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ORIGINAL ARTICLE

# Correlations between periodontitis and loss of mandibular bone in relation to systemic bone changes in postmenopausal Japanese women

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**Abstract** A new method of measuring mandibular alveolar bone mineral density (BMD) was applied to 40 postmenopausal Japanese women aged 50–69 years exhibiting minimal to mild periodontal diseases. Lumbar spine BMD was measured by dual X-ray absorptiometry (DXA) and calcaneus speed of sound (SOS) by quantitative ultrasound (QUS). There were age-related decreases of alveolar BMD, calcaneus SOS and vertebral BMD. There were significant correlations between two of the respective bone mass values. Correlations between clinical dental findings and bone mass data including alveolar BMD, SOS and lumbar spine BMD were investigated. Significant correlations were demonstrated between alveolar BMD and calcaneus SOS or vertebral BMD. Alveolar BMD showed significant correlation with clinical dental findings including periodontal pocket depth and mobility as well as calcaneus SOS and lumbar spine BMD. Using multivariate analysis combinations of univariate predictors, including deoxypyridinoline (DPD), significantly predicted attachment levels. The SOS value was useful combined with other predictors for predicting attachment level. It was concluded that the new method of evaluating alveolar BMD is useful to predict systemic bone mass and strength as well as dental clinical findings.

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**Keywords** Bone mineral density · Bone turnover markers · Osteoporosis · Periodontitis

## Introduction

There are similarities in anatomy, biochemical constituents, and formation and resorption processes between dental and bone tissues. Some systemic diseases affect both tissues, and pathologic processes in one of the tissues could have influences on the other tissue, and vice versa. Postmenopausal osteoporosis is induced by a lack of a sufficient quantity of estrogens, in addition to many other risk factors contributing to bone loss. This condition leads to loss of jawbone that supports dentines. In addition, dental diseases, including periodontal diseases, affect both soft-tissue attachment to the tooth and alveolar bone loss, resulting in decreased support of the tooth [1]. A highly significant correlation was demonstrated between forearm bone mineral density (BMD) and the thickness of mandibular alveolar process in the region of the first premolar [2].

We reported that a bisphosphonate, etidronate, prescribed for patients with osteoporosis to inhibit the resorption process, is also effective for suppression of alveolar bone loss [3] along with an improvement in pocket depth and soft-tissue attachment in patients with osteoporosis and periodontal diseases while the study was extended for 4–5 years [4]. It was also demonstrated that improvement in lifestyle factors and nutritional strategies for the treatment and prevention of osteoporosis might have an additional benefit in reducing tooth loss [5].

In the present investigation, we studied whether clinical dental findings and mandibular alveolar BMD measured by our method [4] have correlations with vertebral BMD estimated by dual X-ray absorptiometry (DXA) and calcaneus speed of sound (SOS) measured by quantitative ultrasound (QUS).

## Subjects and methods

### Subjects and dental examinations

Forty postmenopausal Japanese women with a mean age of 59.4 ± 5.6 (SD) years (50–69 years), with the mean age of climacterium of 51.0 ± 3.8 years (40 subjects) and with minimal or mild periodontitis. The mean body stature was 154.6 ± 4.5 cm, with that at age 20 years 156.3 ± 4.5 cm (38 subjects). Mean body weight was 54.8 ± 6.6 kg, with mean BMI 22.9 ± 2.5. Twenty women were in their fifties and the rest in their sixties.

Dental clinical examination consisted of measurement of the depth of the periodontal pockets and an assessment of the stability of the teeth. The mobility of each tooth was scored as follows:

- Grade 1: movement of the top of the tooth of 0.2–1.0 mm in the horizontal direction
- Grade 2: movement of more than 1.0 mm in the horizontal direction
- Grade 3: movement in both horizontal and vertical directions

The average of these scores for measured teeth was calculated to give an overall mobility score.

Alveolar bone resorption of the cement area was measured from the dental X-ray film by the method of Schei, calculating the mean values of ratio of both distal and mesial sides of each tooth [6] (Fig. 1).

Biochemical parameters of bone turnover were measured: serum bone alkaline phosphatase (BAP) and urinary deoxypyridinoline(DPD) and calcium/creatinine.

### Measurement of alveolar bone mineral density and other bone parameters

Dental X-ray films were taken and assessed for pathological changes, and alveolar bone density was determined as described elsewhere [4].

