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Cyclic fatigue resistance of ProTaper Gold and comparison with ProTaper Universal instruments

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ABSTRACT

Objectives: The purpose of this study was to characterize the cyclic fatigue resistance of the ProTaper Gold system and to compare it with the fatigue resistance of ProTaper Universal system.
Methods: A mechanical device simulate a root canal system with a radius of curvature of 4.7 mm and an angle of curvature of 45° was used to perform the rotational bending tests. Sizes F2 and F3 of ProTaper Gold and ProTaper Universal instruments constituted 4 experimental groups that were analyzed with a rotational speed of 300 rpm and a torque of 4 N.cm. Time to fracture was recorded and number of cycles to fracture was calculated. Statistical analysis was carried using Kolmogorov-Smirnov, T-student and U Mann-Whitney tests ($p<0.05$).
Results: ProTaper Gold F2 group showed higher number of cycles to fracture than ProTaper Universal F2 group ($p<0.05$). Concerning F3 instruments, the same tendency could be stated: number of cycles to fracture of ProTaper Gold F3 group was statistically higher ($p<0.05$).
Conclusions: ProTaper Gold system has proven to be more fatigue resistant than ProTaper Universal. Furthermore, instruments with higher diameters showed lower number of cycles to fracture. (Rev Port Estomatol Med Dent Cir Maxilofac. 2018;59(2):75-79)

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Resistência à fadiga cíclica do sistema ProTaper Gold e comparação com o sistema ProTaper Universal

Palavras-chave:
Endodontia
Resistência à fadiga
Instrumentos níquel-titânio
ProTaper Gold
ProTaper Universal

RESUMO

Objetivos: O principal objetivo deste estudo foi caracterizar a resistência à fadiga cíclica do sistema ProTaper Gold e compará-la à resistência à fadiga do sistema ProTaper Universal.
Métodos: Um sistema mecânico que simula um canal radicular com curvatura de 4,7 mm de raio e angulo de 45º foi usado para desempenhar os testes de resistência à fadiga cíclica. Neste, limas ProTaper Gold e ProTaper Universal dos tamanhos F2 e F3 foram testadas a uma velocidade rotacional de 300 rpm e torque de 4 N.cm, sendo divididas em 4 grupos experimentais. O tempo até a fratura ocorrer foi registado e o número de ciclos até a fratura foi calculado. A análise estatistica foi realizada utilizando os testes de Kolmogorov-Smirnov, T-student e U Mann-Whitney ($p<0{,}05$).
Resultados: O grupo de limas ProTaper Gold F2 mostrou ter uma média de número de ciclos até a fratura superior ao grupo de ProTaper Universal F2 ($p<0{,}05$). Em relação aos intrumentos F3, a mesma tendência ocorreu: o número de ciclos até a fratura dos intrumentos ProTaper Gold foi estatisticamente superior ($p<0{,}05$).
Conclusões: O sistema ProTaper Gold provou ter uma maior resistência à fadiga cíclica que o sistema ProTaper Universal. Além disso, instrumentos de diâmetro maior mostraram ter um menor número de ciclos até à fratura. (Rev Port Estomatol Med Dent Cir Maxilofac. 2018;59(2):75-79)

Introduction

Pulpal treatment may be challenging since a complex root canal anatomy and limitations inherent to instruments used during root canal preparation are major concerns.[1]

Over time several types of endodontic instruments have been developed overcoming their predecessors with new technology. Niquel titanium (NiTi) instruments, for example, had proven to be more resistant to fatigue than stainless steel ones. Even though, instrument breakage may occur often.[2-6] Fracture occurs when an instrument shanks loosely in a canal generating tension/compression cycles until fracture arise at the maximum flexural point.[3,6,7] Apparently, this is one of the major reasons for instrument breakage during treatment and can be measured by the number of cycles to fracture (NCF).[4,8] NCF may be affected by type of wire, surface finish, thermal treatments, cross section and geometry of the instrument.[5,9-13]

