Apical transportation in simulated root canals prepared using HyFlex CM, WaveOne Gold and manual technique

Avaliação do transporte apical em canais simulados preparados com instrumentação manual e com movimentos rotatório contínuo e reciprocante

Gabriela Bonacina[*]
Ana Carolina Neis Cifali[**]
Rafael Chies Hartmann[***]
Maína de Aguiar Pinto[**]
Maristela Gutierrez de Borba[***]
Maximiliano Schünke Gomes[****]

Abstract

Objective: To assess the apical transportation in simulated root canals with different curvature angles prepared using manual instrumentation and rotary and reciprocating motions. Methods: Sixty simulated root canals were prepared using manual instrumentation (Flexofile K-file) (MT), continuous rotation (HyFlex CM) (HF), and reciprocating motion (WaveOne Gold) (WG). A trained operator prepared the canals, and the apical enlargement was standardized up to a #25 file in all systems tested. Two different curvature angles of the simulated root canals were tested: 70° and 50°. Overlapping photographs of the simulated root canals, before and after root canal preparation, were used to measure the apical transportation (mm), using the ImageJ software. Descriptive statistics (mean and standard deviation) were analyzed and the groups were compared with two-way ANOVA followed by Tukey's post-hoc, with α=5%. Results: There was a statistically significant interaction between the effects of group and angle in the apical transportation ($F = 3.740$; $p = 0.031$). Simple main effects analysis showed that HyFlex CM produced a significantly lower apical transportation when compared to WaveOne Gold ($p = 0.02$) and the manual technique ($p < 0.01$), regardless of the angle. However, there were no differences between WaveOne Gold and manual technique in canals with the 70° angle ($p>0.05$). The group with the highest mean apical transportation was the MT, with 0.0917 mm, followed by WG and HF, with 0.0633 and 0.0325, respectively. Conclusion: Simulated root canals prepared with rotary motion (HyFlex CM) showed the lowest apical transportation, followed by the reciprocating motion (WaveOne Gold). The manual technique showed the most unfavorable results, with the highest apical transportation.

Keywords: Root canal preparation. Apical transportation; Rotation. Reciprocating.

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[*] DDS, MSc, Graduate Program in Dentistry, School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.
[**] DDS, School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.
[***] DDS, MSc, PhD, School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.
[****] DDS, MSc, PhD, Graduate Program in Dentistry, School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil, and Medical and Dental Center of the Military Police of Rio Grande do Sul, Brazil.

Introduction

Root canal preparation is one of the most difficult and important stages of treatment, which if well executed results in the mechanical removal of microorganisms by cutting out the infected dentin[1,2]. The influence of these procedures on root anatomy however may result in deformities[3] such as changes in working length, formation of ledges. Apical transportation due to changes in angle of curvature are also mentioned as some of the potential unfavorable consequences of instrumentation, which may interfere in the treatment outcome[4,5].

The constant search for better performance related to root canal preparation is encouraged by the difficulty of obtaining a hermetic and three-dimensional sealing of irregularly shaped root canals[6,7]. In addition, some areas of these canals may be over instrumented at the expense of a healthy dentin wear, reducing root fracture strength[5].

The need to clean and shape the root canals without changing their original configuration involves the challenge of selecting appropriate endodontic instruments[8]. Several systems have been developed to achieve a more effective and fast root canal preparation, preserving the original endodontic anatomy. Recently, HyFlex CM (Coltene, Allstetten, Sweden) and WaveOne Gold (Dentsply/Maillefer, Tulsa, USA) systems have been introduced in the dental market.

HyFlex CM instruments - manufactured from the CMWire alloy (Coltene, Allstetten, Sweden) - were developed for use in continuous rotation kinematics; the lower amount of nickel in the alloy ensure super elasticity and high resistance to cyclic fatigue to the file, increasing its ability to accompany the anatomy of the canal and reducing the risk of transportation[9,10]. The WaveOne Gold system was developed for reciprocating motion, with a counterclockwise cut[11]. Its two sharp edges and the modification of the alloy through repeated heating and cooling provide the file with greater flexibility and thus greater preservation of anatomy[12].

Due to the possible drawbacks of a root canal transportation, several methodologies have been developed to assess the performance of different systems. The literature supports the idea that analyzing variations in root canal curvature after instrumentation is a reliable method to evaluate the tendency of the preparation to maintain (or not) the original anatomy of the canal[13]. The present study aimed to assess the apical transportation in simulated root canals prepared with manual instrumentation and HyFlex CM (HF) and WaveOne Gold (WG) systems.

