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Comparative efficacy of digital panoramic radiograph and cone beam computed tomography in locating mandibular foramen

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Abstract. – OBJECTIVE: The aim of this study was to compare the accuracy of panoramic radiographs (PAN) with cone-beam computed tomography (CBCT) in locating the position of the mandibular foramen (MF).

PATIENTS AND METHODS: A total of 100 patients who underwent CBCT and panoramic imaging were included in the study. The location of the MF was evaluated anterior-posteriorly and superior-inferiorly on both CBCT and panoramic radiographs. Measurements were taken by two examiners, reviewed by a radiologist, and intra-examiner variability was assessed. A comparison of statistical analysis was performed using the Mann-Whitney U test, independent and paired *t*-test. A *p*-value ≤0.05 was deemed significant.

RESULTS: The mean age of the patients was 35.03 years, with 51% females and 49% males. CBCT and panoramic radiographs showed comparable accuracy in locating the left (*p*=0.937) and right (*p*=0.371) MF anterior-posteriorly. In the superior-inferior dimension, the accuracy of CBCT and panoramic radiographs were comparable in locating the right (*p*=0.292) and left (*p*=0.640) MF. The gender-based accuracy of PAN and CBCT radiographs in locating the right (*p*=0.353) and left (*p*=0.985) MF was comparable.

CONCLUSIONS: The study concludes that panoramic radiographs showed comparable accuracy in effectively locating MF in comparison to CBCT. The influence of gender and anatomic location (right and left sides of MF) on MF identification with panoramic radiographs was insignificant. Digital panoramic radiographs are an effective tool in accurately identifying MF location in clinical practice.

Key Words:
Mandibular foramen, Cone-beam computed tomography, Panoramic radiograph, Anatomical variations, Accuracy.

Introduction

Locating the mandibular foramen (MF) has proven to be challenging, leading to difficulties in maxillofacial diagnosis, planning, and therapy. Injuries during surgical procedures have been associated with difficulty in locating the MF, including orthognathic surgeries[1]. Furthermore, for an adequate inferior alveolar nerve block (IANB), the identification of the precise location of MF is a key factor since proximity to the anesthetic needle is critical for a successful IANB[2]. The major factor for a technique failure of the IANB is due to erroneous positioning of the needle that is caused by the anatomical deviation of the MF[1]. Determining the exact position of the MF in a 3D view must allow for a simple process and good positioning when giving an IANB to maximize its success[3].

Cone beam computed tomography (CBCT) provides an accurate and versatile three-dimensional (3D) imagery of the anatomical structures and landmarks[3]. In addition, CBCT is integrated with multiple contemporary systems and software in endodontics, implant dentistry, and maxillofacial surgery for treatment planning and therapy[3]. By contrast, a panoramic radiograph is a simple, efficient, cost-effective, relatively low radiation, easily accessible, and non-invasive investigation[2,4]. Conventionally, panoramic radiographs have been shown[5] to be a critical contributor to the success of mandibular surgical procedures. Most of what was found in the literature regarding the anatomical variations of the MF location was through panoramic radiographs. However,

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there could be a possible misinterpretation or an inaccuracy in the panoramic radiograph due to the two-dimensional limitation of the panoramic imaging[5]. It is suggested that panoramic radiographs are useful in detecting the location of MF on two different panoramic images[4].

The location of the MF significantly varies between populations of different ages and can even vary in the same person on the right and left side[4]. The causes of these disparities can be due to the anatomical variations and differences in the growth of the skull and the face; therefore, an exact and precise measurement of the MF should be done before the beginning of any surgical procedure involving the mandible. Aside from the anatomical variations, gender-based variations have to be considered in the planning of surgical procedures, as females show smaller jaw dimensions than males[5]. Moreover, the distance between MF and the coronoid notch, the inferior border of the mandible, and the anterior and posterior border of the ramus are considerably greater when it comes to males compared to females[6].

