

Benjamin Shamuilov

2019, group 11

Comparison of reciprocating & rotary glide path motion on cyclic fatigue resistance in endodontics: a systematic review.

Master's Thesis

Supervisor

Doctor Tadas Venskutonis

Kaunas , 2019

LITHUANIAN UNIVERSITY OF HEALTH SCIENCES
MEDICAL ACADEMY
FACULTY OF ODONTOLOGY
DEPARTMENT OF DENTAL AND ORAL PATHOLOGY

**Comparison of reciprocating & rotary glide path motion on cyclic fatigue resistance in
endodontics: a systematic review**

Master's Thesis

**The thesis was done
by student**

(signature)

Supervisor

(signature)

.....

(name surname, year, group)

.....

(degree, name surname)

..... **20....**

(day/month)

..... **20....**

(day/month)

Kaunas, 2019

TABLE OF CONTENTS

SUMMARY	7
INTRODUCTION	8
1. SELECTION CRITERIA OF THE STUDIES, SEARCH METHODS AND STRATEGY	10
2. SYSTEMATIZATION AND ANALYSIS OF DATA	14
3. DISCUSSION	23
4. CONCLUSIONS	25
5. PRACTICAL RECOMMENDATIONS	25
6. REFERENCES	26

SUMMARY

Objectives: Aim of the systematic review was to search and analyze the current publications related to the selected topic. Moreover, this review focused on comparing reciprocating glide path motion versus rotary glide path motion on cyclic fatigue resistance in endodontics.

Material and methods. A systematic review was carried out to identify relevant studies reporting data on reciprocating and rotary glide path on cyclic fatigue resistance in endodontic dentistry. The data was extracted from the selected papers. The following key words or their combinations were used during searching: reciprocating, rotary, cyclic fatigue , glide path in endodontics in order to audit the searching method and to get to more accurate information about the reviewed topic. Internet based search engines where used as well as articles and journals from databases such as PubMed, Science Direct and Willey online library databases. The search was done in English language and only English articles published from 2013-2018 were included.

Results. A total of 118 articles were identified after initial search and 5 publications were enrolled in this systematic review. 5 glide path files were analyzed and compared. The evaluation revealed that cyclic fatigue resistance is increased with reciprocating glide path instruments. There was no significant difference in the mean fragment length regarding all the instruments.

Conclusion. Reciprocating glide path instruments exhibited higher cyclic fatigue resistance than rotating glide path instrument. The WaveOne Gold Glider had the highest resistance, the lowest was exhibited by Pathfiles.

Key words: reciprocating, rotary, cyclic fatigue , glide path in endodontics.

Introduction

Since the beginning of endodontic therapy the most fundamental procedure during root canal treatment is cleaning and shaping [1]. The glide path is described as a smooth tunnel running from the canal orifice to the physiological apical foramen of the root canal. Endodontic root canal glide path is the foundation for a generally safer root canal preparation. Without the existence of the glide path, there is no guidance and the ultimate principle of endodontics can not be accomplished. The establishment of a glide path can be influenced by two factors. The first is the degree of canal curvature and secondly the experience of the operator [2, 3]. Difficulties can arise by creating a glide path with manual files causing canal transportation, less centered canal preparations or apically extruded debris [4, 5]. Therefore, it is advised to utilize rotary nickel-titanium (NiTi) instruments in order to attain a better outcome while establishing a glide path, particularly in curved canals. However, the major disadvantage is their unpredictable fracture because of cyclic fatigue. Hence by occurrence of fracture when preparing a root canal, it will ultimately have a crucial impact on the cleaning and preparation of the root canals [6, 7].

The reciprocating motion is usually in a counterclockwise (cutting) direction and then a clockwise (release) direction of movement of the instrument, resulting in constantly engaging and disengaging in the root canal in a back and forth motion. The angle of the counterclockwise direction is greater than the clockwise which enables the file to continue to progress to the apical direction. Continuous rotation on the other hand is a traditional 360° clockwise rotation [7, 8]. The 2 main issues that fractured instruments occur are cyclic fatigue and torsional forces [8]. Frictional resistance is the reason why torsional forces develop. As a result, as the surface area increases there will be greater friction and torsional overloading which therefore creates a higher potential for fracture. Normally when the instrument rotates in a curved canal, cyclic fatigue occurs. The molecules on the outer surface of the file are under tension at the point of curvature while the molecules on the inner surface of the instrument are compressed [9]. The areas of compression and tension alternate while the instrument rotates and therefore leads to fractured file. In general there is no noticeable indication that a fracture is impending. Due to that fact, it is recommended to limit the use of NiTi files to up to five cases [10]. The operator's skill and touch to detect that too much stress is applied on the file during preparation is a critical factor to avoid instrument fracture. Therefore, the recognition of the doctor is a very important step and can be improved by years of experience [11]. Remained dentin shoulders and inadequate prepared cavity walls in the coronal end of the canal can influence the stress and thereby lead to fractured instrument. On the contrary, enlarging the access beyond the borderline can lead to unfavourable bending [12].

