Comparative evaluation of the cyclic fatigue resistance of R-Motion® in comparison to two competitive systems: An in-vitro study based on a case report

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Abstract

Aim

To compare the cyclic fatigue resistance of R-Motion® with two competitive file systems (WaveOne Gold® and Reciproc Blue®) in a simulated root canal based on a case report.

Methodology

A metal replica, designed as a copy of the length and curvature of a mesiobuccal canal of an upper first molar originating from a case report, was used as a test phantom to measure the cyclic fatigue resistance of the following files: R-Motion® 25, WaveOne Gold® primary, and Reciproc Blue® R25. A total of 16 file per group were tested in the same reciprocation motion and cyclic fatigue was measured as time to file fracture. An unpaired t-test was used to analyze the data.

Results

A statistically significant difference ($P < 0,05$) was noted between R-Motion® 25 files and WaveOne Gold® primary files. A statistically significant difference ($P < 0,05$) was noted between R-Motion® 25 files and the Reciproc Blue® R25 files. R-Motion® 25 files were associated with a significant increase in the meantime to fracture when compared to WaveOne Gold® primary files (397,69 ± 66,63 vs 173,50 ± 24,60, respectively) and the Reciproc Blue® R25 files (397,69 ± 66.63 vs 205,13 ± 39.43, respectively).

Conclusion

R-Motion® 25 file showed a significantly higher cyclic fatigue resistance compared to WaveOne Gold® primary file and the Reciproc Blue® R25 file.

DOI

10.23805/JO.2024.663

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Keywords

Paranasal sinuses, odontogenic infections, dental procedures, sinusitis, endoscopic sinus surgery

INTRODUCTION

A recent systematic review demonstrated that the overall incidence of engine-driven NiTi-file fractures is 2,27% (1). Separation of endodontic instruments inside a root canal can jeopardize root canal procedures and affect the success of endodontic treatment (2). A systematic review and meta-analysis concluded that whether apical periodontitis is not present, a retained instrument inside the root canal does not significantly reduce the prognosis of the treatment (3). However, a fractured instrument associated with apical periodontitis can negatively impact the treatment outcome (3,4).

File fracture can occur due to two main mechanisms: torsional stress and cyclic fatigue (5). Cyclic fatigue of an instrument is a flexural fatigue that occurs when the instrument is rotated in a curved canal by repeated compressive and tensile stresses (6). This primarily occurs in acutely curved canals with a short radius of curvature (7). In addition to cyclic fatigue, the mechanical stress on NiTi-files can also be attributed to the torque generated by the motor during root canal preparation (8). Some systems have been designed with specific controllable torque and speed values to extend the life span of NiTi files by reducing the maximum stress on the files (9). The two main motions for engine-driven NiTi instruments are continuous rotation and reciprocation. Reciprocating motion, introduced by Ghassan Yared in 2008, involves the use of NiTi file in a clockwise (CW) and counterclockwise (CCW) motion to increase performance and safety while reducing the number of files used in endodontic treatment (10). This led to the development of Reciproc® (VDW, Munich, Germany) and WaveOne® (Dentsply Maillefer, Ballaigues, Switzerland).

In recent years, various processing procedures have been implemented to enhance the mechanical properties of NiTi files. These innovations led to the development of two categories of NiTi alloys: austenitic-phase (conventional NiTi, M-Wire, R-Phase) and martensitic-phase (CM Wire, Gold and Blue heat-treated NiTi) files. Remarkably, martensitic files are more flexible and resistant to cyclic fatigue compared to austenitic files (11). This significant progress has in turn driven the evolution of WaveOne Gold® (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc Blue® (VDW, Munich, Germany) as the more advanced versions of WaveOne and Reciproc systems.

The metal mass of the NiTi file play a key role in the cyclic fatigue resistance (12). Several parameters influence the NiTi file's mass: cross-sectional shape, diameter, core mass, flute depth, and the number of spiral and taper (12). Recently, R-Motion® (FKG, La Chaux-de-Fonds, Switzerland) reciprocating file system was introduced, with a lower NiTi mass compared to WaveOne Gold® and Reciproc Blue® (13). According to the manufacturer, R-Motion® is claimed to be up to 3.6 times more resistant to cyclic fatigue than standard NiTi reciprocating systems. The R-Motion® files system differs from both WaveOne Gold® and Reciproc Blue® in terms of NiTi phase depending on the temperature. R- Motion®, WaveOne Gold®, and Reciproc Blue® are all martensitic phased files at room temperature. The R-Motion® have a phase transformation from a martensitic phase to an austenitic phase at approximately 32-35 ºCelcius(14), WaveOne Gold® have a phase transformation from martensitic to austenitic phase at approximately 48 ºCelcius while Reciproc Blue® have a phase transformation at approximately 37 ºCelcius (15). No data are present in the literature regarding the comparison of cyclic fatigue resistance of these three reciprocating file systems using a simulated custom-made root canal based on a case report.

