

Research article: Comparison of Mandibular Canal Superior Border Visibility in Panoramic Radiographs and CBCT Images: A Cross-Sectional Study



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ABSTRACT

Introduction: Accurate visualization of the mandibular canal (MC) superior border is critical for dental procedures, yet its visibility on panoramic radiographs (PRs) varies due to local anatomical factors. Cone-beam computed tomography (CBCT) was used in this study to compare MC superior border visibility with PRs and assess the impact of local anatomical factors on PR-based visualization.

Materials and Methods: In this cross-sectional study, CBCT scans and PRs of 360 patients (176 males, 184 females; mean age 47.34 ± 13.66 years) obtained between 2021 and 2022 from a private radiology center in Gilan Province, Iran, were analyzed across 360 dental segments at the second premolar, first molar, second molar, and third molar sites. MC superior border visibility on PRs was compared with CBCT, and its association with age, gender, tooth site, gray level, MC superior border-crest distance, buccal cortical plate thickness, and other factors was evaluated using independent t-tests and Chi-square tests ($\alpha = 0.05$).

Results: MC superior border visibility was significantly higher on CBCT (95.6%) than PRs (84.7%) ($P < 0.001$), with no difference between sides ($P > 0.05$). Visibility on PRs was significantly associated with younger age, male gender, third molar site, higher gray level, greater MC superior border-crest distance, and thicker buccal cortical plate ($P < 0.05$).

Conclusions: CBCT demonstrated higher visibility of the mandibular canal superior border compared with PRs. Limited visibility on PRs, influenced by demographic and anatomical factors, highlights the value of CBCT in cases requiring precise surgical or orthodontic planning.

1. Introduction

Knowledge about the anatomical details of the mandibular canal (MC), such as its status, path, and morphology, is a prerequisite for surgical interventions in the mandible, including dental implant surgery, surgical removal of impacted teeth, bone grafting, orthognathic surgery, apicoectomy, and orthodontic and root canal treatments (1-3). The MC morphology varies across different races and ethnic

groups, and such anatomical variations can increase the risk of MC damage during dental and surgical procedures (4). MC injury can lead to complications such as pain, edema, bleeding, infection, and mouth opening limitation, while nerve injury may cause itchiness, numbness, burning sensation, paresthesia, dysesthesia, pain in the lips, mucosa, and tongue, or even loss of taste (5,6). Comprehensive knowledge of factors influencing MC anatomical variations is essential to minimize these complications.

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Different imaging modalities, such as panoramic radiography (PR), periapical radiography, and cone-beam computed tomography (CBCT), are used to assess MC morphology. CBCT is the most accurate modality due to its lack of superimposition and high resolution (7-9). It also provides relative gray values that may reflect bone quality. However, its higher radiation dose and cost compared to PR and periapical radiography limit its routine use (10,11). In contrast, PR provides a two-dimensional image of three-dimensional structures with a larger field of view than periapical radiography, offering information about the maxilla, mandible, mid-face, nasal cavity, temporomandibular joints, and overall dental status (12,13). Despite its lower cost and radiation dose, PR has limitations, including 1.1 to 1.7 times magnification that varies across image regions, making linear measurements unreliable (14,15). Additionally, PR struggles to evaluate hard tissue morphology and bone density, and its two-dimensional nature leads to superimposition of anatomical structures (16-18). The MC, particularly its superior border, is challenging to visualize, with its lower border being more discernible on both PR and CBCT (19).

Previous studies have reported MC superior border visibility rates of 77.3–98.7% on PRs and 91.8–99.8% on CBCT across tooth sites (19,20). However, these studies often focus on visibility rates without systematically exploring local anatomical factors like buccal cortical plate thickness, MC superior border-crest distance, or cancellous bone density (1,20). For example, Ketabi et al. (1) found no significant effect of cortical bone thickness on MC superior border visibility, while Miles et al. (21) reported associations with age and tooth site, but not bone density. Jung and Cho (20) noted tooth site and age as factors but did not comprehensively assess gender or bone density. In contrast, Kubilius et al. (23) found no association with gender or densitometric parameters, highlighting conflicting findings possibly due to small sample sizes, inconsistent imaging protocols, or population differences (21-23). However, prior studies rarely examined the combined effects of buccal cortical plate thickness, MC superior border-crest distance, cancellous bone gray level, age, gender, and tooth site in a single framework. Additionally, conflicting findings in the literature, potentially due to small sample sizes, inconsistent imaging protocols, or population differences, further highlight the need for a more thorough and systematic analysis to clarify these relationships. This gap is critical because PRs are widely used in clinical practice due to their lower cost and radiation dose compared to CBCT, yet their limitations in visualizing the MC superior border can affect diagnostic accuracy and treatment planning in dental procedures. The present study addresses this gap by evaluating these anatomical factors using CBCT as a reference to improve

the understanding and optimization of MC visualization in PRs, thereby enhancing clinical outcomes in dental implantology, orthodontics, and other surgical interventions.