The majority of nickel-titanium alloy is made out nickel and the rest 45 percent are from titanium. At room temperature NiTi files can be classified into 2 different ways. If the instrument is unstressed the file is at an austenite form. The alloy will change its shape to a martensitic form by exertion of rotation or bending force to the file. The file returns to its primary shape in its austenite form as the force is removed [13]. Although all the benefits of NiTi instruments over stainless steel based on the metallurgical features, the innately memory in traditional NiTi files used in curved canal displayed an issue and there has been a necessity to manufacture instruments with increased file flexibility, non metal memory, greater resistance to fracture, and ideal cutting efficiency. When preparing the canal, the file rotates and therefore experiences stresses. Bending and torsional stresses will obviously result in flexion and compression inside the metal. Finally, the file might separate due to fatigue [14].

To simplify matters in curved canals in an optimize way Controlled memory (CM) NiTi files were introduced and revolutionized the field in endodontics. These files are made of nickel-titanium metal alloy which received a patented thermomechanical treatment. At room temperature Controlled memory files exhibit martensitic characteristics in contrast to conventional NiTi metal. As a consequence resulting in an instrument with extreme flexibility and no memory. Thus, the memory free feature permits the file to adapt to canal curvatures more easily [15].

Aim of the work:

- 1.To compare reciprocating glide path motion versus rotary glide path motion on cyclic fatigue resistance.
2. To compare the time to fracture and fragment lengths of these files.

1. SELECTION CRITERIA OF THE STUDIES. SEARCH METHODS AND STRATEGY

The systematic review conducted according the protocol of following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. The focus question, “Does reciprocating glide path files have better cyclic fatigue characteristic compared with rotary glide path files?,” was proposed by following the PICO principle: Patients – in vitro studies with artificial canals, or special tools for cyclic fatigue testing; Intervention – reciprocating glide path files tested for cyclic fatigue; Comparison – rotary glide path files tested for cyclic fatigued; Outcomes – evaluation of cyclic fatigue, time to fracture and fragment length.

1.1 The main question of the systematic review

The main issue of this systematic review of literature was raised by PICO principle and targeted artificial canals or special tools comparing the cyclic fatigue resistance of reciprocating and rotary glide path files.

1.2 systematic review`s protocol

1.2.1 Literature sources for this systematic review

The literature, systematic review is based on an identification selection of main information source literature studies conducted from electronic databases. Comprehensive search was restricted to English language articles, in the following electronic databases: Medline (PubMed), ScienceDirect and Wiley Online Library. Citations were read and verified. Articles related to the theme were qualified.

1.2.3 Data retrieval strategy

The literature search was conducted in English using the above mentioned databases keywords and their combinations: reciprocating, rotary, cyclic fatigue resistance, glide path in endodontics. A manual search through dental journals as the International Endodontic Journal and Journal of Endodontics was additionally performed.

1.2.4 Selection process of the articles

The studies were selected in several steps: the first stage included all the studies that matched the search by keywords combinations. Then filters were applied excluding the search based on the exclusion criteria. Duplicates were removed in the next step. The articles were further reviewed, including abstracts of articles and rejecting those that did not meet the defined research criteria. At the last stage, after a full text analysis, evaluating their relevance of all articles selection criteria, they were included in this systematic analysis.

The titles of all the articles have been reviewed in order to avoid mistakes in the selection process. At the final selection process for articles 2 investigators took part in the systematic review for assurance on the adequateness of the articles: B. Shamuilov and Dr. T.Venskutonis. If one of the article's eligibility criteria did not match the study was rejected.

1.2.5 Inclusion and exclusion criteria

The final stage of screening involved full text articles review and reading in order to certify study eligibility upon inclusion and exclusion criteria.

Inclusion criteria for the selection were the following:

- Publications written in English language.
- Studies published between 2013-2018.
- Studies performed on artificial canals with minimum amount of 10 files in each group.
- Studies comparing reciprocating and rotary glide path motion or reciprocating glide path motion alone.

Exclusion criteria for the selection were the following:

- Systematic review and review articles.
- Commentaries.

- Practice guidelines.

-Studies performed on animals.

-Studies performed on human teeth due to inadequate analysis assessment.

1.2.5 Quality assessment of included studies

In vitro studies form an essential and crucial role in nowadays dental research by contributing to a significant evidence base. These studies allow us to overcome clinical mistakes by studying, comparing, and analysing various instruments and materials ahead of their clinical usage. Additionally it helps the clinician to learn and understand the basic knowledge of certain materials regarding their composition and different attributes. Theoretically, there are minimal possibilities of error occurring in this type of research. Clinically we cannot study the cyclic fatigue resistance of any glide path instruments. Therefore, Krithikadatta J et al., 2014 published a standardized guidelines in order to improve the transparency and enhance the quality of in vitro studies in dentistry- Checklist for reporting In vitro studies (Cris) [16]. Hence to advance transparency and quality of in vitro research these values have to be considered and present; sample size calculation, meaningful difference between groups, sample preparation and handling, allocation sequence, randomization and blinding and statistical analysis. If these components are present it represents a significant value of the publication. In our research, no additional information was included.

