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Original Article

Is there a change in the mandibular cortical shape index in panoramic radiographs over time? A longitudinal retrospective study

Ahmed Al-Dam[1]*, Yassir Haydar[2]*, Ashkan Rashad[1]

[1]Department of Oral and Maxillofacial Surgery, University Medical Center Hamburg-Eppendorf, Hamburg, [2]Private Practice Heine-Haydar, Gifhorn, Germany

*Both authors contributed equally to this work.

ABSTRACT

Background: A longitudinal study design was conducted to assess the mandibular cortical shape index (CI) in panoramic radiographs retrospectively. An association between age and a deterioration of different radiological parameters on panoramic radiographs was stated in cross-sectional studies. As longitudinal studies are rare, this one is designed to assess radiological changes over time.
Materials and Methods: In this longitudinal study, The archive of the dentomaxillofacial radiology department was searched for panoramic radiographs of patients who have two radiographs with a time lapse of at least 15 years between both. The radiographs were then examined and the CI was categorized into three categories: normal, mild, and severely eroded. The following factors were examined to determine if they had an effect on possible changes of the CI using the Chi-square test: The time period between both radiographs, the gender and the age of the subjects when both radiographs were made also compared using the Kolmogorov–Smirnov test.
Results: Ninety radiographs met the inclusion criteria. The mean age, when the 1st radiograph and the 2nd radiograph were made, was 48.7 and 66.9 years, respectively. A deterioration of the CI over time was observed and only 31.1% of the radiographs remained in the same CI category while 57.8% dropped down by one category and 11.1% dropped down by two. The change of CI was significant ($P < 0.001$ using the McNemar's test).
Conclusion: In this longitudinally designed study, a deterioration of the CI over time when assessing the nonstandardized panoramic radiographs could be confirmed. This study shows that 68.9% of the patients had CI deterioration of at least one category over the average time of 17.96 years. This is the first study to quantify the CI deterioration over time to our knowledge.

Key Words: Bone density, facial bones, mandible, osteoporosis, panoramic radiography

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Address for correspondence:
Dr. Ashkan Rashad,
Department of Oral and Maxillofacial Surgery,
University Medical Center Hamburg-Eppendorf,
Martinistrasse 52, Hamburg 20246, Germany.
E-mail: a.rashad@uke.de

INTRODUCTION

The panoramic radiograph is an imaging modality which is widely used in dental practice. It is the second most used diagnostic X-ray investigation in general dental practice and perhaps the most frequent diagnostic X-rays in the oral and maxillofacial surgical practice.[1-3] The availability of this radiographic modality encourages involved physicians and dentists to evaluate whether a correlation could be found between systemic diseases and findings on

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the panoramic radiographs. This could lead to an early diagnosis of these diseases when signs are identified on the radiographs.

An association between reduced bone mineral density (BMD) and oral bone loss was first suggested as early as 1960.[4] It was confirmed, that the mandible suffers bone loss which is comparable to other sites of the skeleton.[5] An obvious correlation was thoroughly examined and concluded in many publications between osteoporosis and systemic reduced BMD on mandibular radiograph findings, for example, the mandibular cortical index.[6-19] A literature review conducted by Hildebolt revealed a histomorphologic and a microradiographic increase of bone porosity in older patients compared to younger patients. The deterioration of bone quality was more pronounced in female patients than in male.[2] These changes were similar to changes in other sites of the skeleton, i.e., lower arm, spine, and femur.

Most of the studies so far were designed to be cross-sectional studies, i.e., the radiographs of a number of patients were examined in a certain period. The aim of this longitudinally designed study is to evaluate if there is a change in the mandibular cortical index in patients' radiographs when there is at least a 15 years' time lapse between two radiographs of the same patient.

MATERIALS AND METHODS

The archive of the department of dentomaxillofacial radiology of our university center in Germany was searched for radiographs of patients – in terms of a longitudinal analysis – which meet the following inclusion criteria:

- Patients who have at least two panoramic radiographs with a time lapse of 15 years in between
- Patients who were older than 50 years when the second radiograph was made
- No anatomical, pathological, or radiograph-associated factors which affect the assessment of the inferior cortex of the mandible.

