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ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Accuracy, sensitivity and specificity of three imaging modalities in detection of separated intracanal instruments

Precisione, sensibilità e specificità di tre modalità di imaging nel rilevamento di strumenti intracanalari separati

KEYWORDS
Accuracy, CBCT, Nickel Titanium, PSP, Radiography, Separated Instrument

PAROLE CHIAVE
Precisione, CBCT, Nichel-titanio, Radiografia, Strumento separato

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Abstract

Aim: *To compare the accuracy, sensitivity and specificity of CBCT imaging and two dimensional periapical radiography in detection of separated intracanal endodontic instruments with and without root canal filling.*
Methodology: *Eighty (n=80) extracted mandibular molars were randomly divided into four groups (n=20); control, fracture/non-filled, non-fracture/filled, and fracture/filled. Molars were placed in a mandible for imaging. Conventional 2D radiography using D-speed periapical film (SKYDENT, Slovak Republic), semidirect digital radiographs using Soredex Digora Optime system (DIGORAOptime, Soredex, Finland), and cone beam computed tomography using Gendex-GXDP 800 (GENDEX GXDP-800 Kavo, Germany) were acquired. An artifact reduction algorithm was applied. Images were evaluated by three blinded examiners (two endodontists and one radiologist). Qualitative examination for the presence/absence of separated instrument was performed according to a 5-point rank scale (1, definitely absent; 2, probably absent; 3, uncertainty; 4, probably present; and 5, definitely present). Accuracy, sensitivity and specificity were calculated as well as inter-observer reliability. Statistical analysis was performed and significance level was set at 5%.*
Results: *Non-filled groups showed no significant difference between all three tested imaging modalities. Filled groups showed statistically decreased accuracy and sensitivity of CBCT. Good inter-observer agreement was shown.*
Conclusions: *Conventional 2D radiography is a good tool for detection of intracanal separated instruments in filled canals.*

Obiettivo*: confrontare l'accuratezza, la sensibilità e la specificità della CBCT e della radiografia periapicale bidimensionale nel rilevamento di strumenti endodontici intracanalali separati con e senza riempimento del canale radicolare.*
Metodologia: *ottanta (n=80) molari mandibolari estratti sono stati divisi casualmente in quattro gruppi (n=20); controllo, frattura/non riempito, non frattura/riempito e frattura/riempito. I molari sono stati collocati in una mandibola per l'esposizione con radiografia 2D convenzionale con film periapicale D-speed (SKYDENT, Repubblica slovacca), radiografie digitali semidirette con sistema Soredex Digora Optime (DIGORAOptime, Soredex, Finlandia) e tomografia computerizzata a fascio conico con Gendex-GXDP 800 (GENDEX GXDP-800 Kavo, Germania). È stato applicato un algoritmo di riduzione degli artefatti. Le immagini sono state valutate da tre esaminatori (due endodontisti e un radiologo). L'esame qualitativo della presenza/assenza di strumento separato è stato eseguito secondo una scala di 5 punti (1, decisamente assente; 2, probabilmente assente; 3, incerto; 4, probabilmente presente; e 5, sicuramente presente). Sono stati calcolati precisione, sensibilità e specificità, nonché affidabilità inter-osservatore. È stata eseguita un'analisi statistica e il livello di significatività è stato fissato al 5%.*
Risultati: *i gruppi non riempiti non hanno mostrato differenze significative per tutte e tre le modalità di imaging testate. I gruppi riempiti hanno mostrato un'accuratezza e una sensibilità della CBCT statisticamente diminuite. È stato mostrato un buon accordo tra osservatori.*
ConclusionI: *la radiografia 2D convenzionale è un buon strumento per la rilevazione di strumenti separati intracanalali in canali riempiti.*

