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Original Article

Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients

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Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients

Objective: To evaluate the reduction of residual alveolar ridge height on panoramic radiographs and the differences between denture wearers and non-denture wearers.

Materials and methods: The study consisted of 147 individuals (74 men and 73 women) [50 were denture wearers and 50 non-denture wearers (examination groups) and 47 of them were dentate (control group)]. Individuals having diseases impacting on bone were excluded. Vertical measurements were made at 15 sites (central incisors, first premolars and molars at the left and right of both jaws and the distance between the zygoma/orbit). MANOVA (multi-variate analysis of variation) was used for the statistical analysis of the results.

Results: There were significant differences between the alveolar ridge heights of dentate and edentulous groups ($p < 0.001$). Between the denture wearer and the non-denture wearer groups, there was significant difference in the lower jaw ($p < 0.001$), but no significant difference in the upper jaw ($p = 0.635$). There were also differences between men and women ($p < 0.005$) and upper and lower jaws at every measurement sites ($p < 0.01$).

Conclusion: Reduction in residual alveolar ridge height was in close relation with gender, denture usage and edentulousness.

Keywords: alveolar resorption, residual ridge, denture wearer, non-denture wearer, panoramic radiography.

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Introduction

The alveolar ridge, which is the bony structure of the maxilla and mandible that contains the dental sockets, supports the teeth. The structure left after extraction of teeth is called the 'residual alveolar ridge' (RRR) and this term ridge encompasses all the changes that accompany bone loss after tooth extraction[1,2].

Local and anatomical factors have the most influence on RRR[1,3]. The lack of mechanical stress, absence or presence of dentures, number of years of denture use, number of sets of dentures and muscle tone are known functional factors. Anatomical factors include facial form, original size of mandible, original depth of sockets, local bone quality, blood supply and muscle attachments. Inflammatory factors include trauma at extraction, pre-existing or residual infection, local inflammatory mediators and denture hygiene. Finally, age and gender, bone regulatory hormones, diseases such as diabetes, hyperparathyroidism and systemic osteoporosis, and corticosteroid therapy are systemic factors[2,4–7].

It is known that the presence of a tooth has a positive effect on the shape and dimension of mature jaws. After tooth extraction, there follows a phase of remodelling which may result in a reduction in the height of the jaws. After tooth extraction, the socket is filled with a blood clot. Osteoprogenitor cells of the periodontal ligament differentiate into osteoblasts, invade the coagulum, and form woven bone. Later this bone is replaced by cancellous bone. The crest of the residual ridge narrows and the sharp edges of the alveolar processes are reduced. In this way bone is exposed to a loss of height with periosteal osteoclastic resorption. Endosteal apposition accompanies this resorption, but at no time is new bone formation

seen on the periosteal surface of the residual ridge, which remains porous, never developing a complete cortical layer[2,4].

The method used in our study was developed by Xie *et al.*[3], who conducted a study on dentate and edentulous patients. They found that the reduction in the residual alveolar ridge of the edentulous mandible was greater than that of the maxilla. In addition, the percentage reduction in the mandible of women was greater than that in men. Sağlam[8] found similar results.

The residual alveolar ridge has an important impact on the stabilisation and function of dentures. Most authors agree that a reduction in the residual alveolar ridge is closely associated with the use of dentures[3,4,9]. Compressive forces directed onto the mucous membrane from prosthetic restorations affect the metabolism of the underlying tissues by obstructing blood flow and initiating RRR[1,10] and mucosal inflammation can cause resorption via the generation of arachidonic acid metabolites or interleukins[2].

In this study the differences in RRR between dentate and edentulous individuals were explored. The differences between the denture wearer and non-denture wearing edentulous individuals using panoramic radiographs to establish the potential adverse effects of denture wearing on RRR were also examined.

Materials and methods

This study was carried out on a total of 147 volunteer individuals (74 men and 73 women) with an age interval of 40–77, who attended the Department of Oral Diagnosis and Radiology. This study was approved by the Local Ethics Committee (03 November 2004/68).

Individuals with a history of hyperparathyroidism, osteoporosis, hypo and hyper-thyroidism, diabetes, chronic renal disease and malignancy of bone were excluded from the study. They were divided into three groups:

Group I: Dentate subjects (control group): consisted of 47 subjects (23 men and 24 women) with a mean age of 53.4 (range 40–74). Inclusion criteria: (i) no gross attrition of the occlusal surface or incisal edge of the teeth present and (ii) at least 20 teeth present (for the anterior: two in each jaw, for the posterior: two on the left and right of each jaw).

