Motion Kinematics and Cyclic Fatigue Resistance of Nickel – Titanium Rotary Instruments - A Systematic Review

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Abstract

Rotary kinematics plays an important role in understanding the clinical use of the rotary files and the two most commonly associated terms –Torsional and cyclic fatigue. While one is associated with the binding of the tip of the file; the latter occurs in roots with high radii of curvature leading to unforeseen compression – tension of the file .With the introduction of rotary nickel - titanium files ,a plethora of rotary kinematics have helped overcome these short comings . The two most widely accepted rotary kinematis include- rotary motion and reciprocating motion.Thus, the aim of this review article is to provide a systematic analysis on the association between rotary kinematics and the cyclic fatigue resistance of Nickel – Titanium rotary instruments.

Keywords: *Titanium Rotary Files, Cyclic Fatigue Resistance, Rotary Kinematics, Reciprocating Kinematics*

1. INTRODUCTION

Removing pulp tissue remnants, microorganisms, and microbial toxins from the root canal system is essential for the success of root canal treatment (Basmadjian-Charles et al. 2002). Root canals can be cleaned by instrumentation supplemented with irrigants and intra-canal medicaments (Byström & Sundqvist 1985).As stated by de Melo Riberiro et al; 2013 ,introduction of Ni-Ti rotary instruments[1] into endodontic clinical practice has brought about improvement in the mechanical preparation of the root canal system thus eliminating the associated problems with stainless steel instruments, a few of them being perforations ,root canal transportation and ledges.[2]

Rotary Ni-Ti instrumentation can be classified into five groups according to the instrumentation kinematics applied: Rotary motion, Rotational reciprocating motion, Vertical vibration plus rotational reciprocating motion, Vertical vibration and Rotary motion plus rotational reciprocating motion (Adaptive).

However, various factors contribute to the failure of these rotary Ni-Ti instruments.

It is stated earlier by co-workers[2,3]; torsional fatigue occurs when the tip of the rotating file binds in the root canal space where as the file continues to turn .Moreover development of cyclic fatigue is associated with the file undergoing excessive compression – tension strain cycles in the region of maximum angle of curvature of the root canal space.[4]

Thus, the aim of this review article is to provide a systematic analysis on the association between rotary kinematics and the cyclic fatigue resistance of Nickel – Titanium rotary instruments.

2. SEARCH METHODOLOGY

Between March 2007 and March 2017, Medline (PubMed), Scopus, Embase and Google Scholar databases were searched, using the terms such as (Ni – Ti) Nickel – titanium rotary files; rotary and reciprocating motion; torsional and cyclic fatigue. Seventy five articles could be collected after electronic and manual search processes. Screening of the articles were done, followed which articles were eliminated not meeting the search objective. The articles required to demonstrate correlation between rotary and reciprocating file movements and the association of cyclic fatigue. The current review article is laid based on twenty articles.

Table 1. Inclusion and exclusion criteria	
Inclusion Criteria	**Exclusion Criteria**
1. Articles described in vitro studies performed on either extracted fully formed human teeth or an artificial canal model 2. Articles that assessed rotary and reciprocating instruments 3. Articles that assessed cCylic fatigue resistance of roary and reciprocating Ni - Ti rotary endodontic files	1. Tools adapted from an original tool. 2. Articles that did not to meet any of the inclusion criteria

3. LITERATURE REVIEW

Cyclic fatigue has been considered as one of the most leading causative factor for failure of Ni-Ti instruments.[5] As stated by[6] the most suitable tests for rotary Ni Ti files, for investigations of cyclic fatigue is the Dynamic pecking Motion tests,whereas the static tests are not truly able to replicate the clinical practice conditions. Formation of these dynamic systems incorporate specific torque and speed values for the preparation of root canal system. Lifespan of the rotary files is increased by reducing the maximum stress on the surface caused during continuous tension that is used in models of static motion.[7] A fundamental factor that prevents the fracture of the file, even in curved canals ,reducing the stress produced in the rotating files is lied on the fact of use of file in the pecking motion.[8]

Reciprocating kinematics has been developed to increase the performance and safety of the rotary files. Initially, the reciprocating motors rotated files in large equal angles of 90° clockwise (CW) and counter clockwise (CCW) rotation. However, over time, all reciprocating systems utilized smaller and equal, angles of CW/CCW rotation. In 2008, Dr.Yared introduced unequal CW/CCW angles. This lower stress which is induced by the reciprocating motion thus enables the clinician to use a single Ni-Ti file to prepare the entire root canal space.