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Introduction

Although rotary nickel-titanium (NiTi) instruments have the ability to shape root canal systems in a shorter time with less procedural errors, unexpected instrument fracture still does occur (1). The possibility of NiTi instrument separation was shown to range from 0.4% to 4.4% (2).
Sattapan et al (3) identified two modes of fracture; cyclic fatigue and torsional failure. Cyclic fatigue which occurs due to metal fatigue when it rotates freely in a curved canal at the point of maximum flexure (4, 5), while torsional failure happens upon reaching the ultimate shear strength. Many factors influence the occurrence of this mishap including root canal geometry (6), cleaning and shaping techniques (7), debris accumulation (8) sterilization procedures (9), size (5), taper (10), cross section (11), and instrument design (12), as well as the manufacturing technique (13); unfortunately, cyclic fatigue often happens without any visible sign of plastic deformation (2).
Once a separated instrument is observed on a routine radiograph or accidentally happened during root canal treatment, the patient should always be informed (14). From a medicolegal point, it is imperative to accurately diagnose a separated instrument inside a root canal before starting endodontic retreatment procedures. Otherwise, the clinician performing the retreatment might be blamed for it (15). Diagnosis and documentation of separated instruments is deemed mandatory (16).
Intracanal separated instruments may affect the treatment outcome as it prevents adequate root canal disinfection and/or obturation (17). Management of separated instruments includes leaving the instrument inside the root canal after bypassing it, instrument retrieval via orthograde approach, and surgical approach (18). Factors affecting treatment options are the preoperative pulp state, instrument position, remaining radicular dentin thickness, and root canal geometry (18). Proper diagnosis of a separated instrument in a previously filled canal is not that easy because of the continuous radioopaque appearance of the instrument and the root canal filling (19).
Radiation dosage reduction, lack of image processing, and easier manipulation of image contrast, brightness, and sharpness are the main advantages of digital radiography over conventional radiographs (16). A primary limitation of periapical radiography being a two-dimensional image of a three-dimensional object. Cone-beam computed tomographic (CBCT) imaging overcomes this and allows for accurate assessment of morphology and proper diagnosis (20). Yet, CBCT suffers from metallic artifacts which hinders its ability to accurately diagnose separated metallic instruments (20).
CBCT demonstrated better accuracy than two-dimensional periapical radiography in detecting root perforations, external root resorption, and deviated posts (20). However, CBCT requires a longer scan time, and the patient is exposed to a larger X-ray dose compared to conventional or digital radiography (20). Moreover, contradictory results were reported regarding the detection of separated instruments in filled root canals (21).
Therefore, investigation of the best method to image and diagnosis the presence of instruments in filed root canals was of value. Our null hypothesis is that there is no difference in the accuracy of conventional radiography, digital radiography or CBCT to detect separated instruments in filled root canals.

Materials and Methods

Sample Selection and Classification
The current study was approved from the Research Ethics Committee of Ain Shams University (Cairo, Egypt), (approvation number 07062019).
Eighty sound human mandibular molars extracted for periodontal reasons were selected and used. Teeth were randomly divided into four groups (n=20).
Group I: The control group in which root canals were prepared but left unfilled.
Group II: The fracture/non-filled group in

which root canals were prepared, and files were intentionally fractured.
Group III: The non-fracture/ filled group in which root canals were prepared and filled.
Group IV: The fracture/filled group in which root canals were prepared, files were intentionally fractured, then filled till the level of the separated instruments.

Sample Preparation
Endodontic access cavities were prepared in all teeth. Cleaning and shaping of teeth were performed using the WaveOne Gold primary (Dentsply Maillefer, Ballaigues, Switzerland) in the presence of 2.5% NaOCl. Forty rotary NiTi files size 25 taper 0.06 were weakened by making a notch on each file at 3 mm from the tip. Then, file was inserted into the canal through the apical foramen and twisted to induce intra-canal instrument separation in groups II and IV (2, 30). Groups III and IV were obturated using gutta percha (META BIOMED CO, Republic of Korea) and ADSEAL resin sealer (META BIOMED CO, Republic of Korea) in a cold lateral compaction technique. A dry human mandible was covered with utility wax to simulate soft tissue present in the clinical situation (2). Sockets were minimally modified to fit the teeth in the molar area properly.

