

Single file reciprocating systems: A systematic review and meta-analysis of the literature: Comparison of reciproc and WaveOne

Rana Alsilani¹, Fatima Jadu², Dania F. Bogari³, Ahmed M. Jan⁴, Turki Y. Alhazzazi⁵

¹Department of Dental, Batterjee Medical School, Jeddah, Saudi Arabia, Departments of ²Diagnostic Oral Sciences, ³Endodontics, ⁴Oral and Maxillofacial Surgery and ⁵Oral Biology, King Abdulaziz University, Faculty of Dentistry, Jeddah, Saudi Arabia

Corresponding author (email: <talhazzazi@kau.edu.sa>)

Dr. Turki Y. Alhazzazi, Department of Oral Biology, King Abdulaziz University, Faculty of Dentistry, Jeddah, Saudi Arabia.

Received: 22-08-16

Accepted: 29-09-16

Published: 24-10-16

Abstract

The introduction of single-file nickel-titanium (NiTi) reciprocating systems has been a major breakthrough in the field of endodontics. Thus, the aim of this study was to compare the available reciprocating systems, Reciproc and WaveOne, using a meta-analysis with different parameters. A comprehensive electronic literature search for Reciproc and WaveOne using PubMed and Google scholar was initially conducted in September 2014 and updated in September 2016. Inclusion and exclusion criteria were then established. Twenty-six studies were qualified for the systematic review, and only three studies were considered for the meta-analysis using cyclic fatigue resistance as the main parameter. The time to fracture for the Reciproc and WaveOne systems ranged from 119.7 sec to 156.4 sec and 74.8 sec to 99.6 sec, respectively. The pooled difference in mean time to fracture was longer for the Reciproc system by 45.6 sec. This difference was statistically significantly at P value < 0.001 . In conclusion, our study supports the finding that Reciproc is more resistant to cyclic fatigue than WaveOne. However, with regard to other parameters, mixed results were obtained. Well-designed randomized clinical trials comparing both systems under the same experimental conditions should be done in future studies.

Key words: Cyclic fatigue, meta-analysis, Reciproc, systematic review, WaveOne

INTRODUCTION

Canal shaping is an integral part of endodontic treatment because it removes bacteria and facilitates further successful irrigation and obturation.^[1,2] Evolution of endodontic shaping instruments has occurred over time, which has proven to be beneficial for maximizing debridement and decreasing procedural errors.^[2,3] The use of stainless steel hand files and H and K-files were the conventional shaping method.^[3] These hand files were replaced by

rotary systems. This was because of their troublesome use when shaping curved canals and owing to several disadvantages, including both rigidity that may cause many iatrogenic errors (transportations, ledges, and zipping) and the tendency to result in lengthy root canal treatment procedures.^[2,3]

To overcome these difficulties, in 1988, Walia *et al.* introduced nickel–titanium (NiTi) files in endodontics.^[4] He reported that NiTi had greater

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Alsilani R, Jadu F, Bogari DF, Jan AM, Alhazzazi TY. Single file reciprocating systems: A systematic review and meta-analysis of the literature: Comparison of reciproc and WaveOne. *J Int Soc Prevent Communit Dent* 2016;6:402-9.

Access this article online	
Quick Response Code:	Website: www.jispcd.org
	DOI: 10.4103/2231-0762.192945

elastic flexibility than stainless steel.^[4] This finding was later supported by others, and it was proven that NiTi superelasticity was an advantage in curved canals because it reduced forces on the walls, enhanced centering ability, and led to less iatrogenic errors.^[5,6] This flexibility is due to the property of the NiTi alloy, which can undergo transformation between the austenitic and martensitic phases. The NiTi alloy can regain its original shape (austenite) after the application of stress or heat (martensite) in a characteristic called the “shape memory effect.”^[5]

