Residual bone height measured by panoramic radiography in older edentulous Korean patients

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PURPOSE. The aim of this study was to obtain statistical data on the residual bone height at different natural tooth positions by panoramic radiography in edentulous Korean patients aged 60-90 years. **MATERIALS AND METHODS.** The study included the diagnostic panoramic radiographs of 180 randomly selected edentulous patients without systemic diseases affecting bone. The radiographic selection criteria included absence of obvious facial asymmetry, clearly visible anatomic structures, and no surgical and fracture history. The panoramic radiographs of 79 patients met these criteria and were used in the analysis. The same researcher processed all the radiographs by using a standardized method. The height of the residual bone was measured at 18 predetermined sites (7 in the maxilla and 11 in the mandible) on digitized and printed radiographs by using a Digimatic caliper, triangle, and ruler. Gender- and age-related differences were statistically analyzed by using the *t*-test and rank-sum test (α=0.05). **RESULTS.** The maxillary residual bone height did not show significant gender-related differences, but male patients had significantly higher residual bone in the mandible($P<.05$). No significant height differences at the measured sites were noted among the 60s, 70s, and 80s age groups. **CONCLUSION.** Dentists should pay greater attention to older female edentulous patients because they are more prone to rapid residual bone resorption. Residual bone resorption may not be affected by age. ***[J Adv Prosthodont 2014;6:53-9]***

KEY WORDS: Radiography; Panoramic; Alveolar bone loss; Denture, Complete; Dental implants; Maxilla; Mandible

INTRODUCTION

In the natural dentition, the masticatory force is distributed through the periodontal ligament to the alveolar bone. This phenomenon leads to physiologic bone stimulation and formation. After tooth loss, the lack of physiologic stimulation causes disuse atrophy of the alveolar bone. Simultaneously, the distribution of force from the periodontal ligament to the alveolar bone is lost and the masticatory force is loaded directly on the bone surface. Moreover, the gingival recession and scar tissue formed after tooth extraction increase the surface tension of the residual bone during complete removable dental prosthesis use. When this force exceeds the physiologic limit, pathologic bone resorption occurs.

Irreversible, persistent resorption results in insufficient residual bone width in the anterior maxilla. In the posterior maxilla, osteoporosis and pneumatization often lead to insufficient residual bone height. Furthermore, the resorption rate of the mandible is four times that of the maxilla.[1] The rate and amount of bone loss are influenced by various factors such as gender, hormones, metabolism, and parafunctional habits. In edentulous patients, atrophy of the residual ridge is one of the most important factors affecting support, retention, stability, and masticatory function of dental prostheses.[2-4]

Accurate morphologic assessment of the residual ridge and residual bone is crucial for treatment planning with endosteal dental implants. In this regard, panoramic radiog-

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raphy enables visualization of the whole dentition, maxilla and mandible, and temporomandibular joints on a single radiograph. It, to a certain extent, also provides useful information about anatomic structures such as the maxillary sinuses, nasal cavity, inferior alveolar nerves, and mental foramens at low cost.[5]

Since July 1, 2012, treatment with complete removable dental prostheses in edentulous Korean patients aged over 75 years has been covered by national health insurance. Since July 1, 2013, the cost of partial removable dental prostheses has also been covered, and treatment with two endosteal dental implants will be insured from July 1, 2014. As the number of patients treatable with such prostheses is expected to increase substantially, knowledge of the residual bone status of Korean people is necessary.

At present, there is insufficient information on the residual bone parameters of elderly edentulous patients for endosteal dental implant placement in Korea. The aim of this study was to obtain statistical data on the residual bone height at different natural tooth positions by panoramic radiography in edentulous Korean patients aged 60-90 years.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board (IRB) of the Dental Hospital of Dankook University (IRB No. H-1307/007/003). It included the diagnostic panoramic radiographs of 180 randomly selected edentulous patients who had visited the Dental Hospital between 2008 and 2013. The patients had no history of systemic diseases affecting bone, such as thyroid disease, hyperparathyroidism, diabetes mellitus, chronic renal disease, and osteoporosis. Imaging had been performed with a Proline PM panoramic X-ray machine (Planmeca, Helsinki, Finland) by using an amplification ratio of 1:1.3.

