

Effectiveness of ProTaper Universal® and D-RaCe® retreatment files in the removal of root canal filling material: an *in vitro* study using digital subtraction radiography

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ABSTRACT

Aim: To compare the effectiveness of the ProTaper Universal® Retreatment system, the D-Race® NiTi system and Hedström files for removal of filling material from curved root canals.

Methodology: A total of 39 first mandibular molars were selected and their mesiobuccal (MB) canals were used for the study. Teeth were assigned to one of three identical groups (n = 13 per group) according to removal technique: G1 – ProTaper Universal® Retreatment (D1, D2, D3); G2 – D-RaCe® (DR1, DR2); or G3 – Hedström files (35, 30, 25, 20). In all groups, supplementary files were used for re-preparation. Digital subtraction radiography images were produced by superimposing the first radiograph, taken after filling the canal, over the second, taking after removal of the filling, in buccolingual (BL) and mesiodistal (MD) projections. Quantitative data were analyzed using intraclass correlation coefficients and the Kruskal-Wallis and Friedman non-parametric tests ($p \leq 0.05$).

Results: Comparison of groups detected no differences in filling removal between teeth in the ProTaper Universal® Retreatment, D-RaCe® or Hedström file groups for the cervical or mid thirds (for either MD or BL projections). In the apical third (MD projection), ProTaper Universal® Retreatment produced the best results; and Hedström files exhibited the worst results (MD projection). Intra-group comparisons showed that the cervical third was the cleanest and the apical third was the least well-cleaned, for the ProTaper Universal® Retreatment and D-RaCe® groups (MD

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projection), while less filling material was removed using Hedström when the canals approached the apical third (MD and BL projections).

Conclusions: Our findings indicate that the ProTaper Universal® Retreatment system is the best choice for endodontic filling material removal, combined with supplementary instrumentation to achieve better results in the apical third.

Keywords: Gutta-Percha Removal, Nickel-Titanium, Root Canal Retreatment, Rotary Instruments.

Eficácia dos sistemas de retratamento ProTaper Universal® e D-RaCe® na remoção de material obturador: estudo *in vitro* utilizando subtração radiográfica digital

RESUMO

Objetivo: Comparar a eficácia dos sistemas de retratamento ProTaper Universal®, D-RaCe® NiTi e Hedström na remoção de material obturador de canais curvos.

Metodologia: Um total de 39 primeiros molares inferiores foram selecionados, e seus canais mesioibucais (MB) foram utilizados. Os dentes foram atribuídos a um entre três grupos idênticos (n = 13 por grupo), de acordo com a técnica de remoção do material: G1 – ProTaper Universal® (D1, D2, D3); G2 – D-RaCe® (DR1, DR2); ou G3 – Hedström (35, 30, 25, 20). Em todos os grupos, instrumentos complementares foram usados no reprepáro. Imagens de subtração radiográfica digital foram obtidas sobrepondo a primeira radiografia, obtida após o preenchimento do canal, à segunda, obtida após a remoção do material, em projeções bucolingual (BL) e mesiodistal (MD). Dados quantitativos foram analisados usando coeficientes de correlação intraclasse e os testes não paramétricos de Kruskal-Wallis e Friedman ($p \leq 0,05$).

Resultados: A comparação entre os grupos não detectou diferenças na remoção do material obturador entre os dentes preparados utilizando os sistemas ProTaper Universal®, D-RaCe®, ou Hedström nos terços cervical e médio (nas projeções BL ou MD). No terço apical (projeção MD), o sistema ProTaper Universal® produziu os melhores resultados; já os instrumentos Hedström mostraram os piores resultados (projeção MD). As comparações intragrupo mostraram que o terço cervical era o mais limpo, e que o terço apical era o menos limpo, nos grupos tratados tanto com ProTaper Universal® quanto com D-RaCe® (projeção MD); no grupo tratado com instrumentos Hedström, menos material obturador foi removido à medida que os canais se aproximavam do terço apical (projeções MD e BL).

Conclusões: Nossos resultados indicam que o sistema ProTaper Universal® é a melhor escolha para a remoção de material obturador, combinado com instrumentação suplementar para a obtenção de melhores resultados no terço apical.

Palavras-chave: Remoção de Gutta-Percha, Níquel-Titânio, Retratamento de Canal Radicular, Instrumentos Rotatórios.

INTRODUCTION

Endodontic failures are caused by insufficient root canal debridement, inadequate fillings, presence of necrotic tissue or recurrent cavities, and when coronal leakage occurs. Sjogren et al. (1) point out that bacteria can become lodged in places that cannot be reached during endodontic treatment and can impact on resolution of the case.

