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Review Article

Evaluation of cyclic fatigue resistance of nickel titanium rotary instruments: A systematic review and meta- analysis

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ABSTRACT

Background: A number of different thermomechanical treatments of NiTi have been developed to overcome some of the drawbacks of the traditional NiTi alloy, namely, separation and distortion of instruments. The present study analyzes the data on nickel-titanium instruments and their cyclic fatigue resistance.

Materials and Methods: Online electronic data base such as PubMed, Cochrane and Google scholar through 31 January 2000 to 31 January 2020 with only English language literature.

Results: Clinical study of 9 article review & stated that the Cyclic Fatigue Resistance Of Nickel Titanium Rotary Instruments tested in artificial blocks or canals ,tested with different NiTi rotary files between 200-500 rpm and accordingly torque under controled/uncntroled temperature in curved canls fracture occure. The findings of this systematic review and meta-analysis point to the possibility that the temperature at which the instruments are tested may affect the results of cyclic fatigue resistance on NiTi files with a different behavior depending on the heat treatment of the alloy and that an increase in the angle of curvature of artificial canals has a detrimental effect on the cyclic fatigue resistance.

Conclusion: Reciprocal movement exhibited the best performance with regard to cyclic fatigue resistance. The thermal treatment of the instrument's alloy, its cross section, and the glide path seem to influence the cyclic fatigue resistance. The cyclic fatigue resistance of instruments manufactured with the gold heat treatment is not influenced by room or intracanal temperature.

1. Introduction

The process of manufacturing nickel-titanium (NiTi) rotary endodontic instruments was first introduced in 1988.[1] NiTi instruments offer great flexibility, superelasticity, superior cutting ability, and more centered root canal preparation. Therefore, they reduce the risk of canal aberrations and the time required for root canal preparation. NiTi instruments maintain the original canal shape better than a stainless steel file.[2,3]

To increase the functionality and fracture resistance of tools used in root canal preparation, nickel-titanium (NiTi) rotary files' metallurgy and designs have seen considerable advancements recently.[4] Lately, a variety of new thermomechanical treatments for NiTi have been created to get around some of the issues with the conventional NiTi alloy, such as instrument separation and distortion.[5,6] When compared to typical superelastic Ni-Ti instruments, the producers assert that these new thermal treatments provide instruments that are more resistant to cyclic fatigue.[7,8] The two distinct crystal phases of the NiTi alloy, martensite and austenite, are temperature-dependent.[9]

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These two stages' characteristics differ greatly from one another. Heat causes martensitic NiTi to turn into austenite, and once this process is complete, the alloy has acquired shape memory and manifests superelastic properties.[10] The austenite finish temperature is the temperature at which this phenomena is complete.[10]

Since they hinder the disinfection of the entire root canal system, shattered fragments from NiTi endodontic rotary files within the root canal system pose a challenge for the operator.[11]

However, researchers have focused their attention on the NiTi alloys, new surface treatments, and design improvements as crucial variables in the fracture resistance of NiTi endodontic rotary files. Numerous factors, such as root canal shape, instrument geometry, rotational speed, torque, disinfection cycles, the number of clinical uses, and the angle and radius of the root canal system, can end up causing NiTi endodontic rotary files to separate.[12–15]Figure 1a.

The physical characteristics of NiTi endodontic rotary files are therefore improved by surface treatments such electropolishing, ion implantation, cryogenic treatment, and heat treatments, improving their cyclic fatigue resistance.[16]

Instruments made with ProTaper Gold (PTG; Dentsply Maillefer, Baillagues, Switzerland) superior metallurgy have recently been created using patented heat treatment technology. ProTaper Next (PTN; Dentsply Maillefer) files have the same geometry as ProTaper Next instruments. High Af temperatures and a 2-stage unique transformation process are characteristics of PTG files.[17,18]

Newer generation NiTi file systems still utilised in continuous rotational motion are called HyFlex EDM (HEDM; Coltene/Whaledent, Altstätten, Switzerland). The HyFlex CM (HCM; Coltene/Whaledent), the first file system created using the controlled memory (CM) technology, is represented by HEDM as a development of that system.[19] (Figure 1b)

The kinematic properties of files remained unchanged under the WOG system. To improve the flexibility of the files, the cross section, size, and geometry of the WOG system were altered.[20] Moreover, gold was heated to strengthen the WOG's resilience to cycle fatigue[21]. (Figure 1c)

2. Aim

The aim of this systematic review is to evaluate and compare the cyclic fatigue resistance of different nickel titanium rotary instruments.

3. Objective

To evaluate cyclic fatigue resistance of different nickel titanium rotary instruments.

4. Materials and Methods

This review was based on the PRISMA guidelines. The protocol was registered in PROSPERO International Prospective Register of Systematic Reviews CRD42021239408 Eligibility criteria:

The controlled vocabulary (MeSH terms) and free terms were used to define the search strategy based on the elements of PICOS question as follows as:

1. Population (P): Artificial root canals.
2. Intervention (I): Niti rotary instruments.
3. Comparison (C): Root canals prepared with any of rotary NiTi instruments.
4. Outcome (O): Cyclic fatigue resistance of rotary NiTi instruments.
5. Study designs (S): In vitro Experimental Trails.

4.1. Search strategy

The results for this review have been searched into databases – PubMed/MEDLINE, Google Scholar, and Cochrane Databases. The databases were searched up to 31 January 2020. The searches were restricted to English language only. Hand searching was done through various journals for relevant articles related to the topic.

To be considered for inclusion, published articles were required to contain combination of the following keywords NiTi instruments; cyclic fatigue; temperature; reciprocation movement. No limits were applied to the initial search.

5. Inclusion criteria

Nickel Titanium Rotary Instruments, NiTi Rotary files included are: ProTaper GOLD ProTaper Next Wave One Gold Hyflex EDM, Studies which included cyclic fatigue model as Artificial root canals/Blocks. Studies have included which perform Cyclic fatigue tests. Studies where included between 2001 to 2021 In-Vitro studies where included.

