Panoramic Radiography as a Diagnostic Tool for the Evaluation of the Osteoporosis: A systematic Review

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Submitted: 2018-01-19; **Accepted:** 2018-03-07; **DOI**: *10.22037/rrr.v%vi%i.9776*

Introduction: To systematically review the diagnosis of osteoporosis by means of panoramic radiography. **Materials and Methods**: An electronic search was performed in PubMed and Cochrane databases limited to English articles published from the year 1990 until August 2012. Studies were selected based on inclusion and exclusion criteria. The indices in the panoramic radiograph and their normal values, as well as specificity and sensitivity of them in the diagnosis of osteoporosis, were evaluated. **Results:** Among the 2460 articles, 40 were included. Although most of these studies indicated correspondence between radiographic indices and the reduction in bone density, some found no correlation between panoramic radiographic indices and osteoporosis. Mandibular cortical width (MCW) and mandibular cortical index (MCI) were the most studied indices in the diagnosis of osteoporosis. **Conclusions**: Considering the results of this study, panoramic radiography can be beneficial in the diagnosis of the reduction in bone density and osteoporosis in a dental office setting.

Keywords: Osteoporosis; Mandible; Panoramic Radiography; Postmenopausal Women

Introduction

Osteoporosis is a systemic skeletal disease that causes bone density reduction and deterioration of bone tissue and is considered to be the silent disease of modern societies 1. The bone density often decreases in both genders by aging, but this process is accelerated in postmenopausal women; therefore, osteoporosis is rather frequent in middle-aged women, following menopause making them more susceptible to osteoporosis2 and higher risks of bone fractures that result in debilitating pain and decreased quality of life (1). Different methods of bone density measurement include single photon absorptiometry (SPA), dual photon absorptiometry (DPA), single X-ray absorptiometry (SXA), dual X-ray absorptiometry (DXA), and quantitative-computed tomography (QCT) (2-4). Currently, DXA is the most common method for measuring bone density (5-7). These measurements are mainly made over lumbar spine and femur. Based on the World Health Organization (WHO) criteria, the patients with the T-score (bone density) below -2.5 are associated with osteoporosis; whereas, the T-score higher than -1.0 and -2.5 are considered normal and osteopenia, respectively (7).

Osteoporosis affects the jaw bones including mandible as well as other bones in human skeleton3; however, the connection between osteoporosis and oral health has not been completely identified yet. The decreased bone density could be considered a contraindication for dental implants treatment (8); conversely, some studies indicate that patients with osteoporosis or similar conditions face no problem with dental implant therapy and only require a longer recovery time prior to the loading and in order to achieve osteointegration a proper adjustment of the surgical technique is required (9). The conventional methods of jaw radiography can assist the diagnosis of osteoporosis prior to DXA, and help with the elucidation of osteoporosis' effects on the mandible. Osteoporosis can modify the width, shape, and density of mandibular inferior cortex and alter the panoramic indices. Still, some studies don't confirm any relations between the mandible density and other bones of skeleton (3, 4, 6, 10-13). Panoramic radiographs are commonly used as a screening tool in dentistry. Finding a suitable connection between the alterations in panoramic indices and osteoporosis could provide major assistance in predicting the success rate of treatment and probable alterations in the treatment plan.

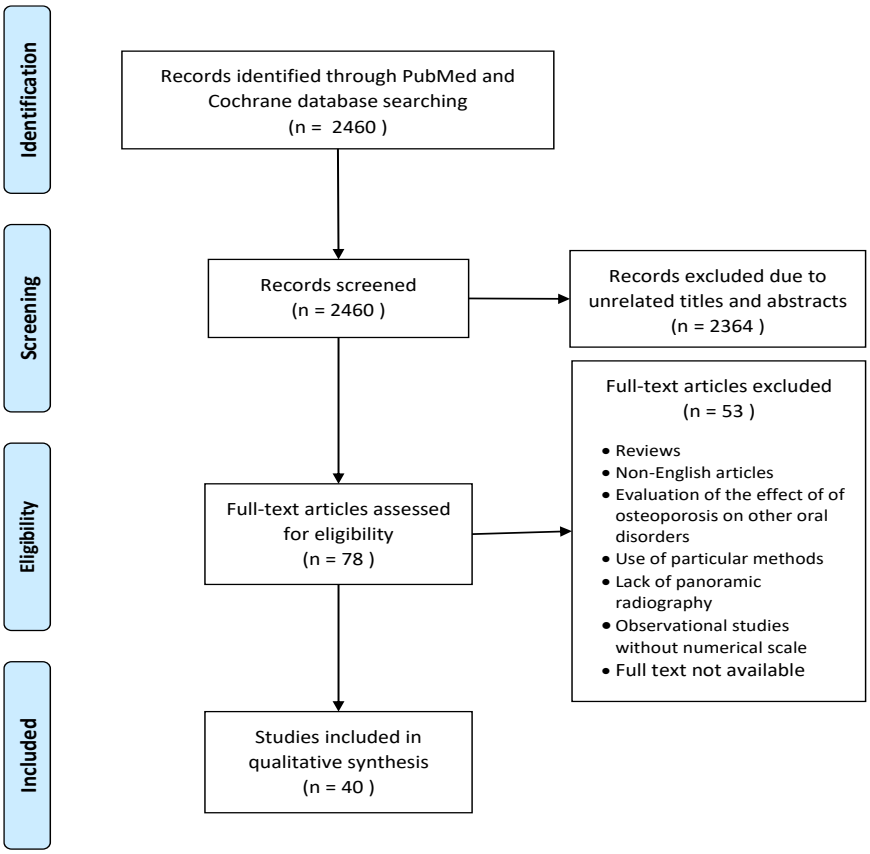

Figure 1. Follow chart demonstrating the search strategy

The current study aims to systematically review the use of panoramic radiography in the diagnosis of decreased bone density and osteoporosis and to propose effectual indices for this diagnosis.

