Osteoporosis and oral bone resorption: a review

Received: 03 May 2009 / Accepted: 20 June 2009

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Abstract This paper is a summary of the published studies on the possible association between osteoporosis and alveolar bone loss. Osteoporosis and low bone mass are considered as a major public health problem. The mandible like other bones of the body has a series of anatomical landmarks that can serve as radiographic indicators. Using these indicators it is possible to evaluate changes in bone with respect to its quantity or quality by different methods of taking images. Higher bone resorption was detected in women with a higher number of pregnancies. Also, the higher educated the patient, the less bone resorption. Women with a background of backaches had more bone resorption to those who did not have this backache background. Finally, it was recognized that it would be possible to clear the quality dimension of the process of mandibular bone resorption. If we can identify the osteoporotic process using a basic panoramic radiography measurement technique, then it is possible to intercept the progress of the disease through early warning and treatment. From the results of this study, it can be concluded the thickness of the mandibular angular cortex can be used as an index for bone resorption. A healthy lifestyle has multiple benefits for the mouth and throughout the body. Dental professionals can play a role in preventing osteoporosis by reinforcing this message.

Keywords Osteoporosis · Oral Bone · Bone resorption

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Introduction

Description of osteoporosis, osteopenia and periodontal disease

Osteoporosis is a complex, multifactorial chronic disease that can progress silently for decades until characteristic fractures result late in life. Because symptoms are rare until a fracture occurs, few people are diagnosed in time to receive effective therapy. As a result, many individuals experience disability and decreased quality of life subsequent to fracture. The exact cause of the increase in bone fragility is not known, but it is thought to include both changes in bone quality, quantity, and architectural configuration. Approximately one third of women aged 65 or older will have one or more vertebral fractures. According to an American study by Hildebolt CF by the year 2050, people over 65 years of age will constitute 22% of the total population, and people over 85 years will compromise 5% of the population [1].

Perhaps the earliest suggestion of an association between osteoporosis and oral bone loss was made in 1960 [2].

Epidemiology: In the United States, as many as 8 million women and 2 million men have osteoporosis (T-score<-2.5), and an additional 18 million individuals have bone mass levels that put them at increased risk of developing osteoporosis (e.g., bone mass T-score<-1.0).

Risk factors: Female sex, advanced age, caucasian race, dementia, low body weight (<58 kg), estrogen deficiency, early menopause (<45 years), low calcium intake [3].

Prevention: Smoking cessation, Calcium intake: 1200–1500 mg/day, regular physical exercise, average daily sunlight exposure: 30 minutes, optimized medications [4].

Diagnosis: The diagnosis of osteoporosis is based on a low BMD T-score at the lumbar spine, total hip or femoral neck [5]. A BMD T-score of -1.0

or higher (i.e, a BMD within 1 standard deviation of that expected for a young, healthy adult of the same sex) is considered normal. A T-score between -1.0 and -2.5 is considered osteopenia, and a T-score of -2.5 or lower (i.e, 2.5 or more standard deviations below the expected BMD) is considered osteoporosis [5].

Treatment: Only bisphosphonates have been demonstrated in large clinical trials to reduce the risk of fractures in patients being treated with glucocorticoids [3].

Definition: Osteopenia/low bone mineral density (BMD) can lead to osteoporosis and is far more prevalent than osteoporosis. The National Osteoporosis Foundation (NOF) has recommendations for prevention and treatment of low BMD; however, the condition remains underrecognized and undertreated [6].

Diagnosis: Scans of bones anywhere in the body can be done with X-rays, known as DXA (Dual X-ray absorptiometry). Scans can also be done with portable

scanners using ultrasound, and portable X-ray machines can measure density in the heel. A study paid for by Merck found that the extent to which osteopenia was diagnosed varied from 28 to 45 percent, depending on the type of machine [7].

