Review Article



# Radiographic assessment of the mandible to diagnose women with osteoporosis—a literature review

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**Background and Objective:** Osteoporosis, a chronic skeletal disorder, is diagnosed using dual X-ray absorptiometry (DEXA), the gold standard method. An orthopantomogram (OPG) can assess the risk of osteoporosis in individuals with low bone mineral density (BMD). Mandibular BMD is closely related to other skeletal regions, making dental radiography a valuable tool for analyzing bone changes in patients with osteoporosis. The current review aims to analyze the literature on the use of dental radiography to analyze mandibular bone changes in women with osteoporosis.

**Methods:** PubMed search was conducted on osteoporosis and radiographic mandibular changes from 2011 to 2021 with keywords like ((bone) OR (mandible) OR (jaw)) AND ((dental radiograph) OR (orthopantomography) OR (CBCT)) AND (Osteoporosis) excluding articles in languages other than English, without full text, case reports, review articles, letters to the editor, conference proceedings, osteoporosis in men, without DEXA as reference test, patients with other systemic diseases, oral conditions like periodontal disease, implants and patients under medication. The database was last searched in December of 2022. Quality of included studies was evaluated using Joanna Briggs Institute Critical Appraisal Tool.

**Key Content and Findings:** The review included 20 observational studies, with 12 using OPG with an average sample size of 118.7, 7 using cone-beam computed tomography (CBCT) with a sample size of 62.57, and 1 using intraoral periapical radiograph (IOPA) with 31 as sample size. Mandibular cortical width (MCW) and mandibular cortical index (MCI) are commonly studied parameters in osteoporosis screening, with varying sensitivity and specificity. Combining MCW and MCI with other indices improves screening performance, with some studies showing MCI diagnostic accuracy is superior. Among the OPG studies, only 3 (25%) were of high quality, and 9 (75%) were of medium quality, while among CBCT studies 5 (71%) were medium-quality articles and 2 (29%) were of low quality and IOPA study was of medium-quality.

**Conclusions:** A combination of indices can be used to identify changes in OPG of osteoporotic women; however, there are insufficient high-quality studies on IOPA and CBCT as alternatives to DEXA are lacking, requiring further research.

**Keywords:** Bone mineral density (BMD); mandible; osteoporosis; orthopantomogram (OPG); dental radiographs

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Received: 29 March 2023; Accepted: 12 January 2024; Published online: 27 March 2024.
doi: 10.21037/fomm-23-33
**View this article at:** https://dx.doi.org/10.21037/fomm-23-33

## Introduction

### *Background*

Osteoporosis is a bone disease causing significant morbidity and mortality worldwide (1). It is characterized by reduced bone mass and deterioration of bone microarchitecture leading to an increased risk of bone fracture (2). Nearly half of the postmenopausal women in India are more likely to develop osteoporosis (3). According to estimates, osteoporosis affects more than 200 million individuals worldwide at the moment. The International Osteoporosis Foundation has released figures showing that 1 in 3 women over 50 and 1 in 5 men may have an osteoporotic fracture over their lifetimes (4). Osteoporosis is frequently underdiagnosed since it may not show any clinical symptoms until a fracture occurs (5). In order to prevent fractures early diagnosis is essential. Though there are different imaging modalities available to detect bone mineral density (BMD), dual-energy X-ray absorptiometry (DEXA) is the preferred method across the world due to its accuracy and minimal radiation exposure exceptionally low radiation dose to patients, short scan times, high resolution images, good precision and inherent stability of calibration (6). World Health Organization (WHO) has defined osteoporosis based on DEXA BMD as T-score ≤–2.5. Osteopenia is a state of low bone mass defined by a BMD T-score between –1 and –2.5 (7). DEXA of the femoral neck is found to have a precision of 2–5% while DEXA of the spine have a precision of 0.5–1% (8). On the contrary, DEXA is unsuitable for widespread use due to its low availability and high price, making it difficult to detect and treat osteoporosis (9). So, cheaper alternative approach to assess skeletal condition is required for screening purposes (10). Dental radiographs are affordable, and a considerable portion of the total population already has them done regularly. As a result, dental radiographs might have a lot of potential as an osteoporosis screening tool. Several review studies explore the utilization of dental radiographs for the diagnosis of osteoporosis. Jaw bone mass is diminished in osteoporotic patients which puts dentists in a potentially beneficial position for patient screening for indications of osteoporosis given that dental radiography may be effective as a rapid way to screen patients for the disease (11). Dentists may also be among the first health professionals to recognize a patient who has osteoporosis but is yet to be diagnosed or a patient who is at risk of developing osteoporosis later in life (12).

Evidence in the literature indicates that the mandibular indices in combination with surveys on the risk of fracture can help in early osteoporosis detection (13). Systematic reviews have investigated the possibility of cone-beam computed tomography (CBCT) for screening patients with low BMD and concluded that CBCT has high accuracy in predicting osteoporosis and strong sensitivity and specificity (14,15). The current literature review focuses on the utility of orthopantomogram (OPG), CBCT, and periapical radiographs in diagnosing women with osteoporosis.

