Iranian J Publ Health, 2008, A supplementary issue on Osteoporosis and Bone Turnover, No.1, pp.63-71

Relationship between Mandibular BMD and Bone Turnover Markers in Osteoporosis Diagnosis

SM Eshaghi, *A Hossein-nezhad, Zh Maghbooli, B Larijani

Bio & Nano Technology Unit of Endocrinology and Metabolism Research Centre, Tehran University of Medical Sciences, Iran

Abstract

Background: The purpose of the present study was to determine mandible bone mineral density and evaluate its correlation with central BMD and bone turnover.

Methods: Two hundred and seven postmenopausal women were enrolled in this cross-sectional study. After receiving the testimonials, questionnaires were completed and physical exams were done. For all participants central BMD was measured through DXA method. In each women periapical radiography performed in two regions of mandible. The plain x-ray films were scanned using a standard film digitizer and standardized in size and intensity using a calibration step wedge phantom. The phantom was placed upper site in film cover. After the film digitized, the developed Matlab software was used to image processing.

Results: Mean age and body mass index of participants were 54.6±6.3 years and 28.57±4.9 kg/m2 respectively. Prevalence of osteoporosis and osteopenia in one of regions in central DXA were 17.4% and 48.2% respectively. There was strong correlation between mandible and total femur BMD (P= 0.001, r= 0.80).In osteoporotic patients bone loss in mandible BMD was more than central DXA (P= 0.02).

Conclusion: The main advantage of the proposed mandible BMD is to help clinicians make more accurate evaluation of Bone loss. Based on developed the suggested system a routine dental X-ray could be used to screen for bone loss.

Keywords: *Mandible, BMD, Osteoporosis, Periapical, Image Processing*

Introduction

Osteoporosis is described as a general skeletal disorder characterized by reduced bone mineral density. It can predispose us to bone fracture. Osteoporotic fractures are associated with high morbidity and mortality among various populations (1, 2).

Different Bone mineral densitometry instruments are used for measurement of the bone mineral density (BMD) and osteoporosis detection. In recent years competent systems such as quantitative computed tomography and dual X-ray absorptiometry (DXA) methods have been developed and widely employed (3).

Osteoporosis and periodontitis are two independent diseases though these diseases are related as both have damage bone tissue, share common risk factors, most prevalence in middle-aged and elderly women (4). Evidence indicated that mandibular bone loss occurs earlier than others. However application of above mentioned techniques for measuring bone density of jaws is not technically easy due to the shape of the bones (5). Dentists have been investigating mandibular bone for a long time for detecting height of the alveolar ridge and mandibular osteoporosis witch have serious consequences like edentulism (6). Also determination of mandibular bone density is of paramount importance for the diagnosis, treatment planning and management of dental procedures such as osseointegrated implants and grafting. Therefore radiographic assessment of bone quality has applications in implantology (1) and in research assessing the relationship between oral bone loss and osteoporosis (6).

Although photodensitometry via periapical and panoramic radiographs has been used to estimate mandibular bone mass, this method has low predictive value for skeletal osteopenia (7-9). A large number of quantitative and qualitative measurements of mandibular bone from radiographs have been devised for this purpose, including densitometry

***Corresponding author:** Tel: +98 21 84902476, Fax: +98 21 88220037, E-mail: ahosseinnezhad@sina.tums.ac.ir

(10, 11) and morphometry (12-14). Many of these require specialized facilities or are time- consuming and necessitate radiography of the highest standards. Advanced methods such as dual X-ray absorptiometry (DXA) and quantitative computed tomography (15, 16) have been applied in edentulous areas, and dual-photon absorptiometry (8).
The correlation between the mandibular and other bone values was found to be as low as with photo densitometry. Digital image analysis techniques for quantisation of bone mass have been applied to oral digital or digitized radiographs. The use of gray-level values for detecting changes in alveolar bone density is under development (17, 18). These changes may also reproduce variation in other sites BMD (19). Mathematical methods for image-processing also are used to make the analysis of morphology easy (20). In this way, the structure of the trabecular architecture has been studied in vertebra (21), in the radius (22), and also on periapical radiographs (18, 23).
Radiographic measurements showed problems with inter observer variation, which suggests that careful training and calibration of observers would be important if they were to be used as an indicator of mandibular BMD (24). In vitro studies have used digital subtraction of oral radiographs (25, 26) to detect density changes in simulated osteoporosis. However, up until now, these new techniques have not been fully developed for use in clinical practice.
On the other hands, in spite of developing deliberate instruments and mentioned methods, still there is doubt in ability of fracture perdition depending only on BMD (27). Furthermore, Biochemical markers of bone turnover may be of value for prediction of individual bone loss and they may help in predicting risk of fracture in elderly women. Recent studies indicate that increased levels of biochemical markers of bone turnover are associated with greater bone loss.
The purpose of the present study was to examine the diagnostic performance of dental periapical radiography and biochemical markers of bone turnover in relation to BMD in postmenopausal women.