ProTaper® Universal (PTU; Dentsply/Maillefer, Ballaigues, CH) is a widely-described system of instruments, with progressive taper over the cutting blades, triangular cross section and center of rotation equal to center of mass. The basic sequence of instrumentation comprehends the use of 6 instruments: 3 to pre-enlarge the coronal and medial third (SX, S1 e S2) and other 3 to shape the apical third (F1, F2 e F3).[14]

Recently introduced in the market ProTaper Gold^RM instruments (PTG; Dentsply Tulsa Dental Specialities, OK, USA), respect the same geometry principles of PTU, with the same number of instruments and directions for use. However, a patented heat treatment called controlled memory wire (CM-Wire®) is used in this instruments' manufacture.[13,15]

Manufacturers proclaim that PTG system has improved fatigue resistance over PTU mainly due to this technology, so several amounts of independent research have been made concerning this issue.

Thus, the main aim of this in vitro study was to analyze the fatigue life of the ProTaper Gold^RM NiTi instruments and to compare the fatigue life of PTG system with its predecessor, confirming recent findings.

Materials and methods

Forty-eight sterile and new rotary files from PTG and PTU systems were experimentally tested at room temperature (≈ 20º) constituting 4 experimental groups (PTG F2= 12), (PTG F3= 12), (PTU F2= 12), (PTU F3= 12).

Those instruments were subjected to a cyclic fatigue test using a static model for cyclic fatigue testing as seen in Figure 1. The instrument was able to rotate freely inside a 45º angle and 4.7 mm radius of curvature artificial canal.

A single operator performed the entire protocol which included first to place the instrument to be tested in the contra-angle and rotate the head of the contra-angle until the instrument was parallel to the part that simulated the apical canal. Ensure that the instrument was perpendicular to the upper part of the block, well-adjusted between the two pieces that impose radius of curvature and angle, and the extremity of the file being well positioned at the established point. After that, the position of the parts was fixed by tightening the bolts. The WaveOne™ motor equipment was in the ProTaper Uni-

Figure 1. Mechanical system used to perform the cyclic fatigue tests. Three bolts were used to prevent the different pieces to move apart and a malleable screen of Teflon supported the device.

versal program with 300 rpm of continuous rotary motion and a torque of 4 N.cm, following manufacturer's recommendations. To initiate the rotation the operator stepped on the pedal initiating the digital chronometer at the same time, until separation of the instrument occurs and the chronometer was stopped when the tip of the instrument come off. Every step was repeated for all instruments under testing.

Time to fracture data (t) was recorded along the experimental tests and NCF was determined. These two parameters have been used to assess cyclic fatigue resistance over the years, in which t presents more clinically relevant information. On the other hand, NCF offers more pertinent information regarding the ability of the instrument design to withstand cyclic fatigue.[6]

NCF is cumulative, thus it can be obtained through the multiplication of the rotation speed by the time elapsed until fracture occurred.[4]

All parameters guaranteed equal experimental conditions ensuring reproducibility of the experiment and the same methodology was used to test all instruments.

IBM® SPSS® Statistics version 22.0.0 was the software used to perform the statistical analyses and Kolmogorov-Smirnov tests evaluated data obtained on time to fracture (sec) and NCF for normal distribution.

T-student test and U Mann-Whitney were used according with normality of the sample. If the results followed a normal distribution the t-student was applied; a non-normal distribution required the application of the U Mann-Whitney test.

The significance was set at 95% confidence level and differences were considered statistically significant when $p<0.05$.

Results

Cyclic fatigue testing, is a simple and reliable approach that determines the cyclic fatigue resistance of an instrument.[(16)] The devices used to determine the fatigue resistance of endodontic instruments allow instruments to rotate until fracture occurs using different geometric curvatures.[3]

Table 1. Descriptive analysis: mean and standard deviation regarding number of cycles to fracture (NCF). Group 1 is the one with higher mean values; the lower values are present in Group 4.