Lasemi et al[2] and Matveeva et al[7] reported a method to detect the location of the MF based on standard measurements, including from the posterior border of the mandible to the midpoint of the MF fossa anteroposteriorly and from the mandibular notch towards the occlusal plane and the MF opening superior-inferiorly. However, these standards can vary based on ethnicity, and their validation in different populations is critical. The precise location of the MF can have a significant impact on various dental and surgical procedures, ultimately leading to more predictable and successful outcomes, particularly in procedures such as IANB anesthesia. In a study by Mathew and Mohan[8] (2023) performed among the South Indian population suggested that CBCT provided more accurate and detailed information regarding the prevalence and patterns of the anterior loop compared to orthopantomogram (OPG). In addition, Wei et al[9] evaluated the detection and characterization of anatomical structures, such as the anterior loop, accessory mental foramen, and lateral lingual foramen, and reported that CBCT offered superior visualization compared to OPG. Moreover, Mall et al[10] explored the varying locations of the mandibular canal and mental foramen using CBCT and OPG and concluded that CBCT exhibited better precision in identifying these landmarks. The working hypothesis in this study was that there is no significant difference in the accuracy of locating the position of the MF between panoramic images and CBCT images. Therefore, the study aimed to compare the accuracy of panoramic radiographs with cone-beam computed tomography in locating the position of the mandibular foramen.

Patients and Methods

Study Site and Sample Size Estimation

The study protocol was reviewed and approved by the Ethics and Review Board at King Saud University (Ref No. IRB-117-2021). This retrospective study was conducted at King Saud University Hospital and Dental University Hospital, Kingdom of Saudi Arabia. The sample size was determined with 80% power and 95% confidence level, using α as 0.05. We considered a significant difference (δ) of 2 mm±3.19[5] in the mean measurements between digital panoramic images and CBCT images as our primary outcome variable. Using the formula Z=1.96 (Z (1.96) 2=3.84), we calculated the required sample size (n) as {2[(2.0)2/ (5)2]} × 3.84, which resulted in a total of 100 patients being enrolled in the study.

Reference Points and Standardization of OPG

The CBCT and panoramic images of Saudi patients between 18 and 80 years who underwent preoperative imaging for various dental purposes were analyzed. The reference points initially were the anterior border of the mandible (AB), the posterior border of the mandible (PB) for the anterior-posterior (AP) dimension in relation to the MF, but only the AB was used, and the occlusal plane (OP) for the superior-inferior (SI) dimension in relation to the MF. The imaging process included setting up the software and imaging unit (Romexis, Planmeca, Hoffman estates, IL, USA). On the touchscreen, the Panoramic Standard program (60 Kv 4 mA 10 s), along with average patient size and jaw, was selected. For patient positioning, glasses, jewelry, all removable appliances, and hair accessories were removed. The patient stood tall, held handles, and walked close to the unit. The chin rest was adjusted, and the patient was made to bite on the stick with anterior teeth in the grooves. The posterior occlusal table was at a slight downward angle. The mid-sagittal laser was aligned between the eyes.

Prior to exposure, the patient was instructed to remain stationary, close lips, swallow, and

suction their tongue to the roof of their mouth for the entire exposure, holding down the exposure button until audible noises ceased.

Data Collection Procedure

A line was drawn horizontally from the anterior-inferior border of the MF to the AB and the distance AP dimension. Another line was drawn vertically from the extension of the first line, relating the location of MF to the occlusal surface of the lower molar, which refers to the OP for the SI (Figures 1 and 2). The data was extracted from Planmeca® (Promax 3D Classic, Helsinki, Finland) viewer and measurements (mm) were entered in Excel sheet (Microsoft Corporation, Washington DC, USA) with the following variables; age, gender, location of right MF anterior-posteriorly on CBCT (Loc CT R AP), location of right MF superior-inferiorly on CBCT (Loc CT R SI), location of left MF anterior-posteriorly on CBCT (Loc CT L AP), location of left MF superior-inferiorly on CBCT (Loc CT L SI), location of right MF anterior-posteriorly on Panoramic radiograph (Loc PAN R AP), location of right MF superior-inferiorly on Panoramic radiograph (Loc Pan R SI), location of left MF anterior-posteriorly on Panoramic radiograph (Loc PAN L AP), location of left MF superior-inferiorly on Panoramic radiograph (Loc PAN L SI).