Material and Methods

Bone mineral densitometry

The subjects for the study were 207 postmenopausal women randomly selected from the participants of Iranian multicenter osteoporosis study (IMOS). All the subjects had undergone bone mineral density (BMD) measurements (T/Z scores) by dual energy X-ray absorptiometery (DEXA) at lumbar spine (vertebrae L2–L4) and hip (femur neck). The BMD (g/cm2) was measured by dual energy X-ray absorptiometery (Lunar-DPX, USA). The coefficient of variation for longitudinal BMD measurements in the DEXA machine averaged at 1.04%.
Normal bone mass was defined as BMD measurements at or above -1 standard deviation (S.D.) from the optimal peak bone density (T-score) of healthy young adult of the same sex.
BMD measurement at or below -2.5 S.D from the optimal peak bone density of healthy young adult of the same sex was osteoporotic and BMD measurement T score between -2.5 and -1 was osteopenia.

Periapical radiography

Periapical radiographs were obtained with a constant current of 8 mA, 70 kVp, and 3 s exposure times, always from the same distance. Holder was used for holding the film packet parallel to the teeth that also prevent bending of the packet. Images were recorded by use of standard radiographic film.

Step wedge phantom

Step wedge phantom was provided from hydroxyapatite composites. These composites contain hydroxyapatite nano powders. The step wedge phantom was composed of five steps of composite. It was designed by the authors, in cooperation with a related manufacturing company. Its segment densities were measured with DXA and corrected with chemical content estimations.
During the exposure, the composite step wedge phantom was placed on the upper of the periapical film packet to provide a reference image on the radiograph. If it was superimposed on any bony structure, a new radiograph was taken after chang-

ing position of the phantom. Also for evaluating of Day-to-day variability in five patients radiography was performed five times over a period of 5 weeks with both phantoms.

Image processing

The plain x-ray films were scanned using a standard film digitizer and standardized in size and intensity using a calibration step wedge phantoms. The developed Matlab software was used to image processing. On the mandibular image, the mean grey levels were measured on the step wedge phantom and the regions of interest. The calibration curve was drown, by plotting against the measured mean grey level values of each step on the step wedge phantom and those values of the measured densities on dual energy X-ray absorptiometery (figure 1). A multivariate stepwise linear regression algorithm was used to select a combination of mandibular measurements that correlates with hip and spine T-scores.

Measurements

Markers of bone formation included osteocalcin (OC). OC was measured by immunoassay (ELISA) using a Bioscience kit (Nortic Bioscience Diagnostic A/S, Denmark). The intra- and inter-assay CV were 2.6% and 4.7%, respectively. Another marker of bone resorption is the serum C-terminal telopeptides of type I collagen: serum crosslaps. Crosslaps were measured by ELISA using a Bioscience kit (Nortic Bioscience Diagnostic A/S, Denmark), with intra- and inter-assay CV of 5.1% and 6.6%, respectively.

Statistical analysis

Data were analyzed by means of a personal computer implemented with dedicated software (SPSS 11.5), to obtain mean±SD values, correlation matrix, Student's t-test, analysis of variance and/or χ^2 tests, as appropriate. The level of significance was settled at <5%, as usual.

Results

In 207 postmenopausal women central BMD was measured through DXA method. The background characteristics of the study population are shown in Tables 1. Mean age and body mass index of participants were 54.6±6.3 yr and 28.57±4.9 kg/m2 respectively. In each women periapical radiography performed in two regions of mandible. Inter and intra assay Coefficient of variance in mandibular BMD lower 2%.