2. Materials and Methods

This cross-sectional study was conducted on 360 patients who presented to a private radiology center in Rasht, Gilan Province, Iran, between 2021 and 2022, and required both PRs and CBCT scans. Images were randomly retrieved from the center's archives using a table of random numbers. The study protocol was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1402.400).

The minimum sample size was calculated to be 549 dental segments assuming the ratio of visibility of the MC superior border to be 0.129 according to a previous study by Ketabi et al, (1) study power of 0.80, and $\alpha=0.05$ using MedCalc version 20.104. However, due to the available data, 360 patients corresponding to 360 dental segments were finally included in the study.

The inclusion criteria were (I) time interval of less than 6 months between PR and CBCT, (II) no surgical procedure at the site during the time interval between PR and CBCT, (III) no history of major surgical procedures or pathologies close to the MC, (IV) absence of traumatic or pathological lesions close to the MC canal affecting the surrounding bone, and (V) absence of patient positioning errors in PR.

To ensure no surgical procedure at the site during the time interval, patient records associated with the radiology center's archives were reviewed. These records included clinical histories, referral notes from referring dentists, and patient self-reported medical questionnaires completed at the time of imaging. Cases with documented surgical procedures during the interval were excluded. Additionally, radiographic evidence of surgical changes or pathological alterations in the mandibular region was assessed by an oral radiologist to further confirm eligibility. The exclusion criteria were (I) presence of a second premolar ahead of the mental foramen, (II) and deformation of MC superior border due to pathological lesions or traumatic injuries.

All radiographs were evaluated by a trained senior dental student under the supervision of an oral radiologist. To assess the visibility of the superior border of the mandibular canal (MC) on PR and CBCT scans, four standardized anatomical regions were evaluated, corresponding to the periapical areas of the second premolar, first molar, second molar, and third molar. The MC superior border was classified as visible if its entire outline could be distinctly traced as a continuous radiopaque line (on PRs) or a clear cortical boundary (on

CBCT coronal sections) in the selected region without interruption or ambiguity. The MC superior border was classified as non-visible if the outline was absent, discontinuous, or indistinguishable from surrounding bone structures due to lack of contrast or superimposition. Visibility assessments were performed independently for PR and CBCT images, with disagreements resolved by consensus between the dental student and the supervising oral radiologist to ensure consistency.

All CBCT images had been taken with X-MIND TRIUM CBCT scanner (ACTEON, Italy) with 100 μ m voxel size and 8 x 11-inch field of view, 90 mA tube current, and 90 kVp tube potential. The CBCT images were evaluated using OnDemand3D software (Cybermed Inc., Seoul, South Korea). All PRs had been taken with SCARA 2 X-ray unit (Planmeca, Finland).

For CBCT measurements, coronal sections were used to assess the superior border of the MC and associated anatomical parameters. Specifically, the coronal section immediately distal to the tooth (or equivalent region in edentulous cases, as described below) was selected to ensure consistency in measurement location across all tooth sites. The coronal plane was chosen because it provides a clear view of the MC's superior border relative to the bone crest and buccal cortical plate, minimizing superimposition of adjacent structures. The software toolbar was used to measure the following parameters:

Cancellous Bone Gray Level: Gray level was measured in a 3 x 3 mm region of interest (ROI) in cancellous bone immediately superior to the MC superior border on the selected coronal section, ensuring the ROI excluded cortical bone. The mean gray value (in Hounsfield-like units, as provided by the OnDemand3D software) was recorded. To minimize the influence of exposure or viewing conditions, all CBCT scans were acquired with standardized imaging parameters (fixed kVp, mA/s, and voxel size) and viewed under consistent display settings (same monitor calibration and ambient lighting conditions) by the evaluators. Additionally, the X-MIND TRIUM CBCT scanner's automated calibration protocol was applied before each imaging session to ensure consistent gray level output. While gray level is not a direct measure of bone density (as in dual-energy X-ray absorptiometry), it is a reliable proxy for relative bone density in CBCT imaging when standardized protocols are used, as supported by previous studies.

MC Superior Border-Crest Distance: The distance between the uppermost point of the MC superior border and the bone crest was measured along the longitudinal axis of the mandibular bone on the coronal section using the software's ruler tool.

