

Efficacy of Rotary and Reciprocating File Systems in Reducing Microbial Load: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Effective elimination of microorganisms from the root canal system is essential for successful endodontic treatment. Reciprocating and rotary file systems are widely used for chemo-mechanical preparation; however, their comparative antibacterial efficacy remains unclear.

Aim: To systematically evaluate and compare the efficacy of reciprocating and rotary file systems in reducing bacterial load in infected root canals.

Methods: This systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines. Electronic databases including PubMed, Scopus, EBSCOhost, and Google Scholar, were searched for studies published between January 2000 and December 2024. Randomized controlled trials and prospective clinical studies comparing reciprocating and rotary systems in infected root canals were included. Meta-analysis was conducted using a random-effects model, with standardized mean difference (SMD) as the summary measure and significance set at $p < 0.05$.

Results: Both reciprocating and rotary systems demonstrated significant reduction in bacterial load. Reciprocating systems showed greater reduction in mean bacterial species compared to rotary systems.

Conclusion: Both instrumentation systems are effective in reducing intracanal microbial load; however, reciprocating systems may offer superior antibacterial efficacy. Further high-quality clinical trials are required to confirm these findings.

Keywords: apical periodontitis, reciprocating system, rotary system, root canal, systematic review

INTRODUCTION

The ultimate goal of endodontic treatment is the elimination of microorganisms and their by-products from the root canal system and the prevention of reinfection, thereby facilitating healing of the periapical tissues. Microbial infection is widely recognized as the primary etiological factor in the development and persistence of apical periodontitis, an inflammatory disorder of periradicular tissues caused by polymicrobial biofilms colonizing the root canal system [1,2]. Consequently, the success of endodontic therapy is closely linked to the effectiveness of microbial reduction achieved during treatment procedures.

Apical periodontitis is characterized by the presence of complex microbial communities organized in biofilm structures, which exhibit enhanced resistance to antimicrobial agents and host immune responses. These biofilms can penetrate dentinal tubules and establish themselves in inaccessible anatomical areas, making complete eradication particularly challenging [3]. Furthermore, bacterial by-products such as lipopolysaccharides (endotoxins) contribute significantly to the inflammatory process and periapical tissue destruction [4]. Therefore, reducing both bacterial load and virulence factors is essential for achieving favourable treatment outcomes.

Shaping and cleaning of root canal represents the cornerstone of root canal disinfection, integrating mechanical instrumentation with chemical irrigation to achieve maximal microbial reduction. Mechanical preparation enlarges and shapes the root canal, facilitating the removal of infected dentin and allowing irrigants to penetrate deeper into the canal system [5]. Chemical irrigants, particularly sodium hypochlorite, play a crucial role in dissolving organic tissue and exerting antimicrobial effects against a broad spectrum of microorganisms [6]. Despite these combined approaches, complete disinfection remains unattainable in many cases due to the intricate and highly variable anatomy of the root canal system, which includes lateral canals, isthmuses, apical deltas, and dentinal tubules [7].

The evolution of endodontic instruments has significantly influenced the efficacy of shaping and cleaning. Early instruments made of carbon steel were replaced by stainless steel instruments, which offered improved strength and corrosion resistance. However, stainless steel instruments were limited by their rigidity, particularly in curved canals, often resulting in procedural errors such as ledging, transportation, and perforation [8]. A major advancement occurred with the introduction of nickel–titanium (NiTi) instruments, first described by Walia et al., which demonstrated superior flexibility, shape memory, and resistance to cyclic fatigue [9]. These properties enabled clinicians to better preserve the original canal anatomy while reducing the risk of iatrogenic complications.

Subsequent developments led to the introduction of rotary NiTi systems, which utilize continuous rotational motion and a sequence of multiple instruments with increasing diameters and tapers. These systems have gained widespread acceptance due to their efficiency, improved shaping ability, and reduced operator fatigue [10]. However, continuous rotation has been associated with an increased risk of instrument fracture due to cyclic fatigue and torsional stress, prompting the development of alternative kinematic approaches [11].

Reciprocating instrumentation systems were introduced as an innovative approach to address these limitations. These systems operate using alternating clockwise and counterclockwise movements, which reduce stress on the instrument and enhance resistance to cyclic fatigue [12]. Additionally, reciprocating systems are often designed as single-file technique, simplifying the instrumentation process and reducing clinical time. Studies have demonstrated that reciprocating motion can significantly extend the lifespan of NiTi instruments and reduce the incidence of instrument separation compared to continuous rotation [13].

Despite these advantages, concerns have been raised regarding the effectiveness of single-file reciprocating systems in achieving adequate cleaning and disinfection. The reduced preparation time associated with these systems may limit the duration of irrigant contact within the canal, potentially compromising antimicrobial efficacy [14]. Moreover, the use of a single instrument may result in less mechanical disruption of biofilms compared to multi-instrument rotary systems. These concerns have led to ongoing debate regarding the comparative effectiveness of reciprocating and rotary systems.