5.1. Exclusion criteria

Studies which does not contain NiTi rotary instruments/files where excluded, Reuse and damage files where excluded. Studies at least contain one of these files ProTaper GOLD ProTaper Next Wave One Gold Hyflex EDM and if not then excluded. Invivo or animal studies where excluded.

A risk of bias which was estimated (low, medium, or high) was assigned to each of the included studies by the investigators. The disagreements were resolved by discussion.

5.2. Statistical and meta analysis

Meta-analysis is a quantitative, formal, epidemiological study design used to systematically assess previous research studies to derive conclusions about that body of research. It is a statistical analysis that combines the results of multiple scientific studies.

5.3. Statistical analysis

The meta-analyses, using random-effects model, were applied with RevMan 5.4 (RevMan 5.4, The Nordic Cochrane Centre, Copenhagen). Heterogeneity was assessed by Q test and quantified with I2 statistics. Data on mean and standard deviation were obtained from selected studies. Mean no. of cycles required for file to fracture (cyclic fatigue) and time taken to fracture were considered as the main outcome. Three separate comparisons were performed: Comparisons of cyclic fatigue between Twisted File & Protaper Next File, Comparisons of cyclic fatigue between Protaper Universal & Protaper Gold File, and Comparison of time taken to fracture between Waveone Gold File & 2shape, using mean difference (MD) for Cyclic fatigue and time taken to fracture. For analyses, if the test showed substantial heterogeneity (I2>50%), a random effects model was applied, or else (I2 ≤50%), a fixed effects model would be used.

5.3.1. Comparison of cyclic fatigue between twisted file & protaper next file

The meta-analyses comparing the cycle fatigue between Twisted File & Protaper Next File included two papers with four comparisons. Due to the inability to examine the reported data, the other research were disregarded. The overall comparative results have been represented as a forest plot. Because heterogeneity was greater than 50% (I2 = 95%) in the meta-analysis of the chosen papers, the random effect model was used. Twisted File needed more cycles to fracture the file than Protaper Next File, with a mean difference of 174.08 (95% CI = 100.57 to 247.59; Z value = 4.64) per cycle. There was a statistically significant difference in the number of cycles needed to split the file (p=0.001). Figure 2

5.3.2. Comparison of cyclic fatigue between protaper universal and protaper gold file

Meta-analyses evaluating cycle fatigue between Protaper Universal and Protaper Gold File includes two papers with five comparisons each. Because the reported data could not be processed, the other investigations were disregarded. A forest plot has been used to represent the results of the overall comparison. Because heterogeneity was greater than 50% (I2 = 96%) in the meta-analysis of the chosen papers, the random effect model was used. Protaper Gold required more cycles to fracture the file than Protaper Universal File did, with a mean difference of -332.65 (95% CI = -464.04 to -202.27; Z value = 5.00). This variation in the quantity of cycles needed to split the file was statistically significant (p=0.001). Figure 3

5.3.3. Comparison of time taken to fracture between wave one gold and 2 shape file

The meta-analyses comparing the cyclical fatigue between Waveone Gold and 2shape File contained two papers with three comparisons. Due to the reported data's inability to be examined, the other research were disregarded. The aggregate comparative findings are shown as a forest plot. The random effect model was used since, in the meta-analysis done for the chosen papers, heterogeneity exceeded 50% (I2 = 100%). With a mean difference of 33.00 (95% CI = -106.81 to 172.82; Z value = 0.46), the number of cycles needed to fracture the file were higher in Waveone Gold than in 2shape File. It was not statistically significant (p=0.64) how many cycles were needed to fracture the file. Figure 4

6. Results

Outcome of Search - In sum, the electronic screening of PubMed and Cochrane identified 1020 articles.

From the initial 1020 studies identified, after the removal of duplicates (565articles), 455 articles were assessed for relevance to the objective of the research.

After the exclusion of 427 articles, 28 articles were assessed for eligibility.

After excluding, invitro studies (10), and studies not in English (09), a total of 09 full-text articles were further assessed and included in the systematic review (Figure 1).

Of the 20 studies7 were categorized as having a moderate risk of bias, and 2 was considered to have a high risk of bias.

There were no statistically significant variations between the fracture length of separated instruments, according to two reviews that conducted studies at controlled temperatures, namely Gianluca Plotino et al and K olcay et al.[22]