Materials and Methods

Study design

The main question in this review was to find the correlation between panoramic radiograph indices and bone density in the dental literature. The inclusion criteria were as follows: 1) articles written in English; 2) articles with available full texts; 3) studies conducted on humans; 4) use of panoramic radiography in diagnosis; 5) use of measurable numerical or determinable scales to diagnose the decreased bone density.

The articles were excluded if they met one of the following: 1) reviews, case report; 2) articles evaluating the effect of other diseases on reduction of bone density; 3) articles studying the effects of medication such as bisphosphonates on jaws; 4) articles evaluating the effect of osteoporosis on other oral and dental disorders; 5) articles evaluating the infrequent or particular methods and parameters; 6) articles assessing the diagnostic ability of dentists with no numerical scale.

Search strategy

In order to find the related articles from the year 1990 until August 2012, an electronic search was carried out in the PubMed and Cochrane limited to the English language articles. The keywords were as follows: 1) osteoporosis AND panoramic radiography; 2) osteoporosis AND mandible and 3) osteoporosis AND panoramic mandibular index.

Screening process and data extraction

Two reviewers independently performed the review process. Any disagreement was solved by discussion. First, the abstracts were evaluated and analyzed on the basis of the inclusion and exclusion criteria. Then, the full texts of the potentially eligible articles were thoroughly assessed. Finally, method, results, and conclusion of the included studies were extracted.

Due to the versatility of the methods, no meta-analysis was performed and the results were evaluated in a qualitative manner.

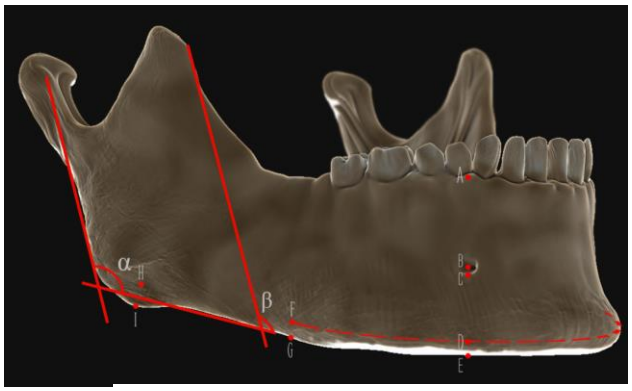

Figure 2. Some of the importance indices; MCW (or MI): DE, PMI: DE/CE, M/M ratio: AE/BE, AI: GF, GI: HI, GA: α, AA: β

Results

Initially, 2460 articles were found by means of these keywords. The review process summarized in figure 1. This review included 40 articles eligible for data extraction (Table 1). Half of these 40 articles had compared the radiographic indices between normal and osteoporotic (osteopenic) patients; 13 had evaluated the correlation between these indices and BMD of axial bones (some of them had also measured the values of these indices as well as the relation between the indices and BMD in control and test groups); the remaining 8 had studied the ability of the dentists in diagnosis of reduced BMD by means of panoramic radiography indices.

The following parameters were used to measure osteoporosis and reduction of bone density by panoramic radiography.

Mandibular cortical width or thickness (MCW, MCT)

The definition was the thickness of the inferior mandibular cortex in mental foramen region. Its normal values range from 4.0 to 5.0 mm (1, 3, 4, 5, 7, 10, 14-19). Other normal values including 3.5mm20, 3.69mm25, 3.7mm 21, 3.9 mm 6, 4.1mm 22, 4.2mm 23, and 7.4 mm 24 have also been reported. (DE, Figure 2)

Panoramic mandibular index (PMI)

It is the ratio of the thickness of the inferior mandibular cortex in the mental region over the distance between the lower border of the mandible and either the inferior or the superior border of the mental foramen, and ranges from 0.32 to 0.39 (6, 10, 11, 16, 21-23, 26, 27); the values of 0.29 25, 0.3 5 and 0.43 24 have also been reported. (DE/CE, Figure 2)

Alveolar crest resorption degree (M/M ratio)

It is the ratio of the total height of mandible over the distance between the lower border of mandible and center of the mental foramen. Its normal values are from 2.16 16 to 2.45 10 (AE/BE, Figure 2).

Mandibular cortical index (MCI)

An indicator of inferior mandibular cortical thickness which is classified into 3 categories according to Klemetti's classification6: C1=sharp and even endosteal margin of cortex on both sides; C2=semilunar defects (lacunar resorption) and/or development of endosteal cortical residues on endosteal margin of either or both sides; and C3=formation of heavy endosteal cortical residue by cortical layer which appears completely porous.

Gonial index (GI)

GI is a measurement of cortical thickness at the gonion region, which in normal patients is 1.25 mm 4 (HI, Figure 2).