Main rotary and reciprocating glide path instruments in endodontics

The PathFile (Dentsply Sirona, USA) nickel-titanium rotary glide path instrument system is composed of three files. The files are manufactured from conventional NiTi alloy. Their tip diameters varying from 0.13mm, 0.16mm and 0.19 mm. The Pathfile have multiple cutting edges, in cross-sectional shape a square and present a 2% persistent taper [17].

ProGlider (Dentsply Sirona, USA) is a rotary glide path preparation instrument fabricated from memory NiTi wire (M-wire), which facilitate increased cyclic fatigue resistance in comparison to the conventional NiTi instruments. The ProGlider glide path instrument features a tip diameter of 0.16 mm and an increasing taper varying from 2% to 8%. Furthermore is consists of 4 cutting edges and has a square cross-section [18].

HyFlex EDM (Coltene/ Whaledent, Altstatten, Switzerland) NiTi glide path files are the primarily file system which are constructed of controlled memory (CM) using EDM (electrical discharging machining) technology. Those glide path files have three horizontal cross-sections differing consistently through their shaft; at the tip quadratic, in the middle trapezoidal and towards the shaft triangular. They are also composed of a single file which has a 5% taper and a diameter of 0.10 mm at the tip [17].

Another rotary glide path instrument is the HyFlex GPF (Coltene/ Whaledent, Allstatten, Switzerland). As the HyFlex EDM, it is manufactured from a controlled memory NiTi wire. The specific characteristic of the control memory allows the file to be very flexible and increases the cyclic fatigue resistance compared to NiTi files without control memory. It has a square cross-section and includes 4 cutting edges [19, 20].

The RaCe ISO 10 (FKG Dentaire, Swiss dental Products) instruments have three ISO 10 tip sizes with 2%, 4% and 6% tapers. The RaCe file with the lowest taper is in cross-sectional design a square whereas the 4% and 6% showed to be triangular in cross-sections. The Scout RaCe has a sequence of 3 instruments which are ISO 10, 15 and 20 tip sized and consist of a 2% taper and a square cross-sectional design [21].

The very first NiTi rotary glide path which is used in reciprocation motion is the R-Pilot (VDW, Munich, Germany). It consists of the M-Wire alloy. The instrument is in cross-section S- shaped. It involves a tip of 0.125mm in diameter and its taper is throughout of 4% [22].

The second reciprocating glide path instrument, the WaveOne Gold Glider (Dentsply Sirona, USA), is a glide path in reciprocating motion that has a 0.15mm tip diameter. It represents a progressively increasing and taper of 2–6% tapers with flute diameters at D1 of 0.170mm, D8 0.413mm, and D16 0.850 mm. Additionally it is manufactured from NiTi wire that received a thermomechanical treatment. As all the WaveOne Gold instruments, the WaveOne Gold Glider has a parallelogram shaped cross-section [23].