In order to make it possible to estimate and evaluate treatment on a patient from a plurality of X-ray pictures

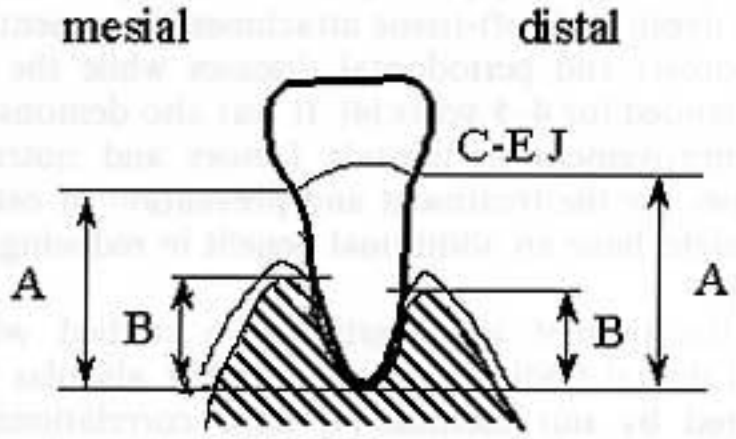


Fig. 1 Calculation of alveolar bone resorption percentage. Alveolar bone resorption = $\{(A-B)/A\} \times 100$ (*CEJ* cement enamel junction) Redrawn from idea of Schei [6]

taken on different days, it is necessary to align the brightness and contrast among the X-ray pictures.

For that purpose, an X-ray picture taken for a normal, healthy person (i.e., a 23-year-old woman having 100% bone mineral density in the example being described) is used as a reference picture for correcting the brightness and contrast of each picture.

Specifically, a histogram hist[x] of a color bar on the reference picture is normalized according to Equation 1. Then, the normalized histogram hist[x] is substituted in Equation 2 and Equation 3, to thereby calculate the brightness mean value Mean and the standard deviation StdDev, which are referred to as the reference mean value RefMean and the reference deviation RefStdDev, respectively.

Similarly, for each of the pictures to be corrected, the histogram hist[x] of its color bar is normalized, and the brightness mean value Mean and the standard deviation StdDev for that picture are calculated. The calculated brightness mean value Mean and standard deviation StdDev, and the reference mean value RefMean and reference deviation RefStdDev are substituted in Equation 4, to thereby correct the pictures with respect to their brightness and contrast, whereby corrected brightness value Y'(i,j) is obtained for each picture.

$$hist[x] = \frac{Num[x]}{TotalNum} \tag{1}$$

where: $x(0 \leq x \leq 255)$ is gradation; Num[x] is the number of pixels for the gradation x in the color bar; and TotalNum is the total number of pixels of the color bar.

$$Mean = \sum_{x=0}^{255} \{x \cdot hist[x]\} \tag{2}$$

$$Mean = \sum_{x=0}^{255} \{x \cdot hist[x]\} \tag{3}$$

$$Y'(i,j) = \frac{\mathrm{Re}fStdDev}{StdDev} \cdot \{Y(i,j) - Mean\} + \mathrm{Re}fMean \tag{4}$$

where Y(i,j) is the brightness value of a picture before correction is provided; and (i,j) is a coordinate of a given pixel.

We used image-editing software (Adobe Photoshop, Adobe Systems, San Jose, CA, USA) to measure the density of the root of the mandibular first premolar. A line was drawn at the apex of the root, parallel with the boundary of the cement-enamel junction. Another line was drawn halfway between the cement-enamel junction and the apex of the root. Lines were then drawn perpendicular to those lines at the mesial and distal spaces of the first premolar. The X-ray film density in the area of the resulting rectangles was measured by first dividing the area into pixels with sides 1/1,524 cm in length. The brightness in each pixel was then compared with a scale