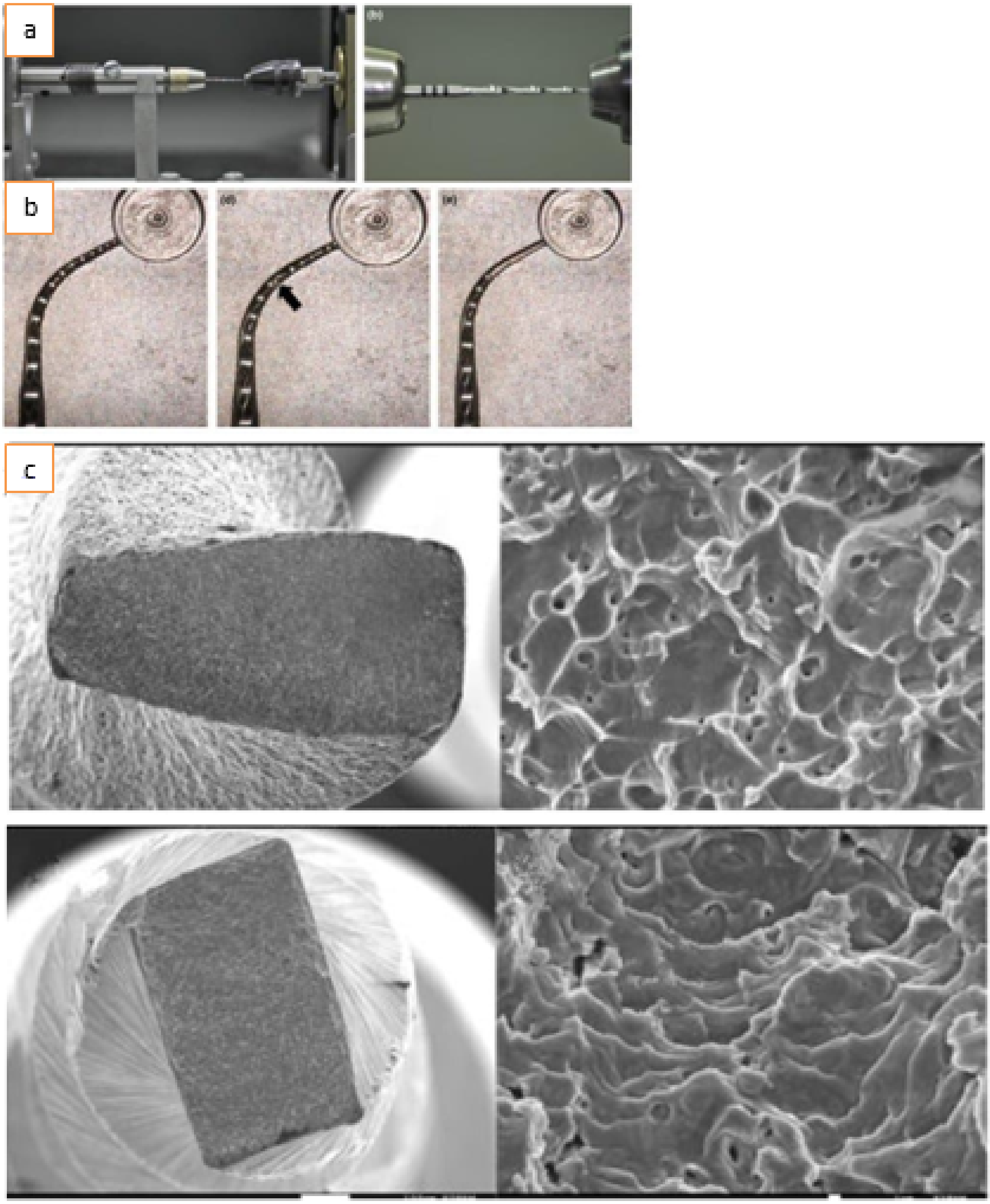

Fig. 1: Static cyclic fatigue device with embedded stainless steel artificial root canal systems;(b).Scanning electron microscopic appearances of HyFlex EDM; (c).Scanning electron microscopic appearances of WaveOne Gold.

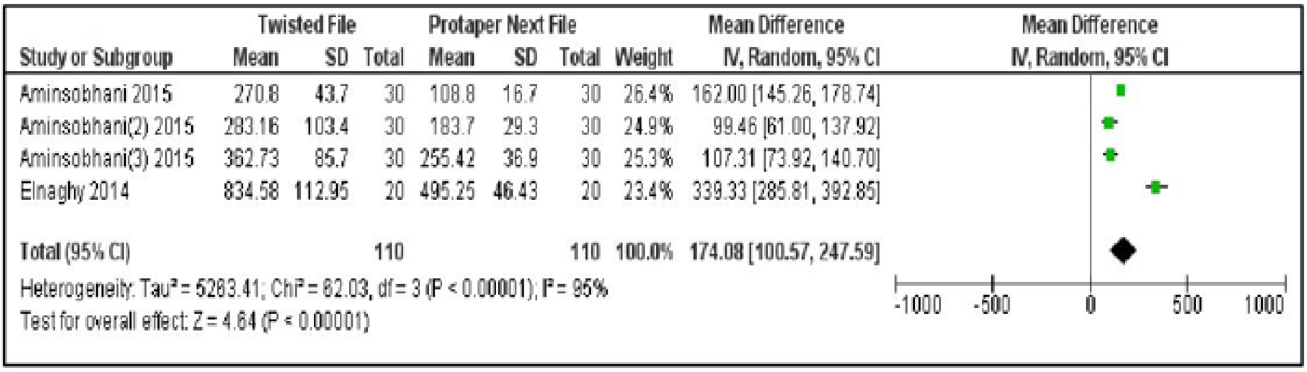

Fig. 2: Comparison of cyclic fatigue between twisted file &protaper nextfile

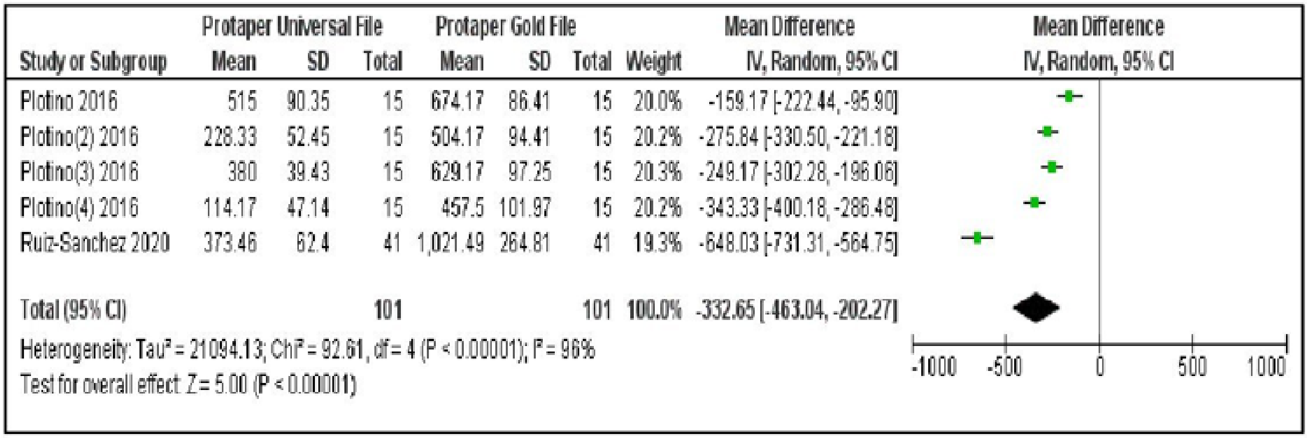

Fig. 3: Comparison of cyclic fatigue between protaper universal and protaper gold file.

