

Influence of clinical usage of GT and GTX files on cyclic fatigue resistance

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Abstract

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Aim To compare static cyclic fatigue resistance of unused, unused and sterilized and clinically used conventional NiTi GT and M-Wire GTX files.

Methodology One hundred and sixty new files (80 GT and 80 GTX series X) were divided into four control groups and four experimental groups ($n = 20$ each). Control groups were new unused files and new sterilized files. In the experimental groups, instruments were used in three (GT1 and GTX1 groups) or four molars (GT2 and GTX2 groups). Cyclic fatigue resistance was tested in stainless steel curved canals (60° , $r = 3$ mm). Each file was rotated until fracture (300 rpm, 2 N cm torque). Time-to-fracture (s) was registered. Mean life, eta and beta parameters of their Weibull distributions were calculated.

Results Unused and sterilized GTX files will last significantly longer than GT files with a probability of

75% and 65%, respectively; whilst mean life was significantly longer for GT than for GTX in used files with a probability of 68%. Sterilized GT files will last longer than unused files with a probability of 66%. In both brands, unused and sterilized files will last significantly longer than files used clinically with a probability higher than 98%. The probability that GT will last longer after being used in three rather than four molars was 62% (statistically significant) and 52% (not statistically significant) for GTX.

Conclusions GTX files had an extended cyclic fatigue life when compared with GT when they were unused or unused and sterilized, but GT were significantly more resistant to cyclic fatigue after clinical usage than GT series X files 3 mm from the tip. Sterilization of files enhanced the cyclic fatigue resistance of GT instruments. Clinical use of files diminished cyclic fatigue resistance.

Keywords: cyclic fatigue, GT, GTX, M-Wire, NiTi rotary files.

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Introduction

Due to their elasticity and cutting efficiency (Walia *et al.* 1988) and their effectiveness in preparing canals (Glosson *et al.* 1995, Short *et al.* 1997), nickel-titanium (NiTi) rotary files have become a popular when shaping root canals (Bird *et al.* 2009). Despite these advantages, fracture of NiTi rotary files caused by cyclic fatigue has remained a primary concern in

endodontics practice because they tend to break unexpectedly as a result of the alternating tension-compression cycles to which they are subjected, usually when rotated near the apical third of a root canal with a large curvature (Sattapan *et al.* 2000).

Manufacturers have changed cross-sectional designs and geometrical traits of NiTi instruments to improve cyclic fatigue resistance. Another strategy to achieve this goal is the use of new alloys: new manufacturing processes optimize the microstructure of NiTi through a novel thermomechanical processing (Ye & Gao 2012), producing a new alloy, M-Wire (Sportwire LLC, Langley, OK, USA), with a substantial increase in flexibility (Johnson *et al.* 2008). Endodontic instruments manufactured with M-Wire

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are expected to have higher strength and wear resistance than similar instruments made of conventional superelastic NiTi wires because of its unique nanocrystalline martensitic microstructure (Ye & Gao 2012).

GT and GT series X files (both manufactured by Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) are two instruments that have the same U-shaped cross-section, passive rounded tip geometry and limited maximum flute diameter. However, GT series X was designed to improve the characteristics of GT files through two significant changes: the land widths vary along the length of the file, and it is made of the new M-Wire alloy (Buchanan 2008).

Apart from many other factors including the radius, the degree of the root canal curvature or the design of the instrument, that affect cyclic fatigue resistance, clinical use of rotary files have been shown to decrease this resistance (Gambarini 2001, Fife *et al.* 2004, Bahia & Buono 2005, Plotino *et al.* 2006, Ounsi *et al.* 2007, Aydin *et al.* 2010). Not only the resistance to CF but also the final preparation of the canal is affected when files are reused (Ounsi *et al.* 2011). However, due to the relatively high cost of NiTi rotary files and against manufacturers' recommendations, clinicians frequently reuse files, despite the enhanced risk of metal fatigue (Bird *et al.* 2009).

How clinical use affects torsional resistance of GT and GTX files has been studied (Kell *et al.* 2009). However, no studies have compared the cyclic fatigue resistance between GT files and GT series X after clinical use.

