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Open Access Review Article

Comparative Evaluation of the Effectiveness of Laser-Assisted Irrigation and Ultrasonic Irrigation on Postoperative Pain in Single-Visit Endodontics: A Systematic Review

Review began 05/07/2025
Review ended 05/26/2025
Published 05/28/2025

DOI: 10.7759/cureus.84947

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Abstract

Effective irrigation plays a critical role in the success of root canal therapy by eliminating residual microbes and debris from inaccessible canal regions. Advanced irrigation techniques have been developed over the years that activate the irrigant leading to increased canal penetration and reduced post-treatment discomfort. These include activation by light, vibration, heat, laser, sonic and ultrasonic methods. The present systematic review compared the effectiveness of laser-activated irrigation (LAI) and ultrasonic irrigation (UI) in reducing postoperative pain following single-visit endodontic treatment. A comprehensive search of electronic databases and grey literature from January 2000 to April 2024 was conducted. Nine randomized controlled trials involving 547 patients met the inclusion criteria. The studies were conducted across four countries and assessed various activation techniques including diode laser, Er:YAG, shock wave-enhanced emission photoacoustic streaming, photon-induced photoacoustic streaming, passive UI, and continuous UI. LAI demonstrated faster pain reduction in the first 24 to 48 hours post-treatment, while UI showed comparable efficacy beyond this period. Both methods were significantly more effective than conventional syringe irrigation. No severe adverse events were reported. The overall risk of bias was found to be low in eight studies, with one study showing some concerns. The results suggest that both LAI and UI are effective in minimizing postoperative pain, with LAI being more effective for early pain control. Integration of either technique is recommended in clinical endodontic protocols to enhance patient comfort and treatment outcomes.

Categories: Dentistry
Keywords: laser-activated irrigation, postoperative pain, root canal disinfection, single-visit endodontics, ultrasonic irrigation

Introduction And Background

The success of root canal treatment (RCT) relies heavily on the thorough disinfection and decontamination of the root canal system to eliminate microbial biofilms, necrotic tissue, and debris. Inadequate cleaning can lead to persistent infections, postoperative pain, and treatment failure [1]. Mechanical instrumentation alone is insufficient to achieve complete debridement, particularly in areas such as lateral canals, isthmuses, and dentinal tubules. These structures are too narrow for instruments to access, allowing residual bacteria and necrotic tissue to remain. As a result, irrigation by chemical agents complements the mechanical preparation by enhancing microbial elimination, dissolving organic matter, and flushing out debris from inaccessible areas within the canal system [2].

Traditionally, syringe-based irrigation with solutions such as sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), and chlorhexidine (CHX) has been widely used in endodontic practice [3]. However, the conventional static irrigation technique by syringes has significant limitations, including limited penetration of irrigants into the complex root canal anatomy, inadequate removal of smear layers, and ineffective disruption of bacterial biofilms. Furthermore, excessive apical extrusion of irrigants can lead to inflammation, tissue damage, and increased postoperative pain. Therefore, advanced irrigation techniques have been developed over the years that activate the irrigant leading to increased canal penetration and reduced post-treatment discomfort [4]. These include activation by light, vibration, heat, laser, sonic and ultrasonic methods [4,5].

Laser-activated irrigation (LAI) uses high-energy light pulses from erbium lasers, such as Er:YAG and Er,Cr:YSGG, to activate the cleaning solution inside the root canal. These laser pulses create tiny shock waves and bubbles (a process known as photoacoustic streaming and cavitation) that rapidly move the irrigant throughout the canal system. This dynamic fluid motion helps to remove the smear layer, push disinfectants deeper into the tooth's fine structures, and break up bacterial biofilms more effectively than conventional methods [6]. The cavitation-induced hydrodynamic forces generated by LAI allow for superior debris clearance in irregular canal morphology which contributes to reduced postoperative pain by decreasing the inflammatory burden. The advantages of LAI include minimal apical extrusion, superior

debris clearance in complex canal anatomy, and enhanced penetration of irrigants into dentinal tubules [7].

Photon-induced photoacoustic streaming (PIPS) and shock wave-enhanced emission photoacoustic streaming (SWEEPS) are advanced laser-activated irrigation techniques that have significantly improved the efficacy of root canal disinfection [8,9]. PIPS utilizes low-energy, short-pulsed erbium lasers (such as Er:YAG) to create photoacoustic shockwaves within the irrigant. These shockwaves induce vigorous streaming and cavitation without requiring the fiber tip to enter the root canal, thus reducing the risk of apical extrusion [8,10]. In contrast, SWEEPS is an enhancement of PIPS that employs paired ultra-short laser pulses to generate synchronized shock waves within the irrigant. This results in intensified fluid agitation and deeper penetration of the irrigant into lateral canals and dentinal tubules [11].

Ultrasonic irrigation (UI) utilizes high-frequency ultrasonic waves (25-30 kHz) to activate the irrigant within the root canal system. It has demonstrated superior efficacy in removing smear layers and bacterial colonies, particularly in curved canals and anatomical complexities [12]. It generates acoustic streaming and micro cavitation, leading to effective disinfection, disruption of bacterial biofilms, and enhanced removal of debris from canal irregularities [13]. The mechanical streaming effect of UI ensures improved contact of disinfecting solutions with root canal walls, leading to better microbial control. However, concerns regarding the apical extrusion of irrigants and potential irritation of periapical tissues have been raised, necessitating an evaluation of its impact on postoperative pain [14].

Despite the proven advantages of LAI and UI in enhancing root canal disinfection, their impact on postoperative pain remains an area of ongoing investigation [15-18]. Postoperative pain in endodontics can result from inflammatory responses, residual bacterial presence, or apical extrusion of debris and irrigants [19]. Over the years, evidence has demonstrated that LAI may reduce pain due to its enhanced antibacterial effects and minimal mechanical stress [20]. Likewise, UI has also been demonstrated to lower pain levels through improved decontamination due to continuous irrigant activation [21]. There is a need to analyze which method is more effective in reducing post-endodontic pain while taking into consideration the differences in study designs, laser and ultrasonic parameters, and pain assessment scales.

Single-visit root canal treatment has become increasingly common in contemporary endodontic practice due to its clinical efficiency, reduced patient visits, and comparable outcomes to multi-visit procedures. It is especially indicated in cases involving vital pulp tissue, controlled symptomatic irreversible pulpitis, or non-complicated necrotic cases without acute infection [22]. For patients with time constraints, dental anxiety, or logistical difficulties in attending multiple appointments, single-visit endodontics offers a practical and patient-centered solution. Additionally, with advancements in disinfection techniques, including laser and ultrasonic activation, adequate canal debridement and microbial control can be reliably achieved within a single appointment [23]. This approach not only minimizes the risk of inter-appointment contamination but also enhances patient comfort and compliance, all of which are directly related to postoperative pain.

In this context, the present systematic review aims to critically evaluate and compare the effectiveness of LAI and UI in reducing postoperative pain in single-visit endodontic treatment. The findings would provide clinicians with a decision on the subject concerning which method is a more effective irrigation activation system for reducing postoperative pain following single-visit endodontic treatment.

Review

Methodology

Protocol Development

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and standardization of the methodology [24]. The protocol was prospectively registered in the PROSPERO database under the registration number CRD42024543644.

Research Question

The research question was formulated using the Population (P), Intervention (I), Comparison (C), and Outcome (O) (PICO) framework to ensure a structured approach. The study aimed to determine whether there is a difference in the effectiveness of laser-activated irrigation and ultrasonic irrigation in reducing postoperative pain in single-visit endodontic treatment. The population included patients with necrotic pulp or irreversible pulpitis, and the intervention involved root canal irrigation. The comparison was made between ultrasonic irrigation and laser-activated irrigation, with the primary outcome measure being the extent of postoperative pain reduction. The review included randomized and non-randomized clinical trials, while cross-sectional studies, in vitro studies, animal-based studies, review articles, letters to the editor, technical notes, case reports, and case series were excluded.

Eligibility Criteria

Studies were included if they investigated patients between the ages of 18 and 65 years, regardless of gender, undergoing root canal treatment. Only articles comparing the effectiveness of laser-activated irrigation with ultrasonic irrigation and specifically reporting postoperative pain reduction were considered. Patients included in the studies were required to have a non-contributory medical history to avoid confounding factors.

Studies were excluded if they involved teeth with developmental anomalies, calcifications, internal or external resorption, or fractures. Similarly, cases with a history of previous endodontic treatment, immature teeth with open apices, or the presence of acute pus discharge were omitted. Additional exclusions were made for studies involving pregnant or lactating women and individuals with mental health conditions that could impact treatment compliance and pain perception.

Search Strategy

A comprehensive electronic search was conducted for studies published between January 2000 and April 2024 using databases such as PubMed, SCOPUS, EMBASE, Google Scholar, and EBSCOhost. The search strategy was structured to maximize the retrieval of relevant literature, including gray literature sources such as Google Scholar, Greylist, and OpenGrey. The systematic approach adopted in the search strategy is outlined in Table *1*. In addition to electronic searches, manual searches were performed in leading endodontic journals to identify relevant articles that may not have been indexed in electronic databases, ensuring a more comprehensive literature review.

