Kataia *et al. Bull Natl Res Cent (2021) 45:120*
https://doi.org/10.1186/s42269-021-00579-x

Bulletin of the National Research Centre

RESEARCH Open Access

Cutting efficiency of two heat-treated files in rotation and reciprocation motions

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Abstract

Background: This study aimed at assessing the effect of different kinematics as well as different instrument designs on efficiency of cutting of two heat-treated nickel–titanium systems. Forty resin canals with 30°-angle of curvature and a length of 16 mm were utilized in this research. They were divided into four groups depending on the instrument and the operating kinematic, group I; Azure rotary system in rotation motion, group II; Azure rotary system in Reciprocation motion, group III; Fanta AF One rotary system in rotation motion and group IV; Fanta AF One rotary system in reciprocation motion. Blocks were labeled and then weighed pre- and post-preparation with delta weight (Δ wt = wt pre − wt post) and data were documented for statistics evaluation.

Results: Resin canals prepared using Fanta AF One rotary system showed significantly higher weight loss than Azure rotary system in both rotation and reciprocation ($P < 0.001$). Insignificant difference was reported for rotation and reciprocation movements in both file systems.

Conclusion: The instrument's cross section revealed a more significant impact on cutting efficiency than the motion used.

Keywords: Rotation, Reciprocation, Cutting efficiency, Heat treatment

Background

Preparation is a stage of prime importance in endodontics, including the biochemical and mechanical phase. Despite the importance of both phases together, mechanical instrumentation is still of critical importance to the total endodontic procedure (Hulsmann et al. 2005).

Many techniques are advocated for Biomechanical preparation these days, but the use of rotary nickel–titanium instruments is the most popular (Almanei 2018). Several nickel–titanium systems are available, which are constantly being enhanced in various aspects; designs, materials, and modes of rotary. These innovations reduce the time needed, complexity in use, fatigue of clinicians, and therefore, increase success rates of these instruments (Saber et al. 2015).

Rotation motion, introduced at the end of the 1980s, is being used to date with most systems available on the market. Nonetheless, Reciprocation, has been suggested attempting to minimize the possibility of instruments separation, as has been announced that it relieves stresses on instruments, enhance resistance to cyclic fatigue and NiTi instruments' lifetime (Bürklein et al. 2012; Plotino et al. 2012).

Reciprocating motion involves a greater counterclockwise angle of rotation, allowing the file to dissect through dentin, whereas the lesser clockwise angle detaches. Because of the larger counterclockwise angle, files constantly accelerate forwards (Bürklein et al. 2012; Plotino et al. 2012; Kim et al. 2012).

Yared (2008) conducted an investigation preparing canals with a single F2 ProTaper file, reciprocating, at differing degrees. This groundbreaking work was a progression in instruments' kinematics, confirming that using files in sequence isn't mandatory to achieve a tapered preparation; hence, recently, instruments to

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be used in reciprocation have been manufactured for single-file preparation.

All along the past decade, dental companies introduced various NiTi rotary instruments with differing cross-sectional designs and various tapers intending to improve the performance of these new systems, thereby making the preparation procedure easier (Cohen 1994). In 2010, a novel heat treatment technology was popularized. This technology introduced the controlled memory wire instruments, produced by a heating and cooling process giving the instruments the ability to be pre-bent and increasing their fracture resistance (Pereira et al. 2015) and flexibility (Testarelli et al. 2011; Zinelis et al. 2010). This novel technology creates a more centralized canal preparation with minimal transportation (Pinheiro et al. 2017).

Nowadays, manufacturers enhance properties of the instruments by thermally treating them (Miyazaki et al. 1982; Frick et al. 2004), as a substitution to only changing their geometrical design (Zinelis et al. 2010).

In the current work, cutting efficiency of recently marketed, heat-treated E3 Azure and Fanta AF one was tested in the two movements; rotary and reciprocation, using one; file 25 taper 0.06.

E3 Azure, having a adjusted S-shape cross section (minimizing file core thus, contributing to better removal of debris and more flexibility), varying pitch and a safe cutting tip, on the other hand, AF F-One file adopting a uniquely designed cross section of two active cutting tips and a flat side-cut, a non-cutting tip. It is also manufactured with control memory wire technology and a titanium surface treatment allowing the file to be more flexible, with increased hardness and fracture resistance (Shanghai Fanta catalogue).

According to the manufacturers' allegations, both files have comparable properties in design and metallurgy, our hypothesis is that there'll be no difference in cutting efficiency between both files, when used in both motions.

Methods

This was an in vitro study performed in the Faculty of Dentistry and the Faculty of Pharmacy research laboratories, the British University in Egypt.

This study has the approval from the Research Ethics Committee of the Faculty of Dentistry the British University in Egypt; Approval Date: 23/2/2021 and Approval Number: 21-010.

Two files having the same size (25/06) were used in this study; E3 Azure BASIC (Poldent Co. Ltd., www.endostar.eu) and Fanta AF One File (Shanghai Fanta Dental Materials Co., LTD).