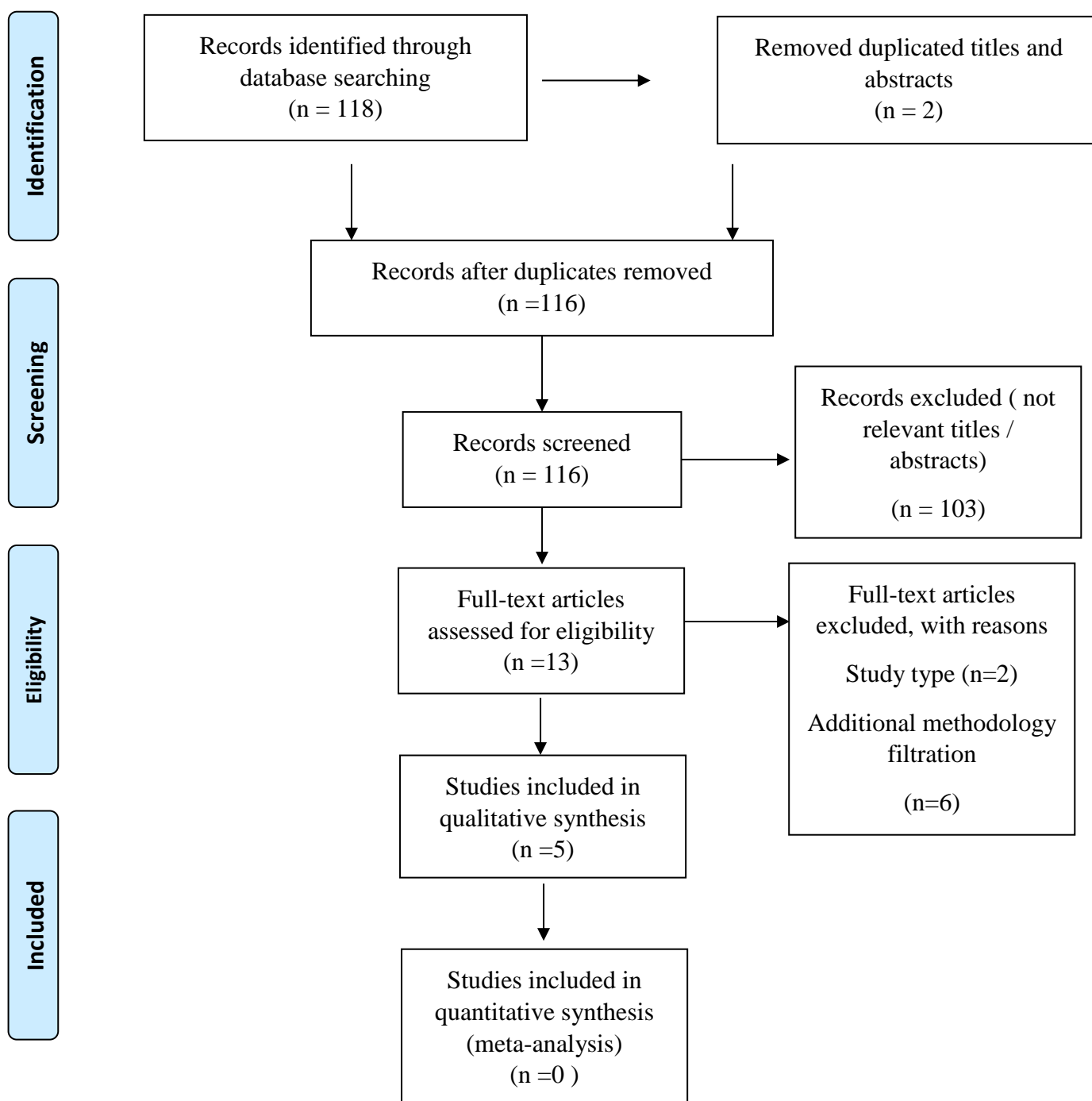
2.SYSTEMATIZATION AND ANALYSIS OF DATA

2.1 Search results

The last literature search was done on 27th of March 2019. There was a total of 118 related topics to this review subject. Duplicates of 2 articles were rejected. From the remaining 116 articles 103 were excluded. 13 full-text articles were assessed for eligibility. 8 full-text articles were excluded; 2 due to their study type that represented randomized clinical trials, 6 due to additional methodology filtration which included studies involving only rotary glide path files. By reviewing articles under the criteria for inclusion and exclusion in this analysis, five were selected for reading full text articles of which all publication were available in full format. The entire article selection procedure has been prepared and depicted according to the PRISMA Flow chart [24].

Based on the literature, results focused on Proglider , HyFlex EDM (Coltene/ Whaledent, Altstatten, Switzerland) NiTi glide Pathfiles, R- Pilot and WaveOne Gold Glider.

Table 1. illustrates by a flow chart the process of filtering.



Briefly, this systematic review is exposed to a certain amount of bias. This is due to the low amount of articles that discussed specifically the comparison of both methods to each other in one single study.

2.2 Characteristics of research

In order to properly organize and for better mentioning of information, a table of characteristic was made for this purpose (Table.2), in which the authors, study title, number of files, angle of curvature, radius of curvature and outcome of cyclic fatigue resistance of each study were displayed.

Upon analyzing the different rotary and reciprocating glide path files, it appears that reciprocating glide path files instruments exhibited higher cyclic fatigue resistance than rotating glide path instrument in all the studies. Generally, all studies were done under a stereomicroscope free of any detectable deficit and abnormalities. In order to decrease the friction of the files synthetic oil or synthetic lubricant was used as lubrication at the artificial canal. Each file was used till fracture was shown. Therefore, time to fracture were recorded and additionally the fractured fragments were also measured.

Table 2. Main characteristics of analyzed studies.

Researcher	Type of study	Number of files	Angle of curvature	Radius of Curvature	Length of canal	Outcome on CFR
C. Keskin et al., 2017 [23]	laboratory study	15 Proglider 15 R-Pilot 15 WaveOne Gold Glider	60°	5mm	Not given	WaveOne Gold Glider and R-Pilot had higher CFR than ProGlider instruments (P < 0.05)
B. Serefoglu et al., 2018 [25]	laboratory study	10 Proglider 10 R-Pilot 10 Waveone	90°	3mm	19mm	WaveOne Gold Glider > R- Pilot > Pro Glider (P < .05)

		Gold Glider				
HS. Topcuoglu et al., 2018 [26]	laboratory study	30 R-Pilot 30 WaveOne Gold Glider	45° & 60°	5mm	18mm	WaveOne Gold Glider has higher CFR than R-Pilot in 60°. No differences in 45°.
G. Uslu et al., 2018 [17]	laboratory study	20 HyFlex EDM 20 R-Pilot 20 Path files	Double s shaped curvature Coronal curve Apical curvature	5 mm 2mm	Not given	R-Pilot had greatest CFR followed by the HyFlex EDM and PathFile in both the apical and coronal curvatures (P < 0.05).
K. Yılmaz et al., 2018 [27]	laboratory study	20 One G 20 HyFlex EDM 20 R pilot 20 Proglider	60°	5mm	16mm	CFR of the R-Pilot was significantly greater than that of the rotary HyFlex EDM, ProGlider and

						One G glide path files. (P > 0.05)
--	--	--	--	--	--	------------------------------------

CFR - cyclic fatigue resistance, **TF** - is time required for failure, **NCF** - Number of Cycles to Failure, **FL** - Length of the Fractured Fragment

