**New Incision and Flap Designs in Autogenous Bone Ring Grafting with Simultaneous Implant Placement and an Evaluation of the Effect of First-Stage Wound Dehiscence in Dogs**

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**Purpose:** The aim of this study was to explore the effect of preventing first-stage wound dehiscence with new types of incision and flap design and to evaluate the effect of wound dehiscence on the bone resorption of the autogenous bone ring graft. **Materials and Methods:** In six beagle dogs, the second and fourth premolars on the bilateral mandible were extracted. After 3 months, on the left extraction sites, conventional alveolar crest incisions were made and the full-thickness flaps were elevated. However, on the right sites, the incisions were made at the mucogingival junction, the split-thickness flaps were elevated toward the lingual side, and the periosteum was elevated toward the buccal side. Then, Straumann implants (Ø 3.3, length 8 mm) were placed with simultaneous autogenous bone ring grafting. Next, the wounds on the left side were closed with periosteal releasing on buccal flaps conventionally, but the semi-thickness flaps on the right side were sutured with the elevated periosteum. After 3 months, the animals were euthanized, and the harvested samples were analyzed using microcomputed tomography and histology. **Results:** The incidence rate of wound dehiscence in the new incision group was 16.7%, which was significantly lower than that in the conventional incision group (75%). There was hardly any vertical bone loss of the bone ring in the samples without wound dehiscence, but in wound dehiscence samples, severe bone loss, 2.47 ± 0.17 mm, was found on the buccal side of the bone ring, which was significantly higher than that on the lingual, mesial, and distal sides, 1.37 ± 0.14 mm, 1.00 ± 0.15 mm, and 1.03 ± 0.05 mm, respectively. **Conclusion:** The use of a mucogingival junction incision and split-thickness flap design can effectively prevent first-stage wound dehiscence in autogenous bone ring grafting, which plays a key role in bone resorption of the graft. *Int J Oral Maxillofac Implants* 2020;35:721–730. doi: 10.11607/jomi.8010

**Keywords:** animal experiment, bone ring, incision design, vertical bone resorption, wound dehiscence

In oral clinics, an increasing number of patients with dentition defects receive dental implant treatment and obtain good masticatory function. However, bone defects of the alveolar ridge caused by periodontal disease, tooth loss, or trauma limit the application of implantation.¹ Therefore, several techniques of bone augmentation were developed to solve the problem; these techniques, such as guided bone regeneration (GBR),² autogenous block bone graft,³ distraction osteogenesis,⁴ and bone splitting,⁵ broaden the indications for dental implantation. Among them, based on its sensitivity, GBR is the most commonly used bone augmentation technique. However, the collapse and exposure of barrier membranes are the main complications of GBR,⁶ especially in vertical bone defects and large area bone defects. At this time, autogenous massive bone grafting seems to be more effective than GBR.

Autogenous bone ring grafting consists of an autogenous block bone graft in which an autogenous cortical bone ring is stabilized with a simultaneously inserted dental implant, which may solve the problem of vertical or three-dimensional alveolar bone defects and shorten the treatment period by at least 3 months. Several clinical cases have been reported in this field, and good osseointegration of the implants and the bone ring graft and clinical success were obtained.⁷⁸ Some animal research has confirmed that autogenous bone ring grafting with simultaneous implant placement is

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Vere swelling, and mucosal perforation.\textsuperscript{17} A prominent complication in the esthetic area was that the vestibular extension was introduced into autogenous bone ring grafting and improved to study whether it can effectively avoid first-stage wound dehiscence. Additionally, the bone resorption of the autogenous bone ring graft when first-stage wound dehiscence occurred was evaluated.

**MATERIALS AND METHODS**

**Animals**
The study was approved by the Ethics Committee of the West China College of Stomatology, Sichuan University in Chengdu, China (No. WCCSIRB-D-2014-041).

