



ORIGINAL ARTICLE

# Accuracy of intraoral digital radiography in assessing maxillary Sinus-Root relationship compared to CBCT



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Received 4 January 2022; revised 19 April 2022; accepted 22 April 2022

Available online 28 April 2022

## KEYWORDS

Cone Beam Computed Tomography;  
Periapical Radiography;  
Maxillary Sinus;  
Maxillary Molars

**Abstract** *Background and Objectives:* The proper assessment of the relation between the roots of the maxillary posterior teeth and the maxillary sinus floor represents a real concern for dental practitioners when conducting any procedure in the involved region. Many imaging techniques have been employed to assess this relation. This study aimed to (1) compare the accuracy of digital periapical radiographs with that of cone-beam computed tomography images in assessing the relationship between the maxillary molar roots and the maxillary sinus floor and (2) determine periapical radiographic features (if present) that could indicate the actual protrusion of roots into the sinus cavity.

*Materials and Methods:* **This observational analytical in vivo** study was carried out on 23 Egyptian patients. Cone-beam computed tomography and digital periapical images were obtained for each patient and assessed by three oral radiologists. Results were statistically analyzed in terms of accuracy, specificity, and sensitivity in addition to the McNemar-Bowker and Fleiss's Kappa test.

*Results:* Despite the presence of a significant difference between the results of both techniques, periapical radiography demonstrated 73% accuracy in displaying the sinus-root relation. Moreover, the continuity of the lamina dura suggests (with more than 70% accuracy) that the root is located outside the sinus and vice versa.

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Peer review under responsibility of King Saud University.



**Conclusion:** The digital periapical technique is considered an accurate method of assessing the sinus-root relation especially when the root is located outside the sinus. One of the most indicative periapical features of root intrusion into the maxillary sinus is the discontinuity of the lamina dura.

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## 1. Introduction

The proximity of the maxillary sinus floor (MSF) to the root apices of the maxillary molars renders it susceptible to the so-called oro-antral fistula during any surgical or endodontic procedure in the involved area. Thus, the treatment plan may be switched from just a simple extraction to a surgical extraction that may require a more advanced method of fistula closure (Lopes et al. 2016). Therefore, a proper assessment of the sinus-root relation through the most suitable imaging modality is required.

Two-dimensional (2D) imaging is a widely used approach that is highly tolerable and widely available at relatively low doses and cost (Alaqel 2016; Low et al. 2008). However, the main drawbacks of this modality are the superimposition of anatomical structures, image distortion through unwanted magnification, and the inability to provide cross-sectional information (Low et al. 2008).

On the other hand, Cone-beam computed tomography (CBCT) provides high-resolution images with a lack of superimposition, absence of geometric distortions, and three-dimensional (3D) display (Scarfe and Farman 2008). However, the radiation dose and cost of CBCT scans are higher than those of the 2D imaging techniques, which is why the use of CBCT should be reserved for selected cases.

Many studies estimated the accuracy of 2D imaging in assessing the sinus-root relation in comparison to CBCT. Some of these studies (Bokkasam et al. 2015; Malina-Altzinger et al. 2015) reported the reliability of panoramic radiographs in estimating the involved relation, while other studies (Dehghani et al. 2017; Roque-Torres et al. 2015; Shahbazian et al. 2014; Terlemez et al. 2019) reported its unreliability, especially when the roots protrude the maxillary sinus (MS).

Hassan B. (Hassan 2010) concluded that both periapical and panoramic radiographs were not reliable in the determination of the exact sinus-root relation. Moreover, Shahbazian et al. (Shahbazian et al. 2015) reported the inadequacy of periapical radiographs in revealing the sinus-root relation.

This conflict inspired researchers to carry out different studies aimed at identifying some panoramic features that may indicate the actual protrusion of the root into the sinus (Lopes et al. 2016; Themkumkwun et al. 2019). Some of these features are root projection into the sinus, the interruption of the MSF, and the darkening of the involved root apical region.

Based on the previous points, there is a fierce debate among researchers about the reliability of 2D imaging in assessing the sinus-root relation. This controversy motivated us to carry out this study aiming to compare the accuracy of intraoral *digital periapical radiographs* with that of CBCT images in assessing the relationship between the maxillary molar roots and the MSF and, also, to determine periapical radiographic features (if present) that could indicate the actual protrusion of roots into the sinus cavity.

