MECHANICAL STRENGTH EVALUATION OF TWO SINGLE FILE SYSTEMS: RECIPROC VERSUS RECIPROC BLUE

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ABSTRACT

Aim The purpose of this study was to analyze the physical characteristics of a new type of endodontic instrument, Reciproc Blue, by testing its flexibility and torsion resistance and how they impact the clinical practice. Material and Method Twelve NiTi instruments were selected from the same manufacturer (VDW, Munich, Germany), having the same ISO specifications, the only difference being the NiTi alloy utilized in the manufacturing process, M-Wire (Reciproc) and CM-Wire (Reciproc Blue). Mechanical behavior was assessed by two tests (a non-destructive test and a resistance test). Results The compression test showed similar results for both types of alloys, but for the CM-Wire heated alloy the fracture point appears at lower values. For the torsional test, the heated CM-Wire alloy instruments had the best outcome, they stiffen, losing elasticity but they increase their mechanical resistance to torsion, in comparison to the other two groups. Conclusions Reciproc Blue is a very useful and resilient endodontic instrument, which increases the safety of the therapeutic act, if the manufacturer protocol is respected.

Keywords: M-Wire, CM-Wire, Reciproc Blue, torsion test, compression test, instrument fracture

INTRODUCTION

Over time endodontics has developed in several direction, either in terms of the technique of mechanical instrumentation of the root canal system, or in the manufacturing technology of the instruments, in order to achieve a predictable treatment. The tendency to find new tools and to improve their characteristics was determined by the need to make an instrument that shortens the working time, is efficient, resistant and reduces the possibility of fracture, while respecting as much as possible the anatomy of the root canal. Development of these instruments could lead to a predictable outcome for the endodontic treatment, lowering the chances of iatrogenicity. [1-4] Buehler designed in `60 a new class of alloy who highlighted the flexibility, controlled memory and resistance of the nickel-titanium (NiTi). [5] The properties of these first alloys derive from the transformation of the reversible phase into solid state between the austenite and martensitic structure. [6,7] The NiTi alloy presents three phases: austenite- which is very stable reticle, martensitic- more unstable and ductile, and an intermediary R-phase- which is transitional in between. [8] The first NiTi rotary instruments were designed in the early'90 by J. McSpadden and B. Johnson, and were quickly adopted by many endodontic specialists around the world. [9] During the root canal preparation, the endodontic

files are subjected to different types of forces, including flexion, torsion, apical pressure and cyclic fatigue. [10] Over the years there has been a constant attempt to improve the mechanical properties of the NiTi alloy which lead to new thermo-mechanical modified alloys, that are much more flexible and resistant to fracture.

Therefore, the purpose of this study, was to mechanically test two single file endodontic systems, Reciproc and Reciproc Blue (VDW, Munich, Germany), in terms of flexibility and torsion resistance.

MATERIAL AND METHOD

Twelve NiTi instruments were selected from the same manufacturer (VDW, Munich, Germany), 4 Reciproc and 8 Reciproc Blue instruments. All of the instruments were the R25 file, with a length of 25mm, a tip diameter of 0,25mm and a taper of 8% on the first 3mm of the file, the only difference being the NiTi alloy utilized in the manufacturing process, M-Wire and CM-Wire respectively. All instruments were examined under the microscope at a 20X magnification, checking the instruments dimensions or any other surface manufacturing faults. After each instrument integrity was analyzed under a microscope, they were divided into three groups and numbered from 1 to 4. For the first two groups of instruments R25 and R25 Blue the testing was performed at a room temperature of 22^{o} C, while in the third R25 Blue group the instruments were heated at 37° C, because it is known the CM-Wire alloy it changes its properties with increasing temperature.

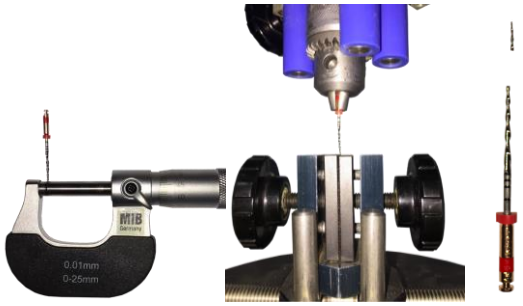
For each group of instruments there were performed two individual tests: first a non-destructive compression test which evaluates the point of maximum strength before bending and a second test of torsion resistance to determine the instrument breaking point. It was evaluated the necessary time and the degrees at which the separation of the instrument occurred.

