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Comparative analysis, *in vitro*, of efficiency of four systems of endodontic retreatment

Universidade Fernando Pessoa
Faculdade Ciências da Saúde
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Comparative analysis, *in vitro*, of efficiency of different systems of endodontic retreatment

Dissertação apresentada à Universidade Fernando Pessoa como parte dos requisitos para obtenção do grau de Mestre em Medicina Dentária.

Assinatura:_____

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Resumo

Objetivos: A remoção completa do material obturador canalar de forma segura e eficiente é o principal objetivo do retratamento endodôntico não cirúrgico. O propósito deste estudo *in vitro* é comparar a eficácia de quatro sistemas de retratamento.

Materiais e Métodos: Oitenta dentes monocanalares, com tratamento endodôntico prévio, foram selecionados para este estudo e divididos em quatro grupos (n=20). Os grupos foram divididos de acordo com o sistema em teste: dois grupos com sistema reciprocante - Grupo 1: Reciproc® e Grupo 2: WaveOne®; e dois grupos com sistema de rotação contínua - Grupo 3: ProTaper Universal Retreatment® e Grupo 4: One Shape®. Todos os dentes foram radiografados, antes e após remoção do matéria obturador com duas incidências – vestíbulo-palatina e mesio-distal – usando um dispositivo personalizado e um sistema de radiografias digital. A área total inicial do material obturador foi medida assim como a área de material remanescente recorrendo ao software de análise Adobe Photoshop CC 2017®. Os dados obtidos foram colocados em tabelas do Microsoft Excel e analisados estatisticamente recorrendo ao GraphPad Prism® versão 5.00 para Windows, GraphPad Software, San Diego Califórnia. O nível de significância foi fixado em 5% para todos os testes ($p < 0,05$).

Resultados: Não existiram diferenças significativas entre os grupos; no entanto, o grupo WaveOne®demonstrou maiores valores de redução, seguido pelo grupo Reciproc®, grupo Protaper Universal Retreatment® e finalmente o grupo One Shape® que demonstrou a menor percentagem de redução.

Conclusões: Este estudo demonstrou que nenhum dos sistemas testados foi capaz de remover completamente o material obturador; no entanto, os sistemas reciprocantes demonstraram ser mais eficientes que os sistemas de rotação contínua.

Palavras-Chave: Retratamento endodôntico; remoção de gutta-percha; limas reciprocantes; limas de rotação contínua; WaveOne; Reciproc; Protaper Universal Retreatment; One Shape.

Abstract

Objective: Complete removal of the root canal filling material securely and efficiently is the main objective of the nonsurgical endodontic retreatment. The purpose of this *in vitro* study is to compare the effectiveness of four systems of endodontic retreatment..

Material and Methods: Eighty single root teeth with previous endodontic treatment were selected for this study and divided into four groups (= 20). The groups were divided according to the system of retreatment using. Two groups with reciprocating system: Group 1 – Reciproc® and Group 2 – WaveOne®; and two groups with continuous rotation system: Group 3-ProTaper® Retreatment Universal and Group 4 – One Shape®. All teeth were radiographed before and after removal of the filling material with two incidences – bucco-lingual and mesio-distal – using a custom made platform and a digital radiographic system. The total area of the initial filling material was measured as well as the area of remaining material using the analysis software Adobe Photoshop CC 2017®. The data, were collected into Microsoft Excel tables and then statistical analysed using GraphPad Prism® version 5.00 for Windows, GraphPad Software, San Diego Califórnia. The level of significance was set at 5% for all the tests ($p < 0.05$).

Results: No significant statistical differences between groups were found; however, the Group WaveOne®showed higher values of reduction, followed by Group Reciproc®, group Protaper Universal Retreatment® and group One Shape® that showed the smallest percentage of reduction.

Conclusions: This study demonstrated that none of the tested systems were able to remove completely the filling material; nevertheless, reciprocating systems proved more efficient than continuous rotation systems.

Keywords: Endodontic retreatment; gutta-percha removal; reciprocating files; continuous rotation files; WaveOne; Reciproc; Protaper Universal Retreatment; One Shape.

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"Põe quanto és no mínimo que fazes."