Six healthy male 1-year-old beagle dogs were fed separately. Food was provided to the dogs three times a day, while water was provided at all times. For each surgical treatment, the dogs were subjected to general anesthesia with pentobarbital sodium (IM, 30 mg/kg; Shanghai Qiaoxing Trading). All dogs received antibiotics (IM, 1 million units, penicillin potassium, Sichuan Jixing Animal Pharmaceutical) for 7 days after each surgery.

**Surgical Procedures**

**Tooth Extraction and Building an Alveolar Defect.** First, the second premolar (P2) and the fourth premolar (P4) on each side of the mandible were extracted. Then, the buccal bone plate and alveolar septum were removed, and ridge defects that were 8 mm long (mesiodistal), 3 mm high (apicocoronal), and 5 mm wide (buccolingual) were created in the extraction sites\textsuperscript{21,22} (Figs 1a and 1b).

**Generation of the Autogenous Bone Ring.** After 3 months of healing, bone rings—a round massive bone composed of cortical bone and a small amount of cancellous bone with a round hole in the center—were harvested before implants were placed. At the buccal region of the first molar, the full-thickness flap was elevated, and the bone plate was exposed. At an appropriate site, the trephine (internal diameter: 6 mm) was drilled 3 mm deep into the bone plate, and while the bone ring was still anchored in the bone, a circular hole with a diameter of 2.8 mm was made in the center of the graft with a round bur, pilot drill, and twist drill in succession (Fig 2a). Then, the bone ring, with a height of 3 mm and a diameter of 6 mm (exterior), was harvested with a periosteum stripper (Figs 2b and 2c).

**Incision and Flap Design.** On the left extraction sites of the mandible, incisions were made on the top of the alveolar ridge, and buccal and lingual full-thickness flaps were elevated (Fig 3a). The periosteal releasing incision was made at a level apical to the mucogingival sulcus depth would be reduced and the width of the keratinized tissue on the buccal aspect of the alveolus would be diminished for this buccal advanced flap.\textsuperscript{18} Some new methods were developed to solve these problems, for example, inverted double flaps, a new technology, with good closure of soft tissue.\textsuperscript{19} However, with this technology, the amount of periosteal release is limited. Therefore, new ways to solve the problem of soft tissue closure in massive bone grafting while reducing complications after surgery need to be explored.

Vestibular extension is an ancient technique used when the vestibular sulcus is too shallow to influence denture restoration,\textsuperscript{20} but this method is hardly used in dental implants. However, in this technological approach, the surface area of soft tissue will be extensively enlarged for a semi-thickness flap design, and the muscle will be released because the attachment of the buccinator or mentalis moves from the crest to the buccal side. These characteristics of this technique are very beneficial to reduce the tension of soft tissue during bone augmentation. Therefore, the technology of vestibular extension was introduced into autogenous bone ring grafting and improved to study whether it can effectively avoid first-stage wound dehiscence.

To be sure, the stability of bone ring graft is an important factor in the success of autogenous bone ring grafting; however, it is still not clear whether there are other factors involved.

Many studies have shown that first-stage wound dehiscence severely affects osteogenesis in bone augmentation.\textsuperscript{10} For example, a clinical study reported that wound dehiscence between stage-one and stage-two surgeries might increase alveolar bone loss in some cases.\textsuperscript{11} Some dentists also found that wound dehiscence was the main problem encountered with augmentation in oral surgery, with a reported incidence of 2.5% to 10%.\textsuperscript{12} Therefore, wound dehiscence is troublesome in the clinic, and it can carry a high risk of complications, such as wound infections, loss of the graft, or even implant failure.\textsuperscript{13} Whether wound dehiscence is the key factor influencing autogenous bone ring grafting requires further study.

