Ridge Dimensions of the Edentulous Mandible in Posterior Sextants: An Observational Study on Cone Beam Computed Tomography Radiographs

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Aims: *To evaluate the ridge dimensions of posterior sextant in totally edentulous mandibles.*

Material and Methods: *Cone beam computed tomography scans of 136 patients were retrospectively included for analysis. At sites corresponding to the second premolar (site a) and the mesial and distal root of first molar (sites b and c, respectively), bone height (BH) and bone width (BW) were measured.*

Results: *BH significantly decreased from site a (11.20 ± 4.03 mm) to site c (10.28 ± 3.33 mm). Males showed a significantly higher BH compared with females at all sites ($P < 0.001$), No significant impact of age on BH was found. BW increased from coronal to apical at all sites. At all height levels, BW increased from mesial to distal ($BW_c > BW_b > BW_a$).*

Conclusions: *BH decreased from mesial to distal, whereas BW showed an increase. Sex showed a significant impact on BH, with males having on average a 2.8 mm greater height than females, but not on BW. Age did not significantly influence the dimensions of the residual bone crest. (Implant Dent 2016;25:1–7)*

Key Words: tooth loss, diagnostic imaging, jaw, body weights and measures

Alveolar ridge resorption and remodeling occurs especially after tooth extraction and results in a decreased ridge dimension[1–3] The volume and rate of bone loss depends on different factors such as sex, hormones, general disease, denture rehabilitation, and metabolism.[4] Moreover, a greater amount of bone resorption can be observed during the first 3 months of healing, with a significant loss of alveolar bone height (BH) and width. Horizontal dimensional changes represent 50% alveolar ridge reduction after 1 year from tooth extraction[1,5] with a resorption that occurs primarily from the buccal aspect.[3]

In the mandible, alveolar ridge resorption is usually greater in the premolar and molar region than in the anterior region, because of the lower position of the reversal line.[6,7] In fact, the reversal line on the mandible lingual side occurs along the mylohyoid ridge, which is the limit between the resorptive alveolar field and depository field of the basal bone.[6–8] Accordingly, the inner aspect of the anterior area of the mandible provides attachment for the genial muscles. These attachments, through the functional forces of the genial muscles, probably protect this area from extreme alveolar bone loss and reduction in vertical height.[9] The different pattern of resorption is reflected in the bone available for implant therapy in edentulous patients. Oikarinen et al[10] suggest that implants of 8 mm or longer could be inserted in the anterior maxilla in more than 50% of patients. It was shown that implantation was possible in almost every jaw with fixture of 8 mm or longer in the canine regions.[10] Instead, in the maxillary posterior region, the proportion of sites with BH ≥8 mm and bone width (BW) ≥6 mm was 28.3%, 18.4%, 8.0%, and 18.2% at first premolar, second premolar, first molar, and second molar sites, respectively.[11]

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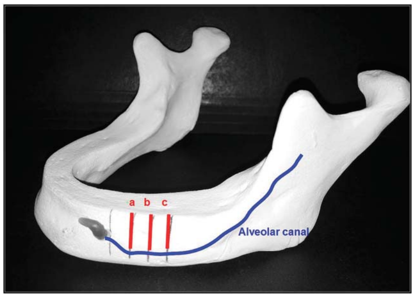

Fig. 1. Site used for the assessment of BH and BW. In both sides of each edentulous mandible, the CBCT cross-sections at 6, 11, and 16 mm (site a, b, and c, respectively) posterior to the most distal section including the mental foramen were used for radiographic measurements. According to previous studies, these positions correspond to the second premolar and the mesial and distal roots of the first molar.[19]

