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Randomised Clinical Trial, Pre-Implant Surgery

Staged horizontal bone augmentation for dental implants in aesthetic zones: A prospective randomized controlled clinical trial comparing a half-columnar bone block harvested from the ramus versus a rectangular bone block from the symphysis

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Abstract. In this study, the clinical outcomes of horizontal ridge augmentation using half-columnar bone grafts from the ramus (group I: 27 patients, 32 implants) versus rectangular bone grafts from the symphysis (group II: 19 patients, 27 implants) were compared; grafts were combined with organic bovine bone and collagen membrane. Cone beam computed tomography images were obtained preoperatively, immediately after restoration (baseline), and 1 year after loading. Four months after grafting, horizontal bone resorption at the alveolar crest did not differ significantly between the two groups ($P = 0.291$). At 4 mm apical to the alveolar crest, horizontal bone resorption in group I was significantly less than that in group II ($P = 0.041$). One year after loading, horizontal bone resorption in group I was lower than that in group II, with no significant difference. The residual thickness of the labial bone at the implant site in group I was significantly higher than that in group II. Horizontal ridge

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augmentation with either a half-columnar autogenous graft from the ramus or a rectangular autogenous graft from the symphysis can provide acceptable results in aesthetic regions. The half-columnar group demonstrated better graft stability both at 4 months after augmentation and 1 year after loading.

Keywords: Onlay; Bone grafts; Half-columnar; Aesthetic zones.

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Introduction

Critical alveolar ridge defects may occur following tooth loss, fracture, or pathological processes. Such defects may compromise ideal implant placement and result in unfavourable outcomes after further prosthetic construction. Different methods have been attempted for ridge augmentation, among which autogenous bone block grafting is an important method because of its advantages, including better biocompatibility and osteogenic potential.[1,2] However, there is no perfect technique at this time. A particulate autogenous graft heals quickly, but also resorbs quickly, while a bone block graft has the problem of poor adaptation between the recipient bed and graft, which leads to a longer healing time and lower success rate.

Dentists typically harvest a rectangular-shaped bone block for onlay grafting to repair alveolar defects. As an alternative to this approach, the present study proposes an onlay bone grafting procedure performed by harvesting a standardized half-columnar block with a trephine form cutter and grafting to a standardized recipient bed that is also created with a form cutter. The preparation of the recipient site using a cylindrical drill of the same diameter as that used to harvest the half-columnar block ensures a perfect fit between the graft and recipient bed, thus promoting faster healing and better clinical outcomes. The mandibular ramus and symphysis are the most commonly used intraoral donor sites for autogenous augmentation.[3] The mandibular ramus is located at the back of the oral cavity and is continuous with the external oblique line, from where a half-columnar bone block can be conveniently harvested using a straight hand-piece and a trephine. Conversely, the symphysis is located at the front of the oral cavity and has a flat morphology, from where a rectangular-shaped bone block can be simply harvested using piezoelectric surgery or a micro-saw. No previous study has compared these techniques in a prospective clinical trial. Therefore, the purpose of this study was to compare the operability, amount of bone gain, and bone graft volumetric stability of a half-columnar bone block grafting technique from the ramus versus a rectangular bone grafting technique from the symphysis, for horizontal ridge augmentation in aesthetic zones.

Materials and methods

Study population

Based on preliminary results, the bone graft resorption of the two groups was expected to differ by 0.55 mm. The number of study subjects required was determined using a 5% statistical significance level, a power of 90%, and a standard deviation of 0.63 mm; the number of patients required in each group was calculated to be about 22.56.

Consecutive patients who required dental implant restoration at the Second Dental Centre of Peking University School and Hospital of Stomatology, Beijing, China, from January 2010 to June 2015, were enrolled and examined using cone beam computed tomography (CBCT). Twenty-seven patients (32 implants) in group I and 19 patients (27 implants) in group II were included in the final analysis. The study process and phases are shown as a flowchart in Fig. 1, according to the CONSORT standards for reporting clinical trials.

The inclusion criteria were a tooth missing in the anterior zone of the maxilla or mandible, presence of an obvious horizontal alveolar ridge defect, a remaining alveolar ridge width $\geq$3 mm and $<$5 mm (according to the preoperative CBCT scans), and the absence of any systemic disease that would contraindicate surgery under local anaesthesia or affect bone healing. The exclusion criteria were a remaining alveolar ridge width $<$3 mm, type I bone density (Lekholm and Zarb classification), acute or chronic infections at the recipient site, bone grafting history, smoking $>$10 cigarettes per day, and patient refusal for an autogenous bone graft.

A single-institution randomized comparative clinical study was designed and implemented. The included subjects were allocated randomly to two groups. A random number was computer-generated for each patient: if the number was odd, the patient was included in group I; if the number was even, the patient was included in group II. Group I patients underwent horizontal ridge augmentation with a standardized half-columnar block harvested from the ramus, and group II patients underwent augmentation with a rectangular bone graft from the symphysis.

