A Retrospective Analysis of Mandibular Bone Height Changes Associated with 81 Screw-Retained Implant-Supported Prostheses with Distal Cantilevers: A Long-Term Follow-up Analysis

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Purpose: *The aims of this study were (1) to evaluate long-term changes in bone height beneath mandibular screw-retained implant-supported prostheses with distal cantilevers and (2) to determine whether the reversal of residual ridge resorption in the posterior mandible is temporary or continues over the long term.* ***Materials and Methods:*** *Panoramic radiographs, obtained at surgery and at two follow-up visits, of 81 patients rehabilitated with mandibular screw-retained implant-supported prostheses with distal cantilevers supported by four, five, or six implants were followed for 5 to 19 years (overall mean follow-up, 9.00 years. Changes and trends in bone height adjacent to the most distal implant were evaluated between each follow-up visit as well as from time of surgery (baseline) to the final visit using two-way analysis of variance, a two-sample* t *test, and piecewise linear regression.* ***Results:*** *Average bone height distal to the distalmost implant at placement was 10.34 ± 6.87 mm. From baseline to the first follow-up exam, a mean bone gain of 0.68 mm was noticed, and a mean gain of 0.26 mm was observed from baseline to the second follow-up exam. A statistically significant bone gain (0.92 mm) was noticed in women (n = 49) between the first and second exams, compared to 0.33 mm in men (n = 32). Individuals experienced both bone gain and loss during the study, with an overall gain. Patients with lower initial bone height experienced greater growth, but this was not statistically significant.* ***Conclusion:*** *Bone growth is associated with mandibular screw-retained implant-supported prostheses with distal cantilevers, and both bone loss and bone growth may occur in the same patient over time. Within the diverse population of this study, women experienced 2.5 times more gain in bone height than men. No correlation could be established between initial bone height and overall bone height changes.* Int J Oral Maxillofac Implants 2013;28:854–859. doi: 10.11607/jomi.2768

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Residual ridge resorption is assumed to be a multifactorial process that affects the mandible after tooth loss. Several factors influence this process, such as metabolic, anatomic, and biomechanical dynamics. Since the early 1980s, increased radiographic bone density around osseointegrated loaded implants has been reported.[1,2] In several case series, rehabilitation of the edentulous mandible with implant-supported prostheses appeared to arrest or reverse the process of residual ridge resorption.[3–8] Betts et al,[5] in a case series of 19 patients, observed bone regeneration following placement of transmandibular implants in

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severely atrophic mandibles in the edentulous areas distal to the distalmost implants during the first year of function, which continued beyond that time. More recently, Reddy et al[9] reported bone growth distal to the most posterior implant in 60 patients rehabilitated with a mandibular implant-supported cantilevered prosthesis who were followed for a maximum of 4 years. Clinical examination of this patient population revealed that 54% of the frameworks' distal extensions were in contact with the mandibular ridge, supporting the hypothesis that shear/tension stress is the major determinant of bone growth.

Bone biology studies have shown that an increase in the biomechanical loads placed on bone cause strains within the bone that lead to stimulation of growth within the bone and an increase in bone volume.[10,11] In a comparison of the effect of fixed and removable implant-supported prostheses on resorption of the posterior mandibular residual ridge, Wright et al[12] not only found greater bone apposition in patients treated with fixed implant-supported mandibular prostheses (mean follow-up time, 2.9 years) but also noted greater bone growth in patients with a lower initial bone height. While the longest follow-up of the bone response distal to the cantilever in a mandibular fixed implant-supported prosthesis was 4 years in 60 patients,[12] it was during the first year that the greatest bone growth was observed. Such findings merit further evaluation in a larger patient population over a longer follow-up period.