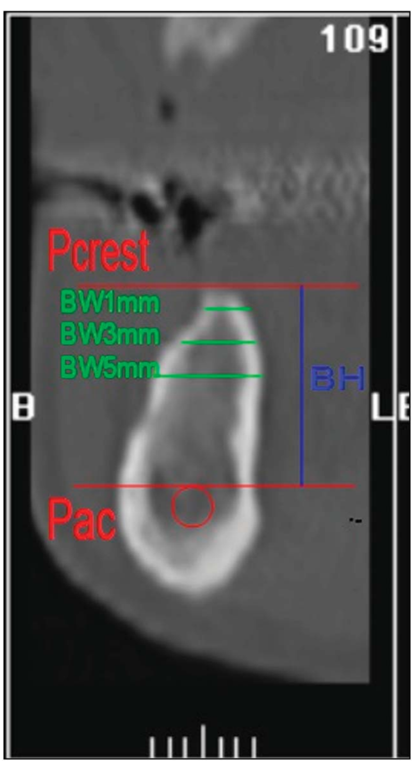

Fig. 2. Reference points and BH and BW measurements on the CBCT cross-section. On each cross-section, lines were traced parallel to the inferior border of the mandible and passing through (1) the most coronal point of the alveolar crest (p_{crest}), (2) 1, 3, and 5 mm apical to p_{crest}, and (3) the most coronal point of the mandibular canal (p_{AC}). BH was measured as the distance (in mm) between p_{crest} and p_{AC}. Bucco-lingual BW was measured at 1, 3, and 5 mm apical to p_{crest} ($BW_{1\ mm}$, $BW_{3\ mm}$, and $BW_{5\ mm}$, respectively).

Table 1. BH and BW at Site a, b, and c as Measured in the Overall Study Population and in Males and Females Subgroups

	Site a				Site b				Site c			
	BH	$BW_{1\ mm}$	$BW_{3\ mm}$	$BW_{5\ mm}$	BH	$BW_{1\ mm}$	$BW_{3\ mm}$	$BW_{5\ mm}$	BH	$BW_{1\ mm}$	$BW_{3\ mm}$	$BW_{5\ mm}$
Female												
N	67	67	64	55	67	67	64	55	67	67	65	57
Mean	9.76	4.00	7.33	9.03	9.76	4.58	8.42	10.13	8.98	5.39	9.71	11.42
Median	9.80	3.79	7.08	8.79	9.60	3.90	8.30	10.20	9.40	4.80	9.79	11.40
SD	3.79	1.61	2.29	2.09	3.79	2.03	2.59	1.95	3.06	2.40	2.63	2.08
Minimum	2.60	1.80	3.15	4.85	2.60	1.60	3.60	5.40	2.40	2.00	4.20	5.55
Maximum	17.60	9.00	12.40	13.80	17.60	10.20	13.28	14.00	16.85	12.60	15.38	15.80
Male												
N	69	68	66	65	68	67	65	64	67	67	67	64
Mean	12.61	3.96	7.19	9.35	12.14	4.50	8.13	10.38	11.58	5.38	9.30	11.36
Median	12.66	3.80	7.20	9.60	11.70	4.55	8.20	10.32	11.80	5.00	9.05	11.60
SD	3.78	1.21	1.64	2.00	3.54	1.41	2.00	2.20	3.08	2.02	2.25	2.25
Minimum	2.22	1.86	3.40	5.00	3.60	1.80	4.60	5.45	3.80	2.05	3.55	5.60
Maximum	19.80	7.40	10.80	13.57	19.20	10.00	12.80	15.26	17.40	11.60	15.20	16.48
Total												
N	136	135	130	120	135	134	129	119	134	134	132	121
Mean	11.20	3.80	7.26	9.21	10.70	4.54	8.27	10.26	10.28	5.39	9.50	11.39
Median	11.36	3.60	7.20	9.20	10.75	4.28	8.20	10.24	10.05	4.80	9.40	11.60
SD	4.03	1.42	1.98	2.04	3.74	1.74	2.30	2.08	3.33	2.21	2.44	2.16
Minimum	2.22	1.80	3.15	4.85	2.40	1.60	3.60	5.40	2.40	2.00	3.55	5.55
Maximum	19.80	9.00	12.40	13.80	19.20	10.20	13.28	15.26	17.40	12.60	15.38	16.48

In the overall study population, BH significantly decreased from site a to site c ($P < 0.001$). Moving from mesial to distal, mean BW measurements showed a significant increase (BWc > BWb > BWa) at all height levels (1, 3, and 5 mm from P_{crest}). BW significantly increased from coronal to apical at all sites.