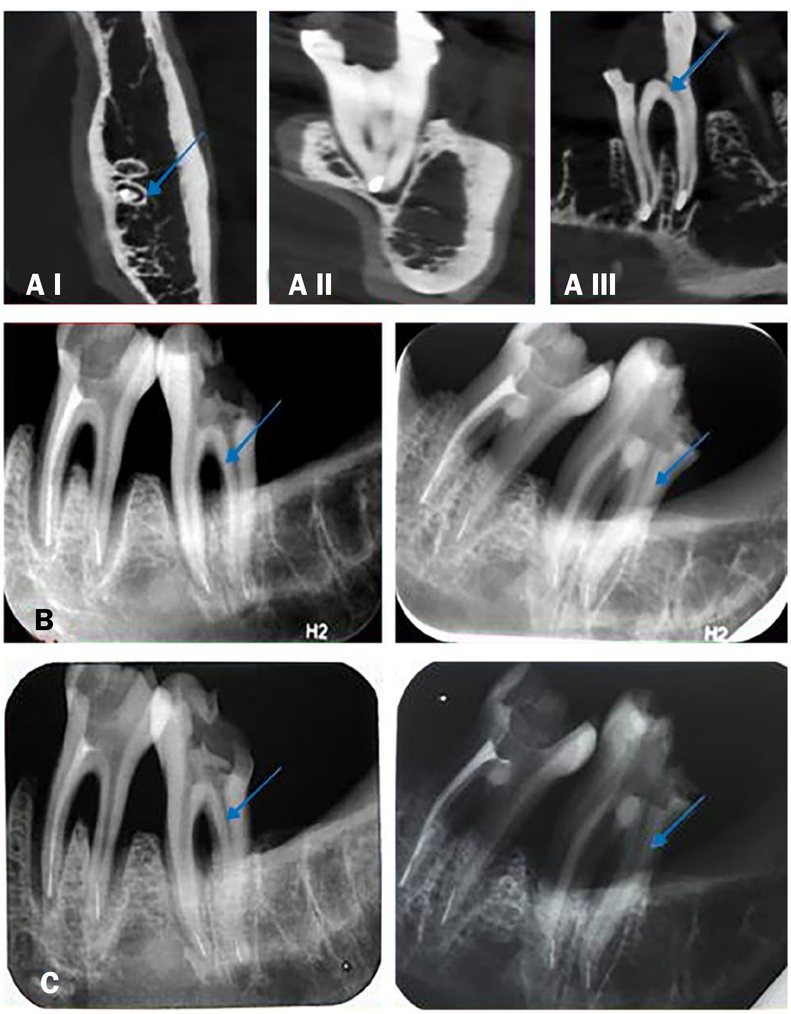

Figure 1
Mesiobuccal canal of lower second molar (blue arrows) radiographed by 3 different Imaging modalities **(A)** CBCT; (I) axial section, (II) coronal section, (III) sagittal section. **(B)** SDDR with two different horizontal angulations and (c) CR with two different horizontal angulations.

Image Acquisition
Conventional Radiography (CR): Rinn-XCP film holder (AZDENT, XCP, film holding system, China) was used to place D-speed periapical film (SKYDENT, Slovak Republic) parallel to the long axis of the tooth and to direct the central beam perpendicular to both. The focus receptor distance was 25 cm. Two radiographs were acquired with two different horizontal angulations (1,2). Image acquisition was performed using FONA-XDC periapical intraoral X-ray machine (FONA-XDC, Assago, Italy) with the following exposure parameters;70 kVp, 7 mA and one second exposure time. Automatic processing was performed using Velopex Extra-X (Velopex Extra-X, Velopex International, England).
Semidirect Digital Radiogarphy (SDDR) were acquired using Soredex Digora Optime system (DIGORAOptime, Soredex, Finland). Photostimulable phosphor imaging plate (PSP) size #2 was held by XCP film holder as for conventional imaging with exposure parameters of 70 kVp,7 mA and 0.04 seconds exposure time.
CBCT Scans: Gendex-GXDP 800 (GENDEX GXDP-800 Kavo, Germany) was used with the following image acquisition protocol: 5*5 FOV, 90 kVp, 5 mA and spatial resolution 0.085 mm.

