Calcium hydroxide fillings in curved canals: influence of apical enlargement using the rotary systems ProTaper, K3, and two hand instrumentation techniques

Preenchimento de canais curvos com hidróxido de cálcio: influência do alargamento apical usando os sistemas rotatórios ProTaper, K3 e duas técnicas de instrumentação manual

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Abstract

Objective: This study aimed to analyze the influence of the instrumentation technique (hand or rotary), and apical enlargement on calcium hydroxide (CH) fillings in curved canals. Materials and method: One hundred and ten simulated root canals were divided into eleven experimental groups (G). Canals were prepared with K-Flexofile hand instruments, using either crown-down (GCD 25, GCD 30 and GCD 35) or step-back (GSB 25, GSB 30 and GSB 35) techniques; and with rotary instruments, using either ProTaper (GPT F1 and GPT F2) or K3 (GK3 25, GK3 30 and GK3 35) systems. The apical diameter corresponded to 0.20 mm (GPT F1), 0.25 mm (GCD 25, GSB 25, GPT F2 and GK3 25), 0.30 mm (GCD 30, GSB 30, GK3 30), and 0.35 mm (GCD 35, GSB 35, GK3 35). A CH paste, previously colored with blue Indian ink, was injected into the canals using a special syringe. The four sides of the blocks with simulated canals were scanned and the images were transferred to the AutoCAD-2008 software, for assessing the amount (%) of filling in the apical 5 mm

(ANOVA; Tukey's Test; α =0.05). Qualitative analysis was also performed regarding the presence or absence of voids (Chi-square Test; α =0.05). Results: In GSB, there was significant difference between diameters 25 and 30. GSB showed lower amount of filling (P<0.05) than GK3, when the apical diameter corresponded to 0.30 mm. GCD showed lower amount of filling (P<0.05) than the other groups (SB, PT, and K3), when the apical diameter corresponded to 0.25 mm. No significant difference was detected when comparing the four sides of the blocks. Conclusion: Preparation technique and apical diameter had slight or no relevant influence on CH paste filling in simulated curved root canals. Statistical differences found in this study may be clinically irrelevant, since the amount of filling, regardless of preparation technique and apical diameter, was very close or equal to 100%.

Keywords: Endodontics. Root canal preparation. Calcium hydroxide.

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Introduction

Endodontic literature has clearly established the correlation among the presence of bacteria, their byproducts and apical periodontitis^{1,2}. Therefore, the main goal of endodontic treatment is to prevent or eliminate infection within root canal systems. Numerous investigations have shown the limited efficiency of mechanical preparation in cleaning the apical third of root canals^{3,4}. Thus, additional chemical disinfection promoted by irrigating solutions and root canal dressings has been suggested^{3,5-7}.

Calcium hydroxide (CH) is one of the most commonly used substances in endodontics. Its antibacterial property stems from its ability to dissociate into calcium and hydroxyl ions resulting in increased pH. The beneficial effect of CH has been related to the break up of fatty acids from gram-negative bacteria, inactivation of endotoxins, and damage to bacterial DNA⁸⁻¹⁰. On the other hand, the effectiveness of CH-based pastes depends on their direct contact with the canal walls¹¹⁻¹⁵, which may be limited by anatomical difficulties in curved canals¹².

The improvement of instrumentation techniques and the advent of nickel-titanium (NiTi) rotary instruments enabled increased apical enlargements, and more centered and tapered preparations in curved canals^{15,16}. Previous studies have shown that the canal preparation size, as the instrumentation technique, significantly influences the mechanical efficacy of irrigation^{17,18}. On the other hand, their ability to improve root canal obturation is controversial¹⁹, and their effect on the quality of CH fillings in curved canals should be further investigated.