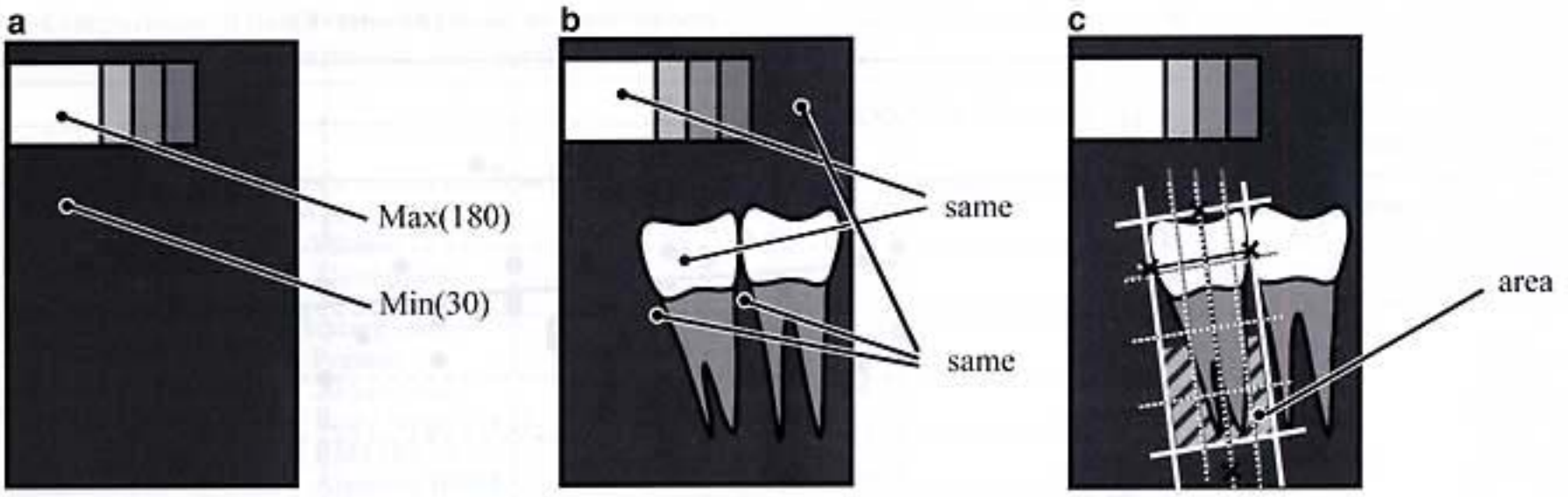


**Fig. 2** Measurement of alveolar bone mineral density. **a** Standard density; **b** comparison of density between standard density and teeth; **c** defining the *area* of interest for the measurement of alveolar density

consisting of 256 steps of brightness (Fig. 2a–c). There was an age-related change of the alveolar bone density (BMD) (Fig. 3a).

The SOS was measured at calcaneus using the QUS method (CM-100 Furuno Electric, Nishinomiya, Japan). Reference data studied in Japanese women was: $1{,}511 \pm 27$ m/s in 656 women with a mean age of 50–54 years; $1{,}498 \pm 24$ m/s in 548 women with a mean age of 55–59 years; $1{,}492 \pm 21$ m/s in 533 women with a mean age of 60–64 years; and $1{,}487 \pm 20$ m/s in 401 women with a mean age of 65–69 years. The young-adult mean value in 371 women with a mean age of 20–29 years was $1{,}538 \pm 33$ m/s [7]. There was a significant age-related decrease of SOS between 50 to 69 years of age (Fig. 3b).

Vertebral BMD was measured by dual X-ray absorptiometry (DXA)(Hologic 4500 W, USA). Reference data were: $0.925 \pm 0.148$ g/cm$^2$ in 2,018 women aged 50–54 years; $0.842 \pm 0.139$ g/cm$^2$ in 2,170 women aged 55–59 years; $0.795 \pm 0.137$ g/cm$^2$ in 2,242 women aged 60–64 years; and $0.771 \pm 0.146$ g/cm$^2$ in 1,744 women aged 65–69 years [8]. There was a significant age-related decrease of BMD between 50 to 69 years of age (Fig. 3c).

## Results

### Comparisons of three parameters of bone mass: alveolar BMD, SOS and vertebral BMD

Alveolar BMD, calcaneus SOS and lumbar spine BMD were significantly lower for women in their 60s than for women in their 50s (Table 1). The annual decrease rate of these bone mass parameters during 9.15 years (the difference in mean age between women in their 50s and women in their 60s) was as follows:

- Alveolar BMD 0.95%
- Calcaneus SOS 0.15%
- Lumbar spine BMD 1.8%

### Comparison of data between subjects in their 50s and subjects in their 60s

There was no significant difference between present stature and stature at age 20 years in all subjects. However, for 60-year-old women the difference was significant. There were no significant differences in body weight and body mass index [kg in body weight/(the stature in meters)$^2$] between subjects in their 50s and subjects in their 60s (Table 1).

The mobility of maxillary teeth was significantly more in subjects in their 60s than in subjects in their 50s, but the difference was not significant for mobility of mandibular teeth. For subjects in their 60s, soft-tissue attachment level was significantly less and periodontal pocket depth in maxillary bone was significantly more compared with subjects in their 50s. Alveolar resorption was significantly more for subjects in their 60s.

Serum BAP, urinary DPD and urinary Ca/Cr were in the normal range but serum BAP and urinary DPD/Cr were significantly higher in subjects in their 60s.

### Correlations among parameters

### Correlations among alveolar BMD, calcaneus SOS and vertebral BMD

While age showed significant negative correlations with lumbar spine BMD and calcaneus SOS, alveolar BMD also showed a significant negative correlation with age (Fig. 1a–c). There was a significant positive correlation between alveolar BMD and lumbar spine BMD or calcaneus SOS, as well as between calcaneus BMD and lumbar spine BMD (Fig. 4a–c).