Treatment: Osteopenia is treated by taking steps to keep it from progressing to osteoporosis and, for a few people, by taking medicine. Lifestyle changes can help reduce the bone loss that leads to osteopenia and osteoporosis [7].

Definition and epidemiology: Periodontitis can be defined as the presence of gingival inflammation at sites where there has been a pathological detachment of collagen fibres from the cementum and the junctional epithelium has migrated apically. Inflammatory events associated with connective tissue attachment loss also lead to the resorption of coronal portions of tooth supporting alveolar bone. Periodontitis is very common, and is widely regarded as the second most common disease worldwide, after dental decay, and in the United States has a prevalence of 30–50% of the population, but only about 10% have severe forms.

Risk factors: Factors that can increase risk of periodontitis include: gingivitis, heredity, poor oral health habits, tobacco use, diabetes, older age, decreased immunity, poor nutrition, certain medications, hormonal changes, substance abuse, ill-fitting dental restorations and lower socioeconomic status.

Prevention: The best way to prevent periodontitis is a program of good oral hygiene [8].

Diagnosis: The studies that were reviewed utilized a minimum diagnostic threshold defining periodontitis, at a given site in terms of clinical attachment loss (Cal) of 2 mm and PPD of 3 mm [9]. The dentist or dental hygienist will inspect the color and firmness of the gums and test the teeth for looseness.

Treatment: In the earlier stages of the disease, most of the treatment involves root planning and curettage (cleaning) under the gum margins. It involves the removal of plaque and inflamed soft tissue in the pockets around the tooth with an instrument called a curette. In more advanced cases, the treatment may become more complex. If after removal of the deposits, fairly deep pockets remain, they can be eliminated by a minor surgical procedure called gingivectomy [8].

Articles about osteoporosis and periodontal disease discussed a number of issues regarding general BMD and oral

alveolar bone loss, early loss of teeth and increased severity of periodontal disease in patients with osteoporosis [10]. Postmenopausal women with osteoporosis and low educational levels have a greater chance of having periodontal disease than do those without osteoporosis [11].

Osteoporosis and periodontitis represent two highly prevalent diseases associated with advancing age. Many of the medical, nutritional, and lifestyle interventions that are beneficial in the management of osteoporosis have the potential to be applied to oral health care and the management of oral bone loss [12]. Postmenopausal osteoporosis may be a possible risk factor for periodontal disease [13].

The imbalance in coupling of bone remodeling causes skeletal osteopenia and osteoporosis. Different studies indicate that the skeletal bone loss in osteoporosis accelerate the decrease in bone density in oral bone. Although the differences in etiology between the two diseases some studies showed that treatment of osteoporosis improved the periodontal health [14].

Risk factors: Low bone mass in the skeleton, which leads to higher risk of osteoporotic fracture, also may be associated with severe periodontitis. Osteoporosis and periodontal disease have some common risk factors, including advanced age, smoking and perhaps calcium and/or vitamin D deficiency [15].

Relationship between osteoporosis, oral signs, body mass index and age, and to assess the possibility of using these parameters as an indicator of postmenopausal osteoporosis. Panoramic radiography is used for evaluating the width of mandibular cortex, mandibular angular cortex, cortical index and degree of alveolar crest resorption. Osteoporotic were more likely to have altered inferior cortex morphology in terms of decrease in cortical bone thickness, than non-osteoporotic patients and age is an important risk factor for osteoporosis [16].

Human studies: Geometric measures of the metacarpal bone were found to be significantly correlated to the number of teeth with attachment loss > 4mm [17]. In a follow-up study, the same metacarpal index was used. For 40 edentulous women and 40 edentulous men, no significant relationship between the metacarpal index and percent resorption of the alveolar ridge was found for men nor for women in a multiple regression analysis that considered age and years edentate- postmenopausal status and was not given nor considered [18].