Group II: Totally edentulous and denture wearers: consisted of 50 subjects (22 men and 28 women) with a mean age of 58.9 (range 44–76). The average denture-wearing period of women was 15.2 years (range 1–30 years); for men it was 12.3 years (range 2–32 years). The average number of dentures used by women was 1.46 (range 1–3 years) and by men it was 1.2 (range 1–3).

Group III: Totally edentulous and non-denture wearers: consisted of 50 subjects with a mean age of 59.8 (range 40–77): 29 men and 21 women.

Procedures

Panoramic radiograph were taken at the same hour of the day by one qualified technician, with particular attention to the horizontal and sagittal positioning of the head with a 70 KvP, a 15-mA panoramic machine (Siemens Orthopos II CD D3200, Münich, Germany), and processed with an automatic processor (Dent X 9000, New York, USA).

Criteria for the selection of panoramic radiograms:

1. Radiographic images of anatomic landmarks such as the inferior and posterior border of the mandible, the inferior points of orbit, and the zygomatic process, must be evident.

2. No gross distortion of images of the maxilla and mandible.

3. Space between the maxillary and mandibular teeth form an approximately horizontal space (upper and lower ridges were not at contact).

4. To control the contrast, an aluminium step-wedge was used during the exposure.

The reference lines and measurement points were marked manually on the panoramic radiographs with a 0.5-mm lead pencil on a standard light box.

First, lines joining the most inferior borders of the two orbits (Ho) and the most inferior borders of the two zygomatic processes (Hz) in the maxilla, a line passing from the most inferior borders of the angles of the mandible and mandibular body (D_1), and a line parallel to D_1 at 10 mm above it (D_2) in the mandible were drawn.

Nine measurement points were determined: the mandibular and maxillary midlines (in maxilla A_1, in mandible C_1); the distal surfaces of the first premolars (FP) on the left and right (in maxilla A_2, in mandible C_2); the distal surfaces of the first molars on the left and right (in maxilla A_3, in mandible C_3); and the distance between the zygoma and the orbit at the midlines (B_1), at the premolar region (B_2), and at the molar region (B_3). In the dentate jaws, the measurement points were accepted as 2 mm above the cemento-enamel junction of the teeth, and in edentulous jaws as the top of the ridge. In the edentulous maxilla, the midline was determined by examining the images

of the nasal septum and the spina nasalis anterior. The first premolars were determined by images of the mesial border of the foramen infraorbitale, and the molars were determined by images of the lower border of the zygomatic process. In the mandible, the midline was determined by images of the foramen linguale and the premolars–molars were determined according to their places on the line D_2 of the dentate jaws (see Figs 1 and 2).

Measurement

The lines in the upper jaws (A_1, A_2, A_3 and B) and the lower jaws (C_1, C_2 and C_3) were measured with a digital compass sensitive to 0.01 mm on a standard light box. Measurements were made by one observer (Canger EM). The compass was occasionally calibrated on a transparent ruler. All measurements were repeated one month later by the same observer.

Statistical analysis

The data were analysed with SPSS[4]. The normality of the data was controlled with Shapiro Wilk's normality test before the statistical analysis, and it was understood that the results were normal. The data were expressed as the mean (Standard deviation). Measurements were evaluated with MANOVA. If a significant result was realised, the Bonferroni correction test was used. The level of significance was set as $p < 0.05$. Repeatability of the measurements was assessed by analysing the difference between measurements made one month apart on the radiograph of the all patients. A paired-sample *t*-test showed that the difference between the first and second measurements for the all patients was insignificant at the 95% confidence level.

Results

Regional measurement

Measurements were performed on 139 upper jaws (42 dentate, 49 edentulous denture wearer, 48 edentulous non-denture wearers) and on 144 lower jaws (45 dentate, 50 edentulous denture wearers, 49 edentulous non-denture wearers). Films on which the measurement points were not visible were excluded from the study (see Table 1, Table 2).

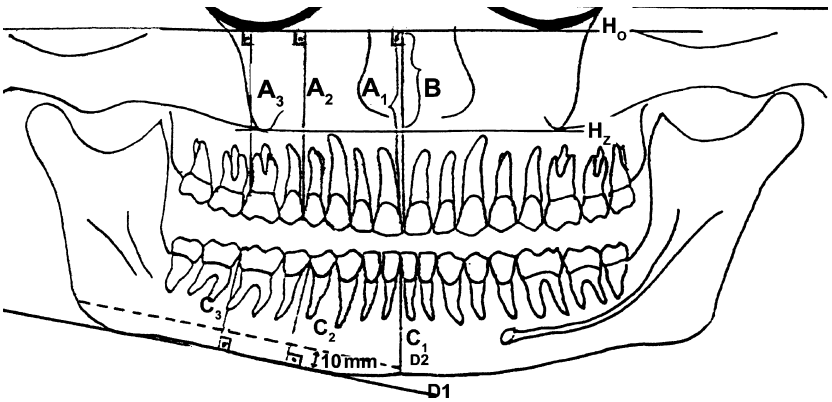

Figure 1 Reference points, measurement lines and points of dentate jaws.