Most of the NiTi rotary systems move in a continuous rotation.^[7-12] However, as in many other systems, the NiTi rotary system appears to have some drawbacks. When rotating in curved canals, it may lead to cyclic fatigue, which is file separation and fracture due to repeated tensile-compressive forces being applied to the file in maximum curved areas.^[13] In some cases, using NiTi files can also be time consuming because they may require multiple exchanges of file sizes; some of these files need prior glide path preparation done with hand files.^[3] This led to the revolution of single-file NiTi reciprocating systems, which has been adopted by Dr. Yared. He has also introduced the Reciproc system. The single-file NiTi system consists of three files, including the R25 (ISO 25; 8%), R40 (ISO 40; 6%), and R50 (ISO 50; 5%); it has respective paper points and gutta-percha and a specific motor (VDW.SILVER) which was made in Munich, Germany.^[3] This concept has many advantages over the conventional rotary NiTi systems: (1) greater time efficiency because it requires only a single file to prepare all the canals with no requirement for prior glide path preparation; (2) single files are made from M-wire (heated NiTi alloy) that give them the greatest flexibility and cyclic fatigue resistance; and (3) reciprocating systems, which move in rotating reciprocation movements (balanced force) with large rotating angles. One movement is counter-clock wise, which engages and cuts dentin, and the other is clock-wise, which disengages the file from the dentin to avoid taper lock and relieves stress on the file. This type of movement prevents file breakage and increases its resistance to both cyclic and torsional fatigue.^[3,14,15]

Another competitive single file NiTi reciprocation system, WaveOne, has also been launched. This system was introduced in 2011 by the Dentsply/Maillefer Company (Ballaignes, Switzerland), and consists of three single-use files, including small (ISO 21; 6%), primary (ISO 25; 8%), and large (ISO 40; 8%).^[16-18] This system also has the same M-wire and reciprocal movement features as Reciproc. Therefore, the aims

of this systematic review and meta-analysis were to review the literature and compare the two reciprocating systems, Reciproc and WaveOne, with cyclic fatigue resistance, bending resistance, centering ability, cutting efficiency, canal debridement, clinical efficiency, and reusability cyclic fatigue resistance as the main parameters. This will help to provide the best available information to dentists in general, and endodontists in specific, to understand the differences between both the systems, and help them to decide whether to use Reciproc or WaveOne in cleaning and shaping the root canal system.

MATERIALS AND METHODS

Prior to the literature search, a research question was defined following the population, intervention, comparison, and outcome (PICO) format: “Does WaveOne single file NiTi system (intervention) compared to Reciproc single file NiTi system (comparison) have longer time to fracture (outcome) when shaping root canals?” A comprehensive electronic literature search for Reciproc and WaveOne using PubMed and Google scholar was initially conducted in September 2014 and updated in September 2016. All the resulting titles and abstracts were screened for topic relevance. Inclusion and exclusion criteria were then established. The articles were selected on the basis of following keywords: (1) Reciproc versus WaveOne; (2) Reciproc and WaveOne; and (3) WaveOne; or (4) Reciproc.

Inclusion criteria

- Original peer reviewed studies
- *In-vitro* and *in-vivo* studies
- Studies comparing Reciproc versus WaveOne or a comparison of WaveOne versus Reciproc or other NiTi systems
- Articles published in English
- Success reported as reduced cyclic fatigue.

Exclusion criteria

- Studies comparing only Reciproc with other systems
- Studies comparing only WaveOne with other systems
- Studies comparing single file reciprocating systems with another NiTi rotary system, and data do not clearly show the difference between Reciproc and WaveOne
- Effects of Reciproc or WaveOne in retreatment cases.

Data extraction

The electronic database literature search resulted in a total of 197 citations. Two of the authors independently reviewed the articles against the checklist to assess evidence for efficacy of therapy or prevention [Table 1]. Disagreement was resolved by consensus. The process of article selection and review is detailed in Figure 1. This systematic review was prepared according to the PRISMA guidelines. Relevant data was then extracted from the final 26 articles selected for the systematic review. Meta-analysis was performed using a random effects model to calculate the pooled time to fracture. To measure publication bias, a funnel plot was graphed, and the Fail-Safe N and Begg and Mazumdar rank correlation tests were conducted. StatsDirect software (StatsDirect Ltd, Cheshire, UK) 2.7.8 was used for the statistical analysis.

