Autogenous Dentin Shell Grafts Versus Bone Shell Grafts for Alveolar Ridge Reconstruction: A Novel Technique with Preliminary Results of a Prospective Clinical Study

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This prospective pilot study presents a novel method using the dentin shell technique for the three-dimensional reconstruction of alveolar bone defects. Autogenous dentin shell (≤ 2 mm) harvested from impacted third molars was fixed at the recipient site as an external barrier. The space between the dentin shell and residual bone was filled with deproteinized bovine bone mineral particles mixed with concentrated growth factor (CGF) pieces. Autogenous bone (gold standard for bone graft) was applied to prepare shell grafts as the control. A total of 13 patients were included in the study and received bone reconstruction with the dentin shell technique (dentin group, n = 7) or bone shell technique (bone group, n = 6), respectively. At 24 weeks postsurgery, cone beam computed tomography results showed no statistically significant difference between the two groups regarding vertical bone gain and vertical and horizontal bone resorption. Histologic and microcomputed tomography analyses revealed significant newly formed bone connecting directly to the resorbed dentin shells. The dentin shell technique restored bone volume successfully without major complications.

Implant dentistry has become a reliable treatment method for oral rehabilitation. However, implant placement could be challenging at some edentulous regions with severe alveolar bone defects. A reconstruction process is necessary to restore bone volume and quality, which are considered important determinants of implant success.1,2 Unlike a postextraction tooth socket that can accommodate graft materials, long-term edentulous alveolar ridges usually undergo extensive bone resorption. The knife-edge or flat alveolar ridges can barely hold and stabilize bone grafts,3 and therefore the volume stability of reconstructed regions is of particular importance.4–6 For these alveolar ridges, grafts formed of a thin but rigid external layer and a loose porous internal portion help enhance stability and facilitate vascularization at the same time, potentially resulting in a better osteoconductive environment.7 A three-dimensional bone reconstruction method, the shell technique, was applied in order to achieve this favorable structure.8

Autogenous bone is shaped to thin shells and fixed at the residual bone as a barrier. Particulate grafts are then used to fill the space isolated by shells. The shell technique has been proven by previous clinical trials to be a viable and predictable procedure.9–13

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Autogenous bone is the current gold standard for bone reconstruction, though it presents shortcomings including donor site morbidity and limited available bone and graft resorption.\textsuperscript{14-16} Autogenous dentin, which shares similar composition as alveolar bone, is considered a promising bone substitute.\textsuperscript{17-19} Type I collagen, the main organic component of dentin, acts as a scaffold in the mineralization of tooth and bone.\textsuperscript{20} Also, growth factors in dentin, such as bone morphogenetic proteins, help induce the differentiation of osteoblasts and promote bone formation.\textsuperscript{21} Human dentin achieved favorable outcomes in many clinical studies.\textsuperscript{18,22-25}

In the present study, the authors adopted a modified three-dimensional bone reconstruction method: the dentin shell technique. Autogenous dentin, harvested from impacted molars, was trimmed to thin shells (≤ 2 mm) and fixed at the recipient site. The space between dentin shells and residual bone was filled with deproteinized bovine bone mineral (DBBM) particles and concentrated growth factor (CGF), an autologous leukocyte-rich and platelet-rich fibrin biomaterial.\textsuperscript{26} The aim of this prospective pilot study was to evaluate the efficiency of the dentin shell technique for alveolar bone defect reconstruction as compared to conventional bone shell technique.

\textbf{Materials and Methods}

The study protocol was approved by the ethical committee of the West China Hospital of Stomatology, Sichuan University (Registration number: WCHSIRB-CT-2014-065). A total of 13 patients needing treatment for alveolar ridge defects before implant placement provided informed consent and were included in the study. The patients were assigned to two groups depending on their preoperation examinations: patients with impacted third molars were assigned to the dentin group, and nonimpacted molars were assigned to the bone group. The inclusion criteria were as follows: (1) aged 18 to 70 years; (2) having a Class IV, V, or VI alveolar process (Cawood and Howell classification)\textsuperscript{3} determined by cone beam computed tomography (CBCT) scan; and (3) in good general health or having systemic disease(s) under good control. Patients were excluded if they met any of the exclusion criteria: (1) previous history of grafting on the site to be operated; (2) necrotizing periodontal diseases or severe chronic periodontitis (Stage IV, Grade C according to the consensus report\textsuperscript{27}); (3) patients who cannot maintain good oral hygiene; and (4) history of radiation therapy in the oral and maxillofacial region.

