J Clin Periodontol 2007; 34: 964–968 doi: 10.1111/j.1600-051X.2007.01142.x

Journal of Clinical Periodontology

Masticatory dysfunction is associated with osteoporosis in older men

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Laudisio A, Marzetti E, Antonica L, Settanni S, Georgakakis I, Bernabei R, Franceschi C, Zuccalà G. Masticatory dysfunction is associated with osteoporosis in older men. J Clin Periodontol 2007; 34: 964–968. doi: 10.1111/j.1600-051X.2007.01142.x.

Abstract

Aim: Thirty per cent of hip fractures occur in men. Nevertheless, the determinants of osteoporosis in men are unclear. Masticatory dysfunction is associated with malnutrition, and might represent an emergent cause of osteoporosis. The aim of this study was to assess the association of bone mineral density and self-assessed masticatory dysfunction in a general older population.

Material and Methods: We assessed the association of masticatory dysfunction with standard parameters of bone mineral density (*T*-score, *Z*-score and the stiffness index) in all 310 subjects aged 75+ living in Tuscania (Italy).

Results: Among men, self-assessed masticatory dysfunction was associated with *T*-score [$\beta = 0.86$, confidence intervals (CI) = 0.15–1.57; $p = 0.019$], *Z*-score ($\beta = 0.86$, CI = 0.16–1.56; $p = 0.017$) and the stiffness index ($\beta = 9.12$, CI = 0.47–17.77; $p = 0.039$) in linear regression modeling, after adjusting. No significant associations were observed in women.

Conclusions: Masticatory dysfunction is independently associated with osteoporosis in elderly men. Evaluation of masticatory function should enter the routine assessment of older men with osteoporosis.

Key words: elderly; periodontal disease; osteoporosis

Accepted for publication 7 August 2007

It has been estimated that 1.31 million new hip fractures occurred in 1990; in the same year, the prevalence of hip fractures with disability was 4.48 million. In addition, there were 740,000 deaths associated with hip fracture (Johnell & Kanis 2004). Osteoporosis is generally considered to be a hallmark of older female populations; however, epidemiological data indicate that 30% of hip fractures occur in men (Cooper et al. 1992). Also, a threefold increase in incident hip fractures is expected to develop by 2030 (Kannus et al. 1999); such a trend is only partially justified by the progressive ageing of Western populations. In addition, mortality after hip fracture is significantly higher in men than in women; of note, the survival of older men is significantly reduced following any type of fracture (Center et al. 1999). Despite such an evidence, knowledge of the determinants of osteoporosis in men in still poor (Amin et al. 2006). In fact, age-related hormonal variations represent the major cause of osteoporosis in women, but not among men (Slemenda et al. 1997). This lack of information about the aetiologic factors of osteoporosis in older men hinders the development of effective preventive programmes in elderly populations.

Inadequate chewing function has been proven to be a relevant, potentially amendable cause of inadequate nutrition in older populations (N'gom & Woda 2002). In fact, several studies have indicated that loss of functional dentition often results in avoidance of selected foods and nutrients (Sheiham et al. 2001). On the other hand, it has been found that nutrition plays a key role in promoting and maintaining bone mass (Bonjour 2005).

We assessed the association, if any, between masticatory dysfunction and bone mineral density in an older unselected population.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.

This research was partially supported as a ''targeted project'' (SS9.4.2) by the Italian Ministry of Health.

Material and Methods

Participants

The study involved all subjects, without exclusion criteria, aged 75 or older living in Tuscania (Italy). These participants had been enrolled in a national study on the genetic determinants of

health status in six towns. Among the 387 participants enrolled in the site, we excluded 77 subjects with missing data for the study variables or treated with biphosphonates. The main characteristics of the study sample according to sex are depicted in Table 1. Data were recorded using dedicated software. All participants underwent ambulatory or home visits by the study physicians, who performed detailed physical and anamnestical examination, ECG, Doppler echocardiography and bone densitometry using portable instruments (Cardioline Delta 1 Plus, Et Medical Devices, Cavareno-Trento, Italy for electrocardiography; Siemens Cypress for Doppler echocardiography; Achilles Express, GE Medical Systems, Madison, WI, USA for bone densitometry), and collected blood samples for serum chemistry and genomic analyses. Also, the study researchers completed a questionnaire that included data on socioeconomical status, lifestyle habits, and physical activity, among others. Smoking was considered as total lifetime pack years for current as well as former smokers. Nutritional parameters were assessed using a validated questionnaire, already adopted in large Italian populations (Gaddi et al. 2001).

Masticatory dysfunction was tested as a self-reported symptom ''Do you experience difficulties in chewing?''; ''Did you change your alimentary habits because of such difficulties?''. Masticatory dysfunction was diagnosed if both questions were answered affirmatively. Drugs were coded according to the Anatomical Therapeutic and Chemical codes (Pahor et al. 1994). Diagnoses were coded according to the International Classification of Diseases, ninth edition, Clinical Modification codes (PHS–HCFA 1980).

