Autogenous bone is an ideal bone graft material due to its osteogenic, osteoinductive, and osteoconductive properties. However, autogenous bone has some limitations, such as the inevitable additional surgery, donor site morbidity, and lack of adequate amount of bone.1 To overcome these disadvantages, several bone substitutes have been developed, including allogeneic, xenogeneic, and alloplastic bone substitutes. These bone substitutes have shown insufficient bone healing outcomes to alter autogenous bone due to their manufacturing process and mechanical properties.2

Dentin is a component of teeth and has histologic similarities to the jawbone. Dentin contains 70% to 75% inorganic content, 20% organic content, and 10% water. The inorganic, organic, and water contents in the jawbone are 65%, 25%, and 10%, respectively.3 According to their structural and biochemical similarities, demineralized dentin matrix (DDM) and demineralized bone matrix (DBM) have similar chemical characteristics. DDM is composed of a highly cross-linked type I collagen with collagenous matrix-binding proteins such as bone morphogenetic proteins (BMPs), fibroblast growth factor, insulin growth factor, and transforming growth factors.4–6

Based on this, autogenous DDM (auto-DDM) was first applied in the maxillary sinus in 2003.7 Many clinical studies have reported the bone healing effect of auto-DDM in various clinical conditions, such as ridge augmentation, socket preservation, and guided bone regeneration.8–12 In 2008, partially demineralized dentin matrix (AutoBT, Korea Tooth Bank) was manufactured via dehydration, degreasing, and ethylene oxide disinfection.3 After partial demineralization, the dentinal tubules are enlarged and the dentin matrix releases the collagen fibers and basic proteins,13,14 which can

Purpose: To compare the clinical outcomes of autogenous and allogeneic demineralized dentin matrices loaded with recombinant human bone morphogenetic protein-2 (rhBMP-2; auto- and allo-DDM/rhBMP-2) by measuring the buccal marginal bone resorption around dental implants. Materials and Methods: This retrospective study included patients who underwent dental implant placement with auto-DDM/rhBMP-2 as the control group and allo-DDM/rhBMP-2 as the experimental group. The primary outcome was buccal marginal bone resorption on CBCT. The resorption was calculated during T0 (from surgery to prosthetic loading), T1 (during the first year after loading), and T2 (during the second year after loading). The secondary outcome was the histologic analysis of five specimens of each group, obtained during the prosthetic procedure. Results: Among the 103 implants, 61 and 42 implants were placed with auto- and allo-DDM/rhBMP-2 matrices, respectively. The resorptions of all periods were similar between the groups (T0: 0.65 ± 0.71 and 0.67 ± 0.81 mm, T1: 0.55 ± 0.60 and 0.59 ± 0.81 mm, and T2: 0.29 ± 0.45 and 0.20 ± 0.30 mm with auto- and allo-DDM/rhBMP-2, respectively). The histologic and histomorphometric analysis revealed similar osteoinductive aspects and proportions of new bone between the groups. Conclusion: Allo-DDM/rhBMP-2 showed comparable outcomes in terms of buccal marginal bone resorption to auto-DDM/rhBMP-2 during the second year after loading. Int J Oral Maxillofac Implants 2022;37:1138–1144. doi: 10.11607/jomi.9692

Keywords: allogeneic, bone substitutes, demineralized dentin matrix, dental implant, rhBMP-2

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promote new bone formation comparable to osteoinductive effects of autogenous cortical bone graft.\textsuperscript{15,16}

With the development of tissue engineering, many researchers have attempted to apply recombinant human bone morphogenetic protein-2 (rhBMP-2) on bone substitutes to enhance bone healing capacity. In 2007, rhBMP-2 was approved by the United States Food and Drug Administration for use at a concentration of 1.5 mg/mL with absorbable collagen sponges in the dental field.\textsuperscript{17} Recently, DDM has been noted as an rhBMP-2 carrier to reduce the supraphysiologic rhBMP-2 concentration (1.5 mg/mL) with the collagen sponges, which can induce complications of short biologic half-life, localized action, low mechanical stability, and rapid clearance.\textsuperscript{14,18–21}

