Comparing the Cutting Efficiency of Heat Treated Nickel Titanium Endodontic Files with Conventional Nickel Titanium Endodontic Files – A Systematic Review

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Abstract

Aim: The purpose of this systematic review was to compare the cutting efficiency of heat treated nickel titanium endodontic files with conventional nickel titanium endodontic files.

METHODS: The study began with targeted electronic searches of PUBMED database, and subject specified databases, followed with exhaustive manual searching and citation mining for all articles reporting the cutting efficiency of heat treated NiTi and/or conventional NiTi files, in human extracted teeth, analyzed under Micro-CT.

Results: Seven articles met the inclusion criteria with a moderate to high risk of bias. Available scientific evidence gives data that there is no significant difference in the cutting efficacy between heat treated NiTi files and conventional NiTi files.

CONCLUSION: Even though heat treatment can improve the mechanical behavior of NiTi alloy, the effect of heat treatment on the cutting efficiency of NiTi instruments is still unclear.

KEYWORDS: Conventional NiTi files,Cutting efficacy, Heat treated NiTi Files, Micro-CT..

Introduction

For sculpting root canals, a variety of nickel-titanium (NiTi) tools have been introduced. Since Walia and colleagues first introduced NiTi instruments in the late 1980s, they have revolutionized the root canal instrumentation by reducing the majority of iatrogenic instrumentation issues typically associated with stainless steel files such as zipping, ledges, transportation, and perforation. Each generation of NiTi instruments has something new to offer and is intended to improve upon previous generations.[1,2]

In the 1990s, the first NiTi rotary instruments hit the market. The mechanical behavior of NiTi alloy is controlled by the relative proportions and characteristics of the micro structural phases, despite significant improvements in file design and manufacturing techniques for NiTi rotary instruments over the past two decades. This is especially true in calcified or severely curved root canals.[3] One of the most popular techniques for modifying NiTi alloy transition temperatures is heat treatment (thermal processing), which has been shown to affect the fatigue resilience of NiTi instruments.[4]

However, heat treated NiTi alloys have been reported to be more flexible with an improved cyclic fatigue resistance and greater angle of deflection at failure when compared to conventional super elasticNiTi alloys.[5] These novel NiTi instruments were made using thermo mechanical techniques, such as M-wire, R-phase, and controlled memory (CM) files, and they have been introduced recently.[6]

The mechanical properties of metallic components can be improved through heat treatments like quenching, annealing, and tempering. Annealing can increase an object's ductility, toughness, and superelasticity while reducing residual stress.7The strength of NiTi alloy diminishes as the annealing temperature rises, according to earlier investigations, which have revealed that the phase transition behaviour of the alloy varies during annealing treatment.[8]

The NiTi alloy exhibits martensitic and R-phase development during heat treatment up to 6000C. These processes can enhance the mechanical properties of NiTi alloys, but it is still unknown how heat treatment affects the cutting efficiency of NiTi instruments.[9-10] It can be assumed that the cutting efficiency of relatively soft and flexible NiTi instruments is lower than that of relatively stiff NiTi instruments. To explain how the heat treatment of the NiTi files during production impacts the cutting efficiency, a thorough review was conducted. The

comparative cutting efficiency of heat-treated NiTi files against regular NiTi files is the major focus of this review work.

Methods and protocol

PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) criteria were used to perform this systematic review. "Does the newer heat treatment increases the cutting efficiency of modern NiTi files compared to the conventional NiTi files in the root canals of human teeth?" was the key question for this review.

The null hypothesis states that there is no distinction between heat-treated NiTifiles and regular NiTi files in terms of cutting effectiveness.

Literature search

The use of ordinary NiTi files, heat-treated NiTifiles, or both in in-vitro investigations was searched thoroughly. The keywords "Conventional NiTi files" or "Standard NiTi files" or "Heat treated NiTi files" or "Micro CT" or "in vitro" or "Cutting efficiency" or "Dentine real" were used to search the PUBMED database and subject-specific data base, which includes the INTERNATIONAL ENDODONTIC JOURNAL (IEJ), JOURNAL OF ENDODONTICS (JOE), AND AUSTRALIAN ENDODONTIC JOURNAL (AEJ). THE PUBMED database and remaining journals were searched from July 2010 through October 2022. The reference list of the chosen articles was also subjected to a forward manual search.