Because wound dehiscence was the major complication in bone augmentation, with a reported incidence of 19.1%,\textsuperscript{14} methods to avoid this complication need to be studied. Although biologic and postsurgical considerations are very important, whether the incision can release the periosteum sufficiently is often the most important criterion for bone augmentation.\textsuperscript{15} Usually, an additional periosteal releasing incision is made at the buccal mucoperiosteal flap to achieve this goal.\textsuperscript{16} However, in massive bone grafting, because the common periosteal releasing incision cannot achieve sufficient soft tissue release, a deeper releasing incision, double incisions, or muscle release is required as a result of various complications, such as advanced bleeding, severe swelling, and mucosal perforation.\textsuperscript{17} A prominent complication in the esthetic area was that the vestibular sulcus depth would be reduced and the width of the keratinized tissue on the buccal aspect of the alveolus would be diminished for this buccal advanced flap.\textsuperscript{18} Some new methods were developed to solve these problems, for example, inverted double flaps, a new technology, with good closure of soft tissue.\textsuperscript{19} However, with this technology, the amount of periosteal release is limited. Therefore, new ways to solve the problem of soft tissue closure in massive bone grafting while reducing complications after surgery need to be explored.
junction with a depth of 1 mm. On the right extraction sites, incisions were made at the mucogingival junction on the buccal side; then, the split-thickness flap was elevated toward the lingual side, and the underlying periosteum and muscle fibers were raised toward the buccal side (Fig 3b, Figs 4a to 4c).

Implant Placement with Simultaneous Bone Ring Grafting. At the bone defect region, the alveolar bone was first prepared with a small trephine drill (external diameter: 6 mm) (Figs 5a and 5b). A bone ring was carefully transferred to the experimental site (Figs 5c and 5d) and held in position using the dental implant (Bone Level Implant SLActive, Ø 3.3 mm, length 8 mm, Straumann), with a requirement that the shoulder of the implant was flush with the upper edge of the bone ring. After the implant was inserted, a cover screw was placed on the implant to achieve submerged healing (Figs 5e and 5f).

Sutures. On the left side, the wounds were closed with interrupted sutures (Figs 3c and 3d). On the right side, the elevated semi-thickness flap was sutured with the raised periosteum on the buccal side with
interrupted sutures (Fig 4d), and the buccal submucosa and periosteum were exposed without a mucosa cover (Figs 3e and 3f). All sutures were removed 7 days after the operation.

Clinical Observation
After the surgery, the wounds in the cavities of the dogs were washed with normal saline once daily for 14 days without anesthesia. The appearance, behavior, reactivity, and social interaction of the dogs were observed during the entire experimental period. The wounds in the oral cavity were observed every day in the 2 weeks following the surgery, and wound dehiscence was registered without other treatment.

Sample Preparation
After 3 months, six dogs were euthanized using an intravenous overdose of pentobarbital sodium. The soft and hard tissues of the mandible were separated. The samples containing one implant were cut down at the mesial and distal edges, 3 mm distant to the implant, with a saw. Then, the harvested specimens were fixed in 4% paraformaldehyde for 24 hours and soaked in 75% ethanol for analysis.

Microcomputed Tomography Analysis
First, the samples were subjected to microcomputed tomography (micro-CT) scanning. The resolution was medium, and the scanning accuracy was 10 μm. The
buccolingual and mesiodistal sections through the middle of the buccal and lingual sides or the middle of the mesial and distal sides, respectively, were made, and on these sections, the distance from the shoulder of the implant to the upper margin of the bone on the buccal, lingual, mesial, and distal sides was measured as the vertical bone loss of the autogenous bone ring on each of the four sides. Photos of the buccolingual section (width: 6 mm) through the middle of the buccal and lingual sides of every sample were taken and compared.

**Histologic Preparation and Analysis**

The specimens were dehydrated for 24 hours with a sequence of 75%, 80%, 90%, 95%, and 100% ethanol and soaked in a mixture of 100% ethanol and methylmethacrylate resin (Technovit 4000, Heraeus Kulzer) at a ratio of 1:1 for 24 hours. Then, the samples were embedded in resin (Technovit 4000) and light-cured for 24 hours. The specimens were then sliced longitudinally and ground to a thickness of 40 to 50 μm with the Exakt cutting and grinding system (EXAKT 300CP/400CS). They were then stained with Stevenel’s blue and van Gieson’s picro-fuchsin (self-prepared) for histomorphometric analysis.