While the well-known process of residual ridge resorption[13] continues in the edentulous patient, it is important to determine whether rehabilitation with a fixed implant-supported prosthesis arrests and even locally reverses this process in a larger patient population. Additional consideration should be given to the influence of factors such as gender, initial bone height, and number of implants placed as they relate to the long-term bone height changes seen in these patients. The hypothesis is that a longer follow-up period of a larger population of patients rehabilitated with a mandibular fixed implant-supported prosthesis will show continuous alveolar bone height gain distal to the distalmost implant. The aims of this study were: *(1)* to evaluate the long-term changes in bone height of mandibular screw-retained implant-supported prostheses with distal cantilevers and *(2)* to determine whether the reversal of residual bone resorption in the posterior mandible is merely temporary or continues in the long term.

MATERIALS AND METHODS

A retrospective analysis of panoramic radiographs of 81 patients with atrophic mandibles rehabilitated with screw-retained implant-supported cantilevered prostheses was completed at the time of implant placement and at two follow-up exams performed at various times. Panoramic radiographs not originally available in digital form were scanned and analyzed using the same computer enhancement method software as those originally obtained in digital format, which allowed for calculations to be carried out to the one hundredth decimal place.[9] The most distal implant on the right was measured to serve as a standard and compared to the known exact length of the implant to correct for magnification error. The height of the mandible was measured distal to the most posterior implant on the right. Each measurement was performed three times by the same examiner, and the average of the three measurements was recorded. Measurements were recorded from panoramic radiographs obtained at time of implant placement (considered as baseline), at the first follow-up exam, and at a second follow-up exam. Patient demographics, date of implant placement, implant type, number of implants, date of definitive prosthesis placement, time intervals, and bone height changes between radiographs were recorded. The measurements were analyzed using two-way analysis of variance, a two-sample *t* test, and piecewise linear regression to evaluate the relationship between changes in bone height and sex, implant number, and initial bone height.

RESULTS

Overall, 32 men and 49 women were rehabilitated with mandibular screw-retained implant-supported prostheses with distal cantilevers, and they experienced a mean bone height gain of 0.94 mm during a follow-up period up to 19 years (Table 1). The greatest change of 3.61 mm in one woman is illustrated in Figs 1a and 1b. Bone height change was statistically significant at each follow-up exam; the greatest gain was seen between baseline and the second follow-up exam (0.68 mm), with a mean follow-up time of 4.53 years (Fig 2). The findings in this study indicate that, while patients experienced an overall bone height gain, both losses and gains were seen (Fig 3).

There were statistically significant differences between men and women in bone height gain (Table 2). The specific duration of follow-up with respect to number of patient observations is shown in Table 3. The mean follow-up time from baseline to the first follow-up exam was 4.53 years, while mean follow-up time from the first to the second follow-up exam was 4.48 years. Overall follow up time from baseline to second follow up exam was 9.0 years. Women experienced three times more bone height gain (0.922 ± 0.11 mm)

Table 1 Comparison of Mean Bone Height Changes at Each Follow-up Exam

Follow-up time	Bone height change (mm) (range)	95% CI	*P*
Exam 1 to baseline	0.68 ± 0.83 (–1.429 to 3.616)	3.9374 to 5.1243	< .0001
Exam 2 to exam 1	0.26 ± 0.49 (–0.670 to 1.830)	0.1446 to 0.3809	< .0001
Exam 2 to baseline	0.94 ± 0.99 (–1.071 to 4.732)	0.6998 to 1.1739	< .0001

95% CI = 95% confidence interval.

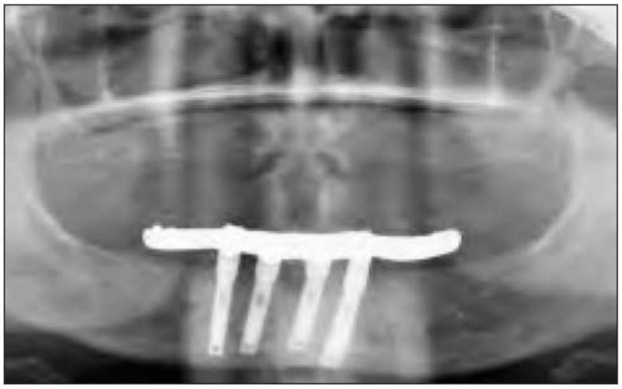

Fig 1a Panoramic radiograph of a patient in the sample, obtained in 1988.