Once a failure of endodontic treatment has been identified, it can be successfully repaired using retreatment or surgical procedures (2,3). Retreatment success rates are high. Ng et al. (4) found an average success rate of 77 % for endodontic retreatment. Torabinejad et al. (5) conducted a systematic review and found that nonsurgical endodontic retreatment offers long-term favorable prognosis and success rate can reach 83% over 4-6 years' follow-up.

Root canal fillings can be removed using hand tools (6), ultrasound (7) or, more recently, rotary nickel-titanium instruments (8). The most frequently used instruments for the removal of filling material include ProTaper UR®, D-RaCe® and Mtwo, which are all rotary nickel-titanium instruments. Studies have been conducted to investigate these instruments, but there is no consensus between authors on their performance (9,10) since each group has studied different dental anatomies.

Several authors have noted that none of the techniques using rotary systems have proven capable of completely removing the filling material from inside root canals (11,12). Removal of root canal fillings requires the use of appropriate materials and the correct sequence of steps, because the technique is difficult to implement. With the objective of facilitating complete removal, some authors have suggested combining rotary systems with manual instruments to complete the removal procedure, bearing in mind that they can be pre-bent (6,13,14).

Furthermore, the root canal filling removal procedure can be made more difficult by dental anatomy, since root complexity is directly related to the possibility of using instruments on them (15). More complex anatomical variations are seen in multi-rooted teeth when they flatten in the proximal direction and are curved; however, most research is carried out on straight canals or single-rooted teeth (7,14,16). This highlights the importance of conducting further work in this line of research, because such canals are often encountered in clinical practice (9).

Based on the literature review summarized above, it is quite clear that there is a need for studies to investigate rotary systems in curved root canals and multi-rooted teeth. Therefore, the objective of this study was to evaluate in vitro the effectiveness of the removal procedure using two specific nickel-titanium rotary systems for retreatment supplemented by manual procedures, in first lower molars.

MATERIALS AND METHODS

Specimen preparation

After ethics committee approval had been granted, 39 first mandibular molars were selected and stored in a 0.1% thymol solution (Farmácia ULBRA, Canoas, RS, Brazil). All teeth had intact (or partially intact) crowns, intact mesiobuccal (MB) roots and fully developed apices. Teeth with intracanal posts, root resorption, canal calcification or root fractures were excluded after radiographic analysis. Samples

were marked with numbers (from 1 to 39) and their mesial and distal sides were identified. Only the MB canal was used in this study.

Canal instrumentation

A single operator prepared root canals using the ProTaper Universal® system. Root canal length was determined using a size 10 K-file (DentsplyMaillefer) introduced passively into the canal until its tip was just visible at the major apical foramen. Canals were prepared under constant irrigation, alternating 2 mL of 1% sodium hypochlorite and 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) trisodium solution, using the crown-down technique, as suggested by ProTaper Universal. A rotary file powered by an electric motor, operating at 300 rpm (Endo-Max; Adiel, São Paulo, Brazil) and coupled to a 16:1 reduction handpiece was used at a torque of 2Ncm. ProTaper Universal instruments were used, as recommended by the manufacturer, specifically, SX, S1, S2, F1, F2 and F3 (master file). Instruments were used 5 times and then discarded. A total of 25 mL of 2.5% NaOCl (Farmácia ULBRA, Canoas, RS, Brazil) was delivered with a 30-gauge needle after each instrument change throughout instrumentation. Once instrumentation was completed, a final flush with 5 mL of a 17% EDTA aqueous solution (Farmácia ULBRA, Canoas, RS, Brazil) was conducted for 3 min, followed by final irrigation with 5 mL of 2.5% NaOCl.

Canal filling

Canals were filled using the lateral compaction technique (17). Before filling, the canal was dried using paper points. A size 35 gutta-percha master cone was selected, positioned and customized. Medium-fine accessory cones (Dentsply) were then laterally compacted. The canal access was repaired using Cavit-G (3M Espe, Seefeld, Germany). Subsequently, teeth were stored under 100% humidity at 37 °C for 2 weeks (9,10,18).

Filling removal

Group1: ProTaper Universal Retreatment group (n = 13) ProTaper Universal Retreatment (PTUR) instruments were used to remove the filling material in a crown-down technique as follows: D1 (size 30, 0.09 taper) for the cervical third, D2 (size 25, 0.08 taper) for the middle third, and D3 (size 20, 0.07 taper) for the apical third, until the working length was reached. Instruments were used coupled to an XSmart electric motor (Dentsply Maillefer), at a speed of 300 rpm and with a torque of 3Ncm⁻¹. Final instrumentation was performed using #25, #30 and #35 stainless steel hand K-files. Irrigation was performed in an identical manner to during the root canal filling phase.

