

# Cone Beam Computerized Tomography Measurement of Alveolar Ridge at Posterior Mandible for Implant Graft Estimation

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Damaging the inferior alveolar nerve (IAN) is the most serious complication when harvesting an autogenous graft from posterior mandible. The objective of this study was to use cone beam computerized tomography (CBCT) to measure dimensions of the alveolar ridge in the posterior mandible for estimation of a safe graft size, and then analyze how it is related to the gender, age, and dentition status of subjects. CBCT scans were screened to include 59 subjects without interfering pathologies. Alveolar height was measured from the alveolar crest to superior border of IAN and also to the inferior border of the mandible. Alveolar width (from buccal to lingual cortical plates) and buccal bone thickness (from buccal cortical plate to mandibular molar mesial root buccal surface) were measured at the coronal, middle, and apical thirds divided from the alveolar crest to the IAN. It was found that males and dentate sites had larger alveolar dimensions than did females and edentulous sites, respectively. Bone volume did not correlate significantly with age. Buccal bone thicknesses increased from coronal to apical and from the first to the third molar generally. A larger bone graft could be harvested from male than female patients, with a mean harvestable graft dimension (height  $\times$  width in mm) for male was  $15.5 \times 3.2$ , and for female was  $14.1 \times 2.9$ . In conclusion, males and dentate arches demonstrate larger alveolar volumes than do females and edentulous regions, respectively. Larger alveolar grafts can be harvested from males compared to the females. Age does not seem to affect alveolar dimension/graft volume.

**Key Words:** cone beam computerized tomography, mandible, bone grafting

## INTRODUCTION

Bone grafts are widely used in the reconstruction of craniofacial skeletal defects and implant prosthetic rehabilitation.<sup>1–3</sup> Successful osseointegration of the dental implant requires adequate volume of bone to support the implant.<sup>4</sup> When alveolar atrophy impairs implant placement, ridge augmentation including guided bone regeneration and bone grafting may be considered.<sup>5–9</sup> Several different types of bone graft materials are available: Autogenous grafts are those obtained directly from the patient. Allografts are collected from the same species but different individuals. Xenografts are procured from different species. Alloplasts are synthetic or inorganic graft materials.<sup>10,11</sup> Among these different materials, autogenous bone grafts are considered the “gold standard” in repair of alveolar atrophy with regard to quantity, quality, and uneventful healing.<sup>4,12,13</sup>

Traditionally, the iliac crest, proximal tibia, rib, and mandible have been the principal sources of autogenous bone.<sup>14–17</sup> An intraoral approach is preferred for ridge augmentation due to the convenience of surgical access, a short operative and anesthesia time, minimal discomfort and morbidity, as well as no concerns of cutaneous scarring.<sup>8,18–21</sup> Bone grafts harvested from the mandible—such as those from the mandibular symphysis, external oblique ridge, and ascending ramus—have been used for alveolar repair to allow implant placement with extremely favorable results.<sup>13,22–24</sup> The mandibular donor site is one of the alternative sources of intramembraneous bone, which maintain their dense quality and undergo less resorption compared with endochondral bone.<sup>25–28</sup>

In the mandible, the ramus/posterior body area offers some advantages over the symphysis as a donor site for alveolar ridge reconstruction, which include minimal esthetic concern, lower incidence of incision dehiscence, and less postoperative neurosensory disturbances.<sup>29–32</sup> The volume of harvestable bone in posterior mandible is dictated by anatomic landmarks, such as the presence of molar teeth and the position of the inferior alveolar nerve canal (IAN).<sup>31</sup> The most serious complication of bone harvesting at this site is injury to the inferior alveolar neurovascular bundle.<sup>2</sup> Therefore, a clear understand-

