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Cyclic fatigue resistance of twisted files, Hyflex cm, Hyflex EDM and Edgefile X3 after immersion in sodium hypochlorite

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Abstract

Aim and Objective: This investigation analyzed the cyclic fatigue resistance (CFR) of three controlled memory (CM) of (twisted files, Hyflex cm, Hyflex EDM and Edgefile X3) after immersion in sodium hypochlorite.

Material and Method: 160 files of a similar brand were arbitrarily allocated to four groups (n=40) and submitted to the immersion protocol: Group 1: no immersion (as control), Group 2: 3 minute in 2.5% NaOCl at room temperature, Group 3: 32.5 minutes in 2.5% NaOCl at 121°C and one cycle of autoclave sterilization, Group 4: To five cycles of the same test protocols as in Group 3. Cyclic fatigue test was performed on rotating/reciprocating all instruments. The number of cycles to failure (NCF) for every instrument was calculated by multiplying the quantity of rotations per minute (RPM) multiplied by total time taken for the instrument to fracture (minutes).

Result: EdgeFile X3 files showed most increased cyclic fatigue resistance, followed by Hyflex EDM files, Hyflex CM files and least resistance displayed by twisted files. Instruments immersed in NaOCl solution after five cycles of autoclave sterilization show increase in cyclic fatigue resistance for heat-treated instruments in comparison with the control group.

Conclusions: This study show that fracture resistance to cyclic fatigue was the most increased for the EdgeFile X3 group followed by Hyflex EDM, Hyflex CM and least for Twisted File group and instruments undergoing dynamic immersion in NaOCl solution for long time and to five cycles of autoclave sterilization increase CFR.

Keywords: Cyclic fatigue, NiTi; reciprocating motion, rotary files, single-use instruments, cyclic fatigue resistance (CFR), number of cycles to failure (NCF)

Introduction

Nickel-titanium (NiTi) instruments are often used for root canal shaping because of their shape memory and superelasticity, which allows NiTi to be more flexible and resilient. Despite these benefits, NiTi instruments appear to be susceptible to separation, owing to cyclic fatigue and torsional shear^[1, 2].

One additional factor that potentially limits the resistance to stress fracture is corrosion that happens during chemico mechanical preparation of passage system, chemical disinfection, and sterilization of endodontic instruments within presence of NaOCl solution. Active ClO⁻ ions have the potential to extend corrosion.

NiTi shape memory and superelastic properties are strongly addicted to the thermomechanical processing and therefore the additional heat treatment of NiTi instruments during autoclave sterilization^[3]. It is verified that the Vickers microhardness increased approximately 18% for NiTi wires after one and five cycles of sterilization in dry heat or autoclave and hypothesized that the deformation of NiTi files caused during clinical use could possibly be reversed using sterilization temperature above 125°C^[4].

The reciprocating movement of the NiTi rotational instrument has appeared to diminish the affect of cyclic fatigue conjointly has appeared to amplify the life expectancy, in comparison with persistent rotation^[5, 6].

Fracture and in general failure were more in bended canals (point 60 ± 10 and sweep 2 ± 1 mm) than in straight and moderately bended canals (30 ± 10) and the same radius [7]. This may be clarified by the over-burdening initiated on the instrument by an unexpected alter in canal curvature which limits the pivoting instrument, giving rise to multidirectional stacking (pressure, twisting, and torsion) that leads to pliable fracture.

When the endodontic writing is surveyed, it is shown that there are numerous variables that influence the CFR. These components incorporate angle and radius of the canal curvature, instrument measure and decrease, movement kinematics, speed of revolution, impact of sterilisation, as well as numerous other factors such as operator's skill and encounter, which may offer assistance to clarify the variations in the predominance of CFR. As of late, a few considers centered on whether or not temperature influences the CFR of NiTi files. In addition to the variables specified over several creators have considered the destructive impact of NaOCl on conventional endodontic NiTi instruments. Some creators have examined cyclic fatigue resistance of unused reciprocating NiTi rotary files after presentation to NaOCl. The point of this study was to survey resistance to cyclic fatigue of three single-use NiTi files after drenching in NaOCl solution. The null hypothesis test that there are differences in the cyclic fatigue resistance between the instruments immersed and those ones not immersed in NaOCl solutions.