## 2. Materials and methods

### 2.1. Study design and population

This is an observational analytical *in vivo* study that was carried out in the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Ain Shams University, from June 2019 to November 2020. Sample size calculation was done according to the findings of the study by Lopes et al. (Lopes et al. 2016), which is considered the closest study to the current one, using an alpha ( $\alpha$ ) level of 0.05 (5%) and a Beta ( $\beta$ ) level of 0.20 (20%) i.e., power = 80%.

The study sample consists of 23 patients (with a total of 342 roots) who were referred by their dentists to our oral radiology clinic to undergo CBCT scanning on the maxillary arch for different purposes such as implant planning and maxillofacial surgery. Participants were selected according to the following criteria:

#### Inclusion criteria

1. The patient's age should be above twenty-one years.
2. Molar roots should have closed apices.

#### Exclusion criteria

- 1- Patients' roots with chronic periapical lesions, root abnormalities (e.g., external resorption), or any intraosseous pathology (e.g., cysts or tumors).
- 2- Orthodontically treated teeth.
- 3- Syndromic or non-syndromic congenital dental anomalies.
- 4- Sinus abnormalities (developmental or acquired)

### 2.2. Ethical consent

The study was approved by the Research Ethics Committee of the Faculty of Dentistry, Ain Shams University, approval number FDASU-Rec IM121804. All patients gave their written informed consent to participate in the study.

### 2.3. Image acquisition, Observation, and scoring

The CBCT images, which are considered our gold standard, were obtained first using an i-CAT next-generation scanner (Imaging Sciences International, Hatfield, PA, United States) operating at a tube voltage of 120 kVp, tube current of 5 mA, voxel size of 0.2 mm, field-of-view of 16 × 6 cm, and scanning time of 26.9 s. Then, digital periapical images were obtained for each patient, on the upper molar region on each side using a paralleling technique by the Evostyle periapical machine (RYCB-X/1 -Italy) operating at an exposure time of 0.1 s, tube voltage of 70 kVp, and tube current of 8 mA using EZsensor HD from VaTech.

CBCT images were assessed on the multiplanar reconstruction screen of i-CAT vision viewer (version 1.9.3.13) while periapical images were assessed on EZ Dent-i (version 2.0.2.0, VaTech, Germany).

The topographic relationship of each root of each maxillary molar to the MSF was studied by three oral radiologists, each with a minimum of three years of experience in the field. Observers were asked to assess each of the two imaging techniques as a separate subset in a random sequence. The examiners were blinded to the patients' data.

Periapical and CBCT images were classified and given scores as follows (Figs. 1 & 2):

- **Score 1:** When the root apex is placed outside the sinus.
- **Score 2:** When the root apex is just contacting the MSF.
- **Score3:** When the root apex is projected into the sinus.

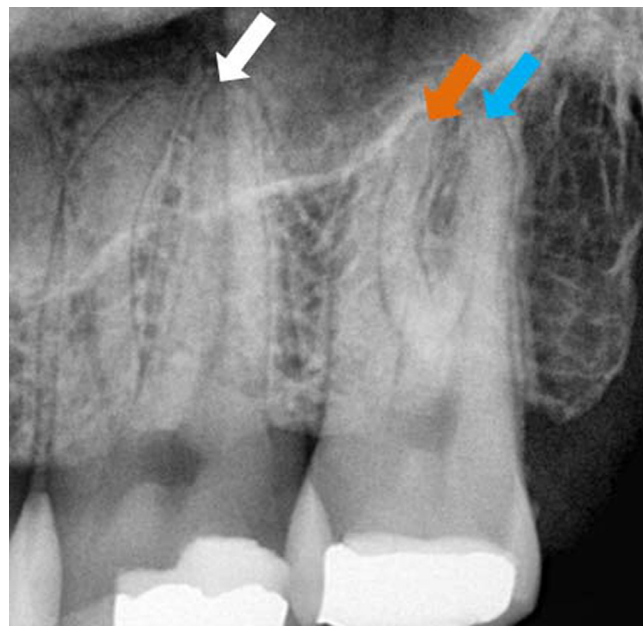
In addition, all roots were assessed and scored for the following radiographic signs on the periapical images only (Fig. 3).

- **A** = Interruption of the MSF
- **B** = Discontinuity of lamina dura
- **C** = Upward bending of the MSF to envelop the root partially or completely

All the data were collected and any disagreement between the observers about the result was solved by a consensus.

