Comparison of the Cyclic Fatigue Resistance of Rotary Nickel Titanium Endodontic Instruments Manufactured From Two Different Alloys

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Abstract: The purpose of this in vitro study was to compare the cyclic fatigue resistance of ProFile GT (Dentsply Tulsa Dental, Tulsa, OK) and ProFile GT Series X (Dentsply Tulsa Dental). Files of taper 0.04, 0.06 and 0.08, 25 mm in length, and ISO sizes # 30 were compared (n = 10 per group). Cyclic fatigue was determined by recording the time until fracture of a file rotating in a simulated canal with curvatures 45 º and 60 º degrees. The files were operated in a cyclic fatigue testing device that was especially designed and made for this test. There was a statistically significant difference between ProFile GT 30/4 in 45˚curvature and ProFile GTX 30/4 in 45˚curvature, as well as, between ProFile GT 30/8 in curvature 45˚and ProFile GTX 30/8 in curvature 45˚.These differences were extremely significant for both ($P < 0.001$). While for ProFile GT 30/6 in curvature 45˚and ProFile GTX 30/6 in curvature 45˚ the difference was not significant ($P > 0.05$). In the simulated canal of 60˚degrees curvature, the differences were not statistically significant between the tested instruments ($P > 0.05$).

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Key Words: Cyclic fatigue, nickel-titanium files, M-Wire, manufacturing process.

1. Introduction:

Walia et al., in (1988) reported about the improved properties of a nickel-titanium alloy for the manufacturing of endodontic instruments.

Endodontic treatment has since benefited from the development of Nickel-Titanium engine-driven instruments because their increased taper allows for simpler and more efficient root canal preparations. As a result, there are now many engine-driven rotary systems available commercially that use Nickel-Titanium instruments of varying designs and dimensions to facilitate cleaning and shaping procedures.

Despite their increased flexibility, separation is still a concern with Nickel-Titanium instruments. The phenomenon of repeated cyclic metal fatigue may be the most important factor in this separation, when instruments are placed in curved canals, Bergman et al.,(2001).

New strategies were developed by the manufacturers to increase instrument resistance to cyclic fatigue. One of these strategies is a thermal treatment procedure where a series of heat treatment and annealing cycles during the drawing of the wire, produces the M wire Nickel-Titanium alloy having greater flexibility and increased resistance to cyclic fatigue compared with files constructed from traditional Nickel-Titanium alloy , Buchanan(2008); GT Series X Brochure(2008) However, the impact of this new alloy on the cyclic fatigue of rotary dental files is yet unclear. Therefore, conducting a study to evaluate cyclic fatigue resistance of engine–driven rotary Nickel-Titanium instruments produced through new manufacturing methods is thought to be valuable.

2.Materials and Methods:

Files types used in this study and their manufacturers were listed in (Table 1). A total of 120 files were tested for cyclic fatigue failure, 60 file from each system (ProFile GT and ProFile GT Series X).

The evaluation of cyclic fatigue resistance of ProFile GT and ProFile GT Series X was performed using 25-mm files size #30 with three tapers 0.04, 0.06 and 0.08 for each system (n=10 of each taper group).

A specially designed custom-made cyclic fatigue testing device and two stainless steel blocks; (8 cm length x 4 cm height and a total thickness of 4 mm with canal depth 2 mm), were used for this study (Figure 1).

Each stainless steel block contained three artificial canals. These artificial canals were designed to accommodate each instrument in terms of size and taper, thus providing the instrument with a suitable trajectory.

The canals had a 5-mm radius of curvature and 45 º and 60 º angles of curvature. The centre of the radius in the curved section of the canal was 7 mm from the tip of the file. The canals measurements were manipulated using an AUTOCAD drawing estimated from the files size and tapers; and 0.2 mm offset was added for each canal width. The angle of curvature was calculated by Pruett′s method which is described as the "curvature radius" for measuring root canal curvatures. Synthetic oil was used as a lubricant, and a glass top face cover was used allowing visualization of the files while rotating in the canal and maintaining the oil within the canals for longer period of time. An endodontic motor (NSK′s Endo-Mate DT, Japan) was used for constant rotational speed and torque.