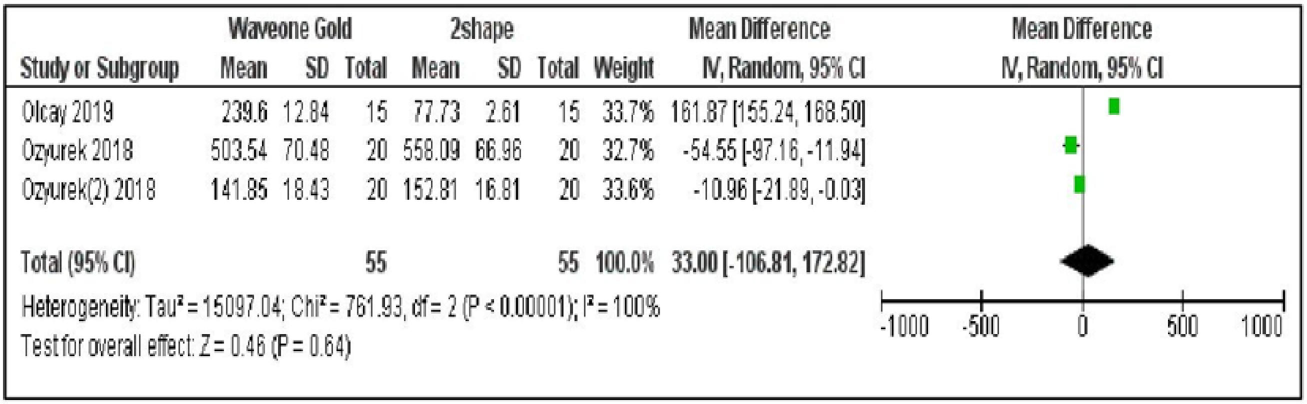

Fig. 4: Comparison of time taken to fracture between waveone gold and 2 shape file

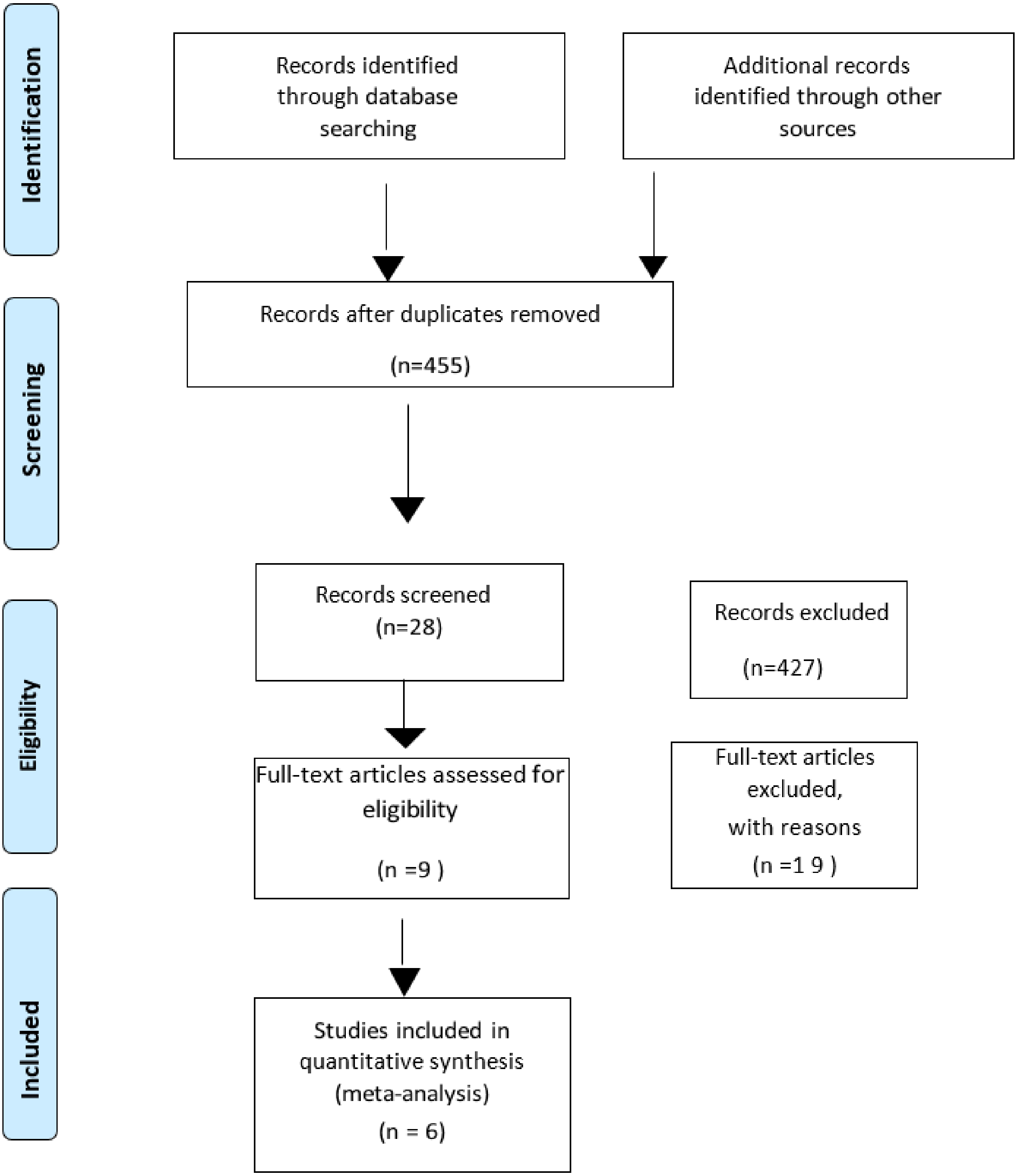

Fig. 5: Flow chart summarizing the articles selection process.

