone ankylosis. The ankylosed root was slowly replaced entirely by bone while preserving the dimensions of the alveolar process during a period of 5 to 8 years.[19,20,21] Real-time polymerase chain reaction (PCR) methodology[22] revealed that extracted teeth for guided bone regeneration in rats had a slower rate of resorption, a higher nestin and sialoprotein gene expression, and numerous undifferentiated neural crest–derived cells compared with iliac bone graft. The autogenous tooth mass was also applied in a socket-shield technique where a tooth is longitudinally sectioned and partially extracted while leaving its buccal portion in the inner aspect of the buccal bony plate.[23] This shield allegedly prevents the resorption of the buccal bone and preserves it because the bundle bone, the periodontal ligament, and its blood supply are kept intact. However, this method requires simultaneous implant placement, in addition to being technically sensitive, and having a complication rate close to 20%.[24]

Dentin, in the form of fully extracted tooth masses, was also applied in ridge augmentation procedures,[11,25–28] which yielded results comparable to those of an autogenous bone block transplantation. A systematic review[29] comprised of six studies described increases in the mean alveolar ridge width of 5.5 mm and 3.9 mm with the use of autogenous tooth blocks and autogenous bone blocks, respectively. Autogenous extracted teeth in a particulate form have been used by means of various production methods.[8,9,10,30,31,32] All of them demonstrated that the dentin particles are a valid bone graft substitute for obtaining socket site preservation.

The aim of this study was to clinically, histologically, and histomorphometrically examine the efficacy of autogenous particulate dentin as a reliable bone grafting biomaterial to preserve and/or restore a destructed socket site. Thus, buccolingual and apicocoronal dimensions would be maintained, followed by a successful implant reconstructive procedure.

MATERIALS AND METHODS

Participants

For patients who were scheduled for single-tooth extraction followed by a single prosthetic implant reconstruction, a socket preservation procedure was indicated as the first-stage surgery. All patients were treated at the postgraduate clinic at Tel Aviv University. Preservation of the socket site was indicated to preserve/restore its volume in all cases. The inclusion criteria comprised ASA 1 or 2 health status, nonsmokers, and no antibiotic consumption at least 6 months prior to the procedure. The patients (8 men and 7 women), whose age range was 27 to 71 years (mean: 50.2 ± 15.3 years), received a thorough explanation regarding the procedure, and each signed an informed consent form. The study was approved by the Tel Aviv University ethics committee.

Since the extraction phase was followed by an immediate particulate dentin grafting procedure, only sockets where bony walls were relatively preserved in at least two walls to achieve a contained grafted site were included. A postoperative CT image was provided in fulfillment of the permission by the university ethics committee in regard to this study.

Surgical Procedure

Buccal and lingual mucoperiosteal flaps were reflected after the administration of a local anesthetic solution (Fig 1). Each tooth was removed atraumatically by