Selection of studies and data extraction

Two different authors independently screened the titles and abstracts of articles from the search results. The eligibility requirements were followed as the entire texts of pertinent papers were examined. A sheet for systematic data extraction was created. The following criteria were taken from the chosen studies: the name and impact factor of the journal where the study was published, sample size, file and tooth types used, specimen preparation, assessment using Micro-CT, other parameters tested in the studies besides cutting efficiency, and study results.

Eligibility Criteria

Prior to conducting a literature search, selection criteria for studies were created. The inclusion and exclusion criteria are summarized in Table 1.

Table 1: Inclusion and Exclusion Criteria.

Exclusion Criteria	Inclusion Criteria
Studies Utilising Open-Apex Teeth, Resin Blocks, And Tooth Models.	Articles Discussing the Cutting Effectiveness of Both Conventional And Heat-Treated Nickel Titanium Endodontic Files...
Studies Done on Endodontic Instruments other Than Nickel Titanium Instruments.	Studies Carried Out on Fully Developed Root Apices in Naturally Occurring Human Teeth.
Studies That Didn't Use Micro-Ct For Evaluation.	Studies Using Both Conventional and Heat-Treated Nickel Titanium Files.
Studies That Don't Contrast Heat-Treated and Normal Nitifiles	Studies Solely Utilising Micro-Ct Analysis
Articles That Are Not In English.	
Articles That Examined the Effectiveness of Retreating Niti Files.	

Risk of Bias and Quality of Evidence

Two authors each separately reviewed each article for quality. A score system for the overview quality assessment questionnaire (OQAQ) was used to determine the risk of bias in the chosen studies. To meet these quality assessment requirements, nine questions with a 0–18 score range were created. In this systematic review, articles with an OQAQ score of 12 or higher were considered to be of good quality. The overall quality assessment questionnaire used to evaluate the quality was modified by Greaves et al. [11] the bias potential is given in Table 2.

Table 2: Bias potential.

	Limoeiro et, al. 2016	Brasil et, al. 2017	Versiani et, al. 2017	Zuolo et, al. 2018	van derVyver et, al. 2019	Yılmaz et, al. 2020	Haupt et, al. 2020
Was the hypothetical question well stated?	2	1	2	2	2	1	1
Was the methodology detailed in a comprehensive way?	2	2	2	2	2	2	2
Were the inclusion and exclusion criteria well defined	1	1	1	1	1	1	1
Were bias covered by examiners?	2	2	2	2	1	2	1
Were the instruments examined under magnification?	2	2	2	2	2	2	2
Was the statistical analysis used in the study?	2	2	2	2	2	2	2
Were the methods used relevant to reach a conclusion?	2	2	2	2	2	2	2
Were the findings relative to the primary question?	2	2	2	2	2	2	2
Were the conclusions made by the author(s) supported by the data?	1	2	2	1	1	2	2
Total score	**16**	**16**	**17**	**16**	**15**	**16**	**15**