This study was approved by the Institutional Review Board of Peking University School and Hospital of Stomatology. All patients understood the surgical procedure and signed an informed consent agreement. The guidelines of the Declaration of Helsinki were followed in this investigation.

Surgical bone grafting procedure

Prior to surgery, the patients received prophylactic antibiotics (500 mg amoxicillin or 150 mg erythromycin in the case of a penicillin allergy). In group I, after incision and flap elevation, the recipient bed was prepared in the form of a half-columnar concavity using a cylindrical drill, in order to adapt the bed to the half-columnar bone graft and also to facilitate the release of growth factors and platelets from the recipient bed to the bone graft. The donor site ranged from the external oblique ridge buccal to the lower second molar to the lateral aspect of the ramus. A standardized half-columnar block was harvested using a trephine form cutter that had the same diameter as the cylindrical drill used to prepare the recipient bed. The diameter of the half-columnar bone graft depended on the dimension and morphology of the bone defect in the recipient bed (Fig. 2). The length of the bone graft depended on the vertical location of the inferior alveolar nerve; this was usually no longer than 10 mm, to prevent nerve injury. A tooth elevator was used to gently separate the bone graft from the donor site.

In group II, the labial cortical plate at the recipient site was perforated using a small round bur to expose more cancellous bone. The mandibular symphysis was exposed using a vestibular incision in the inter-canine region. The osseous cuts were made using piezoelectric surgery (Piezotome; Acteon Equipment, Merignac, France) or a micro-saw (Hager & Meisinger GmbH, Neuss, Germany) in a

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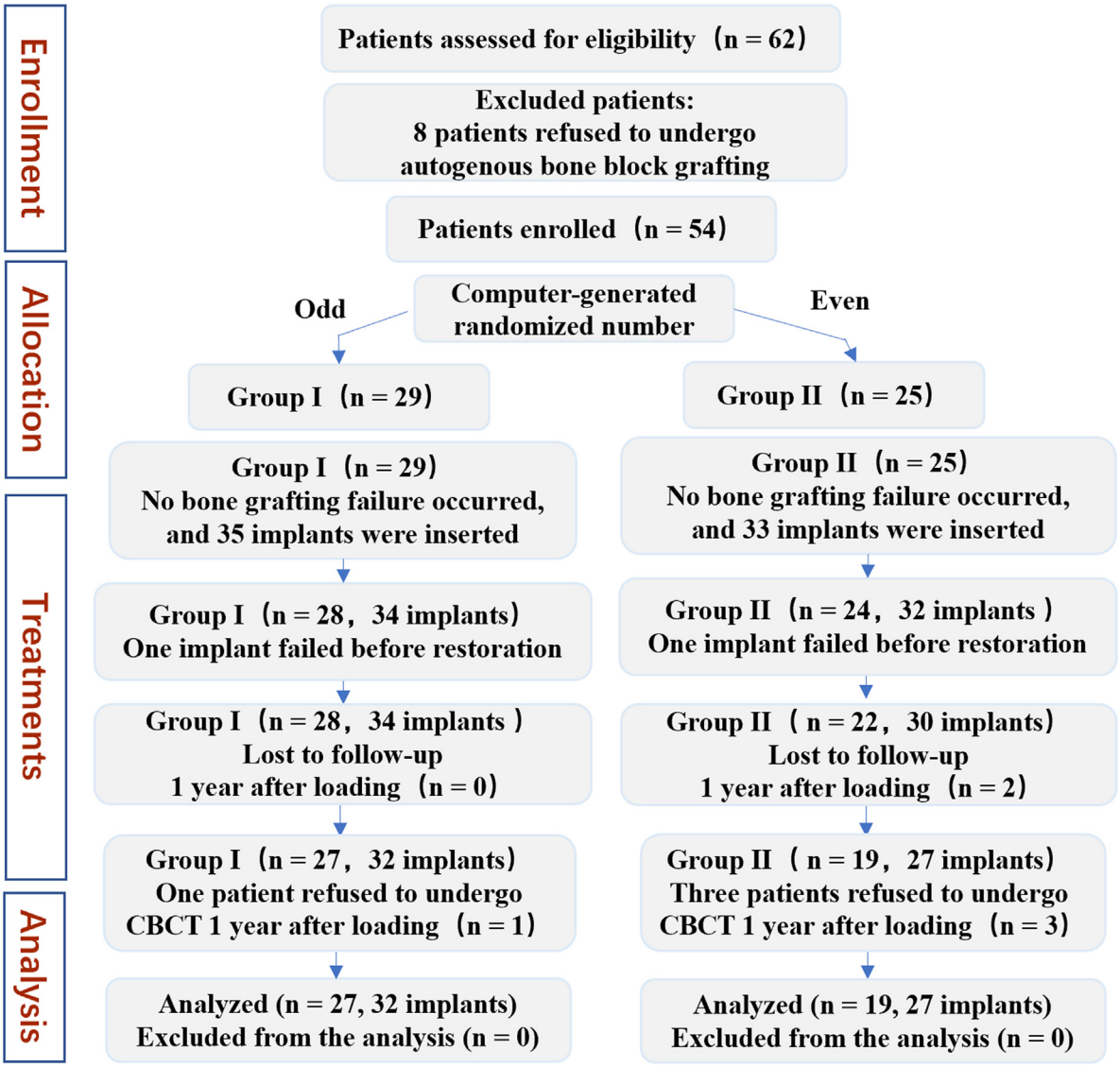