Materials and methods

This study was submitted and approved by the Science and Ethics Commission of the School of Health and Life Sciences (Sipesq #7790) Pontifical Catholic University of Rio Grande do Sul – PUCRS. Sixty L-shaped simulated root canals (Dentsply/Maillefer, Tulsa, USA) measuring approximately 16 mm of length were classified in 70° and 50° curvature angles according to Schneider (1971)[14] (Figure 1). They were previously instrumented with a #10 and a #15 K-file (Dentsply/Maillefer, Oklahoma, USA) in the entire working length (WL) and randomly divided into 3 groups (Table 1). A retention platform was used to fix a photographic camera (Canon EOS 50D, Canon Incorporated, Tokyo, Japan) so to obtain pre- and post-instrumentation pictures in the same position.

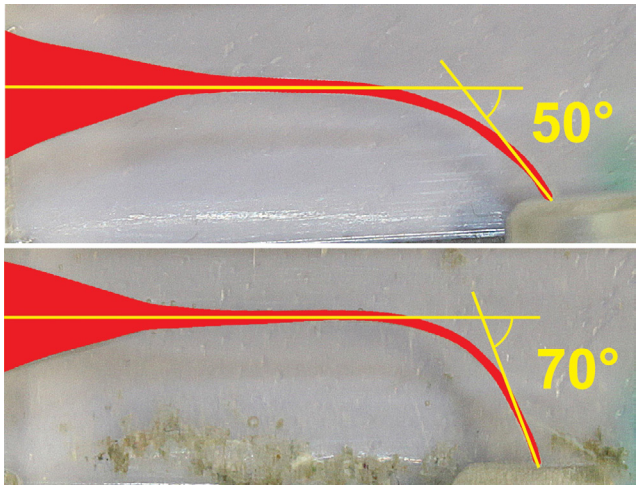

Figure 1 – Angle classification according to Schneider (1971). The upper image illustrates de 50° angle and the lower image illustrates de 70° angle.

Table 1 – Group distribution according to the root canal preparation technique

GROUP	TOTAL (N)	INSTRUMENT	MOTION
1	20	FlexoFile	MT
2	20	WaveOne Gold	RM
3	20	HyFlex CM	CR

MT: manual technique; RM: reciprocating motion; CR: continuous rotation.

One single trained operator prepared the simulated canals. The WG and HF groups were prepared using the VDW motor (VDW Silver, VDW, Munich, Germany) adjusted to the motion recommended by the manufacturer. In order to compare the groups, the preparation was performed up to #25 file (Table 2). The mechanized instruments were used in progressive up and down motions up to three times, including irrigation and the introduction of a #15 file, and using up to three canals. The canals were irrigated with 2 mL of 2% sodium hypochlorite (Iodontec Indústria e Comércio de Produtos Odontológicos Ltda., Porto Alegre, Brazil), aspirated, and flooded again in each instrument use.

Table 2 – Technical sequence according to group.

GROUP	TECHNICAL SEQUENCE
Manual Technique group – MT	Crown-down technique up to #25 FAI
WaveOne Gold group – WG	Primary instrument #25 in all WL
HyFlex group – HF	20.04, 20.06, and 25.06 in all WL

FAI: final apical instrument. WL: working lenght.

The photographs were grouped in pre- and post-preparation for analysis in the ImageJ software. A blinded and trained observer measured both original and prepared canals at two different times to prevent errors. The images were zoomed in for a better visualization. Using the "freehand lines" tool, a point was marked 0.5 mm away from the foramen, in the center of the canal. The images were overlapped and the distance between the center of pre- and post-preparation points was measured (Figure 2). All the data were forwarded to Excel software.

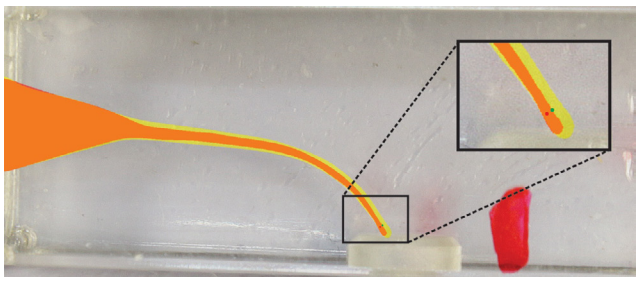

Figure 2 – Overlapping of pre- and post-preparation pictures. Apical magnification (detail) showing the pre (left spot) and post (right spot) preparation points. The linear distance between these points allowed measuring the apical transportation (mm).