Earlier studies evaluated the resistance of cyclic fatigue of ProTaper F2 instrument which is used under reciprocating motion in an artificial canal, speed 250 and 400 rpm tested by static testing equipment. Various studies inferred, cyclic fatigue resistance significantly improved with reciprocating motion when compared to conventional rotation[9] Co-workers did a study to investigate the cyclic fatigue resistance of Ni-Ti endodontic files of continuous rotation GT-Series X, K3 ProFile and safe sider reciprocating instrument in an artificial stainless steel canal with varying angles of cur[3]vature and radii of curvature under static testing devices. Angles of curvatures 30^0 and 45^0 and radii of curvature 5 and 7.5 mm. It was concluded that lifespan of safe sider files were longer in comparison to continuous rotation instruments.[3]

Fatigue resistance of file size 25.0.08 taper Protaper F2,Twisted file and wave one were evaluated under different kinematics ,designed in static testing equipment. The study concluded with results of wave one with extended cyclic fatigue resistance in comparison to the conventional rotary which is used for the motion of Twisted File and Protaper file system.[10]

With the help of a dynamic device setup, the cyclic fatigue resistance of Reciproc R25 files were tested in continuous rotation motion and reciprocating motion at a speed of 300 rpm to produce pecking motion thereby simulating a clinical condition in a curved canal, curvature of 40^0 and radii of curvature 5mm.The outcome predicted increased cyclic fatigue resistance of the files used in reciprocating motion in comparison to continuous motion.[11,7]

Under custom made static set up, three file systems were tested-Reciproc and Wave One in reciprocating motion and ProTaper F2 in rotaion ,the outcome predicted greater number of cycles to fracture of the reciprocating file system – Rreciproc than other file system.Moreover both the file systems used I reciprocating motion showed incresed cyclic fatigue resistance than rotating file.[12]

Evaluation of 4 types of movement kinematics were done. Out of the different movements, some were made to perform continuous rotation at the speed of 300 rpm, while others were run in reciprocation 150^0 CW/ 30^0 CCW or 30^0 CW/ 150^0 degrees CCW. All these systems were run until fracture, in a simulated root canal space with angle of curvature 60^0 and the radii of curvature of 3mm and width 1.5mm under static device setup conditions. The outcome predicted greater cyclic fatigue resistance of files with size 25, 0.08 taper Twisted files when compared to conventional rotary file movements.[13]

The resistance to cyclic fatigue of size 40, 0.04 taper Hyflex Ni-Ti in both motions of continuous rotary and reciprocating were evaluated. This test was performed using a stainless-steel artificial canal with the angle of curvature of 135^0. Two motions of continuous rotation or reciprocation were used (150^0 CCW/ 30^0 CW at 300 rpm). The predictable results concluded with greater cyclic fatigue resistance of reciprocating motion.[14]

Files with size 30, 0.06 taper Twisted K3XF (Sybron Endo Corporation) were tested at different movement kinematics (reciprocating motion and continuous rotating motion at 300 rpm or 500rpm). The results showed that the R-phase file, K3XF was more resistant than a Ni-Ti file under continuous rotation, whilst reciprocating motion increased the cyclic fatigue resistance of all the instruments tested.[15]

The cyclic fatigue resistances of size 25, 0.06 taper reciprocating files, Reciproc in 'RECIPROC ALL', mode and Waveone in 'WAVE ONE ALL mode ,also Mtwo(VDW) and Twisted file(Sybron Endo Corporation) were performed in the continuous rotation movement kinematics. It was observed that files used in reciprocation movement kinematics had greater cyclic fatigue resistance when compared to files performing in rotation movement.[13]

File size of 25 and 40 of different file systems, Mtwo and Reciproc were performed in continuous rotation and reciprocating motion in an up and down pecking motion with dynamic testing methods, therefore, aiming to replicate clinical conditions. Movement kinematics of the file followed manufacturer's instructions (1.4mm in diameter, 60^0 angle of curvature and 5mm radii of curvature) in a stainless-steel model. Cyclic fatigue of Reciproc-Reciprocating instrument was improved in comparison to Mtwo rotary movement[16].

File of size 25, 0.06 taper Race[17] and rotary file Mtwo were used in reciprocating and rotating movement kinematics respectively using a static device for the test of cyclic fatigue with 60 degrees curvature and radii of curvature of 5mm. It was observed that files used in reciprocating movement showed extended fatigue resistance.[18]

The cyclic fatigue resistances of several Ni-Ti instruments designed to operate in reciprocating mode (OneShape, Reciproc25, and WaveOne Primary and the ProTaperF2) were tested. The instruments were tested in curved artificial canals with different angles and radii of curvature (60°/8 mm, 45°/8 mm, 60°/5 mm and 45°/5 mm) .It was seen that continuous rotation instruments had a lower cyclic fatigue resistance.[19]

