Mechanical resistance of carbon and stainless steel hand instruments used in a reciprocating handpiece

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Summary

Aim. **The manual files are still widely used for initial canal negotiation prior the use of nickel-titanium shaping instruments, to determine working length and to verify patency. A mechanical glide path can be performed using manual files with handpieces, such as M4 Handpiece (SybronEndo, USA) that allows a 30°/30° reciprocating motion. The Pathfinders (SybronEndo, USA) are hand files designed to negotiate complex canals, made from stainless steel (SS) or carbon steel (CS) alloys. The aim of this in vitro study was to compare cyclic fatigue resistance of these two different types of manual Pathfinder instruments used in a M4 reciprocating handpiece in double curved artificial canals.**

Materials and methods. **Manual instruments designed for glide path (size #9 ISO .02 taper) made from different alloys were selected: Group SS - stainless steel Pathfinders (Sybron Endo) and Group CS - carbon steel Pathfinders size K2 (Sybron Endo). Ten instruments of each group were tested for resistance to cyclic fatigue with a reciprocating M4 handpiece inside an artificial S-shaped canal; the time to fracture was recorded for each file and data were statistically analyzed (ANOVA).**

Results. **Mean values (and SD) were 527 (± 89) seconds for the CS instruments and 548 (± 104) seconds for the SS files. No significant differences were observed between groups (p=0,062).**

Conclusions. **According to the results, both carbon and stainless steel instruments presented similar fatigue resistance when used with M4 reciprocating handpiece in double curved canals.**

Key words: cyclic fatigue, endodontic instruments, carbon steel, stainless steel, reciprocating handpiece.

Introduction

Despite nickel-titanium (NiTi) rotary or reciprocating instruments have gained popularity among practitioners and endodontic specialists, the stainless steel (SS) manual files are still widely used for initial canal negotiation, to establish an endodontic glide path, to determine working length either radiographically or with the aid of electronic apex locators and to verify patency. Canal negotiation is easier due to the fact the manual SS files usually have a cutting tip: however, this tip and the inherent rigidity of the alloy are theoretically not ideal for instrumentation of curved canals (1,2). Therefore, the tendency nowadays is to use SS instruments only in small sizes (generally smaller than ISO #20) and precurve the instrument when canal curvatures are observed.

Motion and methods of use are also very important in making negotiation easier while preventing iatrogenic errors. It has been shown (3) that when a filing or reaming motion are applied to an instrument inside a curved canal, the greatest amount of cutting occurs at the inner curve and apex because of the action of a lever arm and fulcrum (4). Intending to overcome the curvature influence, the balanced force technique was proposed, resulting in better cleaning and less apical transportation compared to hand filing motion (5-7).

The concept of balanced-forced technique was introduced for manual hand filing, but it can be also be mechanized. The M4 Safety Handpiece (Sybron Endo, Glendora, CA, USA), was developed for mechanical preparation of root canals, using manual endodontic instruments in a 30°/30° reciprocating motion, that can be considered the mechanical expression of the balanced force motion. This M4 handpiece, which can be used with electric endodontic motors or be directly connected to the dental unit, features a 4:1 gear reduction, and os-

cillates 30 degrees in both clockwise/counterclockwise directions. It can be used with most of commercially available SS or nickel-titanium (NiTi) manual files, not only for preparation but also for enhancing final irrigation or for gutta-percha removal (8).
Notwithstanding these interesting properties, a very few number of studies had been published in the last decades about the M4 handpiece (9,10). On the other hand, many studies demonstrated that SS K-files mounted in a Giromatic (MicroMega, Besancon, France) 90°-90° reciprocating handpiece, were able to negotiate narrow canals and maintain the original path, when used up to a size 25 (11-13). The M4 Handpiece presents smaller reciprocation angles than Giromatic (respectively 30°/30° vs 90°/90°), which theoretically should result in a safer movement, because torsional stress and bending stress are lower when angles are smaller. Such a constant and predictable 1/12 turn motion can be consider an improved hand filing, being more precise and reproducible than what can be manually achieved (usually 1/4 or 1/8 turn). Therefore, the M4 handpiece could be used as an alternative for both initial negotiation and creation of an endodontic glide path.
Initial negotiation is the most delicate part of manual hand filing especially in thin, narrow, calcified and curved canals. Clinicians often start by using very small instruments (ISO sizes #6 to #8) that are meant to find the path towards the apex in complex and challenging situations. Therefore, these instruments need a lot of different mechanical properties, which often contradict among themselves: excellent cutting ability, and a cutting tip to progress easily through dentin, but only to a certain amount, due to the risk of apical blockage; flexibility to follow canal anatomy and prevent transportation, but some inherent rigidity is needed to make possible to progress a small instrument through the canal, especially when calcified or constricted. Intending to provide these requirements, special instruments have been manufactured and commercialized for the creation of glide path, such as the Pathfinders (Sybron Endo, Glendora, CA, USA).
The manual Pathfinder instruments present a different design from traditional K-files or Reamers, and they also can be made by using a stiffer alloy, carbon steel (an alloy that cannot be autoclaved) to allow better negotiation in complex canals since they can be consider single use instruments that easily deform and need to be discarded after one use.
Therefore, the aim of this in vitro study was to compare two different types of Pathfinder handfiles (size #9 taper .02) made by stainless steel or carbon steel, used in a M4 reciprocating handpiece for the negotiation of S-shaped artificial canals, to evaluate if different alloys could be more or less beneficial in terms of resistance to cyclic fatigue.