Antegonial index (AI)

It is a measurement of cortical thickness at antegonion region and normally ranges from 4.14 mm 7 to 4.17 mm 24. Values of 2.388 mm 26, 2.72 mm 19, and 3.41mm 4 have also been reported (GF, Figure 2).

Antegonial depth (AD)

Distance between the perpendicular line from the deepest point of antegonial notch and the line parallel to the inferior cortical border of mandible; which normally is 1.42 mm 19.

Antegonial angle (AA)

The angle at the intersection of the perpendicular line from the deepest point of antegonial notch and the line parallel to the inferior cortical border of the mandible which is on average equal to 166 degrees 19 (β, Figure 2).

Gonial angle (GA)

The angle at the intersection of the line tangent to the lower border of the mandible and the line tangent to the posterior border of the ramus whose normal value is reported 125 degrees 19. (α, Figure 2).

Klemetti index (KI)

It is developed for visual evaluation of the inferior cortical border of the mandible. Categories 0 and 1 are referred to as normal in this index (28).

Alveolar bone loss (ABL) or mandibular bone resorption (MBR)

It is an indicator of alveolar bone resorption, which is considered normal at 2.20 mm (5, 22).

Several studies had employed the quantitative values of MCW, PMI, MCI, v-BMD, f-BMD, as diagnostic determinants for osteopenia and osteoporosis.

Table 1. The quantitative and qualitative data from the literature review on the application of panoramic radiography

Authors	Method/the evaluated area for measuring BMD by DXA	Result	conclusion
Passos JS, et al. (2012)[5]	Dental panoramic radiography/lumbar spine and proximal femur	MCT: normal=4.9±1.2 ; osteopenia/osteoporosis= 4.5±0.9 (p=0.04) MBR: normal=2.2±0.3 ; osteopenia/osteoporosis= 2.2±0.4 (p=0.6) PMI: normal=0.3±0.1 ; osteopenia/osteoporosis=0.3±0.1 (p=0.49) MCT and MBR showed highest specificity PMI showed highest sensitivity	Panoramic radiography may be useful for confirming individuals who present with low bone mineral density.
Georgescu A, et al. (2012)[20]	Dental panoramic radiography/ DXA was not used. Using ultrasonography at distal phalanges of the hand	MCT: normal= 3.5±0.4 , osteoporotic group= 2.3±0.5 MCI vs. MCT: C1: MCT of normal group=3.8±0.3, MCT of osteoporotic group=3.0±0.1 C2: MCT of normal group=3.3±0.3, MCT of osteoporotic group=2.3±0.4 C3: MCT of normal group=2.9±0, MCT of osteoporotic group=2.0±0.4	Determination for MCT can be used as a method in patients' selection with postmenopausal osteoporosis or prone to osteopenia.
Haster E, et al. (2011)[21]	Dental panoramic radiography/	Osteoporotic status: MCW= 2.88, PMI= 0.27, MCI= C2 (71.4%) Normal status: MCW= 3.70, PMI= 0.32, MCI= C1 (62.6%)	There were statistically significant differences according to values of the MCW, MCI and PMI between patients with and those without osteoporosis.
Yashoda Devi BK, et al. (2011)[26]	Dental panoramic radiography/ femoral neck	PMI: normal= 0.329± 0.084, osteoporotic group=0.221±0.102 AI: normal= 2.388 ± 0.599, osteoporotic group= 2.000±0.739	PMI values were found to be smaller among female patients with osteoporosis, compared with normal patients, and it has better efficacy in identifying postmenopausal women with osteoporosis in comparison with AI.
Cakur B, et al. (2011)[29]	Dental panoramic radiography/ vertebrae	MA: min= 115 , max=140 , mean= 125±6.67 v-BMD: min= 0.65 , max= 0.81 , mean= 0.75±0.05 v-BMD and MA: r= -0.562(p=0.01) The size of the mandibular angle decreases when osteoporosis increases	The MA may be useful in clinical dental practice to identify osteoporotic men with previously undetected low bone mineral density.
Taguchi A, et al. (2011)[30]	Dental panoramic radiography/ Calcaneus	Younger adult men MCW: mean=4.75, highest through lowest Quartiles=7.01–5.21, 5.20–4.73, 4.72–4.14 and 4.13–2.89 respectively Younger adult women MCW: mean=4.56, highest through lowest Quartiles=6.50–5.19, 5.18–4.60, 4.59–3.88 and 3.87–2.98 respectively Diagnostic efficacy of the MCW is moderate. It is a useful screening tool for low calcaneal BMD in men but not in women.	MCW determined from panoramic radiographs can be used to identify undetected low calcaneus BMD in young adult men, but not in young adult women.
Damilakis J, et al. (2011)[10]	Dental panoramic radiography/ lumbar spine and hip	Healthy: MCW= 4.91±0.91, PMI=0.388±0.16, M/M ratio=2.45±1.73 Healthy+osteopenic: MCW=4.71±1.03, PMI=0.380± 0.18, M/M ratio=2.35±1.17 Osteopenic+osteoporotic: MCW=4.43±1.09, PMI=0.381±0.26, M/M ratio=2.22±0.42 Osteoporotic: MCW=4.16±1.03, PMI=0.395±0.34, M/M ratio=2.13±0.36	Panoramic indices appear to have limited power in their ability to identify women with low BMD at the axial skeleton.
Khojastehpour L, et al. (2011)[14]	Digital panoramic radiography/ lumbar vertebrae and femoral neck	Mean CW vs. BMD of lumbar spine: normal= 4.35 ; osteopenic group= 3.57 ; osteoporotic group= 3.34 Mean CW vs. BMD of femoral neck: normal= 4.29 ; osteopenic group= 3.36 ; osteoporotic gruop= 3.52 Mean CW vs. cortical shape: normal= 4.37 ; moderate	Postmenopausal women with thin or eroded mandibular inferior cortex may have an increased risk for low BMD or osteoporosis.