Cyclic fatigue of files designed to perform in reciprocation were tested. These included Wave

One Primary, One Shape, Reciproc25 and ProTaper F2. These files were investigated in artificial canals with various angles of curvature and different radii. The resistance of cyclic fatigue of reciprocating motion files were improved in comparison to rotary file systems.[20]

One Shape (Micro-Mega SA) and Wave One, two reciprocating file systems were evaluated for their resistance to cyclic fatigue using varying motions (150^0 CW/ 30^0 CCW, 210^0 CW/ 30^0 CCW and 360^0 CW/ 30^0 CCW) and continuous rotation. All the instruments with reciprocating kinematics showed greater fatigue life when compared to rotary kinematics.[21]

4. DISCUSSION

Most of the Ni-Ti rotary systems move in a continuous rotation. However, as in many other systems, the Ni-Ti rotary system appears to have some drawbacks.[22] When rotating in curved canals, it may lead to cyclic fatigue, resulting into fracture and file separation due to repeated tensile-compressive forces being applied to the file in maximum curved areas. In some cases, using Ni-Ti files can also be time consuming because they may require multiple exchanges of file sizes; some of these files need prior glide path preparation done with hand files.[23,24,25]

This led to the revolution of single-file Ni-Ti reciprocating systems, which has been adopted by Dr. Yared. This concept has many advantages over the conventional rotary Ni-Ti systems: (1) greater time efficiency because it requires only a single file to prepare all the canals with no requirement for prior glide path preparation; (2) single files are made from M-wire (heated Ni-Ti alloy) that give them the greatest flexibility and cyclic fatigue resistance; and (3) reciprocating systems, which move in rotating reciprocation movements (balanced force) with large rotating angles. One movement is counter-clock wise, which engages and cuts dentin, and the other is clock-wise, which disengages the file from the dentin to avoid taper lock and relieves stress on the file.[26,27] This type of movement prevents file breakage and increases its resistance to both cyclic and torsional fatigue.[28,29]

However, there are various other factors that can influence the resistance to cyclic fatigue which include the diameter, metal mass, flexibility, cross-sectional shape, and surface finish of rotary files which act as confounding factors[13, 30, 31] and could be considered in future studies. Moreover, most studies were carried out under static and in-vitro conditions which does no replicate clinical conditions. Thus, further studies concerning the same have to be carried out.[32]

5. CONCLUSION

The field of Endodontics has undergone tremendous changes from the use of Stainless steel files to Ni-Ti and in the manner in which these endodontic instruments are driven i.e. in rotary and reciprocating motion. Endodontic instruments used in reciprocation is not a new concept, but in the recent past it has gained more popularity because of changes in the design shape and metallurgy of NI-Ti instruments which can be used in reciprocating motion. Thus, within the limitations of this review article, it was seen that reciprocating instruments were the most fatigue resistant when compared with a conventional Rotary instrument.

REFERENCES

1. Bergmans L, Van Cleynenbreugel J, Wevers M, Lambrechts P. Mechanical root canal preparation with NiTi rotary instruments: rationale, performance and safety. Am J Dent. 2001;14(5):324–33.
2. Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. J Endod. 2006;32(11):1031–43.
3. Wan J, Rasimick BJ, Musikant BL, Deutsch AS. A comparison of cyclic fatigue resistance in reciprocating and rotary nickel-titanium instruments. Aust Endod J. 2011;37(3):122–7.
4. Sattapan B, Palamara JEA, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod. 2000;26(3):156–60.