In the first study described by C. Keskin et al., 2017 [23] no significantly difference was visible according to the mean length of the fractured fragments of all instruments. Between the two reciprocating files the R-Pilot and WaveOne Gold Glider there was no significant difference regarding their cyclic fatigue resistance ($P > 0.05$) but in comparison with the Proglider instruments, they had the highest cyclic fatigue resistance. The study from B. Serefoglu et al., 2018 [25] is dealing with R-Pilot, WaveOne Gold Glider and Proglider instruments with a stainless steel artificial canal of 90 degree and a curvature of 3mm while the study by C. Keskin et al., 2017 involved a curvature of 60 degree and a radius of 5 mm (Table 2). Upon analysing the different rotary and reciprocating glide path files there was no significant difference in the mean fragment length. The ProGlider had the lowest cyclic fatigue resistance and the reciprocating WaveOne Gold Glider had a higher ranking than the R-Pilot.

The study from HS. Topcuoglu et al., 2018 [26] included just reciprocating instruments the R- Pilot and Waveone Gold Glider at 2 different curvatures of 45&60° but the same radius of curvature (Table 2). The R-Pilot and WaveOne Gold Glider files are resembling nearly the same number of cycles to fracture and time to fracture while used in 45° canals ($P > 0.05$). However the WaveOne Gold Glider files had significantly higher time to fracture and number of cycles to fracture values than R-Pilot files when operated in 60° canals ($P < 0.05$). With reference to the file fragment lengths of the 2 reciprocating files, there was no significant difference depending the R-Pilot and WaveOne Gold Glider files depending if operated in 45° or 60° canals ($P > 0.05$). G. Uslu et al., 2018 [17] represents HyFlex EDM, R-Pilot and Path files in double curved canal. Fracture occurred at the beginning at the apical curvature and the at the coronal part. The R-Pilot displayed according to the number of cycles to failure values that it had the greatest cyclic fatigue resistance thereafter the HyFlex EDM and PathFile in both curvatures ($P < 0.05$). Upon the fractured fragments of the instruments at coronal and apical curvatures there was no significant difference obvious in the apical or coronal curvatures. K. Yılmaz et al., 2018 [27] portrays HyFlex EDM, Proglider and the

R-Pilot of a curvature of 60 degree and a radius of 5mm. The greatest cyclic fatigue resistance was the one of the R-Pilot files. There was no significant difference between the HyFlex EDM and the ProGlider ($P > 0.05$). No significant difference ($P > 0.05$) was evident in the mean length of the fractured fragments of the instruments.

Table 3. Main instruments comparison on TF, NCF and FL

Researcher	Files	TF (s)	NCF	FL (mm) \pm SD
C. Keskin et al., 2017 [23]	R-Pilot	1016	3562.46 \pm 963.55	4.45 \pm 0.46
	WaveOne Gold Glider	2111	3465.26 \pm 468.54	4.67 \pm 0.43
	ProGlider	397	1254.20 \pm 356.08	4.63 \pm 0.27
B. Serefoglu et al., 2018 [25]	R-Pilot	Not given	1038 \pm 177	6.8 \pm 0.34
	WaveOne Gold Glider	Not given	1294 \pm 123	7.1 \pm 0.21
	ProGlider	Not given	266 \pm 72	6.9 \pm 0.28
HS. Topcuoglu et al., 2018 [26]	R-Pilot	394.5 /247.2	2185.45 \pm 255.16 /1355.58 328.41	5.01 \pm 1,08/5.32 \pm 1.21
	WaveOne Gold Glider	412.4/368.3	2304.36 \pm 346.21/2116.37 \pm 424.64	5.12 \pm 0.98/ 5.23 \pm 1.36
G. Uslu et al., 2018 [17]	Pathfile	Not given	1675.41 \pm 201.55/1062.03 \pm 127.44	7.84 \pm 1.45/2.12 \pm 0.35
	HyflexEDM	Not given	2262.43 \pm 271.44/1706.72 \pm 209.72	7,76 \pm 1.34/2.19 \pm 0.44
	R-Pilot	Not given	4894.82 \pm 743.11/3607.57 \pm 519.06	7.65 \pm 1.44/ 2.11 \pm 0.29
K. Yilmaz et al., 2018 [27]	ProGlider	329.41 \pm 48.49	Not given	5.33 \pm 0.34
	HyfledEDM	388.21 \pm 46.62	Not given	5.01 \pm 0.32
	R- Pilot	915.71 \pm 173.96	Not given	5.09 \pm 0.29

TF - is time required for failure, **NCF** - Number of Cycles to Failure, **FL** - Length of the Fractured Fragment

To summarize the data presented in Table 3, we observe that in the articles included the reciprocating glide path files have a significantly higher time to fracture and number of cycles to fracture than rotary instruments. R-Pilot was included in all the studies. No significant difference was evident in the mean length of the fractured fragments of the instruments.