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Author (reference)	Country	Year of publication	Study design	Inclusion criteria	Exclusion criteria	Number of samples	Artificial canals/Block & its specification	Included files length size and taper
Gianluca Plotino	Spain	2016	In vitro study	Files Included: Protaper gold & Protaper universal	-	120	Angle of curvature(AOC):60 Radius of curvature(ROC):5mm	PTG:S1F2, PTU:S1F2
Taha Ozyurek	Turkey	2018	–	Hyflex EDM,Wave one Gold, ReciprocBlue, 2Shape	-	160	Stainless steel block- AOC:45 or 90 ROC:5mm Diameter:1.5mm	HEDM:25/0.08, 2Shape:25/0.06, WOG:25/0.07, RB:25/0.08.
Celia Ruiz-Sanchez	Spain	2020	–	Sterial Endodontic Rotary files with 250apical diameter Protaper universal,protaper next, protaper gold,profile vortex blue	-	164	Stainless steel cylinder- AOC:60 ROC:5mm Apical Diameter:250/um Diameter:1.5mm	PTU:25 08F2, PTN:25.06X2, PTG:25.08F2, PVB:25.06
Akanksha Bhatt	India	2018	–	Heroshapers,protaper next,profile vortex,one shape	-	125	Length: 21mm Taper:6% ISo:25size AOC:60 ROC:5mm	Heroshapers,protaper next,profile vortex,one shape :21.06
A.M Elnaghli	Egypt	2014	–	Protaper next, protaper, twisted file, Hyflex	-	-	Artificial canal- AOC:45 ROC:5mm Center segment of canal:5mm Center of curvature:5mm(tip to instrument)	TF:25.06, PTN:25.06X2, Hyflex:25.06 Protaper:20.07F1

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Table 1 continued

Pedulla E	Italy	2017	–	Protaper next,Revo-s, Mtwo,twisted file,Endowave	-	120	Metal bock(36.8mmx25.4mmx9.5mm)- AOC:60 ROC:5mm Center width:1.5mm	PTN :25.0X2,Revo_S SU:25.06 Mtw25.06o:TF:25.06 Endowave:25.06
K olcay	Turkey	2019	–	2shape,protaper next,waveone gold	-	45	ROC:5mm AOC: 60 Width:1.5mm Length:25mm Working length:16mm	2Shape:25/06, WOG:25/07, PTN:25/06
Mohsen AminSobhami	Iran	2015	–	Neoniti,Race,Mtwo,twisted file,Protaper next		150	Stainless steel block- AOC: - ROC:6mm Width:1.5mm Length:20mm Diameter:2.5	Neoniti A1#25, Race:25.06, Mtwo:25.06, TF:25.06, PTN:X2
Silvio Emanuel Acioly Conrado de Menezes	Brazil	2017	–	Waveone gold,prodesigm .R, prodesign logic	-	30	Acrylic resin artificial canal- AOC:60 ROC:5mm COC:5mm Diameter:1.5mm	ProDesign R:25/0.06, ProDesign logic:25/0.06, WOG:25/0.07

Table 2: Selected studies for inclusion in systematic review

Authors	Results	Conclusion
Gianluca Plotino	PTG registered no differences in fatigue life between the 2 temperatures tested ($P > .05$), whereas PTU showed a statistically significant reduction in fatigue life at intracanal temperature compared with room temperature ($P < .05$). PTG instruments exhibited a statistically higher resistance to cyclic fatigue than PTU instruments both at room and intracanal temperatures ($P < .05$). There were no statistically significant differences among the fracture length of separated instruments ($P > .05$).	Intracanal temperature influenced the cyclic fatigue resistance of instruments produced with traditional nickeltitanium, whereas it did not influence the fatigue life of instruments produced with gold heat treatment. Gold heating treatment enhances the resistance to cyclic fatigue of ProTaper instruments.
Taha Ozyurek	In artificial canal with 90° curvature, RB showed a significantly higher cyclic fatigue resistance than the other tested files ($P < 0.05$), while there was no significant difference among the TS, WOG and HEDM groups ($P > 0.05$). When the NCF values were taken into consideration, HEDM reported a significantly higher cyclic fatigue resistance than TS in both canal curvatures analyzed ($P < 0.05$).	Within the limitations of the present study, RB NiTi files showed statistically higher cyclic fatigue resistance in artifi- cial canals with 45° and 90° than the other NiTi files tested. Moreover, the increase in the angle of curvature of artificial canals negatively affects the cyclic fatigue resistance.
Celia Ruiz-Sanchez	Analyzed using the ANOVA test and Weibull statistical analysis. Results: All pairwise comparisons presented statistically significant differences between the time to failure for the NiTi alloy study groups ($p < 0.001$), except between the PTN and PVB study groups ($p = 0.379$). In addition, statistically significant differences between the number of cycles to failure for the NiTi alloy study groups ($p < 0.001$) were also observed.	NiTi CM-Gold wire alloy of the ProTaper Gold endodontic rotary files is more resistance to cyclic fatiguethan Pro File Vortex Blue, ProTaper Next, and ProTaper Universalendodonticrotary files, dueto the elements of the alloy present in the crystalline structure that give the Pro Taper Gold endodontic rotary files greater flexibility and resistance.
Akanksha Bhatt	Time taken to fracture ranged from 7 to 58s in different groups. Analysis of variance show a statistically significant intergroup difference ($p < 0.001$). Tukey HSD test showed the significant differences. The Weibull modulus values ranged from 7.31 to 24.19.	On testing cyclic flexural fracture resistance among the experimental groups the cyclic fatigue resistance was observed in descending order Group IV (Hyflex CM) > Group V (One Shape) > Group II (Protaper Next) > Group III (Profile Vortex) > Group I (Hero Shapers). Hyflex CM files had longest survival time while minimal survival time was shown by Hero Shapers files. The clinical significance obtained from this in-vitro study is that Hyflex CM rotary NiTi files which have superior resistance and long survival time will be helpful in reducing or eliminating one of the reasons for file fracture (due to cyclic flexural fatigue) during the root canal treatment clinically where root canal possesses a sharp bend or has a severe curvature.