Group 2: D-RaCe® Group (n = 13) D-RaCe® retreatment instruments were used according to the manufacturer's instructions (with regard to speed and torque), as follows: DR1 (size 30, 0.10 taper) at a speed of 1000 rpm and torque of 1.5Ncm for the cervical

third and beginning of the middle third and DR2 (size 25, 0.04 taper) at 600-rpm speed and a torque of 0.7Ncm^{-1}) at the working length. Final instrumentation was performed using #25, #30 and #35 stainless steel hand K-files. Irrigation was performed in an identical manner to during the root canal filling phase.

Group 3: Hedstroëm files (n = 13) sizes 35, 30, 25 and 20 Hedström files were used in a circumferential quarter-turn push-pull filing motion to remove gutta-percha and sealer until the estimated working length had been reached. Further apical preparation was performed with stainless steel hand K-files #25, #30 until no residual filling material could be detected.

Radiographic technique

To ensure consistent radiographs for all specimens, an L-shaped wooden platform was manufactured, as described previously in studies by Kunert et al. (19) and Zanette et al. (20). This platform was designed to position the cylinder of the radiographic device (Expectro 70x; Dabi Atlante, Ribeirão Preto, Brazil) perpendicular to the digital sensor (IOX F1; Fimet, Monninkylä, Finland) at a focal distance of 30 cm. The sensor was molded and reproduced using acrylic resin to guarantee an identical position for all radiographic images. Images were obtained at 2 different points in time for each group: after canal filling and after filling removal. Each tooth was X-rayed in both buccolingual (BL) and mesiodistal (MD) projections.

Digital subtraction radiography (DSR)

Pairs of images of the same tooth were subtracted using Adobe Photoshop CS6 version 13.0 (Adobe Systems, San Jose, CA). Subtractions were analyzed after superimposition of images taken after canal filling over images taken after filling removal. The residual canal filling material was assessed visually based on a qualitative analysis and assigned a score of A, B, C, D or E, where A represents absence of material, B up to 25% remnants, C > 25% to 50%, D > 50% to 75% and E more than 75% of material remaining. The area of residual filling was assessed on all root canal surfaces (total area) and for each root canal third (cervical, middle, and apical).

Data analysis

Data on residual root filling, for all three thirds from each of the three groups, were compared using the Kruskal-Wallis non-parametric test. The Friedman test was used to analyze intragroup differences, between root thirds. The Statistical Package for the Social Sciences, version 17.0 for Windows, SPSS Inc, Chicago, IL, USA, was used for these calculations. Statistical significance was set at $p < 0.05$. Two evaluators assessed residual root canal filling material and the results were compared using the intraclass correlation coefficients.

RESULTS

Analysis of residual root canal filling material results for the three thirds indicated that inter-examiner agreement rates were adequate (intraclass correlation coefficient, $p > 0.05$). Table 1 lists the frequencies (n) and percentages (%) of residual canal filling for all three thirds from Groups 1, 2 and 3, as viewed from both BL and MD radiographic projections.

The Kruskal-Wallis non-parametric test only detected statistical differences for the comparison between groups in the MD projection for the apical thirds, for which the best results (lowest amount of residual filling material) were for G1: ProTaper Universal® Retreatment.

The Friedman non parametric test detected statistical differences between thirds (intra-group comparisons) for all three Groups in the MD projection: the greatest amount of filling remaining (scored D and E) was in the apical third, when compared to the mid and cervical thirds. In the BL projection, there was only a statistical difference for G3 (Hedström files): after which there were 11 (84.6%) samples with more than 50% of material remaining in the apical third, with a statistical difference from the mid and cervical thirds (cervical<medium<apical).

TABLE 1 – Frequency (n) and percentage (%) of canal filling material remaining in cervical, mid and apical thirds in Groups 1, 2 and 3, in buccolingual and mesiodistal radiographic projections, n (%)