Table 4. Files investigated in the publications

Files	Metal type	Taper	Tip size
Pathfiles	conventional NiTi alloy	2%	0.13mm, 0.16mm,0.19mm
HyFlex EDM	Controlled memory NiTi alloy	5%	0,10mm
Proglider	memory NiTi wire	2%-8%	0,16mm
R- Pilot	memory NiTi wire	4%	0,125mm
Waveone Gold Glider	Controlled memory NiTi alloy	2%-6%	0,15mm

To conclude the data presented in Table 4 on behalf of the metal type the memory NiTi wire used in our studies are in austenite form at room temperature which exhibit memory shape, will always try to straighten in curved canals leading to undesired stresses which results in cyclic fatigue resistance.

Table 5. Angle & radius of curvature, Artificial canal, lubrication, Statistical analysis test used in all of the studies involved in this systematic review.

Researcher	Angle of curvature	Radius of curvature	Artificial canal	Lubrication type	Statistical data analysis test
C. Keskin et al., 2017 [23]	60°	5mm	Stainless steel	synthetic oil (WD-40; Milton Keynes, UK)	Shapiro–Wilk test Tukey test
B. Serefoglu et al., 2018 [25]	90°	3mm	Stainless steel	synthetic oil (WD-40; Milton Keynes, UK)	Shapiro–Wilk test Tukey test
HS. Topcuoglu et al., 2018 [26]	45° & 60°	5mm	Stainless Steel	synthetic oil (WD-40; Milton Keynes, UK)	Shapiro–Wilk test Tukey test
G. Uslu et al., 2018 [17]	Coronal curve 60° Apical curve 70°	5mm 2mm	double-curved stainless steel	Not given	Shapiro–Wilk test Tukey test Tamhane tests One way Anova test Kruskal–Wallis test
K. Yılmaz et al., 2018 [27]	60°	5mm	Stainless steel operated at 35° water temperature	synthetic lubricant	Shapiro–Wilk test Tamhane tests Kruskal–Wallis test

Quality assessment of articles included in the analysis

While evaluating the quality of the material presented in the publications, all the articles represented the necessary data according to CRIS (Table 6).

Table 6. Quality assessment of all studies used in this systemic review by CRIS

Researcher	Sample size calculation	Meaningful difference between groups	Sample preparation and handling	Allocation sequence, randomization and blinding	Statistical analysis
C. Keskin et al., 2017 [23]	+	+	+	+/-	+
B.Serefoglu et al., 2018 [25]	-	+	+	+/-	+
HS. Topcuoglu et al., 2018 [26]	+	+	+	+/-	+
G. Uslu et al., 2018 [17]	+	+	+	+/-	+
K. Yilmaz et al., 2018 [27]	+	+	+	+/-	+

A quality analysis of all of the 5 studies was done. The allocation sequence and randomization and binding criteria showed an issue in all included studies. B Serefoglu et al., 2018 [25] had an inadequate amount of sample size calculation. However we can conclude that overall moderate study quality was scored.

3. Discussion

This present systematic review compared the cyclic fatigue resistance of reciprocating glide path instruments with rotating glide path instruments. The use of novel reciprocating glide path instruments showed in all the studies higher cyclic fatigue resistance than the rotary glide path instruments. The purpose of the reciprocation motion has been the decrease of torsional stress and the avoidance of torsional failure on the file. Additionally we should keep in consideration that the kinematics are also an important element assisting in achieving an increase on cyclic fatigue resistance on NiTi instruments as in prior studies indicated [28]. In the two studies where ProGlider, R- Pilot and the WaveOne Gold Glider were compared it was shown that the reciprocating files had higher resistance than the ProGlider even though they were not operated at the same angle and radius of curvature. All the files were used until fracture appeared with a 3-mm/s axial movement and thereby the fractured time was calculated. A digital caliper was used to evaluate the length of the fractured fragment and recorded. Afterwards 2 files from each category were examined under a scanning electron microscope, and photomicrographs of the fractured areas were observed at different magnifications. Although the number of instruments tested on the stainless steel artificial canals was very low in these studies, it can be concluded that reciprocation instruments were superior to rotary movements. There was no significant difference in the mean fragment length regarding all the instruments. As in previous studies discussed cross-sectional shape, kinematics movement, angle, thermomechanical treatment has a huge and specific impact on flexibility and fatigue resistance [26]. The study from HS. Topcuoglu et al., 2018 [17] included just reciprocating instruments the R- Pilot and WaveOne Gold Glider at 2 different curvatures of 45° & 60° but the same radius of curvature. However, the WaveOne Gold Glider files had significantly higher time to fracture and number of cycles to fracture values than R-Pilot files when operated in 60° canals which can be due to reduced shape memory of the WaveOne Gold Glider which leads us to the cross-sectional shape of the instruments. While previous studies showed that there is no direct influence of the cross-sectional shape on the resistance, some did though report that there is an impact [29]. The R- Pilot has an S shaped cross-sectional design, on the other hand the WaveOne Gold Glider has a parallelogram shaped shape. Therefore, it is understandable why the WaveOne Gold Glider had a higher time to fracture when operated in a canal of 60 degree due to its smaller area of cross-sectional shape that enhances the cyclic fatigue resistance compared to the R- Pilot which had a greater area that decreases the resistance [10, 30]. Another important factor of the reciprocating glide path instruments is their taper. Yao et al., 2006 reported that the higher the taper while operated in a curved canal, the instrument is getting fractured after considerably less rotation. The Taper of the WaveOne is at 2% increasing to 6% during its active motion. The R- Pilot file