It would be interesting to assess how cyclic fatigue resistance of M-Wire alloy files is affected by clinical usage, compared with traditional NiTi, considering that unused M-Wire GTX files have shown higher cyclic fatigue resistance than unused NiTi GT files (Larsen *et al.* 2009, da Cunha Peixoto *et al.* 2010, Solaiman *et al.* 2010). If resistance of reused GTX files were higher, it would allow more canals to be shaped with a lower risk of fracture compared with traditional NiTi GT files. Therefore, the aim of this study is to compare cyclic fatigue resistance of conventional NiTi GT and M-Wire GT series X files after clinical usage.

Materials and methods

This research was conducted with the approval of the Ethics Committee of Clinical Research of Saint Carlos Hospital, Madrid.

In total, 280 consecutive patients who needed primary root canal treatment in a molar with roots

having a moderate angle of curvature (10–20°) were enrolled. All patients were informed of the aims and design of the study, and written consent was obtained before their enrolment. All the root canal treatments were performed by the same endodontist (AA).

A sample of 80 size 30, 0.06 taper new files (40 GT and 40 GT series X) were sterilized and divided in four groups: GT1 (20 GT), GT2 (20 GT), GTX1 (20 GTX) and GTX2 (20 GTX). GT1 and GTX1 were used to shape the canals of three molars and GT2 and GTX2 in four molars. The number of canals treated with each individual file was also registered. After being used, their resistance to cyclic fatigue was tested. All the files had a tip diameter of 0.30 mm and a 6% continuous taper.

Shaping protocol was as follows: manual shaping to size 20 with K-Flexofile files, ProTaper S1, ProTaper S2, size 20, 0.06 taper GT/GTX and size 30, 0.06 taper GT/GTX (all files from Dentsply Maillefer, Ballaigues, Switzerland). All rotary files reached working length previously determined by a Root ZX electronic apex locator (J Morita Europe GmbH, Frankfurt, Germany) and confirmed radiographically. During the whole shaping procedure, NaOCl 5.25% was used as the irrigant.

After each treatment, files were cleaned using a gauze soaked in 5.25% NaOCl, packaged in a sterilization envelope with indicators that change colour to ensure the optimal functioning of the autoclave, and the number of treated molars and canals was annotated in the envelope.

Instructions of the autoclave Europa B xp (Tecno Gaz S.p.A., Parma, Italy) were followed for the sterilization process. The programme '134 °C packaged' cycle for instruments was chosen: the time exposed was 5 min and the drying time 12 min. Warming-up time and vacuum fractionation could vary between 25 and 30 min. Quality of the sterilization was monitored by physical, chemical and biological methods.

Another sample of 80 size 30, 0.06 taper new files (40 GT and 40 GT series X) was used as controls. They were divided in four groups. In two groups, new unused files were tested: GT-C1 (20 GT) and GTX-C1 (20 GTX). In the other two groups, new unused files were wiped with NaOCl 5.25% and sterilized three times with the same protocol as above: GT-C2 (20 GT) and GTX-C2 (20 GTX).

Cyclic fatigue resistance of all was tested at 3 mm from the tip. Diameter at the tested length was 0.48 mm.

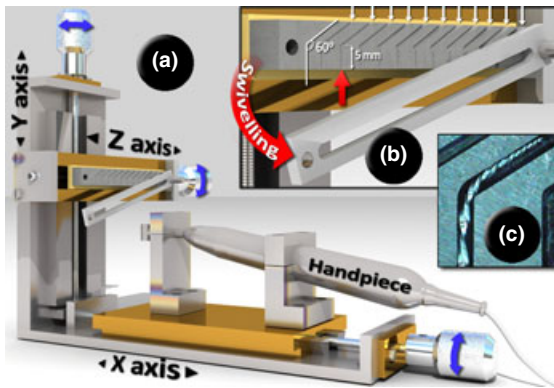


Figure 1 Cyclic fatigue testing device. Insert a: general view. Three axes are shown. Insert b: swivelling motion of grooved stainless steel top face cover and carved open semi-canals (white arrows). Red arrow points to the entrance of a canal. Insert c: image of the bending point of a file before testing.

Cyclic fatigue test device

Cyclic fatigue was tested in a device previously used and described (Arias *et al.* 2012). It consisted of a hardened stainless steel piece with 11 carved open semi-canals (white arrows, insert B in Fig. 1) with a depth 0.1 mm greater than their width and diameters ranging from 0.4 to 1.4 mm. Every semi-canal had two straight portions, joined by a 60° curvature (3-mm radius, insert B, Fig. 1). The first 5-mm straight vertical portion of the canal was the entrance (red arrow in insert B, Fig. 1), whilst in the second 4-mm straight portion rested the tip of the file (insert C, Fig. 1).

