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ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Diagnostic accuracy of two cone-beam computed tomography systems for detection of strip perforation in the mesial root of mandibular molars

Precisione diagnostica di due sistemi di tomografia cone-beam per la rilevazione di stripping nella radice mesiale di molari mandibolari

KEYWORDS
Cone Beam Computer Tomography, Three Dimensional Imaging, Accuracy

PAROLE CHIAVE
Tomografia Computerizzata Cone Beam, Immagine 3D, Precisione

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Abstract

Aim: *This study aimed to compare the diagnostic accuracy of two cone-beam computed tomography (CBCT) systems for detection of strip perforation in the mesiobuccal canal of mandibular molars after root canal treatment.*
Methodology: *The curved mesiobuccal canals of mandibular first and second molars were instrumented as part of endodontic treatment. The canals were strip-perforated using #2 and #3 Gates-Glidden drills in distoaxial direction at 1 to 3 mm distance from the furcation. The canals were filled with gutta-percha and AH26 sealer with lateral compaction technique. The teeth were then mounted in dry bovine mandible and underwent CBCT using Acteon and NewTom CBCT systems. The CBCT scans were evaluated by two observers, and the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the two CBCT systems for detection of strip perforation were determined and compared using the Chi-square test.*
Results: *The sensitivity and specificity for detection of strip perforation were 51.3% and 46.3% for Acteon, and 55% and 38.8% for NewTom CBCT system, respectively. The difference between the two CBCT systems for detection of strip perforation was not significant (Chi-square test, P>0.05).*
Conclusions: *The accuracy of Acteon and NewTom CBCT systems for detection of strip perforation is low, and no significant difference was noted between the two systems in this respect.*

Scopo: *lo studio ha lo scopo di comparare la precisione diagnostica di due sistemi di tomografia computerizzata cone-beam (CBCT) per la rilevazione di stripping nella radice mesiale di molari mandibolari dopo il trattamento canalare.*
Metodologia: *canali mesio-buccali curvi di primi e secondi molari mandibolari erano strumentati durante il trattamento endodontico. I canali erano perforati usando frese Gates-Glidden #2 e #3 in direzione disto-assiale da 1 a 3 mm di distanza dalla forcazione. I canali erano otturati con gutta-percha e cemento AH26 con tecnica di condensazione laterale. I denti erano poi montati in mandibole essiccate di bovino ed erano sottoposte a CBCT usando i sistemi Acteon e NewTom CBCT. Le scansioni CBCT sono state valutate da due osservatori e la sensibilità, la specificità, il valore predittivo positivo (PPV), il valore predittivo negativo (NPV) e l'accuratezza dei due sistemi CBCT per il rilevamento dello stripping sono stati determinati e confrontati utilizzando il test Chi-quadrato.*
Risultati: *la sensibilità e la specificità per il rilevamento dello stripping sono state rispettivamente del 51,3% e 46,3% per Acteon e 55% e 38,8% per il sistema CBCT NewTom. La differenza tra i due sistemi CBCT per il rilevamento dello stripping non era significativa (test Chi-quadro, P>0,05).*
Conclusioni: *l'accuratezza dei sistemi Acteon e NewTom CBCT per il rilevamento dello stripping è bassa e non sono state rilevate differenze significative tra i due sistemi.*

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Introduction

Root perforation is defined as a pathological and/or mechanical communication between the root canal system and the tooth supporting structures (1). Root perforation occurs in 2% to 12% of the endodontically-treated teeth (2) and is responsible for 10% of the endodontic treatment failures. It can compromise the peri-radicular tissue health and root integrity (1, 3).
Strip perforation is longitudinal perforation of the root that commonly occurs in the danger zone of the mesial root of mandibular molars due to over-instrumentation of this region (4). Several tools and techniques such as endoscopes (5), microscopes (6), electronic apex locators (7) and optical coherence tomography scan (8) have been recommended for detection of root perforation. However, none of the abovementioned diagnostic modalities can detect perforations in obturated roots because these modalities are mainly based on visualization of the empty root canal or penetration into it (9).
Cone-beam computed tomography (CBCT) is a valuable diagnostic tool for detection of periapical lesions and evaluation of their healing course (10], vertical root fractures (11), internal and external root canal anatomy (12) and root resorption defects (13). Also, evidence shows that the sensitivity of CBCT is significantly higher than that of periapical radiography for detection of strip perforation; however, the risk of misdiagnosis of strip perforation is still high in both modalities (9).
The patient radiation dose of CBCT is generally higher than that of conventional periapical radiography (14) and it may be used along with periapical radiography in presence/absence of root filling materials for detection of endodontic complications such as strip perforation (15, 16). However, no previous study is available comparing two CBCT systems. Thus, this study aimed to assess the diagnostic accuracy of two different CBCT systems for detection of strip perforation in the mesial root of mandibular molars ex vivo.