Fernando Pessoa

Index

Figures

Index of tables and charts

Index of abbreviations

NSET - Non-Surgical Endodontic Treatment

RCS - Root canal system

NSERT - Non-Surgical Endodontic Retreatment

BL - Bucco-lingual

MD – Mesio-distal

WL - Working length

PTUR - ProTaper Universal Retreatment®

R - Reciproc®

OS - OneShape ®

WO - WaveOne ®

CW - Clockwise

Rpm – Rotation per minute

N/cm – Newtons per centimetres

Ni-Ti - Nickel-titanium

CCW – Counter-clockwise

SF - Single file

MF - Multiple files

I. INTRODUCTION

In the last decades we've witnessed an exponentially evolution in the oral health area, not only due to the fact that we live in an era of increasing technological developments but also due to the quality of dental care as well as the awareness of the general population for dental hygiene and its maintenance has increased exponentially in recent decades (Rao et al., 2016).

The Endodontics is no exception to this fact, on the contrary, as it is one area of Dentistry that had much evolved, enabling a high predictability of treatments and a high rate of success.

Endodontics aim, above all, is to preserve the tooth while manage/eliminate the pain and restore the patient's oral health. (Kasam, Mariswamy, 2016).

Although the Non-Surgical Endodontic Treatment (NSET) reported high success rates up to 86-98%, mainly through the introduction of new materials and techniques, a significant percentage (up to 14%) of patients requires retreatment due to failure (Kasam, Mariswamy, 2016; Tabassum, Khan 2016).

When breakdown of NSET occurs, it's necessary to review in detail the probable cause (s). Usually, this undesirable occurrence can be due to an insufficient cleaning/disinfection of the root canal system (RCS), or inadequate three-dimensional and/or apical limit filling and/or an incompetent coronal restoration (Crozeta et al., 2016).

Is consensus and is also very well documented in all articles so far searched that even with the most up-to-date techniques, endodontic treatment failure occur, mainly because of the presence of infection inside the RCS and, in order to restore the periapical tissues, it is often necessary to remove all the root canal filling material placed, proceed to a re-instrumentation and, most important, end with an efficient disinfection (Vidal et al., 2016).

There are several methods that can be used to remove the gutta-percha from the RCS, namely manual and rotary files or ultrasonic instruments. The improvement of non-surgical endodontic retreatment (NSERT) systems had been exponential in the last years; but, nevertheless, at our knowledge and to date, all bibliography consulted and all the techniques used shown that none of the systems is able to remove completely the

gutta-percha adhered to the root canal walls, particularly in the apical third, where micro-organisms usually persist (Kasam, Mariswamy, 2016; Preetam et al., 2016; Zuolo et al. 2016).

Therefore, the necessity to study properly the systems available on the market so the decisions taken and the systems selected are the more adequate and efficient.

Objective

Evaluate, *in vitro*, the effectiveness of four different systems of endodontic retreatment in removing filling material from extracted teeth.

II. MATERIALS AND METHODS

1. Type of study

We conducted a cross-sectional descriptive observational study.

2. *In vitro* analysis

This project aim to evaluate the effectiveness of four different systems of endodontic retreatment (ER) on removal of root canal filling material previously applied in root canals. Systems used: ProTaper Universal Retreatment® (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc® (VDW, Munich, Germany), WaveOne® (Dentsply Maillefer, Ballaigues, Switzerland) and One Shape® (Micro-Mega, Besançon, France).

Figure 1. Teeth before selection for the study

A single operator did all the experimental protocol.

From a total of 102 single root teeth, 80 were selected using the following inclusion criteria:

- Absence of dental anomaly;
- Absence of prosthetic crowns;
- Absence of horizontal and/or vertical fractures;
- Teeth with the apex closed;
- Permanent teeth;
- Teeth without signs of cracks;
- Presence of a single channel;
- Teeth displaying a good obturation

These teeth were previously endodontically treated by students of the pre-clinical component of Endodontics of the Health Sciences Faculty of Fernando Pessoa University using all the same protocol.

3. Preparation of the sample

All specimens were radiographed with two incidences, mesio-distal (MD) and bucco-lingual (BL), with a fixed distance (8cm), using a system of digital x-rays (Vista Scan®) and were selected those who demonstrate good criteria of filling according to Santos et al. (2010) that includes root filling ending 0.5 to 1.5 mm from the radiographic apex, no voids present in the root filling or between root fillings or root canal walls and root filling continuous taper from the orifice to the apex.

The teeth were then randomly divided into 4 groups of 20, being careful so each group had incisors, canines and premolars and, in each group, were used a retreatment system following the manufacturer's specifications.

