



A REVIEW OF MECHANICAL FACTORS AFFECTING SUCCESS RATE OF ROOT CANAL TREATMENT IN ENDODONTICS

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Manuscript History

Number: **IJIRAE/RS/Vol.06/Issue04/APAE10090**

Received: 12, April 2019

Final Correction: 21, April 2019

Final Accepted: 28, April 2019

Published: **April 2019**

Citation: Bobhate & Kulloli (2019). A REVIEW OF MECHANICAL FACTORS AFFECTING SUCCESS RATE OF ROOT CANAL TREATMENT IN ENDODONTICS. IJIRAE::International Journal of Innovative Research in Advanced Engineering, Volume VI, 327-333. doi://10.26562/IJIRAE.2019.APAE10090

Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India

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Abstract— The aim of this review article was to review the past literature on fatigue analysis of root canal rotary instruments, heat treatments and qualitative techniques used to assess the performance/success of root canal treatment. The article covers the interdisciplinary aspects viz. mechanical and endodontics. Fatigue is responsible for the failure of the 80% of the endodontic file. Under clinical use the fatigue is closely linked with fracture mechanism of endodontic files. During the use of nickel-titanium endodontic file in the canal the file is subjected to torsion, flexion, traction and apical pressure in the root canal curvature, due to which fatigue failure of rotary files takes place. There is large effect of the autoclave on the endodontic file life. The success rate of the root canal treatment depends upon various promising factors such as micro-leakage, percentage filling of root canal, ability of endodontic file to maintain roughness of root canal wall, density of filling, heat treatment process, geometrical parameters of endodontic files. The review article summarizes the review of 36 No's of research articles downloaded from reputed journal. The 36 research papers were shortlisted from 200 No's of research papers by reading their abstracts. The review concluded that the finite element analysis studies of endodontic file are static and requires validation. This review article is helpful for dental practitioners, students, novice researchers, decision makers in the field of the Endodontics.

Keywords— Root canal preparation; endodontic file; rotary instruments; quality assessment;

I. INTRODUCTION

The root canal treatment is done to save the infected or partially damaged teeth. In dentistry, root canal treatment is known as obturation. The process of obturation consist of the filling of the root canal cavity using heated and softened gutta-percha to get the fluid tight seal in between the canal wall and filled gutta-percha. Any obturation process requires the preparation of the root canal which involves the removing dead tissue, substrates and debris from the decayed root canal. The nitinol made fillers are used to perform the preparation process [1]. During root canal preparation the rotary files are firstly placed into the canal and during the placement of files for cutting purpose the files should rotate in counter-clockwise direction and for instrument removal the direction of rotation should be reversed [2].

This should be done for all reciprocating rotary file during preparation of canal. The clockwise and counter clockwise direction is required to be followed by rotary files during preparation of canal with the reciprocating motion. Moreover, if the cyclic fatigue resistance is less for the particular file then its life also will get enhanced. The nitinol and M wire files possess less cyclic fatigue resistance, more life, and good shaping ability [3].

Fatigue is progressively, confined structural destruction caused to Endodontic file subjected to periodic loading. If applied loads are higher than design load, microscopic crack begins forming stress concentrators such as slip bands which propagates suddenly to cause fatigue failure [4]. The fatigue stress value to cause such damage may be less than ultimate tensile limit or yield limit. The ASTM standard described, fatigue life as number of cycles completed by the specimen before failure occurs [5]. The S-N curve is plot of alternating stress verses number of cycles to failure for a given material of M-wire. Typically both the ordinate and abscissa are plotted with logarithmic scale. Knowing the S-N curve and load-time history one can use the Miner's rule to determine the fatigue life of rotating component. In 1842, the scientist August Wohler's investigation resulted to S-N curve.



Fig. 1 Phases of fatigue life for nitinol file

II. A REVIEW OF NITINOL ALLOY'S ENDODONTIC FILE STUDIES

The contemporary literature on the nitinol alloy studies are categorized in two broad groups viz. experimental studies and numerical studies. The experimental studies carried consist of the fatigue life analysis of nitinol file using either strain life, stress life or fracture mechanics approach. While the numerical studies involves the use of numerical methods such as finite element analysis and computational fluid dynamics. Let us discuss the contemporary experimental and numerical studies in following section.