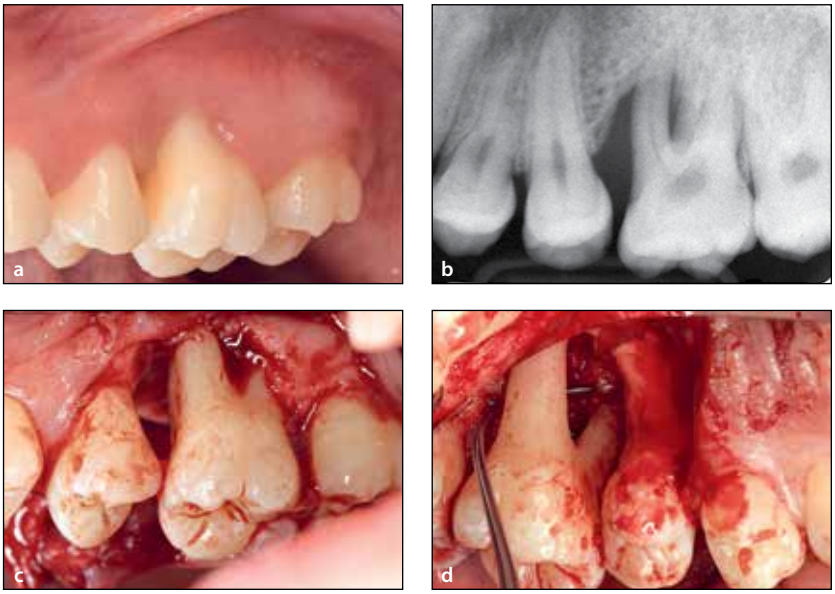
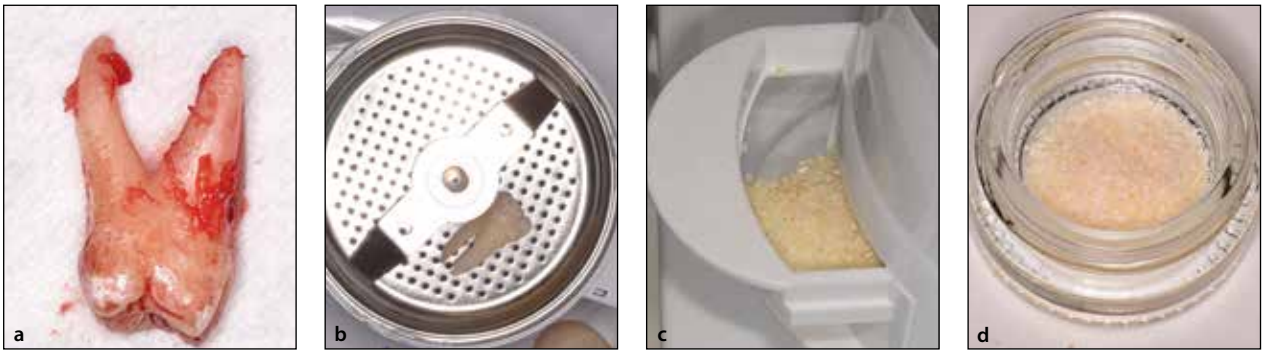


Fig 1 *(Right)* The maxillary left first molar *(a, b)* upon buccal *(c)* and lingual *(d)* soft tissue reflection demonstrated severe periodontal destruction to be replaced by single implant reconstruction.

Fig 2 *(Below)* The extracted first molar *(a)* was freed of all debris and soft tissue remnants and then went through the grinding process *(b, c, and d)* to create particles 250 to 1,000 µm in size.



means of periotomes and designated forceps. At this time, measurement of the buccolingual and crestal bone height of the socket site in relation to the cementoenamel junction of the neighboring teeth was taken by a periodontal probe (UNC15, Hu-Friedy). All foreign bodies, debris, old restorations, root canal sealers, and remaining caries were removed prior to the tooth grinding protocol. Then, the extracted tooth was ground into 250 to 1,200-µm particles (Fig 2) using the Smart Dentin Grinder Device (KometaBio). The particles were soaked for 10 minutes in a "cleanser" solution, which combined 0.5 M natrium hydroxide and 20% ethanol, followed by a second medium of phosphate-buffered solution for 3 minutes to neutralize its pH. At this stage, the socket site was thoroughly debrided from any granulation tissues. Particles were then applied to fill the fresh socket site by a designated carrier (Apex Dental USA), who inserted the graft into the socket site in portions. Then, a bioresorbable membrane was applied on one side, and the last portion of the particles were added to gently pack the site followed by full coverage of the collagen membrane (Geistlich BioGide) over the graft to secure and stabilize the augmented socket site (Fig 3). To obtain full soft tissue closure over the grafted socket, a laterally rotated palatal flap[33] was formed in the maxilla to achieve complete coverage of the membrane. This would leave the palatal donor site partially exposed for secondary healing. In the mandible, lingual and buccal coronally advanced flaps were established. By careful blunt dissection of the attached mylohyoid muscle fibers, the mucoperiosteal lingual flap can be easily released coronally quite extensively[34] to achieve a nontensional full soft tissue closure over the grafted socket. Finally, 5-0 resorbable coated polyglactin 910 (90% glycolide and 10% L-lactide) sutures (Vicryl, Ethicon) were used to approximate the flaps to full and stable primary closure.