Materials and methods

Two different types of size #9 .02 taper manual instruments were selected:
Group SS - stainless steel handfiles, Pathfinders;
Group CS - carbon steel handfiles, Pathfinders CS, size K2.
All the instruments (Fig. 1) were produced by the same manufacturer (Sybron Endo,Glendora,Ca,USA), presenting the same features, to eliminate all variables related to design or manufacturing process; they were visually examined under a stereomicroscope to discard any defective instruments. The device used to test the instrument resistance to cyclic fatigue in double shaped artificial canal have been previously used and described in a peer-reviewed scientific article (14).
The device (Fig. 2) consists of a mainframe to which a mobile plastic support for the electric handpiece is connected, and a stainless steel block containing the artificial canals. The electric handpiece was mounted on a mobile device to allow the precise and reproducible placement of each instrument inside the artificial canal. This placement ensured three-dimensional alignment and the positioning of the instruments to the same depth. The artificial canal was manufactured by reproducing an instrument's size and taper, thus providing the instrument with a suitable trajectory. A simulated root canal with a double curvature was constructed: the

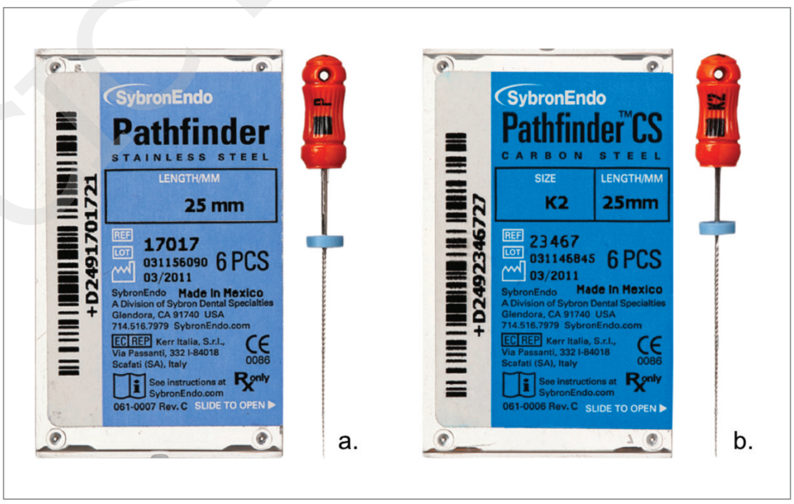

Figure 1. The two types of tested instruments: a. Stainless steel Pathfinder; b. Carbon steel Pathfinder CS K2.

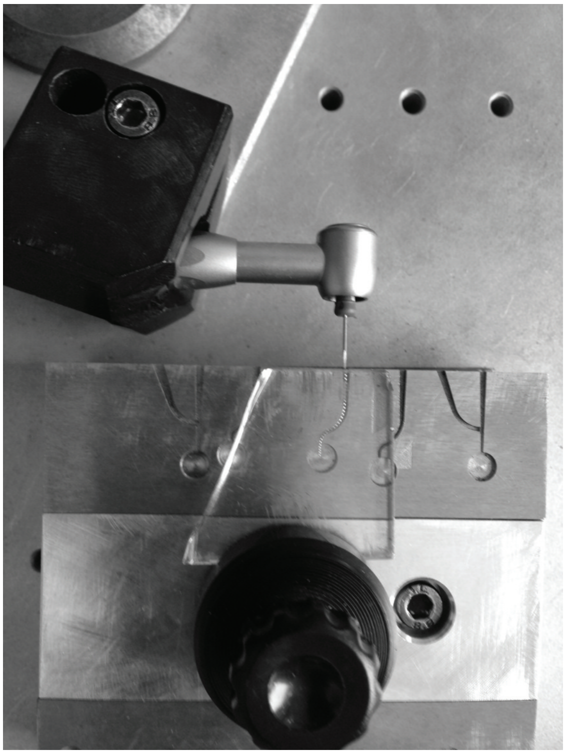

Figure 2. The testing apparatus for cyclic fatigue with double curvature (S-shaped artificial canal).