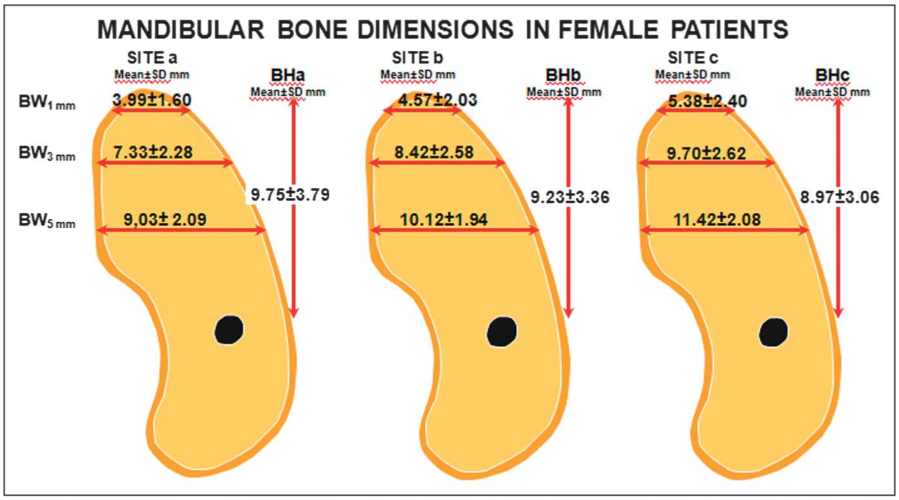

Fig. 3. BH and BW measurements at sites a, b, and c in female subjects. At all sites, BH values were significantly lower compared with those recorded in males ($P < 0.001$), whereas BW measurements were not significantly different between male and female subjects.

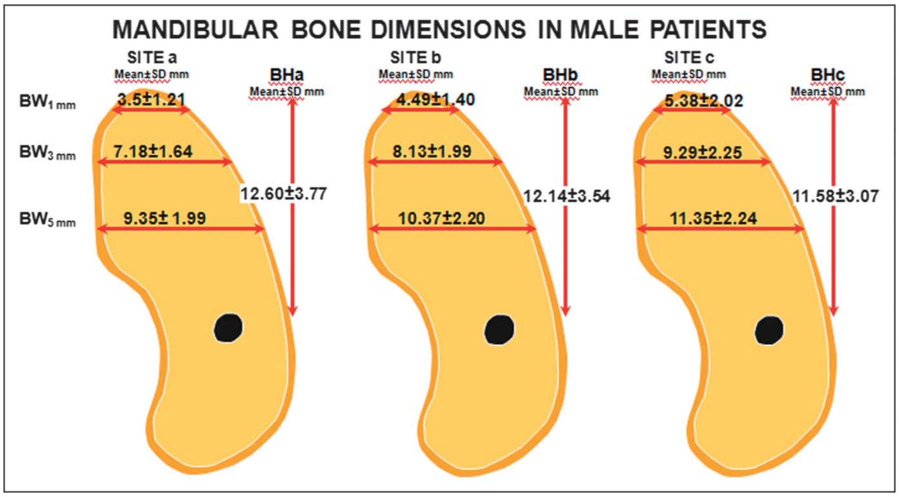

Fig. 4. BH and BW measurements at sites a, b, and c in male subjects. At all sites, BH values were significantly higher compared with those recorded in females ($P < 0.001$), whereas BW measurements were not significantly different between male and female subjects.

The use of removable dentures significantly increases the severity of alveolar bone resorption in edentulous areas. Xie et al[12] reported that the edentulous maxilla has a much greater reduction in radiologic heights if compared with the edentulous mandible both for males and females. The finding is consistent with previous studies.[12,13]

The rate of bone resorption after tooth extraction was described by several authors.[4,8,12,14–18] Such studies were conducted on panoramic radiographs or anatomical specimens. Unfortunately, panoramic radiographs only allow for a bidimensional edentulous ridge evaluation, and the assessment of the true distances between relevant anatomic landmarks may be affected by magnification and distortion. Studies conducted on anatomical specimens,[17,18] although providing a tridimensional and accurate evaluation of the ridge dimensions, are biased by a limited sample size.

The aim of the present observational study was to evaluate the alveolar ridge horizontal and vertical dimensions of the mandible in edentulous patient.