The panoramic radiographs have been performed at different time periods using different panoramic machines. The exposure parameters were set individually according to the size of the patients. The radiographs examined in our study were pseudonymized and examined by an experienced dentist to assess and categorize the mandibular cortical shape index (CI) into one of the three categories according to the classification described by Klemetti *et al*., as follows:[20]

- Normal cortex: the endosteal margin of the cortex is even and sharp on both sides [Figure 1a]
- Mildly to moderately eroded cortex: the endosteal margin shows semilunar defects (lacunar resorption) or appears to form endosteal cortical residues [Figure 1b]
- Severely eroded cortex: the cortical layer forms heavy endosteal cortical residues and is clearly porous [Figure 1c].

The radiographs were placed on an X-Ray Film Viewer, and the CI was assessed for each radiograph.

The results were then statistically analyzed to assess CI changes over time. In particular, the time period between both radiographs, gender, age when the first radiograph was made and age when the second radiograph was made were all examined to determine if they had an effect on possible changes of the CI.

The age was described as a quantitative parameter using the mean value, standard deviation (SD), minimum and maximum as well as the quartiles and it was examined with regard to its normal distribution using the Kolmogorov–Smirnov test.

Absolute and percentage frequencies were indicated for ordinal and nominal scaled parameter. Every two parameter of this scaling were compared in the contingency table which made the examining of dependency possible using the Chi-square test. The mandibular CI and its changes had an ordinal scale and were therefore examined in regard to a linear trend using the Chi-square test. When the expected frequencies were too small, the exact test was chosen.

The tests were performed in a two-sided manner; the chosen significance level was 5%. No alpha-adjusting for multiple tests was applied. Therefore, the results are explorative and descriptive.

The statistical analysis was carried out using IBM SPSS Statistics 21 (SPSS Inc., an IBM Company, Chicago, IL, USA). All operations were performed using SPSS default settings.

RESULTS

Ninety patients met the inclusion criteria, 38 of them were female and 52 were male. The mean age, when the 1st radiograph was made, was 48.70 years (minimum: 24, maximum: 67, SD: 9.90 years) while

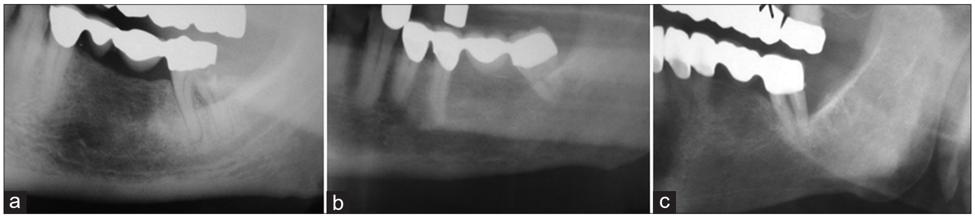

Figure 1: (a-c) Categories of cortical shape index, (a) Normal cortex-endosteal margin of the cortex is sharp and even on both sides of the mandible. (b) Mildly to moderately eroded cortex-the endosteal margin shows semilunar defects (lacunar resorption) or appears to form endosteal cortical residues. (c) Severely eroded cortex-the cortical layer forms heavy endosteal cortical residues and is clearly porous.

the mean age, when the 2nd radiograph was made, was 66.87 years (minimum: 50, maximum: 83, SD: 9.59 years). The average time between both radiographs was 18.49 years (minimum: 15, maximum: 32, SD: 3.60 years). The respective age distributions according to the gender were: For the male patients, the mean age when the 1st radiograph was made was 50.54 years (minimum: 32, maximum: 64, SD: 9.07 years) while the mean age when the 2nd radiograph was made was 68.87 years (minimum: 50, maximum: 82, SD: 8.95 years). The average time between both radiographs was 18.88 years (minimum: 15, maximum: 32, SD: 3.75 years). However, for the female patients, the mean age when the 1st radiograph was made was 46.18 years (minimum: 24, maximum: 67, SD: 10.55 years) while the mean age when the 2nd radiograph was made was 64.13 years (minimum: 50, maximum: 83, SD: 9.88 years). The average time between both radiographs was 17.95 years (minimum: 15, maximum: 30, SD: 3.37 years) [Table 1 and Figure 2].