The radiographic selection criteria of this study were as follows:

1. Clearly visible nasal septum, anterior nasal spine, and nasopalatine foramen
2. Absence of obvious facial asymmetry
3. No surgical and fracture history
4. Clearly visible lower edges of the piriform apertures
5. Clearly visible maxillary sinuses
6. Clearly visible inferior margins of the zygomatic processes of the maxilla
7. Clearly visible mental foramens
8. Clearly visible superior borders of the mandibular canals

The panoramic radiographs of 101 patients did not meet these criteria. Therefore, the panoramic radiographs of 79 patients were used in the analysis.

The coronal width of all the natural teeth except the third molars was measured according to Table 1 to determine the horizontal distances of the teeth from the midline. The horizontal distances were then used to measure the residual bone height at the positions of the natural teeth. For example, the horizontal distance of the maxillary second premolar from the midline was determined as the sum of the widths of the maxillary central incisor, lateral incisor, canine, and first premolar, and half the width of the second premolar (e.g., 8.5 + 6.5 + 7.5 + 7 + 3.5 = 33 mm).The actual distance in the panoramic radiographs was 42.9 mm because of the applied amplification ratio.

Table 1. The coronal width of the natural teeth[6] (unit: mm)

Tooth	Maxilla	Mandible
Central incisor	8.5	5.0
Lateral incisor	6.5	5.5
Canine	7.5	7.0
First premolar	7.0	7.0
Second premolar	7.0	7.0
First molar	10.0	11.0
Second molar	9.0	10.5

The contours of the facial midline (determined from the nasal septum, anterior nasal spine, and nasopalatine foramen), lower edges of the piriform apertures, maxillary sinuses, most inferior margins of the zygomatic processes of the maxilla, mental foramens, and superior borders of the mandibular canals were traced on digitized panoramic radiographs, saved, and printed. The residual bone height was then measured at 18 maxillary and mandibular sites by using a Digimatic caliper (Mitutoyo Corporation, Kawasaki, Japan), triangle, and ruler.

In particular, bilateral parallel lines were drawn at 5.9 and 42.9 mm from the facial midline and through the most inferior margins of the zygomatic processes of the maxilla in the first molar area on the panoramic radiographs. The following maxillary measurements were obtained (Fig. 1):

1. U1: distance from the anterior nasal spine to the residual ridge crest at the midline
2. Central incisor sites 1-1 and 2-1: distances from the lower edges of the piriform apertures to the residual ridge crest along the parallel lines at 5.9 mm from the midline
3. Second premolar sites 1-5 and 2-5: distances from the inferior borders of the maxillary sinuses to the residual ridge crest along the parallel lines at 42.9 mm from the midline
4. First molar sites 1-6 and 2-6: distances from the most inferior borders of the maxillary sinuses to the residual ridge crest along the parallel lines through the most inferior margins of the zygomatic processes of the maxilla in the first molar area

Further, tangents were drawn bilaterally along the lateral border of the mandibular rami and from the most inferior points of the mandibular angles to the most inferior points on the lower border of the mandibular body. Bilateral lines were also drawn from the center of the lower border of the

mandibular body to the bisecting lines at the intersection of the tangents to the mandibular angle–body and rami (A). Then, bilateral parallel lines were drawn at 3.9 mm from the midline, perpendicular to A through the mental foramens, and perpendicular to A at 5.2 mm mesial and 16.3 mm distal to the mental foramens. The following mandibular measurements were obtained (Fig. 1):

1. L1: distance from the inferior border of the mandible to the residual ridge crest at the midline
2. Central incisor sites 3-1 and 4-1: distances from the inferior border of the mandible to the residual ridge crest along the parallel lines at 3.9 mm from the midline
3. First premolar sites 3-4 and 4-4: distances from the inferior border of the mandible to the residual ridge crest along the lines perpendicular to A at 5.2 mm mesial to the mental foramens
4. Second premolar sites 3-5 and 4-5: distances from the inferior border of the mandible to the residual ridge crest along the lines perpendicular to A through the mental foramens
5. Second premolar sites 3-5' and 4-5': distances from the superior border of the mandibular canal to the residual ridge crest along the lines perpendicular to A through the mental foramens
6. First molar sites 3-6 and 4-6: distances from the superior border of the mandibular canal to the residual ridge crest along the lines perpendicular to A at 16.3 mm distal to the mental foramens

The same researcher performed all the procedures, including the screening and observation of the radiographs, measurements, and data recording.