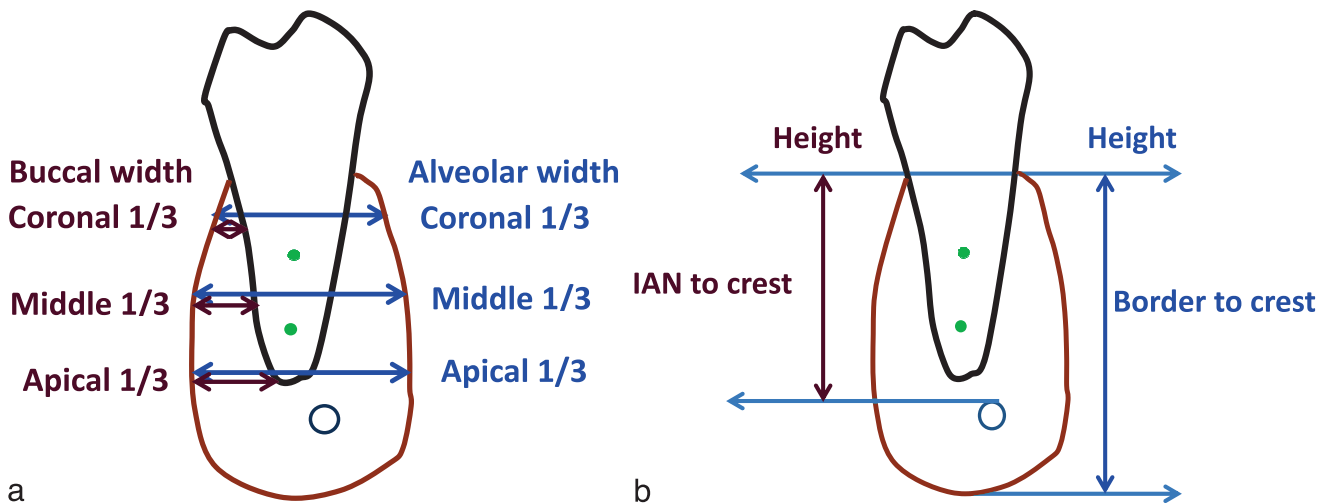
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**FIGURE 1.** Tooth diagrams demonstrate the measurements. (a) Measurements on buccal bone width and alveolar width. (b) Measurements on alveolar heights. IAN indicates alveolar nerve.

ing of applied anatomy in this area will help maximize graft size and minimize risk of nerve and vessel damage.

In the literature, there are limited studies investigating the harvestable graft size for ridge augmentation from the posterior mandibular body and ramus area.<sup>33,34</sup> In addition, detailed understanding is still missing in regard to how a patient’s gender and age affect ridge/graft volume. The aim of this retrospective study is to measure the size of alveolar ridge and available bone for a block graft from the posterior mandible with cone beam computerized tomography (CBCT) and further correlate the findings with the gender, age, and dentition status of patients.

**MATERIALS AND METHODS**

**Patient population**

The electronic patient records of individuals who had CBCT images taken at the Radiology Division, University of Texas School of Dentistry at Houston were screened according to the selection criteria. The exclusion criteria were: (1) systemic/endocrine diseases that influence bone metabolism (eg, osteoporosis, hyperparathyroidism, Paget’s disease, renal osteodystrophy), (2) topical conditions that may affect bone quantity and quality at posterior mandible (eg, moderate to severe periodontal disease, cyst, neoplasm, prior trauma or surgery) except tooth extraction. A total of 59 subjects were included in the study. All subjects were at least partially dentate in the posterior mandible. There were 28 males and 31 females, with an age range of 19–74 years old. Institutional Review Board exemption was obtained for the study after institutional review.

**CBCT image acquisition**

All the subjects had a CBCT scan covering both maxillary and mandibular arches with a field of view of 150 × 90 mm<sup>2</sup>. The scans were acquired at 90 kV, 10 mA, 16 seconds, and a 0.2

mm<sup>3</sup> voxel size with a Kodak 9500 unit (Carestream Health, Inc, Rochester, NY). CBCT images were reconstructed with Anatomage Invivo 5.1 software at 1-mm thickness. All images were displayed on a 19-inch flat panel screen (HP Development Company, Palo Alto, Calif) with a 1920 × 1080 pixel resolution and viewed in a dimly lit environment.