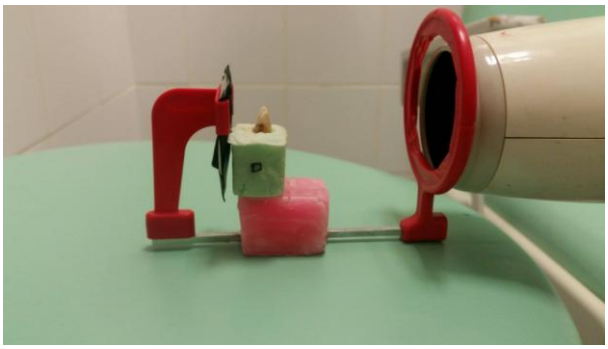

Figure 2. Apparatus used for radiograghy standardization

After gutta-percha removal, all specimens were x-rayed again exactly as mentioned above.

The images were then transferred to an image analysis system (Adobe Photoshop CC 2017®) and the remaining filling material was, then, quantified.

4. Sample re-instrumentation

The instrumentation of RCS was done using the endodontic files described below according to the manufacturer instructions. The canals were irrigated by applying a total of 2mL of 5,25% sodium hypochlorite. All files were used until the working length

(WL) was reached. In all systems, all instruments were cleaned after each use and each file were used in 10 teeth before being discarded. All instruments were used with the WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) motor. In all groups, complete removal of the filling material was considered when the canal walls appeared to be smooth and no remaining filling material was observed on the instrument flutes.

4.1 ProTaper Universal Retreatment® (PTUR)

The PTUR system consists in 3 files with 3 lengths and 3 progressive tapers to fit all parts of the canal (coronal/middle/apical). D1 file (30.09) was used to remove the filling material from the coronal third of the RCS. D2 file (25.08) was used in the coronal two thirds of the RCS. The D3 file (20.07) was used in the apical third with light apical pressure. These files were used in a continuous clockwise (CW) rotation with crown-down technique and brushing motion at the manufacturer's recommended speed (500rpm) and torque (2N/cm).

4.2 Reciproc® (R)

The Reciproc is a single file system namely R25 (25.08). The instrument was moved in the apical direction in a reciprocating motion, using a slow in-and-out pecking motion of about 3 mm in amplitude with a light apical pressure combined with brushing action against the lateral canal walls. After 3 or 4 pecking motions, the instrument was removed and cleaned. This file was used at 300rpm and torque (2N/cm) as recommended by manufacturer.

4.3 OneShape ® (OS)

OneShape is also a single file system that works in continuous CW rotation. The OS file (25.06) was used with light apical pressure until the WL is reached and no further filling material was being removed. These file were used with crown-down technique and brushing motion against the canal walls at the manufacturer's recommended speed (450rpm) and torque (2,5N/cm).

4.4 WaveOne ® (WO)

Canal filling material in the WO group was removed using a small tip size WO file, W25 (25.08). This file was used in a reciprocating motion, in a crown-down technique, using a progressive up and down movement no more than three to four times then the

file was removed and the flutes were cleaned. During the motion was applied a light apical pressure and a brush movement against the lateral canal walls. This file, as a manufacturer recommended, was used at 350rpm and torque (2N/cm).

5. Statistical analysis

The data, before and after filling material removal, were collected into Microsoft Excel tables and then statistical analysis to compare the experimental groups was performed using GraphPad Prism® version 5.00 for Windows, GraphPad Software, San Diego Califórnia. The level of significance was set at 5% for all the tests ($p < 0.05$). A D'Agostino & Pearson normality test was applied to evaluate the normality of data distribution. Krusskal-Wallis with Dunns post test was held to assess whether the removal efficacy of the filling material differ significantly between the four groups in test. A Student t-test was applied to compare the whether there were significant differences between the VP and BL projections.

All tests were carried out in order to compare between the groups tested, which system was more effective.

III. RESULTS

All the teeth had remnants of filling material in the canal, except for 1 tooth in the Reciproc and in the OS groups and 3 teeth in the PTUR and in the WO groups. Analysis of the total area revealed no statistical differences between all systems tested ($p > 0.05$). The present study showed the following results (table 1): in bucco-lingual direction, the highest and the lowest mean reduction values for of the percentage of root canal filling removal were seen at WO system (92.79%) and OS system (82.55%), respectively. Accordingly, in mesio-distal direction, the highest and the lowest mean reduction values for of the percentage of root canal filling removal were also seen at WO system (93.53%) and OS (86.00%), respectively. The rest mean values for the study groups fluctuated between those values.