### *Rationale and knowledge gap*

Osteoporosis affects the mandibular bone mass at a rate similar to that of the skeletal bone mass. BMD of the mandible has been linked morphologically, densitometrically, and architecturally to the BMD of the lumbar spine and femoral neck (16). Consequently, dentists play a crucial role in the early detection of osteoporosis. Several methods have been attempted to be used as an alternative to DEXA. Oral indices such as the number of teeth present, resorption of alveolar bone, mandibular BMD, lamina dura width, mandibular cortical thickness and morphology of the mandibular inferior cortex measured in dental radiographs like OPG, CBCT and intraoral periapical radiograph (IOPA) have been used to predict low BMD. If the radiographic indices are found reliable in identifying patients with low BMD, then dentists may use dental radiographs as a screening technique to refer the patient for a bone densitometry test.

### *Objective*

This literature review aimed to analyze the evidence available in the literature to provide a reliable alternative method to diagnose osteoporosis in women using dental radiographs. We present this article in accordance with the Narrative Review reporting checklist (available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-33/rc).

**Table 1** The search strategy summary

| Items | Specification |
|---|---|
| Date of search | 15 December 2022 – 31 December 2022 |
| Databases searched | PubMed |
| Search terms used | ((bone) OR (mandible) OR (jaw)) AND ((dental radiograph) OR (orthopantomography) OR (CBCT)) AND (Osteoporosis) |
| Timeframe | 11 years (2011 – 2021) |
| Inclusion and exclusion criteria | Observational studies related to osteoporosis in women and bone changes of the Mandible published for a period of 11 years, from 2011 to 2021, in the English language were selected for the study. The following were excluded from consideration: articles written in languages other than English, those lacking the full text, not related to dental radiographs and osteoporosis in men, articles that did not use DEXA as a reference test, articles that included patients with other systemic diseases, other oral conditions like periodontal disease, implants, and patients under medication. Studies that used artificial intelligence, computed-based automated systems, and machine learning were also eliminated. Case studies, review papers, letters to the editor, systematic reviews, questionnaire studies, and conference proceedings were not considered |
| Selection process | Two authors (S.R. and B.D.) independently screened the articles and included them in the review process based on the inclusion and exclusion criteria. The decision of the third author (V.V.) was considered in case of discrepancies between the two authors. The review was performed by three reviewers. After the individual reviews of the three reviewers were finished, a group discussion ensued. When one of the reviewers disagreed, the other two assessed the circumstance and considered whether or not the majority of the group agreed with the data |

CBCT, cone-beam computed tomography; DEXA, dual-energy X-ray absorptiometry.

## Methods

### *Search strategy*

Articles related to the diagnosis of osteoporosis in women and mandibular bone changes were searched in the PubMed database using keywords like ((bone) OR (mandible) OR (jaw)) AND ((dental radiograph) OR (orthopantomography) OR (CBCT)) AND (Osteoporosis). The database was last searched on the month of December 2022.

### *Study selection*

Observational studies related to osteoporosis in women and bone changes of the Mandible published for a period of 11 years, from 2011 to 2021, in the English language were selected for the study. The following were excluded from consideration: articles written in languages other than English, those lacking the full text, not related to dental radiographs and osteoporosis in men, articles that did not use DEXA as a reference test, articles that included patients with other systemic diseases, other oral conditions like periodontal disease, implants and patients under medication. Studies that used artificial intelligence, computed-based automated systems and machine learning were also eliminated. Case studies, review papers, letters to the editor, systematic reviews, questionnaire studies and conference proceedings were not considered. Two authors (S.R., B.D.) independently screened the articles and included them in the review process based on the inclusion and exclusion criteria. The decision of the third author (V.V.) was considered in case of discrepancies between the two authors.

### *Literature screening*

A preliminary review was performed based on the full title and abstract, before proceeding to full-text review. Data like radiographs used, parameters analyzed, observation and inference were extracted from each of the included studies and qualitative analysis was performed. The review was performed by three reviewers. After the individual reviews of the three reviewers were finished, a group discussion ensued. When one of the reviewers disagreed, the other two assessed the circumstance and considered whether or not the majority of the group agreed with the data. A summary of the search strategy has been provided in *Table 1*.

### *Quality assessment*

The Joanna Briggs Institute (JBI) Critical Appraisal Tool was used to evaluate the quality of the papers (17). There are 10 quality indicators in the JBI checklist for diagnostic

test accuracy. These quality indicators were converted to a score of 100%, with a score of >80% being classified as high quality, 60–80% as medium quality, and 60% as low quality. Two authors conducted the quality assessment, while a third author handled the discrepancy between the two assessors.

## Discussion

A total of 269 articles were screened in PubMed those were within the time period of 2011–2021, out of which 172 articles were excluded as they were not related to dental radiographs and osteoporosis based on title and abstracts. 75 articles were excluded based on exclusion criteria like review articles [12], systematic reviews [8], questionnaires [2], articles in languages other than English [2], articles that did not have full texts [5], articles that didn't consider DEXA as a standard method [2], articles that included combination OPG and IOPA or CBCT [4], studies done on male population [5], articles with patients having Implants [7], Periodontitis [5], edentulous dental arch [1], other systemic diseases [9] or those under medication [5], articles that evaluated Temporomandibular joints or Condyles [3], articles with machine learning, artificial intelligence, computer-based automated system [6] were all excluded. Post excluding all the articles that did not fulfill the criterion, a total of 20 papers were included for review.