A. Experimental studies

The nitinol alloy have improved the preparation of the root canal by eliminating the difficulties associated with stainless steel files, such as zips, canal transportation, ledges and perforation etc.[6]. The capacity of the rotary instrument to develop logical cavity that every practitioner can fill effectively with minimum duration are studied in number of the researches [7] Peters et al. [8] reported that torsional fatigue occurs because of rotary files continues to rotate when its tip is blocked in the root canal cavity. Pruett et al. [9] found that flexural fatigue failure occurs when instruments rotation continues in the root canal cavity with large number of tension and compression strain cycles in larger curvature canal. Gao et al. [10] recommended in his study to use files made from R phase and M wire nickel titanium and used reciprocating motions. The cyclic fatigue resistance offered by new files is higher than conventional files. Yared et al. [11] used the instruments with reciprocating motion where in file rotates in one direction to complete half rotation and in reverse direction for remaining half. Plotino et al.[12] compared the efficiency of the continuous motion files and reciprocating files. He had taken cyclic fatigue resistance, cutting efficiency and time taken to prepare the cavity. But later on his studies continued to be debate. Yared et al. [13] found in his another investigation that continuous rotary motion of rotary file, there are higher probability that files get damaged due to torsional stress or cyclic fatigue. Peters et al. [14] found that cyclic fatigue occurs due to free instruments rotation in canal cavity with repeated impact of tension-compression at tip of instrument. Pruett et al. [15] found that cyclic fatigue occurs primarily because of curved cavity and small radius of curvature and instruments gets subjected to tension-compression cycles at point of sharp curvature.

B. Experimental studies

Alessandro scattina et al. [16] used finite element method to study the stress distribution in the Ni-Ti rotary instruments. The study failed to assess the number of cycles to failure. The study used virtual model to calculate the number of cycles to failure and finding out the locations of failure. Diogo Montalvao et al. [17] used finite element method for analysis of cyclic performance Ni-Ti rotary files made up of different materials. Jung-Hong Ha et al. [18] conducted finite element analysis to study the effect of the geometric design on mechanical performance of Ni-Ti rotary files. By varying the cross section of the selected rotary files, authors studied the effect of off centred cross-section on stiffness and stress.

III. A REVIEW OF EFFECT OF AUTOCLAVE ON ENDODONTIC FILES PERFORMANCE

Caroline R. A. Valois et al. conducted study to evaluate the surface of rotary nickel-titanium endodontic files upon the multiple autoclave cycles. The Greater taper and Protaper files were selected for 1, 5 and 10 autoclave cycles under the atomic force microscope. The 15 points on the file profiles were considered, initially being control before autoclaving. The topographic parameters: arithmetic mean roughness, maximum height, and root mean square were measured. These parameters were differentiated on the basis of ANNOVA and Turkey test. The study concluded, the multiple autoclave cycle affects on the surface irregularities and greatly increase depth of it [19]. Heather L. Gnau et al. assess the percentage of new endodontic files (taken directly from the manufacturers' packages) that were contaminated with viable microorganisms and to determine the amount of time new files needed to be immersed in 6% sodium hypochlorite to achieve sterility. New files demonstrated a 6% contamination rate and none of the immersion times in NaOCl achieved file sterility [20]. Spiros Zinelis et al. evaluated the fracture mechanism of H-files (Hedstroem), were embedded in a resin along their longitudinal axis and after metallographic grinding and polishing studied under an incident light microscope. The unused files were free of structural defects however fractured H-files indicated the presence of many cracks, maximum located at flute depth on file profile. Secondary cracks initiated beyond the plane of fractures. Under clinical use the fatigue is closely linked with fracture mechanism of Hedstroem files [21]. Rafael Hof et al. done the mechanical analysis of self adjusting files to explore the mechanical properties. He found that self adjusting files are elastically compressible and effectively removes the dentin and can mechanically endure with minimum loss of efficacy [22]. Matthew Thompson et al. conducted study to evaluate the latest file's system ability to maintain the morphology of root canal wall to be prepared. The study used Hyflex CM and the ProFile ISO filing systems, tested into the acrylic practice blocks of 45° root canal curvature. Even after the autoclave cycles, Hyflex CM and the ProFile systems maintained equal and original canal morphology [23].

IV. A CONTEMPORARY REVIEW OF GUTTA-PERCHA QUALITY ASSESSMENT TECHNIQUES STUDIES

The root canal treatment is done after the preparation of root canal to get perfect fluid tight seal to avoid the infection. The success rate of root canal treatment is dependent on the quality of the filling using gutta-percha. In last decade the various studies investigated the approaches to test the quality of filled root canals using gutta-percha. The various test techniques involves micro-computed tomography, apical dye penetration, radiography, scanning electron microscopy, cone beam computed tomography etc are qualitative techniques. The various numerical techniques were used viz. finite element method and computational fluid dynamics. The quality assessment of dense gutta-percha involve the use of qualitative, quantitative, numerical and analytical methods, the details of which are shown in figure 3.

