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RESEARCH ARTICLE

Evaluation of the Apical Seal after Root Canal Cleaning and Shaping with Two Nickel-Titanium Systems

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Objective: The aim of our study is to compare the ability of two nickel-titanium systems that use different rotation motions to create preparations that could promote a complete filling of the apical third of root canals. **Methods**: We used 36 freshly extracted teeth, randomly divided in two groups, as follows: in Group A we used ProTaper Next, a system characterized by a continuous rotary motion and in Group B the teeth were instrumented with Wave-One, in which the files have a reciprocating motion. All teeth were root filled based on the same protocol, using gutta-percha and AH Plus. The teeth were further prepared for microleakage evaluation based on dye penetration technique, as follows: immersion in 2% methylene blue, longitudinally sectioned and examination of the apical thirds with an operating microscope. The distance of dye penetration along dentin walls was measured using the ImageJ program. **Results**: The comparison between rotational and reciprocating systems showed that reciprocating files significantly promoted a reduced apical microleakage, as demonstrated by unpaired t test, Welch corrected (p=0.0346). **Conclusion**: The use of Wave-One Reciprocating system was considered more effective in the shaping of root canals, as they demonstrating better conditions for the hermetic, tridimensional sealing of apical third of the roots canals.

Keywords: apical microleakage, ProTaper Next, Wave-One, cleaning and shaping, dye penetration technique

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Introduction

The endodontic therapy is performed in order to eliminate all inflammatory and/or infectious dental pulp tissue, with a final hermetic and tridimensional sealing of the entire root canal system, which was demonstrated to provide a high long-term success of the treatment. The correct application of the mechanical and biological phases of cleaning and shaping creates smooth dentin walls, facilitate irrigation and obturation, with concomitant emphasis on the preservation of the shape and location of the apical foramen. [1,2] These principles, introduced by Schilder in 1974, have undergone great transformation in recent years, due to the gradual replacement of the manual instruments by the rotary modeling systems and techniques, represented mainly by continuous movement and alternating reciprocating systems. [3]

During the last decade, many types of Nickel-Titanium (Ni-Ti) rotary files have been introduced on the market, such as ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) and Wave-One (Dentsply Maillefer, Ballaigues, Switzerland). These instruments have an improved cutting efficiency and safety but on the other hand, their disadvantages are represented by the need to use several instruments, an increased fracture risk and cross contamination. [4] The reciprocating motion compared to continuous rotation could be advantageous regarding the reduced stress and time required for the preparation of curved canals, with a single use of a Ni-Ti file. [5] This motion proved to have important benefits: the file rotates at lower speed, the risks of cyclic fatigue and torsional failures are decreased and the treatment is more cost-effective. Wave-One files describe a contraclockwise (CCW) rotation of 170^0 and a clockwise (CW) rotation of 50^0 which means that it takes three reciprocating movements for the instruments to complete 360^0. Therefore, this type of motion was considered more suitable for narrow or sclerotic canals. [6] This method of using only one file that works in reciprocating movement, performs rotations in CCW and CW direction, as follows: the instrument, when rotating in the cutting direction, advances inside the root canal, contacts the dentin and processes the cut, while when rotating in the opposite direction, it is released immediately. [7]

The continuous rotating instruments showed a greater tactile touch and efficiency when Ni-Ti files were used in smaller-diameter and more curved canals, which must be balanced with the risks associated with torque and cyclic fatigue failures. Fortunately, these disadvantages have been greatly eliminated after the continuous improvement in the file designs, use of high performance Ni-Ti alloy and more emphasis on the glide path management. In comparison to reciprocation, the well-designed Ni-Ti files used with continuous rotation, require less inward pressure and improve hauling capacity, pushing the debris out of the root canal. Current motors that drive reciprocating shaping files through equal forward and reverse angles generally require multi-file sequences for an adequate endodontic preparation. Furthermore, the systems that use equal CW/CCW small angles have also limitations, represented by decreased cutting efficiency, need for more inward pressure and low capacity to auger debris in coronal direction. The ProTaper Next system is a new generation of rotary instru-

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ments with Ni-Ti M-wire technology, which is the result of a thermo-mechanical processing that makes the instrument more flexible and resistant to cyclic fatigue compared to conventionally ProTaper files. [8]

Apical leakage is a well-known cause of endodontic failure, being influenced by many variables: different filling techniques, physical and chemical properties of endodontic sealer, presence of smear layer. [9] As microorganisms can survive inside dentinal tubules even after rigorous cleaning and shaping, the hermetical apical seal is desirable to block the remaining bacteria and their by-products and toxins from reaching the periapical tissues. [10, 11]

The aim of our study was to evaluate on extracted teeth, if the type of rotary Ni-Ti system used for endodontic preparation influences the quality of the root filling. The evaluation of the apical seal will be assessed using the dye penetration technique, a method commonly used for microleakage studies, due to its simplicity and cost-effectiveness. The null hypothesis to be tested is that the technique of root canal preparation has no influence on the quality of the endodontic filling.