### *OPG*

Twelve studies that evaluated the changes in the mandible based on OPG, of which four were from India (5,16,18,19), two from Saudi Arabia (20,21), two from Iran (22,23), two from Brazil (24,25) and one from Japan (3) and Korea (26). The mean sample size in the studies was 118.7±110.91 with a range of 40–431. In all the articles, the population was classified as normal or osteoporotic based on DEXA. DEXA of the lumbar spine was used as a standard in 10 studies, the femur in 8, and the hip in one of the studies. Among them, in 6 studies DEXA of both lumbar spine and femur were done. The mean age of the participants included in the studies was 56.88±12.24 years. Mandibular cortical width (MCW) of mandible was studied in 9 articles (75%), mandibular cortical index (MCI) in 6 (50%), and fractal dimension (FD) in 3 (25%) articles. The other parameters evaluated were panoramic mandibular index (PMI), trabecular bone area (TBA), mandibular ratio (M/M ratio), gonial index, antegonial index (AI), and bone resorption severity index (BRSI). Three thresholds were determined for MCW with varying sensitivity and specificity. The cut-off for MCW was obtained as 4.29 mm in an Iranian study with 81.4% sensitivity and 58.3% specificity, compared to 3.35 mm in an Indian study with 55% sensitivity and 93.3% specificity. The MCW threshold for osteoporosis diagnosis was found to be 4.1 mm in a Saudi Arabian study, with a 60.2% sensitivity and 68.4% specificity. Three (25%) of the articles were considered to be of high quality, and nine (75%) were of medium quality (*Table 2*).

### *CBCT*

Out of seven studies, two from Syria (27,28), two from Brazil (29,30) and one each from Egypt (31), Turkey (32) and Korea (8) evaluated the alterations in the mandible using CBCT. The sample size ranged from 38 to 120, with a mean of 62.57. Six studies used DEXA of the lumbar spine as the standard, four used the femur, one used the hip and one did not specify the area. Among them, four studies investigated both the lumbar spine and the femur, one lumbar and the hip, and one lumbar alone. The study participants were 58.82 years old on average. There were four articles that evaluated computed tomography mental index (CTMI), four on computed tomography mandibular index (CTI) and two on computed tomography cortical index (CTCI). In addition to FD, histogram analysis, MCW, cortical quality and radiographic density (RD) were also examined in various papers. Another study used BoneJ-ImageJ to measure connection density, trabecular thickness (Tb.Th), trabecular separation (Tb.S), bone volume fraction (BV/TV), specific bone surface (BS/TV), and bone volume fraction. In one article, a novel CBCT-driven osteoporosis index (3D MOI) was established. Age-related CBCT measurements revealed sensitivity and specificity levels of over 74.0% (*Table 3*). When employing RD, the threshold for lumbar vertebrae was 867–900 while that for the femoral neck was 829–838. Two (29%) were of low quality and 5(71%) were medium-quality articles.

### *IOPA*

A study from Indonesia (33), evaluated the alterations in the mandible based on IOPA. The sample size was 31. Based on DEXA, the population was divided into three categories: normal, osteopenic and osteoporotic. The study used standard DEXA procedure on the lumbar and femur. The average age of the participants was 65.2±7.5 years. Trabecular structural analysis was performed with BoneJ