The null hypothesis of the study was that there would be no differences between the three reciprocating systems in terms of cyclic fatigue resistance. The aim of this study is to test whether R-Motion® is more resistant to cyclic fatigue than WaveOne Gold® and Reciproc Blue®. Rather than using a standardized simulated root canal to test cyclic fatigue, the simulated root canal is custom-made based on a case report, where the R- Motion® file system was used in the mechanical preparation in an upper first molar.

MATERIALS AND METHODS

The manuscript of this in vitro study has been written in accordance with the Preferred Reporting Items for Laboratory Studies in Endodontology (PRILE) 2021 guidelines (16) (Figure 1).

Case report:

A 16-year-old female patient has been referred for root canal treatment (RCT) on tooth #1.6. The patient experiences periodic symptoms, particularly when biting.

Clinical examination reveals slight tenderness to percussion in the affected tooth, with no other evident pathologies. However, the X-ray examination indicates the presence of apical periodontitis on the palatal root. Additionally, the X-ray reveals a significant curvature in the mesiobuccal root (Figure 2).

Treatment:

The treatment was carried out with the use of a rubber dam (Optidam, KavoKerr, Brea, US) and an endomicroscope (Zeiss OPMI Pico, Oberkochen, Germany). After performing the access cavity, the four canals were located. The palatal canal was necrotic, while the three buccal canals were still vital. Subsequently, scouting and estimation of the working length were conducted using a K-file #10 (Dentsply Maillefer, Ballaigues, Switzerland). Glidepath management was then implemented in all four canals, utilizing the R-Motion® Glider. For the final shaping of the canals, the following files were used: R-Motion® 25 for the two mesiobuccal

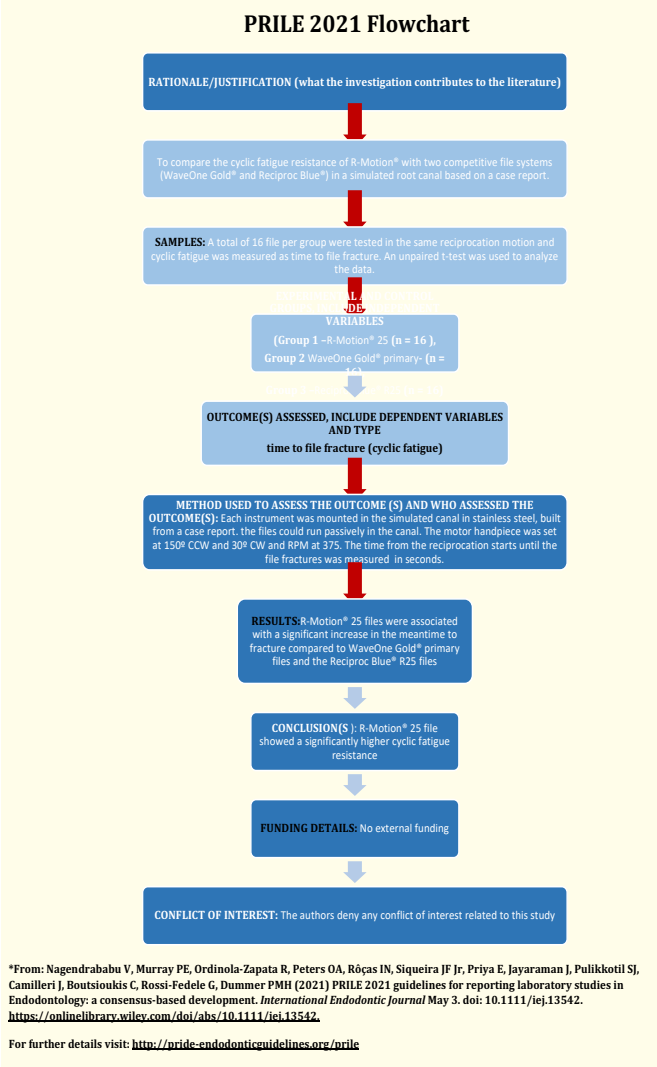

Fig. 1. PRILE Flow chart.

canals, R-Motion® 30 for the distobuccal canal, and R-Motion® 40 for the palatinal canal. Throughout the procedure, irrigation was performed using a 2.5% sodium hypochlorite (NaOCl) solution. The irrigation protocol involved using 5 ml of 2.5% NaOCl with passive ultrasonic activation (PUI) for 15 seconds, employing the Ultra-X system (Eighteeth, Changzhou, China). This process was repeated three times in each canal, with a change of the irrigation solution between each cycle. Additionally, 17% EDTA-C was introduced into each canal for 2 minutes, followed by ultrasonic activation for 15 seconds. To complete the treatment, four master points were fitted, as depicted in Figure 3.