Methods

Our investigation was conducted after we obtain permission from the Ethics Committee of our university and in accordance to Helsinki Declaration. We used 36 freshly extracted human teeth, as part of an orthodontic treatment protocol, that were fixed in 10% buffered formalin solution before endodontic instrumentation. The teeth were randomly selected to the study groups and the endodontic instrumentation was carried out as follows: in Group A 18 teeth were prepared with the ProTaper Next rotary system (Dentsply Tulsa Dental, Oklahoma, USA) and in Group B other 18 teeth were instrumented with the Wave-One reciprocating system (Dentsply Maillefer Instruments SA, Ballaigues, Switzerland). After coronal access, a #10 file was introduced in each canal until it appeared at the apex and from this distance 1 mm was reduced, obtaining the working length. In Group A, initially the root canals of the specimens were explored with a #15 manual K-file, followed by instrumentation with the X1 and X2 files; the procedure was completed with X3 and X4 rotary files. The root canals were kept irrigated with a solution of 2.5% sodium hypochlorite throughout the preparation procedures, using copious amounts of solution after each instrument. In Group B, the root canals were first explored with a #15 K-file and then we used the Wave-One large reciprocating file (40/08) with an in-and-out movement. Likewise, the canals were irrigated with 2.5% sodium hypochlorite. After the biomechanical preparation of both groups, the canals were irrigated with 5 mL of EDTA solution 17%, in order to remove the smear layer. The final irrigation of root canals was performed with 10 mL of 2% Chlorhexidine solution and dried with paper points. For the root fillings we used gutta-percha and AH Plus (Dentsply Maillefer), using the continuous wave of condensation technique. The access cavities were cleaned of endodontic materials just below the cement-enamel junction and filled with glass-ionomer cement. All teeth were incubated at 37 C° 100% humidity for 7 days to allow the complete set of the sealing materials. For microleakage evaluation, all roots surfaces except the apical 3 mm were covered with two coats of nail polish and immersed in a 2% methylene blue dye for 24 hours days. The teeth were rinsed with running water and dried and on each root a buccal and lingual longitudinal groove was made, using diamond disks under water coolant, ensuring that the root canal remains intact. Then each root was split into two halves by levering with a knife. Color photographs were taken using a Sony a6000 camera and transferred to a personal computer. The maximum degree of dye penetration was recorded for each section and the degree of leakage was determined from cement-enamel junction to the coronal limit. The readings were made by two observers that were previously calibrated who used the ImageJ Computer Program in order to measure the extent of dye penetration. The data was submitted to statistical analysis using unpaired t test, Welch corrected ($p<0.05$).

Results

The use of rotary Ni-Ti systems enabled a more predictable canal preparation, with few procedural errors, mainly in narrow, curved canals. The well-known limitation of these instruments, represented by the apically tendency to straighten the canal (zipping), was not observed in our study groups. On the specimens examined, the apical curvature of the canal was maintained and completely filled with endodontic sealer and gutta-percha. The images used for microleakage assessment are presented in Fig.1-3 and the statistical analysis is summarized in Table 1. The mean values of apical microleakage recorded after the use of Wave-One reciprocation technique and ProTaper Next rotary system are presented in Table 1. The use of a visible scale was an indication of the amount of vertical dye infiltration and the exact measurement was further obtained with the computer program. The statistical analysis of the recorded data showed that there is a significant difference

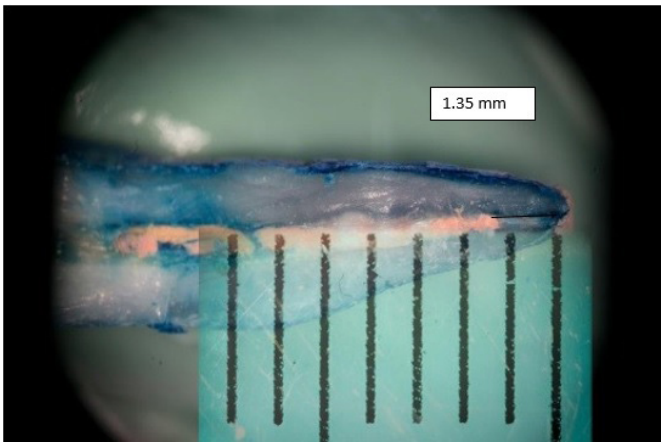

Fig.1 A visual scale was used to illustrate better the value of vertical dye penetration, measured from the apical cement-dentinal junction into coronal direction (Specimen from Group A, 1.35mm).