Postoperative instructions included a 0.2% chlorhexidine-containing mouthwash twice daily for 30 seconds for 1 week, systemic antibiotics for 5 days (amoxicillin 500 mg t.i.d.), and analgesics as needed. Sutures were removed after 10 to 14 days. Follow-up visits took place

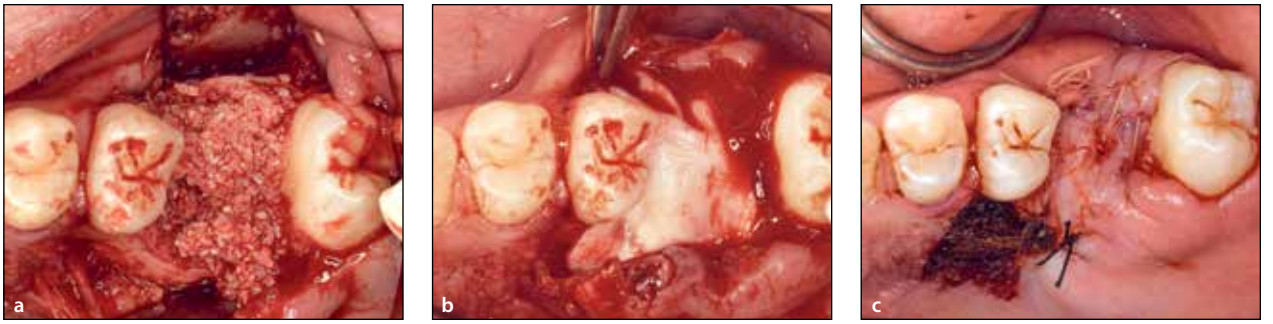


Fig 3 Dentin particles filled the extraction fresh socket site *(a)* to be covered by a resorbable collagen membrane *(b)*. Full soft tissue closure was obtained via a rotated pedicle flap from the palate *(c)*.

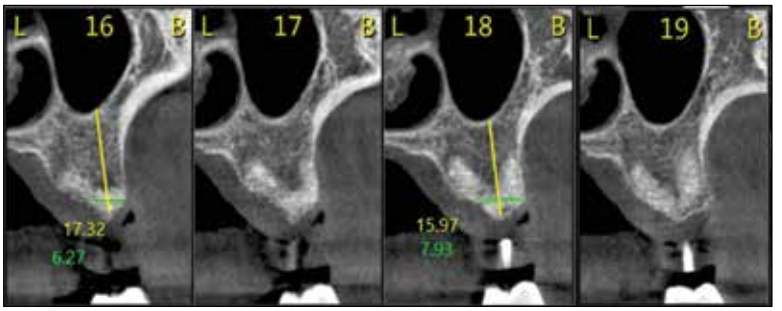


Fig 4 CT scan section cuts revealed that the particulate dentin preserved the entire socket site volume.

every 2 weeks during the first 3 months and every 4 weeks thereafter up to the reentry/implant placement stage at 6 months since the socket preservation procedure. A periapical radiograph was taken when the soft tissue healing had been achieved, and a CT scan was scheduled prior to the reentry/implant placement phase.

Specimen Retrieval and Processing

Implant placement was carried out 6 months following the procedure. The initial osteotomy preparation consisted of harvesting a cylindrical hard tissue specimen from the core of the augmented site by means of a 2.5-/3-mm-diameter trephine bur for histologic processing. Specimens were then fixated in 10% neutral buffered formalin for 1 week followed by decalcification with 5% formic acid for 2 weeks. The decalcified cylindrical specimens were then embedded in paraffin and cut longitudinally into 5-µm-width serial sections by a microtome. Each slide was stained with hematoxylin-eosin and subjected to histomorphometric measurements.

Histomorphometry

Three representative slides from the longitudinal (coronal-apical direction) central core of the specimen cuts were chosen for each case to be eligible for the morphometric measurements. Histomorphometric analysis was conducted with ImageJ software (NIH) to calculate direct bone-to-dentin contact and to evaluate newly formed bone and particulated dentin area fractions in designated regions of interest (ROIs) and given in mean percentages. Two measurements were conducted. First, the whole dentin particle diameter was measured, and a value was produced; then, a second measurement was recorded to provide a second value, which showed the diameter of dentin, which was encircled by newly formed bone. The third value was the percentage of the direct bone-to-dentin contact. The ROIs were determined by the entire photographic area at the core of the specimen in its central length. All measurements were taken by the same investigator (E.N.). Data were then rechecked by the second investigator (Z.A.), who found the coefficient of variation was < 5%; thus, these measurements were highly reproducible.

