

Correlation of periodontal status and bone mineral density in postmenopausal women: A digital radiographic and quantitative ultrasound study

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ABSTRACT

Background: Data suggest that postmenopausal women with osteoporosis are at an increased risk for periodontal attachment loss and tooth loss; however, the extent of relationship between these two diseases is still not clear.

Aim: The aim of the study was to evaluate the correlation of periodontal status and bone mineral density (BMD) in postmenopausal women.

Materials and Methods: The study population included 60 postmenopausal women aged 50–60 years (mean \pm SD: 55.5 \pm 3.4 years). Periodontal status was examined by plaque index, bleeding index, probing depth, and clinical attachment level (CAL). Digital panoramic radiograph was taken to measure the maxillary and mandibular alveolar bone density values. Skeletal (calcaneal) BMD was measured by quantitative ultrasound technique for T-score values. The recorded data for T-score, maxillary and mandibular alveolar bone densities, and periodontal status were subjected to statistical analysis for correlation and regression procedures.

Results: The results showed that mandibular alveolar ($r=0.907$, $P<0.001$) and maxillary alveolar bone density ($r=0.898$, $P<0.001$) had significant positive correlation with calcaneal T-score. Probing depth ($r=-0.316$, $P<0.05$), bleeding index ($r=-0.277$, $P<0.05$), and plaque index ($r=-0.285$, $P<0.05$) showed weak but significant negative correlation with calcaneal T-score and alveolar bone density of both the jaws, whereas CAL showed weak correlation with T-score which could not reach to a statistically significance level ($r=-0.221$, $P>0.05$).

Conclusion: Calcaneal BMD was related to alveolar bone loss and, to a lesser extent, to clinical attachment loss, implicating postmenopausal bone loss as a risk indicator for periodontal disease in postmenopausal women.

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Both osteoporosis and periodontal diseases are bone resorptive diseases. Osteoporosis is a chronic systemic skeletal disease characterized by low bone mass and micro-architectural deterioration, resulting in increased bone fragility and susceptibility to fracture.^[1] In most women, bone mass reaches its peak in the third decade

of life (20–30 years of age) and declines thereafter. This decline in bone mass is accelerated with the onset of menopause, and oral/periodontal symptoms are also found in addition to the systemic manifestations of menopause.^[2] The World Health Organization (WHO) has proposed a set of operational criteria to define osteoporosis in postmenopausal women. Bone measurements are expressed as T-scores, which is the difference between the patient's measurements and a mean value for a young adult population and divided by the young adult standard deviation.^[3] According to the WHO, osteoporosis is considered to be present when bone mineral density (BMD) is 2.5 standard deviations (SDs) below the young normal. Osteopenia is defined as bone density levels between 1 SD and 2.5 SD below normal BMD.^[3]

Periodontitis, an inflammatory disease characterized by resorption of the alveolar bone as well as loss of the soft

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tissue attachment to the tooth, is a major cause of tooth loss in adults. Since loss of alveolar bone is a prominent feature of periodontal disease, severe osteoporosis/osteopenia could be suspected of being an aggravating factor in the case of periodontal destruction.^[4] In recent years, there has been increasing interest in the interrelationship between systemic osteoporosis, oral bone loss, tooth loss, and periodontal disease. A growing body of literature has accumulated regarding the role of osteoporosis in the onset and progression of periodontal disease and tooth loss. The association between these two diseases is biologically plausible as well.

It has been hypothesized that the breakdown of periodontal tissue may, in part, be related to systemic conditions that also predispose the patient to osteoporosis/osteopenia.^[5] However, some other authors^[6,7] have reported a contrasting, weak and inconsistent association between skeletal bone density and periodontal status in postmenopausal women. Within this perspective, the present study was aimed to investigate the possible association between osteoporosis/osteopenia and periodontal status among postmenopausal women.

MATERIALS AND METHODS

The study was a cross-sectional, observational evaluation of postmenopausal woman. From June 2009 to October 2009, a total of 60 subjects were recruited from the outpatients department of Oral Medicine and Radiology, JSS Dental College and Hospital, Mysore.

The study was approved by the Institutional Review Board of JSS Dental College and Hospital, Mysore. Written informed consent was obtained from each included subject prior to commencement of the study.

Inclusion criteria

- 1) Female subjects aged 50–60 years who experienced natural menopause and
- 2) The presence of at least seven natural teeth to provide a reasonable number of teeth.