MATERIALS AND METHODS

Study Population

Deidentified data were obtained from a convenience sample of patients retrospectively selected among those referred for a cone beam computed tomography (CBCT) to a radiologic center (TECNO-MED, Verona, Italy) between January 2012 and September 2012. All CBCT were acquired using a Planmeca ProMax 3Ds, 2011 (Planmeca Oy, Helsinki, Finland). The scan plane had been set parallel to the inferior border of mandibular jaw. Axial (parallel to the scan plane), panoramic (perpendicular to the scan plane, latero-lateral direction) and cross-section (perpendicular to the scan plane, anteroposterior direction), 0.4 mm slices were obtained. Computed tomography (CT) scans were performed according to the following protocol: pitch 1:1, matrix 512 × 512, and field of view 20 cm diameter and 10 cm height, 120 kVp, and 100 mA. The effective radiation dose was 304.5 micro Sv. CT were postprocessed with Planmeca Romexis software (Planmeca Oy). Each patient provided a written informed consent before undergoing the CBCT examination. When a patient had undergone more than 1 CBCT examination, the most recent CBCT was selected for the study. Therefore, each patient contributed 1 CBCT examination.

Radiographs were included in the analysis according to the following criteria regarding the subject: (1) age ≥21 years; (2) totally edentulous mandible (3) presence of a clearly identifiable ridge contour in the edentulous site/s of interest. Radiographs were excluded from the analysis if positive for at least one of the following criteria: (1) total osseous retention of 1 or more teeth in the mandible; (2) radiographic evidence of bone augmentation procedures or signs of invasive surgery; (3) presence of a radiolucent or a radiopaque area related to pathological conditions. (4) partial or total osseous retention of 1 or more residual roots; (5) presence of a dental implant

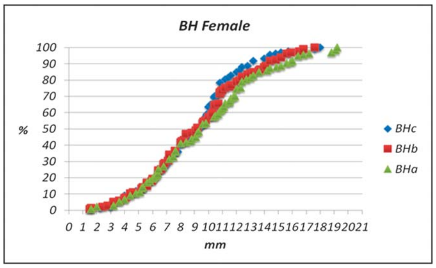

Fig. 5. Cumulative frequency distribution of females according to BH. In females, a BH of 9 mm or higher was present in 55.2% and 49.9% of subjects at site a and c, respectively. Using a BH threshold of 11 mm, the prevalence at site a and c was 36.6% and 20.0%, respectively.

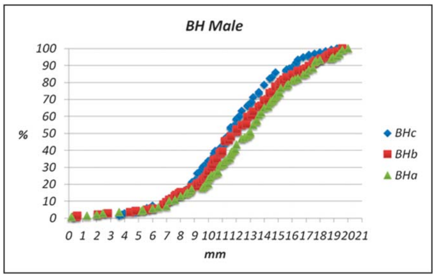

Fig. 6. Cumulative frequency distribution of males according to BH. In males, a BH of 9 mm or higher was present in 82.8% and 77.9% of subjects at site a and c, respectively. Using a BH threshold of 11 mm, the prevalence at site a and c was 68.1% and 57.3%, respectively.

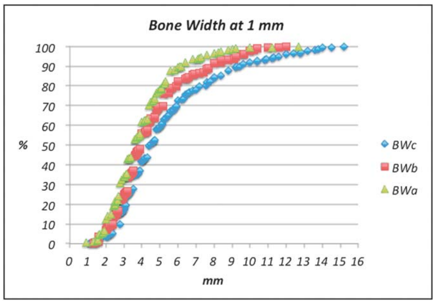

Fig. 7. Cumulative frequency distribution of subjects according to BW at 1 mm apical to p_{crest} ($BW_{1\ mm}$). $BW_{1\ mm}$ was 5 mm or higher in 22.1% of subjects at site a, in 30.8% of subjects at site b, and 40.7% of subjects at site c.

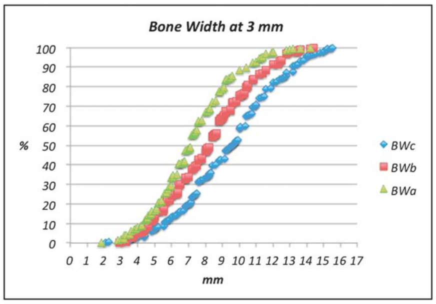

Fig. 8. Cumulative frequency distribution of subjects according to BW at 3 mm apical to p_{crest} ($BW_{3\ mm}$). $BW_{3\ mm}$ was 5 mm or higher in 83.4% of subjects at site a, 86.3% of subjects at site b, and 92.5% of subjects at site c.