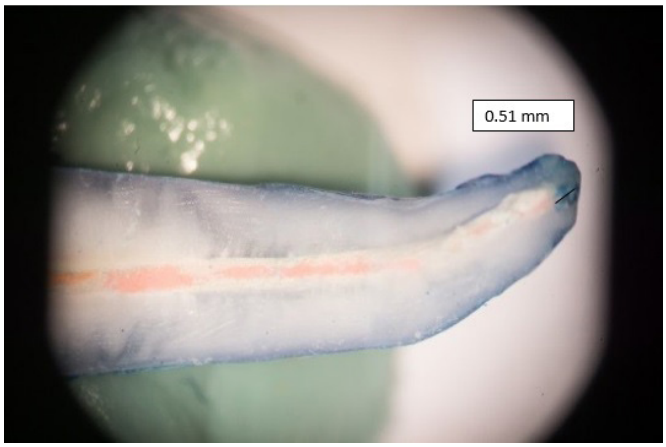

Fig.2 The use of Wave-One system (Group B) maintained the initial shape of the root canal and the apical infiltration of the dye was reduced (0.51mm).

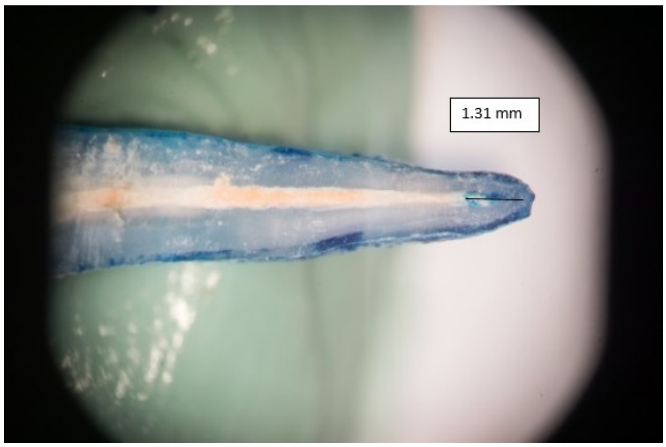

Fig. 3 Specimen from ProTaper Next (Group A), which showed more apical microleakage (1.31mm).

Table 1. The values of vertical apical microleakage recorded in the study groups, based on dye penetration technique

Study group	Number of teeth	Minimal apical microleakage	Maximal apical microleakage	Mean	Standard Deviation
ProTaper Next	18	1.43	1.96	1.617*	0.193
Wave-One	18	0.51	1.83	1.482*	0.174

*Statistically significant differences (p=0.0346, p<0.05)

between WaveOne and ProTaper Next regarding the apical seal, as reciprocating group produced the best apical seal (p=0.0346). Therefore, the null hypothesis was not confirmed.

Discussion

Numerous studies have evaluated the apical sealing using different methods like dyes, radioisotopes, bacteria and their products or methodologies such as light microscopy and digitally captured images for evaluation of sealer-dentin interface. The prevention of apical leakage of root canal fillings implies the presence of a three dimensional apical and coronal sealing. Today, with the new materials and techniques available on the market, the potential of successful outcomes is higher, as these create a better seal between root canal walls and the filling material. Many studies focused on the ability of different Ni-Ti rotary instruments in shaping of simulated root canals or on extracted teeth; in our investigation we used the latter, as the first one is considered to have little relevance to the complex anatomy of the endodontic space.

In our study, we used the dye penetration method, to evaluate and compare the amount of apical microleakage in root canals filled with the same endodontic sealer but shaped with two different Ni-Ti rotary systems, ProTaper Next and Wave-One, which became very popular among dental practitioners, being also considered appropriate for undergraduate teaching. Their characteristics could be summarized as follows: the unequal bidirectional movement of Wave-One system, compared to continuous rotation of ProTaper Next, offers a significant improvement in safety, as the CCW engaging angle is smaller than the elastic limit of the file. Furthermore, different from other reciprocating systems that use equal bidirectional angles, the Wave-One system has an engaging angle which is 5 times the disengaging angle, so that after three engaging/disengaging cutting cycles, the file completes a 360º rotation. This enables the instrument to advance more readily to the working length and enhances auguring debris out of the canal, promoting the biological objectives of cleaning and also, shaping and proper filling of the root canal system. [6, 12] All phases of endodontic therapy are important for the final outcome, as any carelessness may compromise the long-term good results of this therapy. Among these, the biomechanical preparation of the root canal has a special place and a thorough knowledge on instruments used is absolutely necessary for a successful treatment. [13]