Table 1. Characteristics of participants according to sex

	n (%) or mean ± SD		*p*-value
	men (*n* = 121)	women (*n* = 189)	
Demographics and lifestyle habits			
Age (years)	78 ± 6	80 ± 5	0.086
Education (years)	5 ± 4	4 ± 3	0.01
Alcohol consumption	101 (85%)	108 (58%)	<0.0001
Smoking*	7110 ± 11877	461 ± 2687	<0.0001
Dairy products consumption	19 (16%)	24 (13%)	0.501
Use of dentures	75 (63%)	112 (60%)	0.335
Masticatory dysfunction	38 (32%)	91 (49%)	0.002
Comorbid conditions			
Chronic pulmonary disease	35 (29%)	38 (20%)	0.047
Diabetes	16 (13%)	46 (25%)	0.012
Inflammatory bowel disease	4 (3%)	4 (2%)	0.379
Renal disease	2 (2%)	11 (6%)	0.064
Cancer	9 (8%)	18 (10%)	0.344
Diverticular disease	5 (6%)	26 (16%)	0.011
Pancreatic disease	3 (3%)	1 (1%)	0.162
Hyperthyroidism	0 (0%)	3 (2%)	0.227
Medications			
ACE-inhibitors	29 (24%)	59 (31%)	0.002
Sartans	30 (24%)	56 (30%)	0.366
Thiazides	5 (4%)	2 (1%)	0.085
Loop diuretics	19 (16%)	39 (21%)	0.175
Anti-epileptic agents	1 (1%)	7 (4%)	0.114
Statins	10 (8%)	21 (11%)	0.270
Corticosteroids	5 (4%)	7 (4%)	0.536
Oral antidiabetics	10 (8%)	34 (18%)	0.011
NSAIDS	4 (3%)	17 (9%)	0.039
Insulin	1 (1%)	3 (2%)	0.492
Thyroid hormones	0 (0%)	4 (2%)	0.136
Allopurinol	4 (3%)	5 (3%)	0.494
Oestrogen hormones	0 (0%)	0 (0%)	
Antiandrogens	1 (1%)	0 (0%)	0.390
Objective tests			
Stiffness index	84 ± 22	65 ± 14	< 0.0001
T-score†	− 1.1 ± 1.8	− 2.6 ± 1.3	< 0.0001
Z-score‡	− 0.1 ± 1.7	− 0.2 ± 1.1	0.443
Serum albumin (mg/dl)	4.2 ± 0.5	4.2 ± 0.7	0.286
Serum creatinine (mg/dl)	1.1 ± 0.3	0.9 ± 0.3	< 0.0001
Serum calcium (mg/dl)	9.3 ± 0.5	9.4 ± 0.5	0.002
Lymphocyte (count × 1000)	31 ± 8	31 ± 10	0.709
Total cholesterol (mg/dl)	205 ± 37	219 ± 44	0.007
Haemoglobin (g/dl)	14.9 ± 1.5	13.6 ± 1.4	< 0.0001
Body mass index	27 ± 4	28 ± 5	0.002

*Total lifetime pack years.

†Ultrasound measurement, derived from the stiffness index, compared with a younger reference population.

‡Ultrasound measurement, derived from a *T*-score, normalized for age.

ACE, angiotensin-converting enzyme; NSAIDS, Non-steroidal antinflammatory drugs.

Measurement of bone mineral density

As the study enrolled the whole older population of the site, including homebound subjects, a portable instrument was used to assess bone densitometry (Achilles Express, GE Medical Systems). This validated instrument measures bone density and structure using ultrasound bone densitometry. Ultrasound densitometry enables measurement of the physical properties of bone, specifically bone mineral density. The ultrasound measurement contains two criteria: the velocity [speed of sound(s); SOS] and frequency attenuation [broadband ultrasound attenuation (dB/MHz); BUA] of sound wave as it travels through bone (Langton et al. 1984, Rossman et al. 1989). The stiffness is an index combining SOS and BUA, which is calculated by the spread speed of supersonic waves. The formula is $(\mathrm{BUA} - 50) \times 0.671 + (\mathrm{SOS} - 1380) \times 0.28$.This charts the SOS and BUA into biologically relevant ranges.

According to current World Health Organization (WHO) recommendations, the *T*-score was automatically calculated by the built-in software as the difference between the subject bone mineral density (represented by the stiffness index) and the average density in a reference healthy 30 year old of the same sex and ethnicity, divided by the standard deviation of the reference population (WHO Scientific Group 2000). The reference population was derived by the NHANES III study population (Kanis & Gluer 2000). According to the WHO guidelines, osteoporosis is defined as a *T*-score value of − 2.5 or

lower, meaning a bone density that is two and a half standard deviations below the mean of a 30-year-old woman. The *Z*-score was automatically calculated by normalizing the *T*-score for age, as recommended by the WHO.

