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ORIGINAL ARTICLE

Comparative Evaluation of Flexural Properties and Clinical Flexibility Between Two Types of Nickel Titanium Endodontic Files

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ABSTRACT

Objective: To analyze the flexibility of two different generation of rotary endodontic file system by comparing second generation and fifth generation nickel-titanium rotary endodontic files.

Material and Methods: This cross sectional study was performed in the department of operative dentistry, Hamdard university dental hospital, Karachi & at PCSIR laboratory, Karachi. second generation rotary endodontic file selected for this purpose was Protaper, Dentsply files while fifth generation rotary endodontic file selected for this purpose was KometSky. Nickel titanium rotary Endodontic files were loaded on a load testing cell & two-point bending test was performed. The files were measured at 5mm from the tip using a digital caliper (Mitutoyo, Japan) and marked with a rubber stopper. Each file was secured between two metal plates on a load-sensing cell. A universal testing machine (Instron, 5KN model 4301, Norwood, MA) was used to bend the files to a maximum deflection of 4.5mm at a rate of 2mm/minute at room temperature (22ºC +/- 1ºC).

Results: Mean value of 3.7092 was recorded for fifth generation rotary files & 2.846 for second generation rotary endodontic files.

Conclusion: Mean value of the fifth generation endodontic files was highly significant i.e p=0.0001 compared to second generation endodontic file.

Keywords: Rotary endodontic files, second generation rotary files, fifth generation rotary files, flexibility rigidity.

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INTRODUCTION

The foremost objective of Root canal therapy is the treatment or prevention of Apical Periodontitis.[1] The most significant step in this process is efficient chemo-mechanical debridement of the canal.[2] The basic objective of debridement is the removal of residual tissues microorganisms, and dentin debris from the root canal system which, if not properly removed, could lead to persistent apical pathology.[3] Mechanical debridement is performed with endodontic files while chemical debridement is concurrently completed with irrigants.[4]

Since the earliest documented endodontic instruments, which refer back to the nineteenth century, the basic concept of canal preparation has remained the same. A sequence of narrow and tapered metal 'broaches' with cutting edges on the sides act on rotation (reaming motion) or in an in-and-out (filing) motion inside the canals.[5] These manually or motor-operated metal cutting instruments, which are called endodontic files, have been produced with a wide variation of designs, materials and cutting properties. Until recently, stainless steel, a stiff alloy, was the most commonly used material for the manufacturing of endodontic files.[6] The physical properties of the machined endodontic files, however, vary depending on the alloy composition, size (diameter) and geometry of the file. The elastic modulus for stainless steel files is around 340+30 GPa, and their hardness is around 6.5+0.5 GPa. In terms of the requirement for dentine cutting, which has a hardness of around 0.5 GPa, the use of stainless steel that has much higher hardness is in excess of what is actually needed.[7] When it comes to elasticity, stainless steel files are also much too stiff to follow complex root canal architecture. With high elastic modulus, the rigidity increases rapidly as files get larger with unwanted overcutting of dentine that can cause more aberrant preparations and unfavorable instrumentation outcomes.[8] This problem is significant when instrumenting curved roots with large and stiff files, where more forces are conducted laterally while the file is tending to restore its original shape so causing excessive dentine cutting at the outer curvature of the root.[9]

The first manual and mechanical rotary files were formed from straight piano wire that had flats ground on its sides and twisted to result in the configuration of files still used today. Files were first mass-produced by Kerr Manufacturing Co. in the very early 1900's, hence the name K-type file or K-type reamer.[10] Although the term file is commonly used generically to describe all ground or twisted endodontic instruments, more specifically the term file is used to describe an instrument used primarily during insertion and withdrawal motions for enlarging the root canal, whereas a reamer is used primarily during rotation.[11] K-type files and reamers were both originally manufactured by the same process. Three or four equilateral flat surfaces were ground at increasing depths on the sides of wire to form a tapered pyramidal shape that was stabilized on one end and rotated on its distal end to form the spiraled instrument.[12] The number of sides and spirals determined if the instrument was best suited for filing or reaming. Generally, a three-sided configuration, with fewer spirals, was used for reaming or rotation; a three- or four-sided configuration with more spirals was used for filing or insertion and withdrawing.[13] Even though the twisting method of file manufacturing has generally been considered an outdated means of fabricating files and has been replaced by computerized grinding processes for NiTi rotary files, new advances for manipulating shape memory alloys may offer economic and physical property advantages for reconsidering the twisting method of manufacturing for the future.[14]