Examiner Reliability and Evaluation Process

The inter-examiner reliability in this study was assessed through a rigorous process involving two examiners and a radiologist. Both panoramic and CBCT images were independently viewed and evaluated by the two examiners, ensuring a comprehensive analysis of MF localization. To further validate the accuracy and consistency of the results, a radiologist reviewed the images to provide an expert perspective. Additionally, to detect any inter-examiner variability, the images were re-evaluated by each examiner two times, with a two-week interval between evaluations (kappa scores). This repeated assessment allowed for the examination of potential variations in the examiners' interpretations over time.

Patient Selection Criteria

Healthy patients between the ages of 20 and 80 who had no significant medical conditions that could affect the mandibular anatomy were included. Patients with mandibular asymmetry, a history of mandibular fracture, pathology, or mandibular surgery were excluded. In addition, patients older than 80 or younger than 20 were also denied inclusion.

Statistical Analysis

Statistical analysis was performed using the Statistical Program for Social Sciences (SPSS) (Version 24, IBM Corp., Armonk, NY, USA). The normality distribution of the study variables was tested using the Kolmogorov-Smirnov test. Independent *t*-test, paired *t*-test, and Mann-Whitney U test were used to assess the accuracy of panoramic radiographs in comparison to CBCT in locating the MF as well as in relation to the other study variables. A p-value ≤ 0.05 was considered statistically significant.

Results

One hundred patients were recruited in this study; 51% were females, and 49% were males. The mean age of patients was 35.03±11.97 years. Since the age variable was not normally distributed, the median age was identified as 32 years (Table I).

Table II provides data on the location of the right MF anterior-posteriorly, using cone beam computed tomography (CBCT) and panoramic (PAN) radiography. The mean location of the right MF anterior-posteriorly on CBCT was 13.49±2.57. Additionally, the mean location of the right MF anterior-posteriorly on panoramic radiographs was 13.30±2.90. The *t*-value was 0.898, indicating a small difference between the AP location of mandibular foramina anteroposteriorly with CBCT and PAN. There was no significant difference between the mean values (p=0.371), indicating that the probability of obtaining PAN data was equal, as observed by CBCT data.

The mean rank for CBCT data was 95.69, indicating that, on average, the CBCT imaging technique ranked slightly lower in terms of identifying the location of the left MF anterior-posteriorly compared to panoramic radiographs (Table III). The sum of ranks, which represents the total rank of all the observations, was 9,186.00. The mean rank for this group was 96.32, which is slightly higher than the mean rank for the CBCT. When comparing CBCT and panoramic radiographs, there was no statistically significant difference (p=0.937) in the location of the left MF anterior-posteriorly, showing comparable outcomes for both methods.