### Correlations among data of clinical dental findings

Mobility of both maxillary and mandibular teeth showed significant correlations with alveolar bone resorption and pocket depth. Maxillary alveolar resorption and

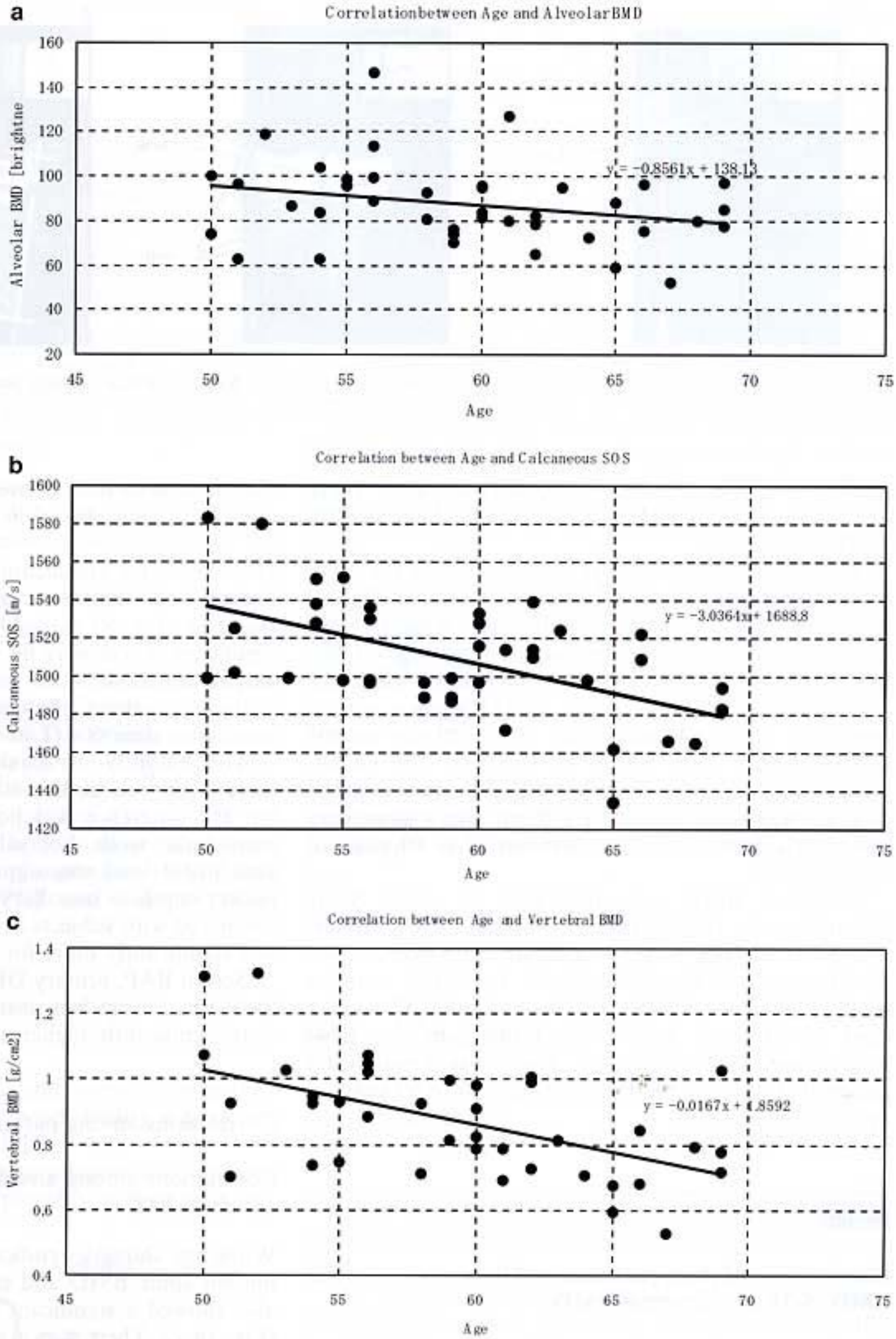


**Fig. 3** Age-related changes of bone mass parameters. **a** Correlation between age and alveolar BMD, $r = -0.258$; **b** correlation between age and calcaneus SOS, $r = -0.556$; **c** correlation between age and vertebral BMD, $r = -0.536$ (*BMD* bone mineral density, *SOS* speed of sound)

maxillary pocket depth also showed significant correlations with maxillary attachment level (Table 2).

## Correlations between parameters of bone mass and BAP

Lumbar BMD showed significant negative correlation with BAP in all subjects and the 50-year olds (Table 3).

## Correlations among biochemical markers of bone turnover and dental clinical findings

Mandibular pocket depth and BAP showed a significant positive correlation, and mobility of maxillary teeth showed a significant positive correlation with urinary DPD (Table 4).