Over the years, the understanding of root canal anatomical features has been considered to improve instrumentation techniques. In this regard, aspects such as the normal dentin apposition in the cervical region and root canals tapered shape²⁰ has been taken into account when determining changes on instrument sequences and designs. Hereof, step-back and crown-down techniques using taper .02

hand files have been suggested to replace the classical instrumentation technique²¹. Moreover, considering NiTi alloy properties, several rotary systems were suggested. The first introduced rotary systems, in which K3 (Sybron Endo, Orange County, CA, USA) is included, offers sequences of instruments with different tapers, ranging from .02 to .12, although keeping ISO-sized tips (ISO 3630-1), as well as a single value of taper for each file²². The option of greater taper allows coronal enlargement during canal instrumentation, enabling safer apical preparations. Instruments presenting variable tapers in the same shaft, such as ProTaper (Dentsply Maillefer, Ballaigues, Switzerland), were designed later, aiming to reduce the number of instruments, while improving the coronal dilatation and avoiding the contact of the file tip with dentinal walls.

The aim of this study was to assess the effect of instrumentation techniques (hand or rotary instruments) and apical enlargement on CH fillings in simulated curved canals.

Materials and method

The sample comprised 110 acrylic blocks with simulated root canals with 35° apical curvature (Endo Training Blocks; Dentsply-Maillefer, Ballaigues, Switzerland) which were randomly assigned to 11 experimental groups (n=10), according to the instrumentation technique and apical enlargement (Table 1). Canal instrumentation was performed with K-Flexofile hand instruments (Dentsply-Maillefer, Ballaigues, Switzerland) using either crown--down (CD) or step-back (SB) technique, and rotary instrumentation using either ProTaper Universal (PT) (Dentsply-Maillefer, Ballaigues, Switzerland) or K3 (SybronEndo, Orange, CA, USA) systems. For hand techniques, the canals were prepared up to sizes 25, 30, and 35 instruments; for ProTaper, apical stops were established by using F1 (20/.07) and F2 (25/.08) instruments; for K3, apical stops were prepared using 25/.06, 30/.04, and 35/.06 instruments.

Table 1 - Experimental			

		Preparation technique			Anical diameter				
		Hand Rotary		Apical diameter					
Group	N	Crow-down	Step-back	ProTaper	K3	20	25	30	35
GCD25	10	X					X		
GCD30	10	X						X	
GCD35	10	X							X
GSB25	10		X				X		
GSB30	10		X					X	
GSB35	10		X						X
GPT F1	10			X		X			
GPT F2	10			X			X		
GK3 25	10				X		X		
GK3 30	10				X			X	
GK3 35	10				X				X
Total	110								

All simulated canals were irrigated with 1% sodium hypochlorite (NaOCl) (Biodinâmica Química e Farmacêutica, Ibiporã, PR, Brazil) and initially explored with size 15 K-Flexofile instruments at the working length (WL; 16 mm). A single operator blinded to the groups performed root canal preparations and CH fillings. Throughout the experiment, acrylic blocks were maintained in a fixed position with a holding device (Neboluz Comercial de Ferramentas Ltda, São Paulo, SP, Brazil).

Hand Preparation

Crown-down technique

Instrumentation was initiated with a large-sized instrument, with a brushstroke action against canal walls and no pressure towards the apex. Two sequential instruments of smaller sizes were used intercalating with NaOCl irrigation, and a size 10 K-file was introduced up to the WL. Coronal preflaring was carried out with #1 and #2 Gates-Glidden drills, and hand instruments of decreasing size were used until the WL was reached. The apical stop was prepared using anticurvature brushing movements with sizes 25, 30 or 35 K-Flexofile instruments, according to the group. Soon after, canals were prepared by stepping back 1 mm a time with three subsequently larger instruments. During the crown-down approach, canals were explored with a size 10 K-file at the WL. Likewise, during the step--back stage, the master apical file was used at each change of file at the WL.

Step-back technique

The preparation was initiated with a size 15 K-Flexofile. Larger-sized instruments were sequentially used along the entire WL, using anticurvature movements, until reaching an apical diameter of 25, 30 or 35, according to the group. Afterwards, simulated canals were additionally prepared with three larger instruments, decreasing the WL in 1 mm for each change of file.