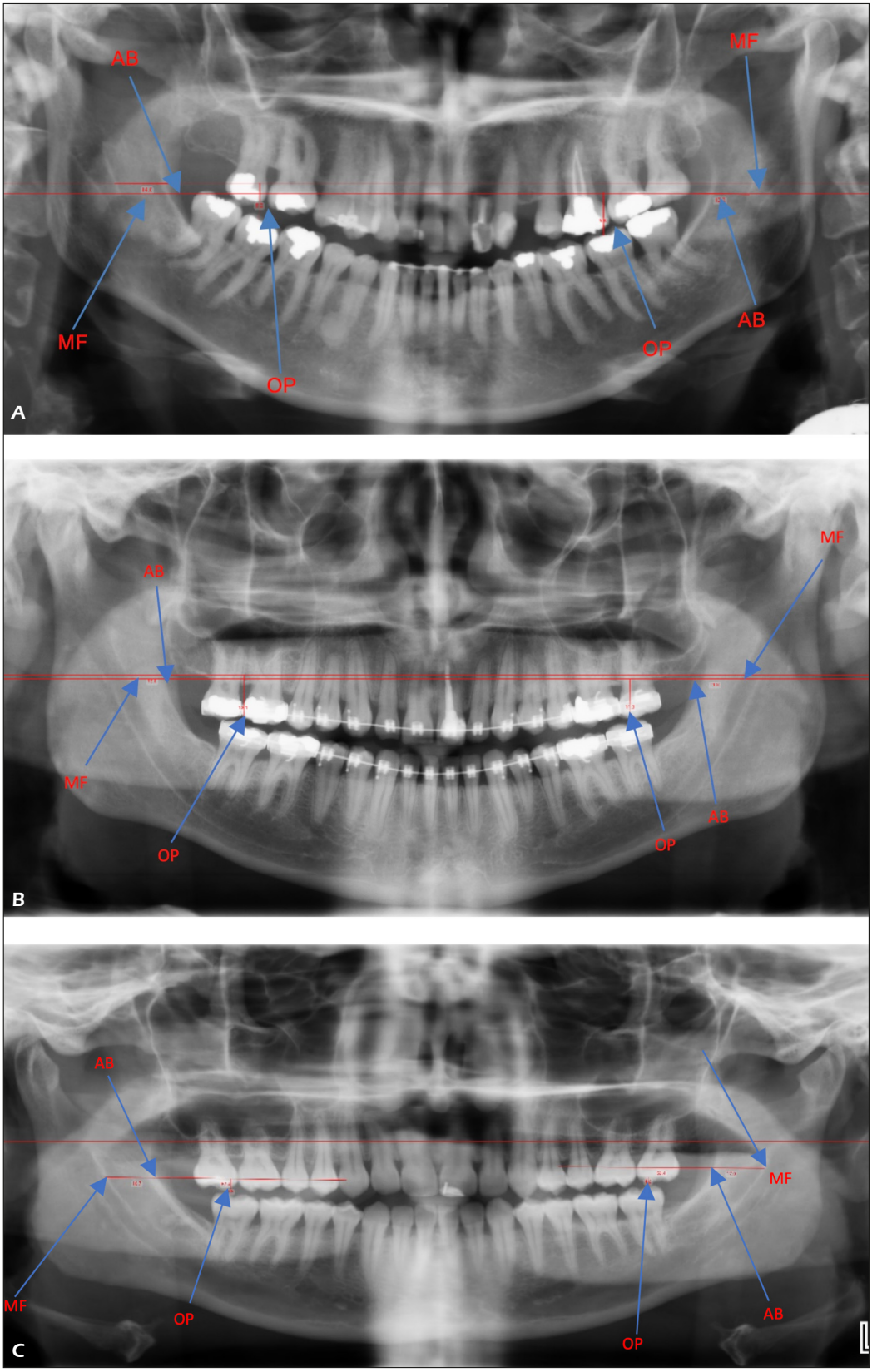

Figure 1. OPG images for patients showing mandibular foramen location. **A**, Patient 1, (**B**) Patient 2 and (**C**) Patient 3. AB – anterior border of the mandible, MF – mandibular foramen, OP – occlusal plane.