Materials and Methods

Total of one hundred and sixty new files were evaluated in the present study

1. Group A: 40 = Twisted File (25/.06) (Sybron Endo, Orange, CA, USA) – 27mm.
2. Group B: 40 = Hyflex CM (25/.06) (Coltene Whaledent, Cuyahoga Falls, OH) - 25mm.
3. Group C: 40 = Hyflex EDM One-File (25) (Coltene Whaledent Pvt. Ltd.) – 25mm.
4. Group D: 40 = EdgeFile X3 (25/.06) (EdgeEndo, Albuquerque, NM, USA) - 25mm.

Each instrument was assessed for absconds or deformities before the analysis with a sound system zoom magnifying lens, and none were disposed of. The files of a similar brand, all from a similar production, were haphazardly allocated to four distinct subgroups of each:

- Group 1: In the control group, the instruments were not immersed in NaOCl and were not sterilized
- Group 2: The instruments were dynamically immersed in 2.5% NaOCl for 3 min at room temperature
- Group 3: The instruments were immersed in NaOCl, under the same conditions as in Group 2, and then files were instrumented and subjected to one cycle of autoclave sterilization at a temperature of 121°C for 32.5 min.
- Group 4: The instruments were subjected to five cycles of the same test protocols as in Group 3

According to Pedullà *et al.* Protocol [8] for dynamic immersion, the endodontic instruments were rotated/reciprocated regarding manufacturers' settings in little glass containers with the sum of the NaOCl solution necessary to contact 16 mm of the instruments length. Immediately after

evacuation all records were washed in bi-distilled water to neutralize the impact of NaOCl, dried and stored in glass vials.

Instruments of all four groups of every manufacturer have been then subjected to cyclic fatigue testing the usage of a mechanical system specially developed for the motive that allowed a reproducible simulation of an instrument confined in a curved canal. The artificial canal was once manufactured via reproducing an instrument's measurement and taper. It provided the instrument with a appropriate simulated root canal with a 60° angle of curvature and 5 mm radius of curvature measured according to the technique of Schneider [8].

The centre of the curvature was once 6 mm from the tip of the instrument, and the curved segment of the canal was once about 6 mm in length. The diameter of the simulated canals is higher than the instruments, allowing free rotation. To reduce friction as the devices contacted the metal canal walls, lubricant oil filled the canal area after each use. Each instrument was allowed to rotate/reciprocate with spontaneous pecking movement until fracture. The time to fracture used to be recorded visually and timing was once stopped as fracture is detected visually and/or audibly.

Data have been analyzed with the aid of the usage of 2-way analysis of variance in software. Statistical significance was once set at p value less than 5%. The number of cycles to failure (NCF) for each instrument was calculated by multiplying the number of rotations per minute (RPM) multiplied by total time taken for the instrument to fracture (minutes).

Result

Comparison among the 4 investigated contraptions indicated statistically significant difference of NCF. EdgeFile X3 files show increased cyclic fatigue resistance, followed by Hyflex EDM files, Hyflex CM files and lowest resistance exhibited by means of Twisted Files in all the 4 groups. Instruments undergoing dynamic immersion in NaOCl solution for 3 minutes followed by five cycles of autoclave sterilization did affect the cyclic fatigue of NiTi files tested, which confirmed an increase of cyclic fatigue resistance for all the heat-treated instruments when compared with the control group.