RESULTS

Fifteen patients participated in the study. All preserved socket sites healed uneventfully, followed by single implant prosthetic reconstruction. CT scans demonstrated that the grafted particulate dentin had preserved the three-dimensional volume of the socket sites (Fig 4). The radiopacity of mineralized tissue showed a buccolingual osseous table as wide as the original volumetrics of the natural roots. This outcome enabled ideal positioning of the subsequent screw-type implant body. At reentry, all treated sites showed a well-preserved ridge with a wide and viable bony table (Fig 5a), which correlated well with the CT scan.

Clinically, measurement of the interdental distance of the previous mesial-distal extracted natural tooth and the related crestal bone level at the time of extraction showed stable socket site preservation. Remeasurement of the buccolingual socket site dimension

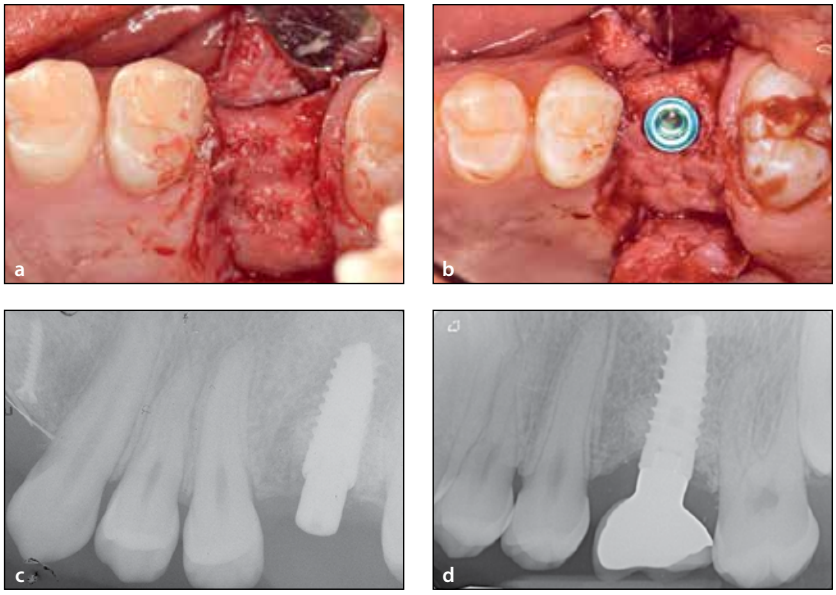


Fig 5 Clinical view at reentry, 6 months after ridge preservation. A well-preserved ridge was evident *(a)* following implant placement *(b and c)*. The periapical radiograph of the definitive prosthesis *(d)*.

and the crestal bone level on the adjacent natural roots was maintained as verified by the periodontal probe. The horizontal plane of the cementoenamel junction of the mesial/distal neighboring natural root line demonstrated that the destroyed socket site had been preserved in its dimension.

All implants (SLA, MIS; Figs 5b and 5c) that were placed showed excellent primary stability of at least 30 Ncm torque. All implants showed excellent primary stability and were placed at an average torque of 30 Ncm. They were all integrated and reconstructed by a prosthesis that was retained by a single screw (Fig 5d). The findings at the follow-up visits demonstrated appropriate function and stable healthy peri-implant conditions. Histologically, newly formed bone was observed in the entire grafted area, particularly around the grafted dentin particles (Fig 6). The grafted particles of various sizes were mostly surrounded by new bone formation in direct contact with the grafted particles (Figs 6 and 7). The grafted particles were connected by osseous bridging (Fig 7). Highly cellular new bone formation was observed around most of the dentin particles. The intimate contact of the cellular ossified tissue and the irregular grafted dentin particle surface was clearly evident. In some areas, the dentin particles were encircled by connective tissue with no evidence of cellular inflammation or foreign body reaction in the surrounding area. Histomorphometric measurements in the designated ROI showed a mean of 38.4% ± 16.5% (17% to 76%) newly formed bone, and a mean of 29.9% ± 14.4% (9% to 56%) of the grafted particles (Table 1). Assessment of the level of osseous conductivity[35] of the grafted biomaterial revealed direct contact between the newly formed bone and the dentin particles, ranging from 35% to 100%, with a mean of 69.1% ± 22.8%.

DISCUSSION

Socket site preservation is a surgical procedure aimed to partially compensate the unavoidable physiologic alveolar ridge resorption that occurs upon the extraction of a natural tooth. An extracted tooth can be replanted as a solid mass in outer enveloped ridge augmentation or grinded into particles to be inserted in a fresh socket site.