As a result of the assessment of the first radiographs, 55 out of 90 (61.1%) patients were found to have a normal CI, and 35 patients (38.9%) had a CI which was assessed to be in the mild category. None of the patients' first radiographs were assessed to be in the severe category. In comparison, when assessing the second radiographs, 4 out of 90 (4.4%) had a normal CI, 65 (72.2%) were assessed to be in the mild and 21 (23.3%) in the severe category [Table 2].

A deterioration of the CI over time was observed. Only 31.1% of the radiographs remained in the same CI category while 57.8% dropped down by one category from "normal" to "mild" or from "mild" to "severe" and 11.1% dropped down by two categories from "normal" to "severe". None of the radiographs was categorized in a higher category in the second assessment compared to the category in the first assessment. We grouped both categories mild and severe into one category [Table 3] to make

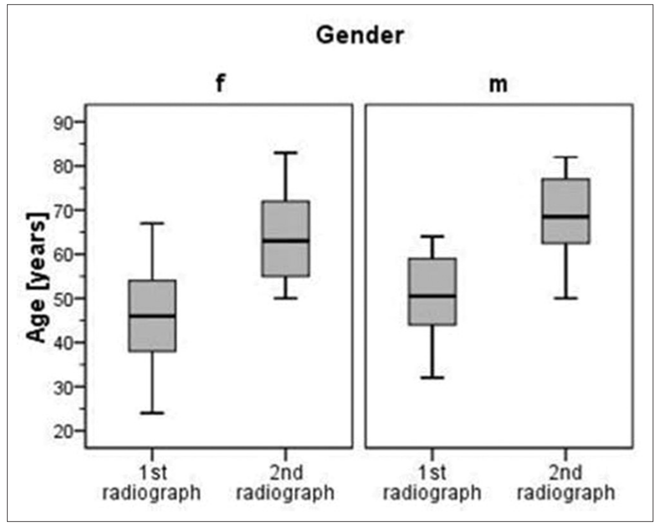

Figure 2: Age distribution of the patients according to gender and time of radiograph. Male patients: the mean age when the 1st radiograph was made was 50.54 years while the mean age when the 2nd radiograph was made was 68.87 years. Female patients: the mean age when the 1st radiograph was made was 46.18 years while the mean age when the 2nd radiograph was made was 64.13 years.

both assessments comparable. This was due to the fact that no radiograph of the first assessment was classified to be in the severe category in contrast to the second assessment. Using the McNemar`s test, a significant ($P < 0.001$) drop of CI was observed from "normal" to "mild/severe" over time.

A statistical analysis was performed to examine whether an effect of gender on the CI assessment in the first or second radiographs exists. Using the Chi-square test, no significant impact of gender was found when assessing the first ($P = 0.224$) or second ($P = 0.393$) radiographs. Furthermore, no significant impact of the gender on the change of CI could be observed ($P = 0.837$).

We examined a possible significant correlation within the radiograph groups (first group and second group) between the age of the patients and

Table 1: Age distribution of the patients according to gender and time of radiograph

Gender	*n*	Mean (SD)	Minimum (years)	Maximum (years)
Female				
Age 1 radiograph	38	46.18 (10.552)	24	67
Age 2 radiograph	38	64.13 (9.878)	50	83
Time between radiographs	38	17.95 (3.377)	15	30
Male				
Age 1 radiograph	52	50.54 (9.067)	32	64
Age 2 radiograph	52	68.87 (8.947)	50	82
Time between radiographs	52	18.88 (3.745)	15	32

SD: Standard deviation

Table 2: Cross table showing the results of the first and second cortical shape index assessments

First assessment	CI assessment 2nd radiograph, *n* (% of total)			Total
	Normal	Mild	Severe	
CI assessment 1st radiograph				
Normal	4 (4.4)	41 (45.6)	10 (11.1)	55 (61.1)
Mild	0 (0.0)	24 (26.7)	11 (12.2)	35 (38.9)
Total	4 (4.4)	65 (72.2)	21 (23.3)	90 (100.0)