**Image measurement**

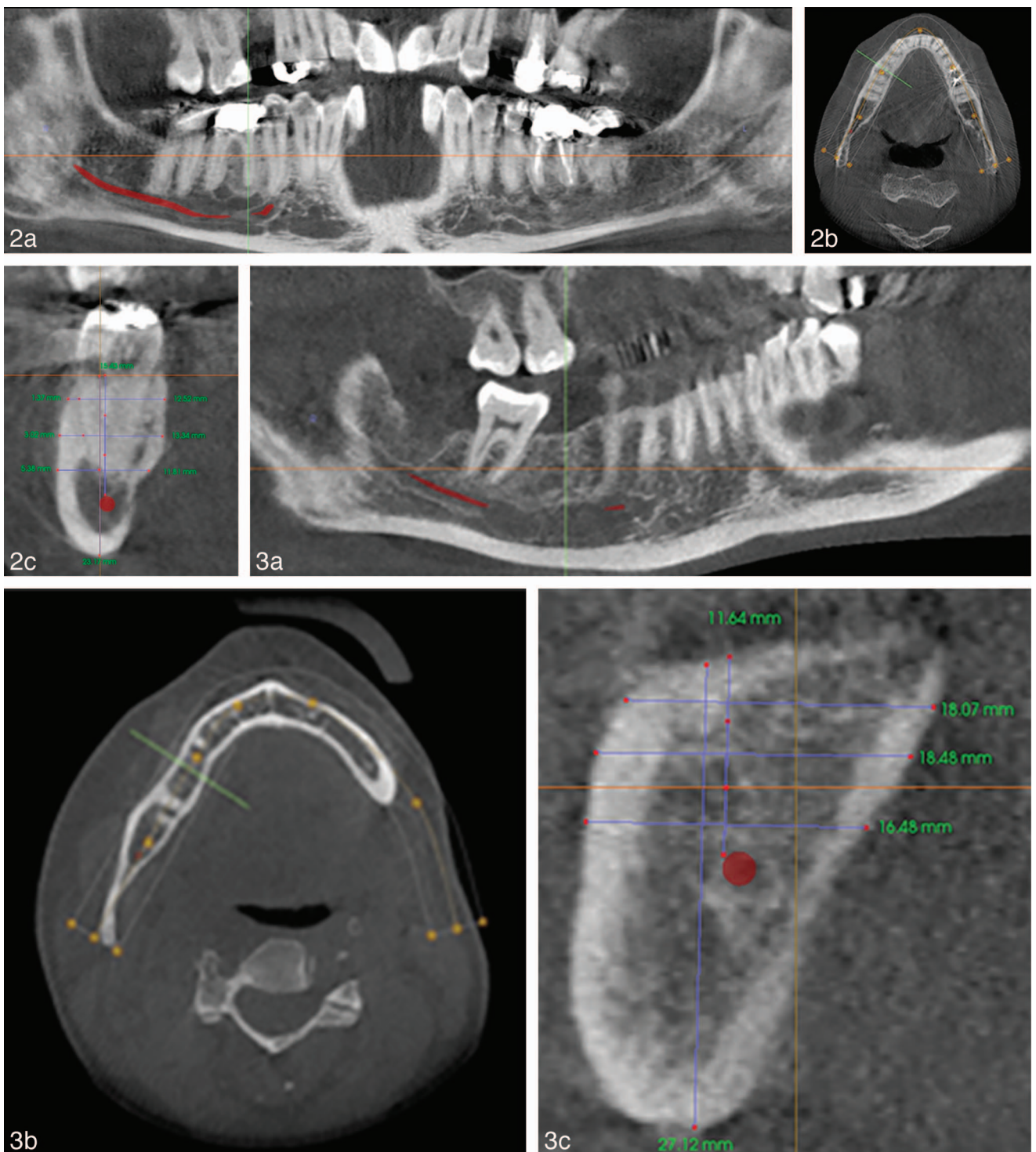
All measurements were performed from molar sites in the posterior right mandible. Before taking measurements, all the images were checked for the consistency of head placement. If head tilting was noticed, the image would be reoriented to ensure that the long axis of the alveolar ridge in the region of the posterior mandible was perpendicular to the floor. The IAN was traced on the reconstructed panoramic view and location confirmed using cross-section views. Cross-sectional views were generated along the distal surface of the mesial root of mandibular molars (see Figure 2b) or in the middle of the edentulous socket. Alveolar height, width, and buccal bone thickness were measured on the cross-sectional views as detailed below (also see Figures 1 through 3). The first (M1), second (M2), and third (M3) molar sites were each measured separately.