ROC curves showed that the Mandibular BMD that was calibrated by Nano composite to diagnose osteoporosis with 85% specificity and sensitivity of 91%.

The mean of BMD in hip and spine were 0.92± 0.13 gram per cm2 and 1.05±0.19 gram per cm2 respectively (Table 1).

Prevalence of osteoporosis and osteopenia in one of regions in central DXA were 17.4% and 48.2% respectively. In osteoporotic patients bone loss in Mandibular BMD was more than central DXA (P= 0.02). There was strong correlation between mandible and total femur BMD that was shown in figure 2 (P= 0.001, r= 0.80). Also there was correlation between mandible and lumbar spine BMD (P= 0.01, r= 0.78). These correlation similar to correlation of spine BMD with hip BMD (r= 0.76, p=0.001) in this study. Mandibular BMD has a negative significant correlation with age (P= 0.01, r=0.79). Mandibular BMD negatively correlated with serum concentration of Osteocalcin (P= 0.01, r= -0.17) but there was not significantly correlation between Mandibular BMD and serum concentration of Cross laps.

In logistic regression analysis Mandibular BMD independently of age and BMI predicted osteoporosis in all regions that evaluate by DEXA (P< 0.01).

Table 1; Characteristics data of study population

Characteristics	mean ±SD
Age(years)	54.6 ±6.3
BMI(Kg/m^2)	28.57±4.9
Menarche age(years)	13.04±1.57
Hip BMD(gr/cm^2)	0.92±0.13
Spine BMD(gr/cm2)	1.10±0.19
Serum Cross laps (ng/mL)	0.29± 0.11
Serum Osteocalcin (ng/mL)	12.09±3.18

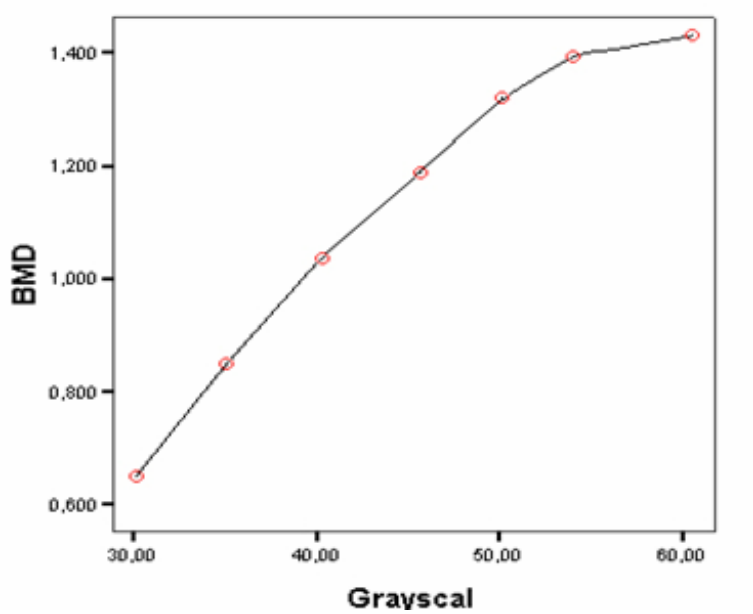

Fig. 1: The calibration curve was drown, by plotting against the measured mean grayscale values of each step on the step wedge phantom and those values of the measured densities on DXA that reported as Mandibular BMD.