In 2017, AutoBT incorporated with rhBMP-2 (auto-DDM/rhBMP-2; 0.2 mg/mL of rhBMP-2, Cowelmedi) was first used in the procedure of socket preservation and showed more active bone formation with the embedding of osteocytes compared to auto-DDM alone.\textsuperscript{18} In 2020, DDM was suggested as a suitable carrier of rhBMP-2 based on histologic review through experimental and clinical studies.\textsuperscript{14}

Furthermore, since 2019, allogeneic DDM (allo-DDM) has been proven to be safe and efficient compared to the clinical outcomes of auto-DDM without any antigenicity and immunogenicity.\textsuperscript{22,23} These results indicate that allo-DDM can be used to overcome the shortcomings of auto-DDM, which include an insufficient amount of auto-DDM and delayed transplantation after extraction. The authors hypothesized that allo-DDM could be used as a carrier of rhBMP-2. The aim of this study was to evaluate the clinical outcomes of allo-DDM incorporated with rhBMP-2 (allo-DDM/rhBMP-2) compared with auto-DDM/rhBMP-2 by measuring buccal marginal bone (BMB) loss around dental implants.

**MATERIALS AND METHODS**

This retrospective clinical study was approved by the Ethics Committee of Seoul National University Bundang Hospital Institutional Review Board (IRB No. B-2011/648-103). The authors have read the Helsinki Declaration for research on humans and have followed the guidelines in this investigation.

**Study Design**

All patients included in this study were adults who underwent single-tooth extraction and implant placement (Dio, sandblasted with large-grit and acid-etching surface with internal connection type) at 4 weeks after the extraction in the premolars and molars (posterior region) with auto- or allo-DDM/rhBMP-2 graft in three-wall (minimum) defects with buccal vertical bone destruction between January 2015 and October 2019.

All surgical procedures were performed by a single expert surgeon (Y. K. K.). The healing period until prosthetic loading was 3 months (range: 3 to 4 months) and 6 months (range: 6 to 8 months) in the mandible and maxilla, respectively. The time points to measure the BMB height were at the time of the surgery, at prosthetic loading, and at 12 ± 2 months and 24 ± 4 months after loading. The inclusion criteria were as follows: (1) single implant placement in the posterior region with bone grafting in the early soft tissue healing period (4 to 6 weeks) after extraction\textsuperscript{24}; (2) age ≥ 20 years; (3) vertical buccal bone loss ≥ 2.5 mm (at least third implant thread exposure); (4) healthy status or well-controlled systemic diseases; and (5) four CBCT scans, taken at the time of surgery, prosthetic loading, and at 1 and 2 years after loading. The exclusion criteria were as follows: (1) previous bone graft surgery at the surgical site; (2) current smoking habit; (3) poor oral hygiene control and untreated periodontitis; and (4) uncontrolled systemic diseases.

The Korea Tooth Bank (KTB) supplied allo-DDM that was manufactured in KTB from impacted third molars and premolars that were extracted and collected during orthodontic treatment at designated dental clinics. Generally, procurement, storage, processing, and packaging were performed separately for teeth obtained from each individual to conform to the Guidelines of Good Practice for Tooth Handling Institution from Korea Administration of Health and Welfare.\textsuperscript{25}

Briefly, the processing procedure for the DDM involved refrigeration of teeth in 70\% ethyl alcohol followed by rinsing and removal of attached soft tissue and pulp using a retrograde technique. The dentin was crushed into particles (300 to 800 \(\mu\)m), followed by defatting and demineralization using 0.6 N HCl with a viral inactivation procedure (Patent: EP 2601982) that was previously reported.\textsuperscript{26} The rhBMP-2 was loaded onto the DDM powder at a concentration of 0.2 mg/mL (Cowellmedi).\textsuperscript{13}