Data analyses

Data of continuous variables are presented as mean values ± SD. Statistical analyses were performed using SPSS for Windows 13.0 software (Chicago, IL, USA); differences were considered to be significant at the $p < 0.05$ level. Analysis of variance (ANOVA) for normally distributed variables in relation to sex was performed by ANOVA comparisons; otherwise, the non-parametric Kruskal–Wallis *H* test was adopted. χ^2 analysis was used for dichotomous variables. Linear regression analysis was used to estimate the association of variables of interest, including masticatory dysfunction, with the *T*-score, the *Z*-score, and the stiffness index after stratifying for sex. The linearity of the variables was assessed using the ANOVA test of linearity; the linearity assumption was assumed to be satisfied at a $p < 0.05$ level. To assess independent correlates of bone mineral density, which might confound the association between bone densitometric parameters and masticatory dysfunction, groups of variables (demographics, comorbid conditions, medications, and objective tests, as depicted in Table 1) were first examined in separate age- and sex-adjusted regression models with the simultaneous introduction of covariates. Those variables, significant at the $p < 0.05$ level in these four initial models, were simultaneously entered into a summary regression model, after stratifying for sex (Table 2). To rule out the potential effect of smoking on the gender-related differences in the association between masticatory dysfunction and bone mineral density, the summary regression models were also analysed after excluding current as well past smokers.

Results

Among the participants, masticatory dysfunction was reported by 129 subjects (Table 1). Masticatory dysfunction was more prevalent among women, as compared with men; however, the prevalent use of dentures did not differ according to sex. As depicted in Table 1, men showed higher education levels, more prevalent alcohol consumption and smoking, chronic pulmonary disease, and higher haemoglobin and serum creatinine levels, as compared with women. On the other hand, women had more prevalent diagnoses of diabetes and diverticular disease, and reported a more prevalent use of ACE-inhibitors, oral antidiabetic agents, and non-steroidal antinflammatory drugs; also, women had higher serum calcium and cholesterol levels and a higher body mass index. As expected, women had lower bone density parameters (*T*-score, *Z*-score, and the stiffness index) as compared with men.

Among men, significant crude associations were observed between masticatory dysfunction and all bone mineral density parameters (Table 2). On the other hand, no significant associations were found between masticatory dysfunction and all the parameters of bone mineral density among women (Table 2). In the four initial linear regression models, age, smoking, inflammatory bowel disease, use of oral antidiabetics and loop diuretics, body mass index, diabetes, serum albumin, haemoglobin, and use of dentures were all associated with indices of bone mineral density at a $p < 0.05$ level. Among men, masticatory dysfunction was still associated with the *T*-score, the *Z*-score, and the stiffness index after simultaneously adjusting for all potential confounders (Table 2). Among women, however, masticatory dysfunction was not associated with the dependent variables using the same regression model (Table 2). Among male non-smokers ($n = 27$), masticatory dysfunction was associated with *T*-score ($\beta = 1.95$; 95% CI 0.14–3.77; $p = 0.036$), *Z*-score ($\beta = 1.91$; 95% CI 0.17–3.65; $p = 0.033$), and with the stiffness index ($\beta = 26.60$; 95% CI 5.30–47.90; $p = 0.017$). Among female non-smokers ($n = 174$), masticatory dysfunction was not associated with the *T*-score ($\beta = 0.11$; 95% CI 0.30–0.52; $p = 0.591$), *Z*-score ($\beta = 0.11$; 95% CI 0.24–0.45; $p = 0.541$) or with the stiffness index ($\beta = 1.33$; 95% CI 3.03–5.69; $p = 0.548$).

Discussion

The prevalence and incidence rates of osteoporotic fractures are constantly increasing in Western countries, paralleling the ageing of populations. Braithwaite et al. (2003) reported that fractures are associated with increased death rates and financial burden. Noticeably, even minor osteoporotic fractures are associated with decreased survival and increased morbidity among men. This probably reflects the role of underlying comorbid conditions, generally referred to as ''frailty'' (Pande et al. 2006). Noticeably, masticatory dysfunction is an acknowledged cause of frailty in older subjects (Fried et al. 2001). Edentulism represents a prevalent condition in older populations; also, it should be considered that use of dentures might not restore chewing ability (Shinkai et al. 2002). In fact, only a fifth of older subjects with dentures report a satisfactory masticatory function (Michael et al. 1990). In the present study, masticatory function was self-assessed. Such an assessment method allows to detect the effects of several factors on chewing function, not

Table 2. Association between masticatory dysfunction and bone mass indices, according to unadjusted and adjusted linear regression analysis

