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Original Research

Detection of Procedural Errors during Root Canal Instrumentation using Cone Beam Computed Tomography

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Abstract:

Background: This study investigated procedural errors made during root canal preparation with nickel-titanium (NiTi) instruments, using cone beam computed tomography (CBCT) imaging method.

Materials and Methods: A total of 100 human mandibular molars were divided into five groups ($n = 20$) according to the NiTi system used for root canal preparation: Group 1 - BioRaCe, Group 2 - K3, Group 3 - ProTaper, Group 4 - Mtwo and Group 5 - Hero Shaper. CBCT images were obtained to detect procedural errors made during root canal preparation. Two examiners evaluated the presence or absence of fractured instruments, perforations, and canal transportations. Chi-square test was used for statistical analyzes. The significance level was set at α=5%.

Results: In a total of 300 prepared root canals, 43 (14.33%) procedural errors were detected. Perforation was the procedural errors most commonly observed (58.14%). Most of the procedural errors were observed in the mesiobuccal root canal (48.84%). In the analysis of procedural errors, there was a significant difference ($P < 0.05$) between the groups of NiTi instruments. The root canals instrumented with BioRaCe had significantly less procedural errors.

Conclusions: CBCT permitted the detection of procedural errors during root canal preparation. The frequency of procedural errors was low when root canals preparation was accomplished with BioRaCe system.

Key Words: Cone beam computed tomography, diagnostic imaging, root canal preparation, rotary instruments

Introduction

Current standards in root canal treatment are based on cleaning and shaping the root canal prior to filling.[1] An important innovation that has a major impact on these procedures has been the introduction of rotary nickel-titanium (NiTi) instruments.[2,3]

A considerable number of rotary NiTi instruments with particular design characteristics (cross-section, cutting angle, helical angle, radial grooves/edge, flutes, etc.) have been introduced in the market over the last years[4-7] and previous studies have been listed the main advantages of their use in the preparation of curved root canals, such as: Maintain working length (WL), allowing root canal preparation to be more centered and better tapered, creating fewer procedural errors when compared to stainless steel instruments, in addition to being faster.[2,3,5,6]

Several methods have been proposed to evaluate the performance and quality of root canal preparation with NiTi rotary instruments, such as histological, radiographic, sectional anatomical, scanning electron microscopy and computed tomography.[3,7-12] However, the destruction of the specimens may impede the simultaneous investigation of different parameters of root canal preparation, and place limitations on these methods.[8,13,14]

Cone beam computed tomography (CBCT) has been used for several clinical and investigational purposes in Endodontics, such as study of root canal configuration, evaluation of root canal preparation and filling, retreatment, three-dimensional (3D) simulation of internal and external tooth structures and diagnosis and treatment of bone lesions.[15-21] Its ability to reduce or eliminate the superimposition of surrounding structures makes CBCT superior to conventional periapical films.[15] Compared with medical tomography, CBCT has some advantages: Lower radiation dose, higher scanning resolution and more accuracy of volume measuring in different directions due to voxels being isotropic which make them different.[16]

Possible procedural errors that may affect the prognosis of the root canal treatment should be considered and evaluated before choosing a new endodontic instrument to be used.[22] Thus, the purpose of the present study was to evaluate procedural errors occurred during root canal preparation using rotary NiTi instruments employing CBCT imaging method.

Materials and Methods

This study was approved by the Research Ethics Committee of the Federal University of Goiás, Brazil (protocol number

042-2011), and written informed consent was obtained from all patients.

Tooth selection

A total of 100 extracted human mandibular molars were obtained from the Dental Urgency Service of the School of Dentistry of the Federal University of Goiás, Brazil. The teeth were stored in 0.2% thymol solution and then immersed in 5% sodium hypochlorite (NaOCl) (Fitofarma, Lt. 20553, Goiânia, Brazil) for 30 min to remove external organic tissues.

Preoperative radiographs of each tooth were taken to confirm the absence of calcified root canals, previous root canal treatment, prosthetic pins and internal and external resorption, and the presence of a fully formed root apex. Radiographic images were acquired using a Spectro X70 electronic X-ray unit (Dabi Atlante, Ribeirão Preto, SP, Brazil), 0.8 mm × 0.8 mm tube focal spot, Kodak Insight Film-E (Eastman Kodak Co, Rochester, NY, USA) and paralleling technique. A radiographic platform was used to standardize all radiographs. All films were processed in an automatic processor, and images were evaluated in a dark room using a light box under a magnifying glass.