All the data were analyzed by IBM SPSS Statistics, version 19 (SPSS China, Shanghai, China). The apical transportation measurements (in mm) were initially analyzed descriptively, calculating the means and standard deviations in each group. The Kolmogorov-Smirnov test was used to verify the normal distribution of the samples. The comparison of means between groups was performed with two-way ANOVA, followed by Tukey post-hoc to identify the differences. The level of significance was set at 5%.

Results

The root canal preparations showed the formation of a ledge in two samples of the manual technique (MT) group and the fracture of instruments in two samples of the WaveGold (WG) group. These events hindered the evaluation of the outcome (apical transportation), leading to the exclusion of these four samples for analysis purposes.

There was a statistically significant interaction between the effects of group and angle in the apical transportation ($F = 3.740$; $p = 0.031$). Simple main effects analysis showed that HyFlex CM (HF) produced a significantly lower apical transportation when compared to WaveOne Gold ($p = 0.02$) and the manual technique ($p < 0.01$), regardless of the angle. However, there were no differences between WaveOne Gold and the manual technique in canals with the 70° angle ($p>0.05$). The group with the highest mean apical transportation was MT, with 0.0917 mm, followed by WG and HF, with 0.0633 and 0.0325, respectively, as described in Table 3.

Table 3 – Overall means, standard deviations, and maximum and minimum values of apical transportation (mm) in the different groups

	Manual technique (n=18)	WaveOne Gold (n=18)	HyFlex CM (n=20)
Mean	0.0917 [a]	0.0633 [b]	0.0325 [c]
Standard Deviation	0.0391	0.0249	0.0193
Min	0.02	0.03	0.01
Max	0.15	0.11	0.05
P value = .001			

Two-way ANOVA, Tukey's post-hoc; α = 5%; letters indicate statistically significant differences between groups.

Discussion

The final configuration of the root canal after shaping procedures tends to a greater wear on the external wall of apical curvatures and the inner wall of the most coronal ones[15]. Great changes from the original axis may lead to perforations, weakening of the dental structure, and difficulty in obtaining a hermetic and three-dimensional sealing of the root canal system[6,7]. The apical transportation is one of the most commonly used parameters to investigate the ability of endodontic instruments to preserve the canal geometry. Under a clinical perspective, it is suggested that an apical transportation greater than 0.3 mm is sufficient to affect negatively the treatment prognosis[5,16].

The present study evaluated 60 resin blocks of simulated canals with two different initial curvature angles (50 and 70°), randomly distributed between the experimental groups. This randomization led to an unequal sample size between the groups, resulting in seven samples with 70° and 13 samples with 50° in the HF group and 10 samples each in the WG and MT groups. However, considering the statistical tests confirmed the normality of data distribution and consequent homogeneity of the study, this factor should not be considered as a selection bias. Simulated root canals in resin blocks present relatively standard shape, size, and taper. In addition, they are easily obtained, enabling a sample size that would require time and ethical procedures if it were composed of extracted human teeth[17]. Although the use of simulated canals does not reliably reflect the action of instruments on dentin walls, its use in research is justified by the simplicity and utility of the method[18].

Previous investigations reported that the mechanized root canal preparation promotes less apical transportation[19]. The results obtained in the present study corroborate the literature, considering the manual technique group presented significantly higher transportation means when compared to the other groups. These values may be explained by the instrumentation technique used or by the design of the instruments selected[20]. The ledge formation in two of the samples from this same group is potentially associated with preparation by stainless steel files[21].

The HyFlex CM and WaveOne Gold systems were selected based on factors that make them unique, such alloys composition, manufacture, and motion applied. As far as we know, there are no previous studies evaluating the occurrence of apical transportation when comparing the systems tested in the present methodology. The HyFlex CM system instruments showed more favorable results in terms of apical transportation[22-24]. The improved performance of the HyFlex CM system is attributed to the greater flexibility provided to their instruments by the CMWire alloy [23, 24]. Although the HyFlex CM system showed lower means of apical transportation even in the samples with 70° of curvature, the deviation did not stop occurring. Thus, present findings suggest that the apical transportation inevitably occurs during the preparation of extremely curved canals, regardless of the technique.

The greater flexibility of WaveOne Gold instruments provides a more centered and conservative preparation, causing a lower level of wear[25]. However, these findings disagree with the results of the present study, especially in samples with more pronounced curvatures. In addition, one of the major complications during root canal preparation is the fracture of the instrument, which may result from cyclical fatigue or torsion[26]. In this experiment, two instruments of the WaveOne Gold system fractured during its second use. It should be considered, however, that the manufacturer recommends the single use of the instrument.

