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Effect of Heat on Surface Changes and Fracture Resistance of NiTi Rotary files: A systematic Review on Implications in Endodontic Practice.

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KEYWORDS

Surface changes, Fatigue Resistance, Autoclave, Sterilization , NiTi Rotary File

ABSTRACT:

Introduction: NiTi rotary files are not immune to challenges, particularly during clinical use. One of the major concerns associated with their application is the generation of heat during root canal preparation.

Objectives: The objectives of this review encompass a thorough assessment of alterations in surface characteristics, such as roughness and topography, of NiTi rotary files following heat exposure.

Methods: This systematic review was conducted following a predetermined protocol, which was registered on the Open Science Framework (OSF) to ensure transparency and accountability in the review process. The research question was formulated using the PICO framework. A comprehensive literature search was conducted to identify relevant studies from various information sources. The following databases were systematically searched, screnner. All the data collected was then extracted.

Results: All the data was then extracted and this review concluded that autoclave sterilization of newer rotary endodontic instruments could increase resistance to cyclic fatigue but the difference observed are not that significant pertaining to all the limitations of this review.

Conclusions: In conclusion, the findings of this systematic review highlight the significant impact of autoclave heat on the surface roughness and fracture resistance of NiTi rotary files. The alterations in surface characteristics and mechanical properties induced by autoclave exposure can influence the files' clinical performance and lifespan.

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1. Introduction

Root canal therapy is a crucial procedure in endodontic practice aimed at preserving and restoring the health of the dental pulp. Central to this process is the use of nickel-titanium (NiTi) rotary files, which have revolutionized root canal instrumentation due to their remarkable mechanical properties, including high flexibility, superior fracture resistance, and shape memory characteristics [1]. These files have significantly improved the efficiency and predictability of root canal treatment, making them a fundamental tool in contemporary endodontics.

Despite their exceptional attributes, NiTi rotary files are not immune to challenges, particularly during clinical use. One of the major concerns associated with their application is the generation of heat during root canal preparation. The interaction between the rotating file and the dentin can lead to heat accumulation, which, if uncontrolled, may result in detrimental consequences for the files themselves and the overall success of endodontic treatment [2]. The heat generated can potentially induce phase transformations in the NiTi alloy, altering its microstructure and mechanical properties [3].Studies have reported that heat accumulation during root canal instrumentation can lead to surface changes in NiTi rotary files, such as alterations in surface roughness and topography [4]. These surface modifications could influence the files' cutting efficiency and contact with dentin, affecting their overall performance during the preparation process [5]. Moreover, heat-induced changes in the microstructure may also influence the fatigue resistance and fracture behavior of NiTi rotary files, thereby impacting their clinical longevity and reliability [6].

To address these concerns and enhance our understanding of the effects of heat on NiTi rotary files, numerous investigations have been conducted [7][8][9]. However, there exists considerable variation in methodologies and contradictory findings among individual studies, necessitating a comprehensive evaluation of the available evidence. Thus, the purpose of this systematic review is to critically analyze and synthesize the existing body of literature to determine the impact of heat on surface changes and fracture resistance of NiTi rotary files.

2. Objectives.

The objectives of this review encompass a thorough assessment of alterations in surface characteristics, such as roughness and topography, of NiTi rotary files following heat exposure [10]. Additionally, the review will delve into the changes in mechanical properties and fracture resistance resulting from heat-induced stress, investigating the potential factors influencing the magnitude of heat generation and its subsequent effects on the performance of NiTi rotary files [11]. By elucidating these essential aspects, this systematic review aims to offer valuable insights into the behavior of NiTi rotary files under heat-induced conditions, providing valuable guidance for their optimal clinical use and enhancing treatment outcomes in endodontic practice.

In conclusion, nickel-titanium (NiTi) rotary files play a fundamental role in modern endodontics, facilitating efficient and effective root canal preparation. However, the potential impact of heat generation during their clinical application poses a significant concern. Understanding the effects of heat on surface changes and fracture resistance of NiTi rotary files is paramount to ensure their reliable performance and longevity. Through a comprehensive synthesis of the existing literature, this systematic review endeavors to shed light on this critical aspect, contributing to the advancement of endodontic practice and the improvement of patient care.

3. Methods

1.1. Protocol Registration:

This systematic review was conducted following a predetermined protocol, which was registered on the Open Science Framework (OSF) to ensure transparency and accountability in the review process. (https://doi.org/10.17605/OSF.IO/C9SNZ)

1.2. Research Question:

The research question was formulated using the PICO framework.

Population: Studies involving nickel-titanium (NiTi) rotary files used in endodontic treatments.

Intervention: Exposure of NiTi rotary files to heat during root canal preparation.

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Comparison: None (as this is a systematic review, both experimental and control groups from primary studies will be included).