**Surgical Procedure**

At 4 weeks after extraction, the implant was placed with simultaneous guided bone regeneration (GBR) using auto- or allo-DDM/rhBMP-2. After flap elevation under local anesthesia (2\% lidocaine HCl with 1:100,000 epinephrine, Huons), the remaining BMB was trimmed to ≥ 0.5 mm thickness. After implant placement and verification of primary stability (Fig 1a), DDM/rhBMP-2 was applied to repair of the buccal defect and decortication (Figs 1a and 1b). Primary closure of the surgical sites was achieved by 4-0 vicryl (Johnson and Johnson) without covering the barrier membranes (Fig 1c).
Patients were instructed to take oral antibiotics (625 mg, amoxicillin, Ilsung Pharmaceutical) three times daily for 3 days and mouthrinse daily with a 0.1% chlorhexidine solution. There were no signs of infection, wound dehiscence, or graft failure during the healing period. For the prosthetic process, the surgical site was reopened. Regarding the intraoperative photographs, a bone sample was harvested from the graft area, where the remaining dentin particles could be observed, using a trephine bur (diameter: 3.0 mm; Dentium) from the patients who consented to undergo biopsy (Fig 1d).

Measurement of BMB Resorption Using CBCT
Using linear measurement tools of CBCT (Vatech), the BMB height around the implant was measured along the center of the implant in a cross-sectional slice from the crest of the BMB and the base of the implant. On the cross-sectional view, a vertical reference was drawn from the radiolucent center of the cover screw to the midcylinder of the implant. The horizontal reference at the marginal crest of the bone was drawn perpendicular to the vertical reference line (Fig 2a). The BMB was measured based on these reference lines relative to the marginal crest and dental implant apex.¹⁰
The time points of the measurement were: immediately after the bone graft (Fig 2a), at the prosthetic loading (Fig 2b), 12 months after loading (Fig 2c), and at the final follow-up 24 months after loading (Fig 2d). BMB resorption was calculated during T0 (initial resorption during healing from surgery to prosthetic loading), T1 (functional resorption during the first year after loading), and T2 (long-term resorption during the second year after loading). In cases of increasing BMB height compared with the baseline, the amount of resorption was set at zero.

### Histologic Observation and Histomorphometry Analysis

A total of 10 specimens—five from each group—were demineralized with 10% formic acid after fixation in 10% neutral-buffered formalin. The specimens were sectioned at a thickness of 5 to 8 μm using a microtome in the longitudinal plane from the middle of the specimen. The slides were stained with hematoxylin and eosin (H&E) and scanned (Panoramic 250 Flash III, 3DHISTECH).

The scanned slides were observed using slide-viewing software (Case Viewer ver. 2.1., 3DHISTECH). The histomorphometric analysis was carried out by trained examiners (E. S. L.), who were blinded to the group allocation. The analysis included the following parameters of % area:

1. new bone—area of normal bone tissue;
2. DDM—area of dentin particles with dentinal tubules; and
3. soft tissue—area with new bone and DDM, including the void and inflammatory tissue.

### Statistical Analysis

The parametric assumptions of the data were verified using Kolmogorov-Smirnov test. Comparisons were analyzed using an independent-sample t test between

<p>| Table 1 Demographic and Clinical Information of Implants with Auto- and Allo-DDM/rhBMP-2 |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Sex (male: female)</th>
<th>Age (y)</th>
<th>At the operation</th>
<th>At loading</th>
<th>First year from loading</th>
<th>Second year from loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 61)</td>
<td>31:30</td>
<td>60.3 ± 8.9</td>
<td>10.65 ± 1.41</td>
<td>10.03 ± 1.55</td>
<td>9.57 ± 1.59</td>
<td>9.66 ± 1.70</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 42)</td>
<td>20:22</td>
<td>61.5 ± 9.8</td>
<td>10.46 ± 1.81</td>
<td>9.82 ± 1.77</td>
<td>9.29 ± 1.57</td>
<td>9.28 ± 1.72</td>
</tr>
<tr>
<td>P</td>
<td>.752</td>
<td>.508</td>
<td>.562</td>
<td>.536</td>
<td>.456</td>
<td>.351</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 29)</td>
<td>16:13</td>
<td>59.8 ± 6.5</td>
<td>10.59 ± 1.21</td>
<td>9.77 ± 1.36</td>
<td>9.27 ± 1.63</td>
<td>9.55 ± 1.62</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 20)</td>
<td>11:9</td>
<td>58.4 ± 10.5</td>
<td>10.27 ± 1.80</td>
<td>9.67 ± 1.74</td>
<td>9.64 ± 1.41</td>
<td>9.18 ± 1.39</td>
</tr>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 32)</td>
<td>15:17</td>
<td>60.7 ± 10.8</td>
<td>10.71 ± 1.57</td>
<td>10.26 ± 1.70</td>
<td>9.81 ± 1.54</td>
<td>9.79 ± 1.83</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 22)</td>
<td>9:13</td>
<td>64.4 ± 8.3</td>
<td>10.64 ± 1.85</td>
<td>9.96 ± 1.82</td>
<td>9.00 ± 1.67</td>
<td>9.42 ± 2.14</td>
</tr>
<tr>
<td>P</td>
<td>.725*</td>
<td>.170*</td>
<td>.805*</td>
<td>.563*</td>
<td>.376*</td>
<td>.746*</td>
</tr>
</tbody>
</table>