Exclusion criteria

- 1) Postmenopausal women whose precise medical history was not confirmed by hospital records;
- 2) Women with a history of surgically induced menopause, tobacco/alcohol abuse, bone destructive lesions of jaw/metabolic bone diseases, diabetes mellitus, thyroid diseases, chronic renal problems and connective tissue disorders; and
- 3) Women on hormone replacement therapy (HRT)/corticosteroids or chemotherapy and /or radiotherapy.

A study population with a range of different levels of both periodontal disease and BMD was intended; therefore, severity of these conditions was not a selection criterion.

Recording of periodontal clinical parameters

The included subjects underwent a complete clinical periodontal examination. All of the clinical measurements were performed by a single examiner (VSB) who was unaware of the woman's bone mineral density.

Selected individuals were examined for periodontal status by plaque index^[8] (Silness and Loe method) for four sites per tooth (buccal, mesiobuccal, distobuccal, and lingual), gingival bleeding index^[9] (Ainamo and Bay, 1975) on the mesial, distal, buccal, and lingual aspects of the teeth, and probing depth measured by computerized probing system^[10] (The Florida Disk Probe System, Florida Probe, Gainesville, FL, USA) with a constant probing force on six sites per tooth (distobuccal, midbuccal, mesiobuccal, distolingual, midlingual, and mesiolingual), and clinical attachment level (CAL) was automatically calculated by a computer program taking cemento-enamel junction (CEJ) as a fixed reference point. Subjects' mean plaque score, probing depth and CAL were computed for the whole mouth, whereas gingival bleeding and was expressed in percent as number of sites affected to total sites examined.

Bone mineral density assessment of alveolar bone

The average density of maxillary and mandibular alveolar bone was recorded by digital radiographic technique. The digital photostimulable storage phosphor (PSP) system^[11] (Digident PSP system, Digident Ltd, Neshar, Israel) was used with the PSP plates loaded in a cassette without intensifying screen and exposed using dental panoramic unit (Orthoslice 1000 C, Trophy, Marne La Vallee, France) in auto exposure mode with a magnification of 1.23. Immediately after exposure, the PSP plates were scanned in the scanner (Combi-X-2000, Digident Ltd, Neshar, Israel) using manufacturer's default settings as advised. Subsequently, the reproduced digital images were transferred to computer for assessment of average density values of maxillary and mandibular alveolar bone.

Ultrasound parameters for assessment of calcaneal bone

The study used ultrasonometer device (Achilles InSight™ bone ultrasonometer, GE Healthcare, General Electric Company, Lunar, Madison, WI) based on quantitative ultrasound technique^[12] (QUS) to evaluate bone status by measuring stiffness index (SI)^[13,14] in the heel (calcaneus bone) for the assessment of BMD. The working position and the components of the ultrasonometer are demonstrated in Figure 1.

Measurement was performed with the patient seated, with left foot placed on the foot positioner of device. The heel was surrounded by warm water encapsulated in inflated membranes because water is the optimum medium for the transmission of ultrasound. A transducer on one side of the heel (Tx) converted an electrical signal into sound wave,

which passed through water membranes and the patient's heel. A transducer at a fixed distance on the opposite side of the heel (Rx) received the sound wave and converted it to an electrical signal that was analyzed by the ultrasonometer program.^[13]

The ultrasonometer device measured the speed of sound (SOS, m/second) and the frequency-dependent broadband ultrasound attenuation (BUA, dB/MHz), and combined them to form a clinical measure called stiffness index.^[13,14]

The SI is a measure of bone strength and is sensitive to bone structure used to predict the risk of bone fracture due to osteoporosis. To calculate SI, a resultant formula^[13] has been empirically derived such that the index has 50% contribution due to SOS and 50% contribution from BUA:

$$SI = [(0.67 \times BUA) + (0.28 \times SOS)] - 420$$

The SI has been scaled in such a way to make the young adult value equal to 100. The normalized and scaled BUA and SOS values contributed equally to the resulting SI over the adult age range. The SI was then used to create T-score by comparing to reference figures for a healthy young adult.

Thus, the obtained data for T-score and maxillary and mandibular alveolar bone density, and periodontal status were subjected to statistical analysis for correlation and regression procedures.