		eroded= 3.81 ; severe eroded= 2.41, The highest validity threshold value for identifying women with low BMD: CW=4.29mm	
Dagistan S, et al. (2010)[24]	Dental panoramic view/ Lumbar	Osteoporosis: MI= 5.71±1.00 , AI= 4.17±0.95 , PMI= 0.35±0.06 Control: MI= 7.40±1.22 , AI= 5.21±0.85 , PMI= 0.43±0.89 There was no statistically significant difference between MCI values in the two groups.	MI, PMI and AI values, as radiomorphometric indices, were found to be smaller among male patients with osteoporosis, compared with normal patients.
Gulsahi A, et al. (2010)[6]	Panoramic radiography/ Jaws and femoral neck	Osteopenia/Osteoporosis: MI= 2.9±1.1 , PMI= 0.26±0.1 , MCI= C3 Normal: MI=3.9±1.0, PMI=0.33±0.09, MCI= C1 No significant differences were observed between the normal and osteopenic/osteoporotic groups for the maxillary and mandibular BMD values	The BMD of the jaws was not correlated with either femoral BMD or panoramic radiomorphometric indices.
Jagelaviciene E, et al. (2010)[25]	Dental panoramic radiography/calcaneus	Mean calcaneus BMD: normal=0.47±0.04, osteopenia=0.37±0.03, osteoporosis=0.29±0.03 PMI: normal=0.29±0.08, osteopenia=0.26±0.07, osteoporosis=0.21±0.06 MI: normal=3.69±0.98, osteopenia=3.34±0.93, osteoporosis=2.69±0.72	Bone mineral density in the calcaneus and the mandible measured reflect general changes in the mineralization of these bones, characteristic of the postmenopausal period.
Leite AF, et al. (2010)[7]	Dental panoramic radiography/ Lumbar spine and hip	Normal: MI=4.28 ±0.93 mm, AI=4.04 ±1.02 mm Osteopenia: MI=3.53 ±1.01 mm , AI=3.41± 0.96 mm Osteoporosis: MI=2.82 ±0.87 mm , AI=2.85 ± 0.88 mm The MI cut off for osteoporosis=3.15 mm The visual estimation of cortical width and MCI demonstrated a positive correlation with BMD No significant difference was observed in mean values of the AD or in the AA and GA	AI and GA cannot be used as osteoporosis predictors. The most accurate indices were the MI, MCI, and visual estimation of cortical width.
Mudda JA, et al. (2010)[31]	Dental panoramic radiography/	Pre-menopausal women: MI= 4.99±0.75 , PMI= 0.41±0.04 , MCI= mostly C1 Post-menopausal women: MI= 4.46±1.09 , PMI= 0.36±0.1 , MCI= mostly C2 MCI was associated with the menopausal status. MI and PMI were a statically significant difference in both group	Radiomorphometric indices could be used by general dentists after a little training to detect post-menopausal women at higher risk of osteoporosis.
Cakur B, et al. (2010)[11]	Dental panoramic radiography/femur and lumbar vertebrae	MI: mean= 5.72±1 ; AI: mean=4.14±0.95 ; PMI: mean=0.36±0.06 f-BMD: mean=0.48±0.02 ; v-BMD: mean=0.75±0.05 No correlation was found between the BMD values of the femur and lumbar vertebrae and values of MI, AI, and PMI.	No significant correlation was found between the mandibular and non-mandibular measurements in men with osteoporosis.
Cakur B, et al. (2009)[3]	mandibular-DXA and panoramic radiography	There were no correlations between skeletal BMD and mandibular measurements(m-DXA and MCI) m-DXA: min=0.003, max=0.270, mean=0.040±0.038 v-BMD: min=0.398, max=0.988, mean=0.737±0.095 f-BMD: min=0.474, max=0.995, mean=0.750±0.121 MCI: min=1.000, max=3.000, mean=1.990±0.584	No significant correlations were found between the mandibular and non-mandibular measures in women with osteoporosis.
Miliuniene E, et al. (2008)[18]	Dental Panoramic radiography/ Lumbar Spine	MI(mean): T-score1(osteoporotic) = 2.6517±1.1208 T-score 2(osteopenia)= 3.2750±1.3157 T-score 3(normal)= 4.1162±1.2973 GI: min=0.5 , max=2.4 , mean=1.2577±0.4273	There was a significant difference between BMD of the lumbar spine and cortical bone height of mandible. A positive correlation between osteoporotic and mandibular radiographic changes was observed.
Cakur B, et al. (2008)[1]	Dental panoramic radiography/ Lumbar vertebrae	Osteoporotic group: m-RD= 0.95±0.18 , v-BMD= 0.74±0.06 , MCI= 2.04±0.54 Correlation between: 1) MCI and v-BMD: significant negative 2) m-RD and v-BMD: not significant 3) m-RD and MCI: not significant 4) Age and MCI & m-RD: not significant	Dental radiographic density and MCI may be useful to identify osteoporotic women with previously undetected low BMD.