In our study, the use of Ni-Ti rotary instrument produced a well tapered root canal form, facilitating the filling and completing the preparation in an acceptable time, also maintaining the canal curvature. This finding is in agreement with observation of other studies and may be explained by the great flexibility of Ni-Ti files, which have a superior ability to follow even the severely curved canals. [14] Therefore, we used manual files only for root canal exploration prior to mechanical preparation, in order to assure a smooth glide path through the internal anatomy of the teeth. One of the advantages of the mechanized instrumentation is the promotion of a faster preparation of the root canal, with less stress for both dental specialists and their patients during treatment. The continuous rotary systems revealed in time their failures, leading to the development of a technique in which only the F2 file of the Protaper Universal system was used in all root canal instrumentation, based on reciprocating kinematics instead of continuous, in order to reduce the instrument fatigue and simplify the preparation steps. [15-17]

Many studies compared the effectiveness of the continuous versus reciprocating movements concluding that Ni-Ti instruments used with reciprocating movements had greater resistance and ability to maintain the initial course

of the canal, showed lower apical transportation and less apical extrusion of dentin, compared to continuous instrumentation. [18, 19] Proper enlargement of the root canal is essential, as microorganisms can penetrate the dentin tubules; furthermore, the pre-dentin must be completely removed during preparation to avoid formation of voids between the endodontic sealer and the root canal walls. Both systems are made from Ni-Ti alloy (M-wire), but they have different cross-sections: Wave One files section varies along their axis, while Protaper Next files have a decentralized rectangular cross-section that creates an enlarged space for removing debris and resulting in asymmetrical movement, where only two edges of the instrument come into contact with the canal wall. The use of large diameter instruments might compromise the root canal, creating morphological changes which can lead to treatment failure. [20] The conservative preparation of the apical third ends up compromising the cleaning of the root canal; accordingly, the diameter of the instruments used in the present study is consistent with the anatomy of the dental elements chosen. In our study, each specimen was instrumented with files of equal diameter, ensuring a correct and reliable standardization and comparability of the experimental groups.

A common method used to evaluate the value of apical microleakage is based on linear measurement of dye penetration. Eosin, Methylene blue, Procian brilliant blue, and Black India Ink are some of the dyes frequently used. In our study we used Methylene blue, as its molecular size is similar to bacterial by-products such as butyric acid, which can leak out of infected root canals to irritate the periapical tissue, it is easy to use and is available. It is an epoxy-bis-phenol resin based sealer that contains adamantine and has the ability to bond to the radicular dentin. However, AH Plus tends to shrink causing early debonding from the root canal wall, but it has a greater adhesion than Epiphany Pentron Clinical Technologies, Wallingford, USA), probably due to the fact that AH Plus has better penetration into the micro-irregularities. [20] The long setting time increases the mechanical interlocking between sealer and root dentin. On the other hand, there is inadequate bonding between the sealer and the gutta-percha point, allowing fluid leakage at this interface. We used the potential of this dye to flow through the apex, in order to determine the quality of endodontic shaping obtained by using ProTaper Next and WaveOne systems. Methylene blue dye showed a great potential to enter through the complex anatomy of the apical third or at the interface between dentin-sealer-core material interfaces. In our study we used AH Plus as the common sealer in both study groups, due to its radioopacity, biocompatibility, ease to use and availability, which determined many researchers to consider it the gold standard for endodontic research.

Conclusion

Shaping ability of Ni-Ti rotary systems is of utmost importance for specialists in Endodontology, as these can influence the apical filling and finally, the treatment outcome. In the current study, the result of the use of rotary NiTi instruments with matched-tapered gutta-percha cones showed minor microleakage in term of linear dye penetration.

Within the limitations of our study, we can conclude that WaveOne with its reciprocating motion created better conditions for a perfect apical seal and preserved the initial shape of the root canal, without apical transportation. Nevertheless, one should take into consideration that this experiment was conducted in vitro, with its inherent limitations and therefore clinical extrapolation should be avoided.

Authors' contribution

Amalia Abageru (Data curation; Methodology; Writing – original draft)
Mihai Pop (Formal Analysis; Methodology)
Monika Kovács (Supervision; Writing – original draft)
Alexandra Stoica (Data curation; Formal analysis)
Monica Monea (Conceptualization; Supervision; Validation; Writing –review & editing)

Conflict of interest

None to declare.

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