Both curvatures tested in the present study are classified as severe, and the curvature of 70° is more pronounced[14]. When comparing only the means of apical transportation of both curvatures, higher values were found in the curvatures of 70°, except in the manual technique group. These results may be explained by the loss of two samples due to root canal deviation and apical blockage, which contributed to reduce the mean apical transportation measured in the remaining samples of the manual group.

Although presenting longer working time, considering it is composed of a greater sequence of instruments than the WaveOne Gold system, the HyFlex CM was the safest system. Even though there were statistically significant differences between the groups tested, the results of the present study are debatable under a clinical perspective, because simulated resin block canals tend to suffer about twice as much wear when compared to human teeth[27]. In addition, the influence of the type of motion applied should be further studied to clarify which factor related to kinematics or the features of the instrument is in fact decisive in the final quality of root canal shaping.

Additional studies are required to test the present hypothesis on extracted human teeth so to assess whether more favorable results are obtained due to the motion used in the preparation or to specific characteristics of the system, such as the type of alloy or the cross-section configuration of the file.

Conclusion

Under the conditions of the present study, simulated root canals prepared with rotary motion (HyFlex CM) showed the lowest apical transportation, followed by the reciprocating motion (WaveOne Gold). The manual technique showed the most unfavorable results, with the highest apical transportation.

Conflict of interest

There were no potential conflicts of interest relevant to this article.

Resumo

Objetivo: avaliar o transporte apical em canais radiculares simulados com diferentes ângulos de curvatura preparados por meio de instrumentação manual e dos movimentos rotativo e reciprocante. Métodos: sessenta canais simulados foram preparados usando instrumentação manual (Flexofile K-file) (MT), rotação contínua (HyFlex CM) (HF) e movimento reciprocante (WaveOne Gold) (WG). O preparo do canal radicular foi realizado por um operador treinado, e o alargamento apical foi padronizado até o instrumento #25 em todos os sistemas testados. Dois diferentes ângulos de curvatura dos canais simulados foram testados: 70° e 50°. Fotografias sobrepostas dos canais simulados, antes e após o preparo do canal radicular, foram utilizadas para medir o transporte apical (mm), utilizando o software ImageJ. Estatísticas descritivas (média e desvio padrão) foram analisadas e as comparações entre os grupos foram realizadas através de ANOVA de duas vias, seguido por post-hoc de Tukey, com α=5%. Resultados: houve interação estatisticamente significativa entre os efeitos do grupo e do ângulo no transporte apical ($F = 3,740$; $p = 0,031$). A análise simples dos efeitos principais mostrou que o sistema HyFlex CM produziu um transporte apical significativamente menor quando comparado ao sistema WaveOne Gold ($p = 0,02$) e à Técnica Manual ($p < 0,01$), independentemente do ângulo. No entanto, não houve diferenças entre o WaveOne Gold e a Técnica Manual em canais com ângulo de 70 ° ($p > 0,05$). O grupo que apresentou maior transporte apical médio foi o MT, com 0,0917 mm, seguido pelo WG e pela HF, com 0,0633 e 0,0325, respectivamente. Conclusão: canais radiculares simulados preparados com movimento rotatório (HyFlex CM) mostraram o menor transporte apical, seguido de movimento reciprocante (WaveOne Gold). A técnica manual revelou os resultados mais desfavoráveis, com maior transporte apical.

Palavras-chave: preparo do canal radicular. Transporte apical. Rotação. Reciprocante.