**Table 2** Overview of articles assessing mandibular changes using OPG

| S. No. | Author, year, country | Sample size | Study population | Age* (years) | Reference test | Parameter analysed | Observation |
|---|---|---|---|---|---|---|---|
| 1 | Khojastehpour L *et al.*, 2011 Iran (22) | 119 | Normal: 50, osteoporosis: 50, osteopenia: 19 | 55.85±8.22 | DEXA-BMD at lumbar vertebrae (L2–L4) and neck of the femur | MCW, MCI | MCI based on lumbar vertebrae: SP 69.4%, ST 80.7%<br>MCI based on femoral neck: SP 67.7%, ST 81.5%<br>MCW: 4.29 mm, ST 81.4%, SP 58.3%, PPV 65.8% |
| 2 | Oliveira ML *et al.*, 2013 Brazil (24) | 73 | Normal: 38, osteoporotic: 35 | 45 to 70 | DEXA: lower spine and hips | FD, PI in angle and body of mandible | Mean FD, PI in normal 1.4, 6.9; osteoporosis 1.36, 6.2 |
| 3 | Kathirvelu D *et al.*, 2014 India (18) | 64 | Normal: 28, low mineral density: 36 | 52.5 (31 to 80) | DEXA: right femur | MCT, PMI, TBA | MCT + PMI + age: ST 92%, PPV 85%, accuracy 84%, AUC 0.89 |
| 4 | Nagi R *et al.*, 2014 India (16) | 120 | Normal: 60, osteoporotic: 60 | 50 to 75 | DEXA: femoral Neck | MCW | Threshold <3.35 mm ST 55.0%, SP 93.3% |
| 5 | Kavitha MS *et al.*, 2015 Korea (26) | 141 | Normal 120, osteoporotic 21 | 64.3 (45 to 92) | DEXA: lumbar spine (L2–L4) and/or femoral neck | MCW, FD, GLCM | MCW showed the highest diagnostic accuracy (85.2%) compared with FD (83.1%) and GLCM (0.8%) |
| 6 | Pallagatti *et al.*, 2017 India (5) | 60 | Normal: 21, osteopenic: 18, osteoporotic: 21 | 57.9±7.68 | DEXA: lumbar spine (L1–L4 and parts of L5 and T12) | Thinning of inferior mandibular cortex at premolar region—graded based on Klemetti index | Accuracy of 5 observers to demonstrate normal bone, osteopenia and osteoporosis was 58.08%, 63.3% and 64.74% respectively |
| 7 | Carmo JZ *et al.*, 2017 Brazil (25) | 198 | Women with amenorrhea due to ovarian failure for at least 12 months | 40 to 53 | DEXA: lumbar spine, femoral neck | MCI, MI | Excellent agreement between MCI and BMD of the lumbar spine (Kappa =0.912) |
| 8 | Balto KA *et al.*, 2018 Saudi Arabia (20) | 431 | Normal, osteopenia, osteoporosis | 57.78±6.24 | DEXA: anteroposterior lumbar spine (L1–L4) and mean of proximal right and left femur | MCW, PMI, M/M ratio | MCW<br>Osteopenia: cut off level 4.6 mm, ST 58.4%, SP 69.4%<br>Osteoporosis: cut off level 4.1 mm, ST 60.2%, SP 68.4% |

**Table 2** (*continued*)

**Table 2** (*continued*)

| S. No. | Author, year, country | Sample size | Study population | Age* (years) | Reference test | Parameter analysed | Observation |
|---|---|---|---|---|---|---|---|
| 9 | Navabi N *et al.*, 2018 Iran (23) | 50 | Osteopenia, osteoporosis | 57.64±6.03 | DEXA: two types of T-scores including TT (trabecular) for lumbar spine, TC (cortical) for femoral neck | MCW, MCI | MCW significantly correlated with BMD (P<0.05)<br>Areas under the ROC curve were 0.773, 0.996, and 0.783 for indices of MCW, TT, and TC |
| 10 | Nakamoto T *et al.*, 2020 Japan (3) | 68 | – | 64.1±8.34 | DEXA: L2–L4 | BRSI | BRSI and lumbar bone density showed a strong negative correlation (P<0.01)<br>BRSI: ST 90.9%, SP 64.7%, and accuracy 75.0%, BRSI threshold 2198 |
| 11 | Alam *et al.*, 2020 Saudi Arabia (21) | 60 | Control: 30, osteoporotic: 30 | 45 to 60 | DEXA: lumbar spine | MCW, PMI, M/M ratio, MCI, FD analysis | Overall prediction accuracy of subjects developing osteoporosis: 95.87%<br>MCI: effective indicators of osseous changes in postmenopausal osteoporosis |
| 12 | Gaur *et al.*, 2013 India (19) | 40 | Normal: 9, osteopenic: 15, osteoporotic: 16 | 40 to 69 (53.5) | DEXA: femoral, spine (L1–L4) | MI, PMI, MCI, gonial index, antegonial index | MCI: ST 100%, SP 88.88%, PPV 96.87%, NPV 100% |

*, data are presented as mean, range or mean ± SD. OPG, orthopantomogram; S. No., serial number; DEXA, dual-energy X-ray absorptiometry; BMD, bone mineral density; MCW, mean cortical width; MCI, mandibular cortical index; SP, specificity; ST, sensitivity; PPV, positive predictive value; FD, fractal dimension; PI, pixel intensity; MCT, mandibular cortical thickness; PMI, panoramic mandibular index; TBA, trabecular bone area; AUC, area under the ROC curve; GLCM, grey level co-occurrence matrix; TT, T-score in trabecular bone; TC, T-score in cortical bone; BRSI, bone resorption severity index; NPV, negative predictive value; SD, standard deviation; ROC, receiver operating characteristic.

and ImageJ—Parameters used bone area fraction (BA/TA) and 2D Tb.Th. The article was of medium quality (*Table 4*).

