ORIGINAL ARTICLE

Diagnostic accuracy of cone beam computed tomography with and without metal artifact reduction algorithm in detection of vertical root fractures of teeth with metallic posts

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Abstract

Background: In cone beam computed tomography (CBCT), metallic structures can cause artifacts in the images, since most teeth suspected to have vertical root fractures (VRF) are endodontically treated and have a metallic post in the root canal, fracture detection may pose a challenge.
Aim: This study aimed to determine the diagnostic accuracy of CBCT using metal artifact reduction (MAR) algorithm in detection of VRF of teeth with metallic posts.
Materials and Methods: A total of 120 single-rooted extracted human teeth were obtained and endodontically treated then placed in an acrylic block, and metallic posts were inserted. After post insertion, the teeth roots were divided into two groups one with induced VRF and the other having intact roots with the posts inserted. Then, each tooth was coded and imaged by CBCT with and without using MAR algorithm.
Results: Using the MAR algorithm improved the diagnostic accuracy but with no statistically significant difference.
Conclusion: In case of presence of metallic posts, CBCT with MAR algorithm can be used to detect VRF.

Introduction

The condition referred to as vertical root fracture (VRF) is a fracture that extends longitudinally from the root apex to the tooth's crown, according to the American Association of Endodontists.[1]

The etiology of VRFs is mainly iatrogenic, usually owing to excessive canal shaping, excessive pressure during gutta-percha compaction, or excessive pressure during post-placement.[2]

On radiographic images, the fracture can be seen as a radiolucent line between the fragments along with a discontinuity of the periodontal ligament shadow.[3]

Cone beam computed tomography (CBCT) has been used for proper diagnosis of root fractures to overcome the inherent disadvantages of anatomic superimposition. CBCT has allowed dental practitioners to visualize teeth three-dimensionally (3D) and with high spatial resolution.[4]

While recent studies have demonstrated the superiority of CBCT in detecting root fractures, there are some limitations to proper imaging when high-density materials such as gutta-percha and intracanal metal posts are present. These materials may create artifacts that impair the quality of CBCT images. Beam hardening and streak artifacts can be superimposed on the root, creating difficulties for image assessment and may even mimic root fractures.[5,6]

Recent CBCT machines can apply metal artifact reduction algorithms that may be effective in reducing metallic posts artifacts which will provide 3-dimensional CBCT images with metallic artifacts reduction and thus allow for better detection of root fractures in teeth with metallic posts. It was demonstrated that the artifact reduction algorithm in the Master 3D machine (Vatech, Hwaseong, South Korea) enhances the contrast-to-noise ratio of the resulting images.[7]

Materials and Methods

Teeth selection, preparation and grouping

Teeth selection

A total of 120 single-rooted extracted human teeth were obtained from Oral Surgery Department in the outpatient clinic at Misr International University.

Selection of the teeth was based on fulfilling the eligibility criteria which were:

1. Maxillary or mandibular single-rooted teeth.
2. Absence of root fracture on clinical examination.

Teeth preparation and grouping

All teeth included in our study were endodontically treated then the gutta-percha in the cervical part of the root was removed using Gates Glidden drills. The roots of teeth were covered by wax [Figure 1].

A rectangular acrylic block was prepared in a rectangular plastic box with sufficient height to hold teeth in a position simulating patient radiographic imaging. Then, eight holes were made in each block to support the teeth included in the study [Figure 1].

Each eight teeth were embedded in each acrylic block with their palatal surfaces directed outside toward the block borders.

The canals were prepared using standardized drills, and the final standardized metallic posts were inserted [Figure 2].

After post insertion the teeth roots were divided equally and randomly into two groups:

- In Group 1
  Induced VRF were created by applying excessive forces to the roots through excessive rotation of posts with larger sizes [Figure 3].
- In Group 2
  The teeth having intact roots with the posts inserted.

Then, each tooth was coded by special code (known only by the researcher).