The files were rotated inside the canal until fracture was visually recognized. The time to fracture was recorded in seconds using a stopwatch. Number of cycles to failure (NCF) was calculated by multiplying the RPM with the time taken to fracture Data were statistically analyzed using student t test.

Table 1: showing the files used in this study and there manufacturer.

Materials	Manufacturer
1. Profile GT (Rotary Nickel-Titanium files)	Dentsply Maillefer,Maillefer CH-1338 Ballaigues, Switzerland
2. Profile GT Series X (Rotary Nickel-Titanium files)	Dentsply Maillefer, Maillefer CH-1338 Ballaigues, Switzerland

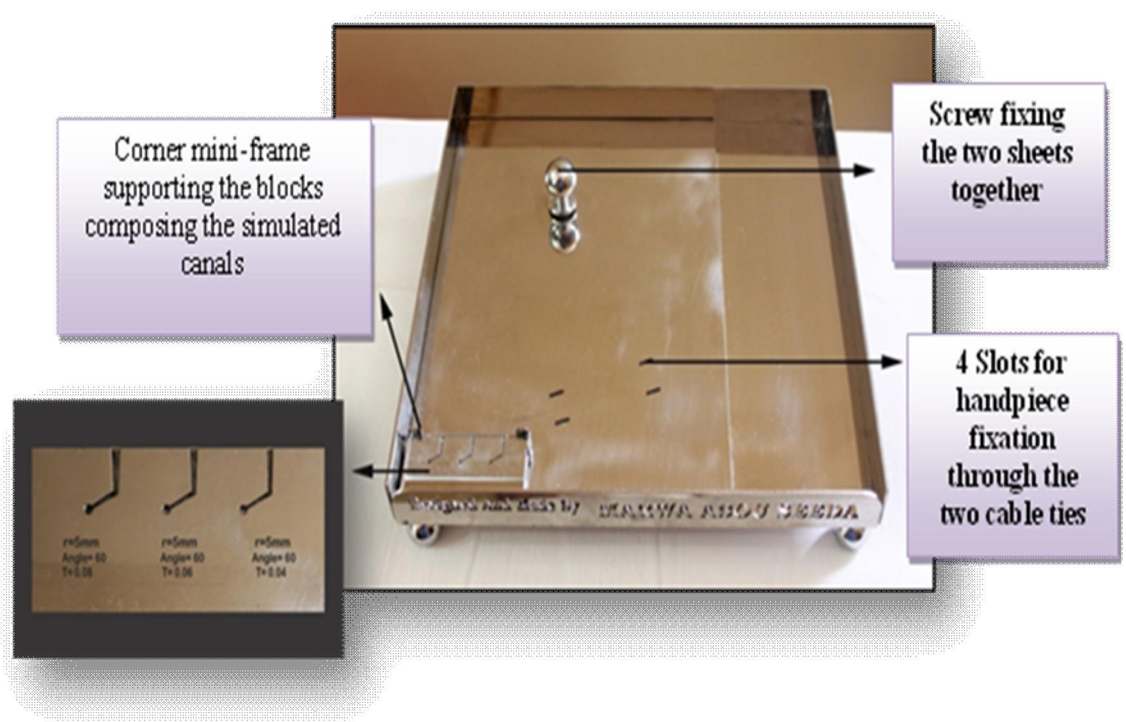

Figure 1: showing the cyclic fatigue testing device designed and made for the study, the lower left figure showing one of the two blocks used in this study

3. Results:

Statistical analysis of the results using student t-test showed that in simulated canals exhibiting 45° degrees of curvature (Table 2 and Figure 2); there was a statistically significant difference between ProFile GT 30/4 and ProFile GTX 30/4 as well as between ProFile GT 30/8 and ProFile GTX 30/8, and these differences were extremely significant for both ($P < 0.001$). As regards ProFile GT 30/6 and ProFile GTX 30/6 the difference was not significant ($P > 0.05$). In the simulated canal of 60° degrees of curvature (Table 2 and Figure 3), statistical analysis showed that the differences were not statistically significant between the tested instruments ($P > 0.05$)