Histologic examination in the setting of preservation procedures for treated socket sites demonstrates new bone formation around the grafted dentin particles, thus indicating the level of osteoconductivity. That level was shown to be excellent following the procedure among all the present study participants. A good degree of connectivity was also evidenced on CT by the presence of bony bridges that had been created and that connected the newly formed bone with the dentin particles. The irregular and highly cellular direct bone-to-dentin contact was considered as reflecting active biodegradation of the grafted material under the process of bone replacement.

In an earlier case series by Kim et al,[8] dentin particles were used as the grafted biomaterial in fresh socket sites, and the postoperative histology disclosed a range of 46% to 87% of newly formed bone in the examined specimens. In a comparative animal study,[25,26]

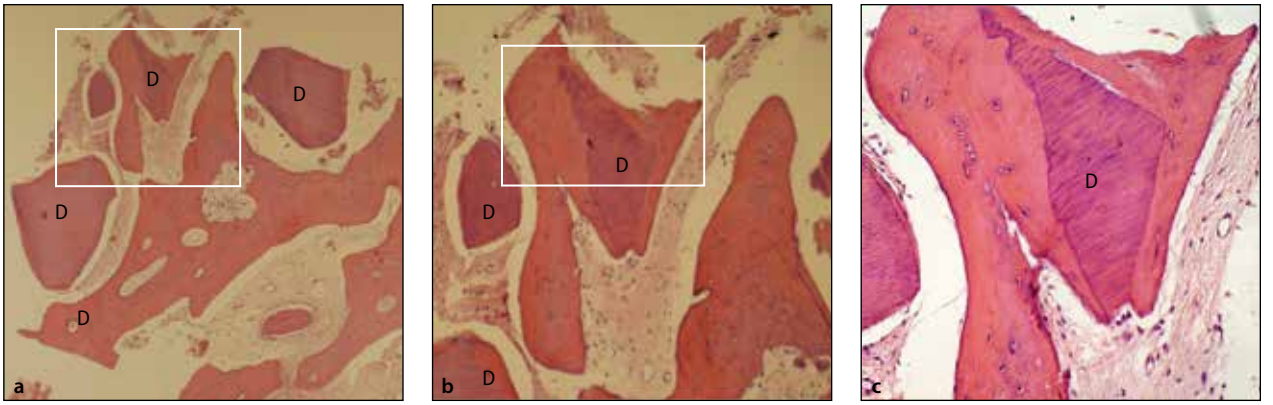


Fig 6 A cylindrical specimen of a 6-month post–socket site preservation procedure *(a)*. Dentin particles (D) encircled by newly formed bone in the grafted socket site *(b)*. Higher magnification of the marked rectangle showed osteocyte-enriched osseous tissue around the biodegradable grafted dentin particle *(c)*. (H&E staining ×4, ×10, and ×20 magnifications, respectively.)