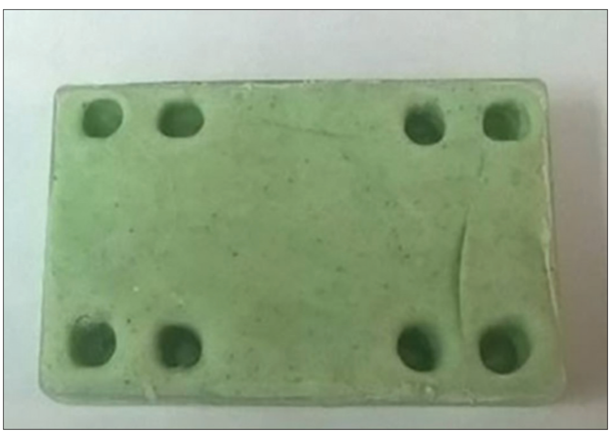

Figure 1: A rectangular acrylic block with eight holes in each block to support the teeth

Imaging of teeth

Each block was sectioned into two halves each containing four teeth to be adjusted to the CBCT field of view and imaged 2 times as follows:

CBCT without metal artifact reduction (MAR) with high resolution

The teeth were imaged using CBCT machine (Scanora3D, Soredex, Finland) after adjusting the control panel for image capturing without MAR algorithm. Parameters were adjusted at KVp = 90 mA = 10 voxel size = 85 μm FOV = 5 × 5 cm and exposure time = 6.1 s.

CBCT with MAR and high resolution

The exposure parameters used were the same as the first protocol but with MAR algorithm adjusted using the SMAR™ control panel before the scan.

All CBCT images were analyzed using software (On Demand 3D) viewer in axial, coronal, sagittal and 3D views to detect presence or absence of root fractures [Figure 4].

Figure 2: Final standardized metallic posts were inserted

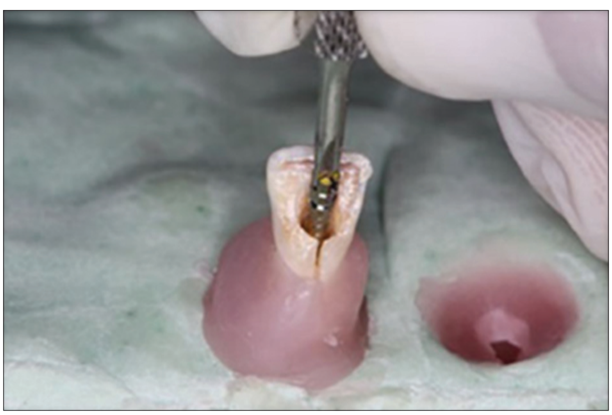

Figure 3: Induced vertical root fractures through excessive rotation of posts with larger sizes

The outcome was binary for the presence or absence of fracture lines.

Blinding

The images were evaluated by two radiologists with an experience ranging from 10 to 25 years for presence or absence of root fractures.

Two radiologists were blinded during periapical radiographs, and CBCT images assessment as tooth preparation and coding was done by a third researcher. Moreover, the statistician was blinded.

Statistical analysis

Data were presented as frequencies and percentages. Receiver operating characteristic (ROC) curve was constructed to evaluate diagnostic accuracy measures of the different modalities. Areas under the ROC curve of the four modalities were compared using z-statistic. Sensitivity, specificity, positive, negative predictive values, and diagnostic accuracy measures were calculated.

The significance level was set at $P \leq 0.05$. ROC curve analysis was performed with MedCalc Version 11.3 for Windows (MedCalc Software bvba).

Results

Frequencies and percentages of fracture detection by different modalities were calculated.

The highest sensitivity was found with CBCT1 (CBCT without MAR algorithm with high resolution) (65%) followed by CBCT2 (CBCT with MAR and high resolution) (55%) [Table 1].