Instruments in all three groups, were subjected to the non-destructive compression test using a MultiTest 5-i (Mecmesin, Villingen-Schwenningen, Germany) system programmed for a testing speed of 5 mm/min and a 3 mm vertical displacement (fig.1). The forces and the obtained data were recorded and processed via a specific software.

Figure 1. Compression test: initial, intermediate and final position of the for the R25 Blue group.

The second test was performed with Vortex-i (Mecmesin, Villingen-Schwenningen, Germany) automated torque tester activated by a computer that measures the torque in Nm and the displacement in degrees, using an angular displacement speed of 1 degree per second. For this test each sample was calibrated to achieve an exact 3 mm grip on each instrument, which is the thinnest and most

fragile portion of the rotary instruments (fig. 2a). Once the instruments were fixed, the automated torque tester has been programmed at 500 degrees of desired movement (fig. 2b). The device moves (clockwise or counterclockwise) to the limit of required degrees, stopping when it reaches maximal angularity and a sensor measures the maximum torsional resistance until the instrument breaking point (fig. 2c).



a **b** **c**

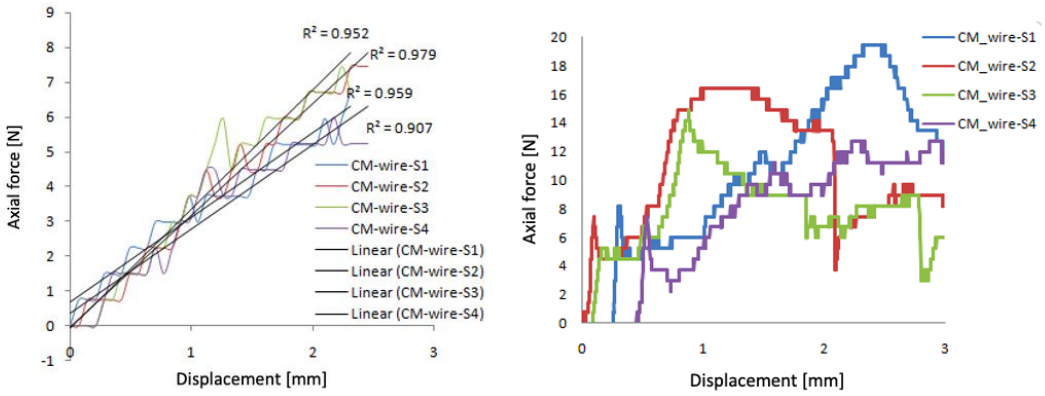
Figure 2. Torsion test: a) instrument calibration, b) the instrument fixed in the test device, c) the fractured instrument.

RESULTS

The compression test (bending test)

The analysis reveals that the linear behavior of the R25 Blue (CM-Wire) alloy at ambient temperature, is caused by a continuous and constant plastic deformation of the instrument (fig. 3a), which demonstrate that it adapts to the root canal anatomy.

For the R25 Blue heated samples, the compression test reveals a significant change in the mechanical behavior due to an increase in instruments rigidity. The fracture point was different, for the small forces applied (0.1N) and the instrument broke at the tip where it has the smallest diameter. Continuing to increase the forces applied up to 8N lead to a fracture which occurred further from the tip of the instrument (fig. 3b).



a **b**

Figure 3. Displacement in relation to the axial force for: a) R25 Blue (CM-Wire) and b) R25 Blue (CM-Wire) heated.

The same test performed for the R25 M-Wire alloy group showed similar results to those of the CM-Wire heated alloy (fig.4). From a quantitative point of view, the force value required for bending M-Wire were lower. Given that

geometrically the instruments are identical, this difference in values is caused by the intrinsic properties of the alloys from which they are made.