It has been suggested that cortical thickness might be a useful parameter to clinically evaluate metabolic bone loss and that a gonial cortical thickness of less than 1 mm was an indicator of metabolic bone loss. Cortical thickness at the gonion was determined with panoramic radiographs in 180 men and women and found to be fairly constant from age 15 to 69, except for men and women over 60 years of age, for whom there was a slight decrease in cortical thickness for men and a marked decrease for women [19]. In a 18 month panoramic study of 100 randomly selected female patients who qualified and were included in the study. The aim of this study was to determine the width of the mandibular angular cortex on the both sides of women using panoramic radiography as well as bone resorption. The selected subjects were asked questions on their age, marital status, education, job, number of pregnancies, menopausal status, and history of backaches. It was shown that an increase in age will increase bone loss, and this process is related to a decrease in the female sexual hormones. Higher bone loss was seen in women with a higher number of pregnancies. Also, the higher educated the patient, the less bone resorption was detected. Women with a history of backaches had more bone resorption comparing to those who did not have it. Finally, it was reported that it would be possible to clear the quality dimension of the process of mandibular bone loss [20].

Experienced greater ridge resorption after ridge augmentation than did the 11 women without indications of metabolic bone loss (cortical thickness ≥ 1 mm) [21].

Quantitative CT (QCT) was first used to study oral-osteoporosis interrelationships in 1989. Regardless of the technique used, scout views, and slice position documentation must be kept and used in subsequent examinations to reduce precision error. Reported precision for QCT ranges from 1–3% in very controlled settings and 4–5% for clinical environments [22].

Evidence linking osteoporosis and alveolar bone loss

In a study of 286 perimenopausal women, no significant differences between dentate and edentate women could be detected with lumbar bone mineral density (BMD) measurements determined by Dual Photon Absorptiometry (DPA) nor with metacarpal index measures [23]. The skeletal measures were not correlated with number of teeth,

pocket depth, nor alveolar bone loss (determined from vertical bitewing radiographs). Although age or years since menopause was not significantly correlated with pocket depth nor number of teeth, years [1].

In the investigation was done for 57 women taking estrogen and 171 controls, there was less tooth loss, attachment loss and established periodontitis for the estrogen group than for the controls, but none of the differences were statistically significant [24].

It seems that there are seven major reasons why there is a lack of consensus among most published studies of osteoporosis and oral bone loss: 1) most studies were cross-sectional in nature, with a lack of control for factors affecting bone, 2) samples were usually severely biased, being either convenience samples or being chosen from health (including dental health) conscious women, 3) sample sizes were small, 4) tooth loss was used as the dependent variable although the causes of tooth loss were unknown (that is, teeth could have been extracted for many reasons other than bone loss), 5) definitions for osteoporosis varied among studies, 6) methods used to measure oral bone were of insufficient precision and accuracy to make the measurements needed, and 7) measurements of oral bone varied as to location measured and types of measurements made [1].

The diagnosis of osteoporosis is often made by using bone density measurements. They are often expressed in relative terms (T-scores and Z-scores); the Z-score is the number of standard deviations from the age matched average value of healthy women. The T-score statistic is a simple transformation of the Z-score, using sample mean and sample standard deviation rather than the population mean and standard deviation. A low Z-score indicates the bone density is lower than it should be for a patient's age and sex. Osteoporosis is defined as a BMD loss of 2.5 standard deviations or more below the established mean [25].

Link between osteoporosis and periodontal disease

Osteoporosis, an age-related condition, is classified into primary and secondary types. Primary osteoporosis encompasses the postmenopausal and senile types; secondary osteoporosis occurs 'secondary' to endocrine and renal diseases. Subjects affected by osteoporosis have an overall reduced bone mass and become highly susceptible to bone

fractures. Dual energy x-ray absorptiometry is the method most often used to determine the risk for osteoporotic fractures. In the past decade, a number of studies have suggested a possible correlation between systemic osteoporosis and alveolar bone loss in periodontal disease pathogenesis. This review addresses the pathogenesis of osteoporosis and emphasizes the multifactorial nature of bone loss. The current concepts in alveolar bone loss resulting from osteoporosis and its implications as a risk factor in periodontal disease development are also presented [26].