#### 2.4. Statistical analysis

The reliability of the digital periapical imaging technique in assessing the sinus-root relation was investigated via three different methods, the first of them being the McNemar-Bowker test. Fleiss's Kappa test was the second test used for further investigation and for detecting the inter-rater and intra-rater



**Fig. 1** Cropped digital periapical image showing: Score 1 (Blue arrow), Score 2 (Orange arrow) and Score 3 (White arrow).

reliability between the observers with regards to CBCT and periapical images.

Moreover, the reliability of digital periapical images was assessed in terms of accuracy, specificity, and sensitivity. This was the same method used to determine if any of our involved periapical features was reliable in indicating the intrusion of the root into the sinus.

### 3. Results

This study involved 23 Egyptian patients with a mean age of  $33.4 \pm 10.7$  with a total of 342 maxillary molar roots. Ten of our study participants were males with a total of 153 roots and 13 of them were females with a total of 189 roots. The inter and intra-rater reliability between the observers upon CBCT and periapical images was high in scores 1 and 3 and low in score 2 in both imaging modalities. The degree of agreement was demonstrated in detail in a previously published study (Eid, El-Badawy, and Hamed 2021).

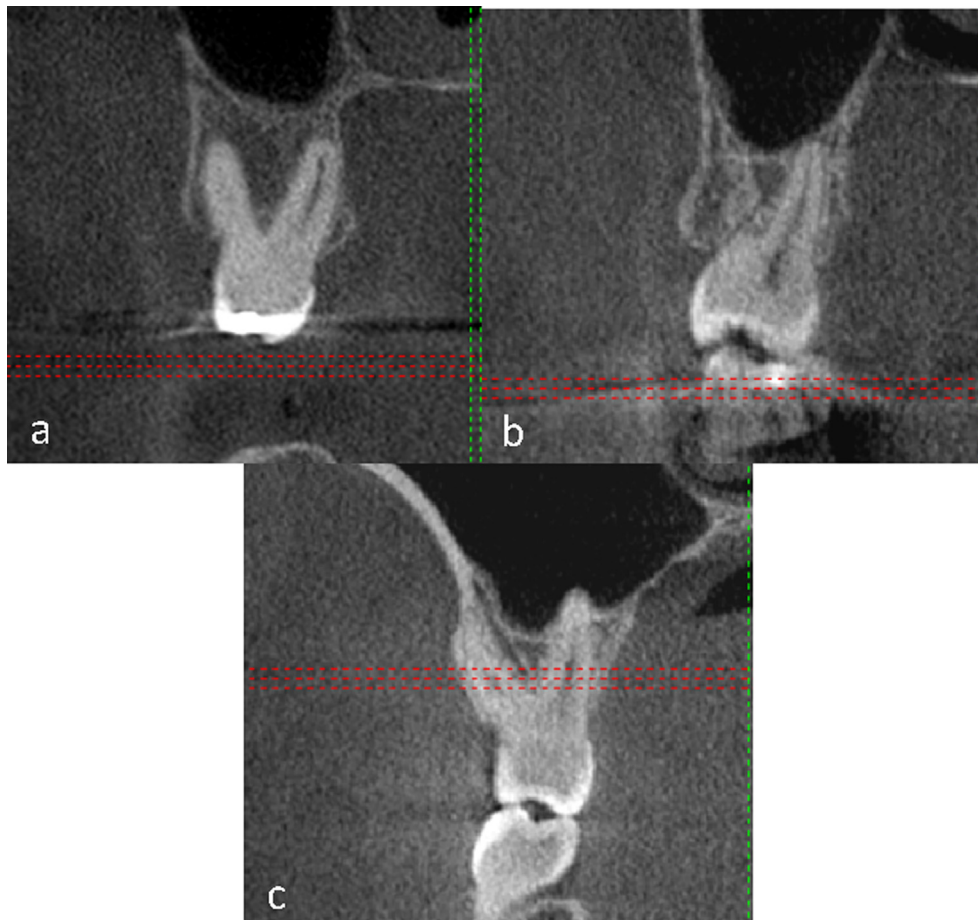
Using the McNemar-Bowker test, the level of statistical significance was set at a p-value  $< 0.05$ . We found a significant difference between the two imaging modalities. Fleiss's Kappa test demonstrated that the intra-rater reliability of the main researcher upon both CBCT and digital periapical readings was exactly the same. It was overall excellent 0.87, excellent 0.96 at roots away from the MSF (Score 1), very good 0.77 at roots at the sinus floor (Score 2), and excellent 0.85 at roots inside the sinus (Score 3).