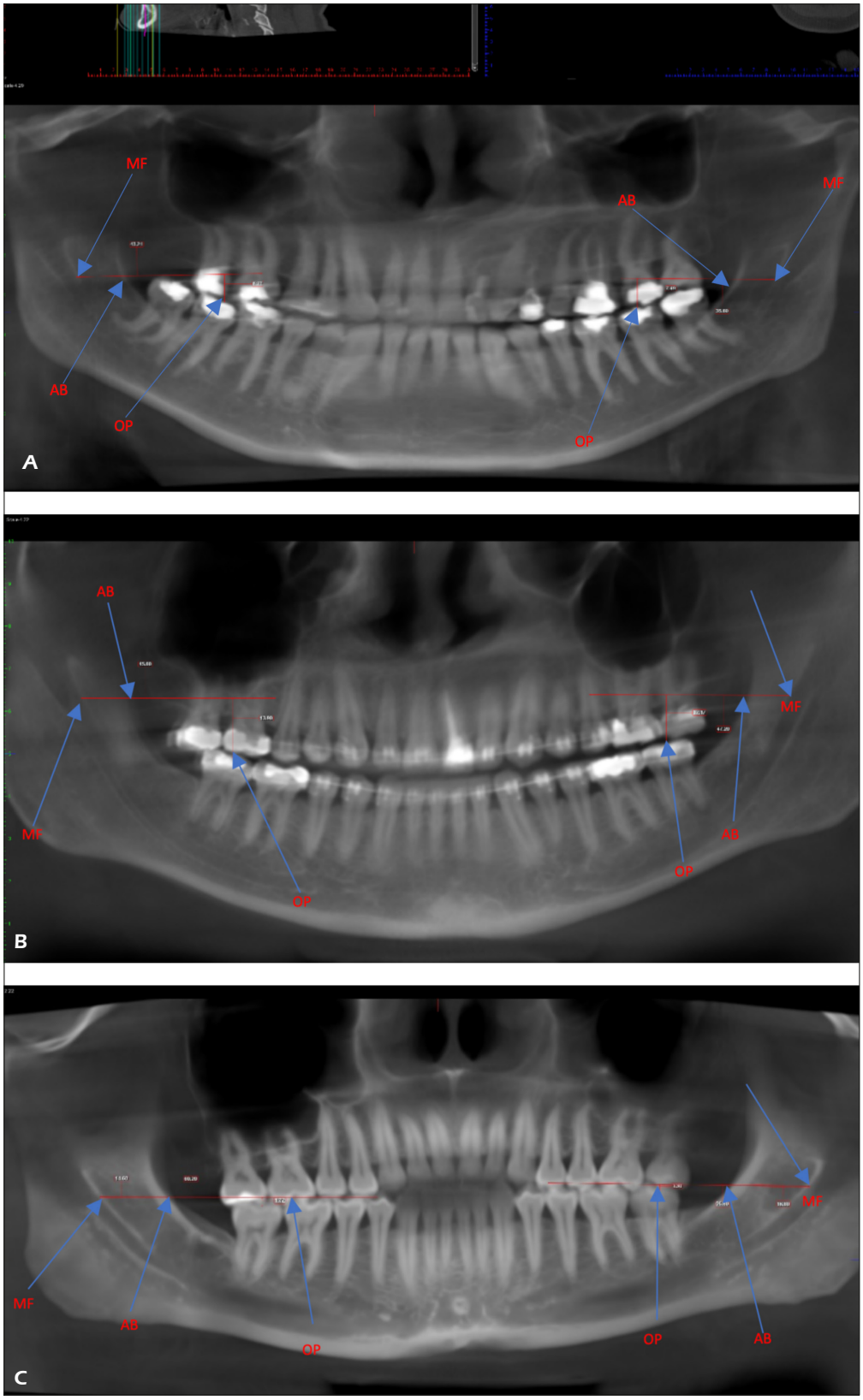

Figure 2. CBCT images for patients showing mandibular landmarks. **A**, Patient 1, (**B**) Patient 2 and (**C**) Patient 3. AB – anterior border of the mandible, MF – mandibular foramen, OP – occlusal plane.

Table I. Distribution of demographic characteristics of study participants.