Statistical analysis

The results were expressed as arithmetic means, considering the SD. Pearson linear correlation coefficient was used to evaluate the interdependence between examined parameters. Multiple regression analyses were conducted to examine the relationship between dependent variables (T-score and CAL) with various potential predictors. Correlation was considered to be significant at the values of $P < 0.05$. All the statistical methods were carried out using a software program (Statistical package version 17, SPSS, Chicago, IL)

RESULTS

This study included 60 postmenopausal women aged 50–60 years, with a mean (SD) of 55.5 (3.4) years. Table 1 summarizes the descriptive statistics results.

Correlations of the parameters

Pearson correlation coefficients between skeletal, alveolar and periodontal parameters are shown in Table 2. Maxillary alveolar bone density showed highly significant positive correlation ($r=0.898$, $N=60$, $P<0.001$) with T-score. Mandibular alveolar bone density correlation ($r=0.907$, $N=60$, $P<0.001$) with T-score was also highly significant.

The scattergram for both the maxillary and mandibular [Figure 2] alveolar bone densities shows that the data points are reasonably well distributed along the regression line, in a linear relationship with no outliers. Further, there was a significant negative correlation ($r=-0.285$, $N=60$, $P<0.05$) between plaque score and T-score. Similarly, bleeding index ($r=-0.277$, $N=60$, $P<0.05$), and probing depth ($r=-0.316$, $N=60$, $P<0.05$) also showed a significant negative correlation with T-score, whereas CAL ($r=-0.221$,

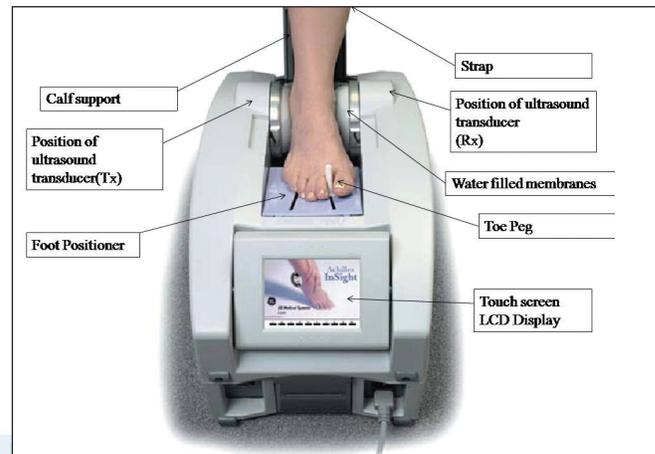


Figure 1: The working position and the components of the ultrasonometer device

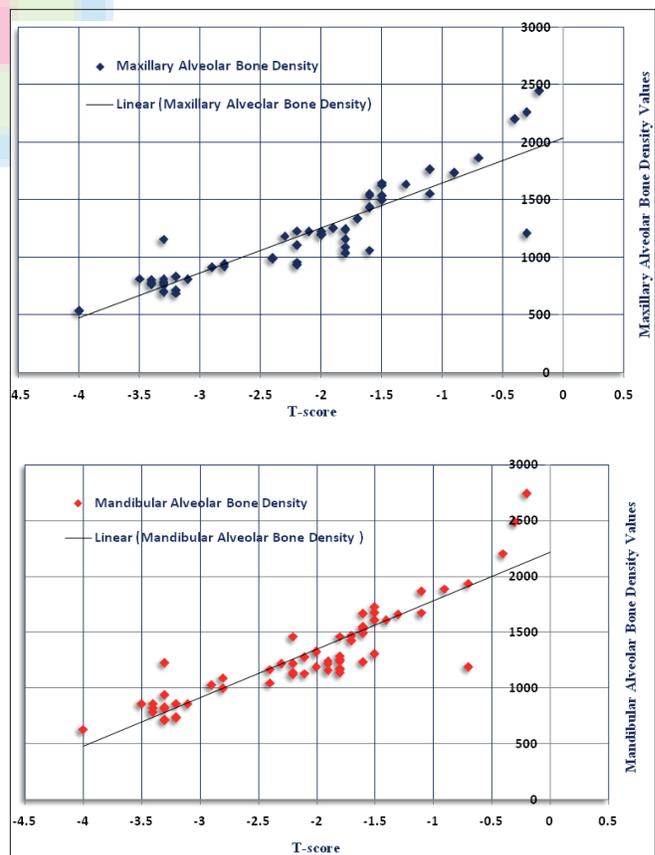


Figure 2: Scattergram showing correlation between mandibular alveolar bone density values and T-score

N=60, $P>0.05$) was weakly correlated with T-score, without statistical significance.