Karayianni K, et al. (2007)[32]	Dental panoramic radiography./ left hip and lumbar spine	OSIRIS: >+1 low risk, <-3 high risk, -3< ≤+1 immediate risk Diagnostic threshold OSIRIS ≤+1and: 1)MCW≤3 s=39% ,sp=95.5% ; 2)MCW≤4.5 s=70.2%, sp=81.8%	The addition of OSIRIS as a stepwise 'follow-up' test to the radiographic assessment of MCW should only be performed if the aim is to have a test for which the highest achievable specificity is desired.
Horner K, et al. (2007)[12]	Dental panoramic radiography./ hip and lumbar spine	There were significant correlations between OSIRIS and MCI assessments diagnostic thresholds: MCI scoreC2 or C1 with an OSIRIS score of ≤+1	MCI has limited diagnostic value for osteoporosis diagnostic by dentists.
Taguchi A, et al. (2007)[33]	panoramic radiography/ lumbar spine and femoral	Cortical erosion finding: Normal: mild to moderate= 3.6%, severe= 9.1% Osteopenia: mild to moderate= 67.9%, severe= 18.2% Osteoporosis: mild to moderate= 28.5%, severe= 72.7% BMD T-score of the lumbar spine: mild to moderate= -1.55± 0.93 , severe= -1.90 ± 1.90 BMD T-score of the femoral neck: mild to moderate= -1.83 ± 0.93 severe= -2.37 ± 0.98	A high percentage of post-menopausal women with undetected low skeletal BMD may be identified based on trained GDPs' analyses of their panoramic radiographs.
Ishii K, et al. (2007)[22]	Dental panoramic radiography/ femoral neck	Osteoporosis: MCW= 3.2±0.9 , ABL= 2.06±0.37 , number of teeth remaining= 20.0±0.83 Normal/Osteopenia: MCW= 4.1±0.9 , ABL= 2.19±0.28, number of teeth remaining= 22.5±7.2	ABL of the mandible on panoramic radiographs may not be useful for identifying postmenopausal women with femoral osteoporosis in comparison with MCW.
Devlin H, et al. (2007)[34]	Dental panoramic radiography/ left hip and lumbar spine	MCW of <3 mm provided diagnostic odds ratios of 6.51, 6.09, and 8.04 for 3 observers. The diagnostic odds ratios were greater for MCW (median, 6.51) than cortical erosion (median, 4.13).	When evaluating panoramic radiographs, only those patients with the thinnest mandibular cortices (i.e., <3 mm) should be referred for further osteoporosis investigation.
Taguchi A, et al. (2007)[35]	Dental panoramic view/lumbar vertebrae	Significant associations were found between cortical width and shape, and v-BMD. Cortical shape normal: v-BMD=1.008 ± 0.010, Mildly to moderately eroded: v-BMD=0.919 ± 0.011, severely eroded: v-BMD=0.826 ± 0.023	Post-menopausal women with alterations of the mandible may have an increased risk for low vertebral BMD or osteoporosis.
Vlasiadis KZ, et al. (2007)[15]	panoramic radiography/ lumbar spine	Only the MCW appears to be close to the statistically Significance limits (p = 0.061). MCW threshuld≤3mm MCW [mean(SD)]: normal= 4.81 (0.91), osteopenia= 4.54 (1.1) , osteoporosis= 4.13 (1.04) MCW and cortical erosion: normal=4.96 mild or severe=4.29	Panoramic radiographs can be useful for the early diagnosis of osteoporosis in postmenopausal women.
Dutura V, et al. (2006)[19]	Dental panoramic radiography/ Lumbar spine and femoral neck	Healthy: GA= 125.39±1.61, AA= 165.95±0.61, AI= 2.72±0.15, MI= 4.23±0.2, AD= 1.42±0.12 Osteopenic: GA= 126.25±1.77, AA=162.04±1.26, AI= 2.39±0.14 MI= 3.78±0.18, AD= 1.70±0.15 Osteoporotic: GA= 126.13±1.92, AA= 159.79±2.29, AI= 2.13±0.12, MI= 3.57±0.17, AD= 1.83±0.19	The antegonial region measurements are likely to assist in the prediction of individuals who are at risk of osteoporosis.
Yasar F, et al. (2006)[16]	Dental panoramic radiography/ Spines	Osteoporotic: MCW= 4.48±1.24 , PMI= 0.36±0.12 , M/M ratio= 1.91±0.38 , FD= 1.40±0.0731 Non-osteoporotic: MCW= 5.04±1.01 , PMI= 0.38±0.09 , M/M ratio= 2.16±0.56 , FD= 1.39±0.056	Osteoporotic patients were more likely to have altered inferior cortex morphology than non-osteoporotic patients.
Taguchi A, et al. (2006)[23]	Dental panoramic view/ lumbar spine and femoral neck	Low risk : CW>4.2mm, immediate risk: 4.2mm≥CW>3mm, high risk: CW≤3mm Cut off threshold: OST=0, CW=4.2mm, any cortical erosion low BMD: OST: se=82.3% sp=55.2%, CW: se=79% sp=50%, cortical shape: se=72.6% sp=74% Osteoprosis : OST: se=86.7% sp=46.9%, CW: se=90% sp=45.3%, Cortical shape: se=86.7% sp=65.6%	Dentists may be able to refer postmenopausal women years for bone densitometry on the basis of incidental findings on dental panoramic radiographs.
Lee K, et al. (2005)[36]	Dental panoramic radiography/ lumbar spine and femoral neck	The diagnostic threshold of MCW: in the lumbar spine= 4.0, se=65.2%, sp= 72.2% In femoral neck=3.9 , se=72.9% , sp=70.9%	Simple visual estimation of the mandibular inferior cortex on panoramic radiographs may be useful for identifying postmenopausal women with low BMD.