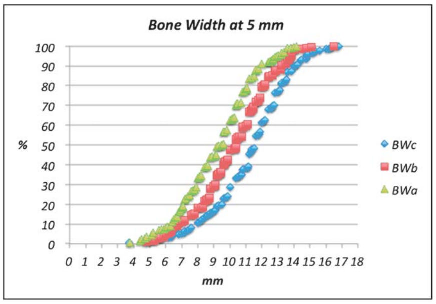

Fig. 9. Cumulative frequency distribution of subjects according to BW at 5 mm apical to p_{crest} ($BW_{5\ mm}$). At all sites (a, b, and c), $BW_{5\ mm}$ was 5 mm or higher in the great majority (≥95%) of subjects.

posterior to mental foramina; (6) presence of osteosynthesis plaques; (7) unreadable CBCT.

Processing of CBCT and Radiographic Measurements

In both sides of each edentulous mandible, the CBCT cross-sections at 6, 11, and 16 mm (site a, b, and c, respectively) posterior to the most distal section including the mental foramen were used for radiographic measurements (Fig. 1). These positions correspond to the second premolar and the mesial and distal roots of the first molar.[19] On each cross-section, lines were traced parallel to the inferior border of the mandible and passing through (1) the most coronal point of the alveolar crest (p_{crest}), (2) 1, 3, and 5 mm apical to p_{crest} ($h_{1\ mm}$, $h_{3\ mm}$, and $h_{5\ mm}$, respectively), and (3) the most coronal point of the mandibular canal (p_{AC}).

At sites a, b, and c, BH and BW were assessed. BH was measured as the distance (in mm) between p_{crest} and p_{AC} (Fig. 2). BH was not measured when the mandibular canal was not evident on the selected cross-section. Buccolingual BW was measured at 1, 3, and 5 mm apical to p_{crest} ($BW_{1\ mm}$, $BW_{3\ mm}$, and $BW_{5\ mm}$, respectively) (Fig. 2). When BH was 5 mm or lower, $BW_{5\ mm}$ was not recorded. When BH was 3 mm or lower, $BW_{5\ mm}$ and $BW_{3\ mm}$ were not recorded. BW assessments were not performed when BH was lower than 1 mm.

Radiographic measurements were performed by two trained examiners (N. F. and M. P.) using magnification loops (×12) and a digital ruler with a 0.01 mm scale. Before study initiation, both examiners were involved in a calibration session, consisting of two sessions (at a 1-week distance) of radiographic assessments on CBCT of 5 edentulous patients not included in the study. The reliability analysis revealed an excellent intrarater (interclass correlation coefficient [ICC] = 0.994 and 0.996) and interrater agreement (ICC = 0.995).

Statistical Analysis

Descriptive statistics was performed using a specifically designed software (IBM SPSS 21, Armonk, NY). After having evaluated the normality of the data using Kolmogorov-Smirnov test, parametric paired *t* test was used to test for differences between the 2 sides of the mandibles. The mean difference between left and right measurements (systematic error) was 0.08 mm, and no significant within-subject differences in each radiographic measurement were observed between contralateral sites. Therefore, the subject was considered as the statistical unit. For each site (a, b or c), each subject was represented by a single value which was derived as the average of the left and right measurements.

A multilevel model was then built to estimate the standard errors of the measurements taking in to account the potential clustering of the data. The 2 level considered were the measurement and the subject. The model included BH and BW as outcome variables and was

Table 2. Multivariate Multilevel Model

	"Empty Model"	Standard Error	"Final Model"	Standard Error	*P*
Fixed part—BH					
Intercept	10.68	0.31	10.90	1.91	
Site (ref. site a)					
Site b			−0.52	0.11	<0.001
Site c			−0.76	0.11	<0.001
Sex male (ref. female)			2.82	0.59	<0.001
Age			−0.02	0.03	0.54
Sex × distance					
Male site b			−0.11	0.15	0.47
Male site c			−0.47	0.15	<0.001
Fixed part—BW					
Intercept	7.68	0.14	3.87	0.94	
Vertical distance (ref. $BW_{1\ mm}$)					
$BW_{3\ mm}$			3.31	0.15	<0.001
$BW_{5\ mm}$			5.37	0.15	<0.001
Sex male (ref. female)			−0.18	0.29	0.53
Age			0.00	0.01	0.83
Dist. f. (ref. site a) × vert. dist.					
$BW_{b\ 1\ mm}$			0.55	0.15	<0.001
$BW_{c\ 1\ mm}$			1.38	0.15	<0.001
$BW_{b\ 3\ mm}$			0.99	0.16	<0.001
$BW_{c\ 3\ mm}$			2.17	0.15	<0.001
$BW_{b\ 5\ mm}$			1.02	0.16	<0.001
$BW_{c\ 5\ mm}$			2.06	0.16	<0.001
Random Part					
Subject level					
Variance BH	13.19	1.62	11.41	1.40	
Covariance BH/BW	−0.84	0.51	−1.27	0.50	
Variance BW	2.05	0.32	2.55	0.33	
Site level					
Variance BH	2.59	0.08	2.40	0.07	
Covariance BH/BW	−0.98	0.11	−0.70	0.06	
Variance BW	9.87	0.30	3.30	0.10	