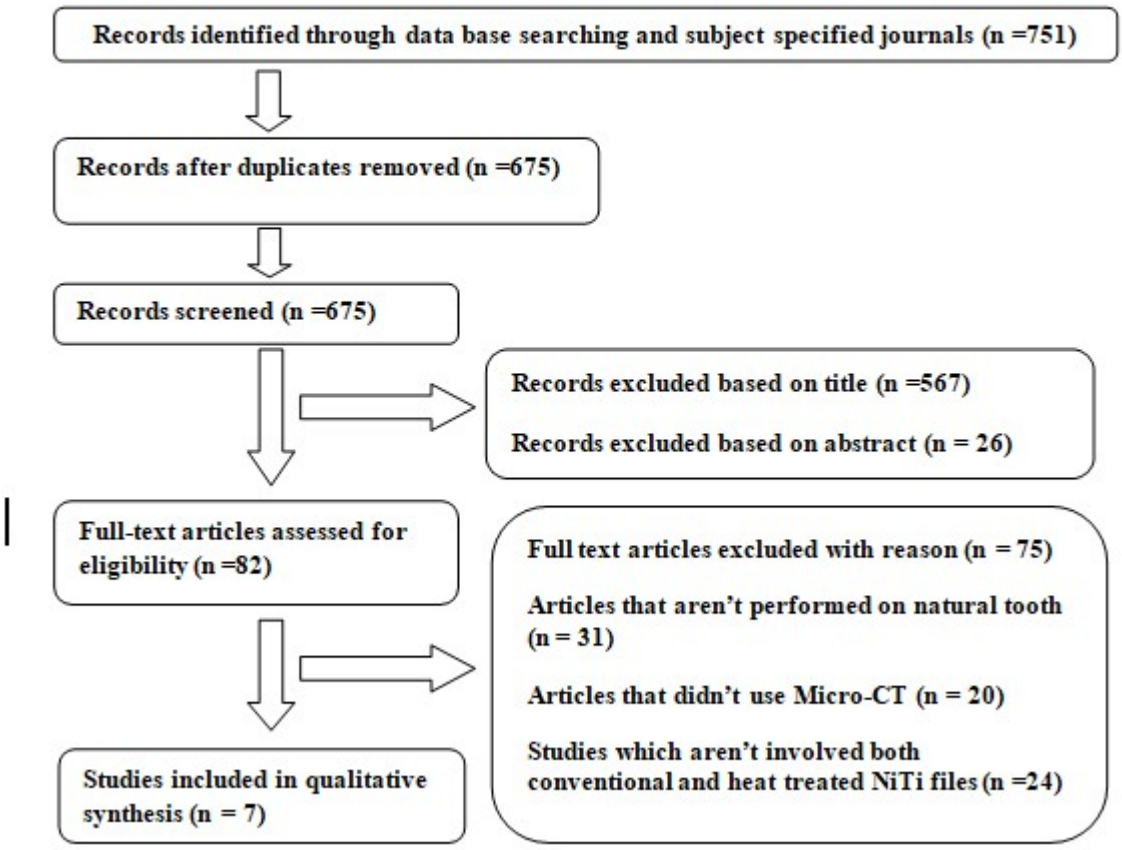
Results

After eliminating duplicate entries from the many databases that were searched, the first search method produced 674 references. The references were narrowed down to 81 papers after a preliminary screening evaluation based on the abstracts and titles. After then, two authors obtained and updated the whole texts of the other articles. The systematic review only included in vitro studies that assessed the cutting effectiveness of conventional and heat-treated NiTifiles in human tooth extraction. The final 7 articles obtained are framed in Table 3.

Table 3: Summary of articles.

	Author/year	Types of files used		Type of tooth used	Assessment	Other parameters tested	Outcomes
		Heat treated Niti files	Conventional niti files				
1	Limoeiro et, al. 2016.[12]	ProTaper Next	BioRace	First and second human mandibular molars	Micro–CT	Canal volume SMI & percentage of untouched canals	Both instrumentation systems were equally effective.
2	Brasil et, al. 2017.[13]	ProTaper Next	BT-RaCe	mandibular molars	Micro–CT	Canal Transportation	There was no discernible difference between the two systems.
3	Versiani et, al. 2018.[14]	EdgeFile, XP-Endoshaper	I-RaCe	Single rooted human Mandibular incisors	Micro–CT	Percentage of unprepared surface area.	Systems like XP-endo Shaper, iRaCe, and EdgeFile displayed comparable shaping abilities.
4	Zuolo et, al. 2018.[15]	Reciproc, and TRUShape systems	BioRace	Mandibular incisors	Micro–CT	Percentage of unprepared surface area.	The most dentine was removed by Reciproc, and the results from TRUShape were in the middle.
5	van derVyver et, al. 2019.[16]	ProTaper Next, WaveOne Gold.	One Shape	Human maxillary molars	Micro–CT	canal transportation	Compared to One Shape and WaveOne Gold, ProTaper Next removed more dentin.
6	Yılmaz et, al. 2020.[17]	Pro Taper Next, Edge File	One Shape	Mesio-buccal canals of maxillary molars	Micro–CT	Apical transportation	The capacity to remove dentin was similar across all systems.
7	Haupt et, al. 2020.[18]	Wave one gold primary, Reciproc	S1 plus standard	Human Mandibular molars	Micro–CT	Changes in surface area, percentage of unshaped canal walls, SMI, canal transportation & centering ratio.	The amount of dentine removed was not considerably different amongst the three NiTi systems.