Study Groups	n	Bucco-lingual (BL)			Mesio-distal (MD)		
		MR (%)	SD (%)	SEM (%)	MR (%)	SD (%)	SEM (%)
PTUR	20	84,70	9,01	2,07	88,50	12,41	2,77
R	20	92,11	15,16	3,39	88,00	12,23	2,73
OS	20	82,55	16,84	3,77	86,00	11,57	2,66
WO	20	92,79	9,47	2,17	93,53	5,88	1,35

Table I: Mean Reduction (MR), Standard Deviation (SD) and Standard Error of the Mean (SEM) of four Retreatment Techniques

It was also possible to see in this study that, despite the WO system show very similar values of reduction in MD as BL the same is not true for the Recipro, PTUR and OS systems. As we can see from the Table I and Chart I, in BL, Reciproc system obtained a higher percentage of reduction of root canal filling material but if we focus on MD we can see that PTUR and OS systems were able to achieve a bigger percentage of reduction.

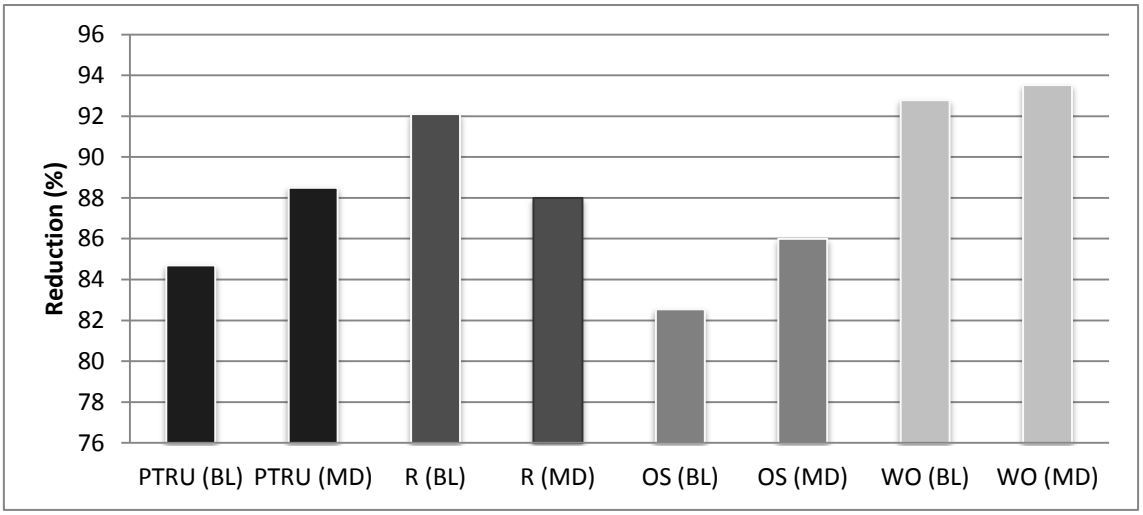

Chart 1. Mean reduction of Reciproc®, Protaper Universal Retreatment®, WaveOne® and One Shape® systems in two views – BL and MD

IV. DISCUSSION

Root canal retreatment usually represents a technical challenge for the operator. Factors like a well compacted filling material makes the removal much more difficult and elevate the risks of iatrogenic accidents (Alves et al., 2016).

Endodontic retreatment, as we know it today, is relatively recent. Currently, there are an enormous number of retreatment systems but it weren't much more than two decades ago that rotary files, as we know it today, were introduced in the market leading to an endodontic retreatment less tedious and faster, contributing to reducing error and less fatigue of the operator as well the patient. However, rotary instrumentation is certainly not a new concept; it was introduced in the late 19th century and has continuously evolved since then (McSpadden, 2007; Colaco et al., 2015).

Until the end of the 80's and beginnings of the 90's, biomechanical preparation was only executed with stainless steel files, which caused commonly errors in the procedure and also instrumental break. Taking into account all these counterparts, the need of creating a safer material files then raised (Matos, 2016).

Although nickel-titanium (Ni-Ti) alloy have been developed, for military purposes, in the 60's, only around 1993, the first Ni-Ti rotary file was presented. Since then, exploration and intensive study in this alloy, took us from a situation of lack of variability and options in Endodontics, to a situation in which we have at our disposal, currently on the market, more than 30 Ni-Ti rotary systems (Abbott, 2008).

