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

Orlando Aguirre Guedes¹, Marcus Vinicius Corrêa da Costa¹, Maura Cristiane Gonçalves Orçati Dorillô¹,
Helder Fernandes de Oliveira², Fábio Luis Miranda Pedro³, Matheus Coelho Bandeça³, Álvaro Henrique Borges¹

Contributors:
¹Professor, Department of Endodontics, School of Dentistry, University of Cuiabá, Cuiabá, Mato Grosso, Brazil; ²Professor, Department of Stomatologic Sciences, School of Dentistry, Federal University of Goiás, Goiânia, Goiás, Brazil; ³Professor, Department of Prosthodontic Dentistry, School of Dentistry, Master Program in Dentistry, UNICEUMA, São Luís, Maranhão, Brazil.

Correspondence:
Dr. Guedes OA. Faculdade de Odontologia, Universidade de Cuiabá, Av. Manoel José de Arruda, 3100, Jardim Europa, 78065-900, Cuiabá, Mato Grosso, Brazil. Fax: +55 65 3363-1271, Tel.: +55 65 3363-1264, Email: orlandoaguedes@yahoo.com.br

How to cite the article:
Guedes OA, da Costa MV, Dorillô MC, de Oliveira HF, Pedro FL, Bandeça MC, Borges AH. Detection of procedural errors during root canal instrumentation using cone beam computed tomography. J Int Oral Health 2015;7(3):28-32.

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.²³

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 years⁴⁻¹² 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.²³⁵⁻⁶

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.³⁷⁻¹² However, the destruction of the specimens may impede the simultaneous investigation of different parameters of root canal preparation, and place limitations on these methods.⁸¹³¹⁴

Conical 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.¹⁰⁻¹¹ Its ability to reduce or eliminate the superimposition of surrounding structures makes CBCT superior to conventional periapical films.¹³ 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-canal 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 #25/0.04 (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).

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, Ibirapora, 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 during root canal preparation … Guedes OA et al
Procedural errors during root canal preparation ... Guedes OA et al

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 of root canal treatment. Different imaging resources had been routinely used before, during and after endodontic procedures. 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.

Diagnostic accuracy is critical for endodontic treatment success. 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. 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.

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 ≤ 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.

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., 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,

| Procedural errors                          | NiTi instruments (%) | P value* |
|--------------------------------------------|----------------------|----------|
| Fracture                                   | BioRaCe 0 (0.00) | ProTaper 5 (11.63) | Mtwo 6 (13.95) | K3 4 (9.30) | Hero Shaper 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. 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. who reported a rotary instrument breakage rate of 3.33% while Alves et al. of 3.88%. The instrument fracture may be associated with operator’s knowledge, experience and technique and instrument’s design and surface treatment. Panitvisai et al. 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. 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, which reported higher levels of canal transportation. Özer 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. identified 26 canals transportation. 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.

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.