The canal selected to test cyclic fatigue was the immediately wider (to the nearest 0.1 mm) to the diameter of the file at the entrance of the semicanal. The diameter of the files at this point was 0.78, so the canal of 0.8 mm width was used (insert B, Fig. 1).

The hardened stainless steel part was attached to a base that allowed the position of files in the three axes of space be adjusted (insert A in Fig. 1). The x-axis platform held the dental handpiece, sliding back and forth on a twisted spindle manoeuvred by a knob, approaching or separating from a second platform that held the stainless steel carved portion. This second platform had two knobs, each one allowing the adjustment of the vertical (*y* axis) or the depth (*z* axis) positions of the canals.

A swivelling, grooved stainless steel top face cover allowed for visualization of the files whilst rotating in

the canal and served to protect the operator (insert B, Fig. 1).

Positioning and testing of files

Files were placed in the handpiece (insert A, Fig. 1) and inserted into the canal; the top face cover was swung and secured (insert B, Fig. 1). Both the canal and the file were lubricated with synthetic oil (Singer All-purpose oil; Singer Sewing Company, Barcelona, Spain) to minimize friction.

The files were rotated at 300 rpm and with a torque of 2 N cm in an X-Smart device (Dentsply Maillefer, Ballaigues, Switzerland).

The motor and a 1/100 s chronometer were activated simultaneously. The file was monitored through the face cover during the test until fracture. The chronometer was then stopped, and the time (s)-to-fracture was registered.

Statistical analysis

A Weibull analysis (Weibull ++ 7; Reliasoft Corporation, Tucson, AR, USA) was used to calculate different parameters (and their 95%) CI for each group:

- Mean life (s). The expected or average time-to-failure.
- Beta, slope or shape parameter (dimensionless). The value is equal to the slope of the regressed line in the Weibull data plot. Different slopes imply different classes of failure modes, and are related to the quality of the designing of the material.
- Eta (s), characteristic life or scale parameter. The expected time that 63.2% of the files will reach without breakage, that is, the probability of failure being 0.63 at this time.

Results

The distribution of reliability versus time per group is shown in Fig. 2.

The mean (SD) number of shaped canals per group and the results for beta and eta (in seconds) parameters and mean life (in seconds) and 95% CIs are shown in Table 1.

When mean life was compared between control and experimental groups, mean life was significantly higher in control groups for both GT and GTX. The probability that GT-C1 and GT-C2 will last longer than GT1 and GT2 was higher than 98%, and the

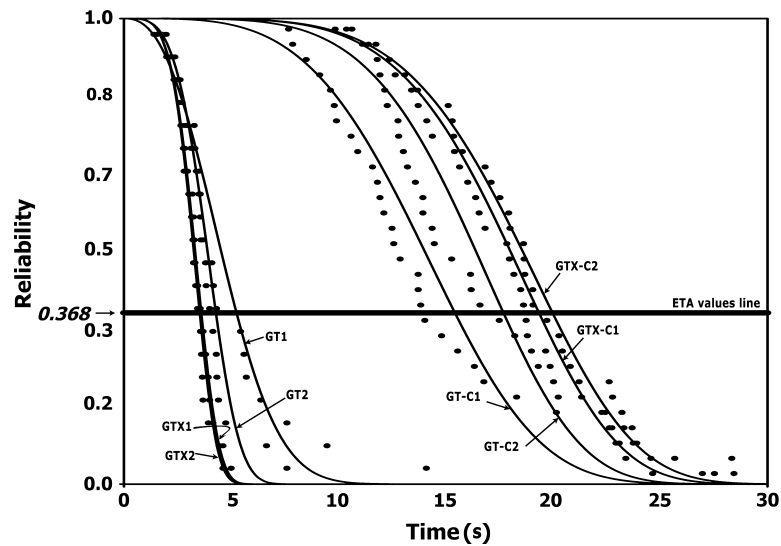


Figure 2 Weibull analysis reliability plot. The vertical scale is reliability, that is, the probability of survival. The horizontal scale is the time-to-failure (s). The horizontal thick dotted line represents Eta values, that is, the time (s) at which 63.2% of the files will survive.