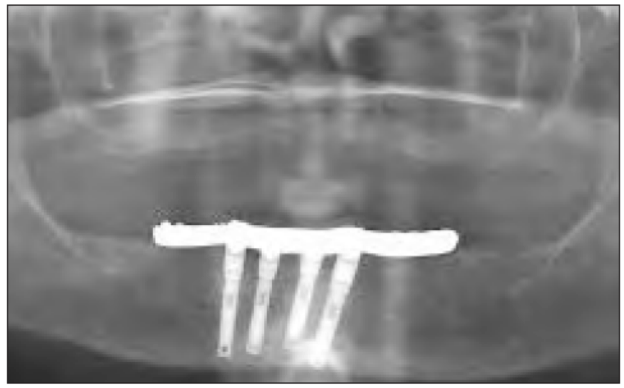

Fig 1b Panoramic radiograph of the same patient in 2006, 18 years later.

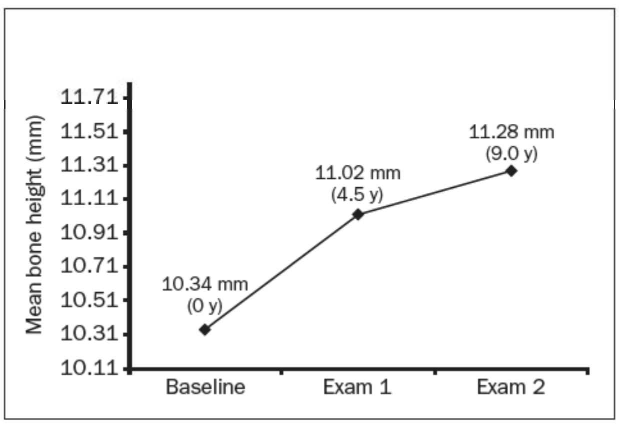

Fig 2 Bone height changes in the entire study population. Mean follow up times were: 4.53 years baseline to first follow up exam, 4.48 years first follow up exam to second follow up exam, 9.0 years baseline to second follow up exam

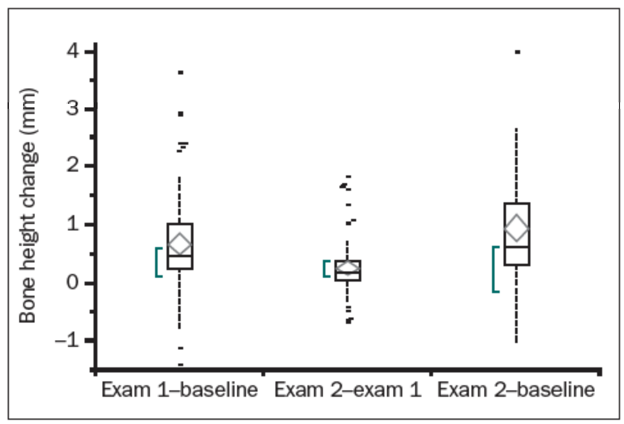

Fig 3 Mean bone height changes between follow-up exams and baseline.

from baseline to the first follow-up exam, compared to 0.299 ± 0.11 mm overall bone height gain in men ($P < .0007$). Both sexes experienced similar bone height gain between the first and the second follow-up evaluation. Overall, both sexes had similar mean initial bone height, but women experienced 2.5 times greater bone height gain than men (Fig 4). While overall greater bone height gain was noted in the female population, more women experienced both gains and losses throughout the years, in contrast to the male population, which showed an overall slow bone height gain, with few cases (5 of 32) showing both bone height loss and gain. The greatest bone height gain was noted in one woman, who showed 3.61 mm of bone height gain at 2 years after rehabilitation. Initial bone height and number of implants placed to support the prostheses (range, four to six) appeared to have no significant impact on bone height changes (Fig 5).