Due to the physical characteristics of Ni-Ti files, these began to be activated by an electric motor of continuous rotation, which brought us several advantages; however, began to notice an increase index of fractures. In seeking to overcome this disadvantage, a new technique using reciprocating movements was put into practice. This method was introduced for the first time in 1985 and is used to relieve the file's stress using counter-clockwise (CCW) (cutting action) and CW (release of the instrument) movements. This new concept of motion offered a greater flexibility and resistance to cyclical fatigue. Despite the widespread knowledge and evident growth of the safety and effectiveness, this reciprocating motion has insufficient knowledge when it comes to be used in retreatment (Dhingra et al., 2015; Silva et al., 2015).

More recently, and in order to optimize the Ni-Ti alloys, some changes were made in the Ni-Ti conventional alloy, in a microstructure level, resulting in a special alloy called M-Wire. Manufactured instruments with M-Wire provide even greater resistance and flexibility compared to conventional Ni-Ti (Koçak, 2016).

Those benefits of M-wire alloy had also been supported by Martinho *et al.* (2015) as well as the greater efficacy of reciprocating systems that they claim being resulting of a wider motion in a CCW direction but a shorter one in the CW course. A greater contact area between filling material and the instruments is achieved because of the movements described above, resulting in a better effectiveness in reciprocating systems than in the continuous rotation files.

Others authors also agreed with a greater efficacy supported on this reverse balance force technique of the reciprocating systems affirming that, in the conclusion of their study, they were able to guarantee that reciprocating technique was the most effective method for removing the fillings (Al-Obaidi, Motea, 2016).

On the contrary, there are also some authors like Akbulut *et al.* (2016) and Silva et al. (2016) defending a similarity in the efficacy between reciprocating and continuous rotary systems claim that don't exist significant differences between the two.

Despite this disagreement between authors, the inability of any one of the systems to remove completely the canal fillings is mutual consensus between them (Jorgensen et al., 2017).

When the issue is the indicated system in retreatment there is an abundant series of factors that need to be taken into consideration and, for better results, we, also, need to know what is more advantageous: a single file (SF) system our a multiple file (MF) one.

According to Bartols *et al.* (2016), in terms of pain reduction and improvement of oral-health-related quality of life, the SF and MF systems shows no statistical differences. However the speed of treatment appears to be higher with SF and the probability of error during the procedure seems to be slightly lower in SF.

In this study, in order to enclose systems with different characteristics/factors - with influence in the efficacy of the gold objective (filling material's removal)- described before, two systems of continuous rotation, the PTUR, for being a reference system in

the field of Endodontics and OneShape because of, as far as we know, unpublished results about this system performing an NSERT, and two reciprocanting systems, Reciproc widely studied and another less studied, although widely known – WO were chosen. In parallel, and encompassing the same 4 systems, we also have the comparison between SF (R, WO and the OS) and MF (PTRU).

Referring to the choice of the previously filled teeth by students of the pre-clinical component of Endodontics of the Health Sciences Faculty of Fernando Pessoa University, we based in Vidal et al. (2016) that uses the same method; this is a perfectly valid specimen choice method once all the teeth had the same protocol of endodontic treatment, were performed by different students but with the same level of experience, were previously radiographed and only the ones that displayed good obturation were selected for the study.

Regarding the method approached for the quantification of the remaining filling material, we based ourselves in some authors as Silva et al. (2015) that also uses the radiographic method but more specifically the authors Al-Obaidi and Mateo (2016) who used the same radiographic method and the same radiographic imaging software (Adobe Photoshop CC 2017®) as well as the same specific software tool (magnetic lasso).

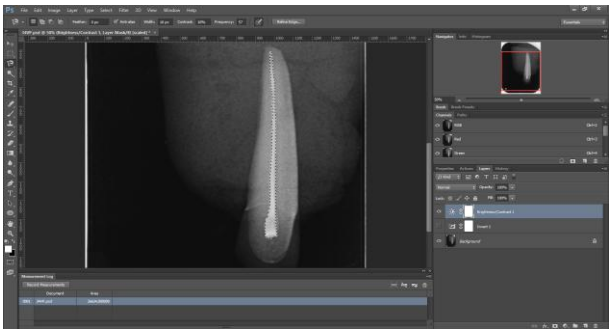

Figure 2. The use of Adobe Photoshop CC 2017® software and magnetic lasso tool to measure the total filling material area inside the root canal