Continued on next page

Table 2 continued

A.M Elnaghli	Twisted Files had a significantly higher resistance to cyclic fatigue than the other instruments (P < 0.05). No significant difference was found in NCF between PTN and HF (P > 0.05); however, there was a significant difference (P < 0.05) of both these systems with PT, which exhibited the lowest mean NCF. The ranking in the NCF values was: TF > PTN > HF > PT. The fracture cross-sections of all brands revealed similar fractographic features, including crack origins, fatigue zone and an overload fast fracture zone.	The new ProTaper Next enhanced its resistance to cyclic fatigue compared with traditionally ground ProTaper and HyFlex (CM Wire) but not the Twisted Files
Pedulla E	Mtwo and TF had significantly higher TtF when compared with all other instruments, both in continuous rotation and reciprocation of OTR motion (P < 0.0001 and P < 0.05, respectively). No difference was observed between Mtwo and TF (P > 0.05), in both motions. PTN was associated with higher cyclic fatigue resistance than Revo-S and EndoWave, both in continuous rotation and reciprocation of OTR motions (P < 0.0001). No difference was observed between Revo-S and EndoWave, in both motions (P > 0.05). Reciprocating OTR motion improved TtF of all instruments (P < 0.0001).	Within the limitations of this study, the instruments tested were associated with greater cyclic fatigue resistance in reciprocation of OTR motion than continuous rotation. Mtwo and TF files had the greatest cyclic fatigue resistance, in both motions. PTN instruments displayed greater cyclic fatigue resistance than Revo-S and EndoWave, both in continuous and in OTR reciprocating motion. No difference was observed between Revo-S and EndoWave, in both movements.
K olcay	WOG > PTN > TS according to TTF results (P = 0.00). PTN > TS according to NCF results (P = 0.00). The FL values showed no significant difference (P = 0.335).	Within the limitations of this in vitro study, it can be concluded that the reciprocal movement exhibited the best performance with regard to the cyclic fatigue resistance. In addition, the PTN instruments showed significantly longer NCF values than the TS instruments. Finally, reciprocating motion can be used more safely than continuous rotation in curved canals due to the higher cyclic fatigue resistance at body temperature.
Mohsen AminSobhami	Neoniti showed the highest and RaCe showed the lowest number of cycles to fracture (NCF) values (P<0.05), indicating the highest and lowest fatigue resistance, respectively. The highest and lowest curvature angles were seen in RaCe and Neoniti, respectively. Regarding the radius of curvature, Twisted file had the lowest and Neoniti had the highest values. The mean NCF of all rotary files was lower in the more coronally curved trajectory.	The fatigue resistance of the evaluated rotary files was lower in more coronally located curvatures. Neoniti exhibited the highest and RaCe exhibited the lowest fatigue resistance compared to other evaluated files.

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Table 2 continued

Silvio Emanuel Acioly Conrado de Menezes	The instrumentation time of the ProDesign Logic file was significantly lower when compared to the other files (P=0.019). The longest times to failure were presented by ProDesign Logic (182.07 sec) and ProDesign R (152.38 sec) files. The same differences were observed for the NCF (910.37 and 761.93). The WaveOne Gold group presented a lower NCF as well as a smaller sum of NCI+NCF (748.33) that was statistically significant when compared to the other groups (P<0.05) respectively.	The use of continuous rotational motion in canals with a glide path provided the ProDesign Logic instrument shorter instrumentation time. The cyclic fatigue resistance of ProDesign R and ProDesign Logic instruments was superior to WaveOne Gold. The thermal treatment of the instrument's alloy, its cross section, and the glide path seems to influence the cyclic fatigue resistance.

7. Discussion

The primary purpose of this systematic review and meta -analysis was to summarize the evidence from multiple studies that have evaluation of cyclic fatigue resistance of nickel titanium rotary instruments. The 9 studies included have tested cyclic fatigue resistance of nickel titanium rotary instruments in different temperature, different angle of curvature of canals, its metallurgy, thermal treatment, cross section and its continuous & reciprocating motion.

The fatigue resistance and superelasticity of NiTi instruments have recently been improved through the use of various thermomechanical treatments. The temperature of the phase change has a significant impact on the mechanical characteristics because the superelastic property is the result of stress-induced martensite transformation, which occurs in conjunction with a reversible phase transformation between austenite and martensite.[4] According to certain authors, martensitic instruments are less likely to fracture than austenitic ones. However, the majority of these experiments were conducted at room temperature, and there is some indication that a rise in temperature may have an impact on the characteristics of NiTi alloys.[23]

ProTaper Universal(S1F2) and ProTaper Gold(S1F2) nickel-titanium rotary files will be evaluated for cyclic fatigue resistance by Gianluca Plotino et al. (2016) at room and intra canal temperatures of 35 oc and with 300 RPM. And the findings indicate that both at ambient temperature and intracanal temperature, PTG instruments shown a significantly higher resilience to cycle fatigue than PTU devices.

Real teeth may mimic clinical conditions better, but because root canal architecture varies, it is impossible to choose real canals with the same curvature in terms of angle and diameter.[24] The kinematic features of the files play a significant impact in the cyclic fatigue resistance of the various instruments, in addition to the alloy used in file production and the heat treatments used.[25]

The study by Taha Ozyurek et al. (2018) compared the cyclic fatigue resistances of four distinct NiTi systems with various metallurgical properties: HyFlex EDM (HEDM), WaveOne Gold (WOG), Reciproc Blue (RB), and 2Shape (TS). HEDM:500rpm & 2.5n/cm T, Wave one Gold, ReciprocBlue, and 2Shape:300 rpm & 2.5n/cm T are files that use rpm% torque. Recriproc Blue outperforms the other evaluated files in terms of cyclic fatigue resistance, and there is no discernible difference between the 2shape, WaveOne Gold, and HyFlex EDM groups. In canal curvatures, NCF values obtained by HEDM revealed a substantially higher cyclic fatigue resistance than TS.