SPSS software (version 18.0, SPSS Inc. Chicago, Il, USA) was used for statistical analysis. The t-test and rank-sum test were used to analyze height differences by gender and age. Differences at the 5% level were accepted as significant.

RESULTS

The panoramic radiographs of 52 male and 27 female patients were analyzed. The patient age ranged from 61 to 86 years, and the mean age was 73 years. The 60s, 70s, and 80s age groups included 24, 40, and 15 patients, respectively.

The residual bone height measured at the 18 sites is presented in Table 2. In the edentulous maxilla, the height at the midline site (U1) was 16.85 mm and that of central incisor sites 1-1 and 2-1 was 13.52 and 13.61 mm, respectively. The residual bone was higher in the facial midline than in the central incisor area. In the second premolar (1-5, 2-5) and first molar (1-6, 2-6) areas, the height of the residual bone was between 5.53 and 5.85 mm. In the edentulous mandible, the height at the midline site (L1) was 21.82 mm and that of central incisor sites 3-1 and 4-1 was 21.70 and 21.74 mm, respectively. The midline residual bone was nearly the same height as the residual bone in the central incisor area. In the second premolar (3-5', 4-5') and first molar (3-6, 4-6) areas, the height of the residual bone was between 7.93 and 8.83 mm.

The t-test did not reveal significant differences in the measured height of the maxillary residual bone by gender. However, male patients had significantly higher mandibular residual bone than female patients ($P<.05$)(Table 3). The rank-sum test showed no significant differences among the three age groups (Table 4).

DISCUSSION

Panoramic radiography is a common imaging technique in dentistry. It is widely used for preoperative radiographic examination of edentulous patients and morphologic assessment before complete removable dental prosthesis and endosteal dental implant placement. Thorpe[7] suggested that it could be used to determine bone density, residual ridge regularity, residual bone height, locations of canals

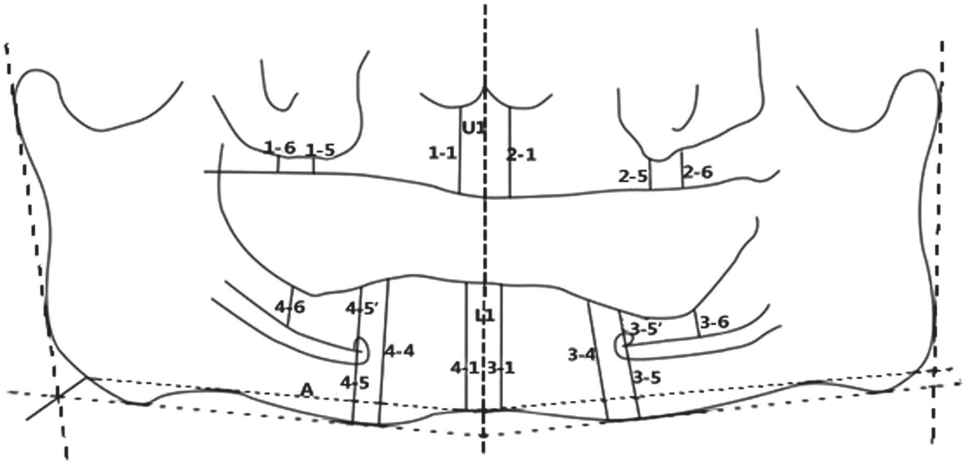

Fig. 1. Vertical distances used to measure the residual bone height of the edentulous patients.

