ORIGINAL ARTICLE

Number of teeth and residual alveolar ridge height in subjects with a history of self-reported osteoporotic fractures

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Abstract The purpose of this case-control study was to determine if elderly subjects with a history of osteoporotic fractures have fewer teeth and greater residual ridge resorption than subjects without such fractures. Patients older than 60 with a panoramic radiograph were invited to a phone interview. Information was obtained regarding fracture history, smoking, and hormone replacement therapy (HRT). The number of teeth was obtained from the panoramic radiograph. The residual ridge height of the edentulous mandible was measured at the site of the mental foramen. Multiple regression models were used to assess the association between fracture status and number of teeth or residual ridge height (controlling for age, gender, HRT, smoking, height and weight). Cases ($n = 93$) were individuals reporting osteoporotic fractures (fractures occurring after minor impact). Controls ($n = 394$) were individuals reporting traumatic fractures ($n = 105$) or no fractures ($n = 289$). Fracture status in this population affect neither the number of teeth nor the residual ridge height. In the regression model, the variables that had a statistically-significant effect on the number of teeth were age ($p < 0.0001$) and smoking ($p < 0.0001$).

There was a dose-effect of smoking on the number of teeth. In the regression model, the variables that had a significantly-significant on residual ridge height ($n = 95$ edentulous subjects) were age and gender. Our conclusion was that in elderly dental-school patients the number of teeth and residual ridge height were not influenced by fracture status. Age and smoking had the most influence ; there was no effect from HRT. The clinical implication is that a history of osteoporotic fractures is not an important cause for tooth loss and residual ridge resorption in an elderly dental-school population.

Keywords Alveolar bone · Dental · Fractures · Panoramic radiograph · Teeth

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Introduction

Osteoporosis is a systemic condition characterized by decreased bone density which may lead to pathological fractures. It has been suggested that osteoporosis may affect tooth loss and alveolar bone loss. Several studies have suggested the compromised quality of the alveolar bone may ultimately influence tooth retention and residual ridge resorption after tooth loss. A correlation between osteopenia (reduced bone density) and periodontal disease and tooth loss has been reported [1, 2], and it has been suggested that osteoporosis may play a role in increased residual ridge resorption [3, 4, 5]. However, these findings have not been consistent with some investigators not finding a correlation between decreased bone density and tooth loss [6], or between decreased bone density and increased residual ridge resorption [7, 8].

To some extent, inconsistent findings may have been due to differences in the types of population studied and the extent to which other risk factors for osteoporosis were taken into account. The purpose of this study was to determine if elderly subjects with a history of osteoporotic fractures have less teeth and greater

residual ridge resorption after tooth loss than subjects without such fractures. Since elderly subjects with osteoporotic fractures have a lower total-body bone mass than subjects without osteoporotic fractures, they may also have fewer teeth and greater atrophy of the residual alveolar ridge if the systemic conditions associated with osteoporosis affect tooth loss and residual ridge resorption.

Methods

Subjects

The subjects are the same as reported in our previous studies [9, 10]. In short: patients born before September 1936, and with a history of financial activities at the School of Dentistry between 1993 and 1996, were identified. Approximately 8, 000 dental charts were reviewed for the presence of a panoramic radiograph. Patients with panoramic radiographs of poor quality were excluded. The patient's birthdate, height and weight were obtained from the chart. A phone interview was attempted for all 1, 154 subjects (see below). The University of Washington's Institutional Review Board approved the study protocol.

Fracture history

A phone interview was attempted for all subjects for whom panoramic radiographs were evaluated. The study purpose was explained and subjects were given the opportunity not to participate. The structured questionnaire requested information regarding fracture history, diagnosis of osteoporosis, smoking, race, medication (including estrogen use for women), specific medical conditions (diabetes, thyroid problems), and age of menopause and/or ovariectomy (women). For subjects with a positive fracture history, the year and circumstances of the fracture were obtained. From the circumstances leading to the fracture it was decided whether the fracture was traumatic or osteoporotic based on the following definition of an osteoporotic fracture: "Fractures are considered to be osteoporotic fractures when they occur in the elderly as the result of minimal trauma: no more severe than that resulting from falling from a standing height" [11]. According to this definition the following fractures were classified as osteoporotic:

- Falling from a height equal to or smaller than standing height (slipped or tripped, fell off chair, stepped off sidewalk curb)
- Minor trauma generated during normal daily activities (stubbed toe, walked into chair)
- Compression fracture of vertebrae (spontaneous or lifting of light object)

All other fractures were classified as traumatic (fractures occurring after great impact such as motorcycle and car accidents, falling out of trees or from roofs, being kicked by a horse).