The inferential analysis showed that EdgeFile X3 had greater mean NCF values than Hyflex EDM, Hyflex CM and Twisted Files groups. The difference in values in suggest NCF have been statistically great ($p < 0.001$) in all groups. In group 1 (control group), post-hoc test showed that EdgeFile X3 and Hyflex EDM files had drastically higher mean NCF ($p < 0.001$) than Hyflex CM with least being in Twisted Files. No other huge differences were seen. In the remaining three groups i.e. group 2 (dynamic immersion in 2.5% NaOCl answer for three minutes), group 3 (1 cycles of autoclave sterilization for 32.5 min) and group 4 (dynamic immersion in 2.5% NaOCl and then 5 cycles of autoclave sterilization), EdgeFile X3 confirmed drastically greater mean NCF ($p < 0.001$) than Hyflex EDM and Hyflex CM with least being in Twisted Files. No other significant differences had been seen.

The NCF's ability for each file in every group are presented below which presents the means and the standard deviations for every instrument type in every of the four groups.

Table 1: Comparison of NCF in each groups among four different types of files

	Group1	Group 2	Group 3	Group 4
Twisted file	286.52± 42.78	246.78± 52.16	176.43± 89.75	342.73 ±67.98
Hyflex CM	467.85 ± 121.73	838.45± 242.86	686.45 ± 198.43	764.87 ±212.87
Hyflex EDM	776.34± 98.43	712.78± 89.73	732.47± 78.90	923.46± 198.12
Edgefile X3	907.67± 178.95	1134.80± 243.78	1320.85± 432.89	1489.45± 321.98

Table 2: Comparison of NCF with respect to each file group among four groups

	Twisted file	Hyflex CM	Hyflex EDM	Edgefile X3
Group1	268.65± 43.87	421.54± 123.87	698.98± 104.76	789.76± 167.43
Group2	265.98± 67.54	865.45± 212.65	732.89±121.87	1156.98±217.97
Group3	176.89± 56.89	712.54± 138.87	786.75±89.56	1234.78±453.65
Group4	345.87± 89.45	745.23± 245.89	965.34±56.89	1453.56±321.98

Discussion

The reciprocating working action has proven to prolong the lifespan of a NiTi instrument, as a result resistance to fatigue, in assessment with continuous rotation. M-Wire alloy was once used in the development of two new instrumentation structures that are in particular designed to be used with reciprocating motion: The Reciproc (VDW GmbH, Munich, Germany) and Wave One^[9]. Wave One has a always reducing taper from its tip to its shaft and is characterised with the aid of exceptional cross-sectional designs over the complete size of the working part. Files have radial lands with modified convex triangular cross area at the tip quit and a neutral rake angle convex triangular cross area at the coronal end. Reciproc archives have a continuous taper over the first 3 mm of their working part accompanied via a lowering taper until the shaft. An S-shaped cross section is used for the entire working part of these instruments^[10].

The cyclic fatigue resistance of NiTi rotary instruments has been a concern of notable interest in the endodontic literature. They have an effect on of torsional fracture, metallic fatigue, or fracture of NiTi rotary units brought about through a mixture of torsional stress and accumulation of fatigue is nevertheless debated^[11]. It has been advised that the cyclic fatigue has accounted for 50%–90% of mechanical disasters compared to a torsional failure. Most of the fractured devices had been analyzed as a flexural failure, implying cyclic fatigue is the predominant mechanism for fabric failure^[12].

In this study, canals had been simulated with a stainless steel device that guaranteed a constant radius of curvature alongside with a constant angle of curvature. The method used in our research for cyclic fatigue is based on a technique described by way of Li *et al.*^[14]. This approach accurately describes the root canal curvature based totally on the angle of curvature and radius of curvature.

To simulate medical conditions, the test protocol chosen for this research covered dynamic immersion in 2.5% NaOCl, most of 5 cycles of autoclave sterilization, and dynamic cyclic fatigue resistance testing. To remain within a sensible time frame of scientific exercise and thinking about the imply life of the manipulate instruments, 3 min was selected as the contact time of the solution with the instrument. The shaft of the instrument was no longer immersed in the irrigating solution as is the case in root canal instrumentation procedures. This additionally served the reason of averting galvanic corrosion phenomenon^[15].