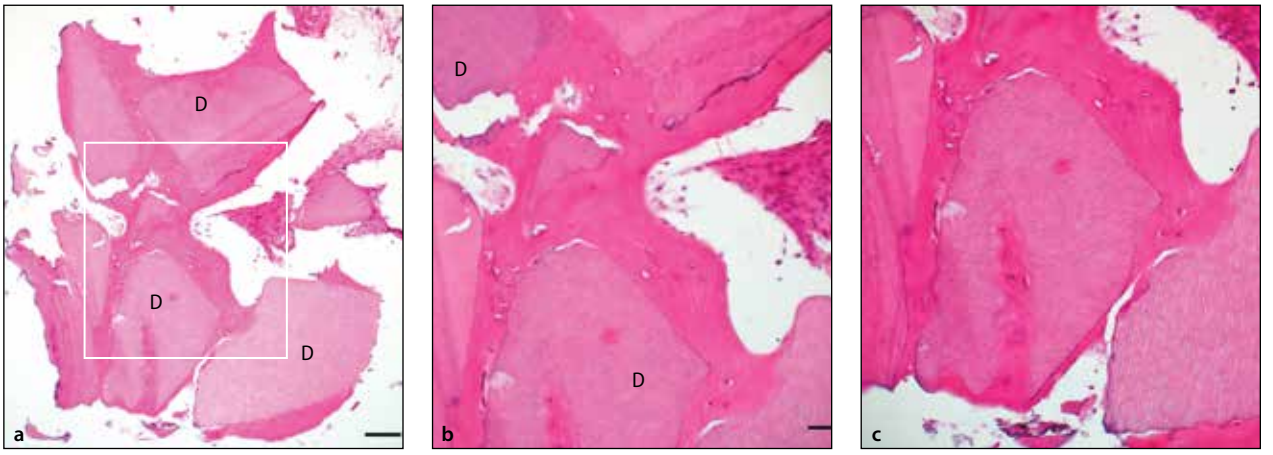


Fig 7 A cylindrical bone core from the dentin augmented socket *(a)*. New bone formation in direct contact with the grafted dentin particles (D) and forming a bridge between them *(b)*. Note the cellular osseous tissue in the interface of the newly formed bone and the dentin particles, implying that the grafted filler underwent replacement resorption *(c)*. (H&E staining ×4, ×20, and ×40 magnifications, respectively.)

Table 1 Percentage Area Fractions of Newly Formed Bone, Biodegradable Grafted Dentin Particles, and Soft Tissue Marrow, and the Percentage of Direct Bone-to-Dentin Contact in a Designated Region of Interest

Sample no.	Sex	Age (y)	Tooth no.[a]	NFB	P-Den	STM	BDC
1	M	71	13	52	42	6	92
2	M	19	26	40	9	51	58
3	M	27	26	56	18	26	86
4	F	37	26	76	14	10	97
5	M	44	26	48	20	32	35
6	M	47	26	52	34	14	100
7	F	59	46	28	21	51	37
8	F	65	36	25	38	37	41
9	M	62	14	44	27	29	76
10	M	51	26	24	48	28	71
11	M	68	24	18	56	26	52
12	F	42	15	17	47	36	76
13	F	50	47	24	36	40	64
14	M	51	17	35	13	52	52
15	M	68	43	37	25	38	100
Mean		50.7		38.4% ± 16.5%	29.9% ± 14.4%	31.7% ± 14.2%	69.1% ± 22.8%

NFB = newly formed bone; P-Den = biodegradable grafted dentin particles; STM = soft tissue marrow; BDC = percentage of direct bone-to-dentin contact.
[a]FDI tooth-numbering system.

autogenous natural root blocks were compared with autogenous bone blocks, which had been harvested from the retromolar area. There were no significant differences between the two grafted biomaterials with regard to the postaugmentation crest width, augmented volume area, or the percentage of direct newly formed bone, grafted root contact. In a recent report,[36] the autogenous dentin particles were combined with platelet-rich fibrin; thus, no primary soft tissue closure was attempted, although ridge augmentation was nevertheless obtained. Histologically, the grafted particles showed biodegradable resorption replacement, which was verified by calculation of the superimposed situations before extraction and at 1 year postgrafting, and there was no evidence of concomitant inflammatory and/or foreign body reaction.[10,36]

The present histomorphometric findings of the newly formed bone and the grafted autogenous dentin particles are similar to findings when allograft,[37] xenograft,[38,39] or alloplast[40] particles were applied for socket site preservation procedures. Likewise, the direct contact of the newly formed bone to the grafted particles demonstrates a high level of osteoconductivity (69%), as in other studies in which various biomaterials of different origins were applied.[35,41]

It is noteworthy to mention a few drawbacks in the present study. The inability to provide multiple CTs (preoperative and postoperative) due to ethical permissions and a lack of matching control sites should be addressed in future evaluation of this biomaterial. Also, in regard to the histologic preparation, the nondecalcification processing, ie, the Karl Donath technique, would be useful to evaluate the organic and nonorganic composition of the grafted shredded tooth substance.

CONCLUSIONS

Within the limitations of the relatively small sample size of this study, autogenous particulate dentin may be utilized as a bone graft biomaterial in socket site preservation procedures. However, these histologic and clinical data apply to two-stage surgical procedures, with socket preservation first and implant placement at least 6 months subsequently. These results demonstrate that particulate dentin is entirely biocompatible and an excellent osteoconductive biomaterial that can be used to preserve the socket site volume in the immediate postextraction phase. The 6-month augmented socket site by the grafted particulate dentin replantation preserves the ridge dimension for a future appropriate implant placement.

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