first coronal curve has 60º angle of curvature with a radius of 5 mm, located 8mm from the tip of the instrument, and the second is apical, with 70º angle and a radius of curvature of 2 mm, whose center was placed at 2 mm, from the tip.
Ten instruments of each group were activated inside the double curved artificial canal with a M4 handpiece (4:1 reduction, 30°/30° reciprocation), mounted in an endodontic motor (ASEPTICO, Woodinville, WA), until fracture occurred.
For each instrument, the time to fracture in seconds (s) was recorded by the same operator with a chronometer to an accuracy of 0.1s. After positioning the instrument into the artificial canal, as soon as the reciprocation started, timing was initiated and it was stopped when instrument breakage occurred. Since the instruments are not fully rotated inside the canal, the actual speed cannot be properly measured. Therefore, time to failure was selected as the most precise way to describe resistance to breakage.
Mean values and standard deviation (SD) were then calculated for each group. Cyclic fatigue data were analyzed by one-way ANOVA test to determine any statistical difference between groups; the significance was determined at the 95% confidence level.

Results

Mean time to fracture was 527 (± 89) seconds for the CS instruments and 548 (± 104) seconds for the SS files. No significant differences were noted between groups (p=0,062).

Discussion

Many dentists fear that manual instruments could easily break when used in an M4 handpiece, especially when working in thin, narrow, constricted or calcified canals. They have read or heard that SS instruments present a high risk of intracanal separation when rotated inside a curved canal (15). This statement is correct, but in clinical practice we need to fully understand how different motions influence performance and safety of endodontic instruments. A recent study from Gambarini et al. (16) showed that SS ISO instruments used in a M4 reciprocating handpiece were significantly more resistant that .02 tapered NiTi rotary instruments designed for glide path. These results can be easily explained due to the fact that M4 handpiece allows only an oscillating movement inside a canal, not a full rotation: consequently, reciprocating SS instruments are very resistant to cyclic fatigue, significantly more than NiTi rotary instruments. In fact, even if the NiTi alloy presents a superior resistance to fatigue, rotation creates much more instrumentation stresses compared to reciprocation and as a consequence failure may occur earlier (17).
Many studies have been published recently showing that reciprocating motions reduce both torsional stress and cyclic fatigue of NiTi, regardless of the different manufacturing process (18-22). Interestingly, no studies have evaluated the differences between a reciprocating movement and the M4 one.
Moreover, in the past many studies have demonstrated that resistance to fracture is dependent on the size, design and manufacturing differences of the SS instruments (24,25). More recently, Gambarini et al. confirmed these data (article in press), showing that file design and manufacturing processes play a significant role in determining resistance to fatigue of SS instruments also when used with a reciprocating handpiece. The K-files and Reamers with flutes created by a twisting process showed greater fatigue resistance, while Hedström files manufactured by a grinding process, were weaker. It has been demonstrated also for NiTi that grinding process is likely to create defects and microcracks on the external surface of the instruments, thus reducing resistance to metal fatigue (24).
On the contrary, the present study demonstrated that in vitro resistance to fracture of manual instruments used in a M4 Handpiece produced with different alloys (carbon vs stainless steel) was not significantly dependent on the different characteristics of alloys. Data showed no statistically significant difference between the two tested instruments.

Conclusion

Carbon steel is a slightly harder and more rigid alloy than SS, and it is being used for Pathfinder instruments because improved cutting efficiency and a slightly high-

er stiffness can be beneficial properties for a small instrument, which is meant to negotiate and pre-enlarge thin, narrow and curved canals. However, in cases of complex anatomy such as double curvature canals, flexibility and resistance to fracture are more important parameters, reducing the risk of iatrogenic errors and intracanal separation.
Hence we may conclude that tested different alloys didn't play a significant role in determining fatigue resistance of the tested instruments. These results support the clinical use of both SS and CS Pathfinder instruments with the reciprocating M4 Handpiece for the creation of an endodontic glide path in the most complex curvatures, when safety is a concern.

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