Fig. 1. CONSORT flow diagram.

surgical hand-piece, and the bone graft was detached from the donor site using a sharp bone chisel (Hu-Friedy Manufacturing Co., LLC, Chicago, IL, USA). The dimension of the graft was determined by including a 5-mm safety margin below the apices and a 5-mm thickness at the lower border of the mandible, while considering the size of the bone defect at the recipient site (Fig. 3).

In all cases, the harvested bone graft was fixed in the recipient bed and secured using a titanium screw, smoothed using a round bur to remove sharp edges, and covered with particulate bovine bone (Bio-Oss; Geistlich Pharma AG, Zurich, Switzerland) and a collagen membrane (Bio-Gide; Geistlich Pharma AG). The flap was released with periosteal incisions and the wound fully sealed with horizontal mattress and interrupted sutures. All patients were instructed to use oral antibiotics (amoxicillin and tinidazole) for 6 days and 0.2% chlorhexidine as a mouthwash three times daily for 2–3 weeks. Following a healing period of 4 months after augmentation, the recipient site was reopened and the healing status of the bone graft was observed. The titanium screw was removed and a Straumann SLA implant (Straumann AG, Basel, Switzerland) was inserted in a second-stage procedure.

The standard surgical protocols for bone grafting and implant insertion were performed by three surgeons who had received standardized training. Immediately after bone grafting, the surgeons were asked to fill out a questionnaire regarding the degree of complexity of the surgery. The duration of the surgery was also recorded.

Clinical evaluation

Before, immediately after, and 4 months after the augmentation, each recipient site was measured intraoperatively using a Vernier calliper. All measurements were performed using specialized measuring stents, which had a notch at the midline of the edentulous space to ensure that each measurement could be performed at the same location through the notch during the different visits (Fig. 4). The following areas of the patient recipient sites were measured: (1) the distance between the top of the stent and the preoperative alveolar

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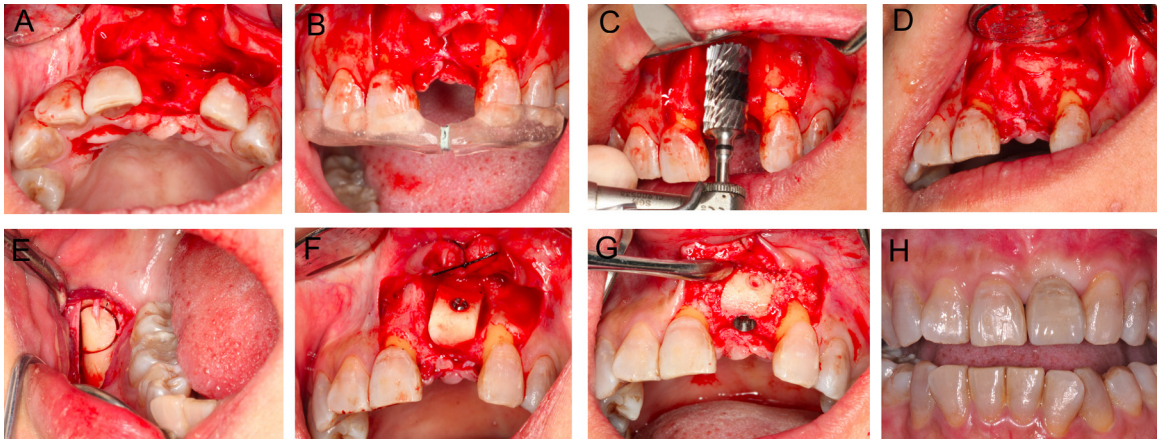

Fig. 2. The case of a patient who underwent autogenous bone grafting with a half-columnar bone block harvested from the ramus: (A) the patient had an obvious horizontal bone defect in the upper incisor region; (B) a measuring stent was used for measurement; (C) a cylindrical drill was used to prepare the recipient site by forming a bed with a concave morphology; (D) the prepared recipient site; (E) a half-columnar bone block was harvested using a trephine bur; (F) the bone graft was fixed with a titanium screw; (G) 4 months after bone augmentation, an implant was inserted; (H) the final restoration.