A 2-level (subject and site) multivariate model was built to investigate the effect of different parameters on BH and BW, and to evaluate the correlation between measurements. Males showed a significantly higher BH compared with females at all sites. The analysis of the interaction factor between sex and site showed a significant, stronger effect of sex on BH at site c compared with site a. The model showed no significant impact of age on BH and no significant impact of age and sex on BW. A significant covariance between BH and BW (−0.7) was detected.

therefore a multivariate multilevel model. A parsimonious model including the predictors that had a statistically significant impact ($P < 0.05$) on one or more of the outcomes was named as the "Final Model." The coefficients were estimated using iterative generalized least squares, and the significance of each covariate was tested using a Wald test. Nested models were tested for significant improvements in model fit by comparing the reduction in −2LL (−2 log likelihood) with a Chi-squared distribution.

RESULTS

Study Population

One hundred forty-one CBCT were examined. Two radiographs were excluded from the study because of the presence of osteosynthesis plaques, two for signs of invasive surgery, and 1 CBCT was not readable in the mandibular posterior sextants. Therefore, data were retrieved from CBCT of 136 subjects (mean age: 67.4 years; range: 27–92 years), including 69 males (mean age: 66.2 years; range: 27–92 years) and 67 females (mean age: 68.7 years; range: 31–91 years).

Radiographic Measurements

Radiographic measurements are reported in Table 1.

In the overall study population, BH significantly decreased from site a (11.20 ± 4.03 mm; range: 2.22–19.80 mm) to site c (10.28 ± 3.33 mm; 2.40–17.40 mm) ($P < 0.001$). $BW_{1\ mm}$ was 3.98 ± 1.42 mm (range: 1.80–9.00 mm) at site a, 4.54 ± 1.74 mm (range: 1.60–10.20 mm) at site b, and 5.39 ± 2.21 mm (range: 2.00–12.60 mm) at site c. Moving from mesial to distal, mean BW measurements showed a significant increase ($BW_c > BW_b > BW_a$) at all height levels (1, 3, and 5 mm from p_{crest}). BW significantly increased from coronal to apical at all sites, the mean value increasing from 3.98 to 9.21 mm at site a and from 5.39 to 11.39 mm at site c.

Radiographic measurements in female and male subjects are reported in Figures 3 and 4, respectively. Males showed a significantly higher BH compared with females at all sites ($P <$

0.001), whereas BW measurements were not significantly different between male and female subjects.

The cumulative frequency distribution of BH in female and male subjects is illustrated in Figures 5 and 6, respectively. At site a, BH was 9 mm or higher in 55.2% of females and 82.8% of males. At site c, BH was 9 mm or higher in 49.9% of females and 77.9% of males. Using a BH threshold of 11 mm, the prevalence at site a was 36.6% for females and 68.1% for males, whereas the prevalence at site c was 20.0% for females and 57.3% for males.

The cumulative frequency distribution of $BW_{1\ mm}$, $BW_{3\ mm}$, and $BW_{5\ mm}$ is illustrated in Figures 7–9, respectively. $BW_{1\ mm}$ was 5 mm or higher in 22.1% of subjects at site a, in 30.8% of subjects at site b, and 40.7% of subjects at site c. $BW_{3\ mm}$ was 5 mm or higher in 83.4% of subjects at site a, 86.3% of subjects at site b and 92.5% of subjects at site c.

Multilevel Analysis

To investigate the effect of different parameters on the dimensions of the edentulous bone crest and to evaluate the correlation between the measurements, a multilevel multivariate model was built with 2 levels (subject and site) and 2 outcome variables (BH and BW) (Table 2).