**Alveolar Heights**

Alveolar heights were measured in two ways: (1) from alveolar crest to superior border of IAN and (2) from alveolar crest to the inferior border of mandible.

**Alveolar Width (From Exterior Buccal to Exterior Lingual Cortical Plate)**

Alveolar width was measured from exterior buccal to exterior lingual cortical plate on the cross-sectional views. The distance from alveolar crest to superior border of IAN was divided into thirds. An average was taken from the 3 measurements for each molar site.



**FIGURES 2 AND 3.** **FIGURE 2.** Reconstructed cone beam computerized tomography (CBCT) views demonstrate the measurements at a dentate site. (a) Reconstructed panoramic view shows the traced inferior alveolar nerve. (b) Mandibular axial view. Green line demonstrates that the cross-sectional view was made along the mesial root distal surface of mandibular molar. (c) Cross-sectional view demonstrates all the measurements. Inferior alveolar nerve is highlighted red. **FIGURE 3.** Reconstructed CBCT views demonstrate the measurements at an edentulous site. (a) Reconstructed panoramic view shows the traced inferior alveolar nerve. (b) Mandibular axial view. Green line demonstrates that the cross-sectional view was made in the middle of edentulous socket of mandibular molar region. (c) Cross-sectional view demonstrates all the measurements. Notice that there is no buccal bone thickness measurement for edentulous site. Inferior alveolar nerve is highlighted red.



TABLE 1  
Patient age and gender information

Age	Males	Females
19–29	7	3
30–39	3	11
40–49	4	5
50–59	6	5
60–69	6	6
70–74	2	1
Total	28	31

*Buccal Bone Thickness (From Exterior Buccal Cortical Plate to Mesial Root Buccal Surface)*

Buccal bone thickness was measured for dentate region only, and it was measured from exterior buccal cortical plate to mandibular molar mesial root buccal surface. For each site with a molar present, the buccal bone thickness was measured at coronal, middle, and apical thirds; an average was taken, similar to how alveolar width was measured.

**Statistical analysis**

Data were presented as means ± standard deviation (SD). The statistical difference was tested using two-tailed *t* test at a *P* value less than .05.

**RESULTS**

Fifty-nine CBCT scans from subjects aged 19–74 were evaluated. Among the subjects, 28 were males and 31 were females (see Table 1). Their dentation status in the posterior right mandible is listed in Table 2.

**Alveolar heights**

There was an increase of alveolar height (border-crest and IAN-crest) from M3 to M1 site (see Table 3). Males demonstrated significantly higher alveolar ridges when compared to females for both measurements (see Table 3). Greater alveolar ridge heights were found in dentate vs edentulous regions, with significance reached at the M1 sites ( $28.3 \pm 2.8$  vs  $24.9 \pm 3.2$  mm for border-crest, and  $17.2 \pm 2.7$  vs  $14.5 \pm 2.9$  mm for IAN-crest, respectively, *P* < .01, see Table 3). On average, edentulous sites lost 2–3 mm of ridge height as compared to

TABLE 2  
Patient dentition status at right mandibular molar sites\*

Tooth Site	Dentate	Edentulous
M1	44	15
M2	48	11
M3	22	37

\*M1 indicates the first molar; M2, the second molar; M3, the third molar.

the dentate sites. There was no significant correlation between alveolar height and patients' age.