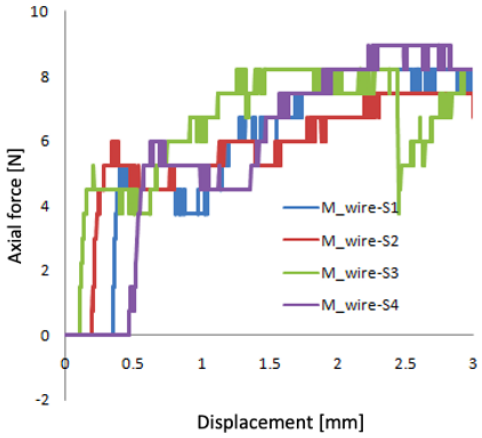
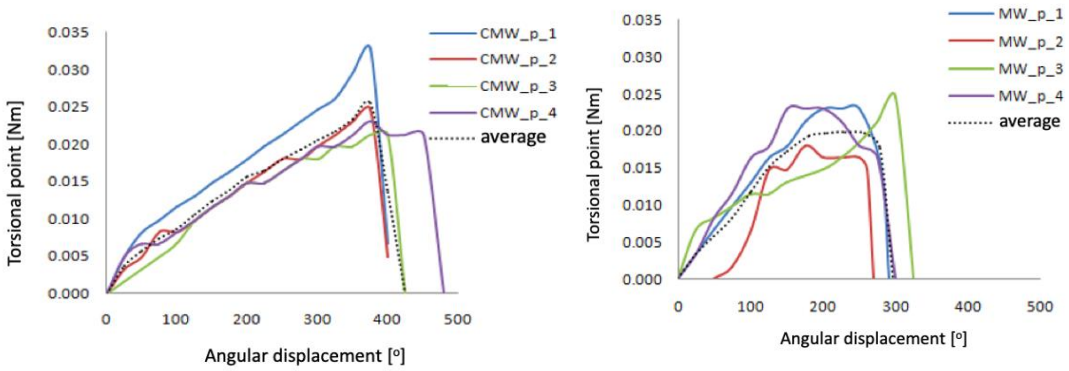


Figure 4. Displacement in relation to the axial force for R25 M-Wire.

Torsional resistance test

The variation of torque in relation with the angular displacement for the first two groups (tested at room temperature) R25 (Reciproc M-wire) and R25 Blue (Reciproc Blue CM-Wire), are presented in the next graphic (figs. 5a and 5b).



a **b**

Figure 5. Torsion test values including the average values for: a) CM-Wire and b) M-Wire.

It can be observed that the torque values in the group R25 M-Wire are similar for all the four samples, with an average value of approximately 0.02N*m. Although the maximum value recorded is very low, due to the very small cross section diameter in the breaking area, the value of the shear stress is very high. The instrument breaking occurred at about 300 degrees of rotation.

For R25 CM-Wire alloy samples tested at room temperature of 22°C, it was observed a linear variation of torque up the breaking point registered at an average of 0.025 N*m, which is clearly a superior value when compared to M-Wire alloy samples. Also, the fracture of the instrument happens at a greater angular displacement comparing to the R25 M-Wire group, being about 420 degrees of rotation.

For R25 CM-Wire heated samples a change in the elastic behavior of the samples was observed (fig. 6), they stiffen, losing elasticity but increasing their mechanical resistance to torsion. The average value of the breaking point is approximately 0.04 N*m, which is a

double value when compared to the unheated samples. At the same time the maximum angular value decreases by about 100 degrees (fig.6).

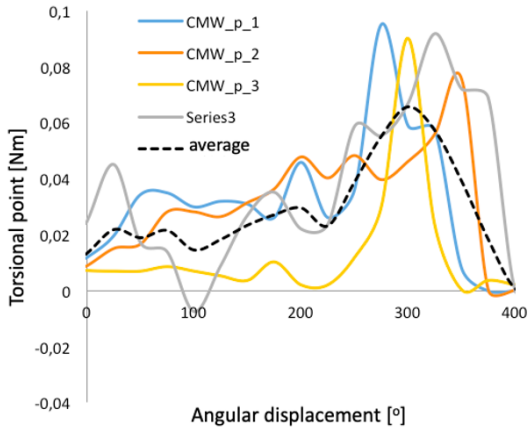


Figure 6. Variation of torque depending on angular displacement for CM-wire samples heated at 37 ° C.