The reliability of the digital periapical paralleling technique was further evaluated in terms of accuracy, sensitivity, and specificity (Table 1). In this test, the true positive is represented in the actual intrusion of the root into the sinus (score 3) in CBCT images, while the true negative is represented in the cases where the root was placed outside the sinus or contacted the MSF in CBCT images (scores 1 and 2 collectively).

The data provided in Table 1 means that if the root is outside the sinus or contacting its floor, the periapical technique can display that correctly by 88%. However, if the root was inside the sinus the periapical technique can predict that by 63% with only a 37% chance of false assumption that the root is inside.

Three features were assessed to help indicate the root intrusion into the sinus on the periapical radiographs: A = Interruption of the MSF, B = Discontinuity of the lamina dura, and C = upward bending of the MSF. The percentage of incidence of these features was 3.5%, 38%, 4%, respectively. Combinations of features occurred only as AB and BC, and never the three factors together. Their incidence percentages were 2.9% and 1.16%, respectively.

The reliability of the periapical features was tested using sensitivity, specificity, and accuracy for each periapical feature separately, and then the combined features. The data in Table 2 and Fig. 4 show that the presence of any of the features strongly suggests the intrusion of the root into the sinus. However, the absence of any of these features does not imply that the root is placed outside the sinus, except for the interruption of the lamina dura, which is the only feature that can indicate both intrusion and extrusion of the root from the sinus. In other words, the continuity of the lamina dura suggests (with more than 70% accuracy) that the root is located outside the sinus and vice versa.



**Fig. 2** Cropped CBCT coronal cuts, **a** shows roots with Score 1, **b** shows root with Score 2 and **c** shows root with Score 3.

#### 4. Discussion

The proper assessment of the sinus-root relation represents a real concern for dental practitioners on conducting any procedure in the maxillary posterior region. For this reason, the current study was conducted to evaluate the reliability of the periapical technique in assessing the sinus-root relation with CBCT images as the gold standard.

Only patients older than 21 years were selected to ensure that each one had complete eruption and formation of both the maxillary molars and MS. Roots with chronic periapical lesions were excluded to avoid any confusion in the observation. Also, teeth under orthodontic treatment were excluded because of the effect of this treatment on their periodontal ligament space and, consequently, the lamina dura. Supernumerary and supplemental teeth were excluded because of their confusing abnormal shapes and positions.

The scoring system implemented in this study was previously proposed by many studies (Bokkasam et al. 2015; Gu et al. 2018; Hassan 2010; Kaushik et al. 2020; Terlemez et al. 2019). It was chosen because of its simplicity in observation and data analysis. Only a few studies used this scoring system in an inverted manner (Makris et al. 2020; Zhang et al. 2019).

The reliability of the periapical technique in assessing the sinus-root relation was assessed by three different tests to reach a decisive conclusion. The McNemar-Bowker test indicated the presence of a significant difference between the