Number of teeth

The number of teeth (excluding third molars) was counted on the panoramic radiograph. Root remnants were counted as teeth (except for root remnants totally imbedded in bone). All measurements were made by the same investigator (AT), who was not aware of the individual's fracture status. For subjects with more than one radiograph the one with the earlier date was selected for the measurements.

Residual ridge measurements

In edentulous subjects, mandibular-height measurements were made using the technique described by Wical and Swoope [12]. The measures were made bilaterally on the panoramic radiograph at the site of the mental foramen. The inferior edge of the mental foramen was traced, and a line parallel to the long axis of the mandible and tangential to the inferior border of the mandible was drawn. A line perpendicular to this tangent intersecting the inferior border of the mental foramen was constructed. The residual ridge height was measured from the lower border of the mandible to the top of the alveolar crest (the total height of the mandible). The measurements were made in millimeters using a plastic millimeter ruler. The mean of the left and right side was used as the exposure measure in the analyses. Residual-height measurements reflect what is left of the alveolar ridge after ridge resorption. The date the patient became edentulous in the lower arch was obtained from the phone interview. For subjects who did not remember, it was obtained from the dental chart. The time of edentulism was obtained by calculating the time period between the date the patient became edentulous, and the date of the panoramic radiograph. Only totally edentulous subjects were included for measurement of the mandibular residual alveolar height.

Statistical analyses

Multiple regression models were used to assess the association between number of teeth and fracture status while controlling for potential confounding variables.

A multiple regression analysis with number of teeth as the dependent variable included the following possible confounding variables: fracture status, smoking (in pack-years—see definition below), age, gender (female on HRT, female not on HRT, and male), and height and weight. All available confounding variables were included

Table 1 Number of teeth in relation to fracture history. Values are means, with the SD between brackets. *HRT* Hormone replacement therapy

	No fracture	Traumatic fracture	Osteoporotic fracture	*p*-value
# subjects	289	105	93	
# teeth	14.8 (10.2)	14.6 (10.0)	14.4 (10.6)	0.949
% edentulous	18.0	19.1	21.5	0.753
Age*	67.6 (7.9)	67.7 (7.2)	69.3 (7.1)	0.181
% women	55	39	78	0.001
% HRT	80.3	88.6	65.6	0.001
% 'never-smokers'	52.2	50.5	48.4	0.801
Smoking (in pack-years)	17.2 (25.0)	19.1 (28.6)	19.7 (26.9)	0.654

*denotes age of subjects at the time of radiographic exposure

in the model in a forward mannerthe goal being to explain away the primary association. Height and weight were taken into account without making any assumptions about their functional relationship. To evaluate the influence of HRT, subjects were classified as either female on HRT, female not on HRT, or male. Thus the gender status was one of 3 options. All statistical analyses were performed using SAS software (Cary, NC, USA).

Results

Subjects

Of the 1,154 eligible subjects (over age 60, availability of a panoramic radiograph), 501 completed the phone questionnaire. Differences between responders and non-responders have been published before [9]. In short, respondents were more likely to be female and about a year older than non-respondents. They also had fewer teeth. The majority of the subjects interviewed were Caucasian (91%) and female (56.9%) with a mean age of 67.99 (SD 7.66). Mean smoking exposure was 18.2 pack-years (SD 26.2) and 257 subjects (51%) never smoked (pack-years was calculated as the number of packs smoked per day multiplied with the number of years of smoking). Mean standing height was 169.6 cm (SD 16.7) and body weight was 74.8 kg (SD 14.3).

Osteoporotic fractures

Ninety-three subjects reported a history of at least one osteoporotic fracture (cases), 289 subjects reported no history of fractures and 105 a history of a traumatic fracture (controls). Fourteen subjects did not remember whether or not a fracture had occurred. These subjects were excluded from the analyses. The reported osteoporotic fractures were all low-energy peripheral fractures (Colles, hip or other), except for two subjects who reported vertebral-compression fractures. Only 5% of the subjects interviewed stated that they had been diagnosed with osteoporosis, while almost 20% reported a fracture which could be classified as pathological or osteoporotic.