Table 2. The residual bone height at the 18 measured sites (unit: mm)

Measured site	Total (n=79)			
	Mean	SD	Min	Max
U1	16.85	4.09	6.07	26.03
1-1	13.52	3.76	2.98	22.79
1-5	5.63	3.75	0.00	18.12
1-6	5.85	3.32	0.00	15.24
2-1	13.61	3.77	3.85	23.12
2-5	5.65	4.30	0.00	22.22
2-6	5.53	3.58	0.00	15.58
L1	21.82	4.78	9.76	34.01
3-1	21.70	4.98	9.62	33.98
3-4	21.33	5.47	9.62	34.05
3-5	19.72	5.91	2.69	34.38
3-5'	8.38	4.34	1.23	23.46
3-6	7.93	3.81	2.56	19.77
4-1	21.74	4.91	9.45	34.53
4-4	21.45	5.48	8.84	33.49
4-5	20.12	5.93	2.69	33.71
4-5'	8.83	4.48	0.65	25.00
4-6	8.03	3.37	1.31	16.25

See Fig. 1 for an explanation of the measured sites.
SD: standard deviation, Min: minimum, Max: maximum.

Table 3. Gender-based comparison of the residual bone height at each measured site (unit: mm)

Measured site	Female (n=27)				Male (n=52)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	*P*
U1	16.85	3.82	8.91	26.03	16.85	4.66	6.07	25.55	.4977
1-1	13.75	3.62	5.54	22.12	13.08	4.06	2.98	22.79	.2281
1-5	5.92	3.80	0.00	16.68	5.08	3.67	0.00	18.12	.1764
1-6	6.15	3.30	1.33	15.24	5.28	3.34	0.00	12.29	.1369
2-1	13.85	3.52	5.44	21.12	13.14	4.24	3.85	23.12	.2164
2-5	5.87	4.03	0.00	19.52	5.22	4.83	0.00	22.22	.2655
2-6	5.86	3.48	0.00	14.22	4.92	3.74	0.00	15.58	.1356
L1	21.04	4.43	12.02	34.01	23.32	5.14	9.76	31.50	.0214*
3-1	20.85	4.59	11.25	33.98	23.33	5.36	9.62	32.17	.0175*
3-4	20.29	5.03	12.40	34.05	23.32	5.83	9.62	33.16	.0094*
3-5	18.64	5.33	8.46	34.38	21.82	6.50	2.69	31.44	.0111*
3-5'	7.76	4.06	1.23	21.38	9.57	4.69	1.51	23.46	.0391*
3-6	7.18	3.34	2.74	19.77	9.38	4.29	2.56	16.92	.0071*
4-1	20.87	4.45	12.58	34.53	23.43	5.38	9.45	30.79	.0133*
4-4	20.32	4.83	11.97	33.49	23.64	6.07	8.84	30.90	.0049*
4-5	18.93	5.19	8.08	33.71	22.41	6.66	2.69	29.74	.0061*
4-5'	8.09	4.30	2.82	21.15	10.24	4.58	0.65	25.00	.0214*
4-6	7.35	3.38	3.21	14.69	9.33	2.98	1.31	16.25	.0062*

See Fig. 1 for an explanation of the measured sites.
SD: standard deviation, Min: minimum, Max: maximum.
*Groups with significant differences at the 5% level.

Table 4. Age-based comparison of the residual bone height at each measured site (unit: mm)