CI: Cortical shape index

Table 3: Cross table showing the results of the first and second cortical shape index assessments after grouping of the cortical shape index categories mild and severe

First assessment	CI assessment 2nd radiograph, *n* (% of total)		Total
	Normal	Mild/severe	
CI assessment 1st radiograph			
Normal	4 (4.4)	51 (56.7)	55 (61.1)
Mild/severe	0 (0.0)	35 (38.9)	35 (38.9)
Total	4 (4.4)	86 (95.6)	90 (100.0)

CI: Cortical shape index

the CI categories they were classified into. Using the Mann–Whitney U-test for the first radiographs, a significant correlation between age and CI assessment was observed (P = 0.002) [Figure 3]. Also using the Kruskal–Wallis test for the second radiographs, a significant correlation between age and CI assessment was stated (P = 0.041) [Figure 4]. However, no significant correlation between the age when the first radiographs were made and the change in CI assessment over time was found using the Kruskal–Wallis test (P = 0.153) [Table 4].

Concerning the question if a correlation between the length of the time lapse between the first and the second radiographs on the one hand and the change in the CI assessments between both radiographs, on the other hand, no significant correlation could be found (Kruskal–Wallis test, P = 0.946) [Table 5 and Figure 5].

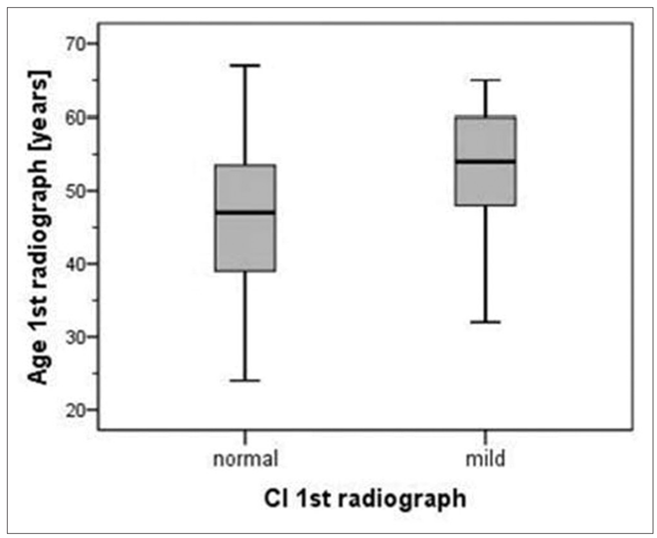

Figure 3: Age distribution among the cortical shape index categories of the first radiographs. An assessment of the first radiographs showed that 55 out of 90 (61.1%) patients were found to have a normal cortical shape index, 35 patients (38.9%) had a cortical shape index which was assessed to be in the mild category. None of the patients' first radiographs were assessed to be in the severe category.

DISCUSSION

Studies assessing the CI over time are rare. In this study, we examined radiographs of patients which have at least time lapse of 15 years in between. The main question of this study was to detect a change of CI assessment over time.

In our study, the mean age of the patients when the 1st radiograph was made was 48.70 years while

Table 4: Change of the cortical shape index category over time in correlation with the age when the first radiographs were made

Change of the CI category	*n*	Mean (SD)	Minimum	Maximum
No change				
Patient's age 1st radiograph (years)	28	51.25 (10.814)	32	65
Patient's age 2nd radiograph (years)	28	69.14 (10.652)	50	83
Deterioration by 1 category				
Patient's age 1st radiograph (years)	52	46.92 (9.387)	24	63
Patient's age 2nd radiograph (years)	52	65.17 (8.937)	50	82
Deterioration by two categories				
Patient's age 1st radiograph (years)	10	50.80 (8.741)	37	67
Patient's age 2nd radiograph (years)	10	69.30 (8.782)	52	82

CI: Cortical shape index; SD: Standard deviation

Table 5: Change of the CI category in correlation with the time lapse between both radiographs

Change of the CI category, time lapse (years)	*n*	Mean (SD)	Minimum	Maximum
No change	28	18.21 (2.685)	15	25
Deterioration by one category	52	18.63 (4.107)	15	32
Deterioration by two categories	10	18.50 (3.308)	15	24