Dating from the late 19th century, the earliest endodontic instruments used for extirpating the pulp and enlarging the canal were broaches

or rasps.[15] Still used today, these instruments are manufactured by hacking a round tapered wire with a blade device to form sharp barbs that project out from its side to form cutting or snagging surfaces.[16] Although mostly used to engage and remove soft tissue from the canal as manual instruments, these historic broach type instruments have the potential for becoming effective rotary instruments.[17] The evolutionary development for endodontic instruments seems to have some cyclic peculiarities and is far from over.[18] Even the tapered pyramidal design originally used as blanks as described above is now being used as rotary NiTi files. Manual stainless-steel files provide excellent manipulation control and sharp, long-lasting cutting surfaces.[19] However, due to the inherent limited flexibility of stainless steel, preparation of curved canals is often a problem for manual files, and the mechanical use with conventional designs and grades of stainless steel poses the likely threat of file breakage or canal transportation.[20]

How well a file performs, while following a specific technique, should not be the measure of the effectiveness of a file; rather, how well the mechanical properties of an Endodontic file can address the requirements of the canal anatomy should be the measure of its usefulness. Since canal anatomies vary, techniques to effectively clean and enlarge the canal may include modifications and may include different types of files. Instrumentations involving more than one type of endodontic files or technique is known as hybrid technique.[21] Therefore, we compare the flexibility of Second generation & fifth generation nickel-titanium endodontic files at 5mm from the tip of the file in terms of mean (N/mm^2). The 5 mm point in Endodontics is significant for evaluating the flexibility of Endodontic files particularly in root canal preparation. This measurement is typically taken from the endodontic file's tip, where stress and deformation are most pronounced when navigating curved canals. Other reasons for selecting 5mm of the tip of the endodontic files for evaluation are:

1) Critical Bending Area: The first 5mm from the tip encounters the most resistance and must flex adequately to negotiate curves without causing excessive stress or breakage.
2) Fracture Risk Zone: Instruments often experience cyclic fatigue near this region, making flexibility crucial for preventing separation.
3) Canal Navigation: Proper flexibility ensures the instrument follows the natural anatomy of the canal rather than creating ledges, zipping or perforations.
4) Standard for Comparison: Many studies and manufacturers assess flexibility at this point to provide a consistent benchmark across different instruments.

MATERIAL AND METHODS

This study was performed in the Department of operative dentistry, Hamdard university dental hospital, karachi & at PCSIR laboratory, karachi. Second generation rotary endodontic file selected for this purpose was Protaper, Dentsply files while fifth generation rotary endodontic file selected for this purpose was KometSky. Dimensions of these files were uniform i.e. length of these files were 25mm, while the diameter of the tip was 0.25mm with a taper of .06 (ISO size 25).

For testing flexibility of rotary files were strictly following ISO 3630-1 standards. The files were measured at 5mm from the tip using a digital caliper (Mitutoyo, Japan) and marked with a rubber stopper. Each file was secured between two metal plates on a load-sensing cell. A universal testing machine (Instron, 5KN model 4301, JOEL, JAPAN) was used to bend the files to a maximum deflection of 4.5mm at a rate of 2mm/minute at room temperature, (22^oC +/- 1^oC). The total duration of study was ten months. Mean difference was used to calculate the sample size, the mean of

group1(Pro file) was 18.2 ± 0.4 & group 2 (Ni Ti wires) was 17.5±1.3.[22] Thirty (30) Comet Sky & Thirty (30) Pro Taper files were used for this experiment with 95% confidence Interval. Power of the study was 80%.[22] Sample size calculation was performed on OpenEpi. Software version 3.0. Samples was collected through Convenience sampling technique.

All the endodontic files were procured from the market. All the batch numbers & Product details were first checked & once the authenticity of the product was verified only then the files were selected. For checking the flexibility of the file Instron 4301 which is JOEL, JAPAN universal testing machine was used. A Two-point bending test was used. Endodontic files were first measured on a digital calliper (Mitutoyo, Japan). Files were measured at 5mm from the tip using the digital calliper. Each file was secured on two metal plates on a load sensing cell. The files were bended to a maximum deflection of 4.5mm at a rate of 2mm/minute at room temperature (22^{o}C +/- 1^{o}C). Each file after being measured with the digital calliper were marked with a rubber stopper. Then each file was secured on the load sensing cell & then measured for the flexibility. Each file was also measured with a digital indicator before mounting on the Universal testing machine for identification of the diameter.