Canal third/scores	DSR in mesiodistal projection				DSR in buccolingual projection			
	G1 ProTaper	G2 D-RaCe®	G3 Hedstroëm	Comparison between groups (p)	G1 ProTaper	G2 D-RaCe®	G3 Hedstroëm	Comparison between groups (p)
Cervical								
A - Absence	2 (15.4)	3 (23.1)	1 (7.7)	0.384	2 (15.4)	-	1 (7.7)	0.542
B - Up to 25%	4 (30.8)	6 (46.2)	7 (53.8)		-	3 (23.1)	1 (7.7)	
C - > 25 to 50%	3 (23.1)	3 (23.1)	4 (30.8)		4 (30.8)	7 (53.8)	5 (38.5)	
D - > 50 to 75%	4 (30.8)	1 (7.7)	1 (7.7)		7 (53.8)	2 (15.4)	6 (46.2)	
E - > 75%	-	-	-		-	1 (7.7)	-	
Mid								
A - Absence	-	2 (15.4)	-	0.204	2 (15.4)	3 (23.1)	1 (7.7)	0.869
B - Up to 25%	5 (38.5)	5 (38.5)	5 (38.5)		1 (7.7)	2 (15.4)	2 (15.4)	
C - > 25 to 50%	4 (30.8)	3 (23.1)	1 (7.7)		1 (7.7)	1 (7.7)	1 (7.7)	
D - > 50 to 75%	4 (30.8)	3 (23.1)	4 (30.8)		7 (53.8)	4 (30.8)	7 (53.8)	
E - > 75%	-	-	3 (23.1)		2 (15.4)	3 (23.1)	2 (15.4)	
Apical								
A - Absence	1 (7.7)	-	-	0.050*	2 (15.4)	-	1 (7.7)	0.101
B - Up to 25%	2 (15.4)	-	2 (15.4)		-	2 (15.4)	1 (7.7)	
C - > 25 to 50%	2 (15.4)	4 (30.8)	1 (7.7)		-	1 (7.7)	-	
D - > 50 to 75%	7 (53.8)	5 (38.5)	1 (7.7)		7 (53.8)	6 (46.2)	1 (7.7)	
E - > 75%	1 (7.7)	4 (30.8)	9 (69.2)		4 (30.8)	4 (30.8)	10 (76.9)	
Comparison between thirds (intra-group), p	00.000†	0.000†	0.000†		0.080	0.184	0.006†	

DSR = digital subtraction radiography.

* Statistically significant difference.

† Significance $p \leq 0.05$ according to Kruskal-Wallis non-parametric test (in columns) and Friedman non-parametric test (in rows).

DISCUSSION

Achieving maximum removal of filling material during root canal retreatment is a challenge for clinicians and therefore any study that adds to knowledge of the subject is welcome. This study responds to this challenge and to the lack of investigations using DSR, by comparing the effectiveness of two NiTi rotary systems designed to remove endodontic filling material: ProTaper Universal® Retreatment and D-RaCe®.

The main findings of this study can be summarized as follows: comparison of experimental Groups showed that: 1) there were no differences in filling removal efficacy between ProTaper Universal® Retreatment, D-RaCe® and Hedström files for the cervical or mid thirds (irrespective of projection, MD or BL); 2) ProTaper Universal® Retreatment achieved the best results in the apical third (on MD projections), since 23.1% (n = 3) of the samples had zero or less than 25% of filling material remaining; 3) Hedström files achieved the worst results in apical third (MD projection), since 76.9% (n = 10) of the samples had more than 50% of filling material remaining. Additionally, intra-group comparison showed that: 1) the cervical third was the cleanest and the apical third was the least-well cleaned after using ProTaper Universal® Retreatment (in MD projection) and D-RaCe® (also in MD projection); and 2) that the proportion of filling material removed reduces when the canal approaches the apical third and Hedström files are used (in both MD and BL projections).

Our results are in agreement with the literature in that none of the retreatment techniques or instruments were effective for complete removal of filling material from the root canal (21). The present study therefore highlights the well-known difficulty of removing gutta-percha and sealer from the entire root canal (3,10,21) and particularly from the apical third of the root, which is the area that is most critical for achieving apical disinfection and periapical healing. It is evident that the ProTaper Universal® Retreatment system was the most effective at removing material from the apical third, which prompts us to suggest that this system is appropriate for retreatment of the mesial canals of mandibular molars. This finding conflicts with the conclusions of a study by Rödiger et al. (9), who found that using D-RaCe® instruments led to significantly less residual filling material than either ProTaper Universal® Retreatment instruments or Hedström files. Factors that could explain the differences between the two studies include methodological differences such as technique and file size used for supplementary apical preparation (re-preparation) and the method employed to evaluate residual filling material.

It should be borne in mind that we used supplementary instruments to complete re-preparation of the root canals and that this could have maximized filling removal. This procedure was adopted with the intention of reproducing clinical scenarios, as has been done by several other authors (10,18,21).

Several techniques for the removal of filling material have been described recently, such as computed tomography (13,22), photographs of tooth halves (18), scanning tooth halves at high resolution (10), preoperative and postoperative micro-CT imaging (9),

and micro-CT with three-dimensional reconstruction (21). In our study, we chose to use DSR because it is a reproducible method that is available at dental schools and enables us to analyze the two radiographic projections selected (BL and MD) after root canal filling and after removal of the material. Our research group has used DSR to evaluate several outcomes (19,20), as have other teams (23,24).

The inadequate efficacy of material removal from the apical third (for all three groups, and particularly for Hedström files) highlights the need for combined efforts to obtain successful removal of root canal filling, cleaning and disinfection. Instrumentation techniques and different instruments and irrigation systems must be continually studied in order to offer the best treatment to patients. In conclusion, our findings indicate that the ProTaper Universal® Retreatment system is the best choice for endodontic filling material removal, supplemented by additional instrumentation to achieve better results in the apical third.

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