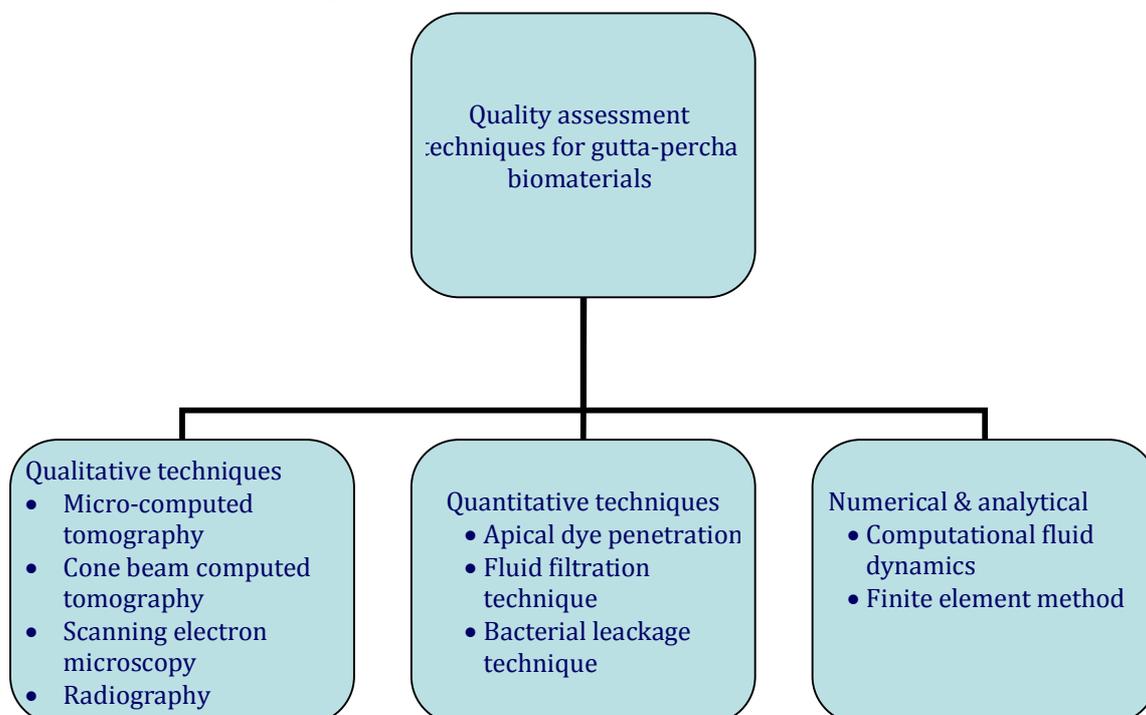


Fig. 2 Classification of gutta-percha quality assessment techniques

TABLE I - REVIEW OF CONTEMPORARY GUTTA-PERCHA ROOT CANAL FILLING QUALITY ASSESSMENT STUDIES

Author and Year	Objectives	Technique	Outcome of research	Future scope	Inference
Mohmmd et al. (2009). [24]	To measure percentage of filling of obturated canal with different biomaterial.	Micro computed tomography	The root canal obturation using gutta-percha gives good quality void less filling	There is need to conduct the clinical study on animal for validation of result.	The micro computed tomography is qualitative assessment technique. Gives considerably good results.
Christos et al. (2010). [25]	To study the influence of needle tip design on irrigation flow in obturated root canal.	Computational fluid dynamics	There is difference in flow pattern for open and close ended needle recorded.	The influence of parameters viz. depth, root canal geometry, taper can be studied.	CFD can be used for study of structure fluid interaction in gutta-percha filling.
Gin et al. (2011). [26]	To evaluate sealability of various post space preparation and obturation techniques.	Apical dye penetration test	Sealability of lateral compaction technique is inferior to vertical compaction.	For accurate outcome of apical sealing ability for gutta-percha the investigation need to be continued.	The results obtained using apical dye penetration tests are non-repeatable and challengeable.
Damir et al. (2012) . [27]	To study the irrigant flow using CFD.	Computational fluid dynamics	The root canal shape of canine is valid for computational fluid dynamic study.	Nil	Conversion of STL file into CAD supported software is possible.
Agnes et al. (2012). [28]	To develop the analytical model describing mechanical behaviour of Ni -Ti rotary files during canal preparation.	Analytical method	The analytical model described is helpful to study the instrument damage	Nil	The mathematical model prepared will provide useful inputs to optimization study.
Matteo et al. (2013). [29]	To assess the quality of root canal treatment performed by dental student with Ni-Ti instrument in to and fro motion.	Radiography, SEM investigations	The use of the files in reciprocating motion is recommended.	The reciprocating motion of Ni-Ti can be implemented.	The results are limited to qualitative technique. Quantitative methods can be used for study.
Daniele et al. (2013). [30]	To quality of filling in canal using micro CT under consideration of post insertion effect.	Micro-Computed Tomography	The root canal obturation techniques under consideration showed higher rate of filling with similar void distribution	Clinical studies are needed to perform for confirming laboratory findings.	The results are limited to qualitative technique. Quantitative methods can be used for study.
Diogo et al. (2014). [31]	To analyse the cyclic fatigue behaviour of two different nitinol endodontics rotary files made from different alloys.	Finite element analysis (static)	The cyclic fatigue behaviour of different nickel-titanium files have been recorded.	Nil	Helps to create CAD models. The study is static and hence dynamic study can be done for more accurate result.