### *Key findings*

The DEXA method is an advance in non-invasive BMD determination which provides a lower absorbed radiation dose, improved spatial resolution and faster scan times. Despite being the best diagnostic method now available, DEXA is expensive and labor-intensive to screen osteoporotic patients. Although BMD can be assessed everywhere on the body, two areas—the lumbar spine and the proximal femur—have been identified as more reliable and representative (25). Osteoporosis can occasionally progress asymptomatically. Instead of having all patients tested for BMD, dentists may use dental radiographs as a screening technique to refer the patient for a bone densitometry test. Given the cost, it is not recommended for every patient to have a DEXA scan if they are unaware that they are at risk or have the disease since they can be assessed with pre-existing dental radiographs. Furthermore, DEXA can be used for further validation and risk management in

**Table 3** Overview of articles assessing mandibular changes using CBCT

| S. No. | Author, year, country | Sample size | Study population | Age* (years) | Reference test | Parameter analysed | Observation |
|---|---|---|---|---|---|---|---|
| 1 | Koh KI, Kim KA 2011 Korea (8) | 42 | Healthy 21, osteoporotic 21 | Healthy: mean =60.0; osteoporotic: mean =66.0 | DEXA: lumbar vertebrae (L1–L3) and femur | CTI, CTMI, CTCI | The intra-observer agreement significantly correlated with all parameters (P<0.05)<br>Significant correlation in the CTI and CTCI<br>No correlation-CTMI |
| 2 | Barngkgei I *et al.*, 2014 Syria (27) | 38 | Lumbar vertebrae: normal 10, osteoporotic 15, osteopenic 13<br>Femoral head: normal 17, osteoporotic 11, osteopenic 10 | 57.9 | DEXA: lumbar vertebrae (L1–L4), Femoral neck | RD as gray values | RD of whole bone: ST 50%, SP 88.9%, accuracy 78.4% respectively, for the femoral neck, ST 46.2%, SP 91.3%, accuracy 75%, for the lumbar vertebrae<br>Threshold for RD: 867–900 (lumbar vertebrae), 829–838 (femoral neck) |
| 3 | Barngkgei I *et al.*, 2015 Syria (28) | 38 | Lumbar vertebrae: normal 10, osteoporotic 15, osteopenic 13<br>femoral head: normal 17, osteoporotic 11, osteopenic 10 | 57.9 | DEXA | Bone cuboids from mental region, basal bone of the mandible between the mental foramen, the extent of the anterior ridge of the ramus at the right and the left mental foramens and the dens obtained. Tb.Th, Tb.S, BV/TV, BS/TV and connectivity density-BoneJ-ImageJ | Jawbone-derived variables had very low sensitivity values |
| 4 | Güngör E *et al.*, 2016 Turkey (32) | 90 | Osteoporosis 26, osteopenia 33, healthy controls 31 | Osteoporosis: 58.52±5.91, osteopenia: 52.67±8.61, healthy controls: 49.81±10.47 | DEXA: lumbar spine (L1-L3), femur | CT value, FD analysis, histogram analysis CTI (I), CTI (S) and CTMI-ImageJ | The strong correlation noted between vertebral BMD and both the right and left mandibular CT value measurements |
| 5 | Mostafa RA *et al.*, 2016 Egypt (31) | 50 | Osteoporosis 25, control (normal) 25 | Osteoporotic: 61.1±4.9, control (normal): 60.1±3.7 | DEXA: lumbar spine | CTCI, CTMI, CTI and FD analysis | Intraobserver agreement showed moderate agreement regarding CTCI (0.576). Strong agreement was found regarding CTMI and CTI, FD showed good Intraobserver agreement (0.701) |

**Table 3** (*continued*)

**Table 3** (*continued*)

| S. No. | Author, year, country | Sample size | Study population | Age* (years) | Reference test | Parameter analysed | Observation |
|---|---|---|---|---|---|---|---|
| 6 | Brasileiro CB *et al.*, 2017 Brazil (8) | 60 | Normal 20, osteopenic 20, osteoporotic 20 | Normal: 55.6, osteopenia: 57.5, osteoporotic: 62.4 | DEXA: femoral neck and lumbar spine (L1–L4) | Region of the mental foramen CTMI, CTI (I), CTI (S) | High degree of interobserver and intraobserver agreement for all measurements (ICC >0.80). The mean values of CTMI, CTI (S), and CTI (I) were lower in the osteoporosis group than in osteopenia and normal patients (P<0.05) |
| 7 | de Castro JGK *et al.*, 2020 Brazil (30) | 120 | Normal 52, osteoporosis 51 | Normal: 64.8±9.8, osteoporosis: 63.9±9.9 | DEXA: lumbar spine (L1–L4) and hip | MCW and cortical quality | Postmenopausal women with osteoporosis were more likely to have MCW thinner than 2.75 mm |
| | | | | | | New CBCT-driven osteoporosis index (3D MOI) | CBCT measurements with age showed the highest AUC, with sensitivity and specificity values above 74.0% |

*, data are presented as mean or mean ± SD. CBCT, cone-beam computed tomography; S. No., serial number; DEXA, dual-energy X-ray absorptiometry; CTI, computed tomography mandibular index; CTMI, computed tomography mental index; CTCI, inferior computed tomography cortical index; RD, radiographic density; ST, sensitivity; SP, specificity; Tb.Th, trabecular thickness; Tb.S, trabecular separation; BV/TV, bone volume fraction; BS/TV, specific bone surface; FD, fractal dimension; BMD, bone mineral density; CT, computed tomography; CTI (S), computed tomography mandibular index (superior); CTI (I), computed tomography mandibular index (inferior); ICC, intraclass correlation coefficient; MCW, mandibular cortical width; 3D-MOI, three-dimensional mandibular osteoporosis index; AUC, area under the curve; SD, standard deviation.