Sample selection

Power calculation using G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany) was carried out on data extracted from a former study (Mittal et al. 2017). Calculations determined that sample size per group can be 10 files. This work was performed on forty simulated clear resin canal blocks (Endo Training Bloc, Dentsply, Maillefer, Tulsa, OK, USA), having a curvature angle equal to 30°, length equal to 16 mm, diameter and taper mimicking an ISO standard File #15/02. Patency was verified for all canals and glide path to size #20 hand K-file taper 2% (Dentsply Maillefer, Ballaigues, Switzerland) was done.

Resin blocks were divided into four experimental groups ($n = 10$) conforming to the type of file and kinematic advocated: E3 Azure/Rotation (A/Rt group; Azure file 25 taper 0.06 used in full rotation), Fanta AF one/ Rotation group (F/Rt: Fanta AF one file 25 taper 0.06 used in continuous rotation), E3 Azure/Reciprocation Group (A/Rec; Azure file 25 taper 0.06 was used in Reciprocation 270/90) and Fanta AF one/Reciprocation Group (F/Rec: file AF2 (25 taper 0.06) used in Reciprocation movement 270/90).

External surfaces of the blocks were coded with numbers using metal pins to be able to identify the canals during the weighing procedures.

Weighing procedure

Prior to preparation, all blocks were weighed (wt. pre) by a four-digit gram high precision balance sensitive scale (Sartorius Precision Balance 2254 S0001, Germany) and established (serial numbered). Blocks were reweighed again after preparation. Measurements were tabulated in a chart by a different operator for later use in subtractive analysis to compare between the cutting efficiency of the two files in the two different motions.

Sample preparation

Using a torque guarded endodontic motor (X-Smart plus Dual, Dentsply Maillefer), set to work at 350 rpms and 2.5 N cm, as advised by the manufacturer, all the canals were prepared by the same operator in a gentle up and down motion. Canals were irrigated with 20 ml of 2.5% NaOCl after instrumentation of a 27-gauge needle.

Evaluation

Data were recorded as delta weight (Δ wt = wt pre − wt post) and tabulated.

Statistical analysis

Data displayed as mean and standard deviation (SD) were inspected for normality by Kolmogorov–Smirnov

Table 1 Displaying means and standard deviation of weight loss recorded in milligrams for Azure and Fanta AF One rotary files in rotation and reciprocation

	Az	F	P value
Rot	3.86 ± 0.541	6.88 ± 0.487	< 0.001
Rec	3.62 ± 0.954	6.42 ± 2.708	< 0.001
P value	0.054	0.06	

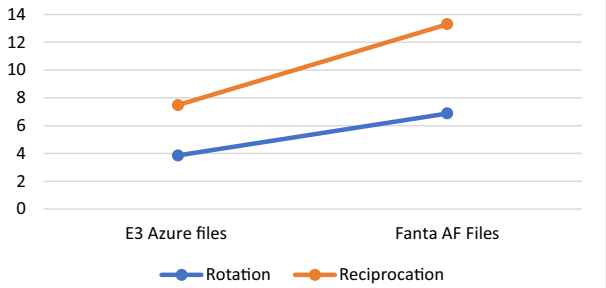

Fig. 1 Showing means of weight loss recorded in milligrams of Azure and Fanta AF One rotary systems in rotation and reciprocation

and Shapiro–Wilk tests. Wt (gm) change displayed nonparametric distribution; therefore, Mann Whitney *U* test was conducted for comparison among experimental groups.

Level of significance was adjusted to $P \leq 0.05$. Statistical evaluation was done using IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 22 for Windows.

Results

Samples instrumented with Fanta AF One rotary system showed significantly higher weight loss than Azure rotary system in both rotation and reciprocation ($P < 0.001$). There was insignificant difference among rotation versus reciprocation movements in both file systems (Table 1, Fig. 1).

Discussion

Biomechanical techniques used in preparing root canals emerged from manual preparations to rotary techniques utilizing nickel–titanium instruments. The use of NiTi rotary files for preparing root canals enabled the creation of consistently tapered preparations more predictably and efficiently, while lessening procedural mishaps, especially in curved canals (Bryant et al. 1998).

Due to continuing search of affordable priced files having good properties, E3 Azure and Fanta AF one file systems which are manufactured using recent innovations to increase files performances (blue heat treatment) and as claimed by the manufacturer can also be used in both rotation and reciprocation motions, were chosen in this study to assess their cutting efficiency.

Simulated resin canals were used for standardizing the study groups. Despite their deficiency of the innate varying hardness, content of water, and the created smear layer when instrumenting which makes them not seem as the best replacement for dentin (Shen and Haapasalo 2008), resin blocks show consistent performance and a great degree of reproducibility as regards to hardness, dimensional stability, fixed curvature, angle, and diameter. Hence, the use of simulated canals sidestepped the variations in morphology and dimensions of canals of extracted human teeth (Al-Omari et al. 1992).

The heat treatment technology used for manufacturing the new rotary systems increased their flexibility and fracture resistance (Mittal et al. 2017).