A standardized Performa was designed with five columns. These columns included the information on Serial number, Type of file system, Grasp length, Force & Stiffness.

Statistical Analysis

Two groups were formed. group 1 was composed of second-generation file system, while group 2 was composed of fifth generation file system. Analysis was performed on IBM, SPSS statistical software (IBM Corp, Armonk,NY) Version 22. All data was statistically analyzed by two-way analysis of variance and post-hoc Tukey test (p = 0.05) to determine any significant differences.

RESULTS

There were total 60 subjects (files) out of which 30 were fifth generation file system and 30 Second generation file system. All files were new & had same length (25mm), which was verified by a Vernier calliper. All files which were tested for testing flexibility of rotary files were followed ISO 3630-1 standards. The files were measured at 5mm from the tip using a digital calliper and marked with a rubber stopper. Each file was secured between two metal plates on a load-sensing cell. A universal testing machine (Instron, 5KN model 4301, Joel, Japan) was used to bend the files to a maximum deflection of 4.5mm at a rate of 2mm/minute at room temperature (22^{o}C +/- 1^{o}C). Data was entered in SPSS Version 22. After each deflection individual readings were entered & verified. Our analysis verified that the fifth-generation file is more flexible (p=0.0001) compared to second generation file with test value 2.89 with 95 Confidence interval, with mean value of 3.7092 for fifth generation rotary files and 2.846 for second generation rotary endodontic files. As clearly showed in Table 1, both files have shown flexibility during the

Table 1. Distribution of the mean values of file systems

S.No.	File system	Mean	Std. Deviation	Std. Error Mean	p-value
1	Fifth generation	3.70	0.11	0.01	0.001
2	Second generation	2.84	0.12	0.01	0.031

experiment but fifth generation rotary files have shown statistically significant results compared to second generation rotary files.

DISCUSSION

Ideally, a nickel-titanium rotary endodontic file should be flexible and resistant to fracture in order to achieve the goal of non-surgical root canal therapy of prevention or resolution of apical periodontitis through proper cleaning, shaping, disinfection and sealing of the root canal system.[1] These properties influence the clinical performance of the endodontic instruments used. Therefore, it is important to have a good understanding of how the files work in order to select an appropriate instrument.

Flexibility of rotary endodontic files is a very important characteristic on which clinicians are dependent upon for cases which have curved canals. Hence, to prevent rather to treat the breakage, is the dictum among the clinicians.[21] There are multiple endodontic rotary file systems which are being developed around the world but unfortunately very few systems are marketed in Pakistani market. Dentist tends to usually stick to the tried & tested system as procuring & maintaining inventory is a difficult & an expensive exercise. Second generation rotary endodontic file system (Protaper universal system, Dentsply) is a very popular Rotary endodontic system used by the dentist & Endodontist all around Pakistan while relatively new in Pakistani market is fifth generation rotary endodontic file system (Comet SKY f6) which is being marketed in Pakistan. The files are made of a conventional austenite 55-45 Ni-Ti alloy.[23] A modified S-shaped cross-sectional design is used for the entire working part of the file. Manufacturer claims that due to double S shaped the core of the file is extremely thin which makes it extremely flexible and leads to an up to 62% lower bending moments then other NiTi files.[7] The reported incidence of separation of rotary nickel titanium instrument is 1.3%–10% in the literature, 44.3% of which are attributed to cyclic fatigue and 55.7% to torsional failure. Cyclic or flexural fatigue occurs when the instrument rotates freely in a curved canal, with repeated compression/tension cycles to the point of maximum flexure to cause fracture of the instrument.[8] Torsional fatigue failure occurs in a narrow canal, when the tip of a rotary file binds while the shank of the hand piece continues to rotate exceeding the elastic limit of the file.[24] Separated instrument compromises disinfection and obturation protocols, leading to failure of endodontic treatment. Removal of rotary nickel titanium instrument is not only challenging, but none of the retrieval systems ensure 100% success rate.[17]