Material and Methods

This ex vivo study evaluated (77) mandibular first and second molars and was approved by the ethics committee of Zahedan University of Medical Sciences (IR.ZAUMS.REC.1397.70).
The teeth were immersed in 5.25% sodium hypochlorite (chloraxid PPH CERKAMED Wojciech Powlowski, Poland) for disinfection and were then stored in distilled water.
All teeth were inspected under an endodontic surgery microscope and those with cracks, fracture or external resorption were excluded. Next, all teeth underwent digital periapical radiography to measure the canal curvature and ensure absence of canal calcification and internal resorption.
Access cavity was prepared and the coronal pulp tissue was removed. Canal patency was ensured using a #15 K-file (Mani Inc., Utsunomiya, Japan), and the working length was determined by introducing the file into the canal and observing its tip at the apical foramen; 1 mm was subtracted from this length to determine the working length.
The root canals were instrumented using #15 to #35 K-files (Mani Inc., Utsunomiya, Japan) with the step-back technique. The canals were repeatedly rinsed with 2% sodium hypochlorite (chloraxid PPH CERKAMED Wojciech Powlowski, Poland) with a 27-gauge needle.
After completion of instrumentation, each canal was rinsed with 2 mL of distilled water and the teeth were stored in distilled water until the next step.

Root perforation

To induce root perforation, danger zone dentin of the mesiobuccal canal was thinned using #2 and #3 Gates-Glidden drills (Dentsply Maillefer, Switzerland) in distoaxial direction at 1 to 3 mm from the furcation level until strip perforation occurred. The perforation was ensured by inserting a #20 K-file (Mani Inc., Utsunomiya, Japan) into the perforation with no resistance felt. Next, the corono-apical diameter of the perforation was measured by a digital caliper with ±0.001-inch accuracy per 6 inches (Mitutoyo Corp., Tokyo, Japan).

Canal obturation

The canals were dried with #30 and #35 paper points (Aridanet, Tehran, Iran). AH26 sealer (Dentsply Maillefer, Ballaigues, Switzerland) was mixed according to the manufacturer's instructions and delivered into the canal using a Lentulo spiral operating at 400 rpm for 5 seconds. Next, a #30 gutta-percha (Gapadent, Tianjin, China) with 0.02 taper was dipped in sealer and reached to the working length. The rest of the canal was filled with #20 and #25 accessory gutta-percha points using #25 and #30 spreaders (Mani Inc., Utsunomiya, Japan) with lateral compaction technique. The roots were stored at 37 °C and 100% humidity for 2 weeks and they were then mounted in extraction sockets in a dry bovine mandible. Three layers of dental wax were applied on the bone surface to simulate the soft tissue and fix the teeth in the extraction sockets.

CBCT

Dry mandible was positioned such that it simulated the position of patients during CBCT in the clinical setting. The CBCT scans were obtained with Acteon CBCT system (Acteon Group, Norwich, United Kingdom) with the exposure settings of 85 kVp, 8 mA, 80×80 field of view, 0.2 mm voxel size and 10 s of exposure time, and NewTom Giano extraoral imaging system (Vila Silverstrini, Verona, Italy) with 90 kVp, 0.6 mA, 80x50 mm field of view, 0.2 mm voxel size and 10 s of exposure time. In this setting, minimum scatter radiation was observed.
Any discontinuation in the external surface of the root at the site of furcation was considered as strip perforation. Two observers independently observed the images in a random fashion and reported their diagnosis as "presence of perforation", "absence of perforation" or "possibility of perforation" (suspected cases when perforation could not be clearly detected).
The two observers discussed the cases with the possibility of perforation until a consensus was reached.