Outcome: Surface changes and fracture resistance of NiTi rotary files.

1.3. Information Sources and Search Strategy:

A comprehensive literature search was conducted to identify relevant studies from various information sources. The following databases were systematically searched:

PubMed, Lilac, Proquest, Ebsco, Google Scholar.

The search strategy utilized a combination of keywords and Medical Subject Headings (MeSH) terms related to "heat," "surface changes," "fracture resistance," and "nickel-titanium rotary files." “autoclave” Fatigue,” “Cyclic fatigue,” “Fatigue resistance,” “Flexural fatigue,” “Fracture resistance,” “Nickel titanium,” “Niti,” “Nitinol,” “Rotary.” Boolean operators (AND, OR) were used to combine relevant search terms to ensure comprehensive coverage of the literature.

1.4. Selection Process:

The process of study selection was conducted in two stages: title/abstract screening and full-text assessment. Two independent reviewers screened the titles and abstracts of retrieved articles to identify potentially relevant studies. Articles that met the inclusion criteria or required further evaluation were selected for full-text assessment. Any disagreements between reviewers were resolved through discussion or consultation with a third reviewer.

Inclusion Criteria:

Studies evaluating the effect of heat on surface changes and fracture resistance of NiTi rotary files.

Experimental or observational studies (e.g., randomized controlled trials, cohort studies, case-control studies, and experimental studies).

Studies published in peer-reviewed journals.

Studies in English language.

Exclusion Criteria:

Studies not relevant to the research question.

Animal studies, reviews, case reports, and conference abstracts.

1.5. Risk of Bias Assessment:

The domains listed below were used: (1) sample standardization, (2) sample size calculation, (3) sample randomization, (4) single-operator, (5) blinding, (6) testing model standardization, and (7) appropriate statistical analysis. The domains were categorized as “+” to specify a low risk of bias (RoB) and “-” to indicate a high RoB. The articles were classed as having a low RoB if they had six or more domains classified as low (+), a moderate RoB if four or five domains were classified as low, and a high RoB if only three or fewer domains were classified as low.

1.6. Data Extraction:

Data extraction was performed using a standardized data extraction form. The following data were extracted from each included study:

Study characteristics (authors, publication year, study design)

Participants' characteristics

Intervention details (heat exposure protocol)

Outcome measures (surface changes and fracture resistance of NiTi rotary files)

Key findings

1.7. Data Synthesis and Analysis:

A narrative synthesis of the findings from the included studies was performed due to the anticipated heterogeneity among the primary studies. The results were organized and presented in a tabular format to facilitate easy comparison and interpretation.

1.8. Ethics and Conflicts of Interest:

As this systematic review involved the analysis of existing literature, ethical approval was not required. All

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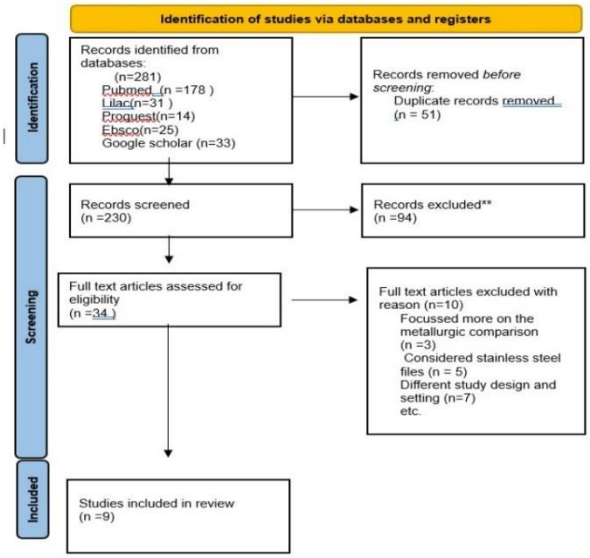
potential conflicts of interest were declared and managed in accordance with ethical guidelines.

4. Results

Study Selection

Figure 1 presents a flowchart of the systematic review process. A total of 9 studies met the criteria for the inclusion.