CI: Cortical shape index; SD: Standard deviation

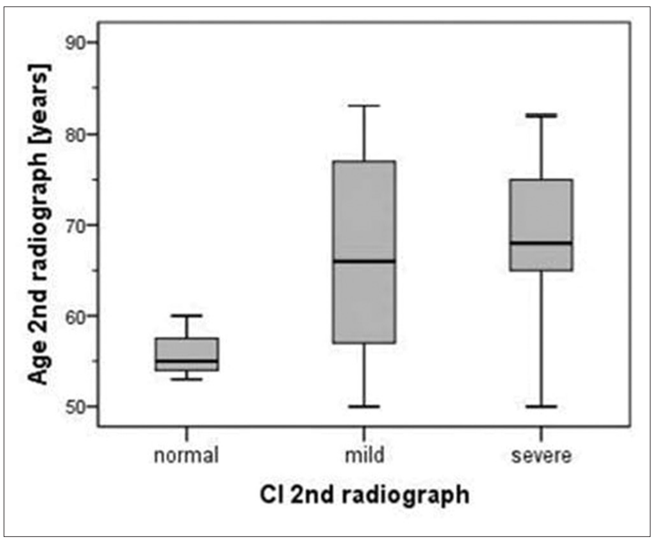

Figure 4: Age distribution among the cortical shape index categories of the second radiographs. An assessment the second radiographs demonstrated that 4 out of 90 (4.4%) had a normal cortical shape index, 65 (72.2%) were assessed to be in the mild and 21 (23.3%) in the severe category.

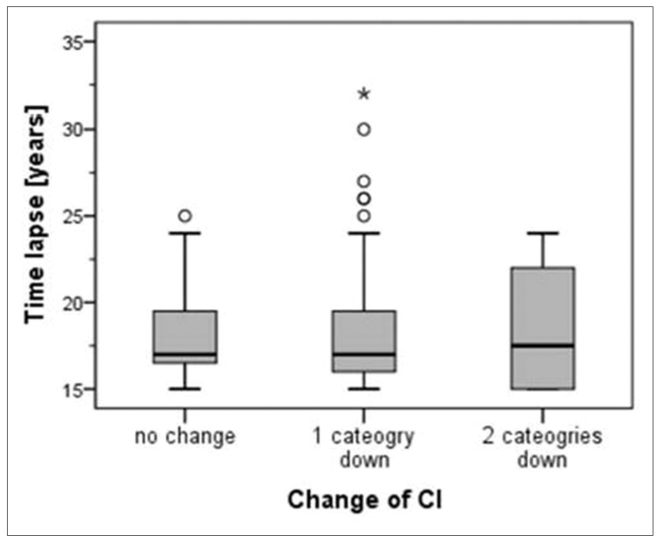

Figure 5: Change of the cortical shape index category in correlation with the time lapse between both radiographs. 31.1% of the radiographs remained in the same cortical shape index category, 57.8% dropped down by one category and 11.1% dropped down by two.

the mean age when the 2nd radiograph was made was 66.87 years. The average time between both radiographs was 18.49 years. Regarding the main question of this study, a deterioration of the CI over time was observed. Only 31.1% of the radiographs remained in the same CI category, 57.8% dropped down by one category and 11.1% dropped down by two. The change of CI was significant ($P < 0.001$ using the McNemar test). Furthermore, a correlation between age and CI was confirmed; this is similar to the findings of other studies.[14,15,19] A statistical analysis was examined to assess whether an effect of gender on the CI assessment in the first or second radiographs exists. Using the Chi-square test, no significant impact of gender was found when assessing the first ($P = 0.224$) or second ($P = 0.393$) radiographs. Furthermore, no significant impact of the gender on the change of CI was observed ($P = 0.837$). A change of the mandibular cortex over time was assumed in the literature,[21] but only few longitudinal studies were published. In a study published by Jonasson *et al.*, the CI (among other parameters) was assessed in panoramic radiographs over a time period of 24 years. The results were then correlated with the skeletal fractures to assess the usefulness of panoramic cortical and trabecular findings for fracture prediction. Deterioration of the CI over time was stated, and it was concluded that dental radiographs contain enough information to identify women who are most at risk of future fracture.[22]