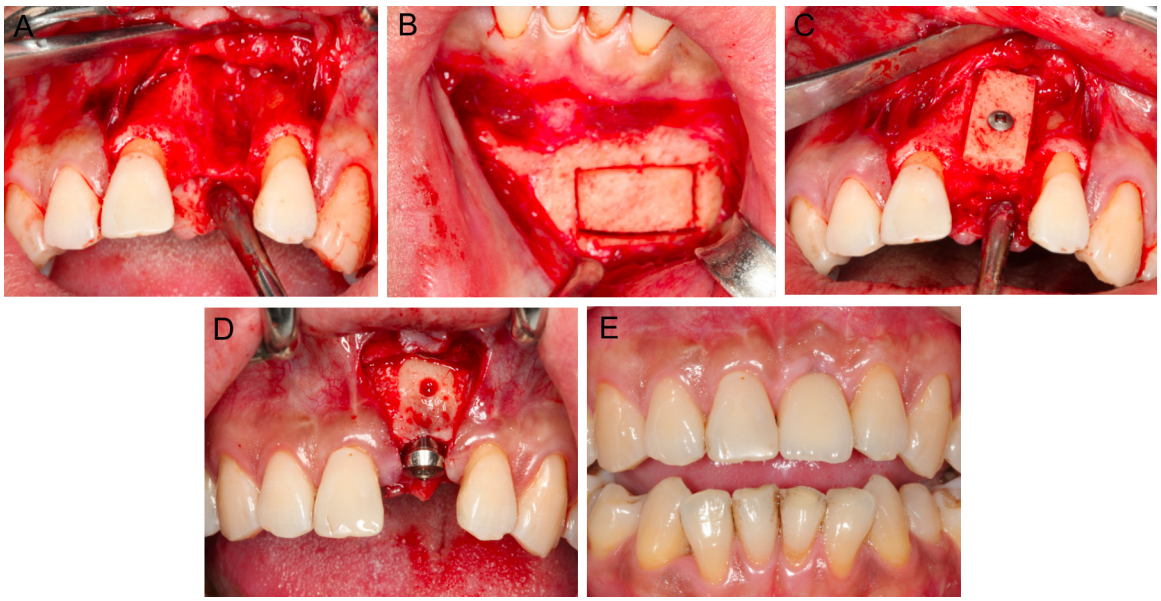

Fig. 3. The case of a patient who underwent autogenous bone grafting with a rectangular-shaped bone block harvested from the symphysis: (A) the patient had a horizontal bone defect at an edentulous site; (B) a rectangular bone graft was harvested using piezoelectric surgery; (C) the bone graft was fixed with a titanium screw; (D) 4 months after bone augmentation, an implant was inserted; (E) the final restoration.

crest, which was defined as parameter 'A', (2) the ridge thickness at A mm apical to the stent top, which was defined as the 'ridge thickness at the level of the initial alveolar crest' (parameter 'B'), and (3) the ridge thickness at A + 4 mm apical to the stent top, which was defined as 'the ridge thickness 4 mm apical to the initial alveolar crest' (parameter 'C') (Fig. 5). Pre- and postoperative measurements were compared, and the amounts of bone gain after bone grafting and early bone resorption during the healing period were calculated.

Radiographic examination

After suprastructure restoration, there was no need to reopen the flap according to routine clinical procedures; therefore, bone resorption immediately after restoration (baseline) and at 1 year after loading was evaluated with the aid of CBCT. Moreover, the residual thickness of the labial bone plate was also measured at the implant sites 1 year after loading. The changes in the peri-implant bone were observed and recorded by an independent investigator who was unaware of the patient group allocations. To ensure that the CBCT measurements were performed at the same intraoral location for each patient, measurement stents were attached

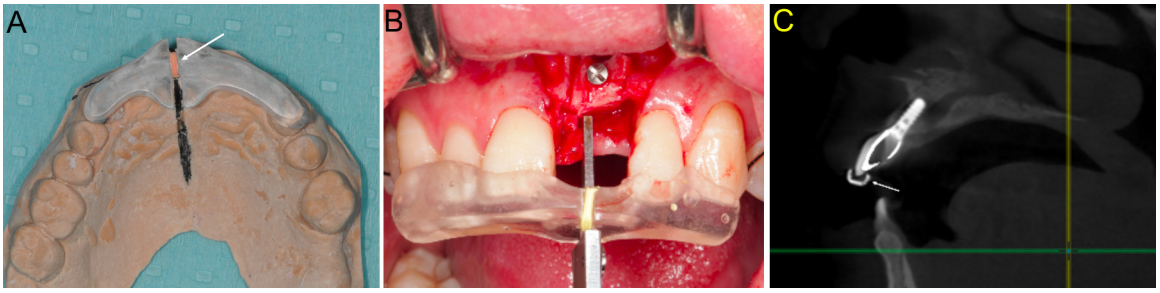

Fig. 4. Intraoral and cone beam computed tomography (CBCT) measurements were performed using a stent: (A) the stent has a notch at the midline of the edentulous space where radiopaque gutta-percha is attached; (B) each intraoral measurement could be performed at the same location through the notch during different visits; (C) each CBCT measurement could be performed in the plane of the developed gutta-percha. The arrow points to the developed gutta-percha on CBCT.