Rotary Preparation

Rotary instrumentation was performed using an electric engine (X Smart, Dentsply-Maillefer, Ballaigues, Switzerland) activated at 300 rpm and 2 N/cm torque. Continuous and pressureless movements were established. For ProTaper, preparation started with S1 and SX instruments at the coronal third followed by S2 instruments at the middle third, with brushing action in a crown-down mode. Apical stop was prepared either with F1 or F2 instruments. For K3, Variable Tip Variable Taper (VTVT) technique was employed, according to

manufacturer's instructions. Sequentially, #25/.10, #25/.08, 35/.06, 30/.04, and 25/.06 instruments were employed. To prepare the apical stop, instruments were used in reverse order, establishing the following final apical diameters: 25/.06, 30/.04 or 35/.06.

Hand and rotary instruments were discarded after every 5 preparations. Following instrumentation, canals were dried with absorbent paper points.

Intracanal delivery of CH paste

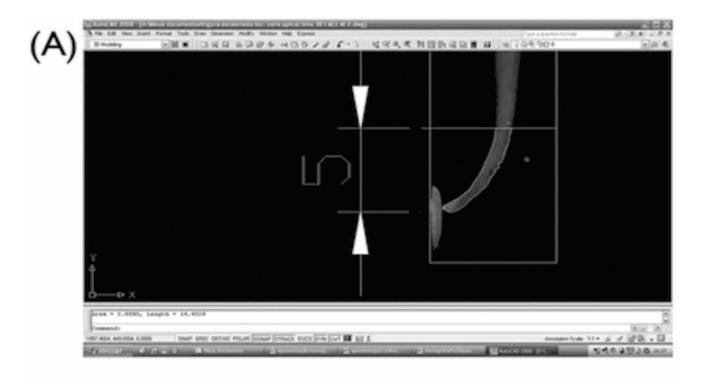
A commercial CH paste supplied in a cartridge was used in this study (CalenTM; S.S. White Artigos Dentários Ltda, Rio de Janeiro, RJ, Brazil). Its composition includes: 2.5 g CH, 0.5 g zinc oxide, 0.05 g colophony, and 1.75 mL polyethylene glycol 400 (vehicle). The paste was delivered from its cartridge on a glass plate, thoroughly mixed with 2 drops of blue Indian ink (Acrilex, São Paulo, SP, Brazil), and the mixture was repacked into the cartridge. The blue-stained CH paste was injected into the canals using a special endodontic syringe (ML syringeTM; S.S. White Artigos Dentários Ltda, Rio de Janeiro, RJ, Brazil) and a long 27G needle (Septoject XL; Septodont, Saint-Maur-des-Fossés, Cedex, France) with a silicone stopper set at the WL. The coronal portion was sealed with 2 mm of temporary restorative material (ColtosolTM; Coltene-Whaledent, Cuyahoga Falls, OH, USA).

Image Acquisition

The four sides of the transparent blocks were scanned at a 600 dpi resolution with a flatbed scanner (Genius ColorPage-HR6X; Kye Systems Corp, Houjie, China). Having the operator as a reference point, the root curvature was disposed to the operator's left, which was considered as the mesial surface in this study. The block was turned in a clockwise direction on the scanner bed, in such a way that the root curvature was then disposed to the front, right, and backsides, simulating the buccal, distal and palatal surfaces, respectively. Thus, four images were obtained, one from each aspect: left or mesial (M), front or buccal (B), right or distal (D), and back or palatal (P). These images were exported to the AutoCAD-2008 software (Autodesk Inc; McInnis Parkway, San Rafael, CA, USA) for quantitative and qualitative analyses.

Quantitative Measurement

First, the apical 5 mm were standardized with a special tool of the AutoCAD software (Polyline), in comparison to the WL (16 mm). Second, the total area in the apical 5 mm was determined. Then, areas of voids, i.e., regions not filled with the blue-stained CH paste, were measured (Fig. 1).