Table 2 Influence of Sex on Bone Height Changes

Sex	Mean bone height at baseline (mm)	Change in bone height (mm)		
		Exam 1 to baseline	Exam 2 to exam 1	Exam 2 to baseline
Men (n = 32)	10.11	0.299 ± 0.11*	0.218 ± 0.10	0.498 ± 0.19*
Women (n = 49)	10.54	0.922 ± 0.11*	0.288 ± 0.07	1.181 ± 0.14*

*$P < .0007$ for comparison of changes in bone height between men and women for exam 1 to baseline; $P < .0051$ for comparison of changes in bone height between men and women for exam 2 to baseline.

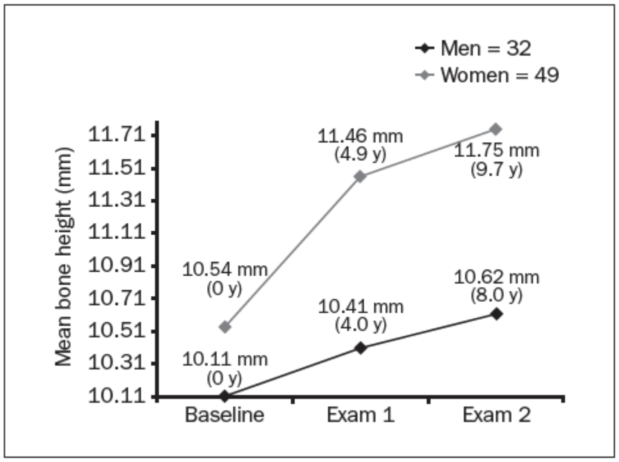

Fig 4 Mean bone height changes by sex.

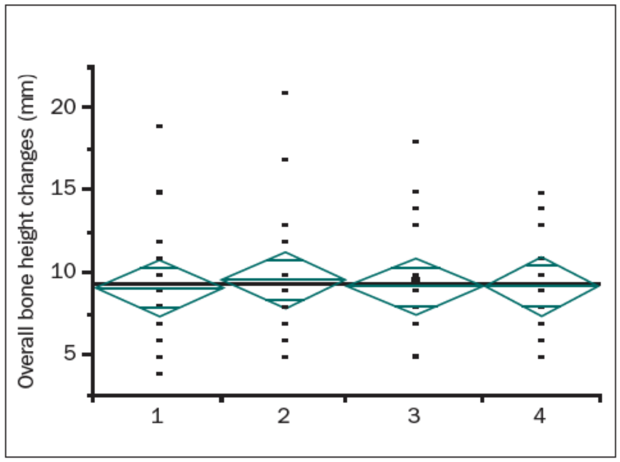

Fig 5 Influence of initial bone height on overall change in bone height. 1 = Bone height ≤ 5.00 mm; 2 = 5.00 mm < bone height ≤ 10.33 mm; 3 = 10.33 mm < bone height ≤ 15.00 mm; 4 = bone height > 15.00 mm. A total of 81 patients were evaluated with measurements completed on the right-most distal implant for each patient.

DISCUSSION

In edentulous patients rehabilitated with fixed implant-supported mandibular prostheses, osseous proliferation in the areas distal to the most posterior implant has been reported.[1,2] The longest follow-up period in the literature gives insight into the bone height changes experienced up to 4 years posttreatment; these indicate that implant placement in the mandibular arch prevents ridge resorption, with a small amount of bone gain observed both clinically and radiographically.[9] Furthermore, the most growth occurred during the first year, followed by a steady gain in bone height during the following 3 years. The current study's findings support those of Reddy and Wang,[14] while for the first time providing information on trends in bone height changes for up to 19 years of observation. Several theories have been suggested to explain the noted change (overall gain) in bone height associated with this treatment. One of those theories is Wolff's law of functional adaptation.[15] According to this theory, bone increases in its configuration when subjected to stress. The overall gain in bone height seen beneath the cantilever area may be associated

Table 3 Years of Follow-up from Baseline to Second Follow-up Exam

No. of years	No. of patients
5	16
6	6
7	13
8	11
9	5
10	11
11	4
12	2
13	3
14	2
15	2
16	0
17	1
18	3
19	2

with the stress distributed from the prosthesis transmitted directly to the bone through the osseointegrated implants. This theory may be further supported by the bone biology literature, which postulates that positive bone remodeling is seen in response to the increased function seen in these patients.