To date, the majority of studies on the relationship between periodontal disease and osteoporosis have been hindered by small sample sizes, limited control of other potential confounding factors, varying definitions of both periodontal disease and osteoporosis, and few prospective studies where the temporality of the association can be established. Systemic loss of bone density in osteoporosis, including that of the oral cavity, may provide a host system that is increasingly susceptible to infectious destruction of periodontal tissue. Understanding the association between these common diseases and the mechanisms underlying those associations will aid health professionals to provide improved means to prevent, diagnose, and treat these very common diseases. This paper reviews the current evidence on the association between periodontal disease and osteoporosis [27].

Assessment of osteoporosis

The association between osteoporosis and oral health remains a matter of controversy. It is important to confirm whether there is a role of osteoporosis in bone loss in the jaws, periodontal diseases tooth loss, and other oral tissue changes. Clinical information concerning systemic osteoporosis and animal studies reporting possible associations between osteoporosis and changes in the dental and oral tissues were included. The review focus was on studies involving (1) methods for assessing bone mineral density (BMD); (2) methods for assessing osteoporosis-related changes in intraoral sites; (3) associations between mandibular BMD and skeletal BMD; (4) changes in the jaws, periodontal tissues, and temporomandibular joint concurrent with osteoporosis; (5) changes in the oral tissues following estrogen deficiency; and (6) effects of estrogen- hormone replacement therapy and/ or calcium and vitamin D on oral health. Evidence from

prospective studies supports the contention that individuals with osteoporosis may be at increased risk for the manifestations of oral osteoporosis; however, such risk is not definitively proven. Studies suggest that findings on dental panoramic radiographs may be used to detect individuals with low BMD [28].

To educate the patients, dentists should be knowledgeable about the oral manifestations of osteoporosis and should collaborate with other health care providers to reduce the possible destructive effects of osteoporosis on the patients' oral health [29].

Some studies have linked low BMD of the mandible and the peripheral skeleton with alveolar bone loss of the mandible and tooth loss. Clinicians have started to focus on some mandibular panoramic indices, such as mandibular cortical index and mandibular cortical thickness, for the identification of elderly individuals who should undergo BMD assessment. In comparison with peripheral BMD measurement equipment in the medical field, the dentist will be able to identify osteoporotic elderly individuals by means of dental panoramic radiographs taken for the diagnosis of the teeth and the jawbones without additional cost. It is likely that the clinician may estimate the future risk of tooth loss in elderly individuals with periodontitis and osteoporosis by panoramic radiographs [30].

It is considered the most common metabolic bone disease, and it constitutes a major public health problem. Given the evidence that alveolar processes provide the bony framework for tooth support, the decline of skeletal mass has to be correlated with an increased risk of oral bone loss and has a negative consequence on tooth stability [14].

The imbalance in coupling of bone remodeling causes skeletal osteopenia and osteoporosis. Different studies indicate that the skeletal bone loss in osteoporosis accelerate the decrease in bone density in oral bone. Although the differences in etiology between the two diseases some studies showed that treatment of osteoporosis improved the periodontal health. Further investigation of the mechanisms behind the relationship between osteoporosis and periodontitis may lead to common treatment strategies [31].

Although numerous studies have documented the possible role of osteoporosis as a deteriorating factor in both tooth loss and mandibular bone resorption, the morphostructural evolution of the edentulous mandible is primarily

correlated to mechanical factors as a result of modifications to its function [32].