RESULTS

Twenty-six studies qualified for the systematic review [Table 2]. Because of the extreme heterogeneity

Table 1: Checklist to assess evidence of therapy or prevention measures

1. Was the study ethical?
2. Was a strong design used to assess efficacy?
3. Were outcomes (benefits and harms) validly and reliably measured?
4. Were interventions validly and reliably measured?
5. What were the results?
 - Was the treatment effect large enough to be clinically important?
 - Was the estimate of the treatment effect beyond chance and relatively precise?
 - If the findings were “no difference,” was the power of the study 80% or better?
6. Are the results of the study valid?
 - Was the assignment of patients to treatments randomized?
 - Were all patients who entered the trial properly accounted for and attributed at its conclusion?
 - Was loss to follow-up less than 20% and balanced between test and controls?
 - Were patients analyzed in the groups to which they were randomized?
 - Was the study of sufficient duration?
 - Were patients, health workers, and study personnel blinded to treatment?
 - Were the groups similar at the start of the trial?
 - Aside from the experimental intervention, were the groups treated equally?
 - Was care received outside the study identified and controlled?
7. Will the results help in caring for your patients?
 - Were all clinically important outcomes considered?
 - Are the likely benefits of treatment worth the potential harms and costs?

of the final selected articles, only three studies were considered for the meta-analysis using cyclic fatigue resistance as the main parameter. The three studies selected for meta-analysis and their results are summarized in Table 3.

The time to fracture for the Reciproac and WaveOne systems ranged from 119.7 s to 156.4 s and 74.8 s to 99.6 s, respectively. The pooled difference in mean time to fracture was longer for the Reciproac system by 45.6 s. This difference was statistically significant at $P < 0.001$ [Figure 2; Table 3].

The Fail-Safe N is 256 and the Begg and Mazumdar’s Kendal tau with continuity correction showed a nonsignificant correlation with P value (one-tailed) = 0.50, which indicates that publication bias was nonexistent in this analysis.

DISCUSSION

It has been shown that endodontic NiTi reciprocating instruments are safe and effective for preparing even the most severe curved root canals in much less chair time.^[19]

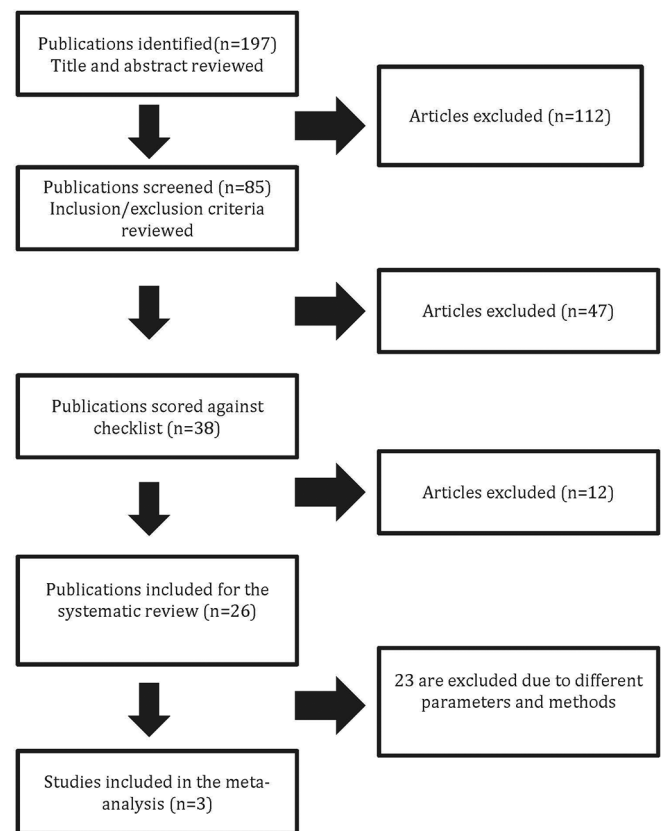


Figure 1: The stepwise process of selecting and reviewing the articles included in the meta-analysis