has an unchanged taper of 4%. That could be a reason why at 60° the WaveOne had a greater resistance in comparison to the R- Pilot. Rotary glide path instruments as the Pathfile consist of a square cross-section with multiple cutting edges and a 2% constant taper. HyFlex EDM (Coltene/Whaledent, Altstätten, Switzerland) NiTi glide path files have three horizontal cross-sections differing consistently through their shaft and a taper of 5%. G. Uslu et al., 2018 [17] reported that in double curved s shaped canal HyFlexEDM had higher cyclic fatigue resistance than the Pathfiles which brings us back to the importance of the shape, cross-section, kinematic movement, taper and the flexibility. HyFlex EDM instruments are produced from a CM alloy and R-Pilot files are made of M-Wire alloy, whereas Pathfiles are made of conventional NiTi alloy and the Proglider instruments are from an M-Wire alloy. Thus Elnaghy et al., 2015 [18] reported that higher fatigue and torsional resistance for the ProGlider file and can be associated with the type of its alloy fabrication. On the other hand, the WaveOne Gold Glider is made of NiTi wire that received a thermomechanical treatment. As in recent study mentioned there is prove that this thermomechanical treatment processes have an influence on the cyclic fatigue resistance as well as on the flexibility of NiTi instruments. Nevertheless, reciprocating motion of the R-Pilot was superior in his study than the rotary instruments [31, 32].

4. Conclusion

Going through this systematic review and analyzing the available limited studies on reciprocating and rotary glide path instruments on cyclic fatigue resistance we can conclude that reciprocation motion is superior to rotation motion. WaveOne Gold Glider > R-Pilot> ProGlider> HyFlex EDM> Pathfiles. The enhanced resistance could be due to the specialized kinematics, cross-section, taper, flexibility and thermomechanical treatment. Based on all studies in this systematic review there was no significant difference regarding the file fragment lengths between all the tested files including the Pathfile, ProGlider, HyFlex EDM, R-Pilot and the WaveOne Gold Glider. Concerning the time to fracture on reciprocating instruments the WaveOne Gold Glider files had higher time to fracture values than R-Pilot. In regard to the rotary files ProGlider and HyFlex EDM showed almost the same time to fracture.

5. Practical recommendations

In order to achieve the best possible outcome while treating a root canal, a glide path should be present. After valuing all criterias the WaveOne Gold Glider is nowadays the optimal option. It is a 1 file system with an easy usage due to its reciprocating motion and flexibility which thereby minimizes the risk of errors during preparation of the canal. It completes the Waveone Gold with the exact reciprocating motion, is produced from NiTi that received a thermomechanical treatment which enhances the strength of the file and allows greater cyclic fatigue resistance. By now it would have been adapted in every dental office if it would have been affordable.

Conflict of interest

The author of this study declares that there are no conflicts of interest.

Fundings

This systematic review was not funded by any means.

6. References

1. West J. The Endodontic Glidepath: Secrets to rotary success. *Dentistry Today*. 2010; 29(9): 90-93.
2. Patiño PV, Biedma BM, Liébana CR, Cantatore G, Bahillo JG. The influence of a manual glide path on the separation rate of NiTi rotary instruments. *J Endod*. 2005; 31(2):114–116.
3. Berutti E, Cantatore G, Castellucci A, Chiandussi G, Pera F, Migliaretti G, Pasqualini D. Use of nickel-titanium rotary PathFile to create the glide path: comparison with manual preflaring in simulated root canals. *J Endod*. 2009; 35(3):408-12.
4. Ha JH, Park SS. Influence of glide path on the screw-in effect and torque of nickel-titanium rotary files in simulated resin root canals. *Restor Dent Endod*. 2012; 37(4):215-9.
5. Alovisi M, Cemenasco A, Mancini L, Paolino D, Scotti N, Bianchi CC, Pasqualini D. Micro-CT evaluation of several glide path techniques and ProTaper Next shaping outcomes in maxillary first molar curved canals. *Int Endod J*. 2016; 50(4):387-397.
6. Plotino G, Grande NM, Cordaro M, Testarelli L, Gambarini G. A review on cyclic fatigue testing of nickel-titanium rotary instruments. *J Endod*. 2009; 35(11):1469-76.
7. Jonker CH, Van der Vyver PJ, De Wet FA. The influence of glide path preparation on the failure rate of WaveOne reciprocating instruments. *SADJ*. 2014; 69(6):266-9.
8. Peters OA, Barbakow F. Dynamic torque and apical forces of ProFile.04 rotary instruments during preparation of curved canals. *Int Endod J*. 2002; 35(4):379-89.
9. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. *J Endod* 2000; 26(3):161-5.
10. Grande NM, Plotino G, Pecci R, Bedini R, Malagnino VA, Somma F. Cyclic fatigue resistance and three-dimensional analysis of instruments from two nickel-titanium rotary systems. *Int Endod J*. 2006; 39(10):755-63.