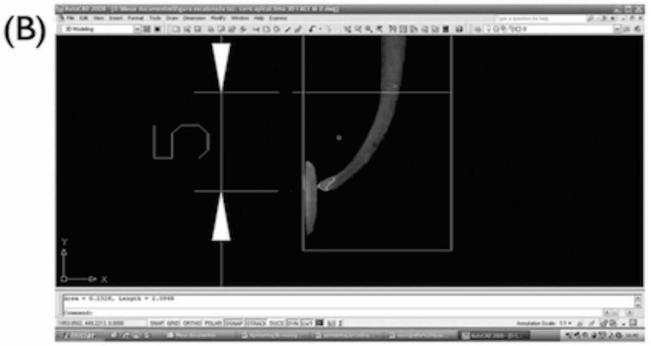


Figure 1 - Method adopted for calcium hydroxide (CH) filling assessment: (A) area delimitation in the apical 5 mm; (B) determination of areas without CH paste. Based on these measures, the amount of CH filling was calculated

The amount of CH paste and the amount of filling deficiencies in the apical 5 mm were considered for statistical purposes. Data were analyzed by ANOVA and Tukey's post-hoc test at 5% significance level.

Qualitative Measurement

The presence or absence of voids in the apical third of the simulated canals was recorded for each surface (B, M, D, and P). In this qualitative analy-

sis, preparation technique and apical diameter were not considered; it was conducted for detecting possible differences between surfaces. Data were analyzed by chi-square test complemented by adjusted residues analysis. A significance level of 5% was established.

Results

Since ProTaper presents different patterns of apical diameters, when analyzing the influence of apical enlargement on paste voids, only hand techniques and the K3 system were considered (Table 2). In this assessment, the comparison of apical diameters in each technique showed significant di-

fferences only related to the step-back preparation, between sizes 25 and 30 (p < 0.05). Although all groups showed amount of filling close to 100%, in the comparison of preparation techniques in each apical diameter, significant differences could be observed between the step-back technique and the K3 system (p < 0.05) when evaluating size 30 apical preparation. The rotary system showed higher amount of filling than the hand technique.

Table 2 - Mean percentage of calcium hydroxide filling in simulated curved canals prepared with different techniques and apical diameters

	Diameter							
Technique*	25		30		35			
	Mean	SD (±)	Mean	SD (±)	Mean	SD (±)		
GCD	99.78 ^{Aa}	0.28	99.84 ^{ABa}	0.43	99.93 ^{Aa}	0.17		
GSB	99.99 ^{Aa}	0.05	99.59 Bb	1.00	99.85 ^{Aab}	0.32		
GK3	100.00 ^{Aa}	0.00	99.90 ^{Aa}	0.16	99.98 ^{Aa}	0.09		

^{*} In this analysis, ProTaper group was not considered.

Distinct capital letters in the columns and distinct small letters in the rows indicate statistically significant difference (α =0.05).

To assess the effects of instrumentation techniques, only instruments with an apical diameter of 0.25 mm were considered in the analysis, including ProTaper F2 instruments, since all techniques contemplate a group with this limit of apical enlarge-

ment. Table 3 shows that, regardless of block side, the crown-down technique presented significantly lower mean percentage of calcium hydroxide fillings than the other techniques. However, all techniques showed an amount of filling very close or equal to 100%.

Table 3 - Mean percentage of calcium hydroxide filling in simulated curved canals prepared with different techniques, with size 25 apical diameters

Group	Mean	Standard-deviation (±)
GCD	99.78 ^B	0.28
GSB	99.99^	0.05
GPT	99.98 ^A	0.08
GK3	100.00 ^A	0.00

Distinct letters indicate significant difference according to ANOVA and Tukey's test (α =0.05).

Qualitative analysis is shown in Table 4. Chi-square test (p = 0.074) indicated that there was no association between filling voids and block sides.

Table 4 - Presence and absence of filling deficiencies in different block sides

		Apical	Total				
Side	Without voids		With	voids	iotal		
	N	%	N	%	n	%	
M	88	80.0	22	20.0	110	100.0	
D	75	68.2	35	31.8	110	100.0	
Р	86	78.2	24	21.8	110	100.0	
В	90	81.8	20	18.2	110	100.0	
Total	339	77.0	101	23.0	440	100,0	

 χ^2 =6.927; p = 0.074

SD: standard-deviation.