Halling A, et al. (2005)[28]	Dental panoramic radiography/ heels	The threshold value that provided the highest validity. (minimum false negative and false positive results) corresponded to category 2 of the KI: se=50.0% , sp=88.9% , PPV=21.4% , NPV=96.7%	Assessment of mandibular cortex patterns is a reliable method to exclude osteopenia/osteoporosis.
White SC, et al. (200ᵒ)[17]	Dental panoramic radiography/ Femoral neck	Normal: MCW= 4.58±0.10 , MCI score= 1.29±0.05 Osteopenia: MCW= 3.86±0.08 , MCI score= 1.56±0.06 Osteoporosis: MCW= 3.16±0.15 , MCI score= 2.16±0.11 Mean subject age, height, and weight were different in the three bone density groups.	Dentists have sufficient clinical and radiographic information to play a useful role in screening for individuals with osteoporosis.
Taguchi A, et al. (2004)[37]	Dental panoramic radiography/ lumbar spine	Diagnostic threshold: CW≤4.5mm , OST≤ -1.0, any cortical eroded BMD in Postmenopausal Women Without Hysterectomy, Oophorectomy, or Estrogen Use: CW: se=89.5% , sp=33.9% ; OST: se=86.8% , sp=57.8% ; cortical shape: se=86.8% , sp=63.6% BMD in Postmenopausal Women with Hysterectomy, Oophorectomy, or Estrogen Use: CW: se=92.5% , sp=35.0% ; OST: se=72.5% , sp=58.1% ; cortical shape: se=80.0% , sp=64.1%	Dentists may be able to refer postmenopausal women with suspected spinal osteoporosis for bone densitometry on the basis of dental panoramic radiographs.
Horner K, et al. (2002)[38]	Dental panoramic tomography/ Spine and Hip	MI: mean= 4.94±0.084, the cut off value≤ 3.15	A thinning of the mandibular cortices (MI≤3 mm) in a normal perimenopausal female is associated with low skeletal bone mass.
Devlin H, et al. (2002)[4]	Dental panoramic radiography/ Lumbar spine and femoral neck	GI: Reduced bone density=1.67±0.368, normal=1.243±0.288 AI: Reduced bone density=2.945±0.583, normal=3.41±0.655 MI: Reduced bone density=3.96±0.88, normal=4.73±0.88 Only MI contributed significantly to a diagnosis of low BMD(threshold=3mm)	Using panoramic radiographic measurement don't lend s to the diagnosis of osteopenia and osteoporosis. These measurements might be useful as a method of risk assessment when combined with other factors.
Drozdzowska B, et al. (2002)[13]	DXA and dental panoramic radiography	Subgroup C1: m-BMD= 1.43±0.28, MCW= 5.27±0.86 , PMI= 0.42±0.06 , M/M Ratio= 2.16±0.58 , MBR= 23.1%±12.1 Subgroup C2: m-BMD= 1.25±0.27 , MCW= 4.58±1.49 , PMI= 0.39±0.12 , M/M Ratio= 1.84±0.44 , MBR= 36.1%±15.2 Subgroup C3: m-BMD= 1.06±0.1 , MCW= 4.00±1.75 , PMI= 0.33±0.19 , M/M Ratio= 1.70±0.44 , MBR=40.4%±17.0 There were no significant differences between subgroups in parameters measured except for significant differences in m-BMD. (p<0.01)	The efficacy of the panoramic-based mandibular indices in diagnosing osteopenia/osteoporosis is low to moderate.
Horner K, et al. (1998)[2]	DXA and dental panoramic tomography	Mean mandibular BMD: 1.12 g /cm²±0.3 MCT: mean= 4.11±1.00-4.39 ±0.91 PMI: mean= 0.3179±12.29%-0.3629±11.35% DXA and densitometry of mandible: Not significant r=0.01, p=0.93; r=0.11, p=0.49 DXA and MCT: significant correlation r=0.50, p=0.001; r=0.36, p=0.021 DXA and PMI: significant correlation r=0.37, p=0.019; r=0.38, p=0.016 Validity of MCT and PMI for observer 1 were significantly greater than densitometry (P=0.04 and 0.02, respectively)	It may be feasible to use MCT and PMI as diagnostic indicators of mandibular BMD, but further work and large sample is required.
Law A, et al. (1996)[39]	Periapical, occlusal and panoramic radiography/ QCT, SPA and DPA was used for spine BMD	Osteoporotic group: FD=3.24±0.07 , MDns=1.4±0.21 , MDs= 0.12±0.03 , PA=1.77±0.32 , PI= 15.8±5.32 Control group: FD= 3.19±0.066 , MDns= 1.24±0.147 , MDs= 0.11±0.019 , PA= 1.83±0.341 , PI= 22.8±8.856	PI was significantly more effective than another method to detect osteoporotic patient. Although FD and MD method also was effective.