**Table 1** Comparisons of data between subjects in their 50s and in their 60s (*BAP* bone alkaline phosphatase, *BMD* bone mineral density, *Cr* creatinine, *DPD* deoxypyridinoline, *SOS* speed of sound)

| | | Subjects in their 50s $n=20$ | Subjects in their 60s $n=20$ | All $n=40$ |
|---|---|---|---|---|
| Physical | Age | | | |
| | Present | 54.8 ± 2.9 | 64.0 ± 3.2 | 59.4 ± 5.6 |
| | Menopause | 50.8 ± 3.0 | 51.1 ± 4.3 | 51.0 ± 3.8 |
| | Stature (cm) | | | |
| | Present | 154.7 ± 4.7 | 154.5 ± 5.7 | 154.6 ± 4.5 |
| | 20-year-old | 155.4 ± 4.3 | 157.2 ± 4.6 | 156.3 ± 4.5 |
| | Body weight (kg) | 54.7 ± 4.2 | 54.9 ± 7.9 | 54.8 ± 6.6 |
| | BMI ($kg/m^2$) | 22.8 ± 2.1 | 23.0 ± 2.9 | 22.9 ± 2.5 |
| Bone mass | Alveolar BMD | 91.3 ± 19.8* | 83.3 ± 15.6* | 87.3 ± 18.5 |
| | Calcaneus SOS (m/s) | 1,518.9 ± 28.1* | 1,498.1 ± 27.2* | 1,508.5 ± 30.4 |
| | Lumbar spine BMD($g/cm^2$) | 0.947 ± 0.169* | 0.793 ± 0.134* | 0.870 ± 0.173 |
| Dental findings | Mobility | | | |
| | Maxillary | 0.30 ± 0.24* | 0.62 ± 0.79* | 0.45 ± 0.61 |
| | Mandibular | 0.42 ± 0.31 | 0.37 ± 0.40 | 0.40 ± 0.37 |
| | Attachment level (mm) | | | |
| | Maxillary | 4.08 ± 0.88 | 4.16 ± 1.79 | 4.12 ± 1.33 |
| | Mandibular | 4.18 ± 0.88* | 3.58 ± 0.82* | 3.86 ± 0.92 |
| | Pocket depth (mm) | | | |
| | Maxillary | 3.08 ± 0.48* | 3.56 ± 0.85* | 3.26 ± 0.72 |
| | Mandibular | 2.80 ± 0.43 | 2.73 ± 0.56 | 2.77 ± 0.50 |
| | Alveolar resorption | | | |
| | Maxillary | 27.38 ± 7.98* | 30.68 ± 8.69* | 29.06 ± 8.65 |
| | Mandibular | 28.96 ± 8.32 | 28.92 ± 7.22 | 23.96 ± 7.88 |
| Biochemical markers | Serum BAP | 25.08 ± 9.47** | 27.26 ± 10.44** | 26.17 ± 10.15 |
| | Urinary DPD/Cr | 5.07 ± 2.26** | 5.87 ± 2.29** | 5.47 ± 2.34 |

*$p>0.01$
**$p>0.05$ Mean ± SD

Multivariate analysis of various parameters in relation to dental clinical findings

Multivariate analysis was performed in relation to dental clinical findings with the use of Stat View 5.0. Both maxillary and mandibular attachment levels were dependent variables, and age, biochemical parameters and SOS were selected as independent variables. When DPD was included as an independent variable, dependent variables were explained significantly by independent variables (Table 5). However, mobility of teeth as dependent variable was not significant in relation to the above independent variables.

## Discussion

While various methods have been proposed for the evaluation of BMD for mandibular bone, most of them were based on dental X-ray pictures of mandibula. Jonasson proposed that measurements of the mandibular alveolar process could be used as one of several

**Table 2** Correlation coefficients among data of clinical dental findings: maxillary ( *max*) and mandibular (*mand*) mobility, alveolar bone resorption, attachment level and pocket depth

| | | Mobility | | Alveolar resorption | | Attachment level | | Pocket depth | |
|---|---|---|---|---|---|---|---|---|---|
| | | max | mand | max | mand | max | mand | max | mand |
| Mobility | max | 1 | - | - | - | - | - | - | - |
| | mand | 0.666* | 1 | - | - | - | - | - | - |
| Alveolar resorption | max | 0.685* | 0.557 | 1 | - | - | - | - | - |
| | mand | 0.299 | 0.385 | 0.257 | 1 | - | - | - | - |
| Attachment level | max | 0.815* | 0.528 | 0.433 | 0.279 | 1 | - | - | - |
| | mand | 0.229 | 0.389 | 0.157 | 0.096 | 0.460 | 1 | - | - |
| Pocket depth | max | 0.757* | 0.814* | 0.529* | 0.144 | 0.723* | 0.367 | 1 | - |
| | mand | 0.029 | 0.230 | 0.136 | 0.053 | 0.057 | 0.288 | 0.382 | 1 |