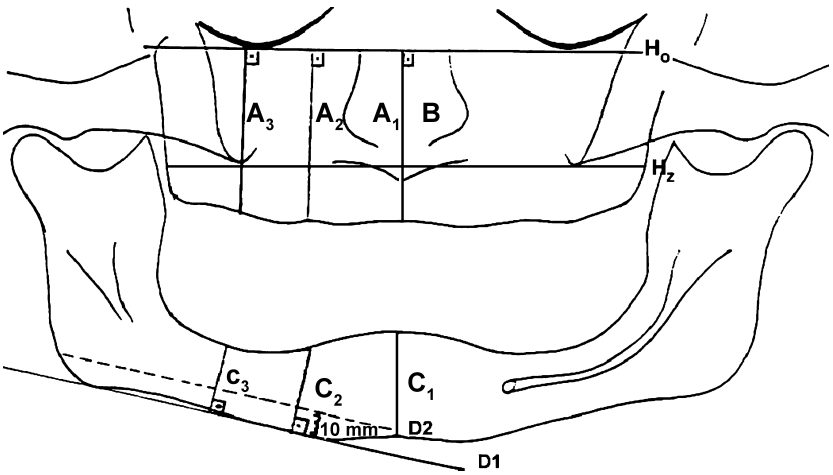

Figure 2 Reference points, measurement lines and points of edentulous jaws.

Table 1 Vertical heights (mm) of maxillary and mandibular bones in dentate group (I) and denture wearer (II) and non-denture wearer (III) groups according to gender.

Groups	*Women* *Region*	*n*	*Mean*	*Max*	*Min*	*Men* *n*	*Mean*	*Max*	*Min*
I	A_1	24	45.98 ± 3.64	48.63	45.17	23	47.57 ± 3.55	49.18	45.89
	A_2	22	44.40 ± 3.39	47.03	42.53	23	46.11 ± 3.21	48.22	43.94
	A_3	23	43.73 ± 3.02	45.52	41.82	21	44.61 ± 3.80	46.37	42.85
	C_1	24	40.55 ± 2.66	42.73	38.85	23	42.81 ± 3.61	44.14	40.46
	C_2	24	38.3 ± 2.36	40.41	35.93	23	41.03 ± 3.5	42.79	38.54
	C_3	22	32.72 ± 2.46	34.48	30.83	23	35.58 ± 3.77	37.08	33.61
	B_1	24	23.38 ± 3.47	25.13	22.35	23	23.81 ± 2.86	25.27	22.62
	B_2	24	23.34 ± 3.50	22.24	19.96	23	23.81 ± 2.83	24.67	22.04
	B_3	24	23.24 ± 3.48	25.09	22.31	23	23.78 ± 2.88	25.22	22.58
II	A_1	28	40.19 ± 3.28	41.61	38.76	21	39.90 ± 4.53	41.55	38.26
	A_2	28	38.18 ± 7.58	40.03	36.33	21	39.90 ± 3.8	42.04	37.76
	A_3	28	36.39 ± 3.82	37.92	34.87	21	37.10 ± 4.3	38.86	35.34
	C_1	28	27.09 ± 5.1	28.68	25.50	22	30.58 ± 4.47	32.23	28.54
	C_2	28	24.05 ± 6.2	25.90	22.20	22	29.07 ± 5.5	30.94	26.68
	C_3	28	19.71 ± 4.03	21.21	18.21	22	24.07 ± 5.41	25.43	21.96
	B_1	28	21.11 ± 2.63	22.26	19.97	22	23.47 ± 3.5	24.71	22.07
	B_2	28	21.10 ± 2.64	22.24	19.96	22	23.43 ± 3.40	24.57	22.04
	B_3	28	21.12 ± 2.68	22.27	19.98	22	23.43 ± 3.40	24.67	22.02
III	A_1	21	38.11 ± 3.52	40.29	36.83	29	42.84 ± 4.53	44.24	41.43
	A_2	20	36.53 ± 3.81	35.77	32.07	29	41.42 ± 5.24	43.24	39.60
	A_3	20	33.68 ± 3.34	35.77	32.07	29	39.25 ± 5.17	40.75	37.75
	C_1	21	30.83 ± 3.93	33.31	29.43	29	37.3 ± 50	38.87	35.73
	C_2	20	28.62 ± 5.04	31.21	26.74	29	34.39 ± 5.21	36.20	32.58
	C_3	21	22.97 ± 3.82	25.24	21.60	29	27.91 ± 4.07	29.40	26.44
	B_1	21	19.60 ± 2.1	21.22	18.44	29	22.85 ± 3.56	23.97	21.72
	B_2	21	19.58 ± 2.06	21.20	18.43	29	22.85 ± 3.57	24.67	22.04
	B_3	21	19.60 ± 2.04	21.22	18.44	29	22.86 ± 3.60	24.00	21.74