Table 2: Studies included for the systematic review and their conclusions

Author	Year	Sample Size (Per group)	Parameter	Conclusion
Ozyurek ^[33]	2016	20	Cyclic fatigue	WaveOne primary showed the lowest cyclic fatigue resistance compared to WaveOne Gold and Reciproc. WaveOne Gold was the most resistant.
Magalhaes RR <i>et al.</i> ^[34]	2016	12	Torsional behavior after clinical use	No significant difference in the reduction of torsional resistance was observed between the two systems.
Topcuoglu <i>et al.</i> ^[35]	2016	40	Cyclic fatigue	Reciproc had higher cyclic fatigue resistance than WaveOne primary in apical curvatures but not coronal ones.
Coelho <i>et al.</i> ^[21]	2016	15	Glide Path on the centric ability of canals preparation	No significant difference was found between both the files in regards to centric ability to prepare the canals, and establishing glide path seems not necessary and increased the total instrumentation time.
Kherlakian <i>et al.</i> ^[26]	2016	70	Postoperative pain and intake of analgesics	No significant differences were found between the tested groups (Reciproc, WaveOne, and ProTaper Next). Reciprocating systems were found to be similar in regards to the incidence of postoperative pain and analgesic intake compared to continues rotation system.
Uzun <i>et al.</i> ^[25]	2016	15	Apical extrusion of debris	Reciproc was associated with less apical extrusion of debris compared to all tested groups including WaveOne.
Pedulla <i>et al.</i> ^[36]	2016	20	Torsional and cyclic fatigue resistance	Cyclic fatigue resistance of the new Hyflex EDM OneFile was significantly higher than Reciproc and WaveOne. Under the condition of this study, no significant difference was found between Reciproc and WaveOne.
de Almeida-Gomes <i>et al.</i> ^[37]	2016	5	Cyclic fatigue	Both Reciproc and WaveOne demonstrated cyclic fatigue resistance compared to other tested groups. However, no significant difference was found between Reciproc and WaveOne.
Higuera <i>et al.</i> ^[38]	2015	15	Cyclic fatigue	Reciproc significantly show higher cyclic fatigue resistance compared to WaveOne but not Twisted File (TF adaptive M-L1).
Helvacioğlu-Yigit <i>et al.</i> ^[27]	2015	15	Dentinal crack formation after canals preparation	No significant differences between Reciproc and WaveOne in crack formation at the apical 3 mm level. No significant difference in cracks formation was found at 6 and 9 mm levels between both reciprocating systems and untreated controls.
Carvalho Mde <i>et al.</i> ^[28]	2015	10	Cleaning effectiveness	The two reciprocating instruments presented similar effectiveness for root canal cleaning.
De Meireles <i>et al.</i> ^[29]	2015	13	Apical transportation and centering ability	No significant difference between systems in apical transportation. Reciproc and WaveOne promoted minimal apical transportation and remained relatively centralized within the root canal.
Gergi <i>et al.</i> ^[28]	2015	30	Dentinal crack formation after canals preparation	Reciproc produced more cracks compared to WaveOne and twisted files adaptive (TFA) rotation system. TFA caused significantly less cracks than the other two systems.
De-Deus <i>et al.</i> ^[24]	2015	20	Apical extrusion of debris	No significant difference was found in the amount of the debris extruded between the two reciprocating systems.
Dagna <i>et al.</i> ^[32]	2014	40	Cyclic fatigue	Reciproc was the most fatigue resistant.
Saber <i>et al.</i> ^[15]	2014	20	Shaping ability	Reciproc and WaveOne instruments respected the original canal curvatures with no significant difference between them.

Contd...

Table 2: Contd...