Table 1

Mean diagnostic values for different imaging methods in the absence of filling material

Imaging method	Accuracy	Sensitivity	Specificity
CBCT	0.889[a]	0.900[a]	0.889[a]
SDDR	0.883[a]	0.900[a]	0.889[a]
CR	0.844[a]	0.833[a]	0.850[a]

Different letters in the same column indicate statistically significance difference ($p<0.05$).

Image Evaluation

Conventional periapical radiographs were evaluated on a view box. Indirect digital images were viewed on an 18.5 inch HD LED monitor with resolution of 1366x768 using DFW 2.7 software. Zoom, brightness and contrast tools were available for use. CBCT images were analyzed using In Vivo Anatomage 5.3 software on an 18.5 inch HD LED monitor with resolution of 1366x768. A multiplanar reformatted screen was used to evaluate the CBCT scans. Zoom, brightness and contrast tools were also used when required. An artifact reduction algorithm was applied to enhance the image quality and the decrease the imaging artifacts.

Images were evaluated by 3 blinded examiners (two endodontists and one oral and maxillofacial radiologist). Qualitative examination for the presence/absence of separated instrument was performed according to a 5-point rank scale (1, definitely absent; 2, probably absent; 3, uncertainty; 4, probably present; and 5, definitely present) (16).

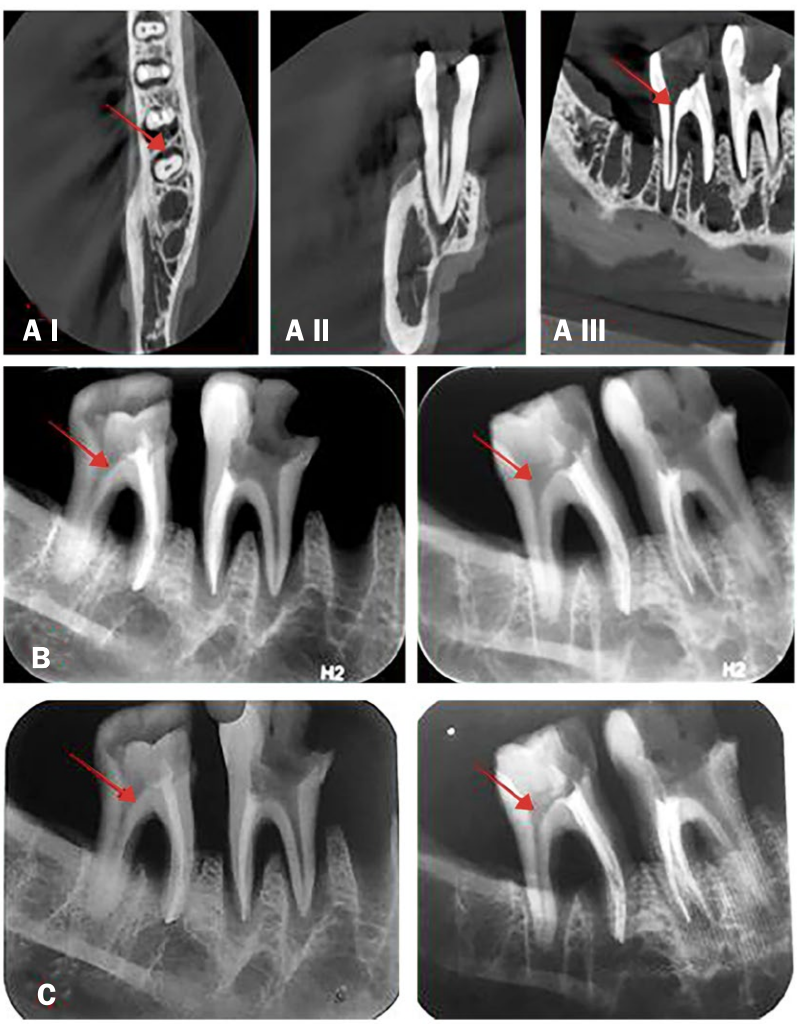

Figure 2

Distal canal of lower second molar (red arrows) radiographed by 3 different Imaging modalities **(A)** CBCT; (I) axial section, (II) coronal section, (III) sagittal section **(B)** SDDR with two different horizontal angulations and **(C)** CR with two different horizontal