Table 1 *N*, mean (SD) number of shaped canals per group and results for beta and eta (in seconds) parameters and mean life (in seconds) and 95% CIs

Group	<i>n</i>	# of shaped canals (mean (SD))	Beta (95% CI)	Eta (95% CI)	Mean life (95% CI)
GT-C1	20	–	3.8 (3–4)	15.4 (13.8–17.2)	14 (12.3–15.9)
GT-C2	20	–	4.9 (3.8–6.3)	17.7 (16.2–19.3)	16.2 (14.6–18)
GT1	20	11.5 (0.8)	2.5 (1.9–3.3)	5.3 (4.3–6.5)	4.7 (3.7–5.9)
GT2	20	13.6 (0.7)	3.8 (2.9–5.1)	4.3 (3.8–4.9)	3.9 (3.3–4.5)
GTX-C1	20	–	5.1 (3.9–6.7)	19.4 (18–20.9)	17.8 (16.3–19.5)
GTX-C2	20	–	5.1 (3.9–6.5)	20 (18.5–21.6)	18.4 (16.8–20.1)
GTX1	20	10.8 (0.7)	4.4 (3.1–6.3)	3.6 (3.3–4.0)	3.3 (3.0–3.7)
GTX2	20	13.6 (1)	4.5 (3.3–6.2)	3.5 (3.2–3.9)	3.2 (2.9–3.6)

probability that GTX-C1 and GTX-C2 will last longer than GTX1 and GTX2 was 100% (all were statistically significant).

However, when control groups were compared between them, the probability that unused but sterilized GT will last longer than unused GT was also statistically significant (66%), although it was not for GTX (54%). And the same happened when experimental groups were compared; the probability that GT1 will last longer than GT2 was 62% (statistically significant), and the probability that GTX1 will last longer than GTX2 was 52% (not statistically significant).

When mean life was compared between brands, it was significantly higher in unused files for GTX than for GT, but it was significantly higher for GT than for

GTX in used files. GTX-C1 and GTX-C2 will last longer than GT-C1 GT-C2 with a probability of 75% and 65%, respectively. However, the probability that GT will last longer than GTX was 72% after shaping three molars (GT1 compared with GTX1) and 68% after shaping four molars (GT2 compared with GTX2).

Discussion

The cyclic fatigue device and the statistical approach used in this study have been discussed previously (Arias *et al.* 2012). Cyclic fatigue resistance of GT and GTX files was tested using new files and after being used in real clinical conditions.

This study tested static cyclic fatigue in a hardened steel canal. The design of the canals did not

reproduce clinical conditions. Many studies tested cyclic fatigue in metal devices: from the Cheung's design in which the file is constricted into a curvature delimited by three stainless steel pins (Cheung & Darvell 2007) to different types of simulated canals (Grande *et al.* 2006, Gambarini *et al.* 2012). The benefit of the device used in this study is that the fulcrum point for the fatigue test can be decided by the operator.

The application of cyclic fatigue at 3 mm from the tip was decided because GT and GTX files are supposed to work only apically when the shaping protocol used in patients is followed. This protocol mixed two different NiTi rotary systems: ProTaper and GT/GTX to gain efficacy when preparing coronal and middle thirds of canals, whilst being conservative in the apical third.

The use of the whole sequence of ProTaper has been reported to have several drawbacks. Canals shaped with rotary ProTaper were progressively straightened after the use of F1 producing transportation (Zhang *et al.* 2008). Hybrid instrumentation has been claimed to be a valid alternative to achieve larger apical diameters diminishing the risk of procedural errors (Setzer *et al.* 2010). It has been recommended that the combination of S1 and S2 with other less tapered and more flexible files avoids apical transportation (Javaheeri & Javaheeri 2007).

Finishing canal shaping with GT or GTX has advantages. ProTaper and GT have been shown to be equally effective in root canal debridement (Williamson *et al.* 2009), but dentinal damage was reduced from 16% when the shaping procedure was completely performed with ProTaper to 4% when it was with GT (Bier *et al.* 2009) and GTX exhibited superior performance than ProTaper regarding both canal transportation and centring (Hashem *et al.* 2012). GTX NiTi rotary files and Profile GT files performed similarly in an extracted tooth model (Iqbal *et al.* 2010).

In this study, files were used in up to four molars following recommendations of Yared *et al.* (2000), who analysed cyclic fatigue in Profile rotary files (with an U-shaped cross-section) and concluded that they could be used safely in up to four human molars.