**Alveolar width**

In general, the M2 and M3 sites demonstrated thicker alveolar width (measured from exterior buccal to exterior lingual cortical plate) than did M1 sites, as shown in Table 4. On average, males had significantly larger alveolar width than females ( $12.6 \pm 2.6$  vs  $10.8 \pm 2.7$  mm for coronal width;  $13.5 \pm 2.2$  vs  $11.9 \pm 2.3$  mm for middle width; and  $11.9 \pm 2.1$  vs  $10.8 \pm 2.0$  mm for apical width, *P* < .05, see Table 4). Dentate ridge also demonstrated significantly larger alveolar width compared with edentulous region, especially for coronal and middle width ( $12.5 \pm 2.0$  vs  $9.8 \pm 3.3$  mm for coronal width, and  $13.0 \pm 2.2$  vs  $12.0 \pm 2.6$  mm for middle width, *P* < .05, see Table 4). Generally, the edentulous ridge had a decreased buccolingual dimension of ~2.7 mm (coronal third), ~1.0 mm (middle third), and ~0.4 mm (apical third). There was no significant change of alveolar width with age.

**Buccal bone thickness**

Buccal bone thickness was measured in the region when a molar was present. In general, mean buccal bone thicknesses increased from coronal to apical and from M1 to M3 area (see Table 5), except some variations at the M3 site. Males had thicker buccal bone than did females in most cases, especially at M1 site ( $1.8 \pm 1.4$  vs  $1.1 \pm 0.8$  mm, *P* < .01, see Table 5). No significant correlation was observed between buccal bone thickness and patients' age.

**DISCUSSION**

Based on the measurements on ridge height (crest-IAN) and buccal bone width, the average estimations of harvestable block graft dimension (height × width in mm) in the dentate patient are  $15.5 \pm 3.5 \times 3.2 \pm 1.7$  for males and  $14.1 \pm 2.6 \times 2.9 \pm 1.3$  for females. A larger size graft can be harvested from posterior mandible in male compared to female subjects in most cases. The finding in the present study is very similar to what was reported by Leong et al,<sup>33</sup> who claimed a safe thickness to harvest in the region of mandibular molars would be ~2.5 to 3.0 mm. Their finding is slightly less than what we discovered, which could be due to the difference in the methodology employed. For the graft thickness, they measured the width of buccal cortical plate, and we measured from the exterior buccal cortical plate to the mesial root buccal surface of mandibular molars, which included a thin layer of cancellous bone between the inner cortical boundary and root surface. The second molar site is identified to have the thickest buccal bone compared to other molar sites, which is consistent with a cadaver study conducted by Rajchel et al.<sup>35</sup> We did not measure the potential length of the graft since this value could be easily obtained clinically via measuring mesial-distal dimension on the ridge.

In the present study, it is found that buccal bone thickness generally increases from coronal to apical and from mesial to distal direction, except for some inconsistency for retained third molars. This is very similar to what was reported in a previous

Measurement	M1	M2	M3	Mean $\pm$ SD	P value
Border to crest					
Male	28.8 $\pm$ 3.2†	26.0 $\pm$ 2.8‡	25.2 $\pm$ 3.1§	26.8 $\pm$ 3.3	†, ‡, § < .01
Female	26.3 $\pm$ 2.8†	23.3 $\pm$ 2.4‡	22.5 $\pm$ 3.0§	24.0 $\pm$ 3.2	
Dentate	28.3 $\pm$ 2.8	24.9 $\pm$ 2.4	24.6 $\pm$ 3.4	26.1 $\pm$ 3.2	< .01
Edentulous	24.9 $\pm$ 3.2	23.2 $\pm$ 4.6	23.2 $\pm$ 3.2	23.6 $\pm$ 3.5	
Overall	27.5 $\pm$ 3.2	24.6 $\pm$ 2.9	23.8 $\pm$ 3.3	25.3 $\pm$ 2.5	
IAN to crest					
Male	17.6 $\pm$ 3.3¶	15.6 $\pm$ 2.7#	13.1 $\pm$ 3.0	15.5 $\pm$ 3.5	¶, # < .01
Female	15.5 $\pm$ 2.2¶	14.1 $\pm$ 1.9#	12.5 $\pm$ 2.8	14.1 $\pm$ 2.6	
Dentate	17.2 $\pm$ 2.7††	14.8 $\pm$ 1.9	13.4 $\pm$ 2.6	15.4 $\pm$ 2.8	†† < .01
Edentulous	14.5 $\pm$ 2.9††	14.5 $\pm$ 4.1	12.3 $\pm$ 3.0	13.4 $\pm$ 3.4	
Overall	16.5 $\pm$ 3.0	14.8 $\pm$ 2.4	12.8 $\pm$ 2.9	14.8 $\pm$ 3.1	