References
1. West JD, Roane JB. Cleaning and shaping the root canal system. In: Cohen S, Burns RC, (Editors). Pathways of the Pulp, 7th ed. St Louis, MO: CV Mosby; 1988. p. 203-57.
2. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14(7):346-51.
3. Esposito PT, Cunningham CJ. A comparison of canal preparation with nickel-titanium and stainless steel instruments. J Endod 1995;21(4):173-6.
4. Yared GM, Bou Dagher FE, Machtou P. Influence of rotational speed, torque and operator’s proficiency on ProFile failures. Int Endod J 2001;34(1):47-53.
5. Mesgouez C, Rilliard F, Matossian L, Nassiri K, Mandel E. Influence of operator experience on canal preparation time when using the rotary Ni-Ti ProFile system in simulated curved canals. Int Endod J 2003;36(3):161-5.
6. Hülsmann M, Peters O, Dummer PM. Mechanical preparation of root canals: Shaping goals, techniques and means. Endod Top 2005;10:30-76.
7. Gekelman D, Ramamurthy R, Mirfarsi S, Paqué F, Peters OA. Rotary nickel-titanium GT and ProTaper files for root canal shaping by novice operators: A radiographic and micro-computed tomography evaluation. J Endod 2009;35(11):1584-8.
8. Peters OA, Laib A, Rüegsegger P, Barbakow F. Three-dimensional analysis of root canal geometry by high-resolution computed tomography. J Dent Res 2000;79(6):1405-9.
9. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Top 2005;10:3-29.
10. Hartmann MS, Barletta FB, Camargo Fontanella VR, Vanni JR. Canal transportation after root canal instrumentation: A comparative study with computed tomography. J Endod 2007;33(8):962-5.
11. Santos SM, Soares JA, César CA, Brito-Júnior M, Moreira AN, Magalhães CS. Radiographic quality of root canal fillings performed in a post-graduate program in endodontics. Braz Dent J 2010;21:315-21.
12. de Alencar AH, Dummer PM, Oliveira HC, Pécora JD, Estrela C. Procedural errors during root canal preparation using rotary NiTi instruments detected by periapical radiography and cone beam computed tomography. Braz Dent J 2010;21(6):543-9.
13. Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. J Endod 2004;30(8):559-67.
14. Tu MG, Chen SY, Huang HL, Tsai CC. Endodontic shaping performance using nickel-titanium hand and motor ProTaper systems by novice dental students. J Formos Med Assoc 2008; 107(5): 381-8.
15. Loftthag-Hansen S, Huumonen S, Gröndahl K, Gröndahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103(1): 114-9.
16. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod 2007; 33(9): 1121-32.
17. Estrela C, Bueno MR, Azevedo BC, Azevedo JR, Pécora JD. A new periapical index based on cone beam computed tomography. J Endod 2008; 34(11): 1325-31.
18. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod 2008; 34(3): 273-9.
19. Estrela C, Bueno MR, De Alencar AH, Mattar R, Valladares Neto J, Azevedo BC, et al. Method to evaluate inflammatory root resorption by using cone beam computed tomography. J Endod 2009; 35(11): 1491-7.
20. Bueno MR, Estrela C, De Figueiredo JA, Azevedo BC. Map-reading strategy to diagnose root perforations near metallic intracanal posts by using cone beam computed tomography. J Endod 2011; 37(1): 85-90.
21. Silva JA, de Alencar AH, da Rocha SS, Lopes LG, Estrela C. Three-dimensional image contribution for evaluation of operative procedural errors in endodontic therapy and dental implants. Braz Dent J 2012; 23(2): 127-34.
22. Alves RA, Souza JB, Gonçalves Alencar AH, Pécora JD, Estrela C. Detection of procedural errors with stainless steel and NiTi instruments by undergraduate students using conventional radiograph and cone beam computed tomography. Iran Endod J 2013; 8(4): 160-5.
23. Estrela C, Bueno MR, Sousa-Neto MD, Pécora JD. Method for determination of root curvature radius using cone-beam computed tomography images. Braz Dent J 2008; 19(2): 114-8.
24. Pécora JD, Estrela C. Challenges of root canal preparation. In: Estrela C. (Editor). Endodontic Science, São Paulo: Artes Médicas Dentistry; 2009. p. 571-90.
25. Mouce RE. Does NiTi nirvana exist? Contemp Endod 2004; 1: 8-13.
26. Lim SS, Stock CJ. The risk of perforation in the curved canal: Anticurvature filing compared with the stepback technique. Int Endod J 1987; 20(1): 33-9.
27. Bonaccorso A, Cantatore G, Condorelli GG, Schäfer E, Tripi TR. Shaping ability of four nickel-titanium rotary instruments in simulated S-shaped canals. J Endod 2009; 35(6): 883-6.
28. Sonntag D, Delschen S, Stachniss V. Root-canal shaping with manual and rotary Ni-Ti files performed by students. Int Endod J 2003; 36(11): 715-23.
29. Panitvisai P, Parunnit P, Sathorn C, Messer HH. Impact of a retained instrument on treatment outcome: A systematic review and meta-analysis. J Endod 2010; 36(5): 775-80.
30. Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. J Endod 2005; 31(12): 845-50.
31. Oliveira CA, Meurer MI, Pascoalato C, Silva SR. Cone-beam computed tomography analysis of the apical third of curved roots after mechanical preparation with different automated systems. Braz Dent J 2009; 20(5): 376-81.
32. Özër SY. Comparison of root canal transportation induced by three rotary systems with noncutting tips using computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011; 111(2): 244-50.