*Significant correlation coefficients ( $p>0.01$)

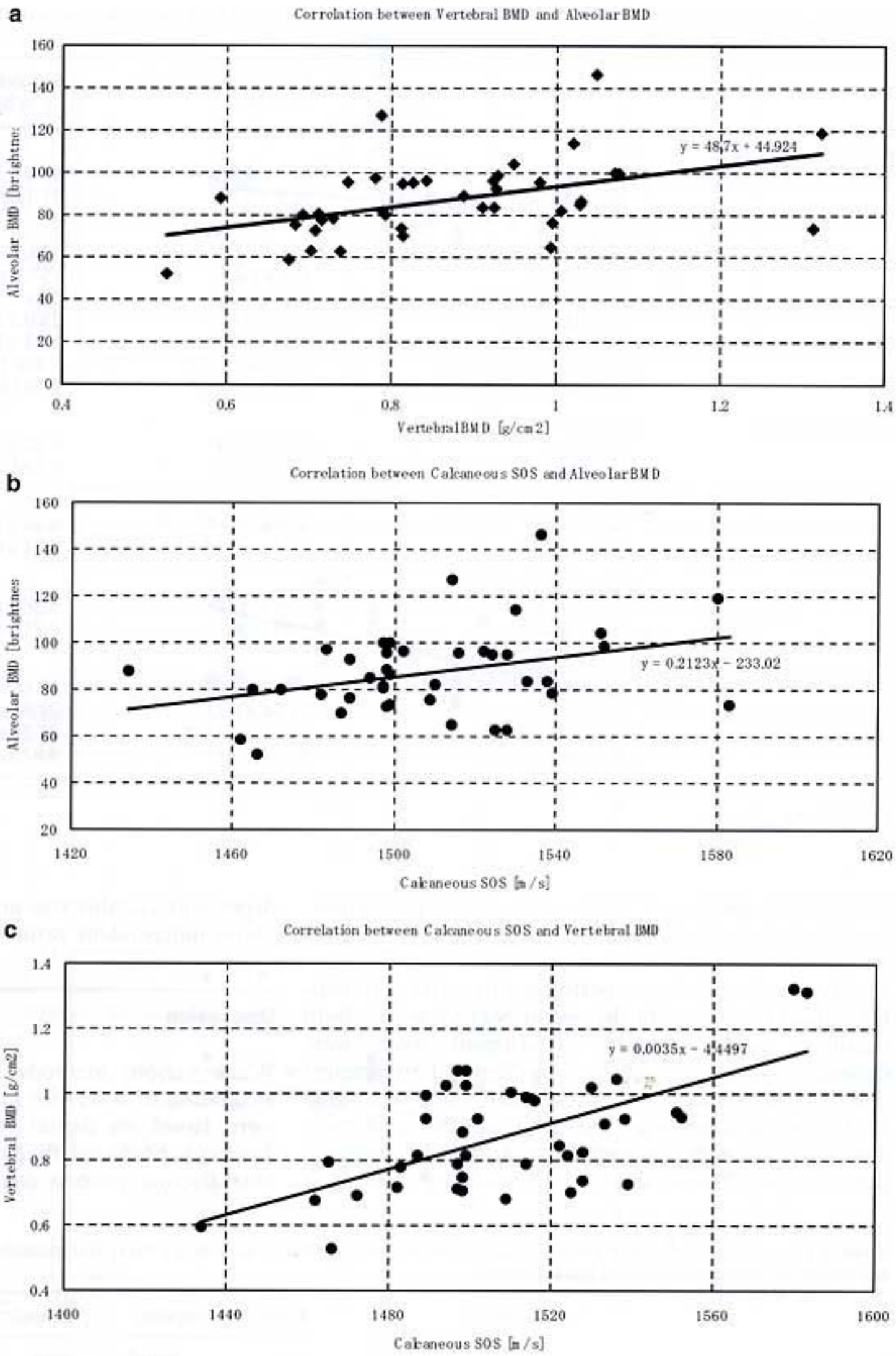


**Fig. 4** Correlations among each parameter of bone mass. **a** Correlation between alveolar BMD and vertebral BMD, $r = 0.456$; **b** correlation between alveolar BMD and SOS, $r = 0.350$; **c** correlation between SOS and vertebral BMD, $r = 0.620$ (*BMD* bone mineral density, *SOS* speed of sound)

parameters to predict skeletal bone density [2]. Jeffcoat and colleagues showed that lumbar spine BMD correlates closely with BMD of alveolar bones measured on X-ray films [9]. In the present investigation alveolar BMD showed significant correlation with lumbar spine BMD and calcaneus SOS. It may well be concluded that alveolar BMD could reflect a systemic bone change. Our group was the first to report the present method of assessing alveolar BMD [4]. One of the advantages is that this method can eliminate technical variation caused by taking X-ray pictures. An automatic process of measuring brightness of divided squares on the film facilitates measuring bone mineral density.