Results of stepwise multiple regression

Multiple regression analyses were conducted to examine the relationship between T-score and CAL with various potential predictors, respectively.

Results of stepwise multiple regression-1

The final multiple regression model with predictor variables (maxillary bone density and mandibular bone density) for the dependent variable (T-score) produced $R^2=0.858$, $F(2, 57)=171.665$, $P<0.001$. Significant variables are shown in Table 3. Adjusted R^2 was 0.853; in other words, about 85.3% of the variability for T-score was accounted by maxillary bone density and mandibular bone density. The plaque score, bleeding score, probing depth, and attachment level did not contribute to the multiple regression models.

Results of stepwise multiple regression-2

The final multiple model with predictor variables (probing pocket depth, bleeding score and maxillary alveolar bone density) for the dependent variable (CAL) produced $R^2=0.885$, $F(3, 56)=144.205$, $P<0.001$. Significant variables are shown in Table 4. The final model accounted for 87.9% of the variance of CAL (adjusted $R^2=0.879$). The T-score,

mandibular alveolar bone density and plaque score did not contribute to the final multiple regression models.

DISCUSSION

The aim of this study was to evaluate the relationship between various periodontal clinical parameters and BMD in postmenopausal women. Our results revealed that there was a significant correlation between maxillary and mandibular alveolar bone densities and calcaneal T-score. Furthermore, our results also suggested the presence of a correlation between periodontal status and calcaneal T-score.

A number of studies^[15-18] have investigated a possible relationship between periodontitis and osteoporosis, and although the literature supports such relationship, its extent remains unclear due to small sample sizes, non-comparable study populations and different study methods used to assess periodontitis and osteoporosis.

Moreover, the evaluation of the relationship between osteoporosis and periodontitis is a complicated issue. It can be understood by the fact that both diseases are multifactorial in etiology. Multiple systemic factors influence the progression of osteoporosis, including age, race, diet, gender, hormone therapy, smoking, genetic factors, exercise and body weight.^[19] Several of these are also risk factors for severe

Table 1: Descriptive statistics of the measured variables

Variables	N	Minimum	Maximum	Mean	SD
T-score (values)	60	-4.00	-0.20	-2.157	0.95
Maxillary alveolar bone density (values)	60	540.00	2455.00	1198.57	419.96
Mandibular alveolar bone density (values)	60	632.00	2748.00	1292.85	462.67
Plaque score [†] (values)	60	0.20	3.00	1.93	0.74
Bleeding score [†] (%)	60	2.70	82.00	47.20	22.65
Probing pocket depth (mm)	60	0.28	4.05	2.65	0.86
CAL (mm)	60	0.78	4.68	3.11	0.83

[†]Measured by Silness and Loe method; [†]Measured by Ainamo and Bay method

Table 2: Pearson correlation coefficients (r) between various parameters measured in 50–60-year-old postmenopausal women (N=60)

Correlations	T S	MNABD	MXABD	PS	BS	PPD	CAL
T S	1	0.907**	0.898**	-0.285*	-0.277*	-0.316*	-0.221
MNABD	0.907**	1	0.901**	-0.356**	-0.244	-0.346**	-0.245
MXABD	0.898**	0.901**	1	-0.396**	-0.346**	-0.396**	-0.273*
PS	-0.285	-0.356**	-0.396**	1	0.517**	0.542**	0.573**
BS	-0.277*	-0.244	-0.346**	0.517**	1	0.522**	0.607**
PPD	-0.316*	-0.346**	-0.396**	0.542**	0.522**	1	0.920**
CAL	-0.221	-0.245	-0.273*	0.573**	0.607**	0.920**	1

**Correlation is significant at the 0.01 level (two-tailed); *Correlation is significant at the 0.05 level (two-tailed); T S = T-score; MNABD = Mandibular alveolar bone density; MXABD = Maxillary alveolar bone density; PS = Plaque score; BS = Bleeding score; PPD = Probing pocket depth; CAL = Clinical attachment level

Table 3: Significant variables of multiple stepwise regression analysis of T-score as dependent variable (N=60)

Predictor variable	B	t	β	P
Mandibular alveolar bone density	0.001	4.505	0.519	<0.001
Maxillary alveolar bone density	0.001	3.730	0.430	<0.001

