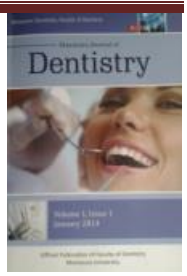

Comparison of the cyclic fatigue resistance of nickel-titanium rotary instruments manufactured using controlled memory wire

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Abstract:

Aim: The purpose of this study was to evaluate the impact of three controlled memory files (Hyflex CM (HCM) , Hyflex EDM(HEDM) , One Curve(OC)) on cyclic fatigue resistance compared to shape memory files (2Shape(2S), Protoper gold(PTG)).

Materials and methods: A total of 50 files were rotated in simulated stainless steel curved canals reproducing size and taper of the files with 45 angle of curvature and 5mm radius of curvature. The time to fracture (TTF) was recorded in seconds, the number of cycles to fracture was calculated (NCF) and the length of the fractured fragments was measured .Data was statistically analysed using IBM SPSS software package version 20.0**.** Quantitative data were described using mean and standard deviation for parametric data after testing normality using Kolmogrov-Smirnov test. Significance of the obtained results was judged at the 5% level.

Results: When comparing the TTF of all the tested files the data obtained from statistical analysis showed that the resistance to cyclic fatigue of tested files arranged from highest to lowest was HEDM ,HCM ,PTG ,2S and OC respectively .When the NCF values were taken into consideration HEDM and HCM reported a significant higher cyclic fatigue resistance than PTG ($p<0.05$) , OC and 2S reported the lowest resistance to cyclic fatigue among the tested files with no significant difference between OC and 2S($p>0.05$) .There was no significant difference between PTG and OC when comparing NCF ($p>0.05$). No significant difference was found in the length of the fractured fragments ($p > 0.05$)**.**

Introduction

The aim of endodontic shaping are to make progressive tapering canal, prevent changing the pathway of the apical foramen however let the apical foramen as little as possible. [1]

At last decades, a count of processes get discussed to get a tapered shaping, many utilizing old manual stainless steel instruments. However variant shapes and mechanical techniques was suggested, they have all many problems especially intrinsic. Connecting to the intrinsic hardness of old stainless steel instruments, faults as zipping, stripping, ledge formation, perforation, canal transportation, and separated files, particularly in canals with large curves can happen that maximize the want to make greater flexible instrument to prevent these errors. [2]

In the beginning 1960s, a nickel–titanium alloy was made by Buehler, a metallurgist discovering nonmagnetic, salt withstanding, waterproof alloys for the area scheme at the Naval Ordnance Laboratory in Silver Springs, Maryland, USA. [3] .

Nitinol is the denomination awarded to belongings of inter-metallic alloys of nickel and titanium that have been detected to have greater flexibility than stainless steel files and have single characteristic of shape memory and super-elasticity. The super-elastic attitude of Nitinol wires get idea that on removing stress they get back to their basic design prior distortion. [4]

However this usefulness, rotary nickel titanium separation files still a trouble. It is showed that rotary NiTi file fracture in two variant methods: torsional failure or flexural failure. [5].

Potential planning suggested to maximize quality and secure of nickel–titanium (NiTi) rotary contain an enhancement in the processing procedure, or the utilize of modern alloys that supply greater mechanical characteristics like heat therapy to the alloy and time difference on end substance reply that is important for maximizing of substance reply. Controlled memory (CM) is a NiTi alloy applied in 2010 which suggested maximizing withstand to separation of the instruments. [8]

HyFlex CM (Coltene Whaledent, Altstatten, Switzerland) is a NiTi rotary framework that was processed in 2011 by utilizing controlled memory (CM) alloy. The NiTi instruments manufactured from CM alloy own no shape memory which old NiTi instruments own, and the HyFlex CM are processed in a specific thermo mechanical technique that goal is to maximize the flexibility of old NiTi instruments. [9]

HyFlex EDM (Coltene Whaledent) is a modern NiTi instrument frame work designed by utilizing CM alloy through electrical discharge machining (EDM) process. EDM process is depended on evaporating and fusing the little parts on the substance through electric sparkles and preparing the file. However this is a way which is extremely utilized in medical processes, Hyflex EDM instrument is the first endodontic file manufactured with this way. [10]