Database	Search strategy	Number
PubMed	("post operative pain"[MeSH Terms] OR "irrigation" OR "laser-activated irrigation" OR "ultrasonic activated irrigation" AND ("root canal therapy") AND “conventional irrigation"[MeSH Terms] AND "diode laser" OR "necrosed teeth" OR "diode laser AND ultrasonics" OR "post-operative pain AND diode laser"[MeSH Terms] OR ("root canal therapy" AND "post-operative pain AND single visit endodontics" OR "post-operative pain AND ultrasonics" OR "laser AND single visit endodontics" OR "post operative pain" AND “randomized controlled trials” AND “comparative studies”	18
EBSCOhost	("post operative pain"[MeSH Terms] OR "irrigation" OR "laser-activated irrigation" OR "ultrasonic activated irrigation" AND ("root canal therapy") AND “conventional irrigation"[MeSH Terms] AND "diode laser" OR "necrosed teeth" OR "diode laser AND ultrasonics" OR "post-operative pain AND diode laser"[MeSH Terms] OR ("root canal therapy" AND "post-operative pain AND single visit endodontics" OR "post-operative pain AND ultrasonics" OR "laser AND single visit endodontics" OR "post operative pain" AND “randomized controlled trials” AND “comparative studies”	07
Google Scholar	("post operative pain"[MeSH Terms] OR "irrigation" OR "laser-activated irrigation" OR "ultrasonic activated irrigation" AND ("root canal therapy") AND “conventional irrigation"[MeSH Terms] AND "diode laser" OR "necrosed teeth" OR "diode laser AND ultrasonics" OR "post-operative pain AND diode laser"[MeSH Terms] OR ("root canal therapy" AND "post-operative pain AND single visit endodontics" OR "post-operative pain AND ultrasonics" OR "laser AND single visit endodontics" OR "post operative pain" AND “randomized controlled trials” AND “comparative studies”	426
Grey literature	("post operative pain"[MeSH Terms] OR "irrigation" OR "laser-activated irrigation" OR "ultrasonic activated irrigation" AND ("root canal therapy") AND “conventional irrigation"[MeSH Terms] AND "diode laser" OR "necrosed teeth" OR "diode laser AND ultrasonics" OR "post-operative pain AND diode laser"[MeSH Terms] OR ("root canal therapy" AND "post-operative pain AND single visit endodontics" OR "post-operative pain AND ultrasonics" OR "laser AND single visit endodontics" OR "post operative pain" AND “randomized controlled trials” AND “comparative studies”	05

TABLE 1: Search strategy across various databases

Screening Process

The screening process was carried out in two phases. In the first phase, two independent reviewers (AG and KS) evaluated the titles and abstracts of all retrieved studies to exclude those that did not meet the eligibility criteria. Studies that fulfilled the inclusion criteria proceeded to the second phase, where the full texts were obtained and assessed for relevance. The same two reviewers independently screened the full-text articles, and any disagreements regarding eligibility were resolved through discussion. If consensus could not be reached, a third reviewer (AS) was involved to finalize the selection. To obtain additional clarifications or missing data, the corresponding authors of selected studies were contacted via email.

Data Extraction

Data extraction was conducted independently by two reviewers (AG and MR) to ensure accuracy and minimize bias. A pilot-tested, customized data extraction form was used in Microsoft Excel 2019 (Microsoft Corp., Redmond, WA, USA) to compile relevant study characteristics. The extracted data included details such as the author(s), country of study, year of study, sample size, study design, details about the activation systems used, outcome measures, key findings, and conclusions. The extracted data were cross-verified by both reviewers, and discrepancies were resolved through discussion. If disagreements persisted, a third reviewer (AS) was consulted to make the final decision.

Quality Assessment of Included Studies

The methodological quality of the included studies was evaluated using the Cochrane Collaboration Risk of Bias (ROB-2) tool [25]. The studies were assessed using a tool based on five domains, including randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each study was assigned an overall risk rating based on these domains. A study was categorized as having a low overall risk of bias only if all domains had a low risk. If one or more domains were rated as high risk, the study was deemed to have a high overall risk of bias. Studies were assigned a moderate risk of bias when one or more domains were classified as uncertain, with none categorized as high risk.

Statistical Analysis

Using the random effects model, the meta-analyses were applied with RevMan 5.4 (RevMan 5.4, The Nordic Cochrane Centre, Copenhagen). Heterogeneity was assessed by a Q test and quantified with I^2 statistics. Data on mean and standard deviation were obtained from selected studies. The postoperative pain score was considered the main outcome. In the studies with more than one laser intervention evaluated, all relevant experimental intervention groups of the study were combined into a single group. For analyses, if the test showed substantial heterogeneity (I^2>50%), a random effects model was applied, or else (I^2 ⩽50%), a fixed effects model would be used. For the sake of providing only valid information, we have restricted reporting of the meta-analysis to only those intervals with heterogeneity of less than 50%.

Results

Study Selection

The systematic search retrieved a total of nine randomized controlled trials satisfying the eligibility criteria [26-34]. The study selection process is illustrated in the PRISMA flow diagram (Figure *1*), and the key characteristics of the included studies are presented in Table *2*.

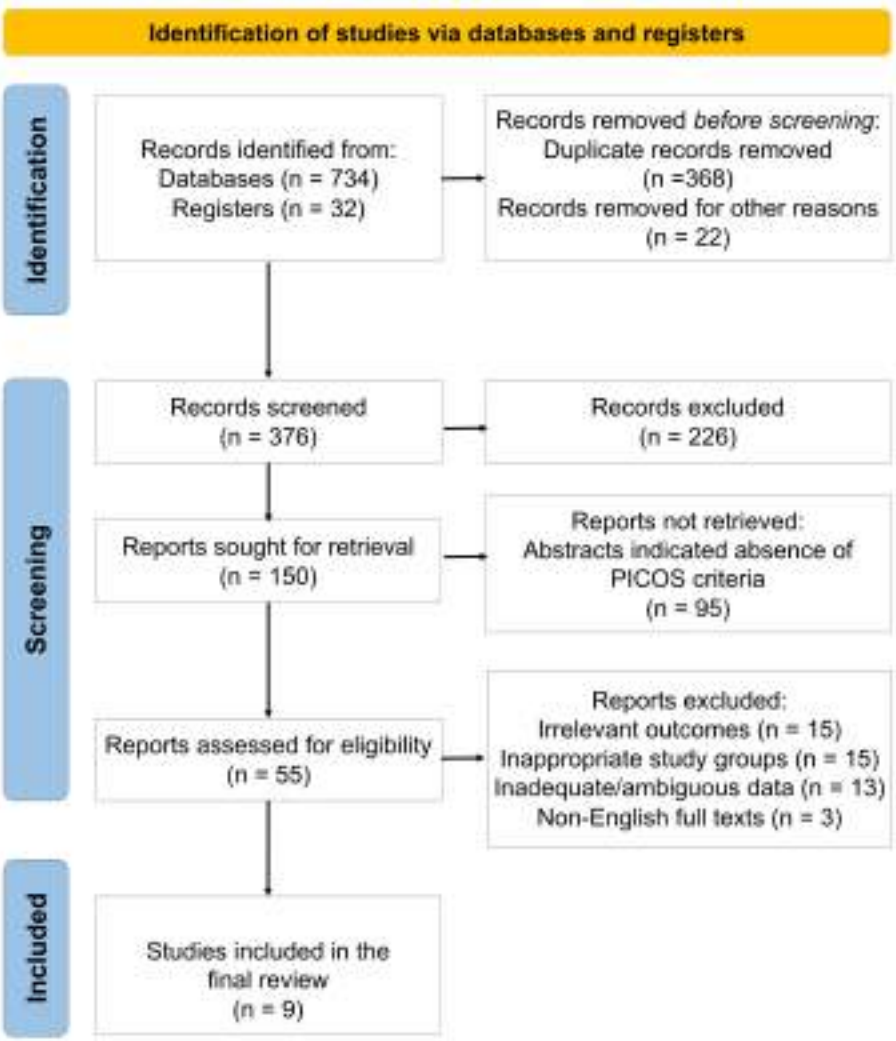

FIGURE 1: PRISMA flow diagram indicating the selection process of the articles in the present systematic review

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PICOS: population, intervention, comparison, outcome, study design

Author (year)	Study design	Country	Sample size	Age range (years)	Gender distribution	Diagnostic criteria	Intervention	Comparator	Outcome measures	Follow-up duration	Baseline pain score	Post-treatment pain score	Reduction in pain (%)	Statistical significance	Adverse events	Conclusion
Verma et al. (2020) [26]	RCT	India	69	18-60	Not specified	Chronic apical periodontitis with CBCT-PAI scores 3-5	LAI, PUI	CSI	Postoperative pain at 7 days (VAS score), Radiographic healing at 6 and 12 months (CBCT-PAI score)	12 months	Not specified	Significant reduction in CBCT-PAI scores in PUI and LAI groups compared to conventional syringe irrigation (p < 0.05)	Higher healing rates in LAI (42.1%) and PUI (36.8%) compared to syringe irrigation (10.5%)	Statistically significant reduction in CBCT-PAI scores in LAI vs. syringe irrigation (p < 0.05); No significant difference between PUI and LAI (p > 0.05)	No adverse effects reported	LAI and PUI demonstrated better clinical and radiographic healing compared to conventional syringe irrigation, with comparable success rates for PUI and LAI.
																Both PUI and

Dedania et al. (2021) [27]	RCT	India	44	18-60	M: 25, F: 19	Non-vital single-rooted teeth with fully formed apices	LD, PUI	Comparison between two irrigation techniques	Postoperative pain at 6, 24, 48 hours, and 7 days (Modified Verbal Rating Scale); Analgesic intake	7 days	Not specified	No significant difference in post-op pain at any time point (p = 0.086)	Pain reduction noted in both groups; slightly higher pain in laser disinfection group in the initial hours	No statistically significant difference (p = 0.086)	No adverse effects reported	laser disinfection were equally effective in reducing post-operative pain, though laser disinfection had a slight advantage in the initial hours.
Liapis et al. (2021) [28]	RCT	Belgium	56	18-78	M: 31, F: 25	Asymptomatic teeth requiring primary root canal treatment	UAI using Irrisafe tip, LAI using Er:YAG laser	Comparison between two irrigation techniques	Postoperative pain at 6, 24, 48, and 72 hours (VAS score); Analgesic intake	72 hours	Not specified	Significantly higher pain in UAI group at 6 hours compared to LAI (p < 0.05), no significant difference at 24, 48, and 72 hours	Pain reduced in both groups over time, no significant difference at later time points	Statistically significant pain difference at 6h (p < 0.05), but not at other time intervals	No severe adverse events; One patient in the UAI group reported severe pain but no complications	Both UAI and LAI resulted in low levels of postoperative pain, with LAI showing lower pain at 6 hours but no clinically significant difference at later time points.
Elmallawany et al. (2022) [29]	RCT	Egypt	40	20-45	Not specified	Necrotic mandibular molars requiring single-visit RCT	CUI, Diode Laser	CSI	Postoperative pain at 6, 12, 24, 36, 48 hours, and 7 days (VAS score); Bacterial reduction (CFU/mL)	7 days	Not specified	Significantly lower pain in CUI with diode laser group at all time points compared to conventional syringe irrigation (p < 0.001)	Higher bacterial reduction in CUI with diode laser (96.51%) compared to conventional syringe irrigation (79.96%)	Statistically significant difference in pain scores and bacterial reduction between groups (p < 0.05)	No severe adverse events reported	CUI with diode laser resulted in significantly lower postoperative pain and higher bacterial reduction compared to conventional syringe irrigation.
Abbara et al. (2023) [30]	RCT	Syria	60	25-44	M: 32, F: 28	Asymptomatic apical periodontitis in maxillary incisors	PUI, XP-Endo file, Diode Laser	Comparison among three irrigation activation systems	Postoperative pain at 1, 3, 7, and 14 days (VAS score)	14 days	Not specified	Diode laser group had significantly lower pain at 1, 3, and 7 days compared to PUI and XP-Endo Finisher (p < 0.05). XP-Endo Finisher group showed the highest pain at 1 and 3 days (p < 0.05). Pain disappeared in all groups after 14	Pain decreased in all groups over time. Diode laser had the lowest pain, XP-Endo Finisher had the highest pain.	Statistically significant pain reduction in diode laser group compared to other groups at 1, 3, and 7 days (p < 0.05), but no difference at 14 days (p > 0.05).	No severe adverse events reported	Diode laser resulted in the lowest postoperative pain, XP-Endo Finisher caused the highest pain levels in the first 3 days, but pain disappeared in all groups after 2 weeks.