Despite their higher flexibility, NiTi endodontic rotary files occasionally fracture inside the root canal system.[26] These fractures are generated by tension from cyclic fatigue, torsional fatigue, or a combination of both.[2,27] The prognosis of the root canal system is impacted by the incidence of fracture of NiTi endodontic rotary files, which ranges from 0.09% to 5%.[28] This is why numerous studies on the cyclic fatigue resistance of NiTi endodontic rotary files have been conducted.[29] In order to examine the cyclic and torsional fatigue resistance of stainless steel endodontic hand files, the American National Standard Institute and the American Dental Association created a standardised approach in 2002. The International Standards Organization (ISO) (ISO 3630/1) also provided a description of the fatigue resistance for 2% taper stainless steel endodontic hand files. Nevertheless, there are no specifications for NiTi endodontic rotary systems exceeding 2% taper's cycle fatigue resistance.[30]

Celia Ruiz-Sanchez and associates (2020) When comparing the time to failure for the NiTi alloy study groups, all pairwise comparisons, with the exception of those between the PTN and PVB study groups, showed statistically significant differences. ProFileVortexBlue, ProTaperNext, and ProTaperUniversal endodontic rotary files' NiTi CM-Gold wire alloy are more resistant to cyclic fatigue.

Akanksha Bhatt et al(2018) aim of the present in-vitro study was to evaluate and compare cyclic flexural resistance of total 125 rotary Hero Shapers, Protaper Next, Profile Vortex, Hyflex CM and One Shape NiTi files manufactured from M wire Technology, CM wire technology and Conventional NiTi alloy with 400 Rpm & 2.5N/Cm torque. Result states that Time taken to fracture ranged from 7 to 58s in different groups .Cyclic flexural fracture resistance among the experimental groups the cyclic fatigue resistance was observed in descendingorder Group IV (Hyflex CM) > Group V (One Shape) > Group II (Protaper Next) > Group III (Profile Vortex) > Group I (Hero Shapers). Hyflex CM files had longest survival time while minimal survival time was shown by Hero Shapers files.

File fracture is the main concern throughout canal shaping procedures.[31] Several factors are responsible for file fracture in use; however, cyclic fatigue has been reported to be a significant cause as the rotary file might be used in curved root canals.[32] The geometric designs, structural characteristics and surface texture have a significant influence on the susceptibility of NiTi instruments to fracture mechanically.[33,34]

A.M Elnaghli (2014) aim of this study was to compare the cyclic fatigue resistance of the new ProTaperNext files with other files including Twisted Files, HeyFlex and ProTaper with Protaper:20.07F1TF: 25.06, PTN:25.06 X2, Hyflex: 25.06 & TF ,HF:500 rpm & PTN, PT:300rpm.Results are as Twisted Files had a significantly higher resistance to cyclic fatigue than the other instruments . No significant difference was found in NCF between PTN and HF , however, there was a significant difference of both these systems with PT, which exhibited the lowest mean NCF.

Table 3: Risk of bias assessment for non-RCT

Study	Comparison group	Sample size calculation	Instruments used a/c to manufacturer's instructions	Standardization of files	Controlled temperature	Single operator	Statistical analysis	Risk of bias
Amirsobhani et al 2015	Y	N	Y	Y	N	N	Y	Medium
Bhatt and Rajkumar 2019	Y	N	Y	Y	N	N	Y	Medium
de Menezes et al 2017	Y	Y	Y	N	N	Y	Y	Medium
Elnaghy 2014	Y	N	Y	N	N	N	Y	High
Olcay et al 2019	Y	Y	Y	N	Y	N	Y	Medium
Ozyurek et al 2018	Y	Y	Y	N	N	N	Y	Medium
Pedulla et al 2017	Y	N	Y	Y	N	N	Y	Medium
Plotino et al 2016	Y	N	Y	N	Y	N	Y	Medium
Ruiz-sanchez et al 2020	Y	N	Y	N	N	N	Y	High