5. Discussion

Niti (Nickel-Titanium) rotary files have revolutionized the practice of endodontics, playing a pivotal role in enhancing the efficiency and precision of root canal treatments. Their remarkable flexibility, resistance to cyclic fatigue, and superior cutting abilities have made them invaluable in shaping and cleaning intricate root canals. These files facilitate the removal of infected or damaged tissue, reducing procedure time and improving patient comfort. However, the demanding mechanical stresses encountered during root canal treatment can lead to wear and structural degradation of Niti rotary files, impacting their effectiveness. [12] Moreover, even the sterilization process can pose challenges, potentially affecting the surface quality of these files. Therefore, meticulous care, regular inspection, and adherence to sterilization guidelines are crucial to ensure their durability and reliability in clinical practice.[13]

Sterilization is of paramount importance in dental procedures, particularly when it comes to Niti rotary files used in root canal treatments. Proper sterilization ensures patient safety and prevents cross-contamination[13] However, it's essential to recognize that the sterilization process, often involving autoclaving, can influence the surface roughness of Niti rotary files. High temperatures and steam pressure in autoclaves, while effective in eradicating pathogens, can also lead to surface alterations on Niti files. These changes in surface roughness can impact the files' cutting efficiency and longevity, potentially compromising the quality of root canal treatments.[14] As such, it is crucial for dental professionals to not only prioritize sterilization but also be cognizant of the potential effects it may have on the integrity of Niti rotary files, emphasizing the need for vigilant maintenance and assessment protocols.

The present systematic review aimed to investigate the effect of heat on the surface roughness and fracture resistance of nickel-titanium (NiTi) rotary files, a crucial aspect in endodontic practice. The synthesis of the evidence from multiple studies has shed light on the impact of heat exposure on the performance and integrity of these essential instruments, providing valuable insights for endodontic practitioners.The review revealed several in vitro studies that explored the effects of autoclave heat on the surface roughness and fracture resistance of NiTi rotary files. Among these studies, three significant investigations stand out, offering valuable data on this subject (Table 1).

Table 1: Evaluation of the collected data from the included articles

First Author	Year	Instrument Type	Type of Alloy	Sample Size	Type of Motion	Sterilization	Sterilization Temperature and time	No. Of Cycles	Surface Roughness	Cyclic Fatigue resistance	Torsional Resistance

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Rashid El Abed	2023	One Curve NiTi file	Heat Treated	30	Rotary	Autoclave	132° for 30 min	1		1286± 219	216.61 ± 35.11
Rahaf A. Almohareb	2022	Race	electropolished	30	Rotary	Autoclave	132° for 4 min	10	0.6708		
		Race Evo	Heat Treated		Rotary	Autoclave	132° for 30 min		0.6398		
Reham Sharroufna	2020	ments (Edg	Heat Treated	24	Rotary	Autoclave	134 ° C for 20 mins	10		1198 : 76 ± 255 : 56	
		Vortex Blue	Heat Treated							606 : 1 ± 145 : 1	
		TruShape	Heat Treated							487 : 8±80 : 7	
Wooyoung Klm	2019	ProTaper Universa		60	Roatry	Autoclave	132 °C for 15 min,	10		2.35	1539.7
		K3XF								2.12	1943.15
		HyFlex EDM								2.01	12,577.60

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		TF adaptive								0.68	1400.2
Das P	2019	Hyflex CM	Heat treated	60	Rotary	Autoclave	121°C at 15 psi for 15 min		41784.93		2228.07
		Hyflex EDM							72344.97		4603.27
Eugenio Pedulla,	2017	Twisted Files	Heat Treated	210	Rotary	Autoclave	134°C For 17 mins	3			548.8
						Autoclave plus chemical(NaOCl)	5% NaOCl at 37°C	3			548.8
		Hyflex CM	Heat Treated		Rotary	Autoclave	134°C For 17 mins	3			732.2
						Autoclave plus chemical(NaOCl)	5% NaOCl at 37°C	3			732.2
J-J Cai	2016	HyFlex	Heat Treated		Rotary	Chemical	5.25% NaOCl solutions at 37 °C for 10 ,in		730±1.6		1412
		M3			Rotary				6.35±.95		1235
Gianluca Plotino,	2016	ProTaper Universal	Heat Treated	120	Rotary	Autoclave	132°C under 29 psi for 4 min	10			
		Pro-Taper Gold			Rotary						
Rahaf A. Almohareb	2023	EdgeTaper Platinum	Heat treated	60	Rotary	Autoclave	132°C under 29 psi for 4 min	10			13.4

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		ProTaper Gold			Rotary						10.6
		TruNatomy Prime			Rotary						9
Nenad Stošić	2023	ProTaper Universal	Heat treated	90	Rotary	Autoclave	134°C for a duration of 23 minutes	5			354 ±15.25
		BioRace			Rotary						1800 ±80.92
		, ProTaper Next			Rotary						1750 ±373.01
		Twisted Files			Rotary						1458 ±100.00
		HyFlex CM			Rotary						12151.41 ±1094.97

6. Conclusion:

In conclusion, the findings of this systematic review highlight the significant impact of autoclave heat on the surface roughness and fracture resistance of NiTi rotary files. The alterations in surface characteristics and mechanical properties induced by autoclave exposure can influence the files' clinical performance and lifespan. Endodontic practitioners should be cautious about the potential implications of heat exposure on these essential instruments and take necessary precautions to ensure optimal use and longevity.

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