*Plaque score, bleeding score, probing pocket depth and CAL were not a significant predictor in this model; Dependent variable: T-score; B = Unstandardized regression coefficient; β = Standardized regression coefficients

Table 4: Significant variables of multiple stepwise regression analysis of CAL as dependent variable (n=60)

Predictor variable	B	t	β	P
Probing pocket depth	0.842	15.830	0.872	<0.001
Bleeding score	0.007	3.713	0.200	<0.001
Maxillary alveolar bone density	0.000	2.827	0.142	0.007

The mandibular alveolar bone density, T-score, and plaque score were not a significant predictor in this model; Dependent variable: CAL; B = unstandardized regression coefficient; β = Standardized regression coefficients

periodontal disease.^[20] Furthermore, local factors, such as bacterial plaque and calculus, may also mask the effect of osteoporosis on periodontal status.

Despite the fact that a number of studies support the relationship between osteoporosis and periodontal status, little is known about the mechanism behind such a relationship. Recently, Geurs^[21] summarized the proposed mechanisms to explain a potential relationship between periodontitis and osteoporosis. The possible mechanism by which postmenopausal osteoporosis leads to more periodontal destructions may be the presence of less crestal alveolar bone per unit volume; this bone of lesser density may be more easily absorbed. Estrogen withdrawal following menopause is associated with increased osteoclast numbers due to enhanced osteoclast formation and activity and reduced osteoclast apoptosis.^[22] A significant connection between periodontitis and osteoporosis can also be confirmed by the action of proinflammatory cytokines and prostaglandins. Since these mediators develop in both periodontitis^[23] and osteoporosis,^[24] there is a possibility of double connection between these two diseases. Cytokines such as interleukin-1 (IL-1) and interleukin-6 (IL-6), tumor necrosis factor (TNF), as well as prostaglandins (PGE), have a stimulating effect on the bone resorption, since they affect differentiation of osteoblasts from precursor cells.^[25] The effect of osteoporosis on periodontitis can be partly explained by the increased number of created proinflammatory cytokines and prostaglandins during osteoporosis.

In the present study, we found a strong and significant correlation between calcaneal T-score and alveolar bone density of both the jaws. Previous studies^[15-18,26] have established strong relationships between systemic bone density and alveolar bone density in postmenopausal women belonging to various populations. In a study of 227 postmenopausal women, Klemetti *et al.*^[27] found that women with higher BMDs in the skeleton seem to retain teeth with deeper periodontal pockets more easily than those with osteoporosis. Similarly, Payne *et al.*,^[28] in a 2-year longitudinal clinical study, compared the alveolar bone height and density changes in 21 osteoporotic/osteopenic women with those of 17 women with normal lumbar spine BMD. The results indicated that osteoporotic/osteopenic women exhibited a higher frequency of loss in alveolar bone height and crestal bone density relative to women with normal BMD. Our results also indicated the same, wherein calcaneal T-score significantly correlated with alveolar bone density.

Our result showed there was significant but weak correlation between the clinical parameters of periodontitis (mean probing depth, bleeding score and probing pocket depth) and calcaneal T-score. These findings are in good agreement with those of the authors^[26,29] who reported a significant relation between systemic osteoporosis

and periodontal status in postmenopausal women. A case-control study^[29] comparing 12 osteoporotic fracture women and 14 normal women found that there was significantly greater loss of periodontal attachment in the osteoporotic women than in the normal women. Similar findings were shown in a cross-sectional investigation^[26] of the association between systemic BMD and periodontal status. In this study,^[26] 30 postmenopausal, Asian-American women were screened for osteoporosis and chronic periodontitis. Periodontal assessments included tooth loss, plaque index, probing depths, and CALs. Statistically significant negative correlations were found between BMD and tooth loss and BMD and clinical attachment loss, which were independent of plaque scores.

In another study,^[30] controlling for known confounders, the relationship between systemic BMD and periodontal disease in 70 postmenopausal Caucasian women aged 51–78 was investigated. The severity of periodontal disease was represented by clinical attachment loss and interproximal alveolar bone loss (ABL). Results showed that mean ABL significantly correlated with BMD. Clinical attachment loss appeared to be weakly related to skeletal BMD consistently at all regions of the skeleton, but the results did not reach the level of statistical significance. We obtained a similar result in this study also, where alveolar bone density significantly correlated with calcaneal T-score but the weakly correlated CAL with T-score could not reach a statistical significance level.