		No.	Percent
Gender	Male	49	49.0%
	Female	51	51.0%
	Total	100	100%
Age			
Mean ± SD	35.03±11.97		
Years			
Median	31.50 years		
Min.	18 years		
Max.	80 years		

Table II. Loc R CBCT (AP) in relation to Loc R PAN (AP).

Variables	Mean	N	SD	*t*-value	*p*-value*
Loc CBCT R AP	13.49	96	2.57	0.898	0.371
Loc PAN R AP	13.30	96	2.90		

CBCT: cone beam computerized tomography, Loc: location, R: right, AP: anteroposterior, PAN: panoramic radiograph. *Paired *t*-test.

Table III. Comparison of Loc L CBCT (AP) to Loc L PAN (AP).

Radiographs	N	Mean rank	Sum of ranks	Mann-Whitney U	*p*-value
Loc L CBCT (AP)	96	95.69	9,186.00	4,530.000	0.937^{ns}
Loc L PAN (AP)	95	96.32	9,150.00		

CBCT: cone beam computerized tomography, Loc: location, L: left, PAN: panoramic radiograph, AP: anteroposterior, ^{ns}not significant (p>0.05).

Table IV presents the performance of CBCT and panoramic radiographs to determine the placement of the MF superior-inferiorly. There were 93 radiographs in the CBCT data for the right MF. The mean rank was 97.12. The overall rank of all the observations in this group, represented by the sum of ranks, was 9,032.50. The value determined when comparing the two groups was 3,894.500.

Similarly, 92 radiographs were included in the panoramic radiograph data for the right MF. This group's mean rank was 88.83, which is lower than the CBCT group's mean rank. The rank of all observations is represented by the sum of ranks, which was 8,172.50. The *p*-value was 0.292, indicating that there was no statistically significant difference in superior-inferior positioning of the right MF between CBCT and panoramic radiographs.

Table IV. Difference between Loc CBCT (SI) and Loc PAN (SI) on both sides.

Radiographs	N	Mean rank	Sum of ranks	Mann-Whitney U	*p*-value
Loc R CBCT (SI)	93	97.12	9,032.50	3,894.500	0.292^{ns}
Loc R PAN (SI)	92	88.83	8,172.50		
Loc L CBCT(SI)	95	96.85	9,201.00	4,289.000	0.640^{ns}
Loc L PAN (SI)	94	93.13	8,754.00		

CBCT: cone beam computerized tomography, Loc: location, R: right, SI: superior-inferior, PAN: panoramic radiograph, ^{ns}not significant (p>0.05).

Table V. Accuracy of panoramic radiographs and CBCT in locating the mandibular foramen by gender.

Variables	Gender	N	Mean	SD	*t*	*p*-value
Loc R PAN AP	Male	47	13.26	3.60	0.130	0.897^{ns}
	Female	49	13.33	2.05		
Loc R CBCT AP	Male	47	13.64	2.83	0.556	0.579^{ns}
	Female	49	13.35	2.32		

CBCT: cone beam computerized tomography, Loc: location, R: right, ^{ns}not significant (p>0.05). *Independent *t*-test.

Ninety-five radiographs were included in the CBCT analysis for the left MF. The mean rank was 96.85. The overall rank of all observations in this group was 9,201.00, represented by the sum of ranks. Furthermore, 94 radiographs were included in the panoramic radiograph data for the left MF. This group's mean rank was 93.13, which was greater than the CBCT group's mean rank. The sum of ranks was 8,754.00, representing the total rank of all the observations within this group. The difference between the superior-inferior location of the left MF between CBCT and panoramic radiographs was not significant (p=0.640).

Table V presents the analysis of the location of the right MF anterior-posteriorly on PAN and CBCT, categorized by gender. The mean measurement for males on panoramic radiographs was 13.26±3.60, while for females, it was 13.33±2.05. The *t*-value, which assesses differences between groups, was not statistically significant (t=0.130, p=0.897). The mean CBCT measurement for males was 13.64±2.83 and 13.35±2.32 for females. There was no statistically significant difference based on gender (p=0.579).