Only three-canalled teeth were used in the study (mandibular molars with distal, mesiobuccal and mesiolingual root canals). All teeth were shorter than 22 mm, and mesial roots had a moderate curvature ($r > 4$ and ≤ 8 mm). The root curvature radius (r) was determined according Estrela *et al.*[23]

After taking periapical radiographs, standard access cavities were made by an endodontist using round diamond burs (#1013, #1014; KG Sorensen, Barueri, SP, Brazil) and Endo Z bur (Dentsply-Maillefer, Ballaigues, Switzerland), with a high-speed hand piece and air-water spray cooling. The WL was determined using #10 and #15 K-Flexofiles (Dentsply-Maillefer, Ballaigues, Switzerland), which were introduced into the root canals until being visible at the apical foramen. The WL was set 1 mm short of the apex. The root canals were randomly divided into five experimental groups of 20 teeth each, and prepared using the following instruments: G1 - BioRaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland); G2 - K3 (SybronEndo, Orange, CA, USA); G3 - ProTaper Universal (Dentsply-Maillefer, Ballaigues, Switzerland); G4 - Mtwo (Sweden-Martina, Padova, Italy); G5 - Hero Shaper (Micro Mega, Besancon, France).

Root canal preparation

The root canals were shaped at a rotational speed of 300 rpm (X-Smart, Dentsply-Maillefer) and 2.9 Ncm torque. In G1, BR0 (#25/0.08), BR1 (#15/0.05), BR2 (#25/0.04), BR3 (#25/0.06), BR4 (#35/0.04) and BR5 (#40/0.04) were used. In G2, the sequence used was #25/0.06 and #25/0.04 (to prepare of cervical and middle thirds), #25/0.02, #30/0.02, #35/0.02 and 40/0.02 (to prepare of apical third). In G3, SX were used for the cervical root preparation, and S1, S2, F1, F2, and F3 were used until the WL. In G4, the sequence used until the WL was #10/0.04, #15/0.05, #20/0.06, #25/0.06, #30/0.05, #35/0.04 and #40/0.04 and in G5, the sequence used was #25/0.06 and #25/.04 (to prepare of cervical and middle thirds), #25/0.02, #30/0.02, #35/0.02 and 40/0.02 (to prepare of apical third).

Two endodontist with more than 5 years of experience, registered at the Brazilian dentistry Association (Goiânia, GO, Brazil), prepared the root canals. The operators had an 8 h theoretical course on rotary instrumentation associated with clinical applications.

During preparations, the root canals were irrigated at each change of instrument with 3 ml of 1% NaOCl solution using a syringe with a 30-gauge needle (Injecta, Diadema, SP, Brazil). Root canals were dried and filled with 17% ethylenediaminetetraacetic (pH 7.2) (Biodinâmica, Ibiporã, PR, Brazil) for 3 min to remove the smear layer. Another 3 ml of 1% NaOCl solution was used for final irrigation.

Image evaluation

After root canal preparation, CBCT images were obtained using a PreXion 3D Inc. (San Mateo, CA, USA), thickness: 0.100 mm (dimensions 1.170 mm × 1.570 mm × 1.925 mm, FOV: 56.00 mm, voxel 0.100 mm, 33.5 s (1.024 views). Tube voltage was 90 kVp, and the tube current was 4 mA. Exposure time was 33.5 s. Images were examined with the scanner's proprietary software PreXion 3D Viewer (TeraRecon Inc., Foster City, CA, USA) in a PC workstation running Windows XP professional SP-2 (Microsoft Corp., Redmond, WA, USA), with processor Intel Core 2 Duo-6300 1.86 Ghz (Intel Corp., Santa Clara, CA, USA), NVIDIA GeForce 6200 turbo cache videocard (NVIDIA Corporation, Santa Clara, CA, USA), and Monitor EIZO-Flexscan S2000, resolution 1600 × 1200 pixels (EIZO NANAO Corp., Hakusan, Japan).