Furthermore, irrigation with 2,5% NaOCl and then drying the canals with sterile paper points. Obturation using hydraulic condensation in the buccal canals using BC GP Points (FKG, La Chaux-de-Fonds, Switzerland) and TotalFill BC Sealer (FKG, La Chaux-de-Fonds, Switzerland). Palatal canal was obturated using warm vertical technic with BC GP Points (FKG, La Chaux-de- Fonds, Switzerland) and TotalFill BC Sealer HiFlow (FKG, La Chaux-de- Fonds, Switzerland). Provisional filling with IRM (Dentsply Sirona, Charlotte, US) and the patient was referred back to own dentist for final restoration (Figure 4).

2 years recall

The patient came for a 2-year recall showing no symptoms nor clinical pathology. The control x-ray shows apical healing on the palatal root (Figure 5).

In vitro study

Based on the case report, a simulated root canal was produced based on the length and the degree of curvature of the MB1 canal. At the 2-year recall a CBCT was taken (FOV 5x5, endo mode, vox 0.085 mm, 90 kV 6,3 mA 8,70 s) using KaVo OP 3D pro (KavoKerr, Brea, US) for precise measurement of the MB1 canal. The degree of curvature was measured using Weine's technique to 88,3º (17). The length of the canal is 13,92 mm, measured from the entrance of the canal to the end of the root filling (Figure 6a and 6b).

On the basis of the measurements, a simulated root canal in stainless steel was produced. The diameter of the canal was 0,5 mm larger than the diameter of the tested files, so the files could run passively in the canal, and therefore no risk of torsional stress (Figure 7).

Three groups of 16 NiTi endodontics instruments with the same iso size tip 0,25 mm was tested:

WaveOne Gold® Primary, Reciproc Blue® R25, and R-Motion® 25.

Each instrument was mounted in the simulated canal with exactly the same depth of 16 mm, measured from the entrance of the canal.

To simulate the temperature in a real canal distilled water with a temperature at 42º Celsius was delivered continuously at the entrance of the canal (Figure 8).

The motor handpiece was set at 150º CCW and 30º CW and RPM at 375. The time from the reciprocation starts until the file fractures was measured in seconds.

Statistical analysis

Means and standard deviation of time to fracture (s) were measured for each file system and static calculations were performed with GraphPad/Prism version 9.5.1 (GraphPad Software, Boston, US) and the three groups were tested against each other with an Unpaired T-test.

RESULTS

Mean values, standard deviation, standard error of mean, and number of tested files for each group are displayed in table 2. A greater time to fracture is caused by an enhanced resistance to cyclic fatigue.

A statistically significant difference was noted between R-Motion® 25 and WaveOne Gold® Primary and Reciproc Blue® R25. When comparing R-Motion® 25 with Reciproc

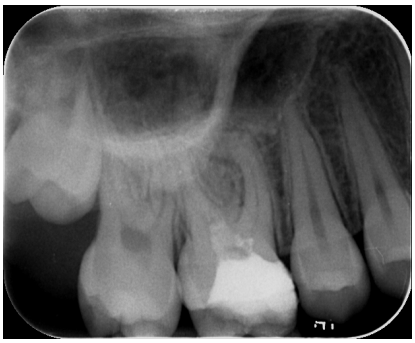

Fig. 2. Pre-operative x-ray showing severe curvature on the mesio-buccal root, and apical periodontitis on the palatal root.

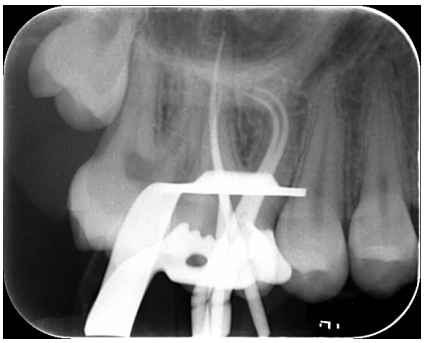

Fig. 3. intra-operatory x-ray with fitted master points.

Fig. 4. Postop x-ray of the root fillings.