The current literature is contradictory with regard to the results of the studies carried out to test and quantify the effectiveness of various systems of endodontic retreatment. Two independent studies published in 2016 by two different authors, Crozeta et al. and Koçak et al., analysed the efficiency of the same three systems of retreatment used in this study (PTUR, R and WO) and got completely different results. Koçak et al. (2016) argues that the system most efficient in removing the filling material was WaveOne,

followed by Reciproc and finally the PTUR. Contradictorily, Crozeta et al. (2016) suggests that Reciproc is the most efficient system, followed by the PTUR and WaveOne respectively. Other studies, carried out by Silva et al. (2015) and Akbulut et al. (2016) suggest, respectively, that WaveOne is better in removing the filling material than PTUR and that Reciproc is also more efficient than the PTUR, which corroborates with the studies mentioned above. We can conclude from these four studies, and other literature reviewed that, although not always be consonance between the results, all the studies suggest a reciprocating system as the more efficient.

The same thing happened in this study, although there were no significant differences between the groups: a reciprocating system (WaveOne) stood out as the most efficient.

This study shows a lot of similarities with the studies of Koçak et al. (2016) by highlighting the system WO as the most efficient, followed by the Reciproc system and the PTUR with values very similar. Other studies, like Akbulut et al. (2016) also show that a reciprocating SF system (WO) is more efficient than a continuous MF rotation system (PTUR).

Although there is no agreement between the studies of the past two years regarding the final results, we can see that, in literature, the Reciproc system and PTUR resemble much in the results; a large number of studies involving the system WO placed it as the most efficacious with exception of Crozeta et al. (2016) that claimed to be the least effective of all system involving in their study. (See annex 1)

With regard OS system, to date and to our knowledge, there was no literature showing the performance of this system in a NSERT. Despite having demonstrated good values of root canal filling material removal, of the four systems studied was the least effective. Nevertheless, and since there were no significant differences between the four groups, this is a system that can be proposed as a good option to NSERT.

V. CONCLUSION

The NSET is a meticulous treatment that follows a series of protocols and steps and when one of these steps fails for some reason, all the treatment can be compromised, leading to a poor prognosis and, in last instance, failure.

When this happens it is the responsibility of the Dentist to find out if it is plausible to attempt a NSERT and, if so, which system is more effective and will lead to a better prognosis.

After extensive research, it was found to be many published scientific studies on this issue but the agreement between them was very rare. (See annex 2) A distinction is made between the reciprocating SF systems (both the WaveOne and Reciproc system) and continuous MF rotation systems (PTUR), being the firsts reffered for better efficiency.

After the procedures of statistical analysis of the data and discussion of the results, within the limitations of this study, it can be concluded the following:

- there was no total removal of the root canal filling material regardless the system used:
- a reciprocating SF system is more efficient than a continuous MF rotatory system;
- the system responsible for a better removal of root canal filling material was the WO system with a total mean of 93.16% of removal, followed by the Reciproc system with 90.06%, PTUR system with 86.6% and, finally, the OS system with 84.28%.
- There were differences in the values of reduction between BL and MD in three of the groups, but there wasn't a significant difference between the two incidences that justifiesthe need of two radiographic views.

This study is intended to be an addition to the information currently available about the systems used on NSERT and taking into account that although new systems appear continuously, as a Dentist, we can always opt for any of the systems described here since they demonstrated effectiveness and have been widely studied.