**Table 4** Overview of articles assessing mandibular changes using IOPA

| S. No. | Author, year, country | Sample size | Study population | Age, mean ± SD | Reference test | Parameter analysed | Observation |
|---|---|---|---|---|---|---|---|
| 1. | Diba SF *et al.*, 2021 Indonesia (33) | 31 | Normal 3, osteopenia 22, osteoporosis 6 | 65.2±7.5 years | DEXA: lumbar and femur | Bone thickness, trabecular thickness percentage of bone area<br>Trabecular structural analysis—BA/TA and 2D Tb.Th | Trabecular thickness, bone percentage significantly correlated with femoral bone mineral density |

IOPA, intraoral periapical radiography; S. No., serial number; DEXA, dual-energy X-ray absorptiometry; BA/TA, bone area fraction; Tb.Th, trabecular thickness; SD, standard deviation.

people who are at risk. Hence, the current study aimed to evaluate the usefulness of existing dental radiographs for the diagnosis of osteoporosis in women. In the majority of the studies included in our review, DEXA of the lumbar spine or femur has been considered a standard reference test to determine the diagnostic efficacy of dental radiographs in diagnosing osteoporosis.

OPG has been a critical component of radiographic dental diagnostics for more than 40 years. Several parameters have been employed to measure and quantify mandibular bone mass as well as to detect symptoms of resorption using OPGs.

- MCW or cortical width index or mental index (MI) is the mandibular cortical thickness (MCT) measured at the line A line perpendicular to the base of the mandible and passing through the middle of the mental foramen.
- PMI is the ratio of MCT and the distance between the inferior mandibular cortex and mental foramen.
- Klemetti index or MCI or cortical erosion is a three-graded system used to assess the changes in the inferior mandibular cortex. It classifies the cortex as normal when the endosteal margin of the cortex is even and sharp on both sides, mild to moderately eroded cortex when the endosteal margin shows semilunar defects, or severely eroded cortex when the cortical layer forms heavy endosteal cortical residue and is clearly porous.
- *M/M* ratio refers to total mandibular height divided by the height from the center of the mental foramen to the inferior mandibular border.
- Gonion index (GI) is the mandibular cortical thickness at the angle of the mandible (gonion).
- AI refers to the cortical width, anterior to the gonion, at a point corresponding to the line of fit on the anterior border of the ascending ramus, down to the lower border of the mandible (antegonial region).
- FD is a value that indicates how completely a fractal appears to fill space.

Among these parameters, MCW and MCI have been commonly employed in most of the studies suggesting their possible use as a predictor test of osteoporosis in postmenopausal women. GI and AI are difficult to determine and less frequently used in the literature.

One of the major limitations of DEXA is that it assesses the BMD rather than the microarchitecture of the bone which is far more crucial in identifying the etiology of osteoporosis. The bone microarchitecture is clinically assessed by high-resolution CT and Q-CT (20). CBCT is a preferred investigation due to its relatively low cost and reduced radiation dose. CT indices have been derived based on modified Ledgerton's classification on OPG images (23).

- CTI (superior) [CTI (S)] is the ratio of the inferior cortical width to the distance from the superior margin of the mental foramen to the inferior border of the mandible.
- CTI (inferior) [CTI (I)] is the ratio of the inferior cortical width to the distance from the inferior margin of the mental foramen to the inferior border of the mandible.
- CTMI, is the inferior cortical width of the mandible.
- CTCI, which was the type of the inferior mandibular cortex.

Periapical radiographs are relatively inexpensive exams that are frequently available in dental offices. Since the trabecular bone can be easily visualized in periapical radiographs, it is likely that, similar to other parts of the skeleton, this may contain significant information about the bone condition on a microstructural level. It is possible to check for early signs of osteoporosis using standard mandibular periapical radiography.

### *Strengths and limitations*

Dentists are well-positioned to screen patients for osteoporosis and may be the first medical professionals to encounter people who have the condition but have not yet received a diagnosis or who are at a high risk of developing it in the future. By lending a helping hand in the early detection of the affected persons, which further results in timely care to avoid further complications, they might further assist the healthcare practitioners as well as the osteoporotic patients. The density of the jaw bone can be measured using intraoral radiography, but the measurements may vary depending on the method of analysis, patient positioning, non-standard imaging positions, and changes in anatomical structures. The other major limitation is the reproducibility of the various indices since some of the studies have involved direct digital OPG while in some studies software to manipulate the images. Also, there are inherent inaccuracies and observer variability when taking measurements from OPG. The quality of radiographs and the diagnostic performance of various parameters vary among the studies. Another drawback is that most of the studies involved postmenopausal women, who are not the appropriate representative of the normal population. Some of the studies included normal and osteoporotic women, but not osteopenic women. It is questionable if osteopenic and osteoporotic women can be distinguished using the same method, given the likelihood that the difference between these two groups may be smaller than the diagnostic ability of the method. The key difficulties encountered in the studies with IOPA were that there were very few studies done utilizing them, therefore it could not be clearly stated whether they are of greater value or not. Although results have shown that they can be used to predict osteoporosis in women, more research is still required to substantiate the findings. Patients with localized inflammation, other bone

diseases, patients under medication, and radiotherapy may have altered bone density which should not be confused with osteoporosis. In the majority of the studies, these were considered as the exclusion criteria. General dental practitioners should always consider this while evaluating dental radiographs.