Previously, different parameters were examined in panoramic radiographs to assess their correlation with changes of systemic BMD. Two of these parameters were the most frequently deployed, namely the CI and the mandibular cortical width (MCW). The CI was first described by Klemetti *et al*.[20] and was assessed according to the method mentioned in the Materials and Methods part of this study. The MCW is assessed according to the method described by Taguchi *et al*.[23] and is the cortical height under the mental foramen measured on both sides. The majority of the studies confirm a correlation between the MCW and bone density[8,11,17,18] and between the CI and the bone density.[10,14,15,24] Some studies examined both parameters and confirmed a correlation of both with the bone density.[12,25]

In our study, we chose the CI as the parameter which we deployed. The cause for that is the fact that using the MCW; the panoramic radiographs have to be standardized. The measurement of the cortical width has to be accurate to allow a comparability between the radiographs and thus often necessitates that the radiographs are done using the same device. The radiographs assessed in this study were made by different devices with different settings which resulted in varying positioning of the patients in the device and different magnification factors. Gomez-Roman *et al*. examined the enlargement ratios of panoramic radiographs. They found that using standardized radiographs, vertical enlargement ratios of up to 1:1.29 and horizontal enlargement ratios of up to 1:1.44 in implant insertion areas.[26] The magnification factors variations in the radiographs we assessed are considered to be higher since different devices were used over a time lapse of over 35 years.

A hypothesis which we assumed was that there was a correlation between the length of the time lapse between the first and the second radiographs on the one hand and the change in the CI assessments between both radiographs on the other hand. Contrary to our assumption, no significant correlation could be found (Kruskal–Wallis test, $P = 0.946$). This could be due to the limited number of radiographs we examined and should be assessed in a larger number of radiographs. Hence, we recommended a multicenter study including even a larger number of female subjects due to the fact that there is an increased rate of cortical changes in postmenopausal women.

CONCLUSION

In this longitudinally designed study, a deterioration of the CI over time when assessing nonstandardized panoramic radiographs was observed. This study shows that 68.9% of the patients had CI deterioration of at least one category over the average time of 17.96 years. This is the first study to quantify the CI deterioration over time to our knowledge. Multicenter studies, including a larger number of radiographs, are necessary to complement our results.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Horner K, Devlin H, Alsop CW, Hodgkinson IM, Adams JE. Mandibular bone mineral density as a predictor of skeletal osteoporosis. Br J Radiol 1996;69:1019-25.
2. Hildebolt CF. Osteoporosis and oral bone loss. Dentomaxillofac Radiol 1997;26:3-15.
3. Li NY, Zhou FT, Jing H, Bu LX, Yang XC, Feng YY. Measurement of mandible bone mineral density of adults in North China. Zhonghua Kou Qiang Yi Xue Za Zhi 2009;44:425-9.
4. Groen JJ, Duyvensz F, Halsted JA. Diffuse alveolar atrophy of the jaw (non-inflammatory form of paradental disease) and pre-senile osteoporosis. Gerontol Clin (Basel) 1960;2:68-86.
5. von Wowern N. Bone mass of mandibles. *In vitro* and *in vivo* analyses. Dan Med Bull 1986;33:23-44.
6. Law AN, Bollen AM, Chen SK. Detecting osteoporosis using dental radiographs: A comparison of four methods. J Am Dent Assoc 1996;127:1734-42.
7. Bollen AM, Taguchi A, Hujoel PP, Hollender LG. Case-control study on self-reported osteoporotic fractures and mandibular cortical bone. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:518-24.
8. Devlin H, Horner K. Mandibular radiomorphometric indices in the diagnosis of reduced skeletal bone mineral density. Osteoporos Int 2002;13:373-8.
9. Taguchi A, Asano A, Ohtsuka M, Nakamoto T, Suei Y, Tsuda M,