The objective of our study was to compare both mentioned systems in terms of flexibility. In light of our analysis, we refute our null hypothesis as the fifth-generation endodontic file is more flexible compared to second generation endodontic file. Mean value of the Fifth-generation endodontic files was highly significant i.e., $p = 0.001$ compared to second generation endodontic file in this study. This gives very clear evidence that fifth generation rotary endodontic files can be used confidently in severely curved canal. In article Bergmans L[25] also states that fifth generation endodontic files are more flexible compared to a similarly-sized fixed tapered file, a decreasing percentage tapered file design, strategically improves flexibility, limits shaping in the body of the canal, and conserves coronal two-thirds dentin. Although author in the above-mentioned article mentioned a different variant of fifth generation endodontic file. Similarly in a study done by Muñoz E, et al the authors found out that the second generation endodontic file was less flexible ($p = 0.05$).[26] Conclusions in another study done by Elheeny AA,[27] were the same as they reported that the second generation endodontic file was less flexible but in that study the authors compared

second generation with third generation endodontic files & the grasping dimension was 3mm from the tip while in our study our grasping length was 5mm from the tip. In another study done by Gambrini[28] the authors evaluated the metallurgic aspect of second generation & fifth generation endodontic files and found out that the fifth generation files were more flexible ($p < 0.05$). In another study done by B A Hattab et al[29] compared two different generations of fifth generation endodontic files and found out that the Komet Sky system was less flexible compared to the other system. In another study done by Masoch L[30] compared third, fourth & fifth generation rotary files & found out that the fifth generation endodontic files were more flexible. In a study done by Viana A C et al compared second & third generation rotary endodontic files and found out that there was no difference in the flexibility of files ($p < 0.05$). Reason for increase in flexibility can be attributed to superior metallurgy & treatment during manufacturing.[31]

The drawback of this study is that the files were grasped at 5mm only which does not take into account curvatures along the length of the canal or the forces placed on various points along the instrument. Reason for this shortcoming was due to limitation in the design of the load sensing cell which failed to grasp the thinner diameter of the file tip at 3mm. Further a better designed load sensing cell can predict better results in future study. Due to ethical consideration this study was not conducted in vivo as that could have led to serious ethical short comings as the clinicians always prefer the vivo trials as a better proven ground. Fifth generation file system used in this study are designed for single use only while the second-generation file system can be used multiple times which has a big economical advantage over fifth generation file system. Important factor which should be considered while evaluating the flexibility of the rotary instruments are the degree of the curvature of canals, Selection of the intra canal irrigants & finally the thermal challenges a rotary file undergoes while autoclaving.

CONCLUSION

Flexibility is beneficial for maintaining the original shape of root canals, especially severe curvatures. Adequate torsional resistance and flexural fatigue resistance favor reducing the occurrence of the intracanal separation. Thus, flexibility and resistance to fracture constitute properties expected for an ideal root canal file. The results in this study demonstrated how the use of modern technologies in metallurgy has led to significant increase in flexibility in fifth generation endodontic files compared to second generation endodontic files. Of course, to confirm what we have described, further research and scientific studies are needed. Better testing methods are needed to enumerate the bending of files in actual use in curved canals. However, dentist & endodontist must follow methods based on evidence based dentistry to minimize chances of file separation. Endodontic world is seeing a revolutionary change with continuously evolving NiTi files systems, it becomes imperative for the clinicians to understand the changes in their design features, impact of thermomechanical heat treatments and kinematics on the performance of those contemporary NiTi systems, so that one can make a judicious choice based on case difficulty and the teeth that have been endodontically treated last longer in the mouth.

Authors contribution

MZA: Contributed to the conception and design of the study, assisted in data collection, and contributed to drafting the discussion and conclusion of the manuscript.

SS: Contributed to drafting the methodology, performed statistical analysis, wrote the results, and crafted the literature review of the manuscript.

AR: Contributed to data collection and assisted in drafting the literature review of the manuscript.

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Institutional ethical board approval
Ethical approval (HCM&D/HUDH/1045-23) was obtained from the research & ethics committee of Hamdard college of medicine & dentistry, Pakistan.

Informed Consent
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Availability of data and materials
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Consent for publication
Not applicable.

Disclaimer of using AI tools
Not utilized. All ideas, arguments, and conclusions presented in the article, however, are entirely the authors' original work. The authors take full responsibility for the accuracy and integrity of the content.

Conflict of Interest
No conflict of interest.

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