\*M1 indicates the first molar; M2, the second molar; M3, the third molar; IAN, inferior alveolar nerve.

study.<sup>36</sup> Lingual inclination of mandibular molar roots and presence of external oblique ridge may partially contribute to these observations.

Compared with dentate region, there was only a significant reduction of alveolar height at M1 edentulous sites. This could be due to variations in the duration of edentulism. Normally, mandibular first molar is one of the permanent teeth erupting the earliest in the oral cavity.<sup>37</sup> It is speculated that first molar has the highest risk of developing caries or other dental lesions from an early age and may be lost way before second and third molars.<sup>38</sup> Our results show that reduction of alveolar width after tooth loss is more prominent coronally than apically. Alveolar bone is under

constant remodeling, which is influenced by occlusal loading. After a tooth loss, there is less stress/loading at the edentulous ridge, and bone resorption is likely to dominate over deposition.<sup>39</sup> Araújo et al<sup>40</sup> found a large number of osteoclasts present on the surface of alveolar crest 1 week after tooth extraction but only a few osteoclasts present apical to the crestal region 2 weeks after extraction. Later on, there was a significant increase of osteoclasts apical to the crest 2–8 weeks after extraction. The differential distribution of osteoclasts on the alveolar ridge after tooth extraction may partially explain why a more pronounced ridge reduction was observed coronally than apically.

Measurement	M1	M2	M3	Mean $\pm$ SD	P value
Coronal width					
Male	11.7 $\pm$ 2.7†	12.7 $\pm$ 2.1‡	13.2 $\pm$ 3.1	12.6 $\pm$ 2.6	† < .05 ‡ < .01
Female	10.2 $\pm$ 2.3†	10.7 $\pm$ 2.4‡	11.6 $\pm$ 3.3	10.8 $\pm$ 2.7	
Dentate	12.0 $\pm$ 1.8§	12.4 $\pm$ 1.8	14.0 $\pm$ 2.2¶	12.5 $\pm$ 2.0	§,   , ¶ < .01
Edentulous	10.2 $\pm$ 1.6§	8.5 $\pm$ 2.7	11.3 $\pm$ 3.4¶	9.8 $\pm$ 3.3	
Overall	10.9 $\pm$ 2.6	11.6 $\pm$ 2.5	12.3 $\pm$ 3.3	11.6 $\pm$ 2.8	
Middle width					
Male	12.4 $\pm$ 2.3#	13.6 $\pm$ 2.0††	14.3 $\pm$ 2.0**	13.5 $\pm$ 2.2	#, ** < .01 †† < .05
Female	10.8 $\pm$ 1.8#	12.2 $\pm$ 2.7††	12.8 $\pm$ 1.9**	11.9 $\pm$ 2.3	
Dentate	12.0 $\pm$ 2.1‡‡	13.2 $\pm$ 2.1	14.4 $\pm$ 1.7§§	13.0 $\pm$ 2.2	‡‡ < .05 §§ < .01
Edentulous	10.5 $\pm$ 2.1‡‡	11.1 $\pm$ 3.5	13.0 $\pm$ 2.1§§	12.0 $\pm$ 2.6	
Overall	11.6 $\pm$ 2.2	12.8 $\pm$ 2.5	13.5 $\pm$ 2.1	12.6 $\pm$ 2.4	
Apical width					
Male	11.5 $\pm$ 2.1	11.9 $\pm$ 2.4	12.1 $\pm$ 2.0¶¶	11.9 $\pm$ 2.1	, ¶¶ < .05
Female	10.4 $\pm$ 1.9	11.1 $\pm$ 2.3	11.0 $\pm$ 1.7¶¶	10.8 $\pm$ 2.0	
Dentate	11.0 $\pm$ 2.1	11.7 $\pm$ 2.4	11.7 $\pm$ 1.6	11.4 $\pm$ 2.1	
Edentulous	10.6 $\pm$ 2.2	10.5 $\pm$ 2.1	11.4 $\pm$ 2.1	11.0 $\pm$ 2.1	
Overall	10.9 $\pm$ 2.1	11.5 $\pm$ 2.4	11.5 $\pm$ 1.9	11.3 $\pm$ 2.1	
Overall width	11.1 $\pm$ 2.3##,***	12.0 $\pm$ 2.5##	12.5 $\pm$ 2.6***	11.9 $\pm$ 2.5	##, *** < .01