Fig. 5. 2-year postop x-ray.

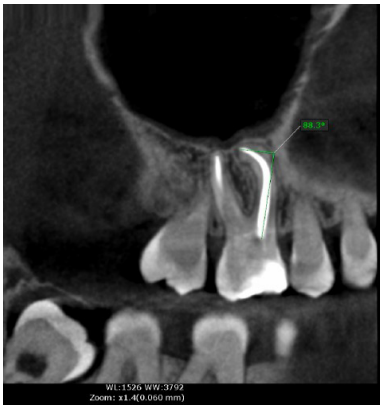

Fig. 6. A) Axial view showing the degree of curvature. B) Axial view from CBCT showing the length of the canal.

Blue® R25, the two-tailed P value was found to be less than 0.0001, with a 95% confidence interval ranging from 232.09 to 153.04. Similarly, when evaluating R-Motion® 25 against WaveOne Gold® Primary, the two-tailed P value was less than 0.0001, exhibiting a 95% confidence interval spanning from 187.93 to 260.45. These findings underscore the noteworthy distinctions in cyclic fatigue resistance among R-Motion® 25, Reciproc Blue® R25, and WaveOne Gold® Primary.

The results also revealed that R-Motion® 25 were associated with a significant increase in the mean time to fracture compared both WaveOne Gold® Primary and Reciproc Blue® R25.

A statistically significant difference was also noted between Reciproc Blue® R25 and WaveOne Gold® Primary. The two-tailed P value is less than 0.0107 with a 95% confidence interval of 7.90 to 55.35.

The findings showed that Reciproc Blue® R25 were associated with a significant increase in the meantime to fracture compared to WaveOne Gold® Primary.

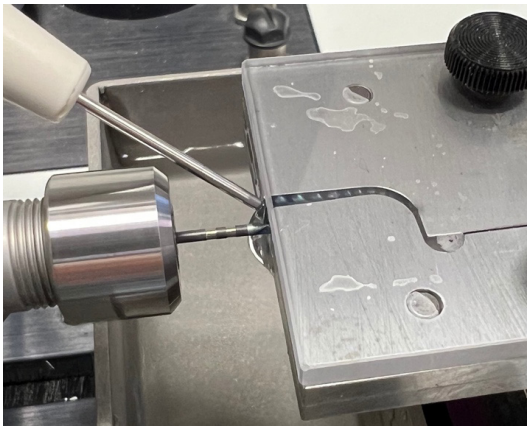

Fig. 7.
Stainless steel replica of the MB1 canal produced on the basis of the measurements from the CBCT taken at the 2-year recall. The canal is 0,5 mm larger in diameter compared to the diameter of the tested files, so the files run passively in the canal with no risk of torsional stress.

Fig. 8
File mounted in the machine. Distilled water at a temperature of 42° Celsius was delivered at the canal entrance continuously through the test.

NITI PHASE	ROOM TEMPERATURE (20 °C)	BODY TEMPERATURE (37 °C)
R-MOTION®	Martensitic	AUSTENITIC
RECIPROC BLUE®	Martensitic	AUSTENITIC
WAVEONE GOLD®	MARTENSITIC	MARTENSITIC

Tab. 1 Summary of the phase transformation properties of the tested files

TIME TO FRACTURE/SEC	MEAN	SD	SEM	NUMBER OF TEST FILES
R-MOTION 25®	397,69 A, B	66,63	6,66	16
RECIPROC BLUE R25®	205,13 B, C	39,43	9,86	16
WAVEONE GOLD PRIMARY®	173,50 A, C	24,60	6,15	16

Same letters indicate statistically significant differences
Abbreviations: SD, standard deviation; SEM, Standard error of mean

Tab. 2 Mean values, standard deviations and standard error of mean of each file tested.

DISCUSSION

Numerous studies have been conducted to assess the cyclic fatigue resistance of various file systems.with WaveOne Gold® and Reciproc Blue® being subjects of comparison. These studies consistently reveal that Reciproc Blue® exhibits superior cyclic fatigue resistance compared to WaveOne Gold® (18–20). To date, there are no studies comparing the cyclic fatigue resistance of R-Motion® with WaveOne Gold® and Reciproc Blue®.

The null hypothesis was rejected, since the present report shows that R-Motion® 25 has an improved cyclic fatigue resistance compared to WaveOne Gold® primary and Reciproc Blue® R25. The findings of the current study also confirm results from previous investigations confirming that Reciproc Blue® R25 has an enhanced cyclic fatigue resistance compared to WaveOne Gold® primary (18–20).