Management of osteoporosis

It is important to define this disease precisely, because the start is without any symptom in many cases. The available recent literature and own studies did not show relationship between tooth loss, bone loss of the mandible, periodontitis and osteoporosis. Association between osteoporosis and oral bone loss were not found in all studies. The findings may be different due to the number of patients studied, the patient sample, the difference in the measuring area of mandibular bone, and the use of measuring techniques and equipments. In addition, the combination of risk factors such as age, menopause, race, genetics, calcium intake, family history, medications and physical activity contribute to osteoporosis [33–36]. However, corticosteroids diminish mandibular bone mass. Assessment to bone mineral density is a major diagnostic test for osteoporosis prediction. Recent findings in prevention and treatment of osteoporosis are reviewed extensively. The positive results of estrogen replacement therapy on the oral bone loss and tooth loss from some large observational American studies are interesting [37].

Systemic treatment involving the bone metabolism affects the jaw BMC/BMD positively or negatively as in other skeletal sites, but the magnitude of this effect is site-specific. Future studies of the effect of bisphosphonates on the jaw BMC and alveolar bone loss, and analyses of the bone quality and jaw BMC/BMD in relation to implant treatment, without or with bone transplantation, are required [27].

The literature suggests a relationship between oral bone loss and skeletal osteoporosis. The study of determine if a relationship exists among alveolar bone loss, alveolar bone density, second metacarpal density, salivary and gingival crevicular fluid interleukin 6 (IL-6), and IL-8 concentrations in premenopausal and postmenopausal healthy women receiving estrogen therapy. Postmenopausal women on estrogen therapy had higher salivary IL-6 concentrations than premenopausal women. Alveolar bone densities were also strongly correlated to second metacarpal densities. Changes in alveolar bone density and levels of bone resorptive cytokines in saliva may be secondary to changes in menopausal status. These changes may

predispose loss of alveolar bone with resultant loss of teeth [38].

Epidemiological studies have shown that post-menopausal women who do not use an estrogen supplement have fewer teeth than those who do. The changes in the dentition of post menopausal women might be due to alveolar bone alterations by estrogen deficiency [39]. According to epidemiological research [40], the oral health status of the aged has a dramatic impact on their quality of life in a variety of physical, social, and psychological ways. Tooth loss is associated with deterioration of the systemic health of the elderly through changes in their dietary intake. Thus, it is essential for dentists to take active steps to preserve older patients' teeth, and to help them maintain their masticatory function [41].

Mandibular Cortical Width (MCV) detected on panoramic radiographs may be useful for identifying postmenopausal women with osteoporosis. There is little known regarding whether alveolar bone loss (ABL) of the mandible detected on panoramic radiographs is a potentially accurate screening tool for osteoporosis in comparison with MCW. Panoramic radiographs is postmenopausal women in comparison with MCW [38].

The fact that dental radiographs are regularly made on a large fraction of the adult population makes their potential use as a marker of skeletal health an exciting avenue of research. In the last four decades numerous research teams have reported oral radiographic findings associated with osteoporosis. The preponderance of the evidence shows that the jaws of subjects with osteoporosis show reduced bone mass and altered morphology. Future efforts should continue to search for oral radiographic signs with high sensitivity and specificity for osteoporosis, identify clinical signs available in the dental office associated with osteoporosis, develop multidisciplinary classification methods including both radiographic and clinical parameters, and automate radiographic and clinical analyses as much as possible to minimize the involvement of the dentist as well as to standardize data collection [32].

The activities of osteoblasts and osteoclasts are controlled by a variety of hormones and cytokines, as well as by mechanical loading. Most importantly, sex hormones are very crucial for keeping bone mass in balance, and the lack of either estrogen or testosterone leads to decreased bone mass and increased risk for osteoporosis.

Patlas et al. did not find any significant changes in the results of the histomorphometric studies between Oophorectomized (OVX) and sham-operated rats when surgery was performed at 10 months of age. Since OVX exerts significant changes only in young rapidly growing rats, this approach is an inappropriate model for postmenopausal osteoporosis, which occurs long after bone growth has ended [42].