Statistical analysis

Two calibrated observers observed the images independently.
The diagnosis of strip perforation was made by not observing the tooth structure at the interface of furcation and root canal filling (figure 1).
The overall agreement between the two observers was calculated using the Cohen's kappa. Values >0.70 indicated excellent agreement, and values <0.70 indicated poor agreement.
The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the two CBCT systems were calculated.

Table 1

Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of the two CBCT systems

First observer	Second observer	Total				
	ACTEON	NewTom	ACTEON	NewTom	ACTEON	NewTom
Sensitivity	55	62.5	47.5	47.5	51.3	55
Specificity	42.5	32.5	50	45	46.3	38.8
PPV	44	48	51	46	47.5	47
NPV	44	46	51	46	47.5	46
Accuracy	48	47	48	46	48	46.5

PPV: Positive predictive value; NPV: Negative predictive value

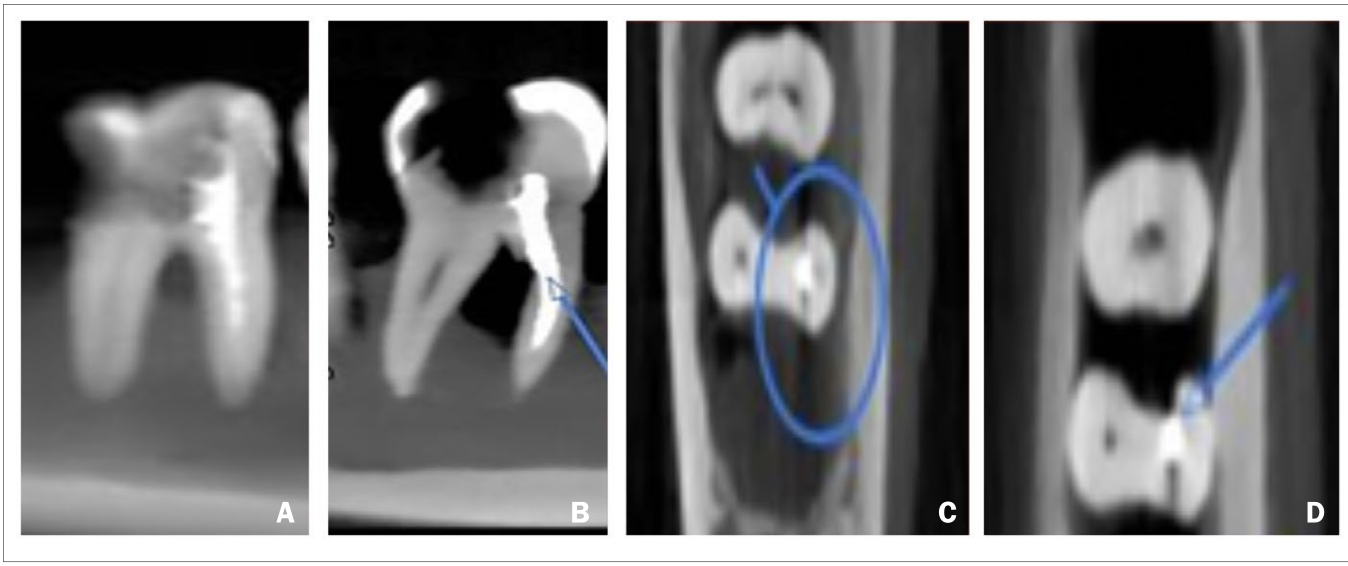

Figure 1
(A) Sagittal section of a tooth without perforation **(B)** sagittal section of a tooth with mesiobuccal canal perforation (arrow) **(C)** axial section without perforation (circle) and **(D)** axial section with perforation (arrow).

The two systems were compared using the Chi-square test. Data were analyzed using SPSS version 20 (SPSS Inc., IL, USA) with 95% confidence interval.