A limited number of studies were conducted on these novel rotary files to assess the effect of these properties on cutting efficiency. This is mostly due to the discrepancy in the criteria of assessment. To our awareness, this is the first study that assesses and compares cutting efficiency of Azure and Fanta AF one file systems.

E3 Azure manufacturer claims that it can be used for the common motions used; rotation, reciprocation and optimum torque reverse.

The heat treatment grants the Azure files their transforming ability from martensite to austenite at body temperature. This technology also permits curving of the file prior to introduction in the canals, allowing them to proceed with ease in curved canals, with decreased liability of ledges and perforations occurrence. The adjusted S-shape cross section of the file decreases its core, granting it flexibility and giving more space for superior removal of debris.

The AF F One, a NiTi Rotary file manufactured to be used in continued rotation has two active cutting tips and a flat side-cut, providing it with better cutting efficiency, as debris are easily cleared up from the flutes to the safe-sided relief area through vertical blades, then out of the canal. Furthermore, the flat side-cut lowers the contact area with canal walls, providing more room for irrigants during preparation and minimizing stresses acting on the file, thus lessening the chances of file disengagement.

In order to lessen the preparation time, recommendations have been made to use a single file in different kinematics for the preparation of the entire canal (Yared 2008). Single file systems are looked at as a breakthrough to a less complicated path, in comparison to multiple file systems (Mittal et al. 2017), by minimizing the cost and clinician's operating time.

For this work, one file was chosen for each system; 25/06, the manufacturers recommended a working speed

of 350 rpm and a torque of 2.5 Ncm. Single file systems introduced today can work in both continued rotation or reciprocating motions (Kumar and Gade 2015). The same operator prepared all the canals; thus, the operator was not a variable (Zhao et al. 2013).

Several methods have been advocated to measure the cutting efficiency; weight loss, (Yguelhenry et al. 1990; Haikel et al. 1996). Post-instrumentation induced debris (Wan et al. 2010) maximum depth of penetration inside the canal (Schafer and Oitzinger 2008a) preparation time (Schafer et al. 2006a; Burklein et al. 2013) and cutting depth in resin blocks (Rubini et al. 2014).

From the varying methods of evaluation, weight loss method provides the utmost reliable quantitative measurement (Chi et al. 2016).

Results of this study demonstrated that samples instrumented with Fanta AF One rotary system showed significantly higher weight loss than Azure rotary system in both rotation and reciprocation ($P<0.001$). The two file systems did not show significant difference with rotation and reciprocation motions.

Prior research showed that S-shaped files with 2 sharp cutting edges (which are the cross-sectional designs of the two files used in this study) are accompanied with better cutting efficiency (Burklein et al. 2013; Rubini et al. 2014; Chi et al. 2016; Schafer and Oitzinger 2008b).

Fanta AF One rotary system displayed the greatest cutting efficiency. This may be due to their distinctive positive cutting angles and the unique geometric design. The flat side-cut contributes to a small cross section, creating greater space between canal walls and the file, which allows for more debris collection and removal capability (Schafer et al. 2006b). This ability to remove debris also adds to the efficiency of mechanical instruments, because the removal of cut dentin chips reduces clogging of the cutting blades (Bergmans et al. 2001; Schafer 1999). This feature kept the flutes unclogged and always ready for more dentin cutting.

Neither Rotation nor reciprocation had an impact on cutting efficiency with both files, the reason behind this may be because each file has a feature in the geometric design that prevented the file screw in and allowed for debris clearance causing the file to remove dentin in both motions.

Conclusion

Within the limitations of this study, Fanta AF One rotary system showed higher cutting efficiency than Azure rotary system in both rotation and reciprocation. Rotation and reciprocation movements did not affect the cutting efficiency in both file systems. Results showed that the cross section impacted the cutting efficiency more than the kinematics used.

Review of the research hypotheses

The research hypothesis that had been pre-proposed wasn't accepted, because Fanta AF One rotary system showed higher cutting efficiency than Azure rotary system in both rotation and reciprocation.

Abbreviations

A/Rt: Azure/Rotation; F/Rt: Fanta AF one/Rotation; A/Rec: Azure/Reciprocation; F/Rec: Fanta AF one/Reciprocation; wt pre: Weight pre-preparation; wt post: Weight post-preparation.

Acknowledgements

Not applicable.

Authors' contributions

MMK and HFK conducted the practical work. MMN did the result analysis and statistics and EMK, the corresponding author, wrote the manuscript, did the plagiarism adjustments needed and is undergoing the submission steps. All authors read and approved the final manuscript.

Funding

This research did not receive any fund from any organization.

Availability of data and materials

The authors declare that the data supporting the findings of this study are available within the article.

Declarations

Ethics approval and consent to participate

Faculty of Dentistry, British University in Egypt, Research Ethics Committee Approval Date: 23/2/2021, Approval Number: 21-010.

Consent for publication

Not applicable.

Competing interests

We declare that there is no competing interest.

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Received: 13 May 2021 Accepted: 16 June 2021
Published online: 27 June 2021

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