												days.			
Krishnakumar et al. (2023) [31]	RCT	India	63	>18	Not specified	Symptomatic necrotic single-rooted teeth requiring primary endodontic treatment	CUI, LAI, Laser Irradiation	Comparison among three irrigation activation techniques	Postoperative pain at 24, 48 hours, and 7 days (VAS, NRS pain scales); Analgesic intake	7 days	Not specified	No significant difference in post-op pain among the three groups at any time interval (p > 0.05)	Pain reduced in all groups over time, with no statistically significant difference between CUI, LAI, and LI	No statistically significant difference (p > 0.05)	One patient in the LI group required analgesics at 24 hours; no severe adverse events reported	There was no statistically significant difference between CUI, LAI, and LI in postoperative pain reduction at any time interval, indicating similar efficacy in managing post-op pain.
Mathevanan et al. (2023) [32]	RCT	India	75	18-65	M: 38, F: 37	Symptomatic irreversible pulpitis in mandibular first molars	PUI using IrriSafe™, LAI using Er:Cr:YSGG laser, Conventional Needle Irrigation	Comparison among three irrigation activation techniques	Postoperative pain at 6, 24, and 48 hours (VAS score); Analgesic intake	48 hours	≥5 cm on VAS scale	PUI had the lowest post-op pain, followed by LAI; CNI had the highest pain at all time intervals (p < 0.05)	Pain reduced over time in all groups, with PUI and LAI showing significantly lower pain than CNI	Statistically significant difference between PUI, LAI, and CNI at all time intervals (p < 0.05)	No severe adverse events reported; CNI group had higher analgesic intake compared to PUI and LAI	PUI and LAI demonstrated significantly lower postoperative pain compared to CNI; PUI resulted in the lowest analgesic consumption.
Mittal et al. (2023) [33]	RCT	India	60	18-44	M: 28, F: 32	Symptomatic irreversible pulpitis in maxillary and mandibular molars	PUI, PIPS, SWEEPS	Conventional Needle Irrigation	Postoperative pain at 24 and 48 hours (VAS score); Analgesic intake	48 hours	8.93 - 9.13 (VAS 0-10 scale)	SWEEPS group had the lowest post-op pain at all time points (p < 0.05); PIPS group had significantly lower pain than CNI; Ultrasonic activation was superior to CNI but less effective than PIPS and SWEEPS	SWEEPS group had the highest reduction in pain, followed by PIPS, then PUI, with CNI showing the least reduction	Statistically significant difference between SWEEPS, PIPS, and other groups at 24h and 48h (p < 0.05)	No severe adverse events reported	Laser-activated irrigation systems (SWEEPS and PIPS) resulted in significantly lower postoperative pain than conventional and ultrasonic activation methods, with SWEEPS being the most effective.
Abbara et al. (2024) [34]	RCT	Syria	80	25-44	M: 36, F: 44	Asymptomatic necrotic maxillary incisors with large-sized periapical lesions	Diode Laser used as IAS, LLLT, Combination of IAS and LLLT	No laser application	Postoperative pain at 1, 3, 7, and 14 days (VAS score); Analgesic intake	14 days	Not specified	Group 4 (IAS + LLLT) had the lowest post-op pain, while the control group had the highest pain at all time points (p < 0.05)	Pain reduced in all groups over time, with the lowest pain levels in the combination group	Statistically significant differences between all groups at 1, 3, 7, and 14 days (p < 0.05)	No severe adverse events reported	The combination of diode laser IAS and LLLT significantly reduced postoperative pain compared to IAS or LLLT alone, suggesting its effectiveness in managing

																		pain following endodontic treatment.

TABLE 2: Data extracted from all the studies included in the present systematic review

LAI: laser-activated irrigation; PUI: passive ultrasonic irrigation; CUI: continuous ultrasonic irrigation; UAI: ultrasonic activated irrigation; PIPS: photon-induced photoacoustic streaming; SWEEPS: shock wave-enhanced emission photoacoustic streaming; CSI: conventional syringe irrigation: XP-Endo: XP-Endo finisher; LD: laser disinfection; LLLT: low-level laser therapy; IAS: irrigation activation system; NRS: numerical rating scale; VAS: visual analog scale; RCT: randomized controlled trial; CBCT-PAI: cone beam computed tomography periapical index; M: male, F: female

Study Characteristics

The included studies were conducted across four different countries, reflecting varied clinical protocols and population characteristics. The majority of the studies were from India (n=5), followed by Syria (n=2), Egypt (n=1), and Belgium (n=1). The total sample size across all nine studies was 547 patients. Most participants were between 18 and 65 years of age, although some studies extended the upper age limit up to 78 years. Gender distribution was reported in most studies, with a relatively balanced male-to-female ratio.

The diagnostic criteria used in the included trials primarily encompassed symptomatic irreversible pulpitis, necrotic pulpal conditions, and asymptomatic apical periodontitis, all of which required single-visit root canal treatment. The irrigation systems evaluated included diode lasers, Er:YAG lasers, SWEEPS, and PIPS techniques under LAI, as well as passive and continuous UI systems. Some studies also included conventional needle irrigation (CNI) and sonic activation for additional comparison.

Baseline and Post-treatment Pain Scores

Most studies used the Visual Analog Scale (VAS) or Numerical Rating Scale (NRS) to assess pain, although specific baseline scores were not consistently reported across all studies. Only Dedania et al. (2021) utilized the Modified Verbal Rating Scale for the assessment of pain in their study [27].

Across the nine included randomized controlled trials, baseline pain scores ranged from 5.96 to 9.42 on 10-point VAS or NRS, with the highest preoperative pain seen in the study by Mittal et al., 2023 on symptomatic irreversible pulpitis and apical periodontitis (9.13 on VAS scale) [33]. In contrast, asymptomatic cases, such as those in Liapis et al. (2021), reported baseline scores below 4 on the VAS [28]. Postoperative scores at six hours showed considerable differences between groups. Liapis et al. reported 4.9 VAS in the LAI group vs. 13.9 VAS in the ultrasonic group [28]. Mathevanan et al. (2023) found six-hour scores of 4.28 VAS for LAI, 4.00 VAS for PUI, and 5.60 VAS for CNI [32]. In Mittal et al. (2023), 24-hour pain scores were lowest in the SWEEPS group (0.93 VAS), followed by PIPS (2.00 VAS), with the CNI group reporting the highest pain (4.53 VAS) [33].

At 48 hours, LAI groups consistently showed lower scores (e.g., 1.20 VAS in Mathevanan et al., 0.13 VAS in the SWEEPS group of Mittal et al.) compared to UI or CNI [32,33]. Elmallawany et al. (2022) reported 5.1 VAS at 48 hours and 0.6 VAS at 7 days for laser-assisted CUI, significantly lower than syringe irrigation (28.6 VAS at 48 hours, 1.7 at seven days). By day 7, most groups reported minimal or no pain [29]. Abbara et al. (2023) found mean scores of 0.67 VAS in the diode laser group and 0.80 VAS in the PUI group [30], while Abbara et al. (2024) observed complete pain resolution (0.00 VAS) in the group receiving combined LAI and LLLT [34].

Overall, the trends indicate that patients presenting with symptomatic pulpitis or apical periodontitis had higher baseline pain levels. Post-treatment pain scores revealed significant variation depending on the activation method. In general, LAI showed lower pain levels within the first 24 to 48 hours compared to UI. However, by the end of the follow-up period (ranging from 48 hours to 14 days), both groups showed a comparable decrease in pain scores. Among the laser methods, diode lasers and SWEEPS techniques consistently demonstrated the most substantial reduction in postoperative pain. Ultrasonic methods also resulted in significant pain reduction compared to conventional irrigation techniques, albeit with a slightly delayed onset.

Statistical Significance in Pain Reduction

Statistically significant reductions in postoperative pain were reported in seven of the nine included studies ($p < 0.05$). Studies using diode lasers, SWEEPS, and PIPS recorded pain reductions exceeding 70% within 48 hours, while ultrasonic techniques generally showed a 50-65% reduction in pain during the same interval. Studies comparing multiple methods noted that while laser techniques offered quicker pain relief, the long-term pain scores equalized between UI and LAI by the end of the follow-up.

Effectiveness of Irrigation Techniques

In studies directly comparing LAI and UI, the former demonstrated faster pain relief within the first 24 hours post-treatment, particularly with diode lasers and photoacoustic streaming techniques. However, UI methods showed pain reduction comparable to LAI after 48 hours and were similarly effective by the end of the observation period. SWEEPS and PIPS showed enhanced effectiveness over both CNI and standard laser methods in one study. Overall, laser and ultrasonic methods were both superior to conventional syringe irrigation in reducing postoperative pain.

Adverse Events and Safety

No severe adverse events were reported in any of the included studies. One study recorded a single instance of severe pain in the ultrasonic group, which resolved without complications. Higher analgesic consumption was occasionally observed in groups receiving manual dynamic agitation or conventional irrigation, but this did not affect the comparative outcomes for LAI and UI.