\*M1 indicates the first molar; M2, the second molar; M3, the third molar.

TABLE 5  
Buccal bone thickness measurement (mm; mean ± SD) in each molar location\*

Measurement	M1	M2	M3	Mean ± SD	P value
Coronal width					
Male	1.1 ± 0.6†	1.5 ± 0.7‡	2.4 ± 1.5	1.4 ± 1.0	† < .01 ‡ < .05
Female	0.7 ± 0.4†	1.1 ± 0.8‡	3.1 ± 2.0	1.4 ± 1.4	
Overall	0.9 ± 0.6	1.6 ± 0.7	3.0 ± 1.8	1.4 ± 1.2	
Middle width					
Male	2.0 ± 1.5§	4.0 ± 2.0	4.1 ± 1.7	3.0 ± 1.8	§ < .05
Female	1.2 ± 0.8§	3.9 ± 1.7	4.8 ± 2.9	3.2 ± 2.4	
Overall	1.6 ± 1.2	3.9 ± 1.8	4.4 ± 2.3	3.1 ± 2.1	
Apical width					
Male	4.0 ± 2.2	6.8 ± 2.3	4.9 ± 2.4	5.4 ± 2.2	< .05
Female	2.3 ± 1.0	7.3 ± 1.4	2.2 ± 0.4	4.7 ± 3.1	
Overall	3.0 ± 1.7	7.0 ± 1.9	4.0 ± 2.3	5.1 ± 2.7	
Overall width					
Male	1.8 ± 1.4¶	4.1 ± 1.7	3.8 ± 1.9	3.2 ± 1.7	¶ < .01
Female	1.1 ± 0.8¶	4.1 ± 1.3	3.4 ± 1.8	2.9 ± 1.3	
Overall	1.4 ± 1.2	4.1 ± 1.5	3.6 ± 1.9	3.1 ± 1.5	

\*M1 indicates the first molar; M2, the second molar; M3, the third molar.

Although we minimized the variables as much as possible—such as recruiting comparable number of male vs female patients, excluding patients with local or systemic conditions that would affect the quality and quantity of alveolar bone at posterior mandible—there are still limitations in the study. Some of these include a relatively small sample size, variations in ethnicities of patients, and duration of edentulism. A large blind clinical trial with CBCT scans pre- and post-ramus grafting will further validate our results and indicate potential complication risk. In addition, this study compared alveolar volume between dentate vs edentulous region with only 1 molar missing. Further analysis is needed to compare harvestable graft size between molar dentate patients vs those missing 2 or 3 consecutive molars, to fully reveal how dentate status affects block graft dimension.

**CONCLUSION**

In conclusion, autogenous block grafts harvested from posterior mandible offer several advantages, such as simplicity of operation and minimal morbidity. This donor site should be considered when a limited amount of bone is needed as grafting material. Our study showed that males and dentate sites have significantly more bone in the molar region and could potentially provide a larger graft than female and edentulous counterparts. Our data indicate a safe harvestable block graft dimension 15.5 × 3.2 and 14.1 × 2.9 (height × width in mm) for males and females, respectively, at dentate posterior mandible.

**ABBREVIATIONS**

CBCT: cone beam computerized tomography  
IAN: inferior alveolar nerve

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