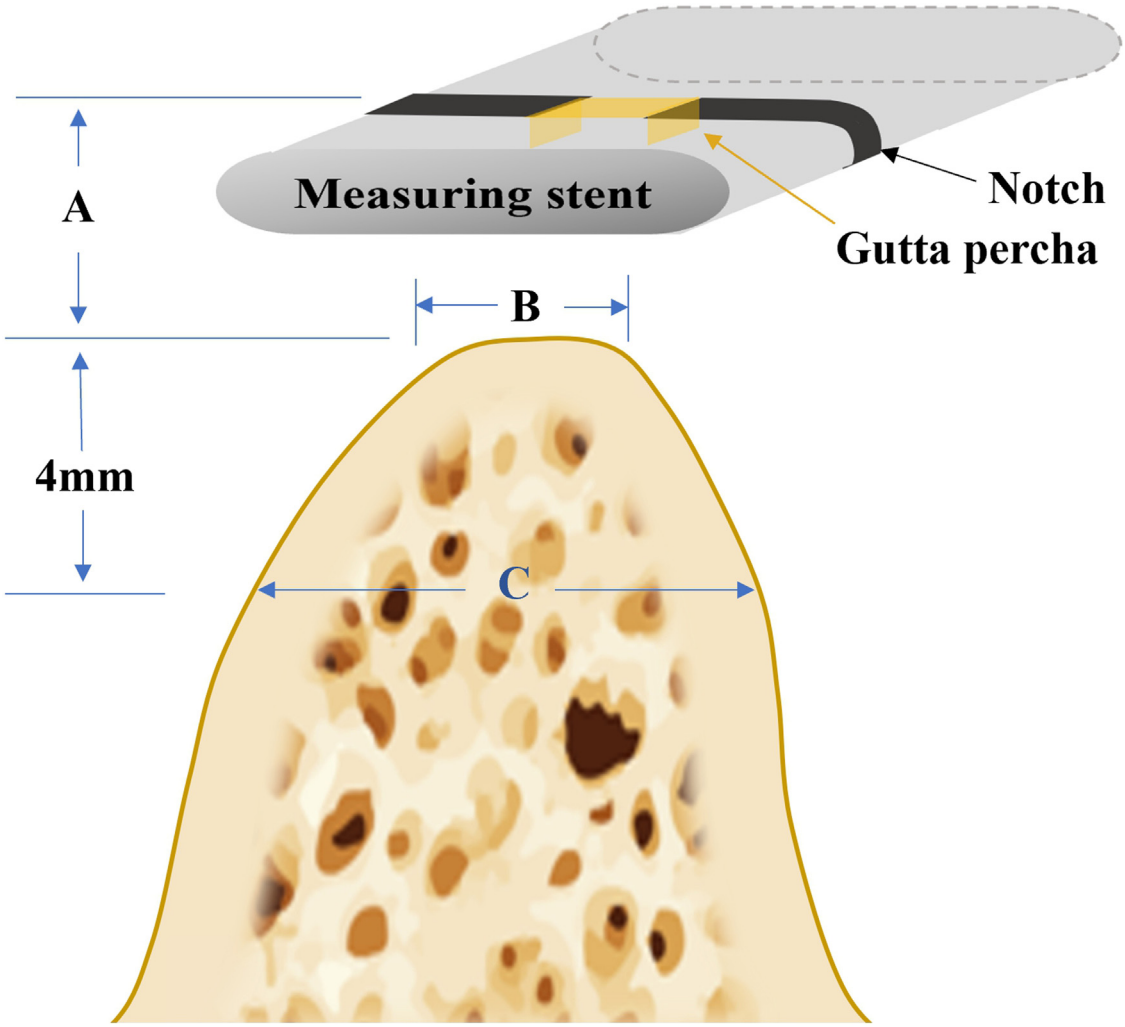

Fig. 5. Measurement method with the aid of the stent. To ensure that the CBCT measurements were performed at the same intraoral location for each patient, measurement stents were attached using radiopaque gutta-percha in the notch and were worn by each patient during CBCT scanning. 'A' represents the distance between the top of the stent and the preoperative alveolar crest; 'B' represents the ridge thickness at A mm apical to the stent top; 'C' represents the ridge thickness at A + 4 mm apical to the stent top.

using radiopaque gutta-percha in the notch and were worn by each patient during CBCT scanning. Each CBCT measurement could be performed in the plane of the developed gutta-percha (Fig. 4C).