One Curve (TS; Micro-Mega, Besancon, France) manufactured of heat treated Nickel-Titanium (C wire) that, according to the industrialist ,it's is to maximize blade flexibility and withstand separation .The Special

characteristic C Wire heat therapy: controlled memory of NiTi maximize the capacity to pre-curve the instrument for

simple enter to the root canal and removal of forces , Patented different cross-section all the length of the cutting part for a centered capacity in the apical third and a good debris elimination to the middle and coronal third that establish the good ability to cut.[13]

Materials and Methods

Fifty Ni Ti files were used in this study, 10 HCM (25 / 0.06), 10 HEDM (25 / 00), 10 OC (25 / 0.06), 10 2shape (25 / 0.06), and 10 Protaper gold (25 / 0.08) were investigated at 25 × magnification under a stereomicroscope (Leica MZ10 F, Wetzlar, Germany) to eliminate the existence of impairments. All mentioned files were examined according to manufacturer's orders, rotation of HCM at (500 rpm) ,HEDM at (500 rpm) ,One Curve at (400 rpm) ,2Shape at (350 rpm) and Protaper Gold at (300 rpm)

The Cyclic Fatigue Testing Device:

Particularly manufactured custom-made equipment for test to cyclic fatigue was utilized in this research. The components of the equipment are a stainless steel block supported in a mainframe which the fabricated canals present in it, and a movable upholding for the electric contra which give accurate with easy resembling position of any file in to the fabricated canal to maintain three geometrically uniformity with placement of the file to the same depth.

The fabricated canal gets overlaid by a tempered glass to stop the files from exiting out and to permit for visualisation of the rotating file. Failure was easily noted because the files were obvious through the glass film.

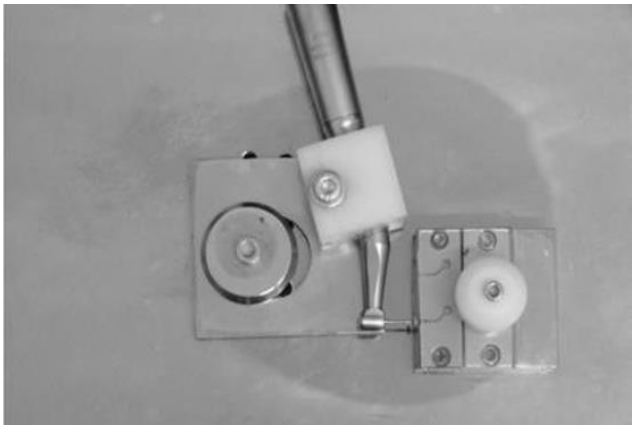


Figure 1. (a) Device for Cyclic fatigue examination.

Fabrication of the Simulated Canals

Two artificial root canals get exactly manufactured in a stainless steel block, the simulated canals get processed therefore it fits every file in terms of dimension and taper, thus allowing the file with an appropriate path that keep the chosen curvature parameters.

The artificial canals were first fabricated using a specific software program (*Solid Works 2012, Waltham, Massachusetts, USA.)* Each canal get curvature angle 45º and 5 mm radius of curvature, the instrument tip is located 2.5mm from the curvature centre and the length of the artificial canal is about 16 mm. (Figure 2) The canal diameter get fabricated so it gets 0.1 mm greater than the original diameter of the file, permitting the file to rotate loosely in to the simulated canal.

To make sure of fineness of the diameter of every canal, a copper reproducible of every file get manufactured greater than the basic diameter of a file by 0.1 mm. The deepness of the canal gets manufactured with rise about 0.5 mm from the extreme size of the file, permitting the instrument to circle loosely in to the artificial canal. The copper reproducible were fixed in accordance with the average of curvature that gets selected to the research. With these passive templates, the simulating canals get fabricated by a die-sinking electrical-discharge processing technique in a stainless-steel template. The templates get strengthened by heating

The Cyclic Fatigue Test

All the files get rotated by using a 6:1 low velocity gear reduction contra (Sirona Dental Systems GmbH, Bensheim, Germany) supplied with a velocity and torque monitored power motor (SIROEndo Pocket; Sirona Dental Systems GmbH, Bensheim, Germany) according to manufacturer's advisable velocity.