	Group	Type of file	Mean ± St. Deviation
NCF	1	PTG F2	549.1 ± 115.1
	2	PTU F2	283.5 ± 33.9
	3	PTG F3	294.5 ± 88.0
	4	PTU F3	158.5 ± 37.57

Descriptive statistics on experimental data regarding NCF for each experimental group are presented in Table 1. The mean value of NCF between group 1 (PTG F2) and group 2 (PTG F3) was found to have a significant statistical difference. The same can be stated between group 3 (PTU F2) and 4 (PTU F3). Instruments with larger diameters (F3) had the tendency to present lower NCF than those with smaller diameters (F2). When comparing data between different systems of files and considering F2 instruments, mean NCF of PTG instruments was higher than PTU instruments ($p<0.05$). For instruments F3, the statistics showed a significant higher mean of NCF for PTG as well.

Discussion

Many factors are linked with the propensity to fracture of rotary NiTi instruments.[9]

The main aim of this in vitro study was to analyze the fatigue life of ProTaper Gold^{RM} system. Moreover, as its manufacturer proclaimed improved fatigue resistance of this system over ProTaper® Universal system, comparing it with its predecessor seemed relevant in order to check on ProTaper evolution.

PTG F2 group proved to be the most fatigue resistant of all groups under test, with higher mean NCF value. Additionally, when considering PTG and PTU systems, instruments of smaller size had highest NCF. These findings corroborate with current literature, since resistance to cyclic fatigue decreases when instrument sizes and respective diameter increases.[11,14,17-21] In fact, when comparing PTG and PTU instruments, PTG F2 and F3 proved to be significantly more resistant to cyclic fatigue than PTU F2 and F3, respectively. Despite the identical architecture and operation of PTG and PTU systems, different manufacturing process among them clearly affects their fatigue resistance behavior. Instruments produced using CM-Wire® were proven to have a higher cyclic fatigue than instruments produced with M-wire® and conventional alloys.[22,23] Moreover, a higher proportion of martensite, which is known to be more flexible than austenitic NiTi, and changes in the phase transformation behavior may be the reason to explain why PTG instruments are more fatigue resistant than PTU systems.[11,13,16,24,25]

Limitations can be noticed in cyclic fatigue testing procedures and in the present study. For instance, to date, there is no specification or international standard to test cyclic fatigue resistance of endodontic rotary instruments. Such a new standard is required to introduce universally accepted testing devices for experimental evaluation of products or prototypes that could also simulate root canals found in real teeth in a clinical environment. In addition, a consensus between researchers should also be reached to find the most accurate statistical analysis.[3]

In this in vitro study, instruments were tested beyond time that the instrument is expected to be active at a specific level when shaping a root canal and no lubrication was used. In addition, pilot experiments had indicated that lubrication with various agents leaded to a higher fatigue life.[18,26] Moreover, and although it minimizes the effect of variables, rotary tests with no axial movement showed lower fatigue resistance when compared with those obtained with dynamic tests.

Until now, there is no specification or international standard to test cyclic fatigue resistance of endodontic rotary instruments. Thus, different results may arise.

That being stated, it is important for clinicians to understand the mechanical differences between systems of files to take advantage of the latest technology.

Conclusions

Regarding Protaper Gold^{RM} system, F2 instrument showed superior cyclic fatigue resistance when compared with F3. Furthermore, comparing data from PTG F2 and F3 with ProTaper® Universal F2 and F3, respectively, ProTaper Gold^{RM} showed a superior behavior on cyclic fatigue resistance, with higher time to fracture (PTG F2 > PTGF3 ≥ PTU F2 > PTU F3).

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. TThe authors declare that no patient data appear in this article.

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Conflict of interest

The authors have no conflicts of interest to declare.

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