\textbf{Surgical Procedure}

For preparation of the dentin shell, the impacted molar was carefully extracted (Fig 1a). After removing enamel and cementum using a bur (Surgerybone, Silfradent), the residual dentin block was cut with a disk saw (Meiringer) along its long axis. The soft tissue was removed, and dentin shells were trimmed to a final thickness of ≤ 2 mm (Fig 1b). For the bone-shell preparation, an incision was made along the mandibular external oblique ridge to expose the donor site. A bone block was harvested using a piezoelectric device (Surgerybone, Silfradent) (Fig 2a). The bone block was cut and trimmed to a cortical bone shell with a thickness of ≤ 2 mm using the disk saw (Fig 2b). For all dentin and bone shells, sharp edges were eliminated to prevent perforation of the overlying soft tissue.

The grafting process was performed under local anesthesia. A midcrestal incision was made and a mucoperiosteal flap was reflected, extending mesially and distally to the second adjacent teeth in order to expose the defect. Cortical perforation, which remains controversial...
and could prolong treatment time, was not performed at the host bone. Ten milliliters of venous blood was collected from each patient and centrifuged to produce a CGF clot, which was then compressed into a 1-mm-thick membrane. The membrane was cut into pieces using surgical scissors (Fig 3a). The dentin or bone shell was placed over the defects and fixed with titanium osteosynthesis screws (Synthes) (Fig 3b). Space between shells and native bone was filled with a mixture of DBBM (Bio-Oss, Geistlich) particles and CGF pieces (Fig 3c). Then, a collagen membrane (Bio-Gide, Geistlich) was used to cover the grafted area (Fig 3d). Primary tension-free closure was achieved with periosteal incision and separation of the elastic fibers. Postsurgical instructions included taking diclofenac sodium (50 mg, bid) for 1 week, amoxicillin (0.5 g, tid) for 5 days, and mouth rinsing with 0.12% chlorhexidine solution three times a day for 1 week. Sutures were removed at 7 to 10 days postoperative. After a healing period of 6 months, dental implant placement was performed. For five patients in the dentin group and four in the bone group, additional bone augmentation using DBBM particles was necessary at the time of implant placement. Further patient and implant demographics are described in Table 1. Implant insertion torques measured from 15 to 35 Ncm for both of the two groups, with 15 Ncm for three and two implants in the dentin and bone groups, respectively. The insertion torque is unavailable for one patient in the dentin group.

**Micro-CT and Histologic Process**

During site preparation for implant placement, drilling led to mobility of two pieces of dentin shell. The two mobile dentin shells were harvested and immersed in 10% formalin solution. A microcomputed tomography (micro-CT) scanner (μCT 50, SCANCO Medical) was used to conduct the examination. Afterwards, the two specimens were dehydrated in a graded series of ethanol and embedded in resin before cutting longitudinally through the center of the dentin shells. The specimens were sectioned and ground down.
to 10- to 20-μm size using the EXAKT 300 CP and EXAKT 400 CS systems. Subsequently, hematoxylin and eosin (HE) and toluidine blue (TB) staining were performed. The prepared sections were examined using a light microscope, and digital images were captured for descriptive analysis.

**Radiographic Measurement**

CBCT data (3D Accuitomo 170, J. Morita) were obtained before grafting surgery (T1), immediately after surgery (T2), and at 24 weeks post-surgery (T3). The radiographs were analyzed using One-Viewer viewing software (J. Morita). A buccolingual section that divided the grafted location into two equal parts was selected (Fig 4a), and the corresponding mesiodistal section was identified to help define reference marks (Figs 4b to 4d). The following reference marks were then defined on the buccolingual section (Figs 4e and 4f):

**Fig 4** (a) Presurgical CBCT of the mesiodistal section. The cementoenamel-junction level of adjacent teeth was marked (red line). Buccolingual CBCT sections of a patient (b) before surgery, (c) immediately after surgery, and (d) 24 weeks later. The red line on the mesiodistal section helps identify the reference level used to measure bone volume at different time points. (e) Enlarged image of Fig 4c. The top of facial bone crest (C), nasal floor (f), and outer border of the buccal (B) and lingual (L) walls were marked. Vertically, the Cf distance (white line) was measured. Horizontally, the distances between B and L were measured at three different levels (2, 4, and 6 mm apical to C) (yellow lines). The three distances were defined as C2-LB-2, C2-LB-4, and C2-LB-6, respectively. (f) Enlarged image of Fig 4d. B, L, and f were marked. The three yellow lines were measured in relation to C in Fig 4e, representing C2-LB-(2,4,6).
Details regarding the measured distances and follow-up visits are summarized in Table 2. Before surgery, the initial bone volume was measured vertically and horizontally: Cf and C1-LB at 2, 4, and 6 mm (C1-LB-(2,4,6)). After a 24-week healing period, the following parameters were defined:

- **Vertical bone gain (VBG):** the increase in Cf between T1 and T3
- **Vertical bone resorption (VR):** the decrease in Cf between T2 and T3
- **Horizontal bone resorption at 2, 4, and 6 mm from the top of the facial bone crest (HR-(2, 4, 6)):** the decrease in C2-LB-(2, 4, 6) between T2 and T3

### Statistical Analysis

Statistical analysis was conducted using IBM SPSS 22.0. Each patient was considered one unit. For patients with more than one grafted region, the region with less vertical bone volume (smaller Cf value) was recognized. When comparing between groups, independent sample t test was applied for initial bone volume, and Mann-Whitney U test was applied for the other parameters (VBG, VR, and HR-(2, 4, 6)). Data were presented as mean ± standard deviation. \( P < .05 \) was considered statistically significant.

### Results

Baseline characteristics of dentin and bone groups are summarized in Table 1. In the dentin group, seven patients received 10 dentin shells. In the bone group, six patients received 11 bone shells. All grafted regions healed uneventfully without postoperative complications. Patient-perceived morbidity (postoperative pain and swelling) and functional impairment (impairment regarding food intake and speech) were similar between the two groups.

### Table 1 Subject Distribution and Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Dentin group</th>
<th>Bone group</th>
</tr>
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<tbody>
<tr>
<td>Patients, n</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Implants, n</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Mean age (y)(^a)</td>
<td>29.14 ± 10.85</td>
<td>36.83 ± 10.83</td>
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<tr>
<td>Sex(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>0 (0)</td>
<td>3 (50)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>7 (100)</td>
<td>3 (50)</td>
</tr>
<tr>
<td>Bone defect classification(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class IV, n (%)</td>
<td>4 (57.14)</td>
<td>3 (50.00)</td>
</tr>
<tr>
<td>Class V, n (%)</td>
<td>2 (28.57)</td>
<td>2 (33.33)</td>
</tr>
<tr>
<td>Class VI, n (%)</td>
<td>1 (14.29)</td>
<td>1 (16.67)</td>
</tr>
<tr>
<td>Implant location(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior region, n (%)</td>
<td>8 (80.00)</td>
<td>10 (83.33)</td>
</tr>
<tr>
<td>Posterior region, n (%)</td>
<td>2 (20.00)</td>
<td>1 (16.67)</td>
</tr>
</tbody>
</table>

\(^a\)Mean ages were compared between groups using independent samples t test (\( P = .229 \)).

\(^b\)The three baseline characteristics were compared between groups using Fisher probabilities (\( P > .05 \) for all).

### Table 2 The Distances Measured on CBCT Images at Different Follow-up Visits

<table>
<thead>
<tr>
<th></th>
<th>Cf</th>
<th>C1-LB-(2,4,6)</th>
<th>C2-LB-(2,4,6)</th>
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<tr>
<td>T1</td>
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<td>√</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>√</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>T3</td>
<td>√</td>
<td></td>
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</tbody>
</table>

Cf = The vertical distance between C (top of facial bone crest) and f (nasal floor or maxillary sinus floor for maxilla; inferior alveolar canal for mandible); C1-LB-(2,4,6) = Using the top of facial bone crest at T1 (before grafting) as a reference level, the horizontal distance between B (outer border of buccal wall) and L (outer border of lingual wall) at 2, 4, and 6 mm apical to C, respectively; C2-LB-(2,4,6) = Using the top of facial bone crest at T2 (immediately after surgery) as a reference level, the horizontal distance between B and L at 2, 4, and 6 mm apical to C, respectively; T3 = 24 weeks postsurgery.
Radiographic measurements are summarized in Table 3. At 24 weeks postsurgery, the average bone height measured 15.98 ± 1.94 mm in the dentin group and 14.07 ± 3.95 mm in the bone group, resulting in VBGs of 2.91 ± 3.75 mm and 2.79 ± 3.95 mm in dentin and bone groups, respectively. No statistical significance was observed in respect to all parameters.