**Table 3** Correlation coefficients among bone mass parameters and BAP ( *BAP* bone alkaline phosphatase, *BMD* bone mineral density)

| | | Bone mass parameters | | |
|---|---|---|---|---|
| | | Alveolar BMD | SOS | Lumbar BMD |
| Serum BAP | All subjects | −0.176 | −0.081 | −0.429* |
| | In 50s | −0.246 | −0.131 | −0.517* |
| | In 60s | −0.060 | 0.035 | −0.338 |

*$p$;>0.01

There was an age-related change of alveolar BMD for the age range 50–69 years. However, the annual decrease of alveolar BMD was not as remarkable as that of vertebral BMD. It may be due to the effect of alveolar bone changes related to periodontitis.

Although dental signs were mild in the subjects studied in the present investigation, alveolar BMD showed significant correlation with periodontal pocket depth of both maxillary and mandibular alveolar bones. Regarding 50-year-old subjects, alveolar BMD showed significant correlation with mobility of both maxillary and mandibular alveolar bones.

**Table 4** Correlation coefficients among clinical dental findings and biochemical markers (*BAP* bone alkaline phosphatase, *BMD* bone mineral density, *Cr* creatinine, *DPD* deoxypyridinoline, *SOS* speed of sound)

| All subjects | | |
|---|---|---|
| Dental clinical findings | Biochemical markers | |
| | Serum BAP | Urinary DPD/Cr |
| Subjects in their 50s | | |
| Clinical dental findings | Biochemical markers | |
| | Serum BAP | Urinary DPD/Cr |
| Subjects in their 60s | | |
| Clinical dental findings | Biochemical markers | |
| | Serum BAP | Urinary DPD/Crs |
| Mobility | | |
| Maxillary | 0.105 | 0.337* |
| Mandibular | 0.095 | 0.171 |
| Pocket depth | | |
| Maxillary | 0.106 | 0.207 |
| Mandibular | 0.293 | −0.033 |
| Mobility | | |
| Maxillary | −0.357 | −0.258 |
| Mandibular | −0.030 | −0.401 |
| Pocket depth | | |
| Maxillary | −0.332 | −0.419 |
| Mandibular | 0.061 | −0.353 |
| Mobility | | |
| Maxillary | 0.211 | 0.529* |
| Mandibular | 0.199 | 0.642** |
| Pocket depth | | |
| Maxillary | 0.366 | 0.551* |
| Mandibular | 0.522* | 0.325 |

*$p$>0.05
** $p$>0.001

The annual change of calcaneus SOS was not as remarkable as in alveolar BMD and lumbar spine BMD, but it showed significant correlations with periodontal pocket depth of mandibular alveolar bone.

In multivariate analyses of age, biochemical markers of bone turnover and SOS in relation to dental clinical findings, both maxillary and mandibular attachment level showed significant contributions by combinations of parameters including urinary DPD/Cr. DPD is a pyridinium cross-link from bone collagen and is considered a specific indicator of bone resorption, although small amounts of DPD are derived from muscle, the cardiovascular system and ligaments [10].

An association between systemic osteoporosis and decreased BMD of jawbones has been reported [2, 9, 11]. Digital-image analysis of jawbones indicated significant deterioration of mandible bone density and lowered levels of structure of trabecular number in patients with osteoporosis compared with control subjects [11]. Choei et al. analyzed BMD of three parts of mandibles from cadavers by dual energy X-ray absorptiometry, demonstrating that the intra-alveolar trabecular bone is affected by both local and systemic influences, whereas infra-alveolar trabecular bone is mostly sensitive to dental status [12].

Chesnut reviewed this problem and raised three questions [13]:

1. Is systemic osteopenia a risk factor for periodontitis?
2. Is systemic osteopenia a risk factor for oral osteopenia, independent of periodontal disease?
3. Is periodontal disease the primary (exclusive) risk factor for oral osteopenia?