### *Comparison with similar researches and explanations of findings*

Beginning in the third decade of life, the density and porosity of human bones start to change. After menopause, this loss of bone mass is increased in women (16). According to estimates, women lose between 0.5% and 1% of their bone mass year after menopause (34). Hence, most of the included studies involved postmenopausal women. There is evidence that the key factor influencing the risk of hip fracture is BMD as determined by DEXA, particularly at the proximal femur (16). It has been shown that there is a strong association between BMD measurements at the femur and lumbar spine and panoramic mandibular indices (35-37). Though the bone mineral density in the spine has a higher area, the MCW is found to predict the rate of BMD better in the femur than in the lumbar spine (23).

A group of researchers from five European institutions began the OSTEODENT project in 2003 aimed to determine the most reliable radiography index for diagnosing osteoporosis in 671 postmenopausal women in the age range of 45 to 70 years of age. MCW was found to be superior to MCI (38). Over time, studies have demonstrated that the MCW has lower diagnostic validity when compared to the osteoporosis index of risk (OSIRIS)—age, weight, current estrogen therapy, and history of low trauma fracture (39).

MCW, TBA, and age were combined by Kathirvelu *et al.* to diagnose individuals with low BMD using OPG. MCW was found to better predict low BMD when compared to TBA which could be due to the diverse trabecular pattern of jaws (18). In cases of localized inflammation, the trabecular bone in the jaws is easily resorbed and/or sclerosed (40). However, the combinational approach performed better suggesting the importance of age in predicting the BMD. The performance of MCW in screening for osteoporosis was further improved by combining it with other parameters like FD. A CAD system was also used to analyze MCW by Kavitha *et al.* MCW was found to independently distinguish the groups better than other textural features. The mean FD decreased in osteoporotic (1.38) patients compared to normal (1.41) subjects. The combination of textural features like FD and grey-level co-occurrence matrix and MCW exhibited better diagnostic efficacy (26). Oliveira *et al.* showed that FD and pixel intensity (PI) were effective in detecting osteoporotic changes. The right side of the body did not show significant changes in PI which could be attributed to anatomical variations unilateral chewing or positioning errors (24). In a study by Roberts *et al.*, when the machine learning method to evaluate the texture of the mandible, FD was a less effective texture feature. They have concluded that despite being clearly observable at the population level, the association between the FD of the mandibular cortex and osteoporosis at other bone locations only generates low specificity when used to determine an individual's osteoporotic state (41).

Balto *et al.* observed that PMI and M/M ratio are of low significance in detecting osteoporosis in postmenopausal Saudi women when compared to MCW. However, MCW had the worst repeatability when compared to PMI, M/M ratio, and number of mandibular teeth (20). The diagnostic threshold for MCW for referring females for bone densitometry has been determined to be 3 mm or less by some of the investigators (42,43). However, the threshold differed in various study populations. Carmo *et al.* suggested that the cut-off threshold of MCW of 3 mm might not be as appropriate for multi-ethnic young Brazilian postmenopausal women as it was for Asian, Greek, and Caucasian ethnicities (25). This could be due to the difference in the sizes of their mandibles (44). Nagi R *et al.* reported that the threshold of MCW <3.35 mm exhibited low sensitivity but very high specificity. They also found that MCW negatively correlated with age, and BMI and positively correlated with femoral BMD (16). The MCW cut-off for osteoporosis was determined to be 4.1 mm in a Saudi Arabian study, while the cut-off for osteopenia was 4.6 mm (20). In a study conducted in Iran, the threshold for osteoporosis diagnosis was determined to be 4.29 mm (22). It could be speculated that the threshold of MCW for identifying osteoporosis in one population could not be used directly for another (44).

Pallagatti *et al.* also validated that MCI can be employed for early detection of osteoporosis (5). Carmo *et al.* diagnosed osteoporosis in 10% of the patients and osteopenia in 50% of the patients using MCI (25). MCI showed good results with 100% sensitivity in a study by Gaur *et al.* However, their sample size was too low to come to a conclusion (19). Alam *et al.* corroborated that along with MCI, aging is a risk factor for osteoporosis. Other

variables including MCW, PMI, M/M ratio, and FD were not indicative of osteoporosis (21). Similarly, Yasar and Akgunlu came to the conclusion that MCI was easy to assess, while MCW and PMI did not lend themselves to the diagnosis of osteoporosis (45). The specificity of MCW was also found to be lower than that of MCI in identifying low BMD which indicates that MCI can identify more subjects with normal BMD (22).

Nakamoto *et al.* developed a BRSI for CAD diagnosis based on the shape of the linear resorption of the mandibular marginal cortical bone on panoramic radiographs. BRSI quantitatively evaluated the mandibular cortical porosity with a threshold of 2,198 (3).