	Unadjusted β (95% CI)	*p*	Adjusted β^* (95% CI)	*p*
Men				
T-score	0.95 (0.23–1.68)	0.011	0.86 (0.15–1.57)	0.019
Z-score	0.99 (0.27–1.70)	0.007	0.86 (0.16–1.56)	0.017
Stiffness index	11.52 (2.56–20.47)	0.012	9.12 (0.47–17.77)	0.039
Women				
T-score	0.16 (− 0.25–0.56)	0.441	0.18 (− 0.22–0.58)	0.367
Z-score	0.07 (− 0.28–0.42)	0.695	0.03 (− 0.33–0.39)	0.869
Stiffness index	1.59 (− 2.77–5.94)	0.473	0.14 (− 4.25–4.53)	0.950

All the covariates were entered simultaneously into the regression models.

*Adjusted for age, inflammatory bowel disease, use of oral antidiabetics and loop diuretics, body mass index, diabetes, serum albumin, haemoglobin, smoking (total lifetime pack years), and use of dentures.

CI, confidence intervals.

always measurable, including functional deficiencies of the tongue, disorders of the oral mucosa, impairment of masticatory muscles, xerostomia, or nervous system disorders (N'gom & Woda 2002). Focusing on subjective health status outcomes is also consistent with the Institute of Medicine's promotion of patient-centred care, among the six strategies designated to improve the quality of care in the United States (Institute of Medicine 2001). It has been reported that self-assessed tools for assessing masticatory function might underestimate chewing problems, as compared with a practitioner's evaluation; however, this represents a conservative bias, which further supports our finding of an association between masticatory dysfunction and reduced bone mineral density (Slagter et al. 1992).

Smoking is an acknowledged determinant of osteoporosis (Lorentzon et al. 2007). As noted by Hyman (2006), statistical adjustment for confounding in epidemiologic studies does not rule out the possible role of effect modification. In the present study, sex-related differences in the association of self-assessed masticatory dysfunction and bone mineral density persisted after excluding all smokers from the analyses.

In the present study, masticatory dysfunction was reported by 42% of all subjects aged 75+ living in the enrollment site. Masticatory dysfunction is a major cause of malnutrition in older populations (Moynihan & Bradbury 2001). As documented by several reports, perceived masticatory ability is strictly associated with comfort in chewing certain foods, which, in turn, affects food selection. Noticeably, it has been found (Shinkai et al. 2002) that poor self-reported chewing ability is associated with significantly decreased intake of dairy products. In turn, reduced consumption of dairy products has been associated with decreased bone density in older populations (McCabe et al. 2004). Interestingly, such an association was significant among men, but not among women; this finding might explain the selective effect of masticatory dysfunction in male participants in the present study. In addition, masticatory dysfunction has been associated with reduced protein intake in older populations (Sheiham et al. 2001). Noticeably, it has been acknowledged that dietary proteins are as essential as calcium for the preservation of bone mineral density and structure (Bonjour 2005). Thus, masticatory dysfunction might affect age-associated bone loss through several nutritional deficits.

Osteoporotic fractures represent an emerging problem in older male populations. In fact, the incidence of such fractures is much greater than generally estimated (Cooper et al. 1992); furthermore, incidence rates are expected to increase steeply in the forthcoming years, due to the progressive ageing of western populations (Kannus et al. 1999). In addition, osteoporotic fractures are associated with significantly worse survival, and with poorer functional ability among men as compared with women (Poor et al. 1995).

Despite such evidence, the pathophysiologic determinants of osteoporosis in men are still far from being elucidated (Amin et al. 2006). It has been acknowledged that oestrogen deficiency is the major cause of bone loss in ageing women (Wu et al. 2002). The overwhelming role of hormonal factors might have concealed the effect of masticatory dysfunction on bone mineral density in our female population. On the other hand, the association between age-associated hormonal variations and decreasing bone mineral density is much weaker in men (Wu et al. 2002). The results of the present study indicate that masticatory dysfunction is reported by nearly 50% of an older unselected population, and that it may represent a significant correlate of osteoporosis in elderly men. Therefore, dental examination should enter the routine assessment of male subjects in whom osteoporosis has been documented. Also, early detection and treatment of masticatory dysfunction might represent a cornerstone in the prevention of osteoporosis and osteoporotic fractures in older populations.

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Clinical Relevance

Scientific rationale for the study: Over a third of osteoporotic fractures occur in men. Yet, the determinants of bone loss in older men are still unknown. Masticatory dysfunction is a frequent, often unrecognized cause of malnutrition in older populations.
Principal findings: This study documented in an unselected older population an independent association between bone mass parameters and masticatory dysfunction among men, but not women.
Practical implications: Masticatory function should be routinely assessed in older men with osteoporosis.