Another possible theory that was actually incorporated into a negative-feedback concept to explain the mechanisms behind Wolff's law is that related to the electromechanical properties of bone first studied by Fukada and Yasuda.[16] Studies have suggested that the electrical properties of bone probably play an important role in remodeling activity and bone growth.[17,18] The term *piezoelectricity* refers to mechanical energy expended in the biologic structures that make up bone that is able to produce electric potential that is sufficient to affect cell behavior, including cell nutrition, enzyme activation/suppression, migratory and proliferative activity of osteoclasts/osteoblasts, and synthetic capacity and specialized cell functions such as cell membrane permeability.[19] Originally, Bassett and Becker[18] proposed that these electric potentials are biologically active, as they are generated by strain or stress in bone. Further research showed that mesenchymal cells involved in osteogenesis were sensitive to such changes.[18,20] It was subsequent to these findings that the piezoelectric properties of bone were incorporated into the explanation of Wolff's law, wherein Bassett and Becker proposed that these electric potentials were the signals that commanded the operation of Wolff's law.[18] Following this premise, the bone height changes noted in this study may be well explained by both theories. The functional pressure (stress) converts to an electrical stimulus by piezoelectric components in bone (collagen, collagen-apatite, protein polysaccharides). The stimulus generated influences cell migration, nutrition, and changes in osseous architecture.

Another interesting consideration is the suggestion of a possible interaction between older age and the electric properties of bone.[21] Mature bone has been shown to not only exhibit a higher piezoelectric constant but has been shown to have higher conductivity corresponding to the age-dependent increase in the inorganic portions of bone density.[22,23] In the present study, none of the patients were children or young adults, further suggesting that older age may also be a contributor to the study's findings. Furthermore, a significantly increased maximum force has been shown to be generated when patients are provided with a mandibular fixed implant supported-prosthesis rather than a conventional complete denture.[24]

Consistent with other similar studies,[12] both bone loss and bone growth were noted in this study's patient population. This finding may be attributed to the sex, age, hormonal changes, and variable amounts of exerted force that men and women in this study experienced during the follow-up period. Among both sexes, bone loss was also seen, although it was most commonly noted in the female population. It has been well documented that different degrees of bone loss in the mandible are associated with the physiologic sex- and age-related skeletal bone mineral content loss seen after menopause and middle age in women.[25]

It has been hypothesized that the initial mandibular bone height may be a significant factor in the observed bone height changes seen in patients with fixed cantilevered implant-supported mandibular prostheses. No specific initial bone height levels have been suggested or considered as a critical value on which to base the bone height changes that follow rehabilitation with this type of prosthesis in the cantilever areas. Similar to Wright et al,[12] no correlation between initial bone height and bone growth in the cantilever area was seen in this study.

Given the limited diversity of this population, an interesting finding of this study is that women experienced greater overall bone height gain than men. Furthermore, a trend of bone height loss and gain was noted in the female population. The male group underwent less of this gain-and-loss trend but rather showed an overall slow continuous increase in bone height. Because there are no other studies in the literature to which to compare these findings after a similar follow-up period, it would be interesting to see whether these trends are noted in other similar patient populations.

CONCLUSION

Within the limitations of this study, long-term follow-up of patients rehabilitated with mandibular screw-retained implant-supported prostheses with distal cantilevers showed that patients experienced a bone height gain overall, with arrest and reversal of residual bone resorption in the posterior mandible. This phenomenon may be a long-term outcome seen in this patient population. In the long term, both bone loss and bone gain are associated with this treatment. Further similar studies are needed to evaluate the noted sex differences and trends in bone height changes experienced by this study's patients.

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