Table 2: Statistical analysis for NCF after cyclic fatigue testing of ProFile GT and ProFile GTX rotary Nickel-titanium files in both simulated root canal curvatures 45 º and 60

comparison		Mean difference	P value
In simulated root canal curvature 45 º	GT 0.04 vs. GTX 0.04	-196.47	P < 0.001 ***
	GT 0.06 vs. GTX 0.06	26.03	P > 0.05 ns
	GT 0.08 vs. GTX 0.08	-187.90	P < 0.001 ***
In simulated root canal curvature 60 º	GTX0.04 vs. GT 0.04	-17.83	P > 0.05 ns
	GTX 0.06 vs. GT 0.06	1.20	P > 0.05 ns
	GTX 0.08 vs. GT 0.08	3.50	P > 0.05 ns

ns not significant *** extremely significant

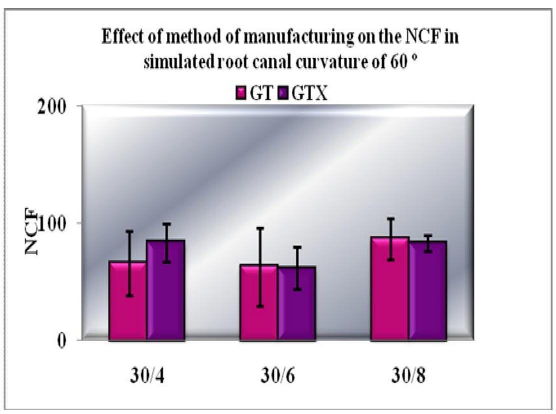

Figure 2: Bar chart showing the NCF of ProFile GT and ProFile GTX in simulated root canals curvature of 45 º

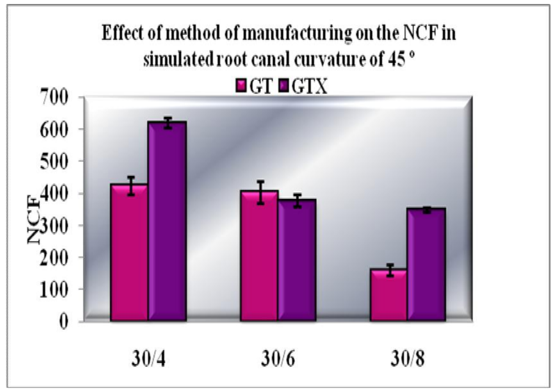

Figure 3: Bar chart showing the NCF of ProFile GT and ProFile GTX in simulated root canals curvature of 60 º

4.Discussion:

The aim of this study was to compare the resistance to cyclic fatigue of a newly developed file made from the M-wire nickel-titanium alloy with another conventional file made from regular nickel-titanium alloy. The present study sought to overcome the limitations of some other laboratory studies in terms of the models used for testing by producing artificial canals specifically designed for each instrument in terms of size and taper, giving it a precise trajectory.

Unfortunately, there is no universally accepted test to measure the cyclic fatigue resistance of Nickel-Titanium rotary files. An ideal model would involve instrumentation of curved canals in natural teeth, however in such tests a tooth can be used only once and the trajectory of the root canal changes during instrumentation making it impossible to standardize the experimental conditions, Plotino et al.,(2009). Differences in testing devices used for evaluation can lead to different results thus compromising the capability of comparing their results, Fife et al.,(2004); Plotino et al.,(2006); Anderson et al.,(2007)

Furthermore, there are no testing protocols approved by the International Standard Organization (ISO) to establish minimum standards for an instrument's cyclic fatigue resistance, Testarelli et al.,(2009).

According to Pruett et al.,(1997); Lopes et al.,(2007); Kramkowski and Bahcall (2009) as they used metallic tubes in their studies where the inner diameter of the tube was larger than that of the endodontic instrument and a lubricant was used throughout the experiments, instruments were allowed to rotate within the canal without significant resistance during the cyclic fatigue tests.