*Independent t test between grafts.
†One-way ANOVA test of the jaw and grafts.

Allo-DDM/rhBMP-2 = allogeneic demineralized dentin matrix incorporated with recombinant human bone morphogenetic protein.
Auto-DDM/rhBMP-2 = autogeneic demineralized dentin matrix incorporated with recombinant human bone morphogenetic protein.

<p>| Table 2 Buccal Marginal Bone Resorption on Auto- and Allo-DDM/rhBMP-2 According to Period and Arch |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Initial resorption</th>
<th>P</th>
<th>Functional resorption</th>
<th>P</th>
<th>Second year resorption</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 61)</td>
<td>0.65 ± 0.71</td>
<td>.874*</td>
<td>0.55 ± 0.60</td>
<td>.764*</td>
<td>0.29 ± 0.45</td>
<td>.340*</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 42)</td>
<td>0.67 ± 0.81</td>
<td>.990*</td>
<td>0.59 ± 0.81</td>
<td>.990*</td>
<td>0.20 ± 0.30</td>
<td>.20± 0.30</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 29)</td>
<td>0.79 ± 0.65</td>
<td>.520†</td>
<td>0.67 ± 0.57</td>
<td>.561†</td>
<td>0.22 ± 0.37</td>
<td>.391†</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 20)</td>
<td>0.60 ± 0.78</td>
<td>.990*</td>
<td>0.46 ± 0.60</td>
<td>.990*</td>
<td>0.24 ± 0.35</td>
<td>.23 ± 0.35</td>
</tr>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-DDM/rhBMP-2 (n = 32)</td>
<td>0.51 ± 0.76</td>
<td>.45 ± 0.61</td>
<td>0.37 ± 0.52</td>
<td>.37 ± 0.52</td>
<td>0.14 ± 0.21</td>
<td>.14 ± 0.21</td>
</tr>
<tr>
<td>Allo-DDM/rhBMP-2 (n = 22)</td>
<td>0.73 ± 0.84</td>
<td>.71 ± 0.95</td>
<td>0.37 ± 0.52</td>
<td>.37 ± 0.52</td>
<td>0.14 ± 0.21</td>
<td>.14 ± 0.21</td>
</tr>
</tbody>
</table>

*Independent t test between grafts.
†One-way ANOVA test of the arch and grafts.

Allo-DDM/rhBMP-2: allogeneic demineralized dentin matrix incorporated with recombinant human bone morphogenetic protein.
Auto-DDM/rhBMP-2: autogeneic demineralized dentin matrix incorporated with recombinant human bone morphogenetic protein.

Initial resorption: during T0 (from surgery to the prosthetic loading).
Functional resorption: during T1 (the first year after loading).
Second year resorption: during T2 (the second year after loading).
auto-DDM/rhBMP-2 and allo-DDM/rhBMP-2 on the BMB heights at every stage, the BMB change between the stages (initial, functional, and second year), and histomorphometric results. Considering the arch distribution, one-way analysis of variance (ANOVA) was used to analyze the BMB resorption according to the four groups (auto- and allo-DDM/rhBMP-2 on the mandible and maxilla, respectively), and post hoc analysis was performed with a correction of type 1 error according to the Bonferroni method. Statistical analysis was performed using SPSS 25.0 for Windows (SPSS). Changes were considered significant if \( P < .05 \). Data were presented as the mean ± SD.