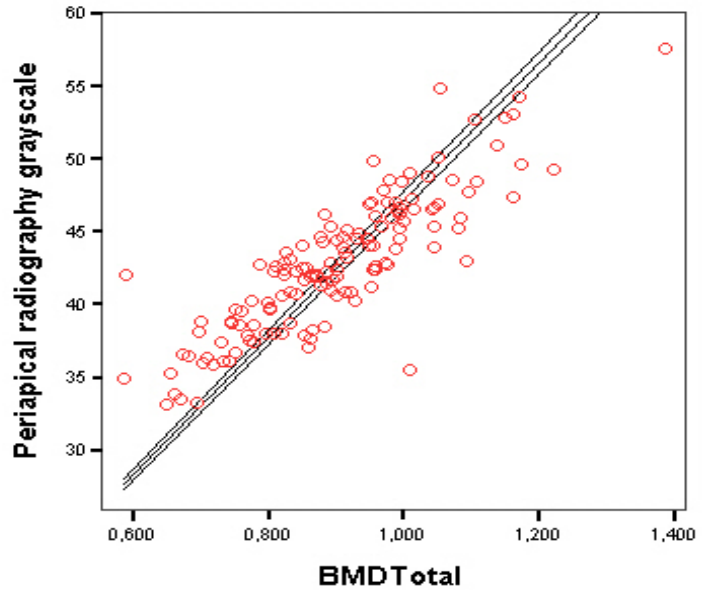

Fig. 2: Linear regression with 95% mean prediction interval between bone mineral density in hip and periapical radiography grayscale.

Discussion

Bone densitometry assessment is used to diagnose osteoporosis, evaluate fracture risk and monitor for changes in bone mineral density. This study used DXA as a gold standard for in vivo measurement of bone mineral density.

Whereas a consistent strong correlation exists between the amounts of bone mineral density (BMD) calculated in the spine, hip, and forearm, (28-30) conflicting results have been reported on the correlation between skeletal BMD and mandibular bone mass. In some studies no relationship has been

found (31, 32), in others only a moderate one (33-35). Diverse assessment techniques may be a possible explanation for the low correlation between skeletal BMD and mandibular bone mass.

Our results demonstrated that mandibular BMD correlated with skeletal BMD. Other studies also have demonstrated a significant correlation between bone mineral density in the mandible or maxilla and the spine or hip (36). Jonasson et al showed that mandibular alveolar bone mass, assessed via the optical density of analog radiographs, was related to skeletal bone mineral density (37).

There is some indirect evidence consistent with our results, which have shown the common influence of systemic factors on oral bone loss and other bones. Postmenopausal women with fractures had a significantly higher number of teeth loss than those without fractures (38-42). Krall referred that osteoporosis may cause periodontal disease and tooth loss (43). It was suggested that tooth loss could be associated with spine fractures in osteoporotic females (44, 45).

Several studies in Finland (46), Japan (47-50), the United States (51-53), Poland (54), and the United Kingdom (55, 56) offer contradictory outlook on the usefulness of mandibular evaluation in women.

Yang et al (57) showed a mandibular cortical bone thinning following ovariectomy due to serum estrogen drop. Estrogen deficiency following ovariectomy in rats has also been shown to affect alveolar bone as well as mandibular basal bone (58).

Our results indicated that mandibular BMD negatively correlated with age. Previous studies have shown that mandibular cortical thickness has a significant negative correlation with age (59) and a significant positive correlation with BMD in other skeletal sites, for example, the forearm and iliac crest (60). The mandible may therefore undergo a similar age-related decline in BMD, as has been observed in other sites.

Our result revealed that mandibular BMD has a significant negative correlation with biochemical markers of bone turnover. It has been suggested that biochemical markers of bone turnover may be useful for identifying fast bone losers. Several cross-sectional studies indicated that bone turnover rate assessed by markers increases after the menopause and that high bone turnover is continued long after the menopause.

Lofman et al reported that the bone markers were correlated to the current bone mass and may predict future bone loss (61).

In conclusion, there is a relationship between mandibular and skeletal BMD. Although periapical radiographic findings and biochemical markers of skeletal turnover cannot replace bone density scanning for the diagnosis of osteoporosis, it is thought that they may help to more precise prediction of fracture risk and to determine sufficiency of osteoporosis therapy. Over all, periapical radiography could be useful as an available, low-priced and simple method in osteoporosis screening.

Acknowledgements

We thank BMD unit of EMRC personnel specially Mrs. Fatemeh Zare and Sara Shirazie for valuable assistance in this study. The research has been granted by EMRC which should be acknowledged to pave the way for young researchers.