Statistical methods

IBM SPSS Statistics software (version 19.0; IBM Corp., Armonk, NY, USA) was used to analyze the data. Mean values and standard deviations were calculated for the measured data. Levene's test was applied to test the homogeneity of variance assumption, and then the independent samples *t*-test was used to compare

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groups I and II. The level of significance was set at 0.05.

Results

Characteristics of the included subjects

One case in group I and two cases in group II experienced wound dehiscence after the onlay bone grafting. With the use of a connective tissue or keratinized gingival graft combined with chloride rinse, the wound dehiscence healed in these three patients. At 4 months after bone grafting, the three cases appeared to have more resorption of the bone graft than the other cases, but no bone sequestration or bone migration was observed. Four cases had numbness of varying degree, and all of them were from group II. One patient had numbness in the chin skin for at least 6 months and also paraesthesia in the lower anterior teeth and gingiva even at 3 years after the suprastructure restoration. Another patient had numbness in the chin for 4 months. The other two patients had paraesthesia when they brushed or touched their lower anterior teeth lasting at least 1 month. Almost all of the patients in the two groups had postoperative swelling and pain for about 3–7 days. Two implants failed before restoration, one in a patient in group I and one in a patient in group II. On the visit for impression, the two implants were found to be loose because of osseointegration failure and were removed. Four months later, re-insertion was performed combined with guided bone regeneration (GBR). These two cases were excluded from the final analysis.

Forty-six patients (29 male and 17 female aged 18–61 years, with a mean age of 37.8 years) and 59 implants were included in the final analysis (Fig. 1, Table 1). There was no statistically significant difference between groups I and II regarding the patient age and sex distribution.

Operability of the two bone grafting techniques

The average duration of bone graft surgery was 78.6 ± 21.2 min in group I and 83.7 ± 35.9 min in group II, with no statistically significant difference between the groups ($P = 0.736$). The postoperative questionnaire filled out by the surgeons demonstrated that they believed that the degree of complexity was similar for the two techniques. In cases that underwent bone grafting from the symphysis, the donor site was more easily accessible, as it is positioned in the anterior region of the mandible. In cases that underwent half-columnar bone grafting from the ramus, the shapes of the harvested bone blocks better fit the morphology of the recipient bed, and thus the bone grafts were placed and rigidly fixed more easily.

Bone gain after bone grafting

The average sizes of the harvested bone blocks in groups I and II are given in Table 2. Horizontal bone gain values immediately after bone grafting in groups I and II are reported in Table 3. No significant difference was observed between the two groups.

Early resorption of the bone graft

When the recipient site was reopened 4 months after bone augmentation, bone graft healing was satisfactory in all 46 cases, but all of them demonstrated varying degrees of early bone resorption. The amount of horizontal resorption at the initial alveolar crest was greater than 4 mm apically. At the initial alveolar crest level, the horizontal resorption in group I (0.59 ± 0.69 mm) and group II (1.13 ± 1.6 mm) did not differ significantly ($P = 0.291$). At 4 mm apical to the initial alveolar crest, horizontal resorption in group I (0.03 ± 0.96 mm) was significantly lower than that in group II (0.87 ± 1.16 mm) ($P = 0.041$) (Fig. 6A).

Resorption amount 1 year after loading

When comparing the CBCT images acquired 1 year after loading with those acquired at baseline, the results showed that, at the level of the initial alveolar crest, horizontal bone resorption in group I (0.24 ± 0.89 mm) was lower than that in group II (1.25 ± 1.01 mm), but the difference was not statistically significant ($P = 0.249$). At 4 mm apical to the initial alveolar crest, horizontal bone resorption in group I (0.20 ± 0.72 mm) was lower than that in group II (0.75 ± 0.63 mm), although this was also not statistically significant ($P = 0.268$) (Fig. 6B).

The residual thickness of the labial bone plate at the implant site in group I was significantly higher than that in group II at

Table 1. Main patient and implant characteristics.

Parameters	Group I ($n = 27$)	Group II ($n = 19$)	Total
Female/male	10/17	7/12	17/29
Age at inclusion (years), mean (range)	37.2 (18–59)	38.4 (22–61)	37.8 (18–61)
Mean residual bone width (mm)	3.4	3.7	3.5
Placed implants, *n*	32	27	59
Failed implants, *n*	1	1	2

Table 2. Sizes of the harvested bone block grafts.