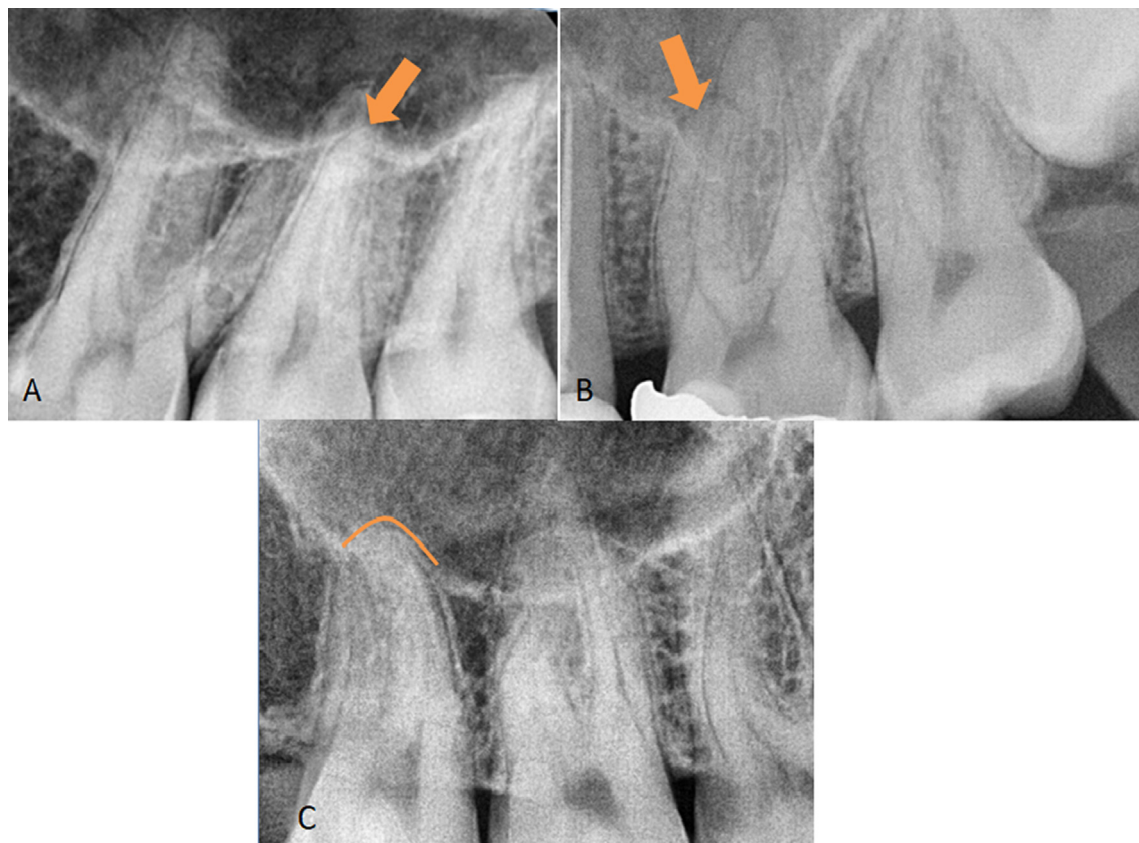
results of CBCT and periapical images. Similar results were reported by Shahbazian et al. (Shahbazian et al. 2015) who used the same statistical test in their study.

Fleiss's Kappa test reported that the highest degree of agreement was in score 1, followed by score 3, and then score 2. These results differ from those reported by Hassan B. (Hassan 2010) who used Cohen's kappa test to report that the highest degree of agreement was in cases where the root intruded the sinus, followed by those where the roots were placed outside the sinus. However, our results were in line with those of Hassan B. in that the lowest degree of disagreement occurred in score 2 where the roots contacted the MSF.

Regarding accuracy, sensitivity, and specificity test, it was not used by any previous study assessing the periapical technique reliability in referral to CBCT. However, we implemented it in this study as it was recently proven that from a statistical point of view, estimates of diagnostic specificity, sensitivity, and positive and negative predictive values against a "ground truth" are most useful in evaluating the diagnostic variability among multiple raters (Marchevsky et al. 2020).

The innovation of the current study lies in its evaluation of the reliability of some periapical features in assessing root intrusion into the sinus. Lopes LJ et al. (Lopes et al. 2016) and Themkumkwun S et al. (Themkumkwun et al. 2019) proposed five features represented in the interruption of the MSF, discontinuity of the lamina dura, upward bending of the MSF to envelop the root partially or completely, the projection of





**Fig. 3** Digital periapical images showing: A = Interruption of the MSF, B = Discontinuity of lamina dura and C = Upward bending of the MSF to envelop the root.

**Table 1** Percentage sensitivity, specificity, and accuracy of the periapical imaging technique in assessing the sinus-root relationship.

<b>Accuracy</b>	0.73	73%
<b>Specificity</b>	0.63	63%
<b>Sensitivity</b>	0.88	88%
<b>False-positive rate</b>	0.37	37%
<b>Positive predictive value</b>	0.63	63%
<b>Negative predictive value</b>	0.88	88%

**Table 2** Sensitivity, specificity, accuracy, false-positive rate, positive predictive value, and negative predictive value for each periapical feature separately and the combined features.