References

1. Friendlander AH (2002). The physiology, medical management and oral implications of menopause. *JADA*, 133: 73–81.
2. Melton III LJ (2003). Adverse outcomes of osteoporotic fractures in the general population. *J Bone Miner Res*, 18: 1139-41.
3. Genant HK, Engelke K, Fuerst T, Gluer CC, Grampp S, Harris ST, Jergas M, Lang T, Lu Y, Majumdar S, Mathur A, Takada M (1996). Noninvasive assessment of bone mineral and structure: state of the art. *J Bone Miner Res*, 11(6): 707-30.
4. Papeckys M (2004). Articular and bone diseases. *UAB Medicina visiems*, 1: 81-90.
5. Noikura T (1996). Quantitative assessment of bone mineral content in dental radiology: methodology and clinical usefulness. *Oral Radiol*, 12: 139-48.

6. Hildebolt CF (1997). Osteoporosis and oral bone loss. *Dentomaxillofac Radiol*, 26: 3-15.
7. Kribbs PJ, Chesnut CH III, Ott SM, Kilcoyne RF (1990). Relationships between mandibular and skeletal bone in a population of normal women. *J Prosthet Dent*, 63: 86-9
8. Kribbs PJ, Chesnut CH, Ott SM, Kilcoyne RF (1989). Relationships between mandibular and skeletal bone in an osteoporotic population. *J Prosthet Dent*, 62: 703-7.
9. Jacobs R, Ghyselen J, Koninckx P, van Steenberghe D (1996). Longterm bone mass evaluation of mandible and lumbar spine in a group of women receiving hormone replacement therapy. *Eur J Oral Sci*, 104: 10-6.
10. Devlin H, Horner K (1991). Measurement of mandibular bone mineral content using the dental panoramic tomogram. *J Dent*, 19: 116-20.
11. Bras J, van Ooij CP, Abraham-Inpijn L, Kusen GJ, Wilmink JM (1982). Radiographic interpretation of the mandibular cortex: A diagnostic tool in metabolic bone loss. Part I. Normal state. *Oral Surg Oral Med Oral Patho*l, 53: 541-5.
12. Benson BW, Prihoda TJ, Glass BJ (1991). Variations in adult cortical bone mass as measured by a panoramic mandibular index. *Oral Surg Oral Med Oral Pathol*, 71: 349 -56.
13. Klemetti E, Kolmakov S, Kroger H (1994). Pantomography in assessment of the osteoporosis risk group. *Scand J Dent Res*, 102: 68-72.
14. Engquist B, Bergendal T, Kallis T (1998). A retrospective multicentered evaluation of osseo-integrated implants supporting overden- tures. *Int J Oral Maxillofac Implant*, 3: 129-34.
15. Klemetti E, Vainio P, Lassila V, Alhava E (1993). Trabecular bone mineral density of mandible and alveolar height in postmenopausal women. *Scand J Dent Res*,101: 166-70.
16. Klemetti E, Vainio P, Lassila V, Alhava E (1993). Cortical bone mineral density in the mandible and osteoporosis status in postmenopausal women. *Scand J Dent Res*, 101: 219-23.
17. Shrout MK, Weaver J, Potter BJ, Hildebolt CF (1996). Spatial resolution and angular alignment tolerance in radiometric analysis of alveolar bone change. *J Periodontol*, 67: 41-5.
18. Shrout MK, Farley BA, Patt SM, Potter BJ, Hildebolt CF, Pilgram TK, et al. (1999). The effect of region of interest variations on morphologic operations data and gray-level values extracted from digitized dental radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 88: 636-39.
19. Hildebolt CF, Bartlett TQ, Brunsden BS, Hente NL, Gravier MJ, Walkup RK, et al. (1994). Bitewing-based alveolar bone densitometry: digital imaging resolution requirements. *Dentomaxillofac Radio*l, 23: 129-34.
20. Hildebolt CF, Rupich RC, Vannier MW, Zerbolio DJ Jr, Shrout MK, Cohen S, et al. (1993). Inter-relationships between bone mineral content measures. Dual energy radiography (DER) and bitewing radiographs (BWX). *J Clin Periodontol*, 20: 739-45.
21. Korstjens CM, Mosekilde L, Spruijt RJ, Geraets WG, van der Stelt PF (1996). Relations between radiographic trabecular pattern and biomechanical characteristics of human vertebrae. *Acta Radiol*, 37: 618-24.
22. Geraets WG, Van der Stelt PF, Elders PJ (1993). The radiographic trabecular bone pattern during menopause. *Bone*, 14: 859-64.
23. White SC, Rudolph DJ (1999). Alterations of the trabecular pattern of the jaws in patients with osteoporosis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 88: 628-35.