BLIOGRAPHY

Articles

1. Al-Obaidi, A. M. M., Motea, Y. H. (2016). A Comparison of the Effectiveness of Reciprocating System with Continuous Rotary Systems in Non-Surgical Endodontic Retreatment (An *In Vitro* study), *Journal Baghdad College Dentistry*, 28(1), pp 57-62
2. Akbulut, M. B. et alii (2016). Efficacy of Twisted File Adaptive, Reciproc and ProTaper Universal Retreatment instruments for root canal filling removal. A cone-beam computed tomography study, *Dental Materials Journal*, 35(1), pp 126–131
3. Alves, F. R. F. et alii (2016). Removal of Root Canal Fillings in Curved Canals Using Either Reciprocating Single- or Rotary Multi-instrument System and a Supplementary Step with the Xp-Endo Finisher, *Journal of Endodontics*, 42, pp 1114-1119
4. Bartols, A., Laus, G., Walther, W. (2016). Multiple-file vs. single-file endodontics in dental practice: a study in routine care, *PeerJ*, 4, pp 2765-2789
5. Colaco, A. S., Pai, V. (2015). Comparative Evaluation of the Efficiency of Manual and Rotary Gutta-percha Removal Techniques, *Journal of Endodontics*, 41, pp 1-4
6. Crozeta, B. M. et alii (2016). A micro-computed tomography assessment of the efficacy of rotary and reciprocating techniques for filling material removal in root canal retreatment, *Clinical Oral Investigations*, 20, pp 2235–2240
7. Dhingra, A., Ruhal, N., Miglani, A. (2015). Evaluation of Single File Systems Reciproc, Oneshape, and WaveOne using Cone Beam Computed Tomography - an In Vitro Study, *Journal of Clinical and Diagnostic Research*, 9(4), pp ZC30-ZC34
8. Jorgensen, B. et alii (2017). The Efficacy of the WaveOne Reciprocating File System versus the ProTaper Retreatment System in Endodontic Retreatment of Two Different Obturating Techniques, *Journal of Endodontics*, 43(6), pp 1011-1013
9. Kasam, S., Mariswamy, A. B. (2016). Efficacy of Different Methods for removing root canal filling material in retreatment - An In-vitro study, *Journal of Clinical and Diagnostic Research*, 10(6), pp ZC06-ZC10

10. Koçak, M. M. et alli (2016). Cleaning efficacy of reciprocal and rotary systems in the removal of root canal filling material, *Journal of Conservative Dentistry*, 19, pp 184-188
11. Martinho, F. C. Et alli (2015). Endodontic retreatment: clinical comparison of reciprocating systems versus rotary systems in disinfecting root canals, *Clinical Oral Investigations,* 19(6), pp 1411-1417
12. Obeid, M. F. et alii (2015). Efficacy of three Ni-Ti rotary systems for removal of filling materials from root canal system of extracted teeth, *Tanta Dental Journal,* 12, pp 259-264
13. Preetam, C. S. et alii (2016). A comparative evaluation of two rotary Ni-Ti instruments in the removal of gutta-percha during retreatment, *Journal of International Society of Preventive & Community Dentistry,* 6(2), pp 131-136
14. Rao, L. N. et alii (2016). Rotary in Retreatment: a Review, *International Journal of Scientific Research,* 5, pp 16-18
15. Santos, S. M. C. Et alii (2010). Radiographic Parameters of Qualuty of Root Canal Fillings and Periapical Status: A Retrospective Cohort Study, *Journal of Endodontics,* 36(12), pp 1932-1937
16. Silva, E. J. N. L. et alii (2015). Effectiveness of rotatory and reciprocating movements in root canal filling material removal, *Brazilian Oral Research,* 29(1), pp 1-6
17. Tabassum, S., Khan, F. R. (2016). Failure of endodontic treatment: The usual suspects, *European Journal of Dentistry*, 10(1), pp 144-147
18. Vidal, F. T. et alii (2016). Evaluation of three different rotary systems during endodontic retreatment - Analysis by scanning electron microscopy, *Journal of Clinical and Experimental Dentistry,* 8(2), pp 125-129
19. West, J (2016). Single Versus Multiple Endodontic File Use, *Dentistry Today*, 35 (12), pp 62-68
20. Zuolo, A. S. et alii (2016). Evaluation of the Efficacy of TRUShape and RECIPROC File Systems in the Removal of Root Filling Material- An Ex Vivo Micro–computed Tomographic Study, *Journal of Endodontics,* 42, pp 1-5

Books

1. McSpadden, J. T. (2007). *Mastering Endodontic Instrumentation.* Tennessee, Cloudland Institute.

Internet

1. Matos, H. R. M. (2016). Endodontia mecanizada, das limas de aço inox a limas de M-Wire. Revisão de Literatura. [Em linha]. Disponível em <http://www.bibliotecadigital.unicamp.br/document/?code=000965144&opt=1>. [Consultado em 04/07/2017].
2. Abbott, J. A. et alli (2008). ENDODONTICS: Colleagues for Excellence. [Em linha]. Disponível em <https://www.aae.org/uploadedfiles/publications_and_research/endodontics_colleagues_for_excellence_newsletter/winter08ecfe.pdf>. [Consultado em 04/07/2017].