Table VI presents the accuracy comparison of panoramic (PAN) and CBCT radiographs in locating the MF in both sexes. For the right side, using Loc R Pan SI, there were 46 male and 46 female subjects. A *p*-value of 0.353 indicated no statistically significant difference between males and females in the accuracy of panoramic radiographs for this anatomical location. Similarly, for the Loc L Pan SI, there were 46 male and 48 female subjects. A *p*-value of 0.985 represents no significant difference in accuracy between genders.

In CBCT imaging Loc R CBCT SI, there were 45 male and 48 female patients. The *p*-value of 0.105 demonstrated no significant difference between both sexes. However, for the CBCT imaging on the left side using the standard inferior view (Loc L CBCT SI), there were 47 male and 49 female subjects. A *p*-value of 0.041 showed a significant difference between genders for CBCT on the left side. Lastly, for the left side with CBCT radiographs using the anterior-posterior view (Loc L CBCT AP), there were 47 male and 48 female subjects. However, it showed comparable outcomes between males and females (p=0.523) in the accuracy of CBCT.

Table VI. Accuracy of panoramic radiographs and CBCT in locating the mandibular foramen within gender.

Variables	Gender	N	Mean rank	Sum of ranks	Mann-Whitney U	*p*-value
Loc R PAN SI	Male	46	43.91	2,020.00	939.000	0.353
	Female	46	49.09	2,258.00		
Loc L PAN SI	Male	46	47.45	2,182.50	1,101.500	0.985
	Female	48	47.55	2,282.50		
Loc L PAN AP	Male	46	46.33	2,131.00	1,050.000	0.566
	Female	49	49.57	2,429.00		
Loc R CBCT SI	Male	45	51.69	2,326.00	869.000	0.105
	Female	48	42.60	2,045.00		
Loc L CBCT SI	Male	47	46.65	2,192.50	853.000	0.041*
	Female	49	50.28	2,463.50		
Loc L CBCT AP	Male	47	53.85	2,531.00	1,064.500	0.523
	Female	48	42.27	2,029.00		

Loc: location; R: right, L: left, PAN: panoramic, AP: anteroposterior, SI: superior inferiorly, CBCT: cone beam computerized tomography. *Significant at <0.05.

Discussion

One of the most critical landmarks in the mandible is the MF. Understanding the position of the MF is key for the identification and management of various dental procedures. Identification of the precise location of the MF maximizes the success of the anesthetic procedures and preservation of the inferior alveolar nerve[10]. The purpose of this study was to compare the accuracy of panoramic radiographs with CBCT in locating the position of MF. The study findings indicate that panoramic radiographs can effectively and reliably be used to locate MF, and their accuracy is comparable to CBCT. Based on the findings, the working hypothesis was accepted.

According to Shokri et al[11], after evaluating the location of the MF in CBCT, they showed no significant difference in the variations of anatomic locations and dimensions measured and no difference between the right and left sides. Their finding was in accordance with the present study. Furthermore, Zhou et al[12] reported slight anatomical variation in MF in their study, as 84.3% of the MF were 4.5 mm below the occlusal plane. In addition, the mean distance between the mandibular lingula and the occlusal plane was 5.9 mm above the occlusal plane. Similarly, a study by Trost et al[13] showed that the position of MF varies; they suggested a "safety zone" where MF is unlikely to be found; it was defined as the superior and posterior thirds of the ramus. The location of MF at the medial aspect of the ramus has been suggested in previous literature in anatomical or radiological investigations.