Results

Table 1 shows the sensitivity, specificity, PPV, NPV and accuracy of CBCT scans for detection of strip perforation of the root. No significant difference was noted by the first (P=0.161) or the second (P=0.436) observer in detection of strip perforation between the two CBCT systems.
In all observations, CBCT scans taken by the Acteon system overall detected 53% (81/154) of strip perforations while the NewTom system detected 58.4% (90/154) of strip perforations with no significant difference between the two systems (P=0.285). Also, considering the accuracy values <50%, none of the two systems had optimally high accuracy for detection of strip perforation.
The overall inter-observer agreement was high for both Acteon (k=0.86) and NewTom (k=0.79) CBCT systems.

Discussion

Root perforations in the cervical third of the root and pulp chamber floor have a poorer prognosis than the perforations in the middle third and apical third of the root.
On the other hand, literature is poor regarding the accuracy of different CBCT systems for detection of strip perforations. Thus, this study aimed to assess the sensitivity, specificity, PPV, NPV and accuracy of two CBCT systems for detection of strip perforation in the mesial root of mandibular molar teeth. Although periapical radiography greatly helps in detection of procedural errors, this 2D modality has limitations due to geometric distortion and provides limited data regarding the size, extension and location of defects (3). Inaccuracy of periapical radiography for detection of root perforation has been previously discussed (3).
Limitation of periapical radiography in detection of root perforations may be related to the location of perforation as well, since the perforation may be masked if it is located in the root surface concavity.
Thus, several imaging modalities have been suggested for enhanced detection of root perforations. CBCT has been specifically designed to provide undistorted 3D images of the maxillofacial region, the teeth and their surrounding structures (17).
Thus, CBCT was used in the present study. The results showed no significant

difference in diagnostic accuracy of the two CBCT systems for detection of strip perforation in root canals filled with gutta-percha and AH26 sealer with lateral compaction technique. The reason may be no penetration of root filling materials into the perforation site in lateral compaction technique. However, in soft gutta-percha technique, gutta-percha penetrates into the perforation site and enhances the detection of perforated region (9). Evidence shows that the lateral compaction technique has lower efficacy in providing lateral seal in the canals compared with the warm gutta-percha technique (18).
On the other hand, evidence shows that presence of root canal filling material decreases the efficacy of CBCT scans for detection of vertical root fractures (11). Radiopaque materials such as gutta-percha and AH26 sealer create streak artifacts on CBCT slices and mimic the fracture lines (19, 20). These artifacts can complicate the detection of perforations and prevent definite diagnosis of strip perforation.
A previous study showed significantly higher sensitivity, specificity and accuracy of CBCT in detection of strip perforations in empty canals. In the obturated root canals, the sensitivity of CBCT was significantly lower than that of periapical radiography (21). Although our study did not compare CBCT with periapical radiography, the results showed that the sensitivity, specificity and accuracy of both CBCT systems for detection of strip perforation were low, which was probably due to the presence of root filling materials in the canal.
Not eliminating the smear layer and dentinal debris during root canal preparation and also after perforation in this study might have resulted in penetration of dentinal debris and smear layer into the perforation site, and subsequent prevention of the entry of root filling material into the perforated region.
This would decrease the visibility of perforation site, which can consequently decrease the sensitivity of both CBCT systems for detection of strip perforation. Moreover, strip perforations were artificially created by the use of Gates-Glidden drills in the mesiolingual canal of molar teeth in our study; thus, the results cannot be generalized to the clinical setting since strip perforations that occur in the clinical setting may be of different sizes (9). Evidence shows that CBCT, irrespective of the presence of root filling materials, can detect medium-size and large perforations significantly better than smaller perforations. Low sensitivity, specificity and accuracy of the two CBCT systems in detection of strip perforations in the mesiobuccal canals of mandibular molar teeth in our study may be due to the small size of perforation.

Conclusions

The results of this ex vivo study revealed no significant difference in sensitivity, specificity, PPV, and NPV of Acteon and NewTom CBCT systems for detection of strip perforation in the mesiobuccal canal of obturated mandibular molars, and the accuracy of both systems was found to be low for detection of strip perforations.

Clinical Relevance

The results of this study showed that cone beam computed tomography (CBCT) is not a suitable tool for detection of strip perforation of endodontically treated mesial root of mandibular molars.

Conflict of Interest

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

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