Watson E, et al. (1995)[27]	Panoramic radiography/ DPA was used to assess the BMD	Case group: PMI= 0.37±0.15 Control group: PMI= 0.38±0.13 There was no difference in the mean PMI between case and control groups.	Further investigations are planned to assess various other osteoporotic definitions and PMI, to identify risk factors for osteoporosis.
Taguchi A, et al. (1995)[40]	Dental panoramic radiography/ DXA was not used, lateral-chest radiography was used to evaluate the thoracic fracture and osteoporotic signs.	Fracture group: MCW=3.9±1.4 , M/M ratio=1.8±0.05 , MCI grade1=55.5% , MCI grade 2=45.5% , Number of teeth present= 6.2±9.3 Non-fracture group: MCW=3.7± 0.9 , M/M ratio=2.2±0.4 , MCI grade 1=78.2% , MCI grade 2=21.8% , Number of teeth present= 19.0±8.3	The number of teeth present was highly related to the fracture status of women. Calculation of the probability of The fracture may be useful in screening for latent osteoporosis.
Klemetti E, et al. (1994)[41]	Dental panoramic radiography/ femoral neck and lumbar	Mean PMI: OST1=0.42 , OST2=0.40 , OST3=0.39 , OST4=0.35 Mean cortex height: OST1=5.5 , OST2=5.2 , OST3=5.0 , OST4=4.6 Classification of patient according to bone mineral density and age. MCI, PMI, and MCW values in OST1-4 groups are correlated significantly with the mineral status of the skeleton. MCW<4mm and C3 showed the highest specificity (100%).	Panoramic radiography should not be used to assess the patient's status regarding osteoporosis, although the means of variables in different mineral density groups of the skeleton may differ significantly.
Klemetti E, et al. (1992)[42]	Dental panoramic radiography/ DXA was not used, QCT was used to measuring BMD of femur, lumbar spine, and mandible.	PMI (mean): 0.38± 0.09 PMI (osteoporotic group): 0.35 PMI was not correlated with BMD of femur, lumbar spine, and mandible PMI difference between the groups with the lowest and the highest BMDN values was significant. (PMI>0.41 in highest value and PMI<0.34 in the lowest value) BMDN and BMDL values correlated with each other as well as with the BMDC value. The BMDT values did not	This study indicates that, at least with panoramic radiographs, it is difficult to find a strong positive correlation between the PMI and the general mineral status of the skeleton

Discussion

This systematic review has been conducted to evaluate the diagnostic efficacy of panoramic radiography in distinguishing the patients with decreased bone mineral density (BMD) and osteoporosis. Radiographic indices are believed to be beneficial in the diagnosis of decreased BMD by many studies (1, 5, 7, 14-21, 23-33, 35-39); however, no meaningful difference in radiographic indices was found between normal and osteoporotic patients by other studies (3, 4, 6, 10-13, 41,42).

Mandibular cortical width or thickness (MCW or MCT), also known as MI, is one of the main indices used by many articles; some of which confirming a correlation between MCW and decreased BMD (2, 4, 5, 7, 10, 14, 15, 18-22, 24, 25, 35, 38, 41). Devlin and Horner considered MCW as the most reliable index when less than or equal to 3mm can be indicative of reduced BMD (sensitivity of 20% and specificity of 100%) or osteoporosis (sensitivity of 25.9% and specificity of 96.3%) 4. MCW was also the most repeatable index in a study by Horner *et al.* 2. Passos *et al.* reported that MCW, which is an index with the highest specificity and positive predictive value and lowest false positives; has the ability to detect more than 80% of the people with reduced bone density disorders (compared to the gold standard) 5. Based on a study by Ishii *et al.*, despite the correlation between alveolar bone loss (ABL) and reduced BMD, MCW is a more reliable index in the diagnosis of osteoporosis compared to ABL 22. Klemeti *et al.* have also found the cortical height related to the PMI, MCI, MCW and the degree of the femur and lumbar spine mineralization. They consider panoramic radiography with low diagnostic value in detecting the osteoporotic patients; nevertheless the combination of MCW<4mm and C3 provides specificity of 100% and sensitivity of 10% 41. Many studies have reported a diagnostic threshold for MCW; some of which considered the MCW of 3mm or less as the most suitable diagnostic threshold (4, 15, 22, 38) which can be used for referral for bone densitometry (4, 38). Also, Leite *et al.* have reported the cutoff point 3.15mm for mental index (MCW) (7). Nevertheless, the diagnostic threshold for MCW of 4 mm is considered optimal by White *et al.* (16). Based on the research by Klemeti *et al.*, the threshold limit of MCV<4mm as the diagnostic index for identifying the risk of osteoporosis, provides the specificity of 85% and sensitivity of 37% (41). Although other studies have reported higher values in the range of 4 to 5 mm (10, 14); it has been reported that even 1 mm decrease in MCW could increase the risk of osteoporosis by 43% 15.

Nonetheless, some studies found no significant difference in MCW between the osteoporotic and the control groups (11, 16, 40). No statically significant differences in MCW, PMI, M/M ratio, number of teeth, FD, age and BMI were observed between the osteoporotic and control group by Yasar *et al.* (16). Taguchi *et al.* also reported that despite the correlation between MCW and BMD of the mandible, there's no difference between the groups with and without fracture; however, they observed an association between the number of missing teeth and presence of fracture (40).

