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Original Article

Detection of simulated vertical root fractures; which is better multi-detector computed tomography or cone beam computed tomography?

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ABSTRACT

Objectives: Multi-detector computed tomography (MDCT) and cone beam computed tomography (CBCT) were compared regarding their ability to detect vertical root fractures.
Methods: Sixty four extracted posterior teeth were included in this study. Using a diamond disc, thirty six teeth were cut vertically to simulate a VRF. Twenty eight teeth were used as control. Fractured and non-fractured teeth were randomly positioned in 4 skulls and mandibles. Scanning was performed first on a 16 slice Siemens MDCT, then by i-CAT Next Generation CBCT. Two observers assessed the multiplanar images for vertical root fractures using a 3-point scale. The first observer repeated the assessment after 1 week. Later, the 2 observers re-assessed the images together to reach a consensus score.
Results: CBCT showed higher sensitivity, accuracy as well as negative predictive value compared to MDCT. The mean area under the curve was 0.917 for MDCT and 0.972 for CBCT. The difference in diagnostic accuracy between the 2 modalities was statistically significant $P = .036$. Inter-observer agreement was 0.971 for MDCT and 0.994 for CBCT, whereas intra-observer agreement was 0.981 for MDCT and 0.985 for CBCT.
Conclusion: Using the specified scanners at the specified exposure parameters, the diagnostic accuracy of CBCT in detecting vertical root fractures was significantly higher than MDCT.

1. Introduction

A vertical root fracture (VRF) is characterized by a cleavage plane that extends partially or completely through the long axis of the root [1], most commonly in a bucco-lingual orientation [2]. Root fractures appear radiographically in one of the following forms; a radiolucent line denoting the fracture, double borders indicating overlapped fragments, periodontal bone loss or as radiopacities representing extrusion of dental filling materials [3].

The percentage of extracted teeth with VRF is disputed to be a lot more than the reported frequency of VRF [3]. This indicates limited ability of the diagnostic methods used in detection of VRF. The clinical and radiologic features of VRF are not distinctive, and substantial evidence of a fracture line is often challenging [4–6,3]. The fracture line is visible radiographically only when the X-ray beam is parallel to the plane of fracture [7]; otherwise, it is very challenging to detect the fracture on two-dimensional radiographs. Three-dimensional imaging enables the clinician to view the tooth from multiple planes and thus, may allow better diagnosis of VRF [8].

Several studies investigated the use of multidetector computed tomography (MDCT) in the diagnosis of root fractures, external root resorption, their results showed higher accuracy than conventional methods although these studies did not take into consideration the high dose of radiation. [9–11] On the other hand, numerous studies weighted digital periapical radiography against cone beam computed tomography (CBCT) in detection of VRFs. Some in vitro experiments showed that CBCT is significantly more accurate than conventional imaging in diagnosing VRF [12–14]

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whereas other trials documented similar ability of the two diagnostic methods in detection of VRF in vitro [15–17] and in vivo [18]. A recent systematic review found overwhelming evidence that the use of CBCT is preferable to periapical radiography for detecting VRFs [19].

To the best of our knowledge, only Khedmat et al. [20] in an in vitro study explored digital radiography, 64-slice multidetector computed tomography (MDCT) (General Electric Co, Milwaukee, WI, USA) and Promax 3D CBCT unit (Planmeca, Roselle, IL, USA) in detecting VRF. In this research, the investigators inserted the teeth in acrylic resin which is different from the clinical situation where the radiologist inspects the teeth in scans of maxillae and mandibles. Therefore we thought it beneficial to compare the performance of Somatom Sensation 16 MDCT and i-CAT Next Generation CBCT in detection of VRF in a clinical setting.

2. Materials and methods

(1) Teeth collection:

The study was expedited from ethical review. Extracted posterior teeth were provided by the Department of Oral Surgery in our Institute and included in this study if they showed no root fractures, external root resorption or malformations.

(2) Vertical Root Fracture:

Twenty eight teeth were left intact to serve as control non-fractured group (NF). Forty seven teeth were artificially fractured in a vertical direction using a diamond disc 13 mm in diameter and 0.15 mm in thickness (SS White Lakewood, New Jersey, USA), both fragments were then re-assembled and glued by cyanoacrylate cement to simulate clinical conditions. Eleven teeth were excluded from the study because they fragmented into multiple parts. The remaining 36 teeth comprised the fractured study group (F).