References

1. Loizides AL, Kakaveisos VD, Tzanetakis GN, Kontakiotis EG, Eliades G. A comparative study of the effects of two nickel-titanium preparation techniques on root canal geometry assessed by microcomputed tomography. J Endod 2007; 33: 1455-59.
2. Siqueira JF Jr, Lima KC, Magalhães FA, Lopes HP, de Uzeda M. Mechanical reduction of the bacterial population in the root canal by three instrumentation techniques. J Endod 1999; 25: 332-35.
3. Celik D, Tasdemir T, Er K. Comparative study of 6 rotary nickel-titanium systems and hand instrumentation for root canal preparation in severely curved root canals of extracted teeth. J Endod 2013; 39: 278-82.
4. Weine FS, Kelly RF, Lio PJ. The effect of preparation procedures on original canal shape and on apical foramen shape. J Endod 1975; 1: 255-62.
5. Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved root canals. Part I: effects of apical transportation on seal root fillings. J Endod 2000; 26: 210-16.
6. López FU, Fachin EV, Fontanella VRC, Barletta FB, Só MVR, Grecca FS. Apical transportation: a comparative evaluation of three root canal instrumentation techniques with three different apical diameters. J Endod 2008; 34: 1545-48.
7. Freire LG, Gavini G, Cunha RS, Santos MD. Assessing apical transportation in curved canals: Comparison between cross-sections and micro-computed tomography. Braz Oral Res 2012; 26: 222–27.
8. Freire LG, Gavini G, Branco-Barletta F, Sanches-Cunha R, dos Santos M. Microscopic computerized tomographic evaluation of root canal transportation prepared with twisted or ground nickel-titanium rotary instruments. Oral Surg Oral Med Pathol Oral Radiol Endod 2011; 211: 143-48.
9. Zhou H, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Mechanical Properties of Controlled Memory and Superelastic Nickel-Titanium Wires Used in the Manufacture of Rotary Endodontic Instruments. J Endod 2012; 38: 1535-40.
10. Sood A, Jindal ASV, Chhabra A, Arora A, Vats A. Comparison of apical transportation, centering ability and cyclic fatigue resistance of four rotary file systems. Dent J Adv Stud 2015; 13: 12-19.
11. Alovisi M, Pasqualini D, Musso E, Bobbio E, Giuliano C, Mancino D, Scotti N, Berutti E. Influence of contracted endodontic access on root canal geometry: an in vitro study. J Endod 2018; 44: 614-20.
12. Pedullà E, Genovesi F, Rapisarda S, La Rosa GRM, Grande NM, Plotino G, Adorno CG. Effects of 6 single-file systems on dentinal crack formation. J Endod 2017; 43: 456–61.
13. Merrett SJ, Bryant ST, Dummer PM. Comparison of the shaping ability of RaCe and FlexMaster rotary nickel-titanium systems in simulated canals. J Endod 2006; 32: 960–62.
14. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg 1971; 2: 271-75.
15. Peter OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004; 30: 559-67.
16. Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Topics 2005;10:30–76.
17. Tharuni SL, Parameswaran A, Sukumara VG. A comparison of canal preparation using the K-file and Lightspeed in resin blocks. J Endod 1996; 22: 474-76.
18. Schäfer E, Florek H. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 1. Shaping ability in simulated curved canals. Int Endod J 2003; 36: 199-207.
19. Guelzow A, Stamm O, Martus P, Kielbassa AM. Comparative study of six rotary nickel-titanium systems and hand instrumentation for root canal preparation. Int Endod J 2009; 42: 1057-64.
20. Ehsani M, Zahedpasha S, Moghadamnia AA, Mirjani J. An ex-vivo study on the shaping parameters of two nickel-titanium rotary systems compared with hand instruments. Iran Endod J 2011; 6: 74-79.
21. Ounsi HF, Franciosi G, Paragliola R, Al-Hezaimi K, Salameh Z, Tay FR, *et al.* Comparison of two techniques for assessing the shaping efficacy of repeatedly used nickel-titanium Rotary instruments. J Endod 2011; 37: 847-50.
22. Kishore A, Gurtu A, Bansal R, Singhal A, Mohan S, Mehrotra A. Comparison of canal transportation and centering ability of Twisted Files, HyFlex controlled memory, and Wave One using computed tomography scan: An *in vitro* study. J Conserv Dent 2017; 20: 161-65.
23. Bürklein S, Börjes L, Schäfer E. Comparison of preparation of curved root canals with HyFlex CM and Revo-S rotary nickel-titanium instruments. Int Endod J 2014; 47: 470-76.
24. Saber S, Nagy M, Schäfer E. Comparative evaluation of the shaping ability of ProTaper Next, iRace and HyFlex CM rotary NiTi files in severely curved root canals. Int Endod J 2015; 48: 131-36.
25. Özyürek T, Yilmaz K, Uslu G. Shaping ability of Reciproc, WaveOne Gold and HyFlex EDM single-file systems in simulated S-shaped canals. J Endod 2017; 43: 805-09.
26. Al-Hadlaq SM, AlJarbou FA, AlThumairy RI. Evaluation of cyclic flexural fatigue of M-wire nickel-titanium rotary instruments. J Endod 2010; 36: 305-07.
27. Nazari MK, Shahab S, Rostami G. Canal transportation and centering ability of twisted file and reciproc: a cone-beam computed tomography assessment. Iran Endod J 2014; 9: 174-49.

Endereço para correspondência:

Maximiliano S. Gomes
Escola de Ciências da Saúde e da Vida
Curso de Odontologia, Pontifícia Universidade Católica do Rio Grande do Sul
Av. Ipiranga, n. 6681
CEP 90619-900, Porto Alegre, RS, Brasil
Tel: +55 051 33203562
Fax: +55 051 3320 3562
E-mail: maximiliano.gomes@pucrs.br

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