Annex 1

Author/ Year	Systems tested	No teeth/ group	Sample analysis	Results (Efficiency - highest to lowest)	Conclusion
Al-Obaidi & Motea (2016)	WaveOne®	10	Digital Radiograph	WaveOne®	The reciprocating technique was most effective method for removing gutta-percha and sealer than continuos rotary technique.
	ProTaper UR®			ProTaper UR®	
	R-Endo®			R-Endo®	
	D-Race®			D-Racere®	
Akbulut et al. (2016)	Twisted File Adaptive®	15	CBCT	Reciproc®	Reciproc and ProTaper UR were equally effective for the removal of root canal filling and both systems exhibited less residual root canal filling than TF Adaptive and hand files.
	Reciproc®			ProTaper UR®	
	ProTaper UR®			Twisted File Adaptive®	
	Hedström®			Hedström®	
Alves et al. (2016)	Reciproc® R25	20	MicroCT	Mtwo®	Mtwo retreatment technique was more effective and faster thant Reciproc in removing filling material from curved canals. Reciproc R40 removed significantly more material than Reciproc R25.
	Reciproc® R40			Reciproc® R40	
	Mtwo®			Reciproc® R25	
Colaco & Pai (2015)	Hedström® + Xylene	10	Microscope and photographed	D-Race®	Rotary retreatment techniques were more efficient than manual techniques in GP removal. Among these techniques, the rotary D-RaCe Retreatment system was most efficient, whereas the manual use of H-files with
	Hedström® +			ProTaper UR®	
				Hedström® + Xylene	

	System B				System B was least efficient.
	ProTaper UR®			Hedström® + System B	
	D-Race®				
Crozeta et al. (2016)	ProTaper UR®	7	MicroCT	Reciproc® R25/R40/R50	PTUR instruments performed equally effective regarding filling material removal compared with W40, R40, R50, W25/W40, and R25/R40/R50. For WaveOne, the use of a single instrument (size 40, taper 0.08) was more effective in removing filling material, while for Reciproc showed similar cleaning ability using a single instrument or a combination of instruments.
	WaveOne® W40			WaveOne® W40	
	WaveOne® W25/W40			Reciproc® R50	
	Reciproc® R40			ProTaper UR®	
	Reciproc® R50			Reciproc® R40	
	Reciproc® R25/R40/R50			WaveOne® W25/W40	
Kasam & Mariswamy (2016)	Hedström®	12	Stereomicroscope and photographed	Ultrasonic Retreatment Tip	Within the limitations of this in vitro study, it can be concluded that retreatment done using ultrasonic retreatment tip proved to be most effective, least time consuming and produced quantitatively lesser amount of apical debris extrusion followed by protaper rotary retreatment files, H files and safe sided H files.
	Hedström® (Safe sided)			ProTaper UR®	
	ProTaper UR®			Hedström®	
	Ultrasonic Retreatment Tip			Hedström® (Safe sided)	
Koçak et al.	ProTaper UR®	22	Stereomicrosc	WaveOne®	WaveOne was significantly more effective than Reciproc

(2016)	WaveOne®		ope and photographed	Reciproc®	in removing the root canal filling. The reciprocating technique was the most efficient method for removing gutta-percha and sealer, followed by the rotary technique and the hand file technique.
	Reciproc®			ProTaper UR®	
	Hedström®			Hedström®	
Preetam at al. (2016)	ProTaper UR®	10	Digital Radiograph	ProTaper UR®	A more effective way of an endodontic retreatment would be the use of both the rotary and hand file systems. The rotary system would help us in achieving the complete removal or filling material form the cervical and middle one third as well as help us in reaching the apical region faster compared to the use of hand files in these areas; the final apical region can be debrided by the use of hand files, thus completing the filling material removal without leaving behind any residual filling materials
	D-Race®			D-Race®	
	Hedström®			Hedström®	
Silva at al. (2015)	ProTaper UR®	20	Digital Radiograph	ProTaper UR®	No differences were observed in the efficacy of the ProTaper Retreatment System and the WaveOne System in removing root filling material. Apical thirds showed more residual filling than middle and cervical thirds, in both groups
	WaveOne®			WaveOne®	
Vidal et al. (2015)	ProTaper UR®	10	Scanning Electron Microscope	ProTaper UR®	Based on our methods and results (…) comparing the three groups, G1 (ProTaper system) had better results without, although significant difference to G2 (K3 system).
	Mtwo®			K3®	
	K3®			Mtwo®	