(3) Mounting the teeth

The 64 teeth were arranged in the sockets of four dry human skulls and mandibles borrowed from the anatomy department. Both the study and the control groups were then covered with a 0.5–1 mm layer of rose wax (Tenatex Red; Kemdent, Swindon, UK) to mimic the periodontal ligament space radiographically in the dental arches. The teeth were randomly arranged in the empty dental alveoli. Each quadrant received two premolars and two molars, summing up to 16 teeth per skull/mandible assembly. The primary investigator tabulated the arrangement of F/NF teeth in the 4 assemblies to be used as the gold standard. To avoid bias, 2 other observers assessed the acquired volumes for VRFs.

(4) Radiographic scanning
(a) Multi-detector computed tomography

Each skull and mandible assembly was held in proper position on a Somatom Sensation 16-slice MDCT (Siemens Medical Systems, Erlangen, Germany) using laser positioning lights and head straps (Fig. 1A). Sixteen axial scans of 0.6 mm thickness were acquired in each rotation (120 kV, 80 mAs, rotation time 0.75 s, 0.6 mm^3 voxel size, 50 cm FOV). The DICOM file was sent to a Siemens workstation (Leonardo, Siemens Medical Systems, Erlangen, Germany) for image interpretation.

(b) Cone beam computed tomography

For CBCT imaging, i-CAT Next Generation (Imaging Sciences International, Hatfield, PA, USA) was used (120 kV, 5 mA, 7 s, 0.125 mm^3 voxel dimensions, 8 × 8 cm FOV, 360° arc of rotation). The skulls were supported in place using a cusom-made transparent plastic holder. Vertical and horizontal lasers were used to position the skull according to the manufacturer's instructions (Fig. 1B). The 3D volumetric images were assessed by the i-CAT Vision™ inherent software (Imaging Sciences International, Hatfield, Pa).

(5) Image Assessment

Both the MDCT and the CBCT images were viewed on a 512 × 512/8-bit matrix. The second and third authors having 16 and 20 years of experience respectively as a maxillofacial radiologists were attuned to diagnose VRF using a standardized scoring system. The primary investigator coded and randomized the MDCT and CBCT scans. Then, the 2 radiologists separately evaluated the MDCT and CBCT volumes in a subdued room. The radiologists were blind to the number and arrangement of fractured teeth in the arches. Images were assessed freely in the three orthogonal planes without time restriction. The observers were instructed to liberally adjust contrast and brightness to allow optimum vision of the images. VRF was assessed using a three point scoring system [21] as follows; (0) Absent, (1) Present, yet poorly defined, (2) Present and well defined. The first observer re-scored the MDCT and the CBCT images after an interval of 1 week to calculate intra-observer reliability. Then after another week, both radiologists re-assessed the slices together to obtain a consensus score.

2.1. Statistical analysis

Inter- and intra-observer agreements were measured by intra-class correlation coefficient. Reliability was evaluated with SPSS® Statistics Version 20 for Windows. Sensitivity, specificity, accuracy,

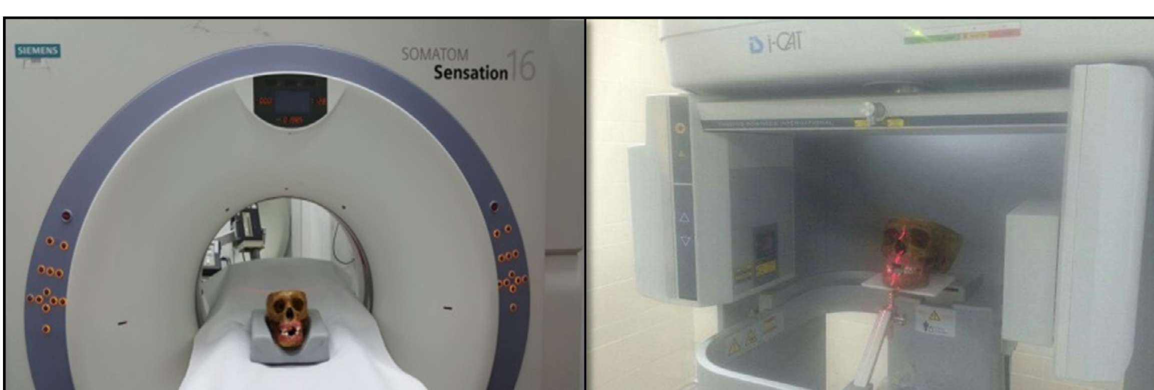

Fig. 1. Skull and mandible scanned by **A**. Somatom Sensation 16 slice MDCT And **B**. i-CAT Next Generation CBCT.