24. Jonasson G (2005). Mandibular alveolar bone mass, structure and thickness in relation to skeletal bone density in dentate women. *Swed Dent J*, 177: 1-63.
25. Southard KA, Southard TE (1994). Detection of simulated osteoporosis in human anterior maxillary alveolar bone with digital subtraction. *Oral Surg Oral Med Oral Pathol,* 78: 655-61.
26. Christgau M, Hiller KA, Schmalz G, Kolbeck C, Wenzel A (1998). Accuracy of quantitative digital subtraction radiography for determining changes in calcium mass in mandibular bone: an in vitro study. *J Periodontal Res*, 33:138-49.
27. Larijani B, Hossein-Nezhad A, Mojtahedi A, Pajouhi M, Bastanhagh MH, Soltani A, Mirfezi SZ, Dashti R (2005). Normative data of bone Mineral Density in healthy population of Tehran, Iran: a cross sectional study. *BMC Musculoskelet Disord*, 2(6): 38
28. Steiger P, Cummings SR, Black DM, Spencer NE, Genant HK (1992). Age-related decrements in bone mineral density in women over 65. *J Bone Miner Res*, 7: 625-32.
29. Ryan PJ, Blake GM, Fogelman I (1992). Measurement of forearm bone mineral density in normal women by dual-energy x-ray absorptiometry. *Brit J Radiol,* 65: 127-31.
30. Horner K, Devlin H, Alsop CW, Hodgkinson M, Adams JE (1996). Mandibular bone mineral density as a predictor of skeletal osteoporosis. *Brit J Radiol*, 69:1019-25.
31. Mohajery M, Brooks SL (1992). Oral radiographs in the detection of early signs of osteoporosis. *Oral Surg Oral Med Oral Pathol Oral Radiol*, 73: 112-7.
32. Southard KA, Southard TE, Schlechte JA, Meis PA (2000). The relationship between the density of the alveolar process and that of post-cranial bone. *J Dent Res*, 79: 964-9.
33. Kribbs PJ, Chesnut III CH, Ott SM, Kilcoyne RF (1990). Relationships between mandibular and skeletal bone in a population of normal women. *J Prosthet Dent*, 63: 86-9.
34. Jacobs R, Ghyselen J, Koninckx P, Van Steenberghe D (1996). Longterm bone mass evaluation of mandible and lumbar spine in a group of women receiving hormone replacement therapy. *Eur J Oral Sci*, 104: 10-6.
35. Jonasson G, Bankvall G, Kiliaridis S (2001). Estimation of skeletal bone mineral density by means of the trabecular pattern of the alveolar bone, its interdental thickness, and the bone mass of the mandible. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 92: 346-52.
36. Arifin AZ, Asano A, Taguchi A, Nakamoto T, Ohtsuka M, Tsuda M, Kudo Y, Tanimoto K (2006). Computer-aided system for measuring the mandibular cortical width on dental panoramic radiographs in identifying postmenopausal women with low bone mineral density. *Osteoporos Int,* 17: 753-59
37. Jonasson G, Jonasson L, Kiliaridis S (2006). Changes in the radiographic characteristics of the mandibular alveolar process in dentate women with varying bone mineral density: a 5-year prospective study. *Bone,* 38: 714-21.
38. Krall EA, Dawson-Hughes B, Papas A, Garcia RI (1994). Tooth loss and skeletal bone density in healthy postmenopausal women.*Osteoporosis Int*, 4: 104–9.
39. Krall EA, Garcia RI, Dawson-Hughes B (1996). Increased risk of tooth loss is related to bone loss at the whole body, hip and spine. *Calcif Tissue Int,* 59: 433-37.
40. Taguchi A, Suei Y, Ohtsuka M, Otani K, Tanimoto K, Hollender LG (1999). Relationship between bone mineral density and tooth loss in elderly Japanese women. *Dentomaxillofac Radiol*, 28: 219–23.