	Group I			Group II		
	Diameter (mm)	Thickness (mm)	Length (mm)	Width (mm)	Thickness (mm)	Length (mm)
Average	6.6	3.9	8.8	6.4	4.3	9.3
Minimum	5	3	5	4.5	3	4.5
Maximum	7.5	6	13	8	7	22
SD	0.7	0.8	2.3	1.0	1.23	4.7

SD, standard deviation.

Table 3. Increase in bone thickness at the recipient site immediately after bone grafting.

	Horizontal bone gain (mm)			
	At the level of the initial alveolar crest		4 mm apical to the initial alveolar crest	
	Group I	Group II	Group I	Group II
Average	3.9	3.3	3.9	3.5
Minimum	2.3	1.9	1.9	1.9
Maximum	6.3	4.6	8	6.8
SD	1.6	1.8	1.4	1.7
t-test ($P = 0.05$)	$P = 0.301$		$P = 0.404$	

SD, standard deviation.

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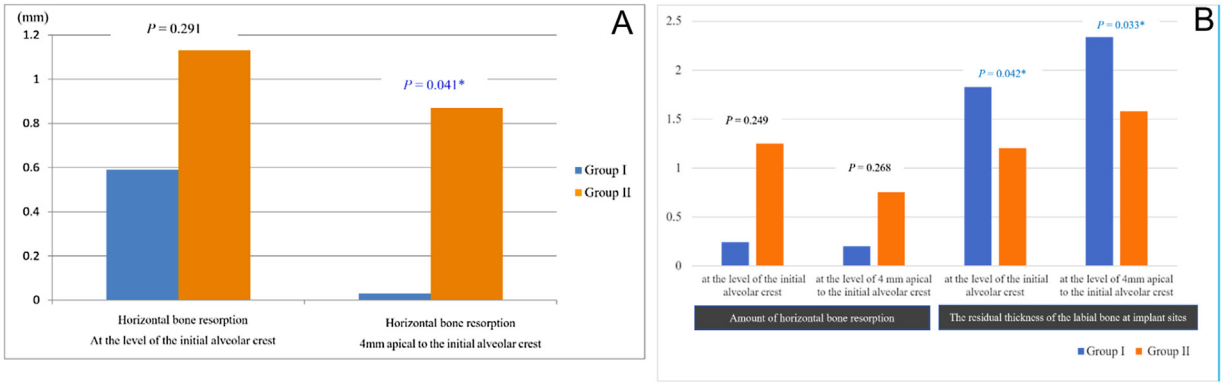

Fig. 6. (A) Early resorption of the bone graft in the horizontal dimension. (B) The amount of resorption and residual thickness of the labial bone plate at the implant site 1 year after loading. The asterisk (*) indicates a statistically significant difference.

the level of the initial alveolar crest (1.84 ± 0.45 mm vs. 1.20 ± 0.34 mm; $P = 0.042$) and at 4 mm apical to the initial alveolar crest (2.35 ± 0.37 mm vs. 1.58 ± 0.46; $P = 0.033$) (Fig. 6B).

Discussion

GBR, bone splitting, alveolar distraction, and autogenous bone block grafting are the most common methods used for bone augmentation in oral implantology.[4,5] Autogenous bone is still considered the gold standard for the repair of bone defects because of its osteoinductive, osteoconductive, and osteogenic properties.[1] An autogenous bone block has better mechanical strength than particulate bone, and thus demonstrates superiority in the repair of severe horizontal bone defects with flat bony arch morphology and vertical defects. Autogenous bone block grafting is considered the preferred modality for repairing Terheyden 2/4 and 3/4 type bone defects.[6] However, a bone block graft has the problem of poor adaptation with the recipient bed, which may lead to a longer healing time and lower success rate.

GBR by means of semipermeable barriers has been reported as a reliable technique for ridge reconstruction.[7–9] Buser et al. reported a gain of bone formation varying between 1.5 mm and 5.5 mm.[7] The contained single tooth gap type of bone defect can also be treated by simultaneous implant placement with GBR, especially when small bone defects such as fenestrations or dehiscence around oral implants are present.[10] However, relevant experience regarding GBR has been reported mostly for limited defects.[7,9,11] In the case of larger defects or 'knife-edge' formed ridges, it is advisable to use autogenous bone blocks.[10] An advantage of corticocancellous bone blocks is that the cortex facing buccally creates very favourable conditions for implant insertion and stability. In contrast, in the case of GBR, the outer aspect of the regenerated tissue after the removal of the membrane is not always as dense as in the case of block grafting.[10] In the present study, most residual ridges could not provide enough primary stability and an ideal insertion angle for the implants, so autogenous blocks were selected.