Author	Year	Sample Size (Per group)	Parameter	Conclusion
Pirani <i>et al.</i> ^[14]	2014	6	Wear and metallographic analysis	Both are safe for clinical; no number of instrument fractured and no spiral distortions were observed under optical microscope. No significant difference was found between both.
Plotino <i>et al.</i> ^[19]	2014	24	Cutting efficiency	Reciproc instruments demonstrated statistically higher cutting efficiency than WaveOne.
Topcu <i>et al.</i> ^[29]	2014	15	Canal debridement	WaveOne performed significantly better than others including Reciproc in removing contrast medium from the canals.
De-Deus <i>et al.</i> ^[39]	2014	12	Bending resistance and dynamic and static cyclic fatigue life	WaveOne presented significantly higher bending resistance than Reciproc. Reciproc instruments resisted dynamic and static cyclic fatigue significantly more than WaveOne.
Park <i>et al.</i> ^[18]	2013	50	Clinical efficiency and reusability	There was no difference under the SEM between the two file groups with no initiation of micro-cracks until they were re-used up to 5 canals
Pedulla <i>et al.</i> ^[31]	2013	45	Cyclic fatigue	Resistance to cyclic fatigue was not significantly affected by immersion in NaOCl, Reciproc associated with higher cyclic fatigue resistance.
Lim <i>et al.</i> ^[20]	2013	10	Centering ability	WaveOne file should be used following establishment of a glide-path larger than #15. However, Reciproc showed better centric ability in 1-2 mm levels with no glide path.
Arias <i>et al.</i> ^[19]	2012	60	Cyclic fatigue	Reciproc more resistant to cyclic fatigue than WaveOne
Plotini <i>et al.</i> ^[30]	2012	15	Cyclic fatigue	Reciproc instruments had a significantly higher cyclic fatigue resistance than WaveOne
Kim <i>et al.</i> ^[40]	2012	10	Cyclic fatigue and torsional resistance	Reciproc had a higher number of cycles to fracture. WaveOne had a higher torsional resistance.

Table 3: Studies included in the meta-analysis

Author	Year	Sample size (per group)	Systems	Method	Results (time to fracture in seconds)	Conclusion
Dagna A. <i>et al.</i> ^[32]	2014	40	Reciproc R25 vs WaveOne primary vs OneShape vs ProTaper (control)	Artificial stainless steel canal with 5 mm radius and 60 angle of curvature	156.4±18.96 vs 99.58±19.71 (time to fracture)	Reciproc was the most fatigue resistant.
Pedulla <i>et al.</i> ^[31]	2013	45	Reciproc vs WaveOne	Artificial stainless steel canal with 5 mm radius and 60 angle of curvature	119.7±17.72 vs 74.8±14.59	Reciproc is associated with higher cyclic fatigue resistance.
Plotini <i>et al.</i> ^[30]	2012	15	Reciproc R25 vs WaveOne primary	Artificial stainless steel canal with 5 mm radius and 60 angle of curvature	130.8±18.4 vs 97.8±15.9	Reciproc instruments were associated with a significantly higher cyclic fatigue resistance than WaveOne.

Our systematic review resulted in 26 studies that fulfilled our inclusion and exclusion criteria. These studies investigated different parameters and compared the Reciproc and WaveOne systems. When considering the shaping ability, Saber *et al.* concluded that Reciproc

and WaveOne instruments respected the original canal curvatures with no significant differences between them. However, Reciproc was significantly faster for preparing root canals^[15] and demonstrated statistically higher cutting efficiency than WaveOne.^[19] Lim *et al.*