Nicola et al. (2015). [32]	To assess the quality of canal preparation using nickel-titanium files.	Micro computed tomography	The nickel-titanium files are best suitable for molar teeth preparation	Nil	The results are limited to qualitative technique. Quantitative methods can be used for study.
Ruyan et al. (2015). [33]	To study irrigation flow pattern for root canal using single vent needle.	Computational fluid dynamics	Micro-CT is best suitable method in conjunction with CFD for studying irrigant flow pattern.	Nil	Boundary conditions given can be used as input for proposed CFD study.
Amir et al. (2015). [34]	To assess the filling of lateral compaction and single cone techniques using gutta-percha.	Micro computed tomography	The single cone and lateral compaction techniques given different voids.	Evaluation of impact of finding of research for long term outcome of obturation needs to be studied.	Unfilled obturated canal zones leads to micro leakage.
Ana et al. (2016). [35]	To detect the fractured nitinol instruments in filled and unfilled root canals.	Radiography and cone beam computed tomography	The instrument fracture is found and CBCT shows less accuracy than the radiography.	Nil	The detection of fractured instruments are done using CBCT and radiography. Fatigue study can be done for life calculation.
Jung et al. (2017). [36]	To evaluate the effect of off-centred cross-sectional designs on stress pattern of nitinol rotary file.	Finite element analysis	The ProTaper Next based off-centred designs is most efficient in flexural response which is clinically desirable.	Evaluation is needed to be carried out while files are rotating in canal lumen.	Helps to create CAD models. The study is static and hence dynamic study can be done for more accurate result.
Mothanna et al. (2017). [37]	To assess the quality of root canal obturation performed by undergraduate dental student.	Radiography	There is variation in the technical quality was observed.	The research should be done more than once to assess the performance of undergraduate dental student.	The results are limited to qualitative technique. Quantitative methods can be used for study.

V. DISCUSSION

The aim of this review article was to review the past literature on fatigue analysis of root canal rotary instruments, heat treatments and qualitative techniques used to assess the performance/success of root canal treatment. The article covers the interdisciplinary aspects viz. mechanical and endodontics. The past studies lacks the exact knowledge about fatigue failures as well as analysis approaches to be followed for correct diagnosis of nitinol made instruments failure. This review article helps to overcome these difficulties. Moreover, the fatigue factors are discussed so that researcher can get idea about failure modes and contributing factor of the nitinol rotary files. The success rate of root canal treatment is dependent on the quality of the filling using gutta-percha. In last decade the various studies investigated the approaches to test the quality of filled root canals using gutta-percha. The various studies reviewed includes test techniques such as micro-computed tomography, apical dye penetration, radiography, scanning electron microscopy, cone beam computed tomography etc are qualitative techniques. The various numerical techniques were used viz. finite element method and computational fluid dynamics.

VI. CONCLUSIONS

The review article conclude that the finite element analysis studies of endodontic file, performed earlier, are static and requires validation by experimental method. This review article is helpful for dental practitioners, students, novice researchers, decision makers in the field of the Endodontics.

ACKNOWLEDGMENT

Author acknowledges the support and guidance received from Dr. Sameer K. Jadhav, PG Teacher, Department of Endodontics and Conservative Dentistry, M. A. Rangoonwala College of Dental Sciences and Research Centre Pune, India.

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