Measured site	60-69 years (n=24)				70-79 years (n=40)				80-89 years (n=15)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	*P*
U1	16.95	5.24	6.07	26.03	17.24	3.86	8.91	25.55	15.63	2.16	15.48	18.36	.1655
1-1	13.15	4.75	2.98	22.17	14.10	3.50	5.54	22.79	12.56	2.35	10.60	15.52	.2239
1-5	4.97	4.68	0.00	18.12	5.93	3.50	0.00	12.62	5.89	2.70	4.67	9.98	.2184
1-6	5.06	3.77	0.00	15.24	6.27	3.23	1.22	13.08	6.00	2.69	3.28	10.79	.3029
2-1	13.36	4.65	3.85	21.12	14.30	3.47	5.44	23.12	12.14	2.49	11.12	15.62	.0623
2-5	5.54	5.52	0.00	22.22	5.56	3.69	0.00	14.55	6.07	3.85	4.24	14.85	.5403
2-6	4.63	3.33	0.00	15.58	5.75	3.68	0.00	14.22	6.40	3.61	4.25	13.78	.2229
L1	21.58	5.32	9.76	34.01	22.09	4.45	13.77	31.50	21.46	5.02	16.51	30.07	.9730
3-1	21.33	5.39	9.62	33.98	21.96	4.78	13.55	32.17	21.60	5.10	17.09	30.46	.9948
3-4	21.51	5.45	9.62	34.05	21.44	5.58	11.85	33.16	20.74	5.55	16.90	17.73	.8437
3-5	20.37	5.62	8.55	34.38	19.34	6.19	2.69	31.44	19.70	5.93	15.63	30.22	.6902
3-5'	7.94	2.93	1.88	13.52	8.97	4.88	1.23	23.46	7.49	4.74	1.88	16.33	.4491
3-6	7.41	3.54	2.56	18.04	8.31	3.98	2.74	19.77	7.75	3.92	3.36	14.02	.7752
4-1	21.57	5.46	9.45	34.53	22.06	4.69	12.82	31.25	21.19	4.85	14.29	29.11	.9013
4-4	22.04	6.09	8.84	33.49	21.24	5.13	11.54	30.90	21.08	5.71	12.24	29.78	.6312
4-5	20.98	6.17	7.96	33.71	19.52	5.96	2.69	29.74	20.33	5.68	12.03	29.73	.5683
4-5'	8.44	3.78	1.40	15.00	9.27	4.76	2.33	25.00	8.26	4.92	0.65	16.18	.8442
4-6	7.95	3.00	2.98	13.86	8.27	3.33	2.68	16.25	7.51	4.13	1.31	14.69	.6284

See Fig. 1 for an explanation of the measured sites.
SD: standard deviation, Min: minimum, Max: maximum.

and foramens, and the vertical dimension before and after treatment. Its main disadvantage is image distortion: the distortion rate of orthopantomograms is generally between 10% and 30%. The distortion rate attributable to the imaging equipment varies depending on the type of machine and imaged anatomic parts.[8] On the other hand, cone-beam computed tomography (CBCT), first applied in dentistry in the 1990s, has the advantages of precise imaging, high definition, low radiation exposure, short scan time, ease of use, and three-dimensional image reconstruction. In the present study, panoramic radiographs were used instead of CBCT images because fewer than 30 edentulous patients have undergone dental CBCT at the Dental Hospital of Dankook University, which would limit the sample size for statistical analysis. However, instrumental errors were minimized by instructing the patients to stay as still as possible and keeping the head position balanced. The error caused by the positional relationship of the equipment, film, and patient was also reduced to the minimum in this manner.

The rate of residual bone resorption is not constant: it is rapid between 6 months and 2 years after tooth extraction and tends to stabilize thereafter.[1,9] The duration of complete removable dental prosthesis use is an important factor, because the longer the duration of use, the greater is the degree of resorption.[10] Moreover, in the initial stage of complete removable dental prosthesis use, residual bone resorption is rapid; with time, the resorption rate tends to slow.[9] The average surface area of the maxillary and mandibular periodontium is 45cm^2. On the other hand, the maxillary and mandibular prosthetic pressure-bearing areas are 22.96 and 12.25 cm^2, respectively. As the mandibular residual ridge receives more pressure, the degree of residual bone resorption is more in the mandible than in the maxilla.[11]

In edentulism, a complete removable dental prosthesis, overdenture, or implant-supported fixed or removable dental prosthesis is needed to restore mastication, esthetics, phonetics, and other functions. In general, an endosteal dental implant longer than 10 mm is considered to be safe. If the residual bone height in the posterior maxilla is below 4 mm, the maxillary sinus floor should be elevated before implant surgery. However, if the residual bone height is above 4 mm, subantral augmentation and implant surgery can be performed simultaneously. Special care is also required for implant placement if the mandibular residual bone height is under 10 mm.[12] In the present study, the average residual bone height in the anterior maxilla was over 13.75 mm. Therefore, implant surgery would not be difficult to perform. However, the average residual bone height in the posterior maxilla was under 5.85 mm. Subantral augmentation is the most effective and reliable

method to resolve such height insufficiency. Onlay graft and placement of short or angulated endosteal dental implants are other options. Short dental implants reportedly have a low success rate,[13] but several studies showed no significant differences in the success rates of short and long dental implants.[14] Further, Aparicio *et al.*[15] showed that angulation increases the initial stability of dental implants because of the increased implant-bone interfacial area.