To decrease friction among the rotating file and the wall of the simulated canals, special high-flow synthetic oil (Super Oil; Singer Co Ltd, Elizabethport, NJ) manufactured to mechanical greasing get sprayed to the canals.

The simulated canal get overlaid by glass film so that preventing the files from getting outside the canal and permitting for looking for the rotating files in the canal and preserving the oil inside the artificial canal for greater time. Separation of the instrument was noted with ease because the files were obvious through the transparent film.

The files allowed to be rotated in to the canals loosely until separation. The number of cycles to fracture (NCF) was studied by this formula (NCF = revolutions per minute X time to fracture (sec/60)) as the five different rotary files were examined at different rpm values.

The data resulted from the test of cyclic fatigue were estimated for the existence of significance through using IBM SPSS software package version 20.0**.** Quantitative data were described using mean and standard deviation for parametric data after normality testing using Kolmogorov-Smirnov test. Significance of the gained outcomes was adjudicated at the 5% level.

(**The used tests were**

One Way ANOVA test; for parametric quantitative variables, to compare between more than two studied categories.

Figure 2. File within the simulating canal inside the stainless steel template, overlaid by glass film.

Results

When comparing the NCF values HEDM and HCM showed a considerable greater resistance to flexural failure than PTG ($p<0.05$) , OC and 2S showed the minimal withstand to flexural failure between the intruments which had been tested with no considerable variant among OC and 2S($p>0.05$) .

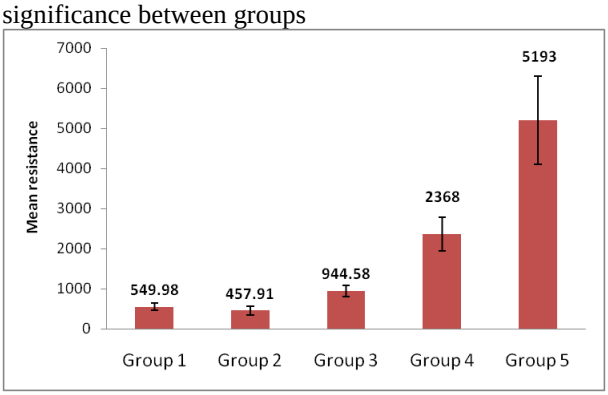
No significant variant was found in between PTG and OC at the time of taking in to consideration NCF ($p>0.05$).

Table (1) : Comparison of mean resistant between studied groups

	One Curve	2Shape	Protaper Gold	Hyflex CM	Hyflex EDM	One Way ANOVA test
NCF Mean± SD	549.98 ±92.48^{AB}	457.91±104.5^{A}	944.58 ±141.01^{B}	2368.0±422.6	5193.0±1099.4	F=166.9 P<0.001*

F:One Way ANOVA test p:probability *statistically significant ($p<0.05$)

Similar letters gives indication about non difference significance between groups



Discussion

This study aims to evaluate the impact of three controlled memory files (Hyflex CM, Hyflex EDM, One Curve) on cyclic fatigue resistance compared to shape memory files (2Shape, Protaper Gold) in artificial canals with 45° angle of curvature. Because of the lack of standardization in root canal anatomy of natural extracted teeth. [16]

We use Stainless Steel artificial canals reproducing diameter and taper of the used Ni Ti files to standardize cyclic fatigue test. [168,169,170]

All the NiTi files rotated inside the artificial canals at speed according to the manufacture instructions; the count of rotations to failure (NCF) has been measured.

Failure of the endodontic instruments occurs due to torsional or flexural loading. Cyclic fatigue happens at the same time, in curved canals, file is subjected to continuous cycle of compression and tensile stresses toward inside and outside the curve, this leads to micro fractures in the metal matrix of the file which propagate during use and coalesce and lead to separation of the file. [3, 4]

The most remarkable cause that related to fracture of NiTi files is fatigue of the metal, illustrating the cycle's number that a file can tolerate under a certain upload status. [171]

Calculation of NCF gives guidelines to the mechanical strength of the styling of the file to tolerate flexural failure as a result of NCF is progressive and it relate to the count of compressive/tensile loads happens in the curved segment of the file. [21] Instead, TtF cannot often be directly utilized as a directory when the examined instruments are utilized with variable velocity, as was the condition of the current research.