That's why canals having the same shape, taper and size were made for this study. As advised by So-Ram Oh et al.,(2010) ,further fatigue failure studies using artificial canals designed specifically to reproduce the size and taper of each file was needed.

For the inapplicability of making the copper duplicate due to absence of available equipments, the canals in this study were made by a new invented method by calculating the file dimensions starting from the tip size and increasing with the taper increase, giving the size of D0 till the end of the cutting part of the file, this was done with the help of an excel sheet for proper calculations and then converting these dimensions to an AutoCAD software to manipulate the dimensions producing three canals having the same dimensions of the three tapers and sizes of the files tested (tip size 30 and tapers 0.04, 0.06, 0.08).

In previous studies, radii of curvature of 2, 5, or 10 mm were usually preferred to test the cyclic fatigue resistance of the instruments. In this study, 5-mm radius was chosen to simulate an abruptly curved canal.

The speed used in this study was selected to match the manufacture recommendation for ProFile GT and ProFile GT Series X Systems which is equivalent to 250 RPM. ENDO-MATE DT (NSK, Japan) motor was used which had valuable properties such as speed control, torque adjustment.

In order to make a standard test, no pecking motion was used; however it is well known that in normal clinical practice it is possible to use the pecking technique to increase the fatigue resistance. However, Cheung et al.,(2007) concluded that the pecking motion introduced an uncontrolled variable that does not contribute to the understanding of the fatigue behaviour of Nickel-Titanium instruments rotating in a curved canal. So, although the simulated canal does not duplicate the in vivo situation, it allows the comparative testing of different instruments in a standardized environment.

The ProFile GT Series X fabricated from M-Wire appeared to offer limited greater resistance to cyclic fatigue than ProFile GT fabricated from regular SE – Wire in a simulated canal model based on the testing result of this study. The tested ProFile GT Series X showed a significantly higher number of cycles to failure in canal curvatures 45˚, but the statistical difference was not significant in 60˚ canal curvature. It was assumed that the super-elasticity of NiTi alloys can be improved by using special thermo-mechanical treatments. The mechanism for this improvement is to suppress slip during stress-induced martensitic transformation by raising the critical stress for slip.

When considering the performance of the files around a sharp curvature of 60° degrees, it was surprising that ProFile GT was superior in the cyclic fatigue resistance than ProFile GT Series X instruments. It is uncertain why ProFile GT Series X instruments performed so well in cyclic fatigue testing at a degree of curvature of 45° yet behaved similarly or worse at an angle of 60°, and why the thermally modified M-Wire did not seem to have any effect in this group. However, this finding indicates that the thermal treatment of the NiTi alloy per se is not the only factor influencing resistance to cyclic fatigue.

Findings of the present study are in agreement with that of Gambarini et al.,(2008) where a stainless steel artificial canal having a 60 º angle of curvature and 5 mm radius of curvature was used. Results showed that size 20/0.06 GT Series X files were not superior in cyclic fatigue resistance to K3 files of similar size and taper made from SE-NiTi alloy.

On the other hand, Johnson et al.,(2008) who compared size 25/0.04 ProFile files made from the M-wire with ProFile files of similar size and taper made from different types of nickel-titanium alloys found that instruments manufactured from M-Wire had superior cyclic fatigue resistance than other instruments manufactured from SE-NiTi alloy. Similar findings were also found by Larsen et al., (2009) when comparing size 20 with both tapers 0.04 and 0.06 ProFile GT Series X made from M-wire with newly introduced TF system, EndoSequence and ProFile systems. GTX files performed significantly better than all other files tested. Moreover, a study conducted by Peixoto et al., (2010) showed that GT Series X instruments were significantly more resistant to cyclic fatigue than were similar GT instruments. This apparent difference in the results given could be ascribed to several factors including difference in file geometry (cross-sectional design), manufacturer and the design of the testing device, Alhadlaq et al., (2010).

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