Discussion

The present study showed that appropriate CH fillings could be achieved in simulated curved canals after using either hand or rotary preparation techniques. The quality of CH fillings has been extensively investigated but most studies are limited to comparisons of different techniques for CH placement within root canals^{12-14,23-28}. Also, some previous results have pointed out that severe root canal curvatures¹³ and small apical diameters²⁸ may impair the optimal delivery of CH pastes. However, this was not confirmed in the study performed by Vier--Pelisser et al.29 (2012). The authors tested hand and ProTaper rotary instruments, using crown-down approaches, and no difference between preparation techniques or between apical diameters (size 25 to 35) was detected. In the present investigation, the K3 rotary system was additionally tested, but similar results were found.

NiTi rotary instruments have significantly changed the way root canal preparation is performed, making it extremely important to evaluate the influence of instrumentation techniques on the quality of CH fillings in curved canals. It is noteworthy that, in this study, a single technique to introduce the CH paste into the canal was chosen, thus variables were limited to preparation technique and extent of apical enlargement. CH dressing placement was carried out by using an injection system (ML syringe $^{\rm TM}$), which has proven to be effective previously 29,30 .

The use of simulated root canals was based on the possibility of sample standardization regarding curvature length and degree²⁴⁻²⁶. Also, the current study assessed the apical third of curved canals, as previous studies have shown this is the most difficult region to be completely filled by CH dressings^{23,29}.

Different assessment methods have been used for analyzing CH placement, such as weighing²⁸ and radiographic examination^{12,24-26}. In the present study, the four sides of the acrylic blocks were scanned to provide a more accurate analysis. To date, apart from tooth clearing²⁷, which also allows a three-dimensional analysis of the intracanal dressing filling, only two-dimensional radiographs^{12,24-26} have been used. Another relevant methodological aspect of this experiment was the quantitative analysis, assessing the mean percentage of canal filling, and not only a qualitative analysis based on scores, as reported by several authors^{12, 24,27}.

Concerning the effect of preparation techniques on paste fillings, significant difference was observed when comparing the step-back technique and the K3 system, showing that tapered preparations may avoid gaps in intracanal dressings. However, this finding was restricted to size 30 apical diameters. Furthermore, despite this statistical difference, the amount of filling was very close to 100% in all groups.

Furthermore, in GSB, size 30 had significantly lower percentage of filling than size 25. Actually, in GSB, the higher the apical diameter, the greater the occurrence of apical deviation, resulting in elbows or zips, since coronal preflaring was not conducted in this group. These procedural errors may have impaired the proper filling of the apical portion. Again, despite the mathematical difference, the percentage of filling was very close or equal to 100% in all groups. Thus, this discrepancy may not be clinically relevant. According to these findings, further enlargement did not determine a decrease in paste voids.

Although there is disagreement amongst endodontic specialists about the ideal apical diameter of root canal preparation, there is universal consensus that the ideal size depends on anatomical, microbiological, and mechanical factors^{31,32}. The majority of studies demonstrate that larger apical preparation sizes result in a greater reduction in the remaining bacteria and debris compared to smaller apical diameters^{17,33}. On the other hand, over-enlargement may cause weakening of dental structure³¹ and, especially when hand techniques are used, may lead to apical deviation³⁴. Considering the additional effects of irrigation and intracanal medications, the need for greater enlargement seems unnecessary. The possibility of filling the apical third of curved canals with calcium hydroxide dressings, as demonstrated herein, should contribute to canals disinfection when anatomical features are interposed.

Often, during chemomechanical preparation in severely curved canals, apical stop is established with small diameter instruments, due to the technical difficulty of enlargement. In the present study, it was possible to compare the four preparation techniques exclusively in those groups prepared up to size 25. The explanation relies on the fact that in canals prepared with ProTaper, the use of F3 instruments corresponding to 0.30 mm would probably culminate in fracture and the consequent loss of the sample.

Another important aspect to be mentioned is the frequent presence of apical deviation in the groups of hand instrumentation, especially those with apical stops corresponding to 0.35 mm. Thus, in severely curved canals, endodontists are faced with a dilemma: to either enlarge the apical region more at the risk of instrument fractures³⁵ and deviations³⁴ or prepare it less and maybe not completely disinfect the root canal system. Simchock and Hicks²⁸ (2006) found that worse results regarding voids within CH dressing fillings were obtained in small apical diameters (size 25) when compared to canals prepared up to size 40. However, according to our results, the amount of CH filling approached 100% for all techniques, even in canals prepared to size 25, and a larger instrumentation would be dispensable for this matter. On the other hand, the technique used for inserting the CH paste is probably a determinant factor to achieve an adequate filling, and the ML endodontic syringe proved to be effective.