A total of 2 examiners (a radiologist and an endodontist) were calibrated using 20% of the specimens, and all images were evaluated to detect the presence or absence of fractured instruments, root perforations (coronal, middle or apical thirds) and deviation from the original trajectory of the root canal (apical transportation). Instruments fractures during preparation were also detected (Figure 1). When a consensus was not reached by the two examiners that interpreted the procedural errors using CBCT, a third observer (an endodontist) made the final decision.

Statistical analysis

Data were analyzed using the IBM SPSS for Windows 21.0 (IBM Corporation, Somers, NY, USA), including frequency distribution and cross-tabulation. Comparative statistical analysis was performed using Chi-square test, and the level of statistical significance was set at 5%.

Results

In a total of 300 root canals prepared, 43 (14.33%) procedural errors were detected (Table 1). The frequency of procedural errors detected using CBCT according to NiTi systems is described in Table 1. The root canals prepared with BioRaCe had significantly less procedural errors compared with those instrumented with other instruments ($P < 0.05$). Most of procedural errors were observed in the mesiobuccal root canal ($n = 21$; 48.84%), followed by distal ($n = 14$; 32.56%) and mesiolingual ($n = 8$; 18.60%) root canals.

Discussion

During a root canal preparation, several challenges may be encountered, such as understanding root canal curvature, determination of anatomical diameter and development of apical sanitization.[24] Thus, the selection of an appropriate instrument for root canal preparation is of importance for the outcome of root canal treatment.[13] In the continuous search to find an ideal instrument, instruments with different design were developed from NiTi alloy. Unfortunately, there is no perfect NiTi rotary system,[25] and a number of accidents and complications can be observed during root canal preparation.[6,10,21,26] The present study intended to evaluate the operative procedural errors during root canal treatment preparation, with five commercially available rotary NiTi instruments, using CBCT scans.

The assessment of procedural errors during root canal preparation by CBCT represents an expressive advance of information in clinical endodontics studies and contributes in planning, diagnosis, the therapeutic process and prognosis

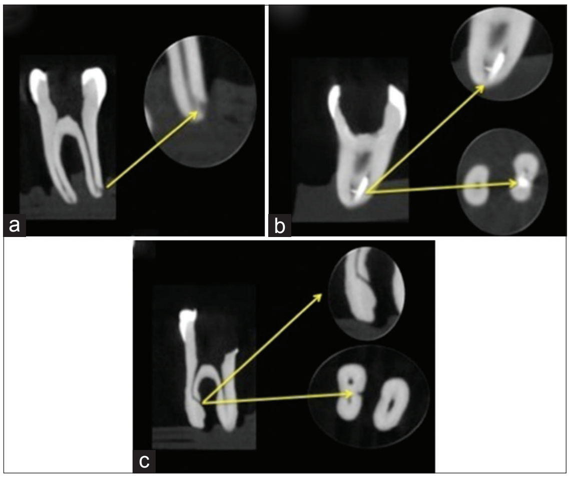

Figure 1: Procedural errors detected using cone beam computed tomography images; canal transportation (a), instrument fracture, (b) and perforation (c).

of root canal treatment. Different imaging resources had been routinely used before, during and after endodontic procedures.[7,11] Conventional radiographic images provide a two-dimensional (2D) rendition of a 3D structure, which may result in interpretation errors. Periapical lesions of endodontic origin may be present but not visible on conventional 2D imaging methods.[16-18]

Diagnostic accuracy is critical for endodontic treatment success.[21] The formation of artifacts, especially near bodies of high density, such as metal pieces (intraradicular cores, crowns and metal restorations) and filling materials may interfere with CBCT images leading to misdiagnosis. Thereby, precautions must be taken to deal with the effect of solid materials in the interior space of root canals on CBCT images.[20] In the present study, the CBCT images were obtained after the root canal preparation and no root filling procedure was accomplished. In addition, the images were analyzed by a specialist in Endodontics and a specialist in dental radiology, presenting expertise in 3D tracking, which used the of map-reading strategy on CBCT images to reduce the problems related to difficult evaluation conditions.[20]

The rotary NiTi instruments used in this study were BioRaCe, ProTaper Universal, Mtwo, K3 and Hero Shaper and the root canals were enlarged according to the manufacturers' recommendation. Comparison of instruments with different tapers was intentional, since one of the main concerns during the preparation of curved root canals is the determination of transversal enlargement that does not cause perforations or excessive wear. The samples were carefully selected and comprised teeth with mesial roots with moderate curvatures ($r > 4$ and $r \leq 8$ mm). A total of 300 root canals were prepared in this study and 43 procedural errors were identified (14.33%). These results confirm the low frequency of procedural errors during root canal preparation using rotary NiTi instruments.[12,22]