11. Shen Y, Haapasalo M, Cheung GS, Peng B. Defects in nickel-titanium instruments after clinical use. Part 1: Relationship between observed imperfections and factors leading to such defects in a cohort study. *J Endod.* 2009; 35(1):129–32.
12. Roda SR, Gettleman BH. Nonsurgical retreatment. In: Hargreaves K, Berman LH, editors. *Cohen's pathways of the pulp*. 11th ed. St. Louis: Elsevier; 2016
13. Zhao D, Shen Y, Peng B, Haapasalo M. Micro-computed Tomography Evaluation of the Preparation of Mesio Buccal Root Canals in Maxillary First Molars with Hyflex CM, Twisted files, and K3 Instruments. *J Endod.* 2013; 39(3):385-8.
14. Yum J, Cheung GS, Park JK, Hur B, Kim HC. Torsional strength and toughness of nickel-titanium rotary files. *J Endod.* 2011; 37(3):382-6.
15. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. *J Endod.* 2013; 39(2):163-72.
16. Krithikadatta J, Gopikrishna V, Datta M. CRIS Guidelines (Checklist for Reporting In-vitro Studies): A concept note on the need for standardized guidelines for improving quality and transparency in reporting in-vitro studies in experimental dental research. *J Conserv Dent.* 2014; 17(4):301-4. doi: 10.4103/0972-0707.136338.
17. Uslu G, Özyürek, T, Yılmaz, K, Gündoğar, M. Cyclic fatigue resistance of R-Pilot, HyFlex EDM and PathFile nickel-titanium glide path files in artificial canals with double (S-shaped) curvature. *Int Endod J.* 2017; 51(5):584–589.
18. Elnaghy AM, Elsaka SE. Evaluation of the mechanical behaviour of PathFile and ProGlider pathfinding nickel-titanium rotary instruments. *Int Endod J.* 2015; 48(9):894–901.
19. Shen Y, Qian W, Abtin H, Gao Y, Haapasalo M. Fatigue testing of controlled memory wire nickel-titanium rotary instruments. *J Endod.* 2011; 37(7):997-1001.
20. Pongione G, Pompa G, Milana V, Di Carlo S, Giansiracusa A, Nicolini E, De Angelis F. Flexibility and resistance to cyclic fatigue of endodontic instruments made with different nickel-titanium alloys: a comparative test. *Ann Stomatol.* 2012; 3(3-4):119-22.

21. Nakagawa RK, Alves JL, Buono VT, Bahia MG. Flexibility and torsional behaviour of rotary nickel-titanium PathFile, RaCe ISO 10, Scout RaCe and stainless steel K-File hand instruments. *Int Endod J.* 2014; 47(3):290-7.
22. R-Pilot brochure. Available at: <https://www.vdw-dental.com/fileadmin/Dokumente/Sortiment/Aufbereitung/Reziproke-Aufbereitung/R-Pilot/VDW-Dental-R-PILOT-Product-Brochure-EN.pdf>.
23. Keskin C, İnan U, Demiral M, Keleş A. Cyclic fatigue resistance of R-Pilot, WaveOne Gold Glider and Proglider glide path instruments. *Clin Oral Investig.* 2018; 22(9):3007-3012.
24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine.* 2009; 6(7).
25. Serefoglu B, Kaval ME, Micoogullari Kurt S, Çalışkan MK. Cyclic Fatigue Resistance of Novel Glide Path Instruments with Different Alloy Properties and Kinematics. *J Endod.* 2018; 44(9):1422-1424.
26. Topçuoğlu HS, Topçuoğlu G, Kafdağ Ö, Arslan H. Cyclic fatigue resistance of new reciprocating glide path files in 45- and 60- degree curved canals. *International Endodontic Journal.* 2018; 51(9):1053-1058.
27. Yılmaz K, Uslu G, Gündoğar M, Özyürek T, Grande NM, Plotino G. Cyclic fatigue resistances of several nickel-titanium glide path rotary and reciprocating instruments at body temperature. *International Endodontic Journal.* 2018; 51(8):924–930.
28. Castelló-Escrivá R, Alegre-Domingo T, Faus-Matoses V, RománRichon S, Faus-Llácer VJ. In vitro comparison of cyclic fatigue resistance of ProTaper, WaveOne, and Twisted Files. *J Endo.* 2012; 38(11):1521-4.
29. Lopes HP, Elias CN, Vieira MV, Siqueira JF Jr, Mangelli M, Lopes WS, Vieira VT, Alves FR, Oliveira JC, Soares TG. Fatigue life of Reciproc and Mtwo instruments subjected to static and dynamic tests. *J Endod.* 2013; 39(5):693-6.

30. Tripi TR, Bonaccorso A, Condorelli GG. Cyclic fatigue of different nickel-titanium endodontic rotary instruments. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006; 102(4): 106-14.
31. Hieawy A, Haapasalo M, Zhou H, Wang Z, Shen Y. Phase transformation behavior and resistance to bending and cyclic fatigue of ProTaper Gold and ProTaper Universal instruments. *J Endod* 2015; 41(7):1134-8.
32. Pereira ES, Peixoto IF, Viana AC, Oliveira II, Gonzalez BM, Buono VT, Bahia MG. Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments. *Int Endod J.* 2012; 45(5):469-74.