Number of teeth

In the 501 subjects, the number of teeth ranged from 0–28 with a mean of 14.6 (SD 10.2); 19% were edentulous (see next paragraph for residual ridge height measurements in these subjects). Table 1 lists the number of teeth in relation to fracture history.

Fracture status did not affect number of teeth in the model ($p = 0.71$). Neither did height, weight and gender ($p = 0.33$, $p = 0.95$ and $p = 0.11$ respectively). The significant variables in the model were smoking and age ($p < 0.0001$ for both). The dose-effect of smoking on the number of teeth is presented in Table 2.

When the number of teeth in relation to gender was compared (ANOVA adjusted for fracture, age, smoking and height/weight), males had more teeth than females not on HRT ($p = 0.05$) and also more teeth than females on HRT ($p = 0.09$). There was no difference in the number of teeth between females on HRT or females not on HRT ($p = 0.93$). The numbers of teeth were 13.6 (females on HRT), 13.7 (females not on HRT), and 16.0 (males).

When the analysis was limited to never-smokers, age was the only significant predictor of tooth loss ($p < 0.0001$). There was no difference in the number of teeth between females on HRT or females not on HRT ($p = 0.89$). The numbers of teeth were 15.8 (females on HRT), 16.0 (females not on HRT), and 19.4 teeth (males).

Residual ridge height

Of the 501 subjects, 95 were edentulous (19%). Two of these could not recall their fracture history. They were excluded from the analyses. Table 3 lists the residual ridge height in relation to fracture history for the

Table 2 Dose-effect of smoking on number of teeth

Smoking in pack-years	*N*	Number of teeth	SD
Never smoked	256	16.7	9.9
1 to <25	84	14.7	10.2
25 to <50	90	11.5	9.8
50 to <75	43	11.2	10.1
75 or more	28	10.6	10.1

Table 3 Residual ridge height in edentulous subjects in relation to fracture history. Values are means, with the SD between brackets

	No fracture	Traumatic fracture	Osteoporotic fracture	p-value
# edentulous subjects	53	20	20	
% women	52.4	63.2	72.2	
Time edentulous (in years)*	24.5 (16.3)	27.3 (16.9)	28.0 (18.7)	0.69
Residual ridge height (in cm)	2.13 (0.89)	2.06 (0.85)	1.93 (0.70)	0.67

*Denotes the time span between the date all lower teeth were lost (obtained through phone questionnaire) and the date of the panoramic radiograph

remaining 93 edentulous subjects. The time at which each arch became edentulous (date of the last extraction) was obtained during the phone interview. For ten subjects who could not recall this information, it was obtained from the dental chart.

There was no difference in the length of time the lower jaw had been edentulous between the three fracture groups. The residual ridge height was smaller in subjects with a history of osteoporotic fractures. A multiple regression analysis with residual ridge height as the dependent variable included the following possible confounding variables: fracture status, smoking (in pack-years), age, gender (female on HRT, female not on HRT, or male), height/weight, and time edentulous. Fracture status ($p = 0.86$), smoking ($p = 0.88$), height and weight ($p = 0.43$ and $p = 0.46$) and time edentulous ($p = 0.31$) did not affect residual ridge height in this model. The significant variables were age ($p = 0.02$) and gender ($p = 0.008$). When residual ridge height in function of gender was compared (ANOVA adjusted for fracture, age, smoking, height, weight and time edentulous) there was no difference between females on HRT and females not on HRT ($p = 0.51$). Males had significantly greater remaining height of the alveolar bone than females on HRT ($p = 0.004$) and females not on HRT ($p = 0.007$). The remaining alveolar heights were 170 mm (females on HRT), 186 mm (females not on HRT) and 251 mm (males).

Due to the small sample size, an analysis limited to never-smokers could not be performed.