41. Kribbs PJ (1990). Comparison of mandibular bone in normal and osteoporotic women. *J Prosthet Dent*, 63: 218-22.
42. Krall EA, Dawson-Hughes B, Hannan MT, Wilson PWF, Kiel P (1997). Postmenopausal estrogen replacement and tooth retention. *Am J Med*, 102: 536-42.
43. Krall EA (2006). Osteoporosis and the risk of tooth loss. *Clin Calcium*, 16(2): 67-73.
44. Von Wowern N (2001). General and oral aspects of osteoporosis: a review. *Clin Oral Invest,* 5: 71-82.
45. Kribbs PJ (1990). Comparison of mandibular bone in normal and osteoporotic women. *J Prosthet Dent*, 63: 218–22.
46. Klemetti E, Kolmakov S, Kroger H (1994). Pantomography in assessment of the osteoporosis risk group. *Scand J Dent Res*, 102: 68-72.
47. Taguchi A, Suei Y, Ohtsuka M, Otani K, Tanimoto K, Ohtaki M (1996). Usefulness of panoramic radiography in the diagnosis of postmenopausal osteoporosis in women. Width and morphology of inferior cortex of the mandible. Dentomaxillofac *Radiol,* 25: 263-67.
48. Nakamoto T, Taguchi A, Ohtsuka M, Suei Y, Fujita M, Tanimoto K, et al. (2003). Dental panoramic radiograph as a tool to detect postmenopausal women with low bone mineral density: untrained general dental practitioners' diagnostic performance. *Osteoporos Int* ,14: 659-64.
49. Taguchi A, Sanada M, Krall E, Nakamoto T, Ohtsuka M, Suei Y, et al. (2003). Relationship between dental panoramic radiographic findings and biochemical markers of bone turnover. *J Bone Miner Res*, 18: 1689-94.
50. Taguchi A, Suei Y, Sanada M, Higashi Y, Ohtsuka M, Nakamota T, et al. (2003). Detection of vascular disease risk in women by panoramic radiography. *J Dent Res*; 82: 838-43.
51. Watson EL, Katz RV, Adelezzi R, Gift HC, Dunn SM (1995). The measurement of mandibular cortical bone height in osteoporotic vs. nonosteoporotic postmenopausal women. *Spec Care Dentist*, 15: 124-8.
52. Bollen AM, Taguchi A, Hujoel PP, Hollender LG (2000). Case-control study on self-reported osteoporotic fractures and mandibular cortical bone. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 90: 518-24.
53. Persson RE, Hollender LG, Powell LV, MacEntee MI, Wyatt CC, Kiyak HA, et al. (2002). Assessment of periodontal conditions and systemic disease in older subjects. I. Focus on osteoporosis. *J Clin Periodontol*, 29: 796-802.
54. Drozdzowska 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: 361-67.
55. Devlin H, Horner K (2002). Mandibular radiomorphometric indices in the diagnosis of reduced skeletal bone mineral density. *Osteoporos Int*, 13: 373-78.
56. Horner K, Devlin H, Harvey L (2002). Detecting patients with low skeletal bone mass. *J Dent*, 30: 171-5.
57. Yang J, Farnell D, Devlin H, Horner K, Graham J (2005). The effect of ovariectomy on mandibular cortical thickness in the rat. *J Dent*, 33: 123-29.
58. Hsieh YD, Devlin H, McCord F (1995). The effect of ovariectomy on the healing tooth socket of the rat. *Archs Oral Biol*, 40: 529-31.
59. Ledgerton D, Horner K, Devlin H, Worthington H (1999). Radiomorphometric indices of the mandible in a British female population. *Dentomaxillofac Radiol*, 28: 173-81.

60. Horner K, Devlin H, Alsop CW, Hodgkinson IM, Adams JE(1996). Mandibular bone mineral density as a predictor of skeletal osteoporosis.*Brit J Radiol*, 69: 1019-25.

61. Lofman O, Magnusson P, Toss G, Larsson L (2005). Common biochemical markers of bone turnover predict future bone loss: a 5-year follow-up study. *Clin Chim Acta*, 356: 67-75.