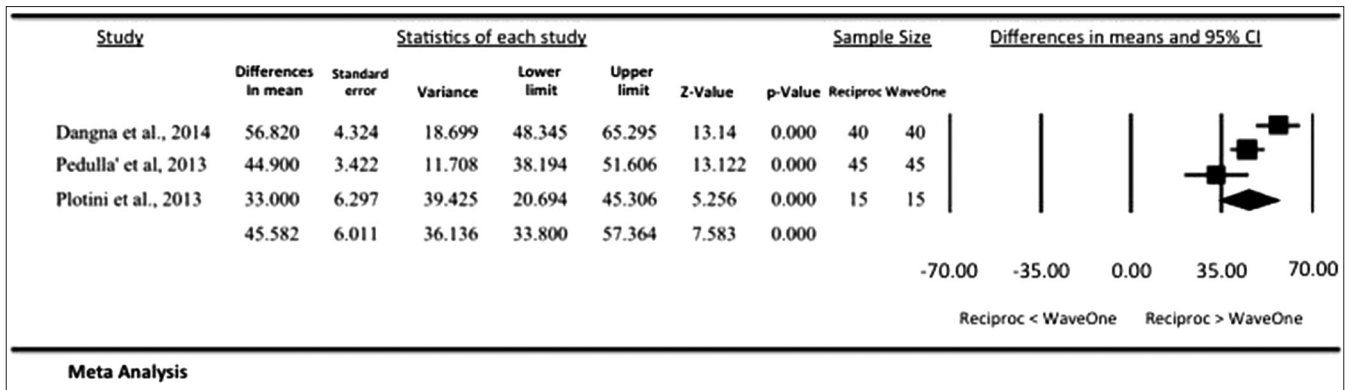


Figure 2: Results of the random effects model used for the meta-analysis demonstrating the detailed statistics for each study

reported that a glide path larger than #15 should be established before using the WaveOne file.^[20] In contrast, Coelho *et al.* reported no significant differences between both the files in regard to maintaining centric ability with or without glide path can be demonstrated, and that glide path seems to be unnecessary and would only result in increased working time.^[21]

Carvalho *et al.* found that both the systems presented similar cleaning effectiveness, whereas Topcu *et al.* reported that WaveOne performed better canal debridement than Reciproc.^[22,23] De-Deus *et al.* evaluated the amount of apical extruded dentin and found that there were no significant differences between the two reciprocating instruments.^[24] In contrast, others found that Reciproc was associated with less apical debris extrusion compared to several other systems including WaveOne.^[25] In regards to postoperative pain and analgesic intake, there was no significant difference between Reciproc and WaveOne systems.^[26] In addition, reciprocating systems also showed no significant difference when compared to continuous rotation systems.^[26] Both the instruments appeared safe for reuse because they showed no microcracks during instrumentation unless they were reused for up to five canals.^[18] However, Helvacioğlu-Yigit *et al.* have shown that significant differences can be noticed only at the apical 3 mm of the prepared canals between the reciprocating systems and untreated controls,^[27] whereas others support that Reciproc indeed can cause more dentinal cracks compared to WaveOne.^[28] Whether these cracks can carry any clinical significance or not is a question that needs to be answered. Moreover, no statistically significant differences were found between files with regard to instrument fracture and spiral distortion.^[14] De Meireles *et al.* reported that both systems showed

similar results with regard to apical transport and both remain centered during canal preparation.^[29]

It is clear that there is disagreement between reports in the literature. It also can be noted that studying different parameters may be advantageous for studying and comparing different systems. However, in the present meta-analysis, only three studies fulfilled the inclusion and exclusion criteria.^[30-32] All of them stated that Reciproc was more cyclic fatigue resistant than WaveOne. One study showed that Reciproc had lower torsional resistance than WaveOne.^[32] Another study showed that cyclic fatigue resistance was not reduced after immersion in sodium hypochlorite with Reciproc being the most fatigue resistant.^[31] These two single-file reciprocating systems appear to differ significantly in the way to achieve more cyclic fatigue resistance. Both systems are made from the same M-wire NiTi alloy, which gives them the greatest cycle fatigue resistant, however, they both have different cross sections consisting of S-shape and concave triangular for Reciproc and WaveOne, respectively. The cross section affected the cyclic fatigue as the smaller cross-sectional area the more fatigue resistant is the wire.^[32] The resulting sample size after reviewing articles and applying the inclusion and exclusion criteria was too small for acceptable statistical power because of the heterogeneity of the experimental conditions. This is one limitation of the study. Most of the included studies involved *in-vitro* tests, which is also a limitation because they did not mimic the real patient’s oral environment.