Buccal Cortical Plate Thickness: The thickness of the

buccal cortical plate was measured at the distal part of the tooth (or equivalent region) on the same coronal section, defined as the shortest distance from the outer buccal cortical surface to the inner cortical-cancellous interface.

Other Measurements: Canal diameter (maximum superior-inferior distance) and total buccal bone thickness (shortest distance from the uppermost point of the MC superior border to the buccal surface, including both cortical and cancellous bone) were also measured on the coronal section.

Dentition status was recorded as the presence or absence of the respective tooth at the site (dental implants were considered equivalent to tooth presence, with measurements taken at the distal section of the crown). In cases of tooth extraction, four 2-mm coronal sections (8 mm) were evaluated for premolars, and five 2-mm coronal sections (10 mm) for molars, starting from the distal surface of the extracted tooth. In cases of complete edentulism, the distal section of the mental foramen was used as a reference for the second premolar site. The data were recorded in a checklist.

Normality of quantitative variables was assessed using the Shapiro–Wilk tests, and homogeneity of variances was evaluated with Levene's test. As the assumptions were satisfied, independent t-tests were applied to compare means between groups. For categorical variables, Chi-square tests were used. All statistical analyses were performed using SPSS version 28 (SPSS Inc., IL, USA), and a $P < 0.05$ was considered statistically significant.

3. Results

A total of 360 dental segments from 176 males (48.9%) and 184 females (51.1%) with a mean age of 47.34 ± 13.66 years (range 12 to 79 years) were evaluated. The gray level was 486.16 ± 241.38 . The mean distance between the MC superior border and bone crest was 14.39 ± 3.24 mm, the mean distance between the MC superior border and the inferior cortex of the mandible was 11.26 ± 1.87 mm, the mean buccal cortical bone thickness was 2.39 ± 0.66 mm, the mean canal diameter was 3.11 ± 0.71 mm, and the mean buccal bone thickness was 5.47 ± 1.58 mm.

Overall, 58.1% ($n = 209$) were edentulous and 41.9% ($n = 151$) were dentate. The MC superior border was visible on 84.7% ($n = 305$) of the PRs and 95.6% of the CBCT scans.

As shown in Table 1, age had a significant effect on the MC superior border visibility on PR images, such that its visibility was higher in younger patients ($P = 0.049$). The MC superior border visibility was significantly greater in males than females (Table 2; $P < 0.001$).

Table 1. Visibility of the MC superior border on PR and CBCT scans based on the mean age

Imaging modality	Visibility	Number	Mean age $\pm$ std. deviation (yrs.)	Statistic*	P value
PR	Not visible	55	51.89 $\pm$ 19.14	2.01	0.049
	Visible	305	46.52 $\pm$ 12.28		
CBCT	Not visible	16	44.94 $\pm$ 19.08	0.72	0.472
	Visible	344	47.46 $\pm$ 13.38		

* Independent t-test, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

Table 2. Visibility of the MC superior border on PR and CBCT scans based on gender

Imaging modality	Gender	Visibility		Statistic*	P value
		Not visible Number (%)	Visible Number (%)		
PR	Male	15 (8.5)	161 (91.5)	12.14	< 0.001
	Female	40 (21.7)	144 (78.3)		
CBCT	Male	5 (2.8)	171 (97.2)	2.08	0.149
	Female	11 (6)	173 (94)		

* Chi square, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

The MC superior border visibility on PR images was significantly different at the four sites ($P < 0.001$), such that it had a greater visibility at the third molar site than

other sites (Table 3). As shown in Table 4, the MC superior border visibility was significantly higher on PRs of cases with a higher gray level ($P < 0.001$).

Table 3. Visibility of the MC superior border on PR and CBCT scans based on tooth site

Imaging modality	Tooth site	Visibility		Statistic*	P value
		Not visible Number (%)	Visible Number (%)		
PR	Premolar	10 (11.1)	80 (88.9)	18.78	< 0.001
	First molar	25 (27.8)	65 (72.2)		
	Second molar	15 (16.7)	75 (83.3)		
	Third molar	5 (5.6)	85 (94.4)		
CBCT	Premolar	2 (2.2)	88 (97.8)	3.27	0.388
	First molar	4 (4.4)	86 (95.6)		
	Second molar	3 (3.3)	87 (96.7)		
	Third molar	7 (7.8)	83 (92.2)		

* Chi square, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

Table 4. Visibility of the MC superior border on PR and CBCT scans based on the gray level