Koh *et al.* observed that there were significant differences in CTI (S) and CTI (I) between the normal and osteoporotic groups, while no significant difference was observed for CTMI (8). Brasileiro *et al.* suggested that CTMI thinner than 3 mm at the mental foramen region may be considered a threshold value when predicting low spinal and femoral BMD (29). CBCT images were for the calculation of Radiographic density (RD), mean voxel gray values, and cortical bone percentage using software provided by the manufacturer and it was found that RD for the whole bony area had the greatest ability to predict osteoporosis in both the femoral neck and the lumbar vertebrae. There are some inaccuracies in the determination of grey values in CBCT, which are related to the lack of water path calibration contrary to conventional CT (27). Güngör *et al.* radiomorphometric index measurements, CT value, and the histogram analysis (HA) and FD methods were used to evaluate jaw bones on CBCT images (32). CT values, HA, and FD measurements in osteoporosis patients were significantly lower than measurements in osteopenia patients and control subjects (11). In contrast, the study by Mostafa *et al.* observed lower FD values in the control group when compared to the osteoporosis group (31). de Castro *et al.* introduced a new CBCT index for assessing osteoporosis called as three-dimensional mandibular osteoporosis index (3D MOI) which is 3 measurements: two quantitative measures evaluating MCW on panoramic reconstruction images (3D MOI PR) and on cross-sectional images (3D MOI CS), and one qualitative measure assessing cortical bone quality (3D MOI CQ). For qualitative and quantitative evaluation of the mandibular cortex, the 3D mandibular osteoporosis index (MOI) has shown sensitivity and specificity in differentiating osteoporosis from normal bone mass density, with good predictive value. Postmenopausal women with osteoporosis presented with a mandibular cortex with C3 classification and a mandibular cortical width below 2.75 mm (30).

OSTEOSYR project was launched after the drop in the economy of Syria due to the civil war and aimed to provide treatment at the lowest possible costs with available medical records. In this project, Barngkgei *et al.* concluded that as determined by CBCT, osteoporosis has no effect on the trabecular bone structure of the mandible and maxilla. However, a high diagnostic accuracy was observed for trabecular bone analysis of dens, which is the odontoid process of the second cervical vertebra (28). It is debatable whether CBCT measurements of the mandible can be used to assess bone mineral density, as it usually has a low resolution (0.3–0.4 mm), causing blur in trabecular structures, which typically have a bone thickness of around 0.1 mm. To identify patients with osteoporosis, CBCT in conjunction with DEXA may be beneficial in cases where dentists prescribe CBCT for other dental reasons.

The mandibular trabecular structures of postmenopausal women was assessed using periapical radiography in the study by Diba *et al.* Trabecular thickness measurements was used as an initial test for bone quality since the loss of trabeculae structure was more severe in osteoporotic postmenopausal women. As a result, using dental radiography, such as periapical radiographs, to screen for bone quality can be a relatively simple and economically viable procedure (33). In a study by Licks *et al.*, the specificity (100%) and sensitivity (81%) of the trabecular morphologic analysis using IOPA, resulted in a total accuracy of 88.3%, making it a crucial factor in the diagnosis of low bone mass (46). The authors were unable to distinguish between individuals with normal and low bone density when the clinical and radiographic components were looked at separately since age is a crucial clinical criterion for osteoporosis.

### *Implications and actions needed*

The available evidence suggests that dental radiographs can be used to detect changes in osteoporotic women. More clinical trials are needed to assess the risk of osteoporosis in early postmenopausal women, since the dental radiograph may not detect small changes in the mandibular microarchitecture. Though the aforementioned studies have come to the conclusion that OPG, and CBCT might be utilized as an alternative approach for assessing BMD, additional research is needed to determine which parameter could be more dependable and accurate to do so. The

majority of investigations have been conducted on healthy individuals; however, people with various other systemic illnesses might be the focus of future research. It is also recommended to validate the thresholds for each CBCT device that best predicts the bone microarchitecture. The general dental practitioners should be aware of the changes that are seen in the dental radiographs of individuals with low BMD, so as to refer them to perform DEXA.

## Conclusions

Mandibular indices evaluated from OPG, used in combination, can be used to detect changes in the mandible of osteoporotic women. It is questionable if CBCT can be used independently to evaluate the BMD provided the scarcity of CBCT studies in the literature. CBCT in conjunction with DEXA can be effective. Also, there is a dearth of studies evaluating the use of IOPA as an alternative to DEXA for evaluating BMD.

## Acknowledgments

*Funding:* None.

## Footnote

*Reporting Checklist:* The authors have completed the Narrative Review reporting checklist. Available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-33/rc

*Peer Review File:* Available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-33/prf

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at https://fomm.amegroups.com/article/view/10.21037/fomm-23-33/coif). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.



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doi: 10.21037/fomm-23-33
**Cite this article as:** Ravindran S, Divya B, Vinoth V, Narayan M, Rameshkumar A, Krishnan R. Radiographic assessment of the mandible to diagnose women with osteoporosis—a literature review. Front Oral Maxillofac Med 2024.