The study findings reveal gender-based differences in the accuracy of panoramic and CBCT radiographs for locating the MF. Panoramic radiographs showed no significant difference between genders for both the right and left sides, indicating their reliability regardless of gender. However, CBCT demonstrated a significant gender-based difference on the left side's standard inferior view, with higher accuracy in females compared to males. No significant gender-related differences were observed in the anterior-posterior view. To strengthen these findings, future research should involve larger and more diverse patient populations, investigate anatomical or physiological gender-related variations, and explore the influence of patient characteristics on MF localization[14,15].

Additionally, it is imperative to acknowledge a recent study by Salsabilla et al[16] (2022), which concludes that the height of the mandible ramus and the distance of the mental foramen on a panoramic radiograph differ significantly between males and females. This contrasts with our findings, and the study further emphasizes the gender-based anatomical variations to be considered in dental radiography.

This study comprehensively utilized both panoramic radiographs and CBCT to maximize the accuracy of MF location. The use of two observers to examine the data also strengthens the reliability of the findings. Furthermore, the incorporation of additional dimensions, such as the anterior border of the ramus to the MF and the occlusal plane, indicates a thorough approach to assess accuracy. The absence of a significant difference in MF location between CBCT and panoramic radiographs suggests that both imaging modalities are comparable in this aspect, which is consistent with the findings of previous studies[7-9,17]. These studies have also reported similar results, demonstrating the reliability of both panoramic and CBCT radiographs in assessing anatomical structures like the MF.

Expanding on the clinical implications, our study provides valuable insights into the decision-making process for clinicians. Accurate mandibular foramen localization is pivotal in optimizing surgical planning and nerve block procedures, such as extractions or surgical interventions. Other applications include local anesthesia, endodontic and orthodontic treatments, and maxillofacial surgeries involving the anterior mandible, thereby potentially improving patient outcomes. The integration of our findings with recent research highlights the clinical relevance of our study[18].

Limitations

It is important to consider the limitations of the study. The age distribution of participants was not uniform, potentially introducing bias. A more diverse and representative sample across different age groups would strengthen the study outcome. Operator experience and variability can influence radiographic measurements and standardization of imaging protocols. Moreover, the resolution of the imaging modalities used (CBCT and panoramic radiographs) was not specified, which could influence the clarity and precision of anatomical localization. Despite these shortcomings, the study's findings contribute valuable insights to the field of dental imaging. Understanding the accuracy and potential differences between panoramic and CBCT radiographs in locating the

MF can aid clinicians in making informed decisions regarding diagnostic and treatment planning procedures. Both imaging modalities have unique advantages and limitations, and this study provides evidence that they can be used interchangeably in specific clinical scenarios.

Future studies should further explicate the clinical relevance, and an investigation into the impact of accurate MF localization on surgical planning and nerve block procedures is essential. Conducting longitudinal studies will be crucial in understanding age-related variations in the MF's location. Additionally, the assessment of emerging imaging modalities, such as digital volumetric tomography (DVT), in comparison with traditional CBCT and panoramic radiographs, will provide valuable insights into their accuracy and potential.

Conclusions

The efficacy of CBCT and panoramic radiographs in the identification of mandibular foramen location was comparable in the measurements made anterior-posteriorly and superior-inferiorly. In addition, there was no gender disparity. Therefore, panoramic radiographs can be used effectively to locate the MF for clinical diagnosis and treatment planning.

Informed Consent
All participants were requested to read and sign a written informed consent form.

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Authors' Contributions
YA, WAM, MA, and AA: Data collection, study design, manuscript writing, and final manuscript approval. MA, AA, and AAL: Data collection, study design, manuscript drafting, data analysis, and manuscript approval. WAM, MA, and AA: Data collection, data interpretation, writing, revising, and editing, and final manuscript approval.

Ethics Approval
The King Saud University, College of Dentistry, Institutional Review Board reviewed the protocol and approved the study (Ref No. IRB-117-2021).

Conflict of Interest
The authors declare that they have no conflict of interest and all authors have read and approved the final draft.

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Data Availability
The raw data of the study can be provided through a reasonable request from the corresponding author.

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