CONCLUSIONS

Our study appears to support the concept that Reciproc is more resistant to cyclic fatigue than WaveOne. However, with regard to other parameters, mixed results were found. Well-designed randomized clinical

trials comparing the shaping ability, clinical efficiency, and reusability of Reciproc and WaveOne under the same experimental conditions should be conducted in future studies.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Mayer BE, Peters OA, Barbakow F. Effects of rotary instruments and ultrasonic irrigation on debris and smear layer scores: A scanning electron microscopic study. *Int Endod J* 2002;35:582-9.
- Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. *J Endod* 2004;30:559-67.
- Yared G. Canal preparation with only one reciprocating instrument without prior hand filing: A new concept. *Int Dent* 2012;2:78-87.
- Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. *J Endod* 1988;14:346-51.
- Bergmans L, Cleynenbreugel JV, Wevers M, Lambrechts P. Mechanical root canal preparation with NiTi rotary instruments. *Am J Dent* 2001;14:324-33.
- Kandaswamy D, Venkateshbabu N, Porkodi I, Pradeep G. Canal-centering ability: An endodontic challenge. *J Conserv Dent* 2009;12:3-9.
- Bryant ST, Thompson SA, al-Omari MA, Dummer PM. Shaping ability of Profile rotary nickel-titanium instruments with ISO sized tips in simulated root canals: Part 1. *Int Endod J* 1998;31:275-81.
- Bindl A, Barbakow F. The Lightspeed technique: Experiences with a rotary canal preparation system. *Endod Prac* 1999;2:10-4.
- Schwartz S, McSpadden J. The Quantec rotary nickel titanium instrumentation system. *Endod Prac* 1999;2:14-9.
- Peters OA, Paque F. Current developments in rotary root canal instrument technology and clinical use: A review. *Quintessence Int* 2010;41:479-88.
- Ruddle CJ. The shaping movement wave of the future. *Endod Pract* 2011;4.
- Bryant ST, Thompson SA, al-Omari MA, Dummer PM. Shaping ability of ProFile rotary nickel-titanium instruments with ISO sized tips in simulated root canals: Part 2. *Int Endod J* 1998;31:282-9.
- Arias A, Perez-Higueras JJ, de la Macorra JC. Differences in cyclic fatigue resistance at apical and coronal levels of Reciproc and WaveOne new files. *J Endod* 2012;38:1244-8.
- Pirani C, Paolucci A, Ruggeri O, Bossu M, Polimeni A, Gatto MR, et al. Wear and metallographic analysis of WaveOne and reciproc NiTi instruments before and after three uses in root canals. *Scanning* 2014;36:517-25.
- Saber SE, Nagy MM, Schafer E. Comparative evaluation of the shaping ability of WaveOne, Reciproc and OneShape single-file systems in severely curved root canals of extracted teeth. *Int Endod J* 2015;48:109-14.
- Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, et al. Effect of canal length and curvature on working length alteration with WaveOne reciprocating files. *J Endod* 2011;37:1687-90.
- Berutti E, Paolino DS, Chiandussi G, Alovisei M, Cantatore G, Castellucci A, et al. Root canal anatomy preservation of WaveOne reciprocating files with or without glide path. *J Endod* 2012;38:101-4.
- Park SK, Kim YJ, Shon WJ, You SY, Moon YM, Kim HC, et al. Clinical Efficiency and Reusability of the Reciprocating Nickel-Titanium Instruments According to the Root Canal Anatomy. *Scanning* 2014;36:246-51.
- Plotino G, Giansiracusa Rubini A, Grande NM, Testarelli L, Gambarini G. Cutting efficiency of Reciproc and waveOne reciprocating instruments. *J Endod* 2014;40:1228-30.
- Lim YJ, Park SJ, Kim HC, Min KS. Comparison of the centering ability of WaveOne and Reciproc nickel-titanium instruments in simulated curved canals. *Restor Dent Endod* 2013;38:21-5.
- Coelho MS, Fontana CE, Kato AS, de Martin AS, da Silveira Bueno CE. Effects of Glide Path on the Centering Ability and Preparation Time of Two Reciprocating Instruments. *Iran Endod J* 2016;11:33-7.