According to quantitative and qualitative assessments, the area closest to the apical stop is where voids were most commonly observed within the medication. Only very small voids were verified (Figure 1B). On the other hand, Sigurdsson et al. 12 (1992) reported that the filling quality was less than adequate in relation to apical limit and density. Estrela et al.²³ (2001) verified that the apical canal third hardly ever proved to be fully completed by the CH paste in their sample. A greater number of failures in the apical region could be explained by the difficulty of inserting the medication in this portion, since this is the farthest location from the canal entrance. In the present study, caution was taken to introduce the injection system needle the closest possible to the WL to ensure an adequate filling.

Based on our findings, CH filling was not affected by block side. In contrast, Vier-Pelisser et al.²⁹ (2012) identified better filling when the curvatures of the canals were directed to mesial and distal. For the authors, curved canals for vestibular and palatal could be present as clinically flawed, with voids within medication, and this problem could go radiographically undetected.

Lastly, studies related to possible factors that might influence successful canal filling with CH dressing paste should be fully exhausted.

Conclusion

The results obtained in the present study led to the conclusion that appropriate calcium hydroxide fillings can be achieved in simulated curved canals after using either hand or rotary preparation techniques, with a minimum apical diameter of 0.25 mm. Statistical differences found in this study may be clinically irrelevant, once the amount of filling, regardless of preparation technique and apical diameter, was very close or equal to 100%.

Resumo

Objetivo: Este estudo teve como objetivo analisar a influência da técnica de instrumentação (manual ou rotatória) e do alargamento apical no preenchimento de canais curvos com hidróxido de cálcio (HC). Materiais e método: Cento e dez canais simulados foram divididos em onze grupos experimentais (G). Os canais foram preparados com instrumentos manuais K-Flexofile, usando a técnica cérvico-apical (GCA 25, GCA 30 e GCA 35) ou ápico-cervical (GAC 25, GAC 30 e GAC 35), e com instrumentos rotatórios do sistema ProTaper (GPT F1 e GPT F2) ou sistema K3 (GK3 25, GK3 30 e GK3 35). O diâmetro apical correspondia a 0,20 mm (GPT F1), 0,25 mm (25 GCA, GAC 25, GPT F2 e GK3 25), 0,30 mm (GCA 30, GAC 30, GK3 30) e 0,35 mm (GCA 35, GAC 35, GK3 35). Uma pasta de HC, previamente pigmen-

tada com nanquim, foi injetada nos canais utilizando uma seringa especial. Os quatro lados dos blocos com canais simulados foram digitalizados e as imagens foram transferidas para o software AutoCAD-2008, para avaliar a porcentagem (%) de preenchimento nos 5 mm apicais (ANOVA; Teste de Tukey; $\alpha = 0.05$). Uma análise qualitativa também foi realizada, em relação à presença ou ausência de espaços vazios (Teste Qui-quadrado; α = 0,05). Resultados: Em GAC, houve diferença significativa entre os diâmetros 25 e 30. GAC apresentou menor porcentagem de preenchimento (P<0,05) do que GK3, quando o diâmetro apical correspondia a 0,30 mm. GCA apresentou menor preenchimento (P<0,05) do que os outros grupos (AC, PT e K3), quando o diâmetro apical correspondia a 0,25 mm. Não foi observada diferença significativa na comparação entre os quatro lados dos blocos. Conclusão: A técnica de preparo e o diâmetro apical apresentaram pouca ou nenhuma influência relevante no preenchimento de canais radiculares curvos simulados com pasta de HC. As diferenças estatísticas encontradas neste estudo podem ser clinicamente irrelevantes, uma vez que a quantidade de preenchimento, independentemente da técnica de preparo e diâmetro apical, foi muito próximo ou igual a 100%.

Palavras-chave: Endodontia. Preparo de canal radicular. Hidróxido de cálcio.

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