Intraoral donor sites include the mandibular ramus, symphysis, maxillary tuberosity, and zygoma.[12] The mandibular ramus and symphysis are considered the most common donor sites for autogenous augmentation because of the low absorption rates after bone grafting.[3,13] Some studies have reported the clinical outcomes of autogenous block bone grafting performed using different methods, but these have yielded contradictory results. Different surgical protocols, loading protocols, and follow-up time-points may be the reasons for the conflicting results.[14]

The present study was designed as a single-institution prospective randomized controlled trial to compare bone augmentation using a standardized half-columnar bone block harvested from the ramus versus a rectangular bone block from the symphysis, combined with organic bovine bone and a collagen membrane. A few studies have reported that vertical alveolar augmentation conveys an increased risk of bone resorption and postoperative complications.[4,15–17] Therefore, all of the patients included in this study underwent horizontal augmentation in the anterior region to ensure comparability and uniformity of the results.

Resorption of an autogenous bone block graft is one of the most frequently reported complications,[4] which is ascribed to the remodelling process during the bone healing period.[18] Nyström et al.[19] reported that substantial bone graft resorption occurs in the first 6 months after surgery, which slows after 6 months and does not continue to an evident extent after 12 months. Jensen and Terheyden[18] reported that 2.8% of cases still required secondary bone grafts because of postoperative resorption. The dentist usually needs to perform excessive bone grafting to compensate for the resorption. Therefore, the stability of autogenous bone grafts is a key point of concern for many dentists. Chiapasco et al.[14] reported that the resorption rate is 20–50% when a bone block graft is performed alone. von Arx and Buser[20] used block grafts harvested from the symphysis or retromolar area, combined with organic bovine bone mineral and a collagen membrane, to repair horizontal ridge atrophy; the results showed that the mean gain in ridge thickness was 4.6 mm, with a mean graft resorption of 0.36 mm at 5.8 months after augmentation. However, no data with respect to the two donor sites were reported. In the present study, the early horizontal resorption (4 months after bone grafting) in group I was significantly less than that in group II at 4 mm apical to the alveolar crest. One year after loading, group I also exhibited less horizontal bone resorption than group II, although no significant difference was found. Moreover, the residual thickness of the labial bone plate at the implant site in group I was significantly higher than that in group II. The group that underwent half-columnar grafting from the ramus appeared to demonstrate better bone graft stability.

To investigate why half-columnar grafting from the ramus exhibited better graft stability, the following factors that are known to affect autogenous bone graft resorption were analyzed: (1) the embryonic origin of the graft (intramembranous bone grafts have minimal resorption compared with endochondral bone grafts),[15] (2) cortical/cancellous ratio,[15,21] and (3)

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adaptation of the bone grafts to the recipient sites.[6] The ramus and symphysis are both intramembranous bones, but a large majority of grafts from the ramus are cortical bone and those from the symphysis are corticocancellous bone. Cortical bone has better mechanical strength to maintain the graft volume and transfer biting forces after loading.[21,22] Moreover, adaptation of the bone graft to the recipient site is critical for incorporation of the graft and recipient bed.[4] Incorporation is a process in which the bone tissue from the recipient site grows into the bone graft and then forms Haversian systems. Bone tissue migrates into the bone graft smoothly only if the bone graft is in close contact with the recipient site, which is also beneficial for graft revascularization.[6] In group I in the present study, a standardized half-columnar block from the ramus was harvested using a trephine form cutter and grafted to a standardized recipient bed that was also created with a form cutter. The graft fit the recipient bed closely because the outer diameter of the cylindrical drill used to prepare the recipient bed was equal to the inner diameter of the trephine form cutter used to harvest the bone graft.

Moreover, intimate contact further improves bone graft stability and consequently prevents vascular injury caused by micromotion of the bone graft. However, bone grafts in group II were detached from the donor sites using a bone chisel, which would result in an irregular contact surface with the recipient bed, inevitably inducing micro-gaps between the graft and the recipient bed and thus obstructing the incorporation process and decreasing graft stability. Tamimi et al.[23] emphasized that micromotion at the graft–recipient interface might increase the rate of graft resorption. However, group I differed in two aspects at the same time when compared to group II, including the origin of the bone graft (dense ramus versus less dense symphysis) and the form cutter technique which creates a better graft adaptation. The aspect that is primarily responsible for the observed effect needs to be determined in future studies.

Within the limitations of this study, it can be concluded that horizontal ridge augmentation in aesthetic regions can provide acceptable clinical results with either an autogenous half-columnar graft from the ramus or a rectangular graft from the symphysis. However, the group that underwent half-columnar grafting appeared to demonstrate better bone graft stability both at 4 months after augmentation and 1 year after loading.

Funding

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Competing interests

We have no competing interests.

Ethical approval

Ethical approval was given by the Medical Ethics Commission of the Peking University School and Hospital of Stomatology (PKUSSIRB-2015220032).

Patient consent

Written patient consent was obtained.

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