In contrast to previous reports, our result is not in agreement with the results of Elders *et al.*,^[6] wherein no significant correlation between periodontitis and spinal BMD has been reported. Likewise, our result differs from the results of Kribbs^[31] who did not find significant difference between the osteoporotic and non-osteoporotic groups in mean. Similarly, our study does not support an age cohort study^[32] of 70-year-old women, in which no statistically significant differences were found in gingival bleeding, probing pocket depth, gingival recession and marginal bone level between 15 women with osteoporosis and 21 healthy subjects.

Until recently, HRT was used in the prevention and treatment of osteoporosis. One recent study^[33] reported a higher likelihood of periodontitis among postmenopausal women not taking HRT compared with premenopausal women (64.4% vs. 46.3%, $P=0.005$). Alveolar bone density and crestal height increased among women taking HRT and/or calcium supplements, which correlated with changes in systemic BMD. This was not a factor in the present study since women taking HRT were excluded from the study.

In the present study, we used digital PSP sensor to assess the BMD of both the jaws. Digital imaging using PSP plates in maxillofacial radiology has been shown to be more accurate than conventional methods of maxillofacial radiography.^[11,34]

With the help of computer software, digital images can be used to analyze bone density change within an area or to detect mineral changes that have occurred over time.^[34]

Numerous investigators^[18,35,36] have utilized dental radiographs to compare the ABL with the BMD of skeletal sites. In the previous studies,^[37-39] interproximal ABL was measured from the cemento-enamel junction to the most coronal aspect of the interproximal alveolar bone for each tooth on the mesial and distal sides from the radiographs. The change was considered for correlating with BMD of skeletal sites. In the present study, we used computer auto generated BMD values for maxillary and mandibular alveolar bone for correlation with BMD of skeletal sites.

Previous studies^[6,7,30] used dual energy X-ray absorptiometry (DEXA) to measure BMD, as this instrument uses a very low level of X-rays produced by an X-ray cathode, to estimate bone mineral content. Recently, QUS^[12-14] methods have been introduced for the assessment of the skeletal status in osteoporosis. Thus, with the advent of ultrasound, it is now possible to measure bone density with a small, portable ultrasound unit designed exclusively for bone density testing. It has been suggested that QUS may provide information about not only bone density but also the micro-architecture and elastic properties of bone.^[13] Furthermore, ultrasound is a mechanical wave with no known biological effect and is safe (it uses no ionizing radiation) at the intensities used clinically.^[13,14] Currently, all of the QUS machines have intensities below the maximum levels imposed by the US Food and Drug Administration (FDA).^[13] Thus, in the present study, we used QUS to measure BMD.

Previously, DEXA bone densitometry was used to records the BMD (g/cm²) at the lumbar spine. In the present study, QUS method was used to measure the BMD of calcaneus bone.^[13] The choice of the calcaneus bone as a measurement site is validated by the fact that it contains 75–90% cancellous bone. Cancellous bone is eight times more metabolically active than cortical bone. Age- and disease-related bone loss is more rapidly apparent at sites where there is a high percentage of cancellous bone. Moreover, calcaneus is highly stressed and weight bearing bone and very active in remodeling process that shows changes within the tissue earlier than compact bone. There is little soft tissue surrounding the calcaneus bone, making it an excellent site for measurement.^[13]

Given the cross-sectional design employed, our findings reflect the cumulative effects of disease processes and prevent the establishment of causal relationships; longitudinal studies would be valuable in establishing a temporal association between systemic and oral bone loss. Therefore, future research should continue to evaluate specific associations between osteoporosis and periodontitis, the temporality of these factors and include subpopulations that

are at increased risk. This knowledge may form the basis for targeting preventive and therapeutic measures to individuals at greatest risk for both diseases.

CONCLUSION

We can thus conclude that systemic bone loss may be a risk indicator for periodontal destruction. A well-designed, large-scale study to determine the role of osteopenia on the prevalence and severity of periodontal disease, and a prospective study to determine whether osteopenia is also associated with the incidence and progression of periodontal disease are needed. Also, intervention studies may be helpful to justify modification of BMD as an approach for the management of periodontal disease. The results of the studies of the relationship between periodontal disease and BMD have a practical significance in the diagnosis, prevention, and treatment of both the diseases.

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