Summary of Findings

Overall, both laser-activated and ultrasonic irrigation techniques were found to be effective in managing postoperative pain following single-visit endodontic treatment. Laser-based techniques, especially diode lasers and SWEEPS, showed faster pain reduction within the first 24 to 48 hours, while ultrasonic irrigation provided comparable long-term relief. These findings affirm the clinical utility of both methods as superior alternatives to conventional syringe irrigation for enhancing patient comfort and treatment outcomes.

Risk of Bias Assessment

The quality of the included randomized controlled trials was assessed using the Cochrane Risk of Bias 2 (RoB-2) tool across five domains. Of the nine studies included in this review, eight were judged to have a low overall risk of bias, indicating strong methodology and reliable outcome reporting. One study (Dedania et al., 2021) was assessed as having some concerns in the domain of randomization, primarily due to insufficient information regarding allocation concealment; however, it demonstrated low bias across all remaining domains [27]. All studies effectively minimized deviations from intended interventions, maintained complete outcome data with minimal attrition, and consistently utilized validated outcome measures such as VAS or NRS. The results were reported as per pre-established protocols, minimizing the likelihood of selective reporting. Overall, the included studies demonstrated a generally low risk of bias, supporting the internal validity and credibility of the synthesized findings (Figure *2*).

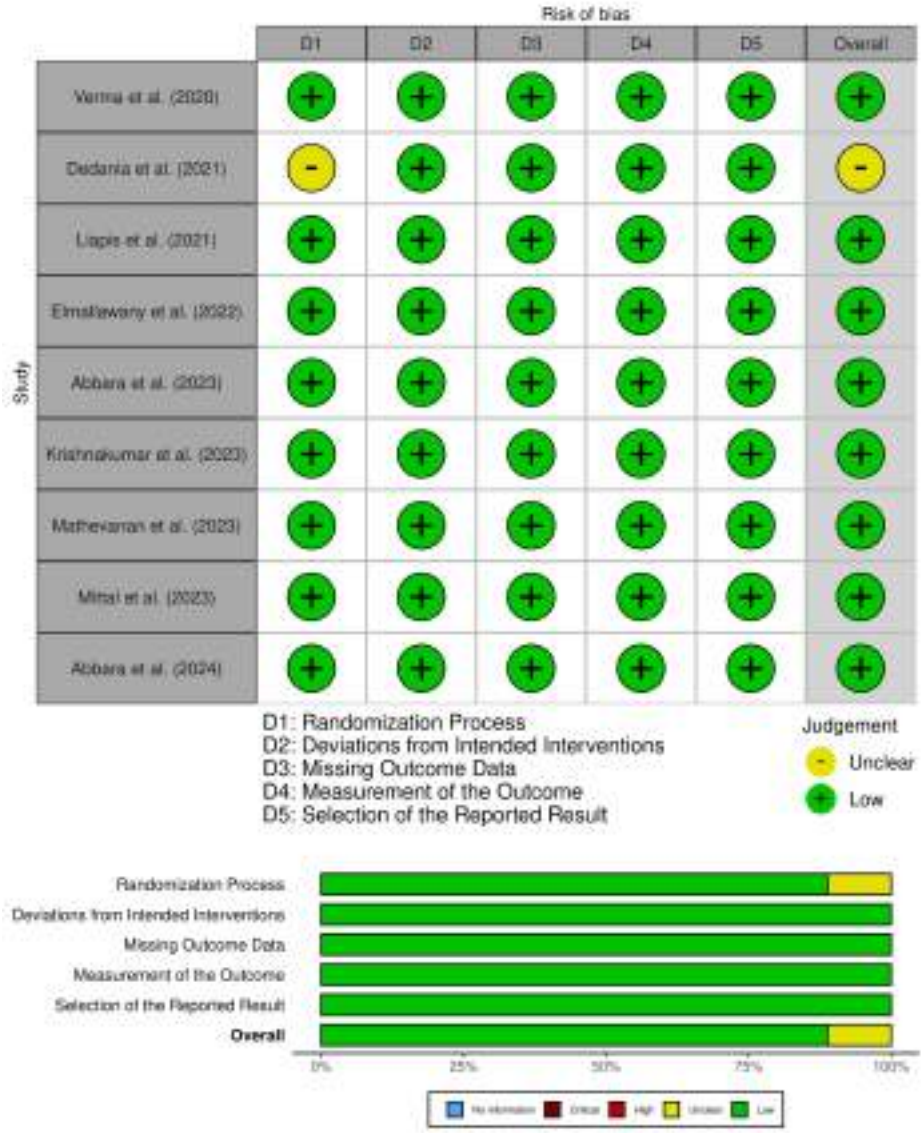

FIGURE 2: Risk of bias (RoB) in the included studies according to Cochrane RoB-2 tool

References: [26-34]

Comparison of Postoperative Pain After 24 Hours

The meta-analysis was performed on seven studies that qualified with the required data outcomes that could be analyzed quantitatively. The results of the overall comparison have been depicted as a forest plot (Figure *3*). With the meta-analysis conducted for selected studies, heterogeneity was more than 50% (I2 = 87%); hence, a random effect model was applied. The cumulative mean pain score after 24 hours was lower in the laser-assisted irrigation group as compared to the passive ultrasonic irrigation group with a standardized mean difference of -0.95 (95% CI = -1.71 to -0.20; Z value = 2.47), and the difference between the two groups was statistically significant (p=0.01).

FIGURE 3: Forest plot showing statistical comparison of postoperative pain after 24 hours across the included studies

Comparison of Postoperative Pain After 72 Hours

The meta-analysis was performed on three studies that qualified with the required data outcomes that could be analyzed quantitatively. The results of the overall comparison have been depicted as a forest plot (Figure 4). With the meta-analysis conducted for selected studies, heterogeneity was equal to 50% (I2 = 50%); hence, a fixed effect model was applied. The cumulative mean pain score after 72 hours was lower in the laser-assisted irrigation group as compared to the passive ultrasonic irrigation group with a standardized mean difference of -0.52 (95% CI = -0.87 to -0.18; Z value = 2.97), and the difference between the two groups was statistically significant (p=0.003).

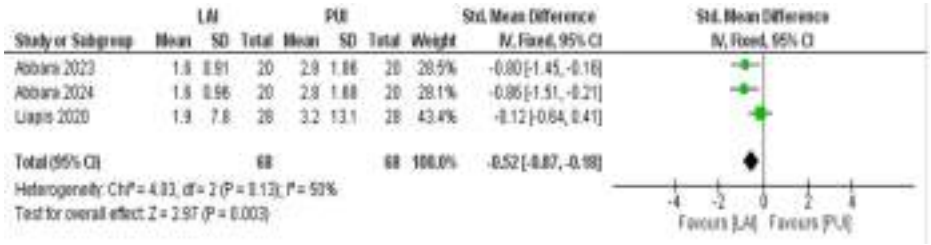

FIGURE 4: Forest plot showing statistical comparison of post-operative pain after 72 hours across the included studies

Discussion

The findings of this systematic review highlight the significant role of advanced irrigation activation techniques, particularly LAI and UI, in reducing postoperative pain following single-visit root canal treatment. Across the included studies, both techniques demonstrated superior pain relief compared to conventional syringe irrigation, with laser-based methods showing a faster initial reduction in pain, while ultrasonic activation exhibited consistent and sustained pain relief over time. These outcomes are in corroboration with the fundamental principles of endodontic pain management, which emphasize the importance of efficient bacterial eradication, debris removal, and minimal apical extrusion of irrigants [35].

Pain Relief in the Initial Hours

One of the key observations was that LAI led to a more rapid reduction in pain, particularly within the first 24 to 48 hours post-treatment. Among the different laser types, diode and Er:YAG lasers demonstrated the most effective pain relief, likely due to their ability to induce significant acoustic microstreaming while also exhibiting photothermal and photobiomodulatory effects. The latter may play a crucial role in modulating inflammatory pathways, reducing nociceptor activation, and promoting faster tissue healing, ultimately leading to a quicker decline in postoperative pain perception [36].

In contrast, UI exhibited comparable pain reduction but with a slightly delayed effect compared to LAI. Passive UI and continuous UI were particularly effective in reducing postoperative discomfort, likely due to their ability to improve fluid penetration into complex canal anatomy. However, unlike LAI, which induces bactericidal effects through light energy, UI relies entirely on mechanical activation. This distinction might explain why studies assessing pain at very early time intervals (six to 12 hours) reported lower scores in LAI groups compared to UI groups. The absence of direct antimicrobial effects in ultrasonic techniques could result in a shorter delay in bacterial regrowth, which, although transient, could account for slightly prolonged inflammatory responses. In the meta-analysis, it was observed that the post-operative

pain levels were significantly lower for LAI as compared to UI at 24-hour and 72-hour intervals.

Long-term Pain Relief

Despite these differences in initial pain reduction, the studies reported that by seven to 14 days postoperatively, both LAI and UI techniques exhibited similar pain levels. This suggests that while LAI accelerates initial pain relief, UI is equally effective in long-term pain reduction. This finding has important clinical implications, as it indicates that for practitioners seeking immediate pain relief, LAI may be the preferred choice. On the other hand, for clinicians who prioritize cost-effectiveness and ease of implementation, UI remains a highly viable alternative. Moreover, the lack of significant differences in pain reduction at later time intervals implies that the overall success of endodontic pain management is ultimately linked to adequate canal disinfection, regardless of the specific activation method employed.

Clinical Implications

The clinical implications of these findings are particularly relevant for managing patient expectations and optimizing treatment protocols. Patients undergoing root canal treatment often experience significant anxiety regarding postoperative discomfort, and these findings suggest that utilizing advanced activation techniques can substantially improve their experience [37]. Since pain perception is influenced by multiple factors, including tissue trauma, bacterial load, and immune response, selecting an appropriate irrigation method tailored to the individual case could enhance patient satisfaction and compliance [38]. For example, in cases with high bacterial burden, extensive periapical pathology, or symptomatic irreversible pulpitis, incorporating laser-activated irrigation may help achieve faster symptom relief. Conversely, in cases where cost and accessibility are concerns, ultrasonic activation provides an effective and more affordable alternative while still delivering significant improvements in patient comfort compared to conventional syringe irrigation.