## RESULTS

A total of 103 implants from 68 patients who gave their informed consent (32 men, 36 women, aged 60.2 ± 9.6 years) were enrolled in this study. Of these, 61 and 42 implants were placed with auto- and allo-DDM/rhBMP-2, respectively. Demographic factors (sex and age) and healing period were equally distributed between the grafts. The BMB heights of auto-DDM/rhBMP-2 were similar to those of allo-DDM/rhBMP-2 at all time points (Table 1).

A total of 29 and 32 implants were placed with auto-DDM/rhBMP-2, and 20 and 22 implants were placed with allo-DDM/rhBMP-2, on the mandible and maxilla, respectively. Total BMB resorption in all periods (T0 = initial, T1 = functional, and T2 = long-term resorption) were similar between the grafts regardless of the arch (Table 2). The total BMB resorption ranged between 0 and 2.3 mm in auto-DDM/rhBMP-2 and between 0 and 2.4 mm in allo-DDM/rhBMP-2.

### Histologic Analysis

All specimens were obtained from the mandible after 3 months of healing period. Both groups showed osteoinductive woven bone formation with the osteoblasts lining the surface of dentin particles (Figs 3a and 3b).

Histomorphometric analysis of 10 specimens (five from each group) revealed similar proportions of new bone (32.91% ± 12.63% and 35.73% ± 11.38%, \( P = .721 \)), and remaining DDM particles (4.73% ± 6.29% and 5.29% ± 4.26%, \( P = .875 \)) between auto-DDM/rhBMP-2 and allo-DDM/rhBMP-2, respectively (Table 3, Figs 3c and 3d).

## DISCUSSION

The demineralization procedure for manufacturing DDM not only enhances the bone healing potential but also has the same viral clearance effect. Allogeneic application of DDM was proven to be as effective and safe as auto-DDM.
in bone augmentation for dental implantation.\textsuperscript{23,29–31} In addition, many studies have demonstrated the effect of auto-DDM/rhBMP-2 in comparison with auto-DDM.\textsuperscript{6,14,18–20,32} However, the validation of allo-DDM/rhBMP-2 has not been reported in clinical research. The authors hypothesized that the effect of allo-DDM/rhBMP-2, in terms of the BMB around dental implants, was not inferior to that of auto-DDM/rhBMP-2, which has been shown to be effective compared with auto-DDM and Bio-Oss collagen for dental implants.\textsuperscript{6,10,23,32} This is the reason why the authors compare allo-DDM/rhBMP-2 to auto-DDM/rhBMP-2.

Both auto- and allo-DDM/rhBMP-2 showed similar BMB resorption at T0 to T2. In particular, the BMB resorption at T2 (0.29 and 0.20 mm) was more stable than at T0 (0.65 and 0.67 mm) and at T1 (0.55 and 0.59 mm) in auto- and allo-DDM/rhBMP-2, respectively (Table 2); the BMB resorption fell under the conventional success criteria, which is defined as bone loss of < 0.2 mm annually during T2.\textsuperscript{33} The arch and the source of DDM (allogeneic or autogenous) did not affect the initial, functional, or long-term resorption of BMB.