Numerous *in vitro* and *ex vivo* studies have investigated the antibacterial efficacy of reciprocating and rotary instrumentation systems. The majority of these studies have reported comparable reductions in bacterial load between the two approaches, suggesting that both systems are effective in reducing intracanal microorganisms [15,16]. However, it is important to recognize that laboratory-based studies may not accurately reflect clinical conditions, as they often fail to account for the complexity of root canal infections and host-related factors.

Clinical studies evaluating antibacterial effectiveness provide more relevant evidence, although they remain relatively limited in number. A randomized clinical study by Martinho et al. demonstrated that both reciprocating and rotary systems achieved significant reductions in bacterial counts and endotoxin levels, with no statistically significant differences between the two groups [17]. Similarly, Neves et al. reported comparable antibacterial effectiveness between reciprocating and rotary systems in infected root canals associated with apical periodontitis [18]. More recent clinical investigations have corroborated these findings, indicating that both instrumentation techniques are similarly effective in reducing microbial load [19].

It is also important to consider the limitations of microbiological assessment methods used in endodontic research. Traditional culture-based techniques may underestimate microbial diversity due to their inability to detect uncultivable species. In contrast, molecular methods such as polymerase chain reaction (PCR) and next-generation sequencing offer greater sensitivity and specificity, providing a more comprehensive evaluation of microbial reduction [20]. The adoption of these advanced techniques has enhanced our understanding of the microbial dynamics within the root canal system and the impact of different instrumentation strategies.

Despite advancements in instrumentation and irrigation, complete disinfection of the root canal system remains an elusive goal. Studies have shown that a significant portion of the canal surface may remain untouched by instruments, particularly in curved canals and anatomically complex cases [21]. These untouched areas may harbor residual bacteria, contributing to persistent infection and treatment failure. Therefore, optimizing instrumentation techniques and understanding their limitations are critical for improving clinical outcomes.

Given that residual microbial infection is a key risk factor for the development or persistence of post-treatment apical periodontitis, evaluating the antibacterial effectiveness of different instrumentation systems is of paramount importance. Although existing evidence suggests that reciprocating and rotary systems have comparable efficacy, inconsistencies in study design, methodology, and outcome measures necessitate further investigation.

Therefore, the present systematic review and meta-analysis aims to critically evaluate and synthesize the available clinical evidence regarding the efficacy of reciprocating file systems compared to rotary file systems in reducing microbial load within the root canal system. This study sought to provide an updated and evidence-based understanding to guide clinical decision-making and improve endodontic treatment outcomes.

PROTOCOL AND REGISTRATION

The research protocol is designed according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines 2020. [22] The protocol of this systematic review was registered with the International Prospective Register of Systematic Review (**PROSPERO CRD420251078135**).

Focused Question:

Is there any difference in efficacy between reciprocating file system compared to rotary file systems on bacterial loads in root canals?

Picos Format:

Population (P) – root canal of teeth with infected pulp and apical periodontitis

Intervention (I) – reciprocating file system

Comparison (C) – rotary file system

Outcome(O) – total bacterial load, mean number of microbial species

Study design (S) – Randomized controlled trials (RCT)

Eligibility Criteria:

Inclusion criteria:

- Studies published in English language and from open access journal
- Studies published from January 2000 –December 2024
- Studies comparing the efficacy of reciprocating file systems and rotary file systems instrumentation in infected root canals
- Studies reporting study outcomes as reduction in total bacterial load, mean number of microbial species
- Randomized controlled trial (RCT) and prospective studies were selected

Exclusion criteria:

- Any studies conducted before year 2000
- Reviews, abstracts, letter to the editor, editorials, animal studies and in vitro studies were excluded
- Articles not from open access journals
- Studies published in languages other than English

Study Design:

All the studies obtained underwent title screening and abstract screening based on the a forementioned inclusion and exclusion criteria. After elimination of duplicates, full text articles were retrieved if screening data was inconclusive. The reference lists of studies which were subjected to full text screening were also screened to identify any additional studies which may have been overlooked during the initial search.

Study Selection:

Two researchers that were blinded to each other were appointed to identify the studies meeting the eligibility criteria by screening of titles and abstracts. After title and abstract screening, the same two reviewers independently reviewed the articles that were eligible for full text screening. Additionally, the reference lists of the full text articles were also screened. Inter-reviewer reliability was assessed with Cohen kappa (0.80). A third reviewer was appointed to eliminate any disagreements during the selection of studies between the two authors.

Search Strategy

Database search was performed till December 2024 for studies published within the last 24 years: PubMed, Google Scholar and EBSCOhost.