- Topcu KM, Karatas E, Ozsu D, Ersoy I. Efficiency of the Self Adjusting File, WaveOne, Reciproc, ProTaper and hand files in root canal debridement. *Eur J Dent* 2014;8:326-9.
- Carvalho Mde S, Junior EC, Bitencourt Garrido AD, Roberti Garcia Lda F, Franco Marques AA. Histological evaluation of the cleaning effectiveness of two reciprocating single-file systems in severely curved root canals: Reciproc versus WaveOne. *Eur J Dent* 2015;9:80-6.
- De-Deus G, Neves A, Silva EJ, Mendonca TA, Lourenco C, Calixto C, et al. Apically extruded dentin debris by reciprocating single-file and multi-file rotary system. *Clin Oral Investig* 2015;19:357-61.
- Uzun I, Guler B, Ozyurek T, Tunc T. Apical extrusion of debris using reciprocating files and rotary instrumentation systems. *Niger J Clin Pract* 2016;19:71-5.
- Kherlakian D, Cunha RS, Ehrhardt IC, Zuolo ML, Kishen A, da Silveira Bueno CE. Comparison of the Incidence of Postoperative Pain after Using 2 Reciprocating Systems and a Continuous Rotary System: A Prospective Randomized Clinical Trial. *J Endod* 2016;42:171-6.
- Helvacioglu-Yigit D, Aydemir S, Yilmaz A. Evaluation of dentinal defect formation after root canal preparation with two reciprocating systems and hand instruments: An *in vitro* study. *Biotechnol Biotechnol Equip* 2015;29:368-73.
- Gergi RM, Osta NE, Naaman AS. Dentinal crack formation during root canal preparations by the twisted file adaptive, Reciproc and WaveOne instruments. *Eur J Dent* 2015;9:508-12.
- de Meireles DA, de Brito TC, Marques AA, Garrido AD, Garcia LF, Sponchiado EC Jr. Micro-computed tomography evaluation of apical transportation and centring ability of Reciproc and WaveOne systems in severely curved root canals. *Int Endod J* 2015;48:814.
- Plotino G, Grande NM, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. *Int Endod J* 2012;45:614-8.
- Pedulla E, Grande NM, Plotino G, Palermo F, Gambarini G, Rapisarda E. Cyclic fatigue resistance of two reciprocating nickel-titanium instruments after immersion in sodium hypochlorite. *Int Endod J* 2013;46:155-9.
- Dagna A, Poggio C, Beltrami R, Colombo M, Chiesa M, Bianchi S. Cyclic fatigue resistance of OneShape, Reciproc, and WaveOne: An *in vitro* comparative study. *J Conserv Dent* 2014;17:250-4.
- Ozyurek T. Cyclic Fatigue Resistance of Reciproc, WaveOne, and WaveOne Gold Nickel-Titanium Instruments. *J Endod* 2016;42:1536-9.
- Magalhaes RR, Braga LC, Pereira ES, Peixoto IF, Bueno VT, Bahia MG. The impact of clinical use on the torsional behavior of Reciproc and WaveOne instruments. *J Appl Oral Sci* 2016;24:310-6.
- Topcuoglu HS, Duzgun S, Akti A, Topcuoglu G. Laboratory comparison of cyclic fatigue resistance of WaveOne Gold, Reciproc and WaveOne files in canals with a double curvature. *Int Endod J* 2016 [Epub ahead of print].
- Pedulla E, Lo Savio F, Boninelli S, Plotino G, Grande NM, La Rosa G, et al. Torsional and Cyclic Fatigue Resistance of a New Nickel-Titanium Instrument Manufactured by Electrical Discharge Machining. *J Endod* 2016;42:156-9.
- de Almeida-Gomes F, de Matos HR, Nunes RF, Arrais AM, Ferreira-Maniglia C, de Moraes Vitoriano M, et al. Cyclic fatigue resistance of different continuous rotation and reciprocating endodontic systems. *Indian J Dent Res* 2016;27:278-82.
- Higuera O, Plotino G, Tocci L, Carrillo G, Gambarini G, Jaramillo DE.

- Cyclic fatigue resistance of 3 different nickel-titanium reciprocating instruments in artificial canals. *J Endod* 2015;41:913-5.
39. De-Deus G, Leal Vieira VT, Nogueira da Silva EJ, Lopes H, Elias CN, Moreira EJ. Bending resistance and dynamic and static cyclic fatigue life of Reciproc and WaveOne large instruments. *J Endod* 2014;40:575-9.
40. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. *J Endod* 2012;38:541-4.