Statistical Analysis

Kendall's coefficient of concordance was used to study the inter-rater reliability. Paired comparisons of receiver operator characteristic (ROC) curves were used to assess the diagnostic accuracy of the imaging methods utilized. The significance level was set at 5% for all tests. Statistical analysis was performed using NCSS version 12 for Windows.

Results

Accuracy, Sensitivity and Specificity

For groups I and II, non-filled, diagnostic accuracy (AUC), sensitivity and specificity values for all imaging modalities tested are shown in table 1. No significant difference was shown between all three tested imaging modalities regarding diagnostic accuracy, sensitivity or specificity (figures 1 and 2).

Table 2

Mean diagnostic values for different imaging methods in the presence of filling material

Imaging method	Accuracy	Sensitivity	Specificity
CBCT	0.526[b]	0.300[b]	0.888[a]
SDDR	0.807[a]	0.900[a]	0.722[a]
CR	0.793[a]	0.80[a]	0.666[a]

Different letters in the same column indicate statistically significance difference (p<0.05).

For groups III and IV, filled canals, accuracy, sensitivity and specificity values for all imaging modalities tested are shown in table 2. CBCT showed a statistically significantly smaller AUC and sensitivity values compared to SDDR (P=0.006) and CR (P=0.005). No significant difference was shown between SDDR and CR regarding accuracy, sensitivity or specificity (figures 3 and 4).