In terms of BMB resorption, many studies have been conducted on the effect of auto-DDM and auto-DDM/rhBMP-2. In 2018, a case series study showed better BMB results for auto-DDM/rhBMP-2 (0.27 mm) compared to auto-DDM (0.77 mm) at the T0 stage.\textsuperscript{23} Another prospective randomized controlled trial revealed that the average BMB resorption was not significantly different at the T0 stage between auto-DDM (0.97 mm), auto-DDM/rhBMP-2 (0.82 mm), and Bio-Oss Collagen (1.14 mm).\textsuperscript{32} Regarding autogenous bone, Kim et al\textsuperscript{34} showed BMB resorption of 0.74 and 1.67 mm at the T0 and T1 stages, respectively, after the autogenous bone graft. Moreover, BMB resorption has been known to occur the most in the first year, ranging from 0.9 to 1.65 mm with autogenous bone graft.\textsuperscript{35,36} Therefore, auto-DDM/rhBMP-2 has been proven to have favorable clinical outcomes compared to autogenous bone, auto-DDM, and Bio-Oss collagen. Compared to autogenous bone, which does not require demineralization, allogeneic bone grafts (DBM) have a lower osteogenic capacity during the antigenic process. Theoretically, however, auto-DDM and allo-DDM have the same efficacy because both DDMs undergo similar demineralization processes. Furthermore, Joshi et al\textsuperscript{37} reported in a randomized controlled pilot study for BMB resorption that allo-DDM showed better results (0.31 mm) than freeze-dried bone allografts (FDBA, 0.87 mm) and ungraft (1.96 mm) at the T0 stage. Um et al\textsuperscript{23} compared the BMB resorption at T0 (0.72 and 0.73 mm) and T1 (0.48 and 0.69 mm) stages on allo- and auto-DDM, respectively. Both studies indicated that allo-DDM could be as effective as auto-DDM, which is superior to FDBA or ungraft. To date, however, very few studies have added allo-DDM in relation to clinical applications, and the effect of allo-DDM/rhBMP-2 for dental implants was first revealed in this study.

In a histologic finding after 3 months in this study, both grafts similarly showed osteoinductive woven bone formation on the surface of dentin particles, and there was new bone formation with developing blood vessels (Fig 3). Histomorphometry showed similar new bone formation (32.91% and 35.73%) and remaining DDM particles (4.73% and 5.29%) in auto- and allo-DDM/rhBMP-2, respectively. In 2018, a histomorphometric report showed that approximately 39% of new bone formation was found in the auto-DDM/rhBMP-2 group, while 33% and 22% was found in the auto-DDM and xenograft groups (Bio-Oss collagen), respectively.\textsuperscript{32} A subsequent case series study in 2019 showed higher new bone formation of auto-DDM/rhBMP-2 than that of auto-DDM (34% and 29%, respectively) without statistical significance.\textsuperscript{15} In a previous preliminary report comparing allo-DDM to auto-DDM, both types of DDM particle were surrounded by newly formed osteoid without inflammatory cell infiltration or impingement of the connective tissue into the allo-DDM particles.\textsuperscript{18} Based on this rationale, the authors hypothesized that allo-DDM could be used as a rhBMP-2 auto-DDM carrier. The function of rhBMP-2 on DDM was postulated as particular incorporation and release kinetics, and rhBMP-2 showed dual release profiles from DDM due to the specific nature of collagen and microporous dentinal tubules in the dentin. In addition, endogenous BMPs in the dentin matrix are major contributing factors for a continuous concentration of BMP on the graft site for a sufficient period of time.\textsuperscript{14} Regardless of the origin of DDM (autogeneic or allogeneic), the present study revealed that rhBMP-2 loaded on DDM enhances osteoinductivity in clinical applications for dental implants.

There were some limitations to this retrospective study, such as different numbers of samples, small numbers of histologic specimens, and unequally distributed samples to the mandible and maxilla. The range of BMB resorption ranges from 0 to 2.3 mm in auto-DDM/rhBMP-2 and 0 to 2.4 mm in allo-DDM/rhBMP-2, which resulted in a large SD, which may have lessened the statistical power of these data. Even with the limitations of this study, allo-DDM/rhBMP-2 showed no severe complications and suitable clinical outcomes around dental implants in terms of BMB resorption. Further studies are required to validate the reduction in the healing period compared with allo-DDM alone.

**CONCLUSIONS**

The clinical outcomes of allo-DDM/rhBMP-2 were comparable to those of auto-DDM/rhBMP-2 on the BMB for dental implants during the second year after functional
loading. As a carrier of rhBMP-2, the validation of allo-DMM was confirmed by the clinical and histologic results for implant dentistry.

ACKNOWLEDGMENTS

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REFERENCES