**Table 5** Multivariate analysis of factors in relation to clinical dental findings (attachment level)

| Independent variables | Dependent variables | |
|---|---|---|
| | Mobility | Attachment level |
| Age | 0.1257 | 0.0335* |
| BAP | | |
| DPD | | |
| Ca/Cr | | |
| SOS | | |

*Significant predictors ( $p$ <0.05)

Wactawski-Wende stated that potential mechanisms by which host factors may influence onset and progression of periodontal disease directly or indirectly include underlying low bone density in the oral cavity, bone loss as an inflammatory response to infection, genetic susceptibility, and shared exposure to risk factors. 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 [14].

In conclusion, it was demonstrated that alveolar BMD measured from dental X-ray films showed significant correlations with lumbar spine BMD and calcaneus SOS, thus reflecting systemic bone changes including bone mass and possibly bone strength. Alveolar BMD also showed significant correlations with clinical dental findings, including periodontal pocket depth and mobility of teeth. SOS was found to predict attachment level, one of the clinical dental findings for periodontitis.

The correlation coefficients were higher for maxillary bones than for mandibular bones—maxillary bone has a higher ratio of spongy bones compared with compact bones [15, 16]. In postmenopausal osteoporosis and glucocorticoid-induced osteoporosis trabecular bones show osteoporotic change earlier.

## References


1. Jeffcoat MK (2003) Periodontal diseases and bone. In: Favus MJ (ed) Primer on the metabolic bone diseases and diseases and disorders of mineral metabolism. ASBMR, Washington DC, pp 536–540
2. Jonasson G, Kiliaridis S, Gunnarsson R (1999) Cervical thickness of the mandibular alveolar process and skeletal bone mineral density. Acta Odontol Scand 57:155–161
3. Takaishi Y, Miki T, Nishizawa Y, Morii H (2001) Clinical effect of etidronate on alveolar pyorrhea associated with chronic marginal periodontitis: report of four cases. J Int Med Res 29:366–365
4. Takaishi Y, Ikeo T, Miki T, Nishizawa Y, Morii H (2003) Suppression of alveolar bone resorption by etidronate treatment for periodontal disease: 4- to 5-year follow-up of four patients. J Int Med Res 31:575–584
5. Gur A, Nas K, Kayhas O, Atay MB, Akyuz G, Sindal D, Aksit R, Oncel S, Dilsen G, Cevik R, Gunduz H, Ersoy Y, Altay Z, Ozturk C, Aekus S, Senocak O, Kavuncu V, Kienap M, Tekeoglu I, Erdogan F, Sarac AJ, Demiralp L, Demirkesen A, Adam M (2003) The relation between tooth loss and bone mass in postmenopausal osteoporotic women in Turkey: a multicenter study. J Bone Miner Metab 21:43–47
6. Schei O, Waerhaug J, Lovdal A, Arno A (1959) Alveolar bone loss as related to oral hygiene and age. J Periodontol 30:7–16
7. Kishimoto H, Yoh K, Ohta H, Gorai I, Hashimoto J, Nakatsuka K, Yoshimoto Y, Makita K (2003) Reference data and cut-off value of quantitative ultrasound measured by CM-100. Osteoporosis Jpn 11:307–310
8. Orimo H, Sugioka Y, Fukunaga M, Muto Y, Hotokebuchi T, Gorai I, Nakamura T, Kushida K, Tanaka H, Ugai T (1996) Diagnostic criteria of primary osteoporosis (revised version of 1996) Osteoporosis Jpn 4:643–652
9. Jeffcoat MK, Reddy MS, DeCarlo AA (2001) Oral bone loss and systemic osteopenia. In: Marcus R, Feldman D, Kelsey J (eds) Osteoporosis, 2nd edn. Academic, San Diego, pp 363–384
10. Robins SP (2001) Pyridinium cross-links as bone resorption markers. In: Eastell R, Baumann M, Hoyle NR, Wieczorek L (eds) Bone markers: biochemical and clinical perspectives. Dunitz, London
11. Tomaszwski T (2002) Assessment of density and mandible bone structure in patients with generic osteoporosis symptoms. Ann Univ Mariae Curie Sklodowska [Med] 57:329–341
12. Choei L, Duboeuf F, Bourgeois D, Briguet A, Lisaac M (2003) Trabecular alveolar bone in the human mandible: a dual energy X-ray absorptiometry study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 95:364–370
13. Chesnut CH 3rd (2001) The relationship between skeletal and oral bone mineral density: an overview. Ann Periodontol 6:193–196
14. Wactawski-Wende J (2001) Periodontal diseases and osteoporosis: association and mechanisms. Ann Periodontol 6:197–208
15. Fanuscu MI, Chang TL (2004) Three-dimensional morphometric analysis of human cadaver bone: microstructural data from maxilla and mandible. Clin Oral Implants Res 15(2):213–218
16. Yoshinobu Ide, Hiroko Agematsu (1999) Mandibular bone changes associated with tooth loss. Clin Ca 9:325–333 (in Japanese)