During implant surgery in a severely atrophied mandible, the inferior alveolar nerve is most likely to be injured. Implant placement in cases of posterior residual bone height under 10 mm should therefore be performed very carefully.[12] A baseline is necessary for accurate height measurement in the posterior mandible. Güler *et al.*[16] used a line tangential to the most inferior points at the mandibular angle and lower border of the mandibular body as the baseline. Contrarily, it is better to determine the baseline by first identifying two fixed points in the mandibular angle region and at the midline of the mandibular lower border. In the present study, tangents were drawn bilaterally along the lateral borders of the mandibular rami and lines were drawn from the most inferior points of the mandibular angles to the most inferior points on the lower border of the mandibular body. From the intersection of these lines, a bisecting line was drawn in the mandibular angle region on each side and another perpendicular line was drawn at the midline. The bilateral points where these lines met on the mandible were joined and used as the baseline for the mandibular measurements. By this method, the two fixed points could be accurately located on all the panoramic radiographs, reducing measurement errors.

In the mandibular anterior region, the average residual bone height was above 20.85 mm. This height is sufficient for implant placement. However, posteriorly, the average residual bone height was below 8.83 mm, which does not allow placement of implants with adequate length. The mandibular residual ridge can be improved by augmentation techniques such as onlay graft, distraction osteogenesis, or relocation of the mandibular canal. In addition, problems such as poor retention, repeated pain, ulceration, and masticatory dysfunction associated with mandibular complete removable dental prostheses can be effectively resolved with a two-implant-supported overdenture.[17] Dental implants should be placed between the mental foramens to avoid using the mandibular posterior region when the residual bone height is insufficient. Complete removable dental prostheses are a suitable option for patients who are not treatable with dental implants because of financial, medical, or morphologic reasons.

No significant differences were found among the age groups in the present study. This result suggests that residual bone resorption is not affected by age, as previously reported.[16] Rather, the durations of edentulousness and prosthetic use are more important. Although a comparative analysis of the duration of edentulousness is warranted, few patients have such records at the Dental Hospital of Dankook University.

No significant differences in the maxillary measurements were noted between the genders. However, the mandibular residual bone was higher in men. This difference could be explained by the lack of female hormones in postmenopausal women, which may hasten residual bone resorption.[18] The reason for the lack of a significant difference in the maxilla might lie in the different bone densities between the mandible and the maxilla. Trabecular bone is often looser in the edentulous maxilla than in the edentulous mandible.[19] Furthermore, mandibular bone atrophy and osteoporosis have been found to be correlated and more prevalent in women. Therefore, women with mandibular osteoporosis may have more advanced mandibular bone atrophy. In contrast, bone atrophy shows no relationship with osteoporosis in men.[5] In addition, according to Mercier,[20] men have greater facial height and amount of resorbable bone after extraction, so the ratio of the potential units of resorbable bone to the years of resorption act in their favor. He also mentioned that women are more likely to undergo tooth extraction because of pregnancy and other reasons. Therefore, they would have a longer duration of edentulousness.

CONCLUSION

In the maxillary and mandibular anterior regions of edentulous Korean patients, the average residual bone height tends to exceed 13.75 and 20.85 mm, respectively, which would be sufficient for endosteal dental implant placement. However, due to the presence of the maxillary sinuse, the average residual bone height in the posterior maxilla tends to be below 5.85 mm. Therefore, subantral augmentation would be required during implant surgery. Furthermore, the placement of endosteal dental implants with adequate length would be difficult in the mandibular posterior region because of the average residual bone height of under 8.83 mm. Placement of complete removable dental prostheses is possible with such measurements. Dentists should pay greater attention to female edentulous patients, especially older women, because of their greater susceptibility to rapid residual bone resorption. Residual bone resorption may not simply be affected by age.

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