Discussion

This study found no substantial association between the number of teeth and fracture status after controlling for age, smoking, gender, and height and weight in a population of free-living (non-institutionalized) elderly seeking care at a University School of Dentistry. In edentulous subjects there was no association between residual ridge height and fracture status (after controlling for the same variables and time edentulous). The results of this study should be viewed with the following limitations and weaknesses in mind. Data were obtained from elderly patients at a University Dental School, who were all ambulant and free-living. This study did not include subjects with severe morbidity resulting from osteoporotic fractures. This study differs from other studies in its method of classification of osteoporosis. Other studies have used a bone-density measurement (usually DXA of the hip, spine or forearm) and classified subjects as osteoporotic when the density fell below a specific cut-off value. The use in this study of pathological fractures as diagnosis of osteoporosis is likely to have identified a different group of subjects than the use of radiographic bone-density measures. In addition, the information regarding fracture history was obtained in questionnaire form, where one out of ten fracture recalls may be incorrect. However the use of self-reported fractures (rather than radiographic confirmation) allowed for a larger study population.

We did not find greater tooth loss in subjects with a history of osteoporotic fractures. This is opposite to the findings by Kribbs [13] and Taguchi and coworkers [2] who reported greater tooth loss in females with diagnosed vertebral-compression fractures. Astrom and coworkers [14] reported that a low number of teeth can be used to predict hip fractures in elderly males and females. The contradictory findings between these studies and ours may be caused by the fact that they did not adjust for confounding variables such as smoking. In our model, the number of teeth was mainly affected by age and smoking. We found a dose-effect of increased smoking on the decreased number of teeth. This was also reported by Krall and coworkers [15]. Thus the lack of adjusting for smoking in the studies by Kribbs, Taguchi et al. and Astrom et al. may explain why they found a significant correlation between fractures and number of teeth.

Alveolar bone loss following tooth extraction may be more severe in subjects with osteoporosis [5, 16]. In our study there was no difference in mandibular alveolar bone height between the fracture groups. Edentulous males had a significantly-greater remaining height of the alveolar bone than edentulous females. It is unclear if this is the result of less residual ridge resorption (RRR) in the males, or results from the fact that males have greater alveolar bone height prior to tooth loss. Other investigators also failed to find a correlation between RRR and bone mineral density [7, 8] or between RRR and menopause. Von Wowern and Kollerup [4] reported no difference in mandibular RRR in women with osteoporotic fractures. They did report a difference in maxillary RRR. An increase in RRR of the mandible was found in subjects with osteoporosis of the vertebrae [5].

Our study did not find an effect of hormone replacement therapy (HRT) on the retention of teeth or on RRR. This is in contrast to other studies which reported that HRT is beneficial in preventing tooth loss in older women [17, 18, 19]. This difference may be caused by differences in number of subjects between the studies, and a difference in confounding factors. The three ref-

erenced studies were substantially larger than our study: 488; 3,921; and 42,171 respectively, compared to 272 women in our study. In addition there may have been a difference between confounding variables such as smoking. In the study by Paganini-Hill [17], smoking among the moderately-affluent well-educated women was relatively low (11%). Smoking in the Nurses' Health Study [18] is also expected to be relatively low (not reported in the paper). Since it is difficult, if not impossible, to completely adjust for the effects of smoking in the model, we did a subgroup analysis which included never-smokers only. We did not find an effect of HRT on the number of teeth. This may be related to insufficient power in this small number of subjects and our crude assessment of HRT (yes/no compared to dose and time exposure). It also may reflect incomplete adjustment of confounding factors (other than smoking) which may have overshadowed the effects of HRT, and possible also of osteoporotic fractures.

In addition, one should keep in mind the subject population used in this study. A university dental school attracts patients with dental problems. Tooth loss in this population may have been primarily determined by dental diseases and trauma. The possible small effects of osteoporotic fracture status and HRT may have been overshadowed by local factors causing tooth loss. The fact that our population may have been at greater risk for tooth loss than elderly at large is supported by the fact that the mean number of teeth in our study was 14.6, which is lower than the reported mean of 19.2 for the 65–69 age group in the NHANES III study [20].

Despite these weaknesses, there are several useful findings in this study, in particular: (1) the effects of smoking and age on tooth loss and residual ridge resorption are emphasized, and reinforce the need to adjust for smoking and age in any study investigating the effects of osteoporosis on the dentition, and 2) a history of osteoporotic fractures has either a small or no effect on tooth loss and residual ridge resorption in a population with high dental disease.

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