5. Dederich DN, Zakariasen KL. The effects of cyclical axial motion on rotary endodontic instrument fatigue. Oral surgery, oral Med oral Pathol. 1986;61(2):192–6.
6. Pessoa OF, Silva JM da, Gavini G. Cyclic fatigue resistance of rotary NiTi instruments after simulated clinical use in curved root canals. Braz Dent J. 2013;24(2):117–20.
7. Kawakami DAS, Candeiro GT de M, Akisue E, Caldeira CL, Gavini G. Effect of different torques in cyclic fatigue resistance of K3 rotary instruments. Brazilian J Oral Sci. 2015;14(2):122–5.
8. Li U-M, Lee B-S, Shih C-T, Lan W-H, Lin C-P. Cyclic fatigue of endodontic nickel titanium rotary instruments: static and dynamic tests. J Endod. 2002;28(6):448–51.
9. De-Deus G, Moreira EJL, Lopes HP, Elias CN. Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement. Int Endod J. 2010;43(12):1063–8.
10. Castelló-Escrivá R, Alegre-Domingo T, Faus-Matoses V, Román-Richon S, Faus-Llácer VJ. In vitro comparison of cyclic fatigue resistance of ProTaper, WaveOne, and Twisted Files. J Endod. 2012;38(11):1521–4.
11. Gavini G, Caldeira CL, Akisue E, de Miranda Candeiro GT, Kawakami DAS. Resistance to flexural fatigue of Reciproc R25 files under continuous rotation and reciprocating movement. J Endod. 2012;38(5):684–7.
12. Arslan H, Alsancak M, Doğanay E, Karataş E, Davut Çapar İ, Ertas H. Cyclic fatigue analysis of R eciproc R 25® instruments with different kinematics. Aust Endod J. 2016;42(1):22–4.
13. Pedullà E, Grande NM, Plotino G, Gambarini G, Rapisarda E. Influence of continuous or reciprocating motion on cyclic fatigue resistance of 4 different nickel-titanium rotary instruments. J Endod. 2013;39(2):258–61.
14. 14.Rubini AG, Sannino G, Pongione G, Testarelli L, Al Sudani D, Jantarat J, et al. Influence of file motion on cyclic fatigue of new nickel titanium instruments. Ann Stomatol (Roma). 2013;4(1):149.
15. Pérez-Higueras JJ, Arias A, José C. Cyclic fatigue resistance of K3, K3XF, and twisted file nickel-titanium files under continuous rotation or reciprocating motion. J Endod. 2013;39(12):1585–8.
16. Kiefner P, Ban M, De-Deus G. Is the reciprocating movement per se able to improve the cyclic fatigue resistance of instruments? Int Endod J. 2014;47(5):430–6.
17. Mejàre IA, Axelsson S, Davidson T, Frisk F, Hakeberg M, Kvist T, et al. Diagnosis of the condition of the dental pulp: A systematic review. Int Endod J. 2012;45(7):597–613.
18. Vadhana S, SaravanaKarthikeyan B, Nandini S, Velmurugan N. Cyclic fatigue resistance of RaCe and Mtwo rotary files in continuous rotation and reciprocating motion. J Endod. 2014;40(7):995–9.
19. Dagna A, Poggio C, Beltrami R, Colombo M, Chiesa M, Bianchi S. Cyclic fatigue resistance of OneShape, Reciproc, and WaveOne: An in vitro comparative study. J Conserv Dent JCD. 2014;17(3):250.
20. Da Frota MF, Espir CG, Berbert FLC V, Marques AAF, Sponchiado-Junior EC, Tanomaru-Filho M, et al. Comparison of cyclic fatigue and torsional resistance in reciprocating single-file systems and continuous rotary instrumentation systems. J Oral Sci. 2014;56(4):269–75.
21. Karataş E, Arslan H, Büker M, Seçkin F, Çapar ID. Effect of movement kinematics on the cyclic fatigue resistance of nickel–titanium instruments. Int Endod J. 2016;49(4):361–4.

22. Mesgouez C, Rilliard F, Matossian L, Nassiri K, Mandel E. Abstract. Int Endod J. 2003;36(3):161–5.
23. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. Int Endod J. 2008;41(4):339–44.
24. Yared G, Dagher FEB, Machtou P. Cyclic fatigue of ProFile rotary instruments after clinical use. Int Endod J. 2000;33(3):204–7.
25. Yared G. In vitro study of the torsional properties of new and used ProFile nickel titanium rotary files. J Endod. 2004;30(6):410–2.
26. Zelada G, Varela P, Martín B, Bahíllo JG, Magan F, Ahn S. The effect of rotational speed and the curvature of root canals on the breakage of rotary endodontic instruments. J Endod. 2002;28(7):540–2.
27. Nguyen HH, Fong H, Paranjpe A, Flake NM, Johnson JD, Peters OA. Evaluation of the resistance to cyclic fatigue among ProTaper Next, ProTaper Universal, and Vortex Blue rotary instruments. J Endod. 2014;40(8):1190–3.
28. Bhagabati N, Yadav S, Talwar S. An in vitro cyclic fatigue analysis of different endodontic nickel-titanium rotary instruments. J Endod. 2012;38(4):515–8.
29. Campbell L, Shen Y, Zhou H, Haapasalo M. Effect of fatigue on torsional failure of nickel-titanium controlled memory instruments. J Endod. 2014;40(4):562–5.
30. Plotino G, Grande NM, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. Int Endod J. 2012;45(7):614–8.
31. Gambarini G, Plotino G, Sannino G, Grande NM, Giansiracusa A, Piasecki L, et al. Cyclic fatigue of instruments for endodontic glide path. Odontology. 2015;103(1):56–60.
32. Caviedes-Bucheli J, Castellanos F, Vasquez N, Ulate E, Munoz HR. The influence of two reciprocating single-file and two rotary-file systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. A systematic review and meta-analysis. Int Endod J. 2016;49(3):255–70.