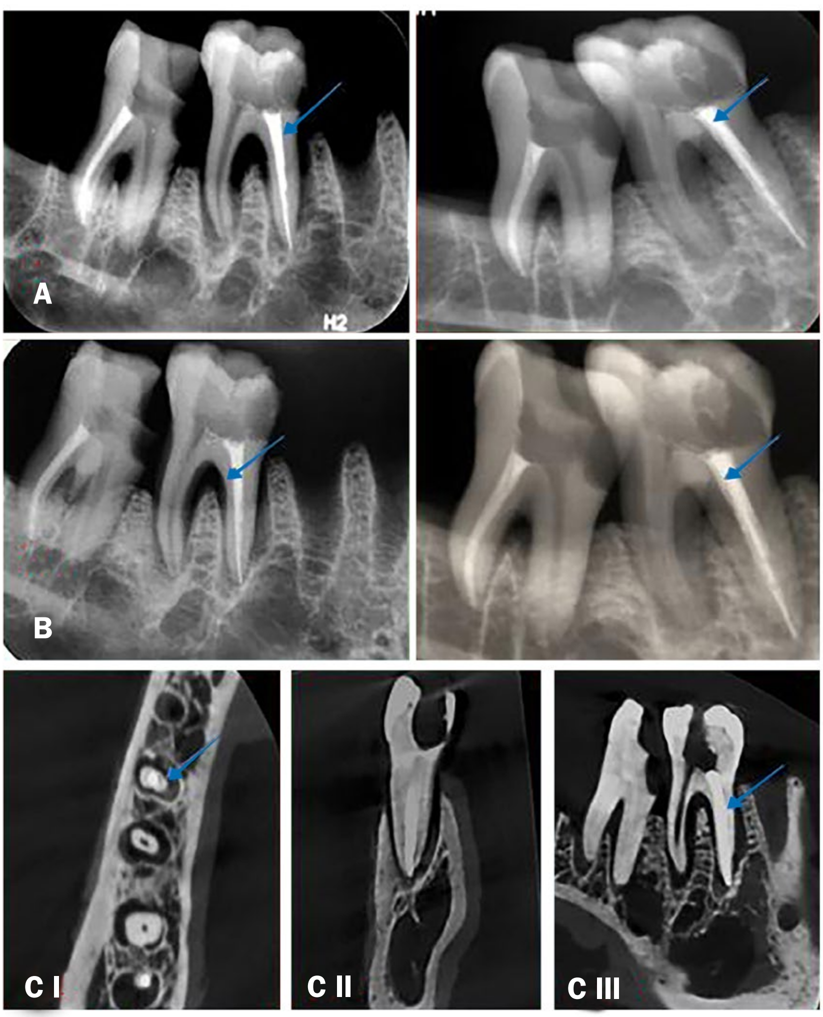

Figure 3
Distal canal of lower second molar (blue arrows) radiographed by 3 different Imaging modalities **(A)** SDDR with two different horizontal angulations **(B)** CR with two different horizontal angulations and **(C)** CBCT; (I) axial section, (II) coronal section, (III) sagittal section.

Interobserver Reliability
There was an overall good agreement between the three observers for all imaging techniques (W=0.813) which was statistically significant (P<0.001). There was a strong agreement for the measurements of CBCT (W=0.878) and CR (W=0.856) which was statistically significant (P<0.001). While for the SDDR, the observers' agreement was excellent (W=0.914) and statistically significant (P<0.001).

Discussion

An intracanal separated instrument may hinder or block the access to the apical part of the canal and compromises the effectiveness of cleaning and shaping procedures. Decision making in the clinical situation to bypass, remove or leave separated instruments will depend on the clinical and radiographic findings (21). Hence, the diagnostic capability of the imaging modality used for assessment of separated instruments should be reliable, especially in the presence of root canal filling materials.
Generally, the ability of radiographs to display high image quality in an image is influenced by spatial and contrast resolution. The spatial resolution, represented as LP/mm, is the ability of radiographs to distinguish fine details in an image (22). With CBCT, images with high spatial resolution are obtained when the high-definition mode and a low voxel size are used for scanning (23). Consequently, CBCT scans with endo mode 0.085 mm voxel