The results of this laboratory study revealed that unused GTX files have a longer mean life than unused GT. To date, most of the published studies that compare cyclic fatigue of unused GT and GTX files suggest that rotary files made from the newly developed M-wire alloy have better flexural cyclic

fatigue resistance than files of similar design and size made from the conventional nickel–titanium alloy (Larsen *et al.* 2009, da Cunha Peixoto *et al.* 2010, Solaiman *et al.* 2010). Only two studies did not find that new M-Wire instruments had better cyclic fatigue resistance when compared with Profile, GT files (Kramkowski & Bahcall 2009) or K3 (Gambarini *et al.* 2008). Moreover, several studies have shown that not only GTX, but also other files made of R-phase and M-Wire alloys are more resistant to cyclic fatigue than files made of traditional NiTi (Gambarini *et al.* 2011, Bouska *et al.* 2012).

In particular, a recent study reported that unused GTX files are more flexible and capable of stress relief at the most critical sections than unused GT files, suggesting that they would have a lower risk of fracture inside the root canals during clinical use (Montalvao & Alcada 2011).

It is not fully understood why a theoretically more resistant new alloy may lose its superiority when it ages, but the results of this study revealed lower resistance to CF of GTX than of GT files after being used in clinical conditions. da Cunha Peixoto *et al.* (2010) observed that pitch lengths were larger in GTX instruments when compared with similar GT instruments, whereas the diameter of GTX files tended to be smaller. It is difficult to anticipate whether this intrinsic characteristic influenced the results of this study, but it may be that wear on the blades that the shaping procedure produces could diminish the advantages of the design of GTX and of the superior alloy and therefore have an influence in the results. At the same time, the results of this study also showed that although GT used files had better cyclic fatigue resistance than GTX files, GT files age more rapidly than GTX (resistance of GT files was significantly affected by the number of canals previously shaped, but this difference was not statistically significant in GTX files). It seems that although resistance to cyclic fatigue is significantly higher in GT than in GTX files, the cyclic fatigue resistance that is expected in GT files when it is used to shape a fourth molar is significantly lower than when it was used in the third. On the other hand, the expected cyclic fatigue resistance in GTX did not significantly differ when shaping the root canals of a third or a fourth molar.

Comparison of cyclic fatigue resistance between new and used instruments has been studied with different NiTi rotary files and various studies agree in the higher resistance of new instruments (Gambarini

2001, Bahia & Buono 2005). It seems accepted that prolonged reuse of NiTi rotary instruments substantially affects their fatigue (Fife *et al.* 2004, Aydin *et al.* 2010). Once again, the results of the present study support that finding.

Debate continues over whether autoclave sterilization or clinical usage is the leading cause of the ageing of NiTi alloys. In the present study, two different methods were used to age files: autoclave sterilization alone and shaping of canals *in vivo* and autoclave sterilization together. Cyclic fatigue resistance did not decrease in files that were only sterilized, but it decreased drastically when they were used *in vivo*. Irrigants used during shaping or the procedure itself seemed to diminish cyclic fatigue resistance. In this study, NaOCl was used with a higher concentration (5.25%), but given that the same irrigant protocol and sterilization process were used with both GT and GTX, it is probable that a different rates of wear of the blades could be responsible for the lower resistance to cyclic fatigue of used GTX files when compared with used GT files. This finding and the fact that the use of 2.5% NaOCl did not alter cyclic fatigue of Profile files (Yared *et al.* 1999, 2000), supports the hypothesis that shaping procedures are the main factor in the decline of cyclic fatigue resistance of files.

Previous studies have also found that autoclave sterilization did not affect cyclic fatigue behaviour of new GT series X files (Hilfer *et al.* 2011) and enhanced cyclic fatigue resistance of new K3XF files (Plotino *et al.* 2012), although it reduced GT series X torsional strength significantly (King *et al.* 2012). In the present study, cyclic fatigue resistance of GTX was not significantly affected by autoclave sterilization, but, unexpectedly, cyclic fatigue resistance of GT was longer when new files were sterilized. This difference suggests that autoclave sterilization does not enhance the alloy when it has been previously altered with heat (M-Wire), but probably the heat of the sterilization process affects conventional NiTi.

Conclusions

GT series X files were associated with higher cyclic fatigue resistance than GT when they were unused or unused and sterilized, but GT were significantly more resistant to cyclic fatigue after clinical usage than GT series X files at 3 mm from the tip. Nevertheless, and in accordance with the claim of the designer of the

file, the improvements in GT series X files do not allow clinicians to shape more canals than they used to shape with GT files (Buchanan 2008).

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