Males showed a significantly higher BH compared with females at all sites ($P < 0.001$), the average difference as calculated from the multilevel model being 2.82 ± 1.16 mm. The analysis of the interaction factor between sex and site showed a significant, stronger effect of sex on BH at site c compared with site a. The model showed no significant impact of age on BH ($P = 0.54$) and no significant impact of age and sex on BW ($P = 0.83$ and $P = 0.53$, respectively). A significant covariance between BH and BW (–0.7) was detected from the model.

DISCUSSION

Panoramic radiograph is often the first choice examination for the evaluation of jaw overall shape, such as mental foramen and mandibular canal position.[4,20] The major advantages of such examination are the visualization of all oral areas, low radiation exposure, and the effectiveness. Instead, major disadvantages are resolution, lack of tridimensional view, high distortion, and presence of phantom images.[21] Furthermore, the average of linear error during bone assessments is 24% for panoramic radiograph and 1.8% for computer tomography scans, respectively.[22] As reported by Peker et al[23] computer tomography (CT), three-dimensional images are more accurate than panoramic radiographic images. The efficiency of CT with the potential of low radiation exposure has been shown for CBCT.[24]

The lack of information on post-extraction healing time may represent a limitation of our study. The time elapsed from extraction was previously shown to be associated with the extent of ridge resorption. In particular, the change in ridge height and width averages 0.64 to 2.03 mm (depending on the socket aspect) and 3.87 mm, respectively, after a period of 3 to 12 months after tooth extraction.[25] Residual ridge resorption may progress furthermore, with a variable rate being maximum within 2 years after tooth extraction and progressively decreasing thereafter.[26,27] All CBCT of present cohort showed a clearly identifiable ridge contour with no evidence of the profile of the socket walls, thus suggesting an advanced healing status of the extraction sites. On the basis of these considerations, it may be speculated that the ridge dimensions reported here are derived from a cohort of edentulous patients where the major dimensional modifications of the ridge after tooth loss had already occurred.

Currently, there are few data in the literature on the vertical dimension of the mandibular bone crest in totally edentulous subjects. Most of the reports[4,12] compared dentate and edentulous subjects. Furthermore, in such studies, monoedentulism was considered. The height of the mandible body as measured from the inferior border of the mandible to the alveolar crest was studied by several authors on panoramic radiographs.[4,8,12,28] As described by Xie et al,[12] the average height of mandible body in the first premolar region was greater than in first molar region; such finding was observed for both male and female edentulous subjects. The authors demonstrated that alveolar ridge resorption is usually more rapid in the premolar and molar region compared with the anterior region. Moreover, Saglam[8] confirmed that the premolar site has greater vertical dimension than the molar. In a study on panoramic radiographs, Guler et al[4] evaluated the distance between the alveolar crest and mandibular canal on panoramic radiographs. In the first molar area, the distance was 9.24 for females and 11.44 mm for males, the values being consistent with those reported in this study.

The study of different sections (site a, b, c) using CBCT images was already reported by Yashar et al[19] and Watanabe et al.[29] BH at the site a, b, and c was significantly greater in men than in women ($P < 0.001$). As confirmed by the literature,[4,8,12,20,28] that bone resorption in female patients is greater than in male patients. Similarly, Soikkonen et al[30] reported that mandibular alveolar atrophy was more severe in woman than in men ($P < 0.001$). Such finding was mainly related to hormonal influences such as postmenopausal depletion of estrogens or secondary or primary hyperparathyroidism and resulting in calcium metabolism. Conversely, Yuguzullu et al[31] concluded that BHs in the first premolar and molar regions were similar in men and women.

In this study, BH was not correlated with age. Consistently, Soikkonen et al[30] reported no significant differences in mandibular BH between three different age cohorts. Also, Yuguzullu et al[31] reported that BH of the premolar and molar regions were similar between different age groups. Other studies, however, suggested that increasing age is associated with a decrease in BH possibly due to increased bone resorption.[28]

BW increased from mesial to distal, with no statistical difference in BW between males and females. This finding is consistent with previous studies.[32]

CONCLUSIONS

In the posterior sextants of totally edentulous mandibles, mean residual

BH and width showed a decrease and an increase, respectively, in the mesiodistal direction. Sex showed a significant impact on BH, with males having on average a 2.8 mm greater height than females, but not on BW. Age did not significantly influence the dimensions of the residual bone crest.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

Approval

No approval from an Ethical Review Board was requested for this retrospective analysis of deidentified data.

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