	R25 M- Wire 22°C			R25 Blue CM- Wire 22°C			R25 Blue heated CM- Wire 37°C		
Sample	**Breaking point (diameter) [mm]**	**Breaking point (length) [mm]**	**Max. torque [Nm]**	**Breaking point (diameter) [mm]**	**Breaking point (length) [mm]**	**Max. torque [Nm]**	**Breaking point (diameter) [mm]**	**Breaking point (length) [mm]**	**Max. torque [Nm]**
1	0.32/0.53	32.0	0.023	0.39/0.54	31.5	0.0328	0.33	32.6	0.149
2	0.32/0.54	32.2	0.0246	0.36/0.52	32.2	0.0213	0.31	32.5	0.103
3	0.33/0.44	32.4	0.0213	0.37/0.55	32.1	0.023	0.31	32.4	0.101
4	0.32/0.54	32.2	0.0312	0.38/0.52	31.8	0.0246	0.32	32.7	0.138

Table 1. Maximum torque values and geometric characteristics of all samples.

From the data analysis it can be observed that the difference of mechanical resistance to torsion between instruments depends on the temperature. Also, it can be observed that the results for each group of instruments are consistent (Table 1).

DISCUSSIONS

Given that Reciproc Blue files are currently considered state-of-the-art in endodontics, there are relative few studies in the literature that analyze in detail their characteristics and performances, most being comparative studies with other single file endodontic systems or CM-Wire alloys. Deus et all (2017) investigated the role of the thermo-mechanical treatment of the CM-Wire in the Reciproc Blue files in comparison with the M-Wire instruments (R25), from an flexural strength and cyclic fatigue point of view. Similar to our results, the R25 Blue demonstrated significantly higher performance than the conventional ones, demonstrating greater flexibility and higher resistance to cycling fatigue and reduced microhardness, while maintaining similar surface characteristics. [11]

In another recent study, Gündoğar și Özyürek (2017) analyzed the resistance to cyclic fatigue of a NiTi alloy single file

rotary instruments with a tip diameter of 0,25mm. The results showed that Reciproc Blue is statistically superior to the WaveOne Gold files and no statistical significant differences were found between the lengths of the fractured fragments of the instruments. [12]

Shen, et al. (2011), studied the structural behavior in the transformation phase and the microstructure of the NiTi CM-Wire alloy rotary instruments, under the influence of temperature. The results showed that CM-Wire heat treatment of the instruments contribute to the increase of the transformation temperature in the austenite phase, thus increasing their mechanical resistance to torsion. [13] In a continuation of the previous study, Shen et al. (2011) tested the behavior of cycling fatigue between conventional M-Wire instruments and CM-Wire. The authors have concluded that the structural modifications of the material significantly improved the life of the instruments and the heat-treated ones (CM-Wire) proved a higher strength and a smaller surface deformation area compared to the conventional M-Wire instruments with the same design. [14]

CONCLUSIONS

The data of the present study showed that the behavior of mechanical torsional strength of the CM-Wire alloy is superior to that of the M-Wire samples. The angular deformation behavior is more stable in the case of CM-Wire samples when compared to the M-Wire ones, the maximum deformation being superior (of about 100 degrees) in the case of Reciproc Blue. The Reciproc Blue samples at ambient temperature (22℃) show a linear plastic deformation behavior, so they have a lower stress state. When used in the root canal, the instruments will therefore have the ability to adapt geometrically to it. Heated up to 37℃, the Reciproc Blue bahavoir changes significantly, becoming more rigid than Reciproc system, therefore the fractural stress increases in the first mm of the instrument. Due to the rigidity, it loses its ability to adapt to the anatomy of the root canal, causing an increase in tension resulting in its fracture. As a final conclusion, Reciproc Blue is a very useful and resilient endodontic instrument, which increases the safety of the therapeutic act when the manufacturer protocol is respected.

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