The prevalence of osteoporotic fractures is increasing dramatically in the Western part of the world and is a major health problem in many countries. In the present review, the cellular and molecular mechanisms controlling bone remodeling and the influence of sex hormones on these processes are summarized [43].

It has been well demonstrated that there is significant association between osteonecrosis of jawbone (ONJ) and bisphosphonates which is used for osteoporosis treatment, so special attention should be paid to ONJ before, during and after treatment of osteoporosis [44]. Also osteoporosis has a direct relationship with malnutrition; the low consumption of calcium in life can cause the maximum reduction of bone mass. This could result in an increased risk of bone fracture. Continuous production of bone matrix by osteoblasts requires that sufficient protein be absorbed from the intestines. A low protein diet, vitamin C deficiency, and a high level of vitamin A can cause osteoporosis.

Because of increasing life expectancy and popularity of dental implants, surgeons face a larger number of osteoporotic patients who require bone augmentation. Relationship between low bone density/osteoporosis and bone graft success is still not clear. Despite the decreased success rate, osteoporosis is not an absolute contraindication for bone augmentation and dental implant placement. The modifiable risk factors for osteoporosis should be eliminated before surgery.

Osteoporotic changes usually start in cancellous bone. The clinical success of a new fixation principle or a new implant is determined by more factors than simply biomechanical advantage [45].

Conclusion

In the dental field, post-menopausal osteoporosis has drawn attention, with some studies suggesting that estrogen influences

tooth retention by preventing resorption of the alveolar bone. Finally, if we can identify the osteoporotic process using a basic panoramic radiography measurement technique, then it is possible to intercept the progress of the disease through early warning and treatment. From the results of this study, it can be concluded the thickness of the mandibular angular cortex can be used as an index for bone resorption. A healthy lifestyle has multiple benefits for the mouth and throughout the body. Dental professionals can play a role in preventing osteoporosis by reinforcing this message. Physicians and dentists collaborate to improve early detection of patients at risk of experiencing or who have osteoporosis. All health care professionals involved in the care of all dental patients, particularly patients who are taking oral bisphosphonates, should discuss patient care decisions. Strategies for reducing osteoporosis risk also may help retard alveolar bone loss. Oral health maintenance is important in patients with osteoporosis. Bisphosphonate therapy or other medical treatment for these people should be discontinued only after consultation with the patient's physician.