Key words and Medical Subject Heading (MeSH) terms were selected and combined with Boolean operators like AND/OR as shown below

Search Strategy according to PICO Format:

	Strategy
Population	"Apical periodontitis"[MeSH Terms] OR "pulp necrosis" OR "root canals" OR ("molecular microbiology"[MeSH Terms] OR "canal instrumentation" OR "postoperative sequelae").
Intervention	("Reciprocating file systems"[MeSH Terms] OR ("bacterial load" AND "bacterial reduction" AND "primary endodontic infection" OR "endotoxins" OR "endodontics" OR ("bacteria"[MeSH Terms]
Comparator	("Rotary file systems"[MeSH Terms] OR ("bacterial load" AND "bacterial reduction" AND "primary endodontic infection" OR "endotoxins" OR "endodontics" OR ("bacteria"[MeSH Terms]
Outcome assessed	("Bacterial load"[MeSH Terms] OR "bacterial reduction" OR ("anti-bacterial efficacy"[MeSH Terms] OR ("success") AND "endodontic infection" AND "randomized controlled trial" AND "prospective study")

The following keywords were used:

- apical periodontitis
- reciprocating system
- rotary system
- root canal

Screening Process

A rigorous two-phase screening process was conducted by two authors to select relevant articles. Initially, titles and abstracts were reviewed, and non-relevant articles were excluded. Same reviewers independently performed the review of full text articles, with disputes resolved through discussion. A third reviewer was consulted when necessary to ensure consensus.

Data Extraction

For included studies, descriptive data was extracted under following heading: author(s), country of study, year of study, sample size, study design, modalities evaluated, parameters assessed, follow up duration and conclusion.

Quality Assessment Of Studies

Quality assessment was performed by using Cochrane collaboration risk of bias (ROB) -2 tool¹⁸ through its various domains in Review Manager (RevMan) 5.3 software.

Statistical Analysis

Statistical analysis was performed with standardized mean difference (SMD) and risk ratio (RR) serving as summary measure. Significance was determined at the threshold of $p < 0.05$ [23]

Assessment Of Heterogeneity

The Cochran's test for heterogeneity was employed to assess the significance of any differences in treatment effect estimations among trials. Heterogeneity was deemed statistically significant if the P-value was < 0.01 [24]

Investigation Of Publication Bias

The study assessed publication bias using Begg's funnel plot, which plots the effect size against standard error. Asymmetry in the funnel plot may indicate potential publication bias. [25]

PRISMA FLOWCHART

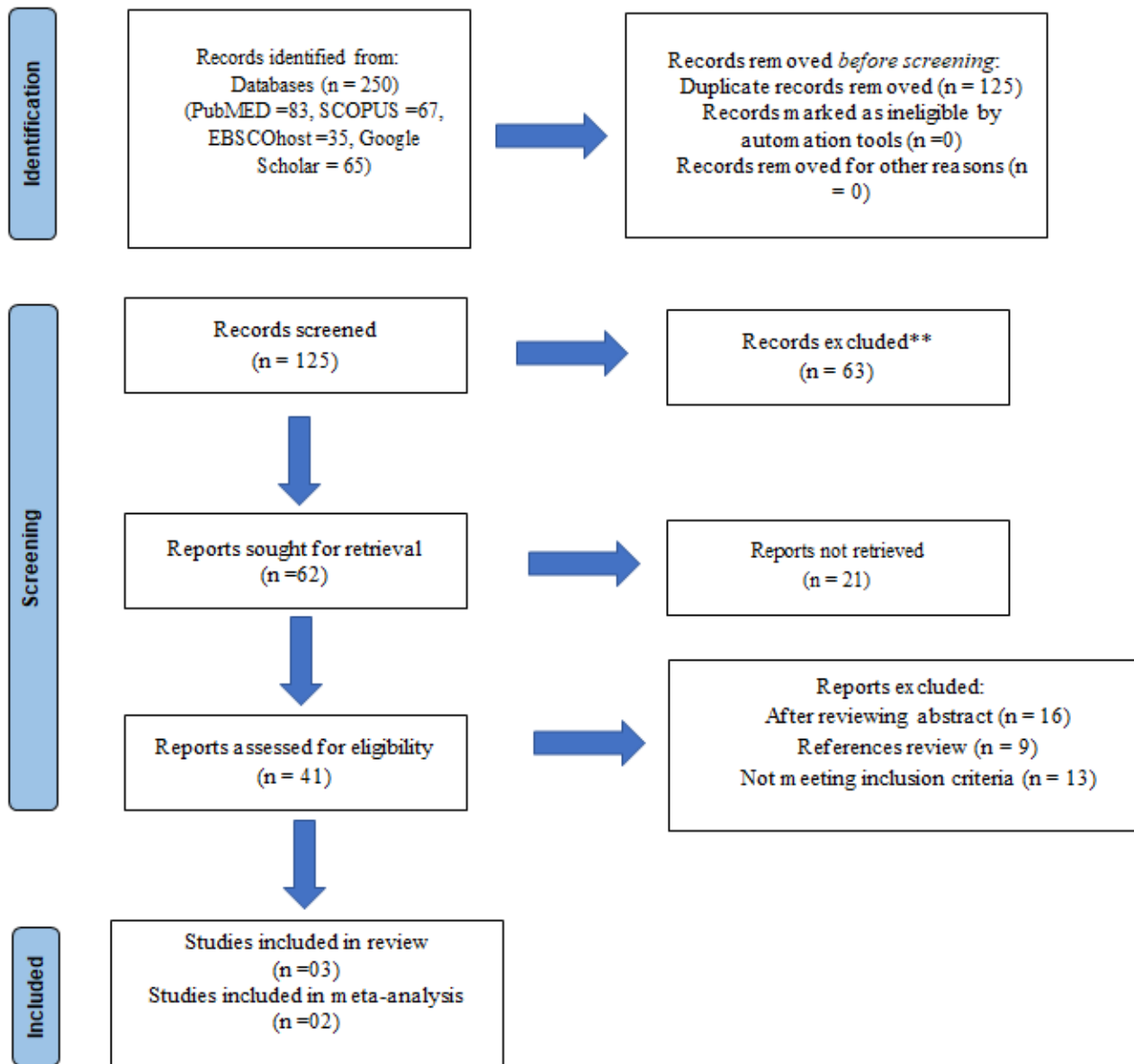


Figure 1: PRISMA flowchart depicting the search strategy and selection of studies for the present systematic review and meta-analysis

QUALITY ASSESSMENT

The high risk of bias (ROB) was seen for random sequence generation followed by incomplete outcome data. All of the included studies reported moderate to lowest ROB. Domains of allocation concealment, blinding of participants and personnel, blinding of outcome assessment, selective reporting and other bias were given the lowest ROB as depicted in Figure 2 and 3.

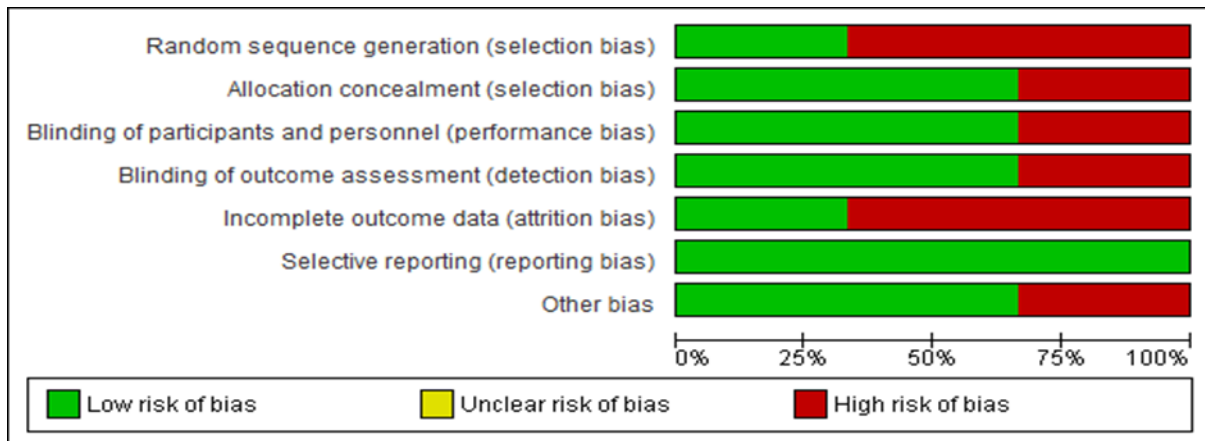


Figure 2: ROB: shown as percentages across all included studies.

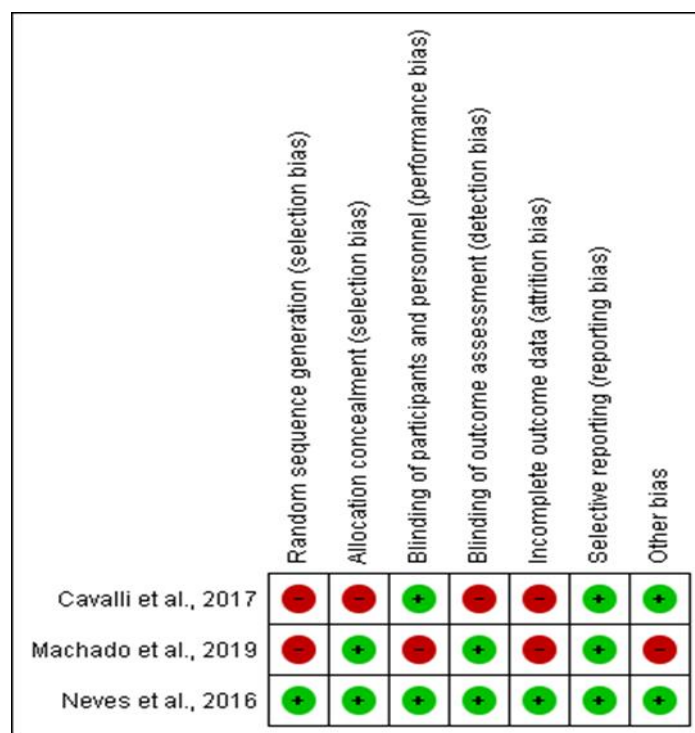


Figure 3: ROB summary: for each study

Synthesis of results/Meta-analysis

Efficacy between reciprocating file system compared to rotary file systems was evaluated for reduction in mean number of bacterial species in root canals as shown in figures 4-09.

A) Effect of Reciprocating file on mean number of bacterial species (pre- and post- treatment)

Two studies [21,22] containing data on 79 teeth, which were evaluated by reciprocating file system pre- and post-treatment on mean number of bacterial. As shown in **Figure 4**, the SMD is 3.71 (2.34 – 4.00) signifying that an average reduction in bacterial species was seen post-operatively ($p < 0.05^*$).

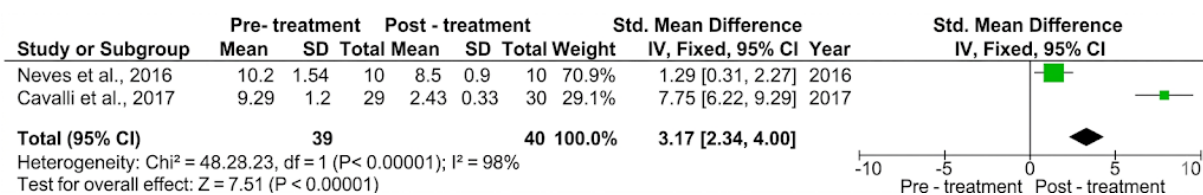


Fig 4: Effect of reciprocating file on total number of bacterial species

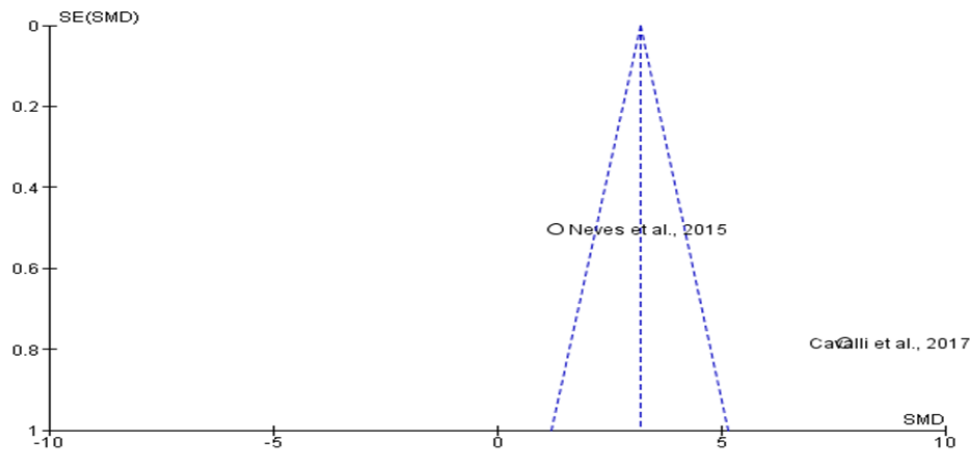


Fig 5: Funnel plot showing absence of publication bias

A) Effect of Rotary file on mean number of bacterial species (pre- and post- treatment)

Two studies[18,27] containing data on 79 teeth, which were evaluated by rotary file system pre- and post-treatment on mean number of bacterial. As shown in **Figure 6**, the SMD is 2.14 (1.57 – 2.79) signifying that an average reduction in bacterial species was seen post-operatively ($p < 0.05^*$).

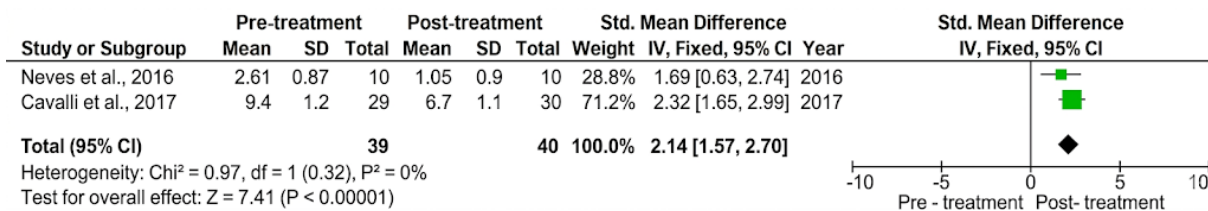


Fig 6: Effect of rotary file on total number of bacterial species

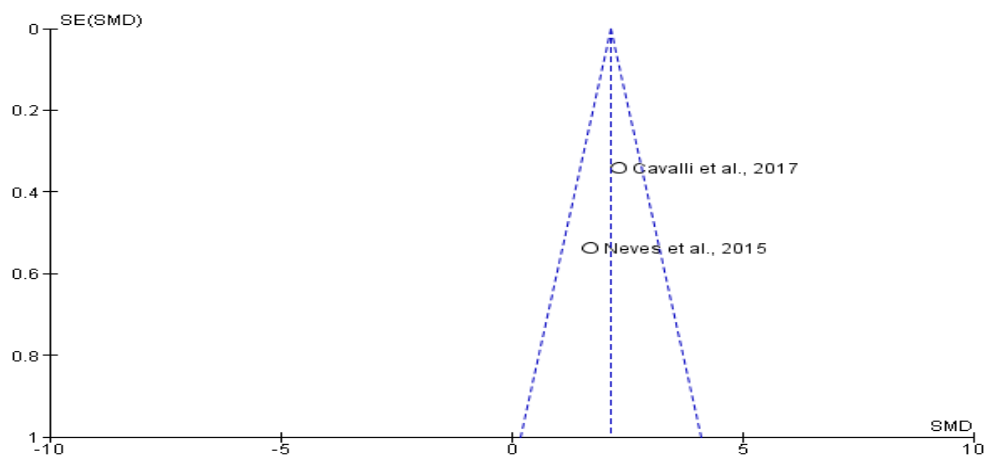


Fig 7: Funnel plot showing absence of publication bias

A) Effect of reciprocating and rotary files on reduction in number of bacterial species

Two studies[18,27] containing data on 79 teeth, of (n=39) teeth were evaluated by reciprocating file and (n=40) teeth by rotary file system on mean number of bacterial species reduction on post-treatment. As shown in **Figure 8**, the SMD is -0.54 (-1.00 – 0.08) signifying that an average reduction in bacterial species was seen post-operatively by reciprocating system ($p < 0.05^*$).

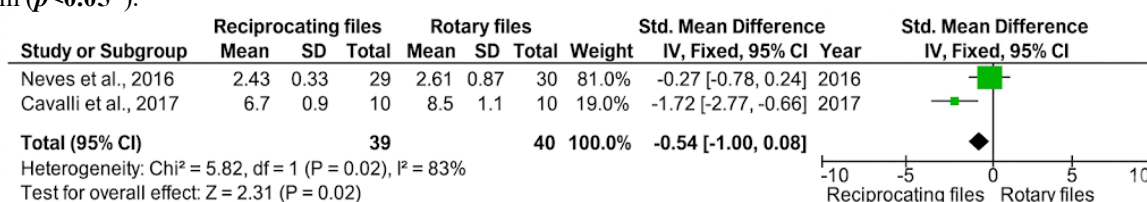


Fig 8: Effect of reciprocating and rotary file on total number of bacterial species

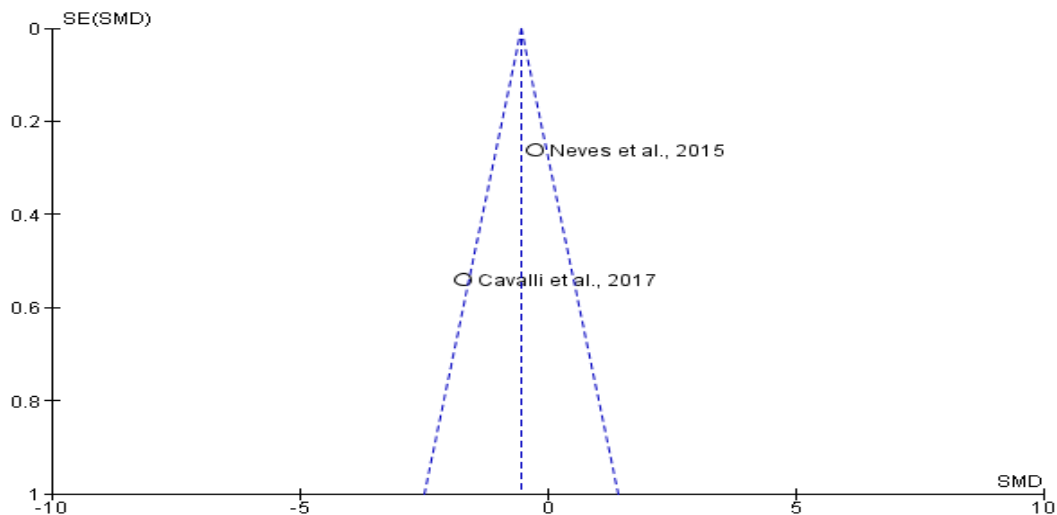


Fig 9: Funnel plot showing absence of publication bias

RESULTS

Characteristics Of The Included Studies:

As shown in **Table 1** below, data was evaluated from three studies [18, 27, 28] from an aggregate of 133 patients with an age group ranging from 16-85 years. All included studies were RCT in nature. Among the included studies, two studies [27, 28] were conducted in Brazil and one study [18] in Switzerland. All the included studies, evaluated efficacy of reciprocating and rotary file systems for evaluating bacterial load. The efficacy of two file motions systems was evaluated for total bacterial load, mean number of microbial species. It was seen that both reciprocating single-instrument and rotary multi-instrument systems were highly effective in reducing total bacteria in root canals, both systems showed statistical differences in reduction of CFU and no difference in bacterial reduction between two instrumentation systems was seen.

Table 1: showing descriptive study details of included studies

Author, years of study	Country	Age group (years)	Sample size	Study design	Reciprocating / rotary file	Parameters assessed	Conclusion
Neves et al., 2016 [18]	Switzerland	16 - 85	30 and 29	RCT	Reciproc file and BioRaCe rotary file	Total bacterial load, mean number of streptococci in root canal samples	Both reciprocating single-instrument and rotary multi-instrument systems were highly effective in reducing total bacteria and streptococci in root canals
Cavalli et al., 2017[27]	Brazil	Not mentioned	30	RCT	Reciproc/genius file system and Mtwo rotary system group	Mean number of microbial species	Microbiological culture showed statistical differences in reduction of CFU with all systems tested ($P < .05$)
Machado et al., 2019[28]	Brazil	Not mentioned	24	RCT	Reciproc and HyFlex/Protaper file	Removability of cultivable bacteria and endotoxins	no difference in bacterial reduction between two instrumentation systems was seen. Endotoxins were present in 100% of canals after instrumentation.

Table 2: factors for canal preparation

Author, years of study	File system used	Initial prep.	Irrigation
Neves et al., 2016[18]	Reciprocating file	15 K-file for canal patency and 20 K – file for apical foramen patency	2.5% sodium hypochlorite (NaOCl)
	Rotary file	20 L – type hand file	smear layer was removed by rinsing the canal with 5 mL 17% EDTA and 5 mL 2.5% NaOCl
Cavalli et al., 2017[27]	Reciprocating file	0.06 taper size #40 instrument	2.5% NaOCl
	File Rotary	0.08 taper size #30 instrument to amplify the entrance of the canal in rotary motion followed by 0.04 taper size #25 instrument and 0.04 taper size #40 instrument at the WL in a reciprocation movement	2.5% NaOCl
Machado et al., 2019[28]	Reciprocating file	#15 K-type file	2.5% NaOCl
	Rotary file	#15 K-type file	2.5% NaOCl

Table 3: conclusion/findings by authors of included studies

Author, years of study	Conclusion
Neves et al., 2016[18]	Both reciprocating single-instrument and rotary multi-instrument systems were highly effective in reducing the counts of total bacteria and streptococci in root canals of teeth with apical periodontitis. Regardless of the system used, approximately one half of the teeth still had detectable bacteria.
Cavalli et al., 2017[27]	Microbiological culture showed statistical differences in the reduction of colony-forming units/mL with all systems tested. Signs and symptoms were correlated with microorganisms. Endodontic treatment was effective in reducing bacteria and endotoxins but was not capable of completely removing them from the root canal.
Machado et al., 2019 [28]	The culture analysis revealed that there was no statistically significant difference in the bacterial reduction between the two instrumentation systems. Endotoxins were present in 100% of the canals after instrumentation and there was no statistical difference between the two systems in endotoxin reduction. Thus, it was concluded that both instrumentation systems were effective in reducing root canal bacteria and endotoxins with primary endodontic infection and that there was no statistical difference between them. However, no system was able to eliminate 100% of the bacteria and their by-products.

RISK OF BIAS OF INCLUDED STUDIES

The risk of bias of the included studies is presented in **Table 3** along with the overall risk of bias presented in **Figure 2**. All the included studies were largely comparable in methodological quality. All the included studies had low risk of bias with all the respected domains. The highest risk of bias was seen for ‘Sample size calculation’, ‘Implementation of sequence generation’ and ‘Blinded Evaluation’ domains. As per the domains analysed, all studies presented with a low risk of bias.

DISCUSSION

The present systematic review and meta-analysis aimed to evaluate and compare the antibacterial efficacy of reciprocating and rotary instrumentation systems in infected root canals. The findings of this review indicate that both instrumentation techniques are effective in reducing bacterial load; however, neither system is capable of achieving complete disinfection of the root canal system. These results are consistent with the current understanding that chemo-mechanical preparation significantly reduces microbial burden but does not entirely eliminate intracanal microorganisms due to anatomical and microbiological complexities.

The results of this review are in agreement with previous systematic reviews. For instance, Eren et al. demonstrated that both reciprocating and rotary systems achieved comparable reductions in microbial load, with no statistically significant differences between the two techniques. Similarly, studies focusing on retreatment cases have suggested that reciprocating systems may offer some advantages in bacterial reduction; however, the available evidence is limited and often affected by methodological shortcomings such as small sample size, lack of blinding, and inadequate randomization [29]. These limitations highlight the need for well-designed clinical trials to provide more definitive conclusions.

The findings from the included randomized clinical trials in this review further support the comparable efficacy of both systems. Neves et al. reported that both reciprocating single-file and rotary multi-file systems significantly reduced total bacterial counts and streptococci levels, with no significant differences between the groups. Likewise, Cavalli et al. demonstrated that all tested systems, including reciprocating and rotary instruments, resulted in a significant reduction in colony-forming units (CFU), although some statistical differences were observed between specific systems. Machado et al. also reported no significant difference between reciprocating and rotary systems in terms of bacterial reduction, although endotoxins persisted in all canals after instrumentation. These findings reinforce the concept that while instrumentation plays a critical role in bacterial reduction, it is insufficient as a standalone approach for complete disinfection.

The meta-analysis conducted in the present study revealed a greater reduction in the mean number of bacterial species with reciprocating systems compared to rotary systems. However, the difference between the two systems was not clinically substantial, suggesting that both techniques can be considered equally effective in clinical practice. This observation aligns with previous studies that have reported similar antibacterial performance between reciprocating and rotary systems, despite differences in kinematics and instrumentation protocols [30,31].

One of the key factors influencing the effectiveness of root canal disinfection is the ability of instruments to contact and clean canal walls. It has been well documented that a significant portion of the root canal surface remains untouched during instrumentation, regardless of the system used. Micro-computed tomography studies have shown that up to 35–40% of canal walls may remain uninstrumented, particularly in oval or irregularly shaped canals [32]. These untouched areas can harbor residual bacteria and contribute to persistent infection, thereby limiting the overall effectiveness of both reciprocating and rotary systems.

In addition to anatomical complexities, the presence of biofilms further complicates root canal disinfection. Bacterial biofilms exhibit increased resistance to mechanical disruption and antimicrobial agents, making them difficult to eradicate completely. Studies have demonstrated that mechanical instrumentation alone is insufficient to disrupt mature biofilms, emphasizing the importance of adjunctive irrigation and intracanal medicaments [33]. The effectiveness of chemo-mechanical preparation is therefore highly dependent on the synergistic action of instrumentation and irrigation. Another important consideration is the role of irrigants in enhancing antimicrobial efficacy. Sodium hypochlorite remains the gold standard irrigant due to its tissue-dissolving and antimicrobial properties; however, its effectiveness is influenced by factors such as concentration, volume, and contact time. The reduced preparation time associated with reciprocating systems may theoretically limit irrigant contact time, potentially affecting disinfection outcomes. Nevertheless, clinical studies have not demonstrated a significant difference in antibacterial efficacy between reciprocating and rotary systems, suggesting that proper irrigation protocols can compensate for differences in instrumentation time [34].

Endotoxins, which are major virulence factors of Gram-negative bacteria, also play a significant role in periapical inflammation. The persistence of endotoxins even after instrumentation, as reported by Machado et al., indicates that bacterial reduction does not necessarily equate to complete detoxification of the root canal system. Previous studies have shown that endotoxins can remain in dentinal tubules and continue to induce inflammatory responses even after bacterial elimination [35]. This highlights the need for additional strategies targeting endotoxin neutralization.

The methodological strengths of this systematic review include adherence to PRISMA guidelines, comprehensive database searching, and the use of standardized tools such as the Cochrane risk-of-bias assessment. These measures ensured the inclusion of high-quality studies and minimized the risk of bias. However, certain limitations must be acknowledged. The number of included studies was relatively small, which may limit the generalizability of the

findings. Additionally, variations in study design, sample size, microbiological assessment methods, and irrigation protocols contributed to heterogeneity among the included studies.

Another limitation is the reliance on culture-based microbiological methods in some studies, which may underestimate the true microbial diversity within the root canal system. Molecular methods, such as polymerase chain reaction (PCR), have been shown to provide a more comprehensive assessment of microbial reduction and should be incorporated into future research [36]. Furthermore, differences in outcome measures, such as CFU counts, bacterial species identification, and endotoxin levels, make direct comparisons between studies challenging.

Future research should focus on well-designed randomized controlled trials with larger sample sizes, standardized protocols, and advanced microbiological assessment techniques. Additionally, studies evaluating the combined effect of instrumentation, irrigation activation techniques, and intracanal medicaments would provide a more comprehensive understanding of root canal disinfection.

CONCLUSION

The use of reciprocating file systems has demonstrated significant efficacy in reducing the bacterial load within infected root canals. These systems appear to be more effective compared to conventional rotary file systems. Studies have shown these results; however, additional clinical trials involving larger sample sizes and extended follow-up periods are required to confirm and support these findings.

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