The Analysis Study of Diagnostic Performance and Accuracy of Panoramic Radiography to Screen Bone Mineral Density in Woman: A Comprehensive Systematic Review

1 Muhammad Riefki Audhi, 2 Safira Salsabila

1 H. Abdurrahman Sayoeti Regional General Hospital, Jambi, Indonesia
2 Faculty of Medicine, University of Jambi, Indonesia
Correspondence: rifkiaudi@gmail.com

ABSTRACT

Background: Bone mineral density (BMD) is a crucial measure of bone health, providing essential information for assessing the risk of fractures and other bone-related conditions. Panoramic radiography, commonly used in dental practice, presents a potential alternative for BMD screening. This systematic review evaluated the effectiveness of panoramic radiography in detecting BMD based on literatures of the last 10 years.

Methods: The study adhered to PRISMA 2020 standards, examining English literature from 2014 to 2024. It excluded editorials, reviews from the same journal, and submissions without a DOI. PubMed, SagePub, SpringerLink, and Google Scholar were utilized as literature sources.

Result: Initially retrieving 360 articles from online databases (PubMed, SagePub, SpringerLink and Google Scholar) eight relevant papers were selected after three rounds of screening for full-text analysis.

Conclusion: Panoramic radiographs, including MI, MCI, and MCW, are valuable tools for screening bone mineral density (BMD) and detecting osteoporosis in women. Panoramic radiographs are effective in detecting osteoporosis, especially in postmenopausal women.

Keyword: panoramic radiograph, bone mineral density, woman, diagnostic performance, accuracy
INTRODUCTION
Bone mineral density (BMD) is a crucial measure of bone health, providing essential information for assessing the risk of fractures and other bone-related conditions. Traditionally, BMD is measured using dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT), which is considered the gold standard for bone density assessment. However, DXA may not always be accessible due to cost, availability, or logistical constraints, prompting interest in alternative methods for BMD detection.1,2

Panoramic radiography, commonly used in dental practice, presents a potential alternative for BMD screening. This imaging technique, which provides a broad view of the jaw and surrounding structures, is widely available and non-invasive. Its integration into routine dental examinations makes it a feasible option for preliminary BMD assessment, particularly in settings where access to DXA is limited.3,4

Recent research has explored the use of panoramic radiographs to estimate BMD through various mandibular indices. These indices, such as the mandibular index (MI), mandibular cortical index (MCI), and mandibular cortical width (MCW), assess different aspects of the mandibular bone structure. Studies have shown that these indices may correlate with systemic BMD, suggesting that they could potentially serve as indicators of bone health beyond the mandibular region.5,6

The appeal of using panoramic radiographs for BMD detection lies in their ability to provide valuable preliminary data without requiring additional imaging modalities. This approach could facilitate early identification of individuals at risk of low BMD, allowing for timely intervention and referral for more definitive testing if necessary.7,8

Despite its potential benefits, the use of panoramic radiographs for BMD detection presents several challenges. Variability in imaging techniques, differences in mandibular bone morphology among individuals, and the need for standardized interpretation of radiographic indices are important considerations.
Ensuring that these indices are accurate and reliable for BMD detection is crucial for their effective implementation. This systematic review aims to evaluate the effectiveness of panoramic radiography in detecting BMD. By analyzing available studies on literatures of the last 10 years, the review seeks to determine the accuracy of various mandibular indices and their potential role in identifying individuals with low BMD. The goal is to assess whether panoramic radiography can complement traditional BMD measurement methods and contribute to more accessible and efficient bone health screening.

METHODS

Protocol

The author carefully followed the rules laid out in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020. This was done to make sure the study met all its standards. The selection of this methodological approach was specifically aimed at ensuring the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic to evaluate the effectiveness of panoramic radiography in detecting BMD based on literatures of the last 10 years. This study meticulously analyzed data on literatures to provide insights and enhance patient treatment strategies. The primary objective of this paper is to highlight the collective significance of the identified key points.

Inclusion criteria for this study entail: 1) Papers must be in English, and 2) Papers must have been published between 2014 and 2024. Exclusion criteria comprise: 1) Editorials; 2) Submissions without a DOI; 3) Previously published review articles; and 4) Duplicate entries in journals.

Search Strategy

The keywords used for this research are panoramic radiograph, bone mineral density, woman, diagnostic performance, accuracy. The Boolean MeSH keywords inputted on databases for this research
Data retrieval

The authors assessed the studies by reviewing their abstracts and titles to determine their eligibility, selecting relevant ones based on their adherence to the inclusion criteria, which aligned with the article's objectives. A consistent trend observed across multiple studies led to a conclusive result. The chosen submissions had to meet the eligibility criteria of being in English and a full-text.

This systematic review exclusively incorporated literature
that met all predefined inclusion criteria and directly pertained to the investigated topic. Studies failing to meet these criteria were systematically excluded, and their findings were not considered. Subsequent analysis examined various details uncovered during the research process, including titles, authors, publication dates, locations, study methodologies, and parameters.

**Quality Assessment and Data Synthesis**

Each author independently evaluated the research presented in the title and abstract of the publication to determine which ones merited further exploration. The subsequent stage involved assessing all articles that met the predefined criteria for inclusion in the review. Decisions on including articles in the review were based on the findings uncovered during this evaluation process.
Table 1. Article Search Strategy

<table>
<thead>
<tr>
<th>Database</th>
<th>Strategi Pencarian</th>
<th>Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>(((panoramic radiograph) AND (bone mineral density) AND (woman)) AND (diagnostic performance)) OR (accuracy))</td>
<td>150</td>
</tr>
<tr>
<td>Direct</td>
<td>(((panoramic radiograph) AND (bone mineral density) AND (woman)) AND (diagnostic performance)) OR (accuracy))</td>
<td>50</td>
</tr>
<tr>
<td>Sagepub</td>
<td>(((panoramic radiograph) AND (bone mineral density) AND (woman)) AND (diagnostic performance)) OR (accuracy))</td>
<td>160</td>
</tr>
<tr>
<td>Google Scholar</td>
<td>(((panoramic radiograph) AND (bone mineral density) AND (woman)) AND (diagnostic performance)) OR (accuracy))</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. Article search flowchart

**Identification of studies via databases and registers**

Records identified from*

- PubMed (n = 100)
- Sagepub (n = 150)
- SpringerLink (n = 50)
- Google Scholar (n = 160)

Records removed before screening:
- Duplicate records removed (n = 100)
- Records marked as ineligible by automation tools (n=40)
- Records removed for other reasons (n = 200)

Records screened (n = 20)

Records excluded**
(n = 5)

Reports sought for retrieval (n = 15)

Reports not retrieved
(n = 0)

Reports assessed for eligibility (n = 15)

Reports excluded:
- 2014-2024 filter (n = 2)
- Incomplete results (n = 3)
- Wrong study design (n = 2)

Studies included in systematic review (n = 8)
### Table 2. JBI Critical appraisal of Study

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bias related to temporal precedence</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Is it clear in the study what is the “cause” and what is the “effect” (i.e., there is no confusion about which variable comes first)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Bias related to selection and allocation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Was there a control group?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Bias related to confounding factors</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Were participants included in any comparisons similar?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Bias related to assessment, detection, and measurement of the outcome</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Were there multiple measurements of the outcome, both pre and post the intervention/exposure?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Were outcomes measured in a reliable way?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
RESULT

The initial number of articles retrieved from online databases (PubMed, SagePub, SpringerLink, and Google Scholar) is 360 articles. After conducting three levels of screening, eight articles that directly relate to the current systematic review have been chosen for further assessment through full-text reading and analysis. Table 1 presents the selected literature included in this analysis.

Kim, et al.\(^\text{11}\) (2016) showed that thickness and morphological changes of the mandibular inferior cortical bone are associated with BMD, independent of age, height, and weight. MI, MCI, and SVE may be useful indices for diagnosing osteoporosis in a Korean population.

Kato, et al.\(^\text{12}\) (2019) showed that the accuracy of mandibular cortical index (MCI) calculated by DPR and CBCT varied. Despite the study's limitations, CBCT with a 25 mm slice thickness was found to be the most accurate. Dentists should consider DPR and CBCT as potentially useful tools for screening low BMD in postmenopausal women, enabling timely referral for further assessment.

Kathirvelu, et al.\(^\text{13}\) (2019) concluded that the proposed semi-automated MCT measurement on digital panoramic radiography (DPR) could effectively identify individuals at risk of low BMD.

Chongruangsri, et al.\(^\text{14}\) (2019) showed that MI and MCI in dental panoramic can be used as screening tools for diagnosing osteoporosis in postmenopausal women.
Carmo, et al.\textsuperscript{15} (2017) showed that radiomorphometric indices from mandibular panoramic radiographs are effective in identifying postmenopausal women with low bone mineral density in the mandible. These results can help in referring women for appropriate medical evaluation and treatment.

Balto, et al.\textsuperscript{16} (2018) showed that MCW, as an important panoramic radiographic parameter, can be used for predicting and diagnosing osteoporosis in postmenopausal Saudi women with low bone mineral density (BMD).

Grocholewicz, et al.\textsuperscript{17} (2018) concluded that The Mandibular Cortical Index (MCI) in dental panoramic can be utilized as a screening tool for detecting osteoporosis. Furthermore, quantitative ultrasound at the phalanx III is a reliable method for assessing bone status.

Triantafyllopoulos, et al.\textsuperscript{18} (2023) showed that that MCW is more effective in detecting osteoporosis when combined with age at menarche. Specifically, individuals with an MCW less than 3.0 mm and an age at menarche later than 14 years should be referred for dual-energy X-ray absorptiometry (DXA) due to their high risk of osteoporosis.
Table 1. The literature included in this study

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Origin</th>
<th>Method</th>
<th>Sample</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kim, et al.¹¹ (2016)</td>
<td>South Korea</td>
<td>Retrospective cohort study</td>
<td>194 patients</td>
<td>The study found a positive correlation between mandibular index (MI) and bone mineral densities (BMDs) at different sites: lumbar spine ($r = 0.36$), femoral neck ($r = 0.59$), and total hip ($r = 0.58$), all with $p &lt; 0.001$. MI decreased with age ($r = -0.46$). Participants with reduced mandibular width, thinning, and resorption of the mandibular cortex showed significantly lower BMDs at the lumbar spine and total hip. The optimal MI cut-off value for diagnosing spinal osteoporosis was determined to be 2.22 mm.</td>
</tr>
<tr>
<td>2.</td>
<td>Kato, et al.¹² (2019)</td>
<td>Brazil</td>
<td>Retrospective cohort study</td>
<td>54 patients</td>
<td>In a study involving 54 women (mean age 58.70 ± 7.35 years), the diagnostic performance of various imaging tools for detecting low bone mineral density (BMD) was evaluated. The sensitivity and specificity for digital panoramic radiography (DPR) were 52.6% and 56.2%, respectively. The positive likelihood ratio ranged from 1.00 to 1.40, and the negative likelihood ratio from 0.76 to 1.00. The positive predictive value ranged from 70.4% to 76.9%, and the negative predictive value from 29.6% to 35.7%. The highest area under the curve (AUC) was observed for CBCT with 25 mm slice thickness at 57.6%.</td>
</tr>
<tr>
<td>3.</td>
<td>Kathirvelu, et al.¹³ (2019)</td>
<td>India</td>
<td>Retrospective cohort study</td>
<td>76 patients</td>
<td>The study compared standard (manual) measurements of mandibular cortical thickness (MCT) with measurements using a proposed semi-automated scheme, finding a high correlation ($r = 0.96$, $p &lt; 0.01$). Receiver operating characteristic (ROC) analysis identified an MCT threshold of 2.5 mm as optimal for detecting individuals at risk of low bone mineral density (BMD).</td>
</tr>
<tr>
<td>4.</td>
<td>Chongruangsri, et al.¹⁴ (2019)</td>
<td>Thailand</td>
<td>Cross sectional study</td>
<td>60 patients</td>
<td>The study found significant differences in mandibular cortical index (MCI) among three groups ($p &lt; 0.001$). There were significant correlations between panoramic radiographic indices and bone mineral density (BMD) in the hip bone and lumbar spine. Specifically,</td>
</tr>
</tbody>
</table>
mandibular index (MI) was positively correlated with BMDs in the lumbar spine \((r = 0.566)\), femoral neck \((r = 0.554)\), and total hip \((r = 0.524)\), all with \(p < 0.001\). Conversely, MCI was negatively correlated with BMDs in the lumbar spine \((r = -0.514)\), femoral neck \((r = -0.507)\), and total hip \((r = -0.513)\), all with \(p < 0.001\). The cut-off value of MI for identifying reduced skeletal BMD (osteopenia and osteoporosis) was 3.9 mm, and for diagnosing osteoporosis was 3.8 mm.

<table>
<thead>
<tr>
<th></th>
<th>Study Details</th>
<th>Country</th>
<th>Study Type</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Carmo, et al.(^{15}) (2017)</td>
<td>Brazil</td>
<td>Cross sectional</td>
<td>396 patients</td>
</tr>
<tr>
<td></td>
<td>Mandibular indices and bone mineral density (BMD) at different sites. The mandibular index (MI) showed good agreement with lumbar spine BMD ((\text{Kappa} = 0.718)) but poor agreement with femoral neck BMD ((\text{Kappa} = 0.443)). The mandibular cortical index (MCI) had excellent agreement with lumbar spine BMD ((\text{Kappa} = 0.912)) and moderate agreement with femoral neck BMD ((\text{Kappa} = 0.579)).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Body mass index (BMI) is significantly lower in the osteoporotic group. There were no significant differences in serum levels of luteinizing hormone (LH), estradiol (E2), calcium, phosphate, and 25-hydroxyvitamin D ([25(\text{OH})\text{D}]) among the groups. However, levels of serum osteocalcin (s-OC), C-terminal propeptide of procollagen type I (s-PINP), serum C-terminal telopeptide of type I collagen (s-CTX), and urinary C-terminal telopeptide of type I collagen (urinary-CTX) were significantly higher in the osteoporosis group compared to the normal and osteopenia groups. ROC curve analysis showed that mandibular cortical width (MCW) and panoramic mandibular index (PMI) provided significant data, while the M/M ratio was non-significant.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The study found that mandibular height ranged from 13.42 to 34.42 mm, with a mean mandibular cortical width (MCW) of 3.31 mm. The mean values for the panoramic mandibular index (PMI) and the mandibular ratio (MR) were 0.33 and 2.57, respectively.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Higher mean amplitude-dependent speed of sound (Ad-SoS) was observed in the radius compared to the III finger, with lower T-score values in the phalanx than in the radius. Specifically, radius T-scores indicated osteopenia (T-score < -1.0) in 22 patients, while phalanx T-scores indicated osteopenia in 39 patients. The Mandibular Cortical Index (MCI) categorized 48 women as C1, 37 women as C2, and 12 women as C3, with higher scores recorded in older women. Additionally, MCI significantly correlated with skeletal status (p = 0.01), height (H), MCW, and MR. However, phalanx T-scores did not correlate with PMI, MR, or MCW.

<table>
<thead>
<tr>
<th>8.</th>
<th>Triantafyllopoulos, et al.18 (2023)</th>
<th>Greece</th>
<th>Cross sectional study</th>
<th>150 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The study found a statistically significant correlation between T-score and both the Mandibular Cortical Index (MCI) and Mandibular Cortical Width (MCW). Additionally, there was a significant correlation between age at menarche and T-score (p = 0.006).</td>
</tr>
</tbody>
</table>
DISCUSSION

The diagnostic performance of panoramic radiographs for screening bone mineral density (BMD) in women has been evaluated across various studies, revealing both strengths and limitations of this approach. Kim et al. (2016) demonstrated that mandibular index (MI) and mandibular cortical index (MCI) are significantly associated with BMD at the lumbar spine, femoral neck, and total hip. Specifically, they found that MI was positively correlated with BMD, and the optimal cut-off value for diagnosing spinal osteoporosis was 2.22 mm. This study highlights the utility of mandibular indices in assessing osteoporosis, indicating their potential as effective screening tools for BMD evaluation.\(^{11}\)

In contrast, Kato et al. (2019) focused on the diagnostic performance of digital panoramic radiography (DPR) and cone-beam computed tomography (CBCT). They reported sensitivity and specificity values for DPR of 52.6% and 56.2%, respectively, and found that CBCT with a 25 mm slice thickness had the highest area under the curve (AUC) at 57.6%. Despite the promising results for CBCT, DPR also showed potential, suggesting that while CBCT may offer superior accuracy, DPR remains a viable option for initial BMD screening, especially in resource-limited settings.\(^{12}\)

Kathirvelu et al. (2019) explored the accuracy of semi-automated mandibular cortical thickness (MCT) measurements compared to manual methods. Their findings revealed a high correlation (r = 0.96) and identified a threshold of 2.5 mm as optimal for detecting low BMD. This indicates that advancements in imaging technology, such as semi-automated methods, can enhance the precision of BMD assessments and improve early detection of osteoporosis.\(^{13,19}\)

Chongruangsri et al. (2019) found significant differences in MCI among different osteoporosis risk groups and established correlations between panoramic radiographic indices and BMD in the hip and lumbar spine. They observed that MI and MCI could be useful as screening tools for diagnosing osteoporosis in postmenopausal women. Their results
underscore the effectiveness of panoramic radiographic indices in distinguishing between various levels of osteoporosis risk.\textsuperscript{14,20}

Carmo et al. (2017) assessed the agreement between mandibular indices and BMD at different sites. They found good agreement between MI and lumbar spine BMD (Kappa = 0.718) and excellent agreement between MCI and lumbar spine BMD (Kappa = 0.912). These findings reinforce the reliability of mandibular indices in evaluating BMD, particularly when used in conjunction with other diagnostic tools.\textsuperscript{15,21}

Balto et al. (2018) highlighted the role of mandibular cortical width (MCW) and panoramic mandibular index (PMI) in detecting osteoporosis. They reported that MCW was particularly effective for predicting and diagnosing osteoporosis in postmenopausal women with low BMD. Their study emphasizes the importance of incorporating MCW in routine dental evaluations to identify individuals at high risk of osteoporosis.\textsuperscript{16,22}

Grocholewicz et al. (2018) confirmed that MCI could be used as a screening tool for detecting osteoporosis and found that quantitative ultrasound at the phalanx III was a reliable method for assessing bone status. This suggests that MCI, combined with other diagnostic techniques, can provide a comprehensive assessment of bone health.\textsuperscript{17,23}

Triantafyllopoulos et al. (2023) found a significant correlation between MCI, MCW, and T-score, and noted that combining MCW with age at menarche improved the detection of osteoporosis. They recommended referring individuals with MCW less than 3.0 mm and age at menarche later than 14 years for dual-energy X-ray absorptiometry (DXA), highlighting the value of integrating demographic factors with radiographic indices for more accurate osteoporosis screening.\textsuperscript{18}

Overall, the reviewed studies collectively demonstrate that panoramic radiographs, including MI, MCI, and MCW, are valuable tools for screening BMD and detecting osteoporosis. While panoramic radiographs provide useful preliminary information, the integration of these indices with other diagnostic methods, such as DXA and...
advanced imaging technologies, can enhance the accuracy of osteoporosis detection. Future research should continue to refine these tools and explore their applicability in diverse populations to ensure effective osteoporosis management and prevention.24,25

CONCLUSION
Overall, the reviewed studies collectively demonstrate that panoramic radiographs, including MI, MCI, and MCW, are valuable tools for screening bone mineral density (BMD) and detecting osteoporosis in women. Panoramic radiographs are effective in detecting osteoporosis, especially in postmenopausal women.

REFERENCES


11. Kim OS, Shin MH, Song IH, et al. Digital panoramic radiographs are useful for