References

- Hildebolt CF (1997) Osteoporosis and oral bone loss. *Dentomaxillofac Radiol* 26(1): 3–15
- Groen JJ, Duyvnsz F, Halsted JA (1960) Diffuse alveolar atrophy of the jaw (non-inflammatory form of paradental disease) and pre-senile osteoporosis. *Gerontol Clin (Basel)* 2: 68–86
- Fauci AS, Harrison TR, Kasper DL, Braunwald E, Hauser SL, Longo DL et al. (2008) *Harrison's Principles of Internal Medicine*: Editors, Anthony S. Fauci...[et Al.]. 20 ed. McGraw-Hill Professional
- Baum E, Peters KM (2008) The diagnosis and treatment of primary osteoporosis according to current guidelines. *Dtsch Arztebl Int* 105(33): 573–582
- Vondracek SF, Linnebur SA (2009) Diagnosis and management of osteoporosis in the older senior. *Clin Interv Aging* 4(1): 121–136
- Buencamino MC, Sikin AL, Jain A, Thacker HL (2009) An observational study on the adherence to treatment guidelines of osteopenia. *J Womens Health (Larchmt)* 18(6): 873–881
- WHO Scientific Group on the Prevention and Management of Osteoporosis. Prevention and management of osteoporosis: report of a WHO Scientific Group. World Health Organization; 2000
- Carranza FA, Newman MG, Takei HH, Kleokevold PR (2007) *Clinical Periodontology*. 10 ed. St. Louis: Elsevier Inc
- Savage A, Eaton KA, Moles DR, Needleman I (2009) A systematic review of definitions of periodontitis and methods that have been used to identify this disease. *J Clin Periodontol* 36(6): 458–467
- Edwards BJ, Migliorati CA (2008) Osteoporosis and its implications for dental patients. *J Am Dent Assoc* 139(5): 545–552
- Gomes-Filho IS, Passos Jde S, Cruz SS, Vianna MI, Cerqueira Ede M, Oliveira DC, dos Santos CA, Coelho JM, Sampaio FP, Freitas CO, de Oliveira NF (2007) The association between postmenopausal osteoporosis and periodontal disease. *J Periodontol* 78(9): 1731–1740
- Reddy MS (2002) Oral osteoporosis: is there an association between periodontitis and osteoporosis? *Compend Contin Educ Dent* 23(10 Suppl): 21–28
- Lopes FF, Loureiro FH, Pereira AF, Pereira AL, Alves CM (2008) Association between osteoporosis and periodontal disease. *Rev Bras Ginecol Obstet* 30(8): 379–383
- Tayeb Y, Goultschin J, Fogel M, Schwartz Z (2003) The relationship between osteoporosis, osteopenia and periodontitis. *Refuat Hapeh Vehashinayim* 20(1): 8–22
- Kaye EK (2007) Bone health and oral health. *J Am Dent Assoc* 138(5): 616–619
- Yasar F, Akgunlu F (2006) The differences in panoramic mandibular indices and fractal dimension between patients with and without spinal osteoporosis. *Dentomaxillofac Radiol* 35(1): 1–9
- Phillips HB, Ashley FP (1973) The relationship between periodontal disease and a metacarpal bone index. *Br Dent J* 134(6): 237–239
- Ward VJ, Stephens AP, Harrison A, Lurie D (1977) The relationship between the metacarpal index and the rate of mandibular ridge resorption. *J Oral Rehabil* 4(1): 83–89
- Bras J, van Ooij CP, Abraham-Inpijn L, Kusen GJ, Wilmsink JM (1982) Radiographic interpretation of the mandibular angular cortex: A diagnostic tool in metabolic bone loss. Part I. Normal state. *Oral Surg Oral Med Oral Pathol* 53(5): 541–545
- Ardakani FE, Niafar N (2004) Evaluation of changes in the mandibular angular cortex using panoramic images. *J Contemp Dent Pract* 5(3): 1–15
- Bras J, van Ooij CP, Van den Akker HP (1985) Mandibular atrophy and metabolic bone loss. Mandibular ridge augmentation by combined sandwich-visor osteotomy and resorption related to metabolic bone state. *Int J Oral Surg* 14(1): 16–21
- Lang P, Steiger P, Faulkner K, Gluer C, Genant HK (1991) Osteoporosis. Current techniques and recent developments in quantitative bone densitometry. *Radiol Clin North Am* 29(1): 49–76
- Elders PJ, Habets LL, Netelenbos JC, van der Linden LW, van der Stelt PF (1992) The relation between periodontitis and systemic bone mass in women between 46 and 55 years of age. *J Clin Periodontol* 19(7): 492–496
- Norderyd OM, Grossi SG, Machtei EE, Zambon JJ, Hausmann E, Dunford RG, Genco RJ (1993) Periodontal status of women taking postmenopausal estrogen supplementation. *J Periodontol* 64(10): 957–962
- Jeffcoat M (2005) The association between osteoporosis and oral bone loss. *J Periodontol* 76(11 Suppl): 2125–2132
- Koka S, Forde MD, Khosla S (2006) Systemic assessments utilizing saliva: part 2 osteoporosis and use of saliva to measure bone turnover. *Int J Prosthodont* 19(1): 53–60
- Von WN (2001) General and oral aspects of osteoporosis: a review. *Clin Oral Investig* 5(2): 71–82
- Chohayeb AA (2004) Influence of osteoporosis on the oral health of menopausal women. *Gen Dent* 52(3): 258–261
- Tozum TF, Taguchi A (2004) Role of dental panoramic radiographs in assessment of future dental conditions in patients with osteoporosis and periodontitis. *N Y State Dent J* 70(1): 32–35
- Sanfilippo F, Bianchi AE (2003) Osteoporosis: the effect on maxillary bone resorption and therapeutic possibilities by means of implant prostheses—a literature review and clinical considerations. *Int J Periodontics Restorative Dent* 23(5): 447–457