<b>Feature</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>AB</b>	<b>BC</b>
<b>Sensitivity</b>	0.06	0.6	0.1	0.05	0.02
<b>Specificity</b>	0.99	0.83	1	0.99	1
<b>Accuracy</b>	0.53	0.71	0.5	0.53	0.52
<b>False-positive rate</b>	0.01	0.17	0	0.005	0
<b>Positive predictive value</b>	0.83	0.77	0.8	0.9	1
<b>Negative predictive value</b>	0.52	0.68	0.5	0.52	0.51

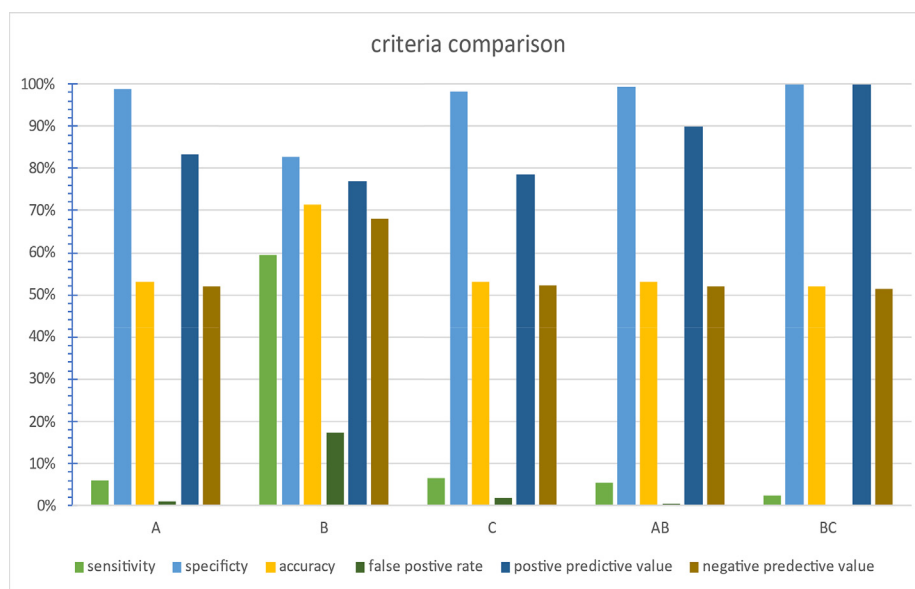
the root into the sinus, and the darkening of root periapical region.

The current study involved only three of the previous features represented in the interruption of the MSF, discontinuity of lamina dura, and upward bending of the MSF to envelop the root partially or completely. The other two features were ignored in this study because root projection is already involved in the scoring system and the darkening of the periapical region is very controversial and can be mistaken for the periapical lesion.

The result of this study showed that the discontinuity of the lamina dura is considered the only indicative feature of actual root protrusion into the sinus with more than 70% accuracy. However, Lopes LJ et al. (Lopes et al. 2016) reported that the MSF interruption and root projection into the sinus are indicative panoramic signs of actual root protrusion into the sinus. However, Themkumkwun S et al. (Themkumkwun et al. 2019) reported that the projection of the root apex in the sinus cavity and the darkening of the involved root apical region are the panoramic indicators of root protrusion into the MS.

## 5. Limitations

One limitation of this study is that only three periapical radiographic features, i.e., the interruption of the MSF, discontinuity of lamina dura, and upward bending of the MSF to envelop the root partially or completely, were investigated.



**Fig. 4** Sensitivity, specificity, accuracy, false positive rate, positive and negative predictive value for each periapical feature separately and the combined features (A = Interruption of the MSF, B = Discontinuity of the lamina dura, and C = Upward bending of the MSF).

In the future, it will be interesting to assess the reliability of other periapical features such as root deflection, narrowing, and change in density, to determine root intrusion into the sinus.

## 6. Conclusion

1. The digital periapical technique is considered an accurate method of assessing the sinus-root relation, especially when the root is located outside the sinus.
2. One of the most indicative periapical features of root intrusion into the MS is the discontinuity of lamina dura.

### Ethics approval and consent to participate.

The study was approved by the Research Ethics Committee of the Faculty of Dentistry Ain-Shams University, approval number FDASU-Rec IM121804. All patients gave their written informed consent to participate in the study.

### Consent for publication.

Not applicable.

### Availability of data and materials.

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

### Funding.

Not applicable.

### Authors' contributions.

Esraa Ahmed Eid performed the data collection. Fatma Mostafa El-Badawy aided in designing the study and optimizing the study methodology. Walaa Mohamed Hamed performed the final revision and supervision. All authors offered meticulous aid in writing, revising and approving the final manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgement

We gratefully acknowledge Dr. Kareem Samir for his efforts in observation and statistical analysis, Dr. Amr Ramah for his aid in observation and Dr. Haneen Mousa for her endless support.

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