The variety of instances the instrument can be reused is recommended to fluctuate between 1 and 10. (Gambarini *et al.* and Inan *et al.*), relying on the canal prerequisites and the kind of instrument usage. Clinicians regularly recycle NiTi files owing to financial considerations^[16]. A study has mentioned that the dynamic immersion in 2. 5% NaOCl for

long time did effect the cyclic fatigue resistance of NiTi files. On the contrary, some other study confirmed a reduction in fatigue resistance of NiTi files after immersion in a heated NaOCl solution. This study was executed as there are no studies related to the impact of both NaOCl and autoclave sterilization on reciprocating archives when used in reciprocating motion in two distinct canal curvatures.

In the existing study, reciprocating dynamic immersion in NaOCl for short time i.e 3 mins did not minimize the cyclic fatigue resistance of reciprocating NiTi files. Significant variations were discovered between the one of a kind NiTi files. Under the prerequisites of the existing study, five cycles of autoclave sterilization extensively influenced the cyclic fatigue produced by modern heat-treated alloy. These devices confirmed a statistically giant expand in the range of cycles to reason fracture after the sterilization. These results are in contrast with these bought by way of Hilfer *et al.* who suggested a massive decrease of the mean NCF after sterilization exhibited by using the group of twisted files suggesting that any enthalpy generated throughout autoclave processing did no longer furnish ample energy to allow a heat treatment impact that ought to motive a crystalline phase trade with these new manufacturing techniques^[17].

On the contrary, the effects of some studies find out advocate that autoclave sterilization might improve mechanical properties of instruments. NiTi is a very sensitive alloy to both thermal and mechanical stress. Thermal treatment of the alloy is acknowledged to produce a higher arrangement of the crystal structure as a consequence leading to multiplied flexibility and also changes in the proportion of phases of the alloy, therefore main to extended resistance or plastic behavior.

The 2.5% NaOCl solution was once used because it is recommended to maintain the canal moist with an energetic irrigant. NaOCl solution dissolves the nickel part on the surface of the NiTi instrument and causes corrosion on the devices (Sarkar *et al.*, 1983)^[12] which may affect the resistance of the NiTi file. In current studies, it has been reported that NaOCl solution negatively impacts the cyclic resistance of the files (Alfawaz *et al.*, 2018; Plotino *et al.*, 2010)^[17]. However, Ped-ullà *et al.* (2013)) suggested that the cyclic fatigue resistance of Rec-ipro and Wave One archives were no longer affected by way of NaOCl solution^[18].

According to the present study, NaOCl remedy itself did no longer alter not affect the NCF of the NiTi devices tested. This result confirmed that the new steel treatment on the warmth treated instruments probable did not permit the corrosive effect by the sodium hypochlorite solution. The result of this study is in sync with a study by way of Pedulla *et al.*^[19] the place he reported that static or dynamic immersion in 5% NaOCl did not drastically decrease the

cyclic fatigue resistance of Twisted Files.

A enormous decrease in cyclic fatigue resistance of instruments was located in a find out about by Peters *et al.*, after immersion in a heated NaOCl solution (60°C) for 1 hour^[20]. O'Hoy *et al.* suggested corrosion of NiTi instruments after immersion in NaOCl solution overnight^[21]. But this situation does not simulate the realistic time-frame of the root canal method.

Conclusion

Within the limitations of the study, it can be concluded that EdgeFile X3 exhibited highest cyclic fatigue resistance, followed by Hyflex EDM, Hyflex CM and the least CFR by Twisted Files, after dynamic immersion in NaOCl solution and/or after autoclave sterilization as compared to the control group. Multiple autoclaving cycles substantially increased the cyclic fatigue resistance. Immersion in sodium hypochlorite solution along with repeated cycles of autoclave sterilization did have an effect on the cyclic fatigue of NiTi files, which confirmed increase in cyclic fatigue resistance for all the four heat-treated files, when compared with the control group.

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