31. Bianchi A, Sanfilippo F (2002) Osteoporosis: the effect on mandibular bone resorption and therapeutic possibilities by means of implant prostheses. *Int J Periodontics Restorative Dent* 22(3): 231–239
32. White SC (2002) Oral radiographic predictors of osteoporosis. *Dentomaxillofac Radiol* 31(2): 84–92
33. Horner K, Devlin H, Alsop CW, Hodgkinson IM, Adams JE (1996) Mandibular bone mineral density as a predictor of skeletal osteoporosis. *Br J Radiol* 69(827): 1019–1025
34. Drozdowska B, Pluskiewicz W, Tarnawska B (2002) Panoramic-based mandibular indices in relation to mandibular bone mineral density and skeletal status assessed by dual energy X-ray absorptiometry and quantitative ultrasound. *Dentomaxillofac Radiol* 31(6): 361–367
35. Patel SH, Murphy KP (2006) Fractures of the proximal femur: correlates of radiological evidence of osteoporosis. *Skeletal Radiol* 35(4): 202–211
36. Cakur B, Dagistan S, Sahin A, Harorli A, Yilmaz A (2009) Reliability of mandibular cortical index and mandibular bone mineral density in the detection of osteoporotic women. *Dentomaxillofac Radiol* 38(5): 255–261
37. Wactawski-Wende J (2001) Periodontal diseases and osteoporosis: association and mechanisms. *Ann Periodontol* 6(1): 197–208
38. Streckfus CF, Johnson RB, Nick T, Tsao A, Tucci M (1997) Comparison of alveolar bone loss, alveolar bone density and second metacarpal bone density, salivary and gingival crevicular fluid interleukin-6 concentrations in healthy premenopausal and postmenopausal women on estrogen therapy. *J Gerontol A Biol Sci Med Sci* 52(6): M343–M351
39. Binte AR, Tanaka M, Kohno S, Ikegame M, Watanabe N, Nowazesh AM, Ejiri S (2007) Relationship between porotic changes in alveolar bone and spinal osteoporosis. *J Dent Res* 86(1): 52–57
40. McGrath C, Bedi R (2004) Why are we 'weighting'? An assessment of a self-weighting approach to measuring oral health-related quality of life. *Community Dent Oral Epidemiol* 32(1): 19–24
41. Ritchie CS, Joshipura K, Hung HC, Douglass CW (2002) Nutrition as a mediator in the relation between oral and systemic disease: associations between specific measures of adult oral health and nutrition outcomes. *Crit Rev Oral Biol Med* 13(3): 291–300
42. Patlas N, Zadik Y, Yaffe P, Schwartz Z, Ornoy A (2000) Oophorectomy-induced osteopenia in rats in relation to age and time post-oophorectomy. *Cells Tissues Organs* 166(3): 267–274
43. Lerner UH (2006) Bone remodeling in post-menopausal osteoporosis. *J Dent Res* 85(7): 584–595
44. Rustemeyer J, Bremerich A (2009) Bisphosphonate - associated osteonecrosis of the jaw: what do we currently know? A survey of knowledge given in the recent literature. *Clin Oral Investig* (Epub ahead of print)
45. Curtis R, Goldhahn J, Schwyn R, Regazzoni P, Suhm N (2005) Fixation principles in metaphyseal bone—a patent based review. *Osteoporos Int* 16 (Suppl 2): S54–S64

Source of Support: Nil, **Conflict of interest:** None declared.