PMI is another index, considered suitable for diagnosis of reduced BMD by some researchers (2, 5, 22, 24, 26, 27, 31). Conversely, some studies did not find a significant correlation between PMI and reduced BMD and osteoporosis (6, 11, 16, 27, 42). Since Gulsahi *et al.* detected no correlation between PMI, MCI, MI, and mandibular and maxillary BMD; they considered PMI an unreliable index in the diagnosis of reduced BMD and osteoporosis; they also found no correlation between the BMD of the jaws and either femoral BMD or panoramic radiomorphometric indices (6). Although Damilakis *et al.* reported a significant reduction in MCW of women with the T-score below -1 as well as women with osteoporosis; they did not confirm any correlation between PMI and M/M ratio, and detection of osteoporosis (10). Nevertheless, Horner and Devlin found PMI correlated with mandibular BMD; still, they believed PMI had no superiority over MCW in the diagnosis of osteoporosis 2. Posses *et al.* also confirmed the relation between PMI (with a diagnostic threshold of 0.3) and BMD; yet both MCW and PMI had little connection with BMD of the lumbar spine and proximal femur regions (5).

MCI is considered to be the most accurate parameter for evaluation of the risk of osteoporosis by Yasar *et al.* (16). They also found a significant difference between osteoporotic and non-osteoporotic groups even in younger age range and in non-fractured patients and classified the risk of osteoporosis (which in C3 is 12.6 times higher than C2 and 142.8 times higher than C1, and in C2 is 12 times higher than C1) 16. Hastar *et al.* observed that MCI values were significantly influenced by gender, as 68.5% and 2.8% of women belonged to C2 and C3 categories, while only 21.8% and 0% of men had C2 and C3 categories, respectively; also 3.2% of the osteoporotic patients belonged to C2 and 71.4% of them had the C3 categories (22). Leite *et al.* found qualitative indices such as MCI and simple visual estimation, highly correlated with osteoporosis (7). Based on their study, all postmenopausal women with normal BMD values had C1 category (specificity and predictive value of 100%); while the patients in C2 category who had very thin mandibular cortices were classified as osteoporotic; which shows the importance of the role of visual estimation alongside the MCI index 7.

The M/M ratio was not an accurate index in relation with reduced BMD and osteoporosis (10, 16) and showed the difference between the fractured and non-fractured groups in merely one study (40). Dutura *et al.* reported that compared to the control group, the values of AD and AA were respectively higher and lower in the osteoporotic group; whereas no difference was found in GA values (19). Conversely, another study showed no meaningful difference between these three indices (7). Although some studies are indicative of a reduction in AI values in osteoporotic patients (7, 19, 24); one study was conducted on osteoporotic men, found no correlation between AI, MI and PMI, and the BMD of the lumbar spine and femur (11).

In a study by Karayianni *et al.* the MCW≤+3mm, and OSIRIS≤+1 (having higher diagnostic efficacy) were considered the diagnostic thresholds (32). However, Horner *et al.* considered the MCI (C1 and C2 categories) together with the OSIRIS≤+1 as the diagnostic threshold (12).

Taguchi *et al.* showed that OST and cortical shape has similar diagnostic efficacies, and both have low values in postmenopausal women with a history of hysterectomy, oophorectomy, or consumption of estrogen. They also determined the MCW≤4.5mm and OST≤-1 as the diagnostic threshold 37. Similar results were achieved in another study by Taguchi, in which the specificity for cortical shape was significantly higher than that for OST and MCW. In this study, the MCW≤3mm was detected in 60% of the patients with low BMD and 90% of those with osteoporosis; the OST index was easily clinically employed and also had a similar diagnostic efficacy (23).

Based on the study by Law *et al.* (39), compared to other radiographic indices, PI was proven significantly more reliable in the diagnosis of osteoporosis; although FD and MD were also effective.

Due to the various methods used by the included studies and the heterogenicity of the results, in the current systematic review no meta-analysis was performed. Application of panoramic radiograph for screening osteoporosis has great advantages especially for dental implant treatment. Further studies with more precise methodology considering gender differences are required to achieve a conclusive outcome.

Conclusion

Based on the results of this systematic review, mandibular bone density is correlated with panoramic radiography indices. Since mandible is affected by osteoporosis, these indices can help

diagnose the decreased bone density in the mandible as well as other bones of the skeleton. MCW and MCI are the indices with the most specificity for evaluation of the risk of osteoporosis. Since the decreased bone density might be detected on panoramic radiographs; dentists are potentially capable of screening of the osteoporosis.

Definition

- Definition of osteoporosis based on universal World Health Organization classification (WHO): Osteoporosis was defined as a Bone mineral density T-score of -2.5 or less at either the lumbar spine or the femoral neck.
- Normal: T-score greater than 1.0
- Osteopenia: T-score between -1.0 and -2.5
- Detection of osteoporosis based on Dual-energy X-ray absorptiometry: by assessment of bone mineral density in lumbar vertebrae, hip, calcaneus, and femoral neck.

Conflict of Interest: 'None declared'.

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Please cite this paper as: Bakhshaei P, Mirfasihi A, Eslami S, Motamedian SR, Khojasteh A. Panoramic Radiography as a Diagnostic Tool for the Evaluation of the Osteoporosis: A systematic Review. Regen Reconstr Restor. 2018;3(2): X-X. Doi: 10.22037/rrr.v%vi%i.9776.