One of the major drawbacks of conventional syringe irrigation is the inability to control irrigant flow beyond the apex, often leading to chemical irritation and periapical inflammation. Both LAI and UI reduce the risk of apical extrusion due to their efficient intracanal fluid dynamics, but studies suggest that UI may pose a slightly higher risk of extrusion, especially when high-powered activation is used. This could be due to the continuous movement of irrigants within the canal system in UI, whereas LAI relies on intermittent pulses of energy that create localized cavitation without generating excessive fluid pressure at the apex [39]. This finding reinforces the importance of proper technique selection based on case-specific factors such as canal morphology, periapical status, and the presence of open apices, where apical extrusion may be more problematic.

Furthermore, Mittal et al. (2023) assessed photoacoustic and photoactivated streaming techniques such as SWEEPS and PIPS and found that they achieved even greater pain reduction compared to conventional laser activation methods [33]. These techniques take advantage of shock wave generation and enhanced fluid energy transfer, leading to superior smear layer and debris removal while minimizing procedural discomfort [24]. Their impact on postoperative pain highlights the potential future directions for endodontic irrigation, where combining laser-induced streaming with optimized irrigant formulations could further enhance pain control and healing outcomes.

From a broader perspective, the absence of severe adverse events across all included studies underscores the safety and reliability of both ultrasonic and laser-based irrigation systems. While some studies reported higher analgesic consumption in groups with manual dynamic agitation, this likely reflects higher mechanical stress and inadequate fluid activation rather than any intrinsic issue with UI or LAI [30]. This reinforces the clinical preference for technologically advanced activation methods, as they not only enhance treatment efficacy but also improve patient comfort without introducing additional risks. The clear benefits in pain reduction, bacterial elimination, and enhanced healing make both LAI and UI valuable additions to the clinician's armamentarium. However, the decision to use laser or ultrasonic activation should be based on case-specific factors, operator experience, and available resources. Future research should focus on long-term clinical outcomes, patient-reported quality-of-life measures, and comparative cost-benefit analyses to further refine the optimal irrigation protocols for modern endodontic therapy.

Conclusions

The findings of this systematic review confirm that both laser-activated irrigation LAI and UI significantly reduce postoperative pain following single-visit root canal treatment, with LAI providing faster initial pain relief and UI demonstrating sustained long-term effectiveness. Laser techniques, particularly diode and Er:YAG lasers, as well as advanced streaming methods like SWEEPS and PIPS, showed the most substantial reduction in pain within the first 24 to 48 hours, while PUI and CUI remained highly effective alternatives with comparable pain reduction beyond a week. Both techniques outperformed conventional syringe irrigation, reinforcing their necessity in modern endodontic practice. No severe adverse effects were reported, further validating their clinical safety and efficacy. Given these results, the integration of LAI or UI should be considered a standard approach for enhancing patient comfort and improving endodontic

outcomes, with selection based on case complexity, resource availability, and operator preference.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Original Article

A comparative evaluation of the resistance to vertical root fracture after removal of separated instruments using three instrument retrieval systems: An *in vitro* study

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Abstract

Introduction: Separated instruments have been retrieved from root canals using different systems of instruments. However, it has been a common observation that usage of available retrieval systems may weaken the roots of teeth making them prone to fracture and subsequent failure of the treatment as a whole. Hence, the following study was conducted to evaluate and compare the resistance to vertical root fracture after retrieval of separated instruments from the root canal using Ultrasonic U Files, Ultrasonic Tip (Acteon Endo Success ET25 Retreatment Tip), or the Endo Rescue System under magnification of the dental operating microscope.

Materials and Methods: Forty-two moderately curved mesiobuccal roots of extracted decoronated mandibular first molar teeth were hemisectioned to standardize them to a length of 15 mm each. Following biomechanical preparation, 4-mm length ProTaper gold rotary finishing files F2 were intentionally separated in the middle third of the mesiobuccal root canal and verified radiographically. The samples were then randomly divided into three groups, and retrieval of the separated instrument was performed using the Ultrasonic U files, Ultrasonic ET25 Retreatment tip, or Endo Rescue System, respectively. After retrieval of the separated instruments, the samples were subjected to testing for vertical root fracture resistance using a universal testing machine with an accuracy of ± 1%. The data collected from all the samples were then subjected to statistical analysis.

Result: Ultrasonic U files (Group A) showed the highest vertical root fracture resistance, with a statistically significant difference from the samples treated with ET 25 Ultrasonic retreatment tips(Group B). No significant differences were observed between Group A and C or Group B and Endo Rescue System (Group C) ($P > 0.05$).

Summary and Conclusion: It was observed that Ultrasonic U files offer the least reduction in the vertical root fracture resistance after removal of separated instruments followed by the Endo Rescue system and then the ultrasonic ET25 retreatment tips. While no single instrument retrieval system is universally suitable for all situations due to various factors such as root anatomy, instrument type, location, size, pulpal status, and operator skill, clinicians should determine the treatment protocol by carefully considering the tooth's future prognosis.

Keywords: Instrument separation; retrieval; vertical root fracture

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Date of submission : 23.10.2024
Review completed : 29.12.2024
Date of acceptance : 06.01.2025
Published : 03.02.2025

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_750_24

INTRODUCTION

Instrument separation during endodontic treatment is a challenging issue, influenced by factors such as operator

How to cite this article: Lobo WM, Sayed A, Sapkale K, Ramugade M, Benavides AC. A comparative evaluation of the resistance to vertical root fracture after removal of separated instruments using three instrument retrieval systems: An *in vitro* study. J Conserv Dent Endod 2025;28:182-6.

skill, root canal anatomy, and instrument type.[1,2] While various methods exist for retrieving fractured instruments, including ultrasonics and microtube systems, there is growing concern about how these retrieval techniques affect the remaining tooth structure, particularly its resistance to vertical root fractures.[3,4]

The primary focus of research has often been on the success rate of removing separated instruments, with less emphasis on how these methods compromise the strength of the remaining tooth. The study conducted aims to address this concern by comparing vertical root fracture resistance after using three commonly used retrieval systems: Ultrasonic U Files, ET25 Retreatment Ultrasonic Tip, and Endo Rescue system.

By investigating the impact of these retrieval techniques on the vertical root fracture resistance, the study seeks to provide clinicians with valuable insights into how different methods affect the structural integrity of the tooth. This information will help in making more informed decisions, balancing the effectiveness of instrument retrieval with the preservation of tooth strength.

MATERIALS AND METHODS

This study was conducted in the department of conservative dentistry and endodontics at the institution. It was approved by the ethical committee of this institution Ref: GDCHM/ETHICAL COMMITTEE MEETING/4126/2020 dated October 16, 2020.

Sample size determination

The sample size was determined as 42 extracted mandibular first molar teeth with a total of 14 samples per group using the estimates of mean and standard deviation values from literature keeping the power of the study at 80%, with a 5% type I error and 20% type II error.

Sample selection

Freshly extracted sample teeth were placed in a 2.5% sodium hypochlorite solution for 15 min for the dissolution of soft tissue remnants. Later, the teeth were stored in 10% formalin solution.

Inclusion criteria

1. Mandibular first molar teeth with sound crown and root
2. The mesial root is moderately curved (Schneider's classification)
3. Mature apex.

Exclusion criteria

1. Endodontically treated teeth
2. External or internal resorption
3. Teeth with developmental anomalies
4. Teeth with preexisting root fractures, cracks, or root caries.

Sample preparation

Forty-two moderately curved mesiobuccal roots of extracted decoronated mandibular first molar teeth were hemisectioned to standardize them to a length of 15 mm each. These root surfaces were assessed under the dental operating microscope to exclude any teeth with preexisting root fractures or cracks following which each root was embedded into silicone impression material that was allowed to set within a custom-made metal ring which was held firmly on a laboratory bench top. The root canal was cleaned and shaped using the ProTaper Gold Rotary File System (Dentsply Sirona) till the finishing file F1.

Intracanal fracture of instruments

ProTaper Gold F2 rotary finishing files were notched 4 mm from the tip using a round bur to facilitate controlled breakage. The notched files were inserted into the canal until resistance was encountered and then rotated with pressure to fracture the instrument. Radiographs were taken to confirm that the fracture occurred in the middle third of the mesiobuccal root canal. The fractured instruments were examined under a dental operating microscope.

Grouping

The samples were randomly divided into three groups ($n = 14$):

- Group A – Separated instruments were retrieved using Ultrasonic U Files attached to an ultrasonic unit with an Endochuck. An endosonic file was inserted into the fragment's coronal end and activated to create a trough. A precurved #10 K-file was then used to bypass the fragment. Once bypassed, the fragment was dislodged through irrigation and agitation with the endosonic file at low power. Confirmation of removal was done with a radiograph
- Group B – Separated instruments were retrieved using an Acteon EndoSuccess ET25 ultrasonic tip. The canal was instrumented up to the fragment, and a staging platform was created with a modified Gates Glidden bur under magnification.[5] The coronal segment of the fragment was exposed by dry ultrasonic troughing with the tip at low power, which was then used to trephine dentin around the fragment in a counterclockwise motion until it was freed. A radiograph confirmed the successful retrieval
- Group C – Separated instruments were retrieved using the Komet Endo Rescue System Kit 4601. A straight line access to the fragment was created with a cylindroconical bur with a noncutting tip. The canal entrance was relocated using a Gates Glidden bur #4, and direct access to the fragment was established with

a Gates Glidden bur #3. The excavation was performed with a centering drill, and the fragment was removed using a trepan bur rotated counterclockwise. The fragment was held in the trepan bur by dentin residues.

The samples were pulled out from their molds, and after adequate irrigation, root surfaces were assessed under a dental operating microscope to detect cracks, fractures, and perforations.

Preparation for mechanical testing

The samples were mounted in a custom box filled with self-cure acrylic resin and tested with a universal testing machine accurate to ±1%. The samples were fixed so that a 5-mm diameter flat plugger applied axial force to the root at a crosshead speed of 1 mm/min [Figure 1]. The force at which each root fractured, indicated by a sharp drop in force and an audible cracking sound, was recorded in Newtons.

The data collected from all the samples were then subjected to statistical analysis using Statistical Package for Social Sciences (SPSS v 26.0, IBM) (IBM, India Private Limited, Bengaluru, Karnataka,India) [Table 1 and Graph 1].