Imaging modality	Visibility	Number	Mean $\pm$ std. deviation	Statistic*	P value
PR	Not visible	55	376.97 $\pm$ 196.57	4.30	<0.001
	Visible	305	505.84 $\pm$ 243.71		
CBCT	Not visible	16	446.95 $\pm$ 83.59	1.66	0.108
	Visible	344	487.98 $\pm$ 246.17		

* Independent t-test, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

The mean distance between the MC superior border-crest was significantly greater in cases with visible MC superior border on CBCT scans ($P = 0.004$) but not on PRs (Table 5). The buccal cortical plate thickness had a significant effect on the visibility of the MC superior

border on PR ($P = 0.012$) but not on CBCT ($P = 0.292$), such that the mean buccal cortical plate thickness was greater in cases with a visible MC superior border on PRs (Table 6).

Table 5. Visibility of the MC superior border on PR and CBCT scans based on the MC superior border-crest distance (mm)

Imaging modality	Visibility	Number	Mean $\pm$ std. deviation (mm)	Statistic*	P value
PR	Not visible	55	13.97 $\pm$ 2.86	1.05	0.296
	Visible	305	14.47 $\pm$ 3.31		
CBCT	Not visible	16	13.66 $\pm$ 1.17	3.13	0.004
	Visible	344	14.44 $\pm$ 3.30		

* Independent t-test, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

Table 6. Visibility of the MC superior border on PR and CBCT scans based on the mean buccal cortical plate thickness (mm)

Imaging modality	Visibility	Number	Mean $\pm$ std. deviation (mm)	Statistic*	P value
PR	Not visible	55	2.18 $\pm$ 0.76	2.53	0.012
	Visible	305	2.42 $\pm$ 0.64		
CBCT	Not visible	16	2.46 $\pm$ 0.26	1.08	0.292
	Visible	344	2.38 $\pm$ 0.67		



* Independent t-test, PR: Panoramic radiograph, CBCT: Cone-beam computed tomography

The MC superior border-inferior mandibular cortex had no significant effect on the visibility of the MC on either CBCT ($P = 0.548$) or PR ($P = 0.702$). The buccal bone thickness had no significant effect on the visibility of the MC on either CBCT ($P = 0.407$) or PR ($P = 0.765$). Canal diameter had no significant effect on the visibility of the MC on either CBCT ($P = 0.532$) or PR ($P = 0.160$). Dentition status had no significant effect on the visibility of the MC on either CBCT ($P = 0.236$) or PR ($P = 0.567$). Laterality had no significant effect on the visibility of the MC on either CBCT ($P = 0.265$) or PR ($P = 0.745$).

Visibility of the MC was significantly higher on CBCT scans than PRs ($P < 0.001$), such that in 45 cases (12.5%), their MC superior border was visible on CBCT scans but not on PRs. In only 6 cases (1.7%), the MC superior border was visible on PRs but not on CBCT scans.

4. Discussion

This study evaluated the influence of local anatomical factors on the visibility of the mandibular canal (MC) superior border on panoramic radiographs (PRs) using cone-beam computed tomography (CBCT) as a reference. The findings revealed no significant association between MC superior border visibility and the MC superior border-inferior mandibular cortex distance, dentition status, total buccal bone thickness, or canal diameter. However, significant associations were observed with age, gender, tooth site, gray level, MC superior border-crest distance, and buccal cortical plate thickness. The MC superior border was visible in 95.6% of CBCT scans compared to 84.7% of PRs, confirming CBCT's superior diagnostic accuracy, consistent with Ketabi et al. (1) and Jung and Cho (20). This enhanced visibility likely stems from CBCT's three-dimensional imaging, which mitigates superimposition issues inherent in PRs, as noted by Angelopoulos et al. (9). This finding underscores CBCT's value in preoperative planning for dental implants, where precise visualization of the MC is critical to avoid nerve injury (5, 6).

Gender differences were evident, with males exhibiting significantly higher MC superior border visibility than females, aligning with Miles et al. (21) and Iwanaga et al. (22). This may be attributed to anatomical

variations, such as thicker cortical bone in males, which enhances radiographic contrast (22). In contrast, Kubilius et al. (23) reported no gender association, potentially due to their smaller sample size or ethnic differences affecting bone morphology. These discrepancies highlight the need to consider population-specific factors when interpreting radiographic outcomes.

Age was inversely associated with MC superior border visibility, consistent with Miles et al. (21). This may reflect age-related bone density reduction, which reduces radiographic contrast (10). Conversely, Kubilius et al. (23) found no age-related differences, possibly due to their younger cohort (mean age 42 vs. 55 in this study) or less sensitive densitometric methods. These findings suggest that older patients may require CBCT for accurate MC assessment, particularly in complex surgical cases.