et al. Observer performance in diagnosing osteoporosis by dental panoramic radiographs: Results from the osteoporosis screening project in dentistry (OSPD). Bone 2008;43:209-13.
10. Halling A, Persson GR, Berglund J, Johansson O, Renvert S. Comparison between the Klemetti index and heel DXA BMD measurements in the diagnosis of reduced skeletal bone mineral density in the elderly. Osteoporos Int 2005;16:999-1003.
11. Lee K, Taguchi A, Ishii K, Suei Y, Fujita M, Nakamoto T, *et al.* Visual assessment of the mandibular cortex on panoramic radiographs to identify postmenopausal women with low bone mineral densities. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:226-31.
12. White SC, Taguchi A, Kao D, Wu S, Service SK, Yoon D, *et al.* Clinical and panoramic predictors of femur bone mineral density. Osteoporos Int 2005;16:339-46.
13. Bozic M, Ihan Hren N. Osteoporosis and mandibles. Dentomaxillofac Radiol 2006;35:178-84.
14. Taguchi A, Tsuda M, Ohtsuka M, Kodama I, Sanada M, Nakamoto T, *et al.* Use of dental panoramic radiographs in identifying younger postmenopausal women with osteoporosis. Osteoporos Int 2006;17:387-94.
15. Yaşar F, Akgünlü F. The differences in panoramic mandibular indices and fractal dimension between patients with and without spinal osteoporosis. Dentomaxillofac Radiol 2006;35:1-9.
16. Amorim MA, Takayama L, Jorgetti V, Pereira RM. Comparative study of axial and femoral bone mineral density and parameters of mandibular bone quality in patients receiving dental implants. Osteoporos Int 2007;18:703-9.
17. Devlin H, Karayianni K, Mitsea A, Jacobs R, Lindh C, van der Stelt P, *et al.* Diagnosing osteoporosis by using dental panoramic radiographs: The OSTEODENT project. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:821-8.
18. Devlin H, Allen P, Graham J, Jacobs R, Nicopoulou-Karayianni K, Lindh C, *et al.* The role of the dental surgeon in detecting osteoporosis: The OSTEODENT study. Br Dent J 2008;204:E16.
19. Al-Dam A, Blake F, Atac A, Amling M, Blessmann M, Assaf A, *et al.* Mandibular cortical shape index in non-standardised panoramic radiographs for identifying patients with osteoporosis as defined by the German osteology organization. J Craniomaxillofac Surg 2013;41:e165-9.
20. Klemetti E, Kolmakov S, Kröger H. Pantomography in assessment of the osteoporosis risk group. Scand J Dent Res 1994;102:68-72.
21. Roberts M, Yuan J, Graham J, Jacobs R, Devlin H. Changes in mandibular cortical width measurements with age in men and women. Osteoporos Int 2011;22:1915-25.
22. Jonasson G, Sundh V, Hakeberg M, Hassani-Nejad A, Lissner L, Ahlqwist M. Mandibular bone changes in 24 years and skeletal fracture prediction. Clin Oral Investig 2013;17:565-72.
23. Taguchi A, Suei Y, Ohtsuka M, Otani K, Tanimoto K, Ohtaki M. Usefulness of panoramic radiography in the diagnosis of postmenopausal osteoporosis in women. Width and morphology of inferior cortex of the mandible. Dentomaxillofac Radiol 1996;25:263-7.
24. Sutthiprapaporn P, Taguchi A, Nakamoto T, Ohtsuka M, Mallick PC, Tsuda M, *et al.* Diagnostic performance of general dental practitioners after lecture in identifying post-menopausal women with low bone mineral density by panoramic radiographs. Dentomaxillofac Radiol 2006;35:249-52.
25. Taguchi A, Suei Y, Sanada M, Ohtsuka M, Nakamoto T, Sumida H, *et al.* Validation of dental panoramic radiography measures for identifying postmenopausal women with spinal osteoporosis. AJR Am J Roentgenol 2004;183:1755-60.
26. Gomez-Roman G, Lukas D, Beniashvili R, Schulte W. Area-dependent enlargement ratios of panoramic tomography on orthograde patient positioning and its significance for implant dentistry. Int J Oral Maxillofac Implants 1999;14:248-57.