The measurement results of the dentate jaws indicated that the first premolars (FPs) were located at 35% of the horizontal length of the mandible (D_2) and the first molars (FMs) were located at 53% of the horizontal length of the mandible (D_2).

1. In the upper jaws, the vertical heights of the dentate group were greater than the two edentulous groups ($p < 0.001$).

2. Between the two edentulous groups there were statistically insignificant, but mathematically significant differences existed ($p > 0.05$). The vertical heights of the non-denture wearer group were greater than the denture wearer group.

3. In the lower jaw, results were different from the upper jaw. The vertical height of the dentate jaw was greater than the two edentulous groups. This difference was statistically significant ($p < 0.001$). Contrary to the upper jaw, the vertical height of the non-denture group was greater than the denture wearer group. This difference was also statistically significant ($p < 0.001$).

Table 2 *p*-Value comparisons of the groups and genders.

	Group I	*Group II*	*Group III*	*Women*	*Men*	*Different Group*
A_1	a*	b**	b**	a	b	III
A_2	a*	b**	b**	a	b	($p < 0001$)
A_3	a*	b**	b**	a	b	
C_1	a*	b*	c*	a	b	
C_2	a*	b*	c*	a	b	
C_3	a*	b*	c*	a	b	
B_1	a‡	b**	b**	a	b	($p < 0.001$)
B_2	a†	b**	b**	a	b	
B_3	a†	b**	b**	a	b	

abb = first group is different, the other groups are not different.
abc = both groups are different from each other.
*$p < 0.001$.
**$p > 0.05$.
†$p < 0.05$.
‡$p = 0.005$.

4. There were significant differences between men and women (in the maxilla $p < 0.005$, in the mandible $p < 0.001$). The height in men was greater than that in women.

Discussion

Panoramic radiography is widely used because an image of both jaws can be produced on one film with a relatively low dose of radiation, and is common in routine examinations, especially for edentulous patients before the construction of complete dentures[3,5,8,11,12]. It is an advantage to know the magnification factors and appropriate positioning of the head by using guides, such as the light cross and the chin brace, can minimise errors and eliminate distortions and image magnifications[12–16]. Reproducibility studies may also be possible by using a panoramic radiograph[15,17,18].

To visualise RRR on panoramic radiographs, Wical and Swoope[19] determined the pre-resorption level of the mandible by multiplying the distance between the lower border of the foramen mentale and the lower border of the mandible by three. The difference between the two values gave the amount of the resorbed mandible. However, this method only supplies information about RRR in the foramen mentale region and no information can be obtained from the other parts of the mandible and maxilla. Xie *et al.*[3] later developed a method that took into account the other parts of the mandible and maxilla.

By using this technique, Xie *et al.*[3] found statistically significant differences between dentate and edentulous subjects in both sexes. The vertical residual alveolar heights of the edentulous mandible and maxilla were less than that in dentate individuals. In addition, the reduction in the residual alveolar ridge of the edentulous mandible was greater than that of the maxilla. RRR in the maxilla is three or four times smaller than that of the mandible because its wider surface area and thin cortical and thick trabecular bone structure help the maxilla to absorb the biting forces more effectively than the mandible[20]. For dentate jaws Sağlam[8] was unable to find a significant difference between men and women, but found that the height of the mandible was greater in men than in women. In edentulous jaws, the height of the maxilla and mandible was significantly greater in men compared with women. He also stated that the reduction in the residual alveolar ridges of the maxilla and mandible was more pronounced in women than in men.

To our knowledge, there has been no study on RRR in non-denture wearing patients using panoramic radiographs. In our study, we found significant differences between the dentate and two edentulous groups in both sexes. There was no statistical difference between the denture wearing and non-denture wearing group. The vertical heights of the non-denture users were greater, especially in the mandible, when compared with the denture-wearing group. In the maxilla, the vertical heights of the two edentulous groups were similar.