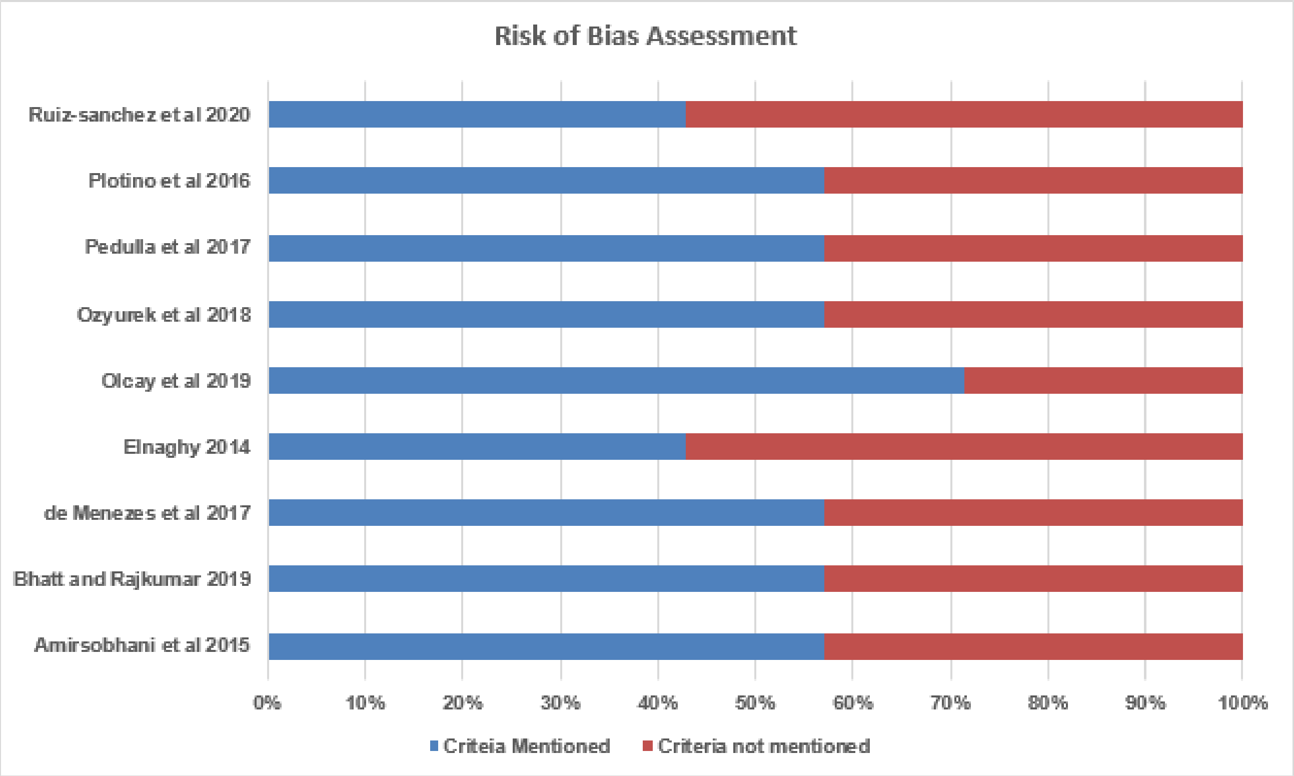

Fig. 6: Non-RCT Risk of bias graph

Examining ProTaper's resistance to cyclic fatigue is the goal of Pedulla E et al's (2017) study. Then, using EndoWave, Revo-S, Mtwo, Twisted Files, or both to reciprocate Optimal Torque Reverse motion or rotate continuously (OTR). PTN:25.0X2, Endowave:25.06, and Revo S SU:25.06 Mtw25.06o:TF:25.06 at 300 Rpm. According to the findings, Mtwo and TF had significantly greater TtF than all other instruments, both in continuous rotation and reciprocation of OTR motion, while PTN had stronger cycle fatigue resistance than Revo-S and EndoWave, both in continuous rotation and reciprocation of OTR motion.

In order to increase the cycle fatigue resistance of the NiTi files, the research suggests that reciprocating motion is substantially more effective than continuous rotation.[35,36] It is possible that the transition from martensite to austenite in the NiTi files was brought on by a rise in temperature. While operating in the root canal, where the temperature is about 37°C, the properties of the NiTi files at room temperature may change. Because the temperature in the root canal is higher than the austenite starting point (As) value, the martensitic characteristics of the NiTi files can change from the martensitic phase to the austenitic phase.[37]

The WOG, PTN, and TS NiTi instruments were the focus of a 2019 study by K olcay with the purpose of assessing their cycle fatigue resistances. Using an immersed transducer temperature sensor, these were tested in a specially constructed stainless steel metal block submerged in a water bath. The reciprocal movement showed the best performance in terms of cycle fatigue resistance, with WOG > PTN > TS according to the TTF data. Also, compared to the TS instruments, the PTN instruments displayed NCF values that were noticeably longer.

Mohsen AminSobhami et al (2015) aim to compare the cyclic fatigue resistance of Neoniti A1 #25, RaCe 25/.06, Mtwo 25/.06, Twisted file 25/.06 and ProTaper Next X2 file. With 300Rpm and 2N/cm Torque. Results states that Neoniti showed the highest and RaCe showed the lowest number of cycles to fracture (NCF) values (P<0.05), indicating the highest and lowest fatigue resistance.Regarding the radius of curvature, Twisted file had the lowest and Neoniti had the highest values.

Mechanized instrumentation saw significant advancements that allowed for the introduction of a number of systems with unique designs and differentiating metallurgy (40). ProDesign R and ProDesign Logic files have not received as much attention as WaveOne Gold's principal system,[21,38,39] according to studies.[40] ProDesign R and ProDesign Logic files are produced in the exact same way; the only difference is the cutting direction. When spinning in the opposite direction from ProDesign Logic, PDR is active.

To determine the fracture resistance of WaveOne Gold main, ProDesign R (25/0.06), and ProDesign Logic (25/0.06) files, with various RPM and Torque as WaveOne Gold, prodesigm, Silvio Emanuel Acioly Conrado de Menezes et al. (2017) set out to do. Prodesign logic:350 rpm & 1N/Cm T, R:350 rpm & 4N/Cm T. As a result, The ProDesign Logic file had significantly reduced performance when compared to the other files (P=0.019) but was still superior than WaveOne Gold in terms of cycle fatigue resistance. The WaveOne Gold group offered a lower NCF as well as a smaller sum of NCI+NCF (748.33), whereas ProDesign Logic (182.07 sec) and ProDesign R provided the longest timeframes to failure.

8. Conclusion

The findings of this systematic review and meta-analysis point to the possibility that the temperature at which the instruments are tested may have an impact on the results of cyclic fatigue resistance on NiTi files with varying behaviour depending on the alloy's heat treatment, and that an increase in the angle of curvature of artificial canals has a detrimental effect on cyclic fatigue resistance. The temperature inside the canal or at room temperature has no effect on the cyclic fatigue resistance of instruments made with the gold heat treatment.

For cycle fatigue resistance, reciprocal movement demonstrated the best performance. Due to the higher cycle fatigue resistance at body temperature, reciprocating motion can be used more safely than continuous rotation in curved canals. The instrument's alloy's thermal treatment, its cross section, and the glide path appear to have an impact on how resistant it is to cyclic fatigue.

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10. Conflicts of interest

There are no conflicts of interest.

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