As reported in a previous study, there are many factors that contribute to the cyclic fatigue resistance of a file, with the mass of the NiTi file playing a pivotal role (12). The cross-sectional mass of the NiTi in the R-Motion® 25 file is less than that of the WaveOne Gold® primary file and the Reciproc Blue® R25 file (13). Moreover, while a review concluded that martensitic files exhibit superior cyclic fatigue resistance compared to austenitic files (11), this in vitro study surprisingly reveals a different outcome. During cyclic fatigue tests, the WaveOne Gold® primary files are in found in a martensitic phase while the R-Motion® 25 files and the Reciproc Blue® R25 files are in austenitic phases. Therefore, it indicated that the mass of the NiTi file plays a more crucial role than its phase in cyclic fatigue resistance. From the findings emerged that the differences in cyclic fatigue resistance could be related the different masses of the NiTi files, where greater cross-sectional metal mass reduces fatigue resistance. Therefore, it cannot be concluded that the martensitic phase NiTi-files have an increased resistance to cyclic fatigue compared to the austenitic phased NiTi-files.

Furthermore, in this study, efforts were made to isolate the cyclic fatigue resistance factors as well as mimic the actual temperature in the root canal, acknowledging that temperature has a substantial impact on the lifetime of instruments in clinical settings as reported in a previous review (21). This prevuous study demonstrated that cyclic fatigue resistance tests performed at room temperature should be considered as having little significance, and the scientific and clinical utility of fatigue resistance tests is very limited (21).

In this study, distilled water at 42°C was used to mimic body temperature. During an endodontic treatment, NaOCl and EDTA are usually used during chemo-mechanical preparation to act as lubricants. It was demonstrated that immersion of a NiTi file in NaOCl for a period of time ranging from 1 to 5 minutes does not reduce the cyclic fatigue resistance of a reciprocating file (22). On the contrary, 17% EDTA can reduce the cyclic fatigue resistance of a NiTi file after 3 minutes immersion (18,23). Therefore, in the present study, the use of distilled water instead of NaOCl used in clinical setting should not alter the results. However, the use of heated distilled water is a limitation in this study because the exact temperature in the artificial canal remains unknown. As a matter of fact, distelled water at 42 °C was used, but one could expect a fall in the temperature in the artificial canal. Since the Reciproc Blue® exhibit a phase transition to complete austenitic phase at approximately 37° Celsius (Table 1) it is possible that the Reciproc Blue® files is in a martensitic/ austenitic phase during the tests, potentially influencing results.

Another limitation of this in vitro study is the time of file separation. Even if we choose the file that broke fastest in the experiment (135 seconds WaveOne Gold® primary testfile #2), this does not replicate a clinical situation. In an endodontic treatment, a rotating or reciprocating file typically does not remain at working length beyond a curvature for an extended duration, but rather engages in a constant in-and-out motion within the root canal. Furthermore, another limitation relies on the presence of additional factors that may influence the outcome. As a matter of fact, the present study does not account for the torsional stress limit of the files.

Future research should aim to understand how files respond to torsional stress and cyclic fatigue and focus on

developing more accurate temperature control systems. This would enable a closer approximation of the in vivo conditions.

CONCLUSION

Within the limitation of this in vitro study, based on a case report, it is shown that the R-Motion® 25 file has a significantly higher cyclic fatigue resistance compared to the WaveOne Gold® primary file and the Reciproc Blue® R25 file. Moreover, significantly difference between the WaveOne Gold® primary file and the Reciproc Blue® R25 file, with the Reciproc Blue® R25 file having improved cyclic fatigue resistance compared to the WaveOne Gold® primary file.

Authors contributions

Kenneth Jordy (Formal Analysis, Investigation, Writing – original draft, Writing – review and editing), Giulia Malvicini (Formal Analysis, Data curation, Methodology, Writing – original draft, Writing – review and editing), Ashkan Tavakkoli (Data curation, Methodology, Writing – original draft, Writing – review and editing), Carlo Gaeta (Supervision, Methodology, Validation, Data curation), Simone Grandini (Data curation, Methodology, Conceptualization, Supervision, Project Administration).

Acknowledgment

This research received no specific grants from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Funding statement

No external funding, apart from the support of the authors' institution, was available for this study.

Conflict of interest disclosure

The authors deny any conflict of interest related to this study.

Patient consent statement

Informed consent was obtained from all subjects involved in the study.

Relevant reporting guidelines paperwork

The present observational study is reported according to the Preferred Reporting Items for Laboratory Studies in Endodontology (PRILE) 2021 guidelines (Nagendrababu et al., 2021).

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