The loss of vertical height is four times greater in the anterior region of the jaws than the posterior regions. In addition, the rate of resorption is more rapid in the first year of denture wear[2,4,20] and it is known that denture wearing can stimulate or accelerate RRR[21]. Impression techniques, impression and base materials, artificial teeth and their placement on the ridge are some of the possible prosthetic factors[1]. Furthermore, if there is not sufficient interocclusal distance, the forces directed onto the residual ridges may increase to a pathological degree[1,10]. It had previously been proposed that inserting dentures prevent ridges from resorption, and that disuse atrophy is an important factor in the resorption of edentulous jaws. Campbell[22] stated that the ridges of denture wearers were smaller than those of non-denture wearers, and claimed that resorption in the jaws of denture wearers was worse than in the non-denture wearers. Pietrokovski *et al.*[23] showed that residual ridges were significantly wider in non-denture wearers. All these results seem to support the hypothesis that the occlusal forces applied through the dentures accelerate RRR and that RRR is associated with denture wearing[19,24]. The purpose of dentures is to restore function and morphology. In patients treated with prostheses, mechanical stresses may be derived from the occlusal (functional) forces and be applied to the underlying tissues via the dentures. If these stresses are tolerated by the host, remodelling of the remaining tissues may occur. In cases of excessive stress, dysfunctional remodelling such as bone resorption will occur[24]. Milam and Schimitz[25] explained this resorption mechanism using three models: under excessive mechanical stresses, tissues are either destroyed directly or damaged indirectly. They advanced their theory by the addition of the concept of oxidative stresses, in which mechanical stresses generate free radicals that cause resorption of bone or injury of the TMJ. However, the effects of individual differences such as the period of edentulousness, systemic condi-

tions, the quality and function of the dentures, age, gender, the periodontal condition of the teeth before extraction, and the vertical height of the existing ridges are not remissible in the evaluation of RRR. From the point of view of these results, our study seems to be consistent with other studies.

In our study, significant differences were detected between women and men in every part of the jaw in both edentulous groups. Although the exact adverse affects of gender and age on RRR have not yet been established, the greater rate of RRR within women is attributed to the accelerator effect of oestrogen deficiency on generalised mineral loss from the skeleton during and after menopause[5,6].

Occlusal harmony in complete dentures is necessary if the dentures are to function efficiently, and to preserve the supporting structures. Uneven occlusal contacts damage the uniform distribution of occlusal forces, and accelerate the RRR. The resiliency and the displaceability of the supporting soft tissue tend to disguise premature occlusal contacts. It is the responsibility of the dentist to identify and correct these occlusal discrepancies.

What can be done to protect the bone under the dentures? The results of a study by Crum and Rooney[26] indicated that the use of the mandibular overdenture helped preserve alveolar bone in the mandible. Retention of the teeth in the anterior part of the mandible was advantageous. They suggested that the discrete proprioceptive ability of the teeth under an overdenture acted as a signal against the physiological overload of the system and thus prevented bone resorption. Similarly, Van Waas *et al.*[27] stated that retention of tooth roots, even if they are in poor condition, has a positive effect on the reduction of alveolar bone loss. In addition, with the use of implant-supported dentures, it was shown that bone loss decreased significantly when compared with conventional dentures and that the height of the posterior ridges increased[28,29]. Wowern and Gotfredsen[30], Wright *et al.*[31], Kordatzis *et al.*[32] and Wright and Watson[33] in their follow-up studies, compared implant-supported dentures with conventional ones. They all indicated that implant-supported dentures showed a minimal reduction in the residual alveolar ridges and that patients were more comfortable. Meijer *et al.*[34] also showed bone growth around implants in their 5-year follow-up study.

Conclusions

1. The vertical heights of the dentate group were greater than the denture wearer and non-denture wearer group.

2. The vertical heights of the non-denture wearer group were greater than the denture wearer group, especially in the mandible. In the maxilla, there were no significant differences between the vertical heights of non-denture and denture wearer groups. It can be suggested that the maxilla may protect itself since it is wider than mandible, and its composition helps the maxilla to accomplish the forces being applied on it. Also, factors such as the denture-wearing period, the materials used (base, artificial teeth, etc.), impression techniques, and the planning of the dentures have to be considered as important.

3. Reductions in the RRR in women are more pronounced than men especially in those of advanced age. This situation could be explained by post-menopausal changes and by the fact that conditions such as osteoporosis affect women more than men.

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