The files will have a mean count of rotations to fracture that is specified by certain parameters, and the utilization of greater rotational velocity will exhaust the beneficial existence of the tool. [172]

Greater velocities could rise the file temperature, resulting in more surface tension and early fatigue failure. [172]

It has been theorized perfect to assist files qualification by estimating (TTF) and (NCF) because files were rotated at variant rpm values as (TTF) is more clinically pertinent guide us to how the instrument can be used clinically however (NCF) is greater guided to the mechanical feature of the file itself. [3]

However, transforming the TTF to NCF permits adjuster assist in any case of the rotational velocity. [174]

In the present research, the rotational velocity was utilized according to the manufacture recommendations.

The comparison of resistance to cyclic fatigue between variable endodontic files must speculate many changes like transversal size, taper, cross-sectional styling, and processing mechanics. [161]

Although, a great shortage of many researches that have examined the fatigue attitude of NiTi instruments is that the different participating indexes cannot be all removed and this leads to complication in quantifying the influence of a unique difference on failure attitude. [140]

The producing techniques about the NiTi are useful to influence the mechanical characters of the root canal files.

Basically martensitic instruments are soft, ductile and have reported a greater flexibility and an influenced withstand to cyclic fatigue in comparison to traditional austenitic files, thus, manufacturers produced modern NiTi alloys. [175]
HCM, HEDM and OC are manufactured from control memory NiTi wire; controlled memory files are at most in the martensitic stage and have been processed by a thermo mechanical technique that monitors the file memory and produce the files more flexible and more cyclic fatigue resistant. [176]
2S was made from T-wire heat treatment alloy With the aim to Increase resistance to instrument fracture (+40%) and provide more flexibility for a better negotiation of curvatures while PTG exposed to thermo-mechanic processing

subjected on the NiTi files are supposed to give the great level of shape memory and super-elasticity behaviour.

The alloy is not the only effecting agent improving the mechanical properties of the instrument; the size and cross-sectional styling could influence the fatigue of the metal. [177]
Actually, some investigators noted that there is a relation among cross-section and resistance to stress whereas the greater the volume of the metal, the little the withstanding to fatigue. [178] Other authors, on the contrary, noted that these agents did not have an effect. [179]
This study showed that HEDM and HCM NiTi files present a considerably greater flexural failure withstand than other experimented instruments ($p<0.05$) when taking in to consideration both TTF and NCF ,the cause for greater resistance to cyclic fatigue of HEDM files may be due to CM wire and EDM process which subjected while the processing of files. [180]
In present study, OC files showed greater resistance to cyclic fatigue than 2S when comparing NCF this may belongs to that CM property which fabricated by thermo mechanical procedure that the memory of the material has monitored by and the files will be highly flexible and has more cyclic fatigue resistance. [179]
No statistically difference in significance in terms of resistance to cyclic fatigue was noted among OC file and TS file when taking in to consideration both TTF and NCF ($p>0.05$).
PTG presents greater resistance to cyclic fatigue than OC by statistically significance when comparing TTF and by no statistically significance when comparing NCF this may be explained by the thermal and mechanical processing subjected on the NiTi files as Post heat treatment is utilized after the processing of the flutes of a file. The temperature used is in a zone of 371-511°C for a different period of time. Files show two phase particular conversion behaviour and high Af temperature around 50°C similar to CM wire. [33]
These results can demonstrate the greater cyclic fatigue resistance of PTG instruments. PTG shows minimal shape memory than NiTi. So, operators have not to be amazed to see an unopened bundle of files which show a little degree of curvature. This is not a deficiency, but rather, usefulness as noted by the manufacturer. Further, after withdrawal a PTG file from a curved canal, the file will be noted to keep a track of root canal which instrumented. [15]

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