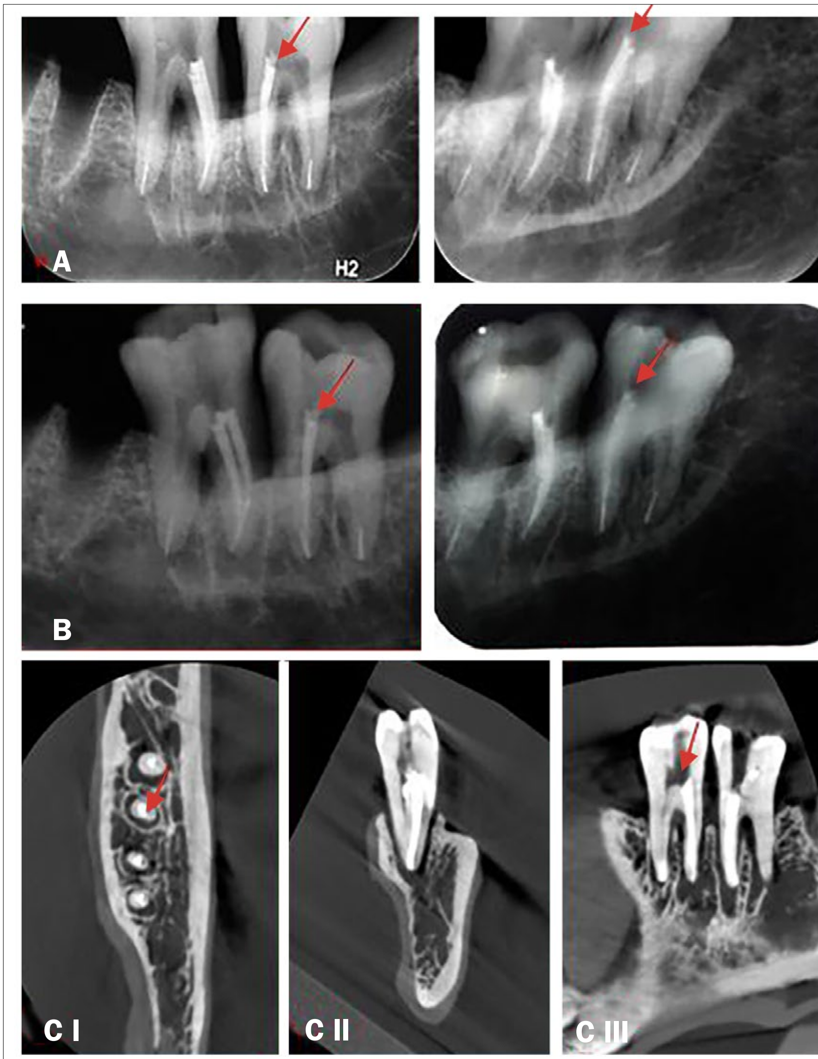

Figure 4
Distal canal of lower second molar (red arrows) radiographed by 3 different Imaging modalities **(A)** SDDR with two different horizontal angulations **(B)** CR with two different horizontal angulations and **(C)** CBCT; (I) axial section, (II) coronal section, (III) sagittal section.

size was selected in the present study.
A limited FOV 5x5 was also used in this study. According to Patel al (25), it is suitable for endodontic purposes as the produced reconstructed images are of high diagnostic power because of the higher spatial resolution than that those of larger FOV scans. Moreover, only the region of interest is irradiated. Thus, the effective dose to the patient is reduced.
Five points scale was used in the present study as it has the advantage of not expecting a simple Yes/No answer from the respondent, but rather allow for degrees of opinion, even in case of hesitation. Therefore, quantitative data could be obtained, which means that the data can be analyzed with relative ease (16).
The interpretation of images with respect to clarity is a subjective judgment of its appearance, which comprises both the technical qualities of the image as well as experience, skill and visual perception of the viewer. There was an excellent inter-observer reliability as their diagnostic scores for all imaging techniques were nearly comparable whether in the presence or absence of the filling material.
PSP plates also have better contrast detectability in addition to the increased exposure latitude in comparison to conventional periapical films, which enable them to distinguish between different densities on the radiographs (16). This explains the high accuracy, sensitivity and specificity of indirect digital radiography used in the current study.
The results of our study showed that the accuracy and sensitivity of CBCT were negatively affected by the presence of gutta percha. This agrees with Khedmat et al (26), who concluded that the presence of gutta-percha reduced the accuracy, sensitivity and specificity of CBCT, and Kobayashi et al (27) who reported that one of the drawbacks of CBCT images was its low contrast resolution which is the ability to distinguish different densities or shades of grey within a radiographic image (21).
The decreased accuracy and sensitivity in the present study is not related to the CBCT artifacts but rather to its inherent low contrast resolution. Inherent or induced artifacts caused by the intracanal metallic and non-metallic fillings are considered to be a significant limitation of CBCT (25). Therefore, an artifact reduction algorithm was applied in the present study to enhance the image quality and avoid beam hardening effect from the gutta-percha filling.
The higher specificity value of CBCT in filled canals compared to SDDR and CR may be explained by the evaluators' difficulty in detecting separated instrument. This could be due to proper condensation of the filling material and the absence of the gap between filling material and the separated

instrument. Hence, there was a tendency to answer "probably absent" or "absent", which resulted in a high number of "negative" answers, consequently increasing the number of "true-negative" cases (24).
It should be pointed out that our results were confined and limited to only one type of intraoral digital imaging and CBCT imaging systems. Results may vary if other direct or semi-direct digital systems and CBCT scanners were used. Within limitations of the current study, the null hypothesis is rejected and we conclude that conventional 2D radiography is a useful tool for the detection of intracanal separated endodontic instruments in filled canals.

Clinical Relevance

Conventional two-dimensional radiography is a useful tool for the detection of intracanal separated endodontic instruments in filled canals.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Acknowledgments

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