**Micro-CT and Histologic Outcomes**

The micro-CT image is shown in Fig 5. The outer surface of the dentin shell and the walls of holes that accommodated osteosynthesis screws are irregular, indicating varying degrees of dentin resorption. New bone formation and DBBM particles can be observed in the pore.

TB stain showed the resorption of dentin on the outer surface facing overlaying soft tissues. Significant bone formation was observed on the resorbed area and extended to the adjacent dentin surface (Fig 6a). New bone combined with the dentin shell and was composed of lamellar bone and small flat osteocyte lacunae (Fig 6b). Results from the HE stain are presented in Fig 7. New bone filled the gaps between DBBM particles and covered the dentin shell both on the DBBM interface and on the outer surface. At both sides, dentin underwent resorption and connected directly with new bone (Figs 7a and 7b). Layers of osteoid were found covering the bone surfaces, indicating an active osteogenesis process (Fig 7c).

**Discussion**

This prospective study was designed to evaluate the use of the dentin shell technique for reconstruction of alveolar bone defects. Autogenous dentin was presented as a possible alternative to autogenous bone by comparing dentin shell technique with bone shell technique.
In the present study, dentin was simply cleaned and shaped before grafting. To the authors’ knowledge, this is the first clinical application of chemically unchanged, slice-type dentin. In recent years, chemical modification, especially demineralization, has been deemed an essential step for dentin application before grafting.\textsuperscript{18,22} It has been reported that demineralized dentin was able to induce new bone formation, but new bone was not observed in regions grafted with nondemineralized dentin.\textsuperscript{29} As demineralization is a complicated and time-consuming process, the extracted teeth need to be sent to other institutes for preparation, leading to a prolonged treatment time.\textsuperscript{23,30} The nondemineralized dentin shells used in this study can be prepared chairside in only 30 minutes. The grafting procedure was performed in one
surgery, immediately after tooth extraction. Moreover, histologic outcomes showed new bone formation on both outer and inner surfaces of the dentin shell, suggesting osteoconductive and even osteoinductive capabilities of chemically unchanged dentin.

High mechanical strength is another advantage of chemically unchanged dentin. It is expected to help improve the structural stability, which is essential for the shell technique. In the present study, the dentin group generally presented less bone resorption than the bone group, although no statistical significance was found. The findings may be related with the rigidity of dentin shells. Similarly, in a recent prospective controlled study, dentin-grafted regions showed significantly less resorption than autogenous bone-grafted regions.

In the current study, CBCT results showed vertical bone gain of 2.91 ± 3.75 mm in dentin group and 2.79 ± 3.95 mm in bone group. All grafted regions were capable to accommodate suitable dental implants after the healing period. During the bone reconstruction procedure, shell grafts served as rigid frames that supported and maintained the space for bone regeneration. Dentin and bone shells help restore bone volume and quality, which are prerequisites for implant primary stability.

All patients included had a Class IV, V, or VI alveolar ridge according to the Cawood and Howell classification, which generally characterizes these ridges by their knife-edge or flat shape. Frequently performed bone augmentation techniques for these deficient alveolar ridges include autogenous onlay block bone grafting and guided bone regeneration using polytetrafluoroethylene membrane and titanium mesh. Compared to these techniques, the dentin shell technique prevents bone harvesting procedures and consequent surgical injury at donor sites. Surgical cost is also reduced because no additional material is needed.

However, the application of the dentin shell technique is limited for certain cases. Nonfunctioning teeth provided sources for dentin shells in the present study, and thus the technique is not applicable for patients without a donor tooth. Large-scale bone defects that exceed the space that dentin shells can maintain may also be excluded from this treatment. In addition, as only impacted teeth without periodontitis were collected in this study, the safety of using dentin tissue harvested from periodontally diseased teeth is still unclear. Although promising results have been obtained from animal experiments, future clinical studies regarding this issue are needed, and the application of this technique may be expanded.

The present study has some limitations, including the small sample size and short follow-up period. The authors compared baseline values to confirm the similarity and comparability between groups. Potential confounding factors were controlled to some extent. Within the limitations of this study, the dentin shell technique could be considered for the reconstruction of severe alveolar bone defects. Further prospective studies are suggested to evaluate the long-term efficacy and safety of this surgical technique.

Conclusions

Both the dentin shell and bone shell techniques restored bone volume successfully without major complications. Within the limitations of this study, autogenous dentin appeared to be a possible substitute to autogenous bone for the reconstruction of severe alveolar bone defects.

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