PRISMA flow chart



Discussion

The goal of the current experiment was to compare the cutting effectiveness of conventional and thermally treated NiTi files.

Because of the hardness of the dentin and the fact that root canals are frequently narrow and curved, only studies that examined extracted teeth were included in this review. This is because testing file systems in natural dentin is thought to be more advantageous than using standardized artificial canals.[12]

A nondestructive micro-CT method was chosen for these investigations because it is widely considered as the gold standard for quantitative and qualitative morphologic analyses of root canals and has several uses, one of which is assessing the effects of preparation on canal anatomy. Innovative, non-destructive, and repeatable technology called micro-CT imaging creates incredibly thin sections of the object as well as a real 3-D reconstruction of it. By deducting the values for the treated canals from those obtained for the untreated counterparts, the amount of dentine removal was calculated.[17]

NiTi instruments that have undergone heat treatment have fewer intrinsic flaws, a harder, more flexible surface, and improved fatigue resistance and cutting performance.

Limoeiro et al., reported that Pro Taper Next and Bio Race both removed almost the same quantity of dentine.[12]This could be related to Pro Taper Next's offset asymmetric design.[19]

Reciproc R25, which is made of heat-treated alloy (M wire) and has an S-shaped cross section, Wave one Gold, which is made by grinding the instrument followed by a special thermo mechanical treatment, and S1 plus standard, which is made from a conventional austenite NiTi alloy, did not significantly differ from one another in terms of cutting efficiency, according to Haupt et al.[18]

When Van derVyver et al., tested the cutting effectiveness of the WaveOne Gold, which is produced from a heat-treated gold metal alloy, the

One Shape, which is made of ordinary austenite NiTi, and the Pro Taper Next, they found that the latter two were inferior to the former.[16]

Versiani et al., evaluated the cutting effectiveness of XP-endo Shaper, made of M-wire, and EdgeFile, formed of an annealed heat-treated NiTi alloy; they came to the conclusion that the XP-endo Shaper, iRaCe, and EdgeFile systems demonstrated a similar ability to shape.[14]

One Shape, which is made of ordinary austenite NiTi, Pro Taper Next, which is made of M-Wire, and EdgeFile, which is built of an annealed heat-treated NiTi alloy, were all found to have equivalent dentin removal abilities when Yilmaz et al., compared their cutting efficiency.[17]

When Brazil et al., compared the cutting effectiveness of Pro Taper Next, which is built of M-Wire, to BT-RaCe, which is made of traditional austenite NiTi, they came to the conclusion that there was no discernible difference between the two systems. [13]

Only the Reciproc system and Pro Taper Next heat-treated NiTi files demonstrated greater dentine removal than the compared Reciproc system, which may be attributed to its reciprocating kinematics, larger taper size (0.08 in the first 3 mm), and design (sharp cutting edges and smaller cross-sectional area), which affect its flexibility and increase its cutting efficiency in a brushing motion.[20,15] Pro Taper Next remove debris in a coronal direction. The remaining heat-treated NiTi files tested demonstrated a comparable level of dentine removal to traditional NiTi files, which will increase cutting efficiency as the blades remain in touch with the surrounding dentin walls.[21]

Based on their thermo-mechanical history, thermal treatments have been shown to affect the mechanical properties and transformation characteristics of NiTi alloys. By altering the microstructure of the NiTi alloy through heat treatment, the alloy's mechanical properties can be improved.[22] Because the heat-treated files have a higher resistance to cyclic fatigue and an increase in ductility, the likelihood of file fracture during clinical use may be decreased.[10]

The proposed null hypothesis, according to which there is no difference between heat-treated and regular NiTi files in terms of cutting efficacy, was accepted. The mechanical characteristics of NiTi instruments are improved by the more recent heat treatment; however, cutting efficiency is mostly affected by instrument size, form, and design.

Conclusion

The impact of heat treatment on the cutting effectiveness of NiTi instruments is still unknown, despite the fact that it can enhance the mechanical behaviour of NiTi alloy.

Within the constraints of this review, it can be said that heat treated NiTi files can be used more safely, even in canals with extreme curvature, as both those types of files removed dentine to a similar degree.

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