The frequency of procedural errors according to the instrument used was statistically significant ($P < 0.05$). The root canals prepared with BioRaCe had significantly less procedural errors ($n = 2$; 0.67%) (Table 1). This result is similar to that observed by Alves *et al.*,[22] which found low frequency of operative errors made by undergraduate students with the use of BioRaCe. Higher number of procedural errors was observed in the groups instrumented with Mtwo ($n = 15$; 5.00%) and ProTaper ($n = 14$; 4.67%) rotary NiTi instruments,

Table 1: Frequency of procedural errors according to NiTi instruments systems detected using CBCT images.

Procedural errors	NiTi instruments (%)					*P* value*
	BioRaCe	ProTaper	MTwo	K3	Hero Shaper	
Fracture	0 (0.00)	5 (11.63)	6 (13.95)	4 (9.30)	2 (4.65)	*P*<0.05
Perforation	2 (4.65)	9 (20.93)	9 (20.93)	3 (6.98)	2 (4.65)	
Canal transportation	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.33)	0 (0.00)	
Total	2 (4.65)	14 (32.56)	15 (34.88)	8 (18.60)	4 (9.30)	

*Chi-square test. CBCT: Cone beam computed tomography root perforations were the main operative procedural error in both groups. Bonaccorso *et al.*[27] compared the shaping ability of ProTaper, Mtwo, BioRaCe and BioRaCe + S-Apex instruments in simulated canals and observed that ProTaper instruments caused more pronounced canal transportation in the apical curvature than the others instruments and that the use of BioRaCe + S-Apex resulted in significantly fewer canal aberrations. For the authors the occurrence of operative accidents (ledges, zips/elbows and instrument failures) in teeth prepared with ProTaper and Mtwo might be explained by the increase in the taper 0.04 (S2) to 0.07 (F1) in the ProTaper system and by the fewer spirals per unit length in the Mtwo files.

The overall frequency of fractured instrument, in this study, was found to be 6.57% (n = 17). It was found a significant difference in the number of fractured instruments between the rotary NiTi instruments systems (Table 1). No instrument fracture was observed in BioRace group. The same was observed by Bonaccorso *et al.*[27] de Alencar *et al.*[12] reported a rotary instrument breakage rate of 3.33% while Alves *et al.*[22] of 3.88%. The instrument fracture may be associated with operator's knowledge, experience and technique and instrument's design and surface treatment.[28] Panitvisai *et al.*[29] determined, by a systematic review and meta-analysis, the impact of a retained instrument on root canal treatment outcome. Two case-control studies were identified and included, covering 199 cases. Weighted mean healing for teeth with a retained instrument fragment was 91%. The two studies were homogeneous, with the risk difference of the combined data of 0.01, indicating that a retained fragment did not significantly influence healing. For Spili *et al.*[30] in the hand of experienced operators, endodontic instrument fracture had no adverse influence on the outcome of root canal treatment and retreatment and the presence of preoperative periapical radiolucency is a more clinically significant prognostic indicator.

Interestingly, in the present study, just one canal transportation was identified (K3 group). This result contrasts with the results observed in previous studies,[10,31,32] which reported higher levels of canal transportation. Özer[32] compared the shaping ability (apical transportation and straightening) of 3 NiTi rotary instruments (ProTaper Universal, Hero 642 Apical and FlexMaster) in curved root canals using CBCT and observed that apical transportation occurred with all the instruments despite their non-cutting tips. Using a similar method, Oliveira *et al.*[31] identified 26 canals transportations. Most of them were observed after mechanical preparation with NiTiFlex and K-flexofiles activated by reciprocating system. The small number of canal transportation identified in the present study may be explained by not achievement of the root filling procedure. Canal transportations are best viewed when the root canals are filled.[22]

Despite the existence of one ever-present risk factor, the root canal preparation outcome with rotary NiTi instruments is mostly predictable. Further researches should be conducted with the purpose of adding knowledge that will produce answers to questions, as the best instrument.

Conclusions

CBCT permitted the detection of procedural errors during root canal preparation. The frequency of procedural errors was low when BioRaCe system was used.

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