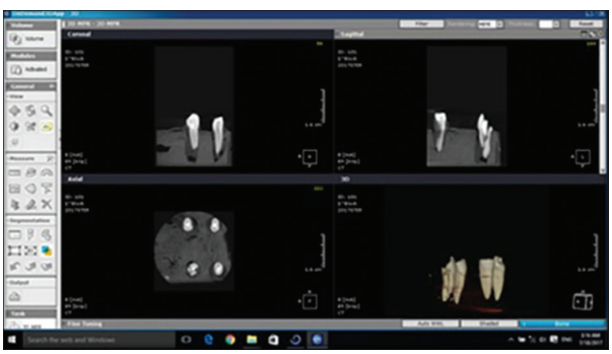

Figure 4: (On-demand 3D) Software

The highest specificity was found with CBCT2 (100%) [Table 1].

The highest positive predictive value was found with CBCT2 (100%) followed by CBCT1 (83%) [Table 1].

The highest negative predictive value was found with CBCT1 (71.2%) followed by CBCT2 (69%) [Table 1].

ROC curve analysis revealed that the highest diagnostic accuracy was found with CBCT2 (77.5%) followed by CBCT1 (75.9%).

Using the MAR algorithm improved the diagnostic accuracy from CBCT1 (75.9%) to CBCT2 (77.5%) but with no statistically significant difference ($P \geq 0.05$) [Table 2].

Discussion

Accurate diagnosis of VRF depends on a careful clinical examination, complete evaluation of the case, and on an imaging examination which assesses the integrity of the bone and the dental structure.[8]

Detection of VRF is not only influenced by the type of imaging examination, either conventional radiography or CBCT, but also by the presence of material in the root canal such as MPs, filling material, or remaining restorative material. Hence, in our study, we used CBCT with and without MAR algorithm to detect VRF in the presence of metallic posts. Teeth roots were covered by wax to simulate soft tissue.[9]

Only single-rooted teeth included in the study to avoid the superimposition of other endodontically treated roots.

Induced VRF were created by applying excessive forces to the roots through excessive rotation of posts to try to mimic the shape of fracture line in clinical situation.

Our results showed that the highest diagnostic accuracy was found with CBCT2 (77.5%) followed by CBCT1 (75.9%).

Considering using the MAR algorithm improved the diagnostic accuracy from CBCT1 (75.9%) to CBCT2 (77.5%) but with no statistically significant difference.

This went with the results of Tofangchiha *et al.* 2017[10] who stated that high-density bodies shows strong beam hardening and scattering effect artifacts that lead to images unsuitable for diagnostic purposes which are comparable with which reported increased accuracy using artifact reduction algorithm.

On the contrary, Bechara *et al.* 2012[7] reported lowered accuracy while using MAR algorithm. This can be explained by their usage of phantoms in their study. As the influence of the metal artifact tool may vary depending on the particularities of a given study: If a phantom is used, if a clinical condition is

Table 1: Sensitivity, specificity, predictive values, diagnostic accuracy, AUC and 95%, 95% CI for the detection of fracture by different modalities

Modality	Sensitivity %	Specificity %	+PV %	-PV %	Diagnostic accuracy %	AUC	95% CI
CBCT1	65.0	86.7	83.0	71.2	75.9	0.758	0.672–0.832
CBCT2	55.0	100.0	100.0	69.0	77.5	0.775	0.690–0.846

CBCT: Cone beam computed tomography, AUC: Area under the ROC curve, CI: Confidence interval, ROC: Receiver operating characteristic

Table 2: Results of *z*-test for pairwise comparisons between AUC of CBCT1 and CBCT2

Modalities	Z-statistic	*P* value
CBCT1 versus CBCT2	0.311	0.756

*Significant at $P \leq 0.05$, AUC: Areas under the curve, CBCT: Cone beam computed tomography

simulated, which artifact-inducing material is used, and if specific materials are employed.[11]

CBCT with high resolution and MAR showed lower sensitivity than CBCT without (MAR) and this is attributed to that AR algorithm is activated based on a threshold. Any structure denser than the threshold will be corrected, all the attenuation information from high-density objects is removed as well, which may decrease the ability to confirm presence of fracture (true positive fracture),[7] however, this AR algorithm showed the highest specificity due to its higher ability to confirm absence of fractures (true negative fracture) due to decreased metal artifacts that may mimic fractures.

Conclusion

In case of presence of metallic posts, CBCT with MAR algorithm can be used to detect VRF.

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