**Statistical Analysis**

The results of wound dehiscence were reported as the incidence rate, and the chi-square test was employed to estimate the difference between the two groups with different types of incisions and flap designs. In the statistical analysis of the vertical bone loss, the measurements were reported as the mean, standard deviation, and median. A normal distribution was not assumed with respect to the small sample size. Kruskal-Wallis nonparametric analysis of variance was employed to estimate the differences in the vertical bone loss over the four sides of the implant and between the two groups, those with or without wound dehiscence. The significance level chosen for all statistical tests was \( P \leq 0.05 \). The statistical analysis was processed using SPSS for Windows Release 19.0, standard version (IBM SPSS).

**RESULTS**

**Clinical Observation**

All six animals were healthy throughout the experimental period, and no implant or bone ring losses were observed (Fig 6a). On the first day after the surgery, a thin layer of white mucosal cell coverage was observed on the wound surface of the mucogingival incision, and after 7 days, normal mucosa formed without any inflammation. The dehiscent wounds were rinsed with normal saline three times a day without any other treatment. These wounds became smaller after 7 days, healed after 14 days, and finally, a small opening formed above the healing screw (Fig 6b). There was hardly any bone loss around the bone ring graft without wound dehiscence (Figs 6c and 6d), but vertical bone loss was obvious when wound dehiscence developed during bone ring grafting (Figs 6d and 6e).

In the group with an alveolar crest incision, no acute infection was observed, but the incidence rate of
wound dehiscence was 75%. In the other group with a mucogingival incision, similarly, no infection occurred, and the wound dehiscence incidence, 16.7%, was significantly lower than that of the group with an alveolar crest incision (Table 1).

**Table 1** Incidence of Wound Dehiscence of the Two Types of Incisions and Flap Designs

<table>
<thead>
<tr>
<th>Groups</th>
<th>Total number</th>
<th>Acute infection</th>
<th>Wound dehiscence</th>
<th>Incidence of wound dehiscence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveolar crest incision</td>
<td>12</td>
<td>0</td>
<td>9</td>
<td>75.0%*</td>
</tr>
<tr>
<td>Mucogingival junction incision</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td>16.7%*</td>
</tr>
</tbody>
</table>

*Statistically significant difference between the two groups.

Microcomputed Tomography Analysis

According to the buccolingual section of micro-CT scanning, when there was no wound dehiscence during bone ring grafting, the autogenous bone rings and implants integrated successfully, and there was little bone resorption on both the buccal and lingual sides (Fig 7a). However, bone resorption was severe in the group with first-stage wound dehiscence, especially on the buccal side (Fig 7b).

Through analyzing all samples with first-stage wound dehiscence regardless of the type of incision and flap design, the largest vertical bone loss of the bone ring was found on the buccal side, which was significantly higher than that on the lingual side; the smallest bone loss was found on the mesial and distal sides, which were almost equal, and there was a significant difference compared with that on the buccal or
lingual side. In the samples without wound dehiscence, there was hardly any vertical bone loss, and a significant difference was found on the four sides compared to that of the group with wound dehiscence (Table 2).

**Histologic Analysis**

According to the hard tissue slicing, in the group without wound dehiscence, the bone rings and implants had osseointegrated together well, and new bone was visible at the interface between the bone ring and the implant. In the bone ring, the Haversian canal was neatly arranged, images of the osteocytes were clear, and no obvious bone resorption or osteoclast cells were observed. The bone ring and the base alveolar bone had fully integrated together with a visible boundary (Figs 8a, 8c, 8e, and 8g). However, in the group with wound dehiscence, bone resorption was obvious at the upper edge of the implant, but the residual bone ring was still integrated with the implant and the base alveolar bone (Figs 8b, 8d, 8f, and 8h).

**DISCUSSION**

How to avoid wound dehiscence in massive bone augmentation is still an issue for dental clinicians. The most commonly used method to solve the problem is a buccal advanced flap with a periosteal releasing incision.
The results of histologic analysis. (a, c, e, g) The vertical hard tissue sections were magnified 10, 20, 40, and 100 times for the bone ring graft sample without wound dehiscence. (b, d, f, h) The vertical hard tissue sections were magnified 10, 20, 40, and 100 times for the bone ring graft sample with wound dehiscence.
Unfortunately, of the 12 samples using this method in the present experiments, 75% of the wounds still developed dehiscence. From the analysis, one of the possible reasons was the high attachment of the buccinator of the dogs to the top of the alveolar crest with a huge pulling force. Of course, another likely cause was that the dog’s behavior was uncontrollable. However, the most likely cause was that the periosteal releasing incision was not deep enough to relax the tension. Some scholars believe that the buccal flap margin might cover the lingual or palatal site at least 3 to 5 mm; otherwise, there is excess tension in the flap, which means that the closure is insufficient. If overlapping does not occur, muscle release should be performed using dissection scissors. However, if the muscle was released, massive bleeding and postoperative hematoma would follow, which was why it was less used in people.

When the incision was made at the level of the mucogingival junction, the split-thickness gingival flap was raised toward the lingual side, and the underlying flap containing the periosteum and muscle fibers was elevated toward the buccal side. As a result, the full-thickness mucogingival flap was divided into two layers. The buccal margin of the upper semi-thick flap could be sutured with the lingual margin of the underlying flap, providing several advantages. First, the space covered by soft tissue to accommodate the bone graft was enlarged. Second, the attachment point of the buccinator was displaced from the alveolar crest to the buccal side, and the pulling force of the buccinator was relieved to some extent. Third, the vestibular sulcus was extended passively, which was very important for the esthetic area, even if the wound dehiscence incidence was reduced due to good postsurgical management of wounds in humans. According to the present study, only 2 of the 12 samples developed wound dehiscence using this type of incision and flap design, which verified that this technology can effectively prevent wound dehiscence during autogenous bone ring grafting. After analyzing the cause of failure in the two samples, periosteal releasing incisions could possibly be made on the lingual flap to release more tension.

It was not clear whether the exposed submucosa and periosteum on the buccal side in this mucogingival junction incision and suture design needed treatment or not. A similar condition occurred in the traditional vestibular extension, and it healed naturally without any treatment. The same results were found in the present experiments, and usually the mucosa healed completely within 7 days. Otherwise, to increase the buccal keratinized gingiva of the implant, the exposed surface of the submucosa and periosteum was a good site for keratinized gingiva acceptance. On the other hand, with the progress of bioengineering, an increasing number of biomaterials can be used to cover these mucosal wounds.

Although wound dehiscence during stage-one surgery wounds hardly develop into an acute purulent infection, many complications occur, especially when bone augmentation is applied, such as vertical bone loss, graft loss, and gingival recession. On the basis of the present experiments, wound dehiscence was a very important factor that influenced the resorption of the bone graft around the implant. As long as the cover screw was exposed during osseointegration, the vertical bone resorption would eventually significantly increase, even though no obvious infection developed. A clinical study reported that wound dehiscence between the stage-one and stage-two surgeries might increase crestal bone loss in some cases and could be reduced by professional follow-up sessions and antibacterial treatments. Many studies have verified that lipopolysaccharide (LPS) can induce bone resorption, and wound dehiscence can induce bacterial colonization and LPS production.

Another interesting result of the present experiments in the samples with wound dehiscence was that the largest vertical bone loss of the bone ring graft was found on the buccal side, followed by the lingual side, and the smallest was found on the mesial and distal sides. In cases of wound dehiscence, the bone ring could still integrate with the lower base alveolar bone and implants. These results indicated that soft tissue coverage of the graft, on one hand, can avoid the invasion of bacteria and, on the other hand, can provide a blood supply for the graft. When wound dehiscence occurred, the bone ring could only obtain a blood supply from lower, mesial, and distal natural bone, and the upper and buccal part of the bone ring would develop necrosis due to ischemia.

CONCLUSIONS

The use of a mucogingival junction incision and split-thickness flap design can effectively prevent first-stage wound dehiscence in autogenous bone ring grafting, and wound dehiscence plays a key role in bone resorption of the autogenous bone ring graft.

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