In the present study, dentition status showed no significant association with MC superior border visibility, which contrasts with the findings of Miles et al. (21) and Jung and Cho (20). This discrepancy may be related to differences in imaging modality, population characteristics, or study design. Edentulous regions may exhibit altered bone remodeling, affecting radiographic clarity (6). However, Kubilius et al. (23) found no such association, likely due to their focus on PR-based densitometry rather than CBCT's volumetric analysis. This discrepancy emphasizes the importance of imaging modality in detecting subtle anatomical variations.

Spatially, MC superior border visibility was highest at the third molar site, differing from Ketabi et al. (1), who reported peak visibility at the second premolar. This variation may result from differences in mean age (55 vs. 48 in Ketabi et al.) or regional bone thickness, as the third molar site often has denser cortical bone (3). These findings suggest site-specific considerations in implant planning, particularly in posterior mandibular regions.

Gray level, indicative of bone density, was significantly associated with MC superior border visibility in this study, unlike Kubilius et al. (23), who used PR-based densitometry. CBCT's ability to quantify gray levels volumetrically likely accounts for this difference, offering a more precise assessment of bone

density (10). Similarly, increased buccal cortical plate thickness enhanced MC superior border visibility, contrasting with Ketabi et al. (1). This may reflect our larger sample size ($n = 300$ vs. $n = 200$) or ethnic differences influencing cortical bone thickness. Poor MC superior border visibility on PRs may indicate a thin cortical plate, a critical factor in orthodontic anchorage and implant stability (16).

Laterality had no effect on MC superior border visibility, consistent with Kubilius et al. (23), suggesting symmetrical mandibular anatomy. However, discrepancies with Iwanaga et al. (22) regarding dentition status may stem from their focus on cadaveric samples, which lack dynamic bone remodeling seen in vivo.

This study has some limitations. Its retrospective design restricted control over imaging parameters and may have introduced bias. The single-center sample limits generalizability to other populations. CBCT gray level values may vary between devices, reducing reproducibility. Although patient records and radiographs were reviewed to exclude intervening surgery or bone-affecting medications, incomplete documentation could not be entirely avoided. Including dentate, implanted, and edentulous sites, despite using standardized landmarks, may have reduced comparability between PR and CBCT. Moreover, visibility assessment was partly subjective, and only buccal bone parameters were measured, while lingual bone thickness was not evaluated. Finally, the cortical thickness of the MC superior border itself was not assessed, which could play an important role in its radiographic detectability. Future studies should employ prospective designs with larger, diverse cohorts to validate these findings across populations. Investigating the impact of specific CBCT settings (e.g., voxel size, field of view) on MC superior border visibility could enhance diagnostic precision. Additionally, correlating MC superior border visibility with clinical outcomes, such as implant success rates or nerve injury incidence, would strengthen practical implications. Exploring machine learning algorithms to predict MC visibility based on anatomical and densitometric parameters could further refine preoperative assessments.

5. Conclusions

This study confirms CBCT's superior visualization of the MC superior border compared to PRs, with visibility influenced by age, gender, third molar site, cancellous bone gray level, MC superior border-crest distance, and

buccal cortical plate thickness. These findings advance our understanding of anatomical factors affecting MC visualization, offering novel insights into site-specific and demographic variations. Clinically, poor MC superior border visibility on PRs may be associated with lower cancellous bone gray levels, thinner buccal cortical plates, or other anatomical factors, suggesting a need for CBCT in cases where PRs provide inadequate visualization for precise surgical planning. This is particularly relevant in implantology and orthodontics to minimize nerve injury risks. While cancellous bone gray level, as measured in CBCT, serves as a proxy for relative bone density, it does not directly measure bone density, and clinicians should interpret these findings cautiously, considering additional diagnostic tools when assessing bone quality. These results advocate for tailored imaging protocols based on patient demographics and anatomical sites to optimize treatment outcomes.

Ethical Considerations

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Guilan University of Medical Sciences (Approval code: IR.GUMS.REC.1402.400).

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Authors' Contributions

Mostafa Hashemi: Investigation, Writing-Original Draft, Data curation **Hadi Ranjzad:** Visualization, Supervision, Project Administration **Farzane Ostovarrad** Methodology, Investigation, Visualization, Supervision, Resources **Ata Ollah Shahmalekpour:** Writing-Edit & Review, Data Curation.

Conflict of Interests

The authors declare that they have no conflicts of interest relevant to this study.

Availability of Data and Material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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