RESULTS

The force required to fracture the roots was the greatest in the Ultrasonic U files (Group A) and it was the least for the Ultrasonic ET25 Retreatment tip (Group B). Hence, the roots from which separated instruments were retrieved using the Ultrasonic U files (Group A) were the most resistant to vertical root fracture and were statistically highly significant when compared with those roots wherein the separated instruments were retrieved using the ET 25 Ultrasonic retreatment tips (Group B) [Table 2 and Graph 2].

There was a statistically nonsignificant difference seen ($P > 0.05$) for the values between Groups A versus C [Table 2 and Graph 3].

There was a statistically non-significant difference seen ($P > 0.05$) for the values between Groups B versus C [Table 2 and Graph 4].

Table 1: Intergroup comparison of fracture load

	n	Mean	SD	SE	Median	χ^2	*P* value of Kruskal–Wallis test
A	14	826.214	296.2172	79.1674	730	10.133	0.006**
B	14	538.964	133.9031	35.7871	546.75		
C	14	727.321	332.0970	88.7567	745.50		
Total	42	697.500	288.1304	44.4595			

**Statistically highly significant difference seen for the values between the groups ($P<0.01$) with higher values in group A SD: Standard deviation, SE: Standard error

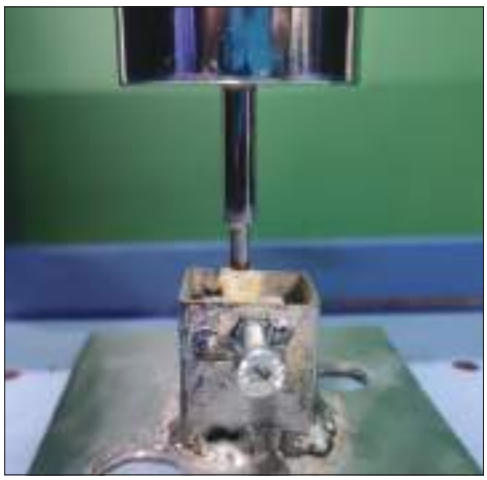


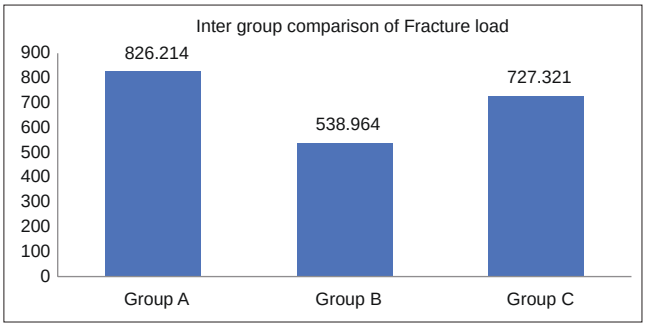
Figure 1: Sample mounted in self-cure acrylic resin subjected to universal testing machine

DISCUSSION

Endodontic therapy aims to cure pulpal and periradicular diseases through effective cleaning, shaping, and obturation of the root canal system. Advances in instrumentation, from barbed broaches to rotary nickel-titanium (NiTi) files, have significantly improved these processes.[6-8] However, despite their benefits, NiTi rotary files still face issues such as torsional stress and cyclic fatigue, leading to a clinical fracture rate of 2.27%.[9,10]

Management of separated instruments must be a systematic yet dynamic process, with the clinician constantly reassessing progress and considering alternative treatment options when necessary. Each individual case of instrument retrieval has its own unique characteristics that will dictate the approach taken to manage the case. As ultrasonics and holding techniques are the most commonly used systems for instrument retrieval, this study was conducted to evaluate the effect of Ultrasonic U files, ET25 Retreatment ultrasonic tips, and the Endo Rescue system on the vertical root fracture resistance of the tooth following removal of the separated instrument.

Mandibular first molars were chosen for this study due to

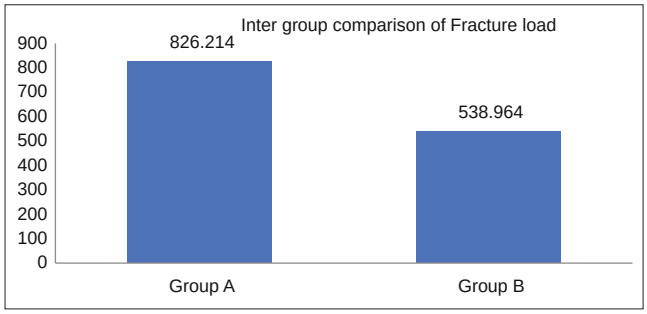


Graph 1: Intergroup comparison between Ultrasonic U Files (Group A), Ultrasonic ET25Retreatment Tip (Group B), and Endo Rescue System (Group C)

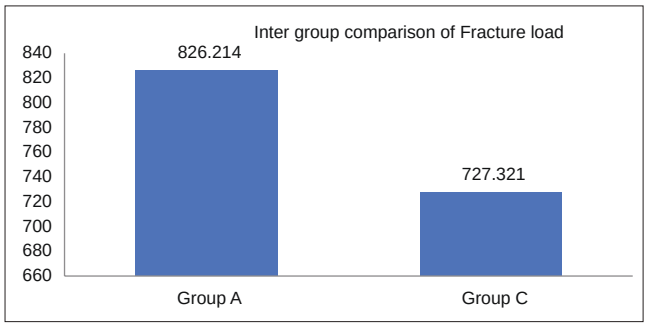
Table 2: Intergroup pairwise comparison using Mann–Whitney *U*-test

Group	Versus group	Mann–Whitney *U*	*Z*	*P* value of Mann–Whitney *U*-test
A	B	16.000	−3.768	0.000**
A	C	85.000	−0.597	0.550#
B	C	70.000	−1.287	0.198#

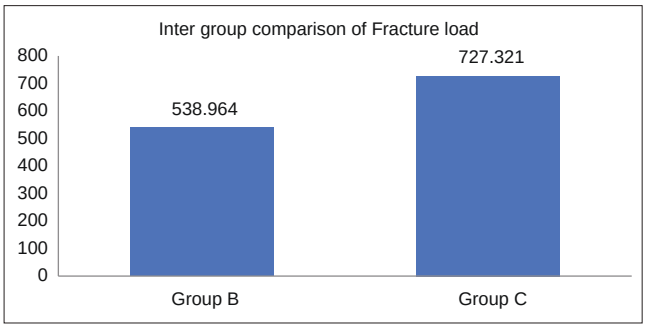
**Statistically highly significant difference seen ($P<0.01$) between group A vs B. #Statistically non-significant difference seen ($P>0.05$) for the values between groups A vs C. #Statistically non-significant difference seen ($P>0.05$) for the values between groups B vs C



Graph 2: Intergroup comparison between Ultrasonic U Files (Group A) and Ultrasonic ET25 Retreatment Tip (Group B)



Graph 3: Intergroup comparison between Ultrasonic U Files (Group A) and Endo Rescue System (Group C)



Graph 4: Intergroup comparison between Ultrasonic ET25 Retreatment Tip. (Group B) and Endo Rescue System (Group C)

high instrument separation rates in their mesial roots, as observed by Hülsmann and Schinkel,[11] Ward *et al*.,[12] Wu *et al*.,[13] and Ungerechts *et al*.[14] Iqbal *et al*.[15] noted that the severe lingual curvature of the mesiobuccal root canal increases the likelihood of instrument separation. The samples were hemi sectioned and decoronated at 15 mm from the root apex so as to achieve standardization and to provide optimal conditions for the removal of fractured instruments eliminating coronal factors.

After removing the separated instruments, samples were tested for vertical root fracture resistance directly as obturation could lead to dentinal defects, as noted by Blum *et al*.,[16] Shemesh *et al*.,[17] and Kumaran *et al*.[18] wherein it was concluded that teeth subjected to both lateral compaction and warm vertical condensation resulted in defects. Testing was conducted by applying force vertically along the long axis of the sample to ensure uniform force distribution, as recommended by Cobankara *et al*.,[19] Teixeira *et al*.,[20] and Sagsen *et al*.[21]

In the current study, Group A (Ultrasonic U files) showed the highest vertical root fracture resistance with a mean of 826.214 N, followed by Group C (Endo Rescue System) with a mean of 727.321 N. Group B (Ultrasonic ET25 Retreatment tip) had the lowest fracture resistance with a mean of 538.964 N. The superior performance of Group A is attributed to the small tip diameter (0.2 mm) and the absence of a need for a staging platform, which minimizes radicular dentin loss.

The Endo Rescue System (Group C) exhibited moderate fracture resistance, with no statistically significant difference ($P > 0.05$) compared to the other groups. This is in accordance with a study conducted by Gerek *et al*.[22] (2012) where the reduction in vertical root fracture resistance proved to be statistically nonsignificant following a comparison in the removal of separated instruments with Masserann kit (holding technique) and ultrasonics. However, previous studies have stated holding techniques to be more aggressive while removing separated instruments from the root canal as compared to ultrasonics.[23]

The least resistance to vertical root fracture following the removal of separated instruments was observed in the group using Ultrasonic ET 25 retreatment tip (Group B). This is in agreement to the study conducted by Fu *et al*.[24] which stated that use of this ultrasonic tip evidently increases the root canal volume owing to the need for the creation of a staging platform to gain access to the separated instrument, leading to microcrack formation, with the former being the primary reason for decreased vertical root fracture resistance.

Given that this study is *in vitro*, the results may not directly translate to clinical scenarios, highlighting the need for additional research.

CONCLUSION

Ultrasonic U files demonstrated the least reduction in

vertical root fracture resistance after the removal of separated instruments, followed by the Endo Rescue System and Ultrasonic ET25 retreatment tips. Given the variability in root anatomy, instrument type, location, size, pulpal status, and operator skill, no single retrieval system is universally ideal. Clinicians should choose their treatment protocols based on a thorough assessment of the tooth's future prognosis.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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European Journal of Clinical Pharmacy
Print ISSN: 2385-409X, **Online ISSN**: 3105-0409
Website: https://farmclin.com/

Comparison of Rotary Files System During Root Canal Preparation

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Received: 20-01-2026
Revised: 09-02-2026
Accepted: 16-02-2026
Published: 06-03-2026

Abstract: Background: This study was conducted to compare the rotary files during root canal preparation.**Material and methods:** A total of one hundred mandibular premolars that were newly extracted were categorized into five groups, each containing twenty teeth, for the purpose of biomechanical preparation. Group I included untreated teeth, while Group II employed manual files. Group III utilized ProTaper rotary instruments, Group IV incorporated K3 rotary instruments, and Group V made use of Easy RaCe rotary instruments. Subsequently, the roots were horizontally sectioned at 3, 6, and 9 mm from the apex for microscopic examination. Flaws were identified in the dentin. The analysis of the groups was conducted using a chi-square test.**Results:** A statistically significant difference was observed between the groups (P = 0.006). Group I exhibited no defective roots. The rotary groups, including the Hand K-file, ProTaper, K3 SybronEndo, and Easy RaCe, all displayed imperfections in the dentin. Nevertheless, the variations among the different rotary systems evaluated in this study were not statistically significant. Furthermore, the occurrence of dentinal defects did not show a significant difference among the groups.**Conclusion:** When compared to hand instrumentation, there may be a higher risk of dentinal abnormalities when using rotational tools.

Keywords: Endodontics, Rotary, Manual, Dentin, Dentinal defects.

How to Cite: horat, R. S., Kamble, S. S., Ahmed, S. A. B., Ramugade, M., Dhawan, J., & Naseem, F. Comparison of rotary files system during root canal preparation.*European. Journal of Clinical Pharmacy*. 2025. 7(1) 6489-6492

INTRODUCTION

The ultimate goal of endodontics is to achieve a flawless three-dimensional seal of the root canal system, which is realized through the meticulous design of the canal's diameter and shape.1 One of the critical phases in this process is biomechanical preparation, which plays a significant role in eliminating bacteria and debris from the root canal, thereby facilitating successful endodontic treatment.[2,3] However, during the instrumentation of the root canal, various complications may arise, including perforations, ledge formation, canal transportation, and the development of cracks in the root dentin.[4,5]

In the pursuit of effective biomechanical preparation, there are instances where we inadvertently compromise the integrity of the root dentin, leading to the emergence of dentinal cracks and subtle fractures, ultimately resulting in treatment failure.[6]

Due to the presence of craze lines or microcracks, root fractures may occur, which can propagate as a result of the repeated application of stress from occlusal forces. Various procedures, including biomechanical preparation, obturation, and retreatment, can lead to varying degrees of dentinal damage.[7]

Consequently, this study was undertaken to evaluate the comparison of different rotary files and the associated dentinal damage observed during root canal treatment as seen through a stereomicroscope.

Material and methods

A total of one hundred mandibular premolars, recently extracted, were selected, cleaned using a periodontal scaler, and subsequently stored in pure filtered water until further analysis. Following the application of a diamond disk to excise the coronal portions of each tooth, the measured remaining root length was found to be sixteen millimeters. To eliminate the potential for cracks on any of the root surfaces, a stereomicroscope with a magnification of 12 was employed.

Group I: Left unprepared and served as Group 1.

Group II: Prepared using stainless steel K-files up to apical size 25 at the working length and step-back technique was used till file no. 60.

The canal's patency was assessed in each of the subsequent three groups utilizing a #10 K-file. Subsequently, a K-file with a width of fifteen millimeters was introduced into the canal until it became visible through the apical foramen. By subtracting one millimeter from this measurement, we were able to determine the working length.

Group III: Prepared using ProTaper rotary system sequentially at the speed of 300 rpm using a crown-down technique. Canal preparation was finished with F2 (25/.08) till working length.

Group IV: K3 rotary system sequentially at the speed of 300 rpm using a crown-down technique. Canal preparation was done with file 25/.06 till working length.

Group V: Easy RaCe rotary system sequentially at the speed of 300 rpm. Canal preparation was done with file 25/.06 till working length.

In the canal preparation process, each canal was irrigated with three percent sodium hypochlorite between the use of each instrument. This procedure was consistently applied across all groups. Dolo Endogel, which comprises seventeen percent EDTA and ten percent carbamide peroxide, was employed between each successive instrument in the groups that utilized a rotating system for preparation. Furthermore, in all groups, the EndoActivator equipped with a no. 25 tip was operated for thirty seconds to vigorously agitate the solution, ensuring thorough cleaning of the canals. Throughout the experimental procedures, all roots were maintained in a damp state using filtered and purified water.

The analysis of the collected data was conducted using the statistical software SPSS 17.0. To assess whether there was a statistically significant difference among the experimental groups concerning the presence of defective roots, a Chi-square test was performed.

Additionally, a chi-square test was executed to ascertain the number of defects present in each group at various horizontal sections. The criterion for statistical significance was set at P less than 0.05.

Results

Table 1: Comparison of number and percentage of teeth showing defects

Defect	Control group	Hand K-file	ProTaper-rotary	K3- rotary	Easy RaCe rotary	Total
Absent	05	06	11	21	41	84
Present	00	02	07	03	04	16
Total	05	08	18	24	45	100

It was concluded that a statistically significant difference existed between the groups (P = 0.006). In Group I, no abnormal roots were identified. The investigation revealed that the Hand K-file, ProTaper, K3 SybronEndo, and Easy RaCe rotary groups exhibited dentinal imperfections. Nevertheless, the differences observed were not statistically significant for all rotary systems examined in this study. The results suggested that while there were variations in the occurrence of dentinal abnormalities, these variations did not reach statistical significance.

DISCUSSION

The main objective of chemomechanical root canal preparation is to maintain the original pathway of the canal while thoroughly cleaning the entire root canal system. A frequent complication linked to mechanical canal preparation is vertical root fracture (VRF), which often results in the loss of the tooth.8 Various NiTi instruments with distinct designs have been developed, yet all tend to cause incomplete cracks or even VRF.

Therefore, it is crucial to prevent such defects. Bier et al.9 indicated that craze lines appeared in 4% to 16% of cases, which could progress to fractures during retreatment or after prolonged functional stresses, such as those from chewing. This evidence suggests that root canal preparation using NiTi rotary systems, along with any subsequent procedures in endodontics, such as obturation and retreatment with rotary systems, can lead to the formation of fractures or craze lines.

According to our research, the occurrence of cracks in root dentin was higher following instrumentation with OneShape compared to HEDM and ProTaper Next. Liu et al. also reported similar findings, noting cracks in 35% of roots treated with OneShape.
The configuration of the file can influence the shaping forces exerted on root dentin; such forces have the potential to induce root fractures. ProTaper Next features a rectangular cross-section design with variations in tapering throughout its length. The off-centered rectangular design of ProTaper Next may have resulted in a lower incidence of cracks compared to OneShape.10

This particular design produces a swaggering motion, which mitigates the screw effect, reduces the risk of taper lock, and lessens the torque applied to the file. In contrast, OneShape possesses an asymmetrical cross-section along its entire length and features a variable pitch, along with a noncutting safety tip.11
In this specific study, a statistically significant difference was observed between the groups (P = 0.007). In Group I, no abnormal roots were identified. It was found that the Hand K-file, ProTaper, K3 SybronEndo, and Easy RaCe rotary groups exhibited dentinal imperfections. Nevertheless, the differences among all the rotary systems examined in this research were not statistically significant. The results suggested that while there were variations in the occurrence of dentinal abnormalities, these variations did not reach statistical significance.

Wilcox et al12 claimed that the amount of tooth structure removed was associated with vertical root fractures. A previous study reported that the ProTaper Next X2 instrument removed similar amounts of dentin compared with other instruments with larger taper sizes. The design features of the ProTaper Next might be related with the greater crack formation at the 3- and 9-mm levels than with the K3XF and RECIPROC.

Furthermore, Bier et al9 stated that the instrument taper affected the incidence of microcracks in root dentine. In this study, the apical preparation size was standardized to the size of #25 instrument. Nevertheless, for the final apical taper there were two different sets: 0.06 for K3XF and ProTaper Next and 0.08 for RECIPROC and TF Adaptive system. The larger apical taper in the TF Adaptive group may have contributed to the greater crack formation at the 3-mm level.

Abou El Nasr13 and Abd El Kader13 stated that the alloy of the instrument affects the number and percentage of dentinal cracks. Root canal instruments with greater flexibility were associated with fewer microcracks in the root structure. The total frequency

(percentage) of microcracks in the groups was 3 (3%) for K3XF, 13 (14%) for ProTaper Next, 3 (3%) for RECIPROC, and 16 (17%) for TF Adaptive. In the present study, the results revealed a significant difference in the incidence of microcracks among the experimental groups at the 3- and 9-mm levels. Hence, the null hypothesis is rejected.

CONCLUSION

Although Ni-Ti rotary instruments offer numerous benefits compared to hand tools, the process of preparing root canals may lead to varying levels of dentinal damage, contingent upon the intensity of the device's application. Increased taper, higher rotational speeds, and aggressive cutting techniques can elevate the stresses exerted on the dentin wall, potentially contributing to this issue. Such factors may lead to the emergence of dentinal irregularities. The results of this study indicate that the ProTaper rotary system inflicts greater harm on the dentin than alternative rotary systems such as K3 and Easy RaCe.

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International Journal of Life Sciences, Biotechnology and Pharma Research Vol. 15, No. 2, February 2026 Online ISSN: 2250-3137
Print ISSN: 2977-0122

DOI: 10.69605/ijlbpr_15.2.2026.64

Original Research

A Comparative Evaluation Of Pulp Response To Mineral Trioxide Aggregate And Biodentine As A Direct Pulp Capping Agent On Vital Human Healthy Tooth: An Ex-Vivo Study

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Received: 16 December, 2025 Acceptance: 28 January, 2026 Published: 16 February, 2026

Abstract
Background: Direct pulp capping aims to preserve pulp vitality by promoting healing and reparative dentine bridge formation following pulp exposure. Mineral trioxide aggregate (MTA) and Biodentine are calcium silicate–based materials widely used for this purpose; however, direct histological comparisons in healthy human pulp are limited.
Aim: To evaluate and compare the histological response of healthy human pulp following direct pulp capping with MTA and Biodentine.
Methods: Sixty-six clinically and radiographically healthy human premolars indicated for orthodontic extraction were included. Teeth were randomly allocated into three groups: Group 1 (MTA, n=22), Group 2 (Biodentine, n=22), and Group 3 (control, n=22). Standardized mechanical pulp exposure was performed, followed by direct pulp capping with the respective materials. Teeth from experimental groups were extracted at 15 days (for inflammatory response) and 65 days (for dentine bridge formation). Histological evaluation was performed blindly by three oral pathologists assessing inflammatory response, dentine bridge formation, morphology, continuity, and thickness. Data were analyzed using Chi-square and Fisher's exact tests ($p<0.05$).
Results: Both MTA and Biodentine demonstrated favorable pulpal responses with absence or minimal inflammatory cells in the majority of samples. No necrosis was observed in any group. Dentine bridge formation was evident in all experimental samples, with complete and continuous bridges observed slightly more frequently in the MTA group. However, differences between MTA and Biodentine for inflammation, dentine bridge formation, morphology, continuity, and thickness were statistically non-significant ($p>0.05$).
Conclusion: Both MTA and Biodentine exhibit excellent biocompatibility and induce predictable reparative dentine bridge formation in healthy human pulp. Their histological performance as direct pulp capping agents is comparable.
Keywords:Direct Pulp Capping Agents, MTA,Biodentine

Introduction

The primary objectives of managing direct pulp exposure include isolation of the exposure site, debridement and decontamination when required, placement of an appropriate pulp-capping material with an impervious seal, and induction of reparative dentine bridge formation. Healing of exposed pulp tissue is characterized by reorganization of damaged soft tissues, differentiation of odontoblast-like cells from subodontoblastic cells, and formation of a reparative dentine bridge [1].

Over the past two centuries, a wide range of materials have been used for direct pulp capping with variable success. An ideal pulp-capping material should

DOI: 10.69605/ijlbpr_15.2.2026.64

control infection, adhere to dentine to prevent microleakage, be easy to handle clinically, and promote dentine bridge formation [2-3]. Historically, materials such as zinc oxide eugenol, corticosteroids and antibiotics, inert materials, collagen, calcium phosphate, hydroxyapatite, resin adhesives, lasers, glass ionomer and resin-modified glass ionomer cement, growth factors, recombinant insulin-like growth factor-I, bone sialoprotein, propolis, novel endodontic cements, Emdogain, EndoSequence root repair material, TheraCal, and castor oil bean cement have been explored with varying degrees of success [4]. Despite these efforts, predictable dentine bridge formation remained inconsistent.

The introduction of calcium hydroxide into dentistry by Hermann in 1930 marked a major milestone [5-6]. Due to its antimicrobial properties, ability to induce calcific bridge formation, and favorable healing response, calcium hydroxide gained widespread acceptance and was regarded as a universal pulp-capping agent [7-8]. However, subsequent studies demonstrated that its high pH causes superficial pulp necrosis, it possesses poor mechanical properties, and it fails to provide an adequate seal against microleakage [9-10]. Additionally, calcium hydroxide tends to dissolve and disintegrate over time, creating voids that permit bacterial infiltration. These limitations prompted the search for superior materials [11].

A major breakthrough occurred with the introduction of mineral trioxide aggregate (MTA) in 1993. MTA is composed primarily of refined Portland cement and bismuth oxide, with trace amounts of SiO_2, CaO, MgO, K_2SO_4, and Na_2SO_4. Its principal constituents include dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, and tetra-calcium-alumino-ferrite [12-13]. MTA demonstrates excellent mechanical properties, achieving compressive strengths of 40.0 MPa at 24 hours and 67.3 MPa at 21 days, with negligible solubility after setting [14-16]. Owing to its superior biocompatibility, sealing ability, and healing potential, MTA became the material of choice over calcium hydroxide. However, its clinical use is limited by difficult handling characteristics and prolonged setting time.

To overcome these drawbacks, Biodentine—a newer calcium silicate-based material—was introduced. Biodentine consists of a powder containing tricalcium silicate, dicalcium silicate, calcium carbonate, and zirconium dioxide as a radiopacifier, and a liquid containing calcium chloride as a setting accelerator [17-18]. Biodentine exhibits rapid setting and progressive improvement in compressive strength, reaching approximately 300 MPa after one month, which is comparable to natural dentine (297 MPa) [19]. Furthermore, Biodentine demonstrates superior sealing properties compared to MTA [20].

Although the biocompatibility, sealing ability, and reparative potential of both MTA and Biodentine have been well documented, and their use as direct pulp-capping materials has yielded promising results compared with calcium hydroxide, there is a paucity of literature directly comparing these two materials. Therefore, the present study was undertaken to evaluate and compare the histological response of healthy human pulp following direct pulp capping with calcium silicate-based materials i.e. MTA and Biodentine.

Material and methods

This study was carried out in the department of conservative dentistry and endodontics of this Dental College, with the support of department of dentofacial orthopedics, department of oral and maxillofacial surgery and department of oral and maxillofacial pathology. This study was approved by the ethical committee of this institution as per the letter no. PG-T/E1/2134/2017 and dated 25/10/2017. Sixty-six healthy human premolars which were advised for extraction for orthodontic reasons; were selected for this study.

Sample selection: Each of the selected 66 teeth were randomly allocated to one of the following Group (n = 22) by lottery method.

Groups	Material	No. of teeth (n)
Group1	MTA	22
Group2	BIODENTINE	22
Group3 (Control)		22

Inclusion Criteria

1. Clinically and radio graphically mature healthy premolar teeth scheduled for extraction for orthodontic reasons
2. Age group of patient 15-25 years, both male and female subjects.

Exclusion Criteria

1. Teeth having dental caries, pulpal disease, periradicular lesion and periodontal disease.
2. Teeth with fracture or having history of trauma.
3. Tooth anomaly.
4. Teeth having attrition, abrasion, erosion, abfraction.
5. Teeth having restoration.
6. Patient having systemic disease.
7. Patient with habits and parafunctional habits.
8. Patient having hypersensitivity.

Methods

Details of the patients leading extractions of premolar teeth for orthodontic treatment selected from the department of oral and maxillofacial orthopedic on the

DOI: 10.69605/ijlbpr_15.2.2026.64

day of their prescheduled appointment as per the department protocol. patient and parent were explained about this study. A study information aim voluntary contribution form was given to the patient following W.H.O. guideline. World Health Organization consent forms were signed by patients and/or parents after receiving a detailed explanation about the experimental rationale, clinical procedures, and possible risks associated with the study.

Operative Procedure

1. A detailed case history were taken for all the patients, followed by clinical examination and standard intraoral periapical radiographs for each tooth; to assure the absence of caries, trauma, periapical, and periodontal lesions.
2. The procedure commenced with the administration of local anesthesia. Teeth were cleaned using 0.2% chlorhexidine solution.
3. After rubber dam application, occlusal cavities were prepared by sterile diamond bur (SF-31; Mani, Inc., Japan) at high speed under air-water spray coolant.
4. Pulp exposure of approximately 1mm was performed in the centre of the pulp floor by means of a sterilized round diamond point (BR-45, Mani, Inc., Japan) under water cooling. One bur was used for each cavity.
5. Complete hemostasis was achieved by applying gentle pressure on the exposed site with cotton pellet moistened with sterile saline.
6. After haemostasis, the exposure site was dressed with pulp capping materials directly in contact with the pulp tissue.
7. In Group-1, exposed pulp and surrounding dentin will be capped with MTA (MTA Angelus white), manipulated according to manufacturer's recommendations. After placing MTA, a wet cotton pellet was placed directly over the material till its initial set. After 10min of initial set cotton pellet was removed followed by resin-modified glass ionomer cement base and composite restoration was given.
8. In Group-2, Biodentine (Septodont, Saint Maur des Fosses, France) was mixed in accordance with the manufacture's recommendation. The mixture was applied on exposed pulp, followed by composite restoration was given.
9. After composite restoration, every restoration was evaluated for any occlusal prematurity or under filled margin which may cause hypersensitivity.
10. After completion of restoration patient were advised to report for extraction of teeth from Group-1 (n=11) and Group-2 (n=11) 15 days and remaining 22 teeth, Group-1 (n=11) and Group-2 (n=11) 65 days later by a designated oral surgeon in the Department of Oral and Maxillofacial Surgery in Dental College and Hospital. Normal healthy teeth from Control group-3 (n=22) were advised for extraction as per scheduled given by the oral and maxillofacial surgeon.
11. Patient were given the contact details of the operator for the purpose of communication in case of any discomfort.
12. Patient were asked to informed to the department in case of any symptoms like hypersensitivity, pain, soreness, swelling and sinus tract.

Histological Examination

After the preparation of the specimen all the all the patient's data on 66 slides were covered and blindly evaluated under microscope (4x, 10x and 40x) by three experienced oral pathologists. Slides of teeth extracted after 15 days were observed for inflammatory reaction according to criteria given by **Cox et al(1982) [21].**

Inflammatory cell response

1	Absent or very few inflammatory cells
2	Mild or average number < Inflammatory cells
3	Severe inflammatory lesion appearing as an abscess or dense infiltrate involving one-third or more of the coronal pulp
4	Completely necrotic pulp

-Slides of the teeth extracted after 65 days were observed for dentine bridge formation, morphology of dentinal bridge, continuity of dentinal bridge and thickness of dentinal bridge according to criteria given by **Faraco et al and Medina et al** [22-23].

Dentine bridge formation

1	Presence of a dentine bridge directly adjacent to some portion of the medicament interface Morphology of dentinal bridge Inflammatory cell response Continuity of the dentinal bridge
2	Presence of a dentine bridge distant from the medicament interface
3	No evidence of any dentine bridge formation in any sections

DOI: 10.69605/ijlbpr_15.2.2026.64

Morphology of dentinal bridge

1	Dentine or dentine associated with irregular hard tissue
2	Only irregular hard tissue deposition
3	Only a thin layer of hard tissue deposition
4	No hard tissue deposition

Continuity of the dentinal bridge

1	Complete dentine bridge formation
2	Partial/incomplete dentine bridge formation extending to more than one-half of the exposure site but not completely closing the exposure site
3	Initial dentine bridge formation extending to not more than one-half of the exposure site
4	No dentine bridge formation

Thickness of dentinal bridge

1	>0.25 (mm)
2	0.1-0.25 (mm)
3	<0.1 (mm)
4	Partial or absent bridge

Statistical analysis: The means and standard deviations of the measurements per group were used for statistical analysis (SPSS 22.00 for windows; SPSS inc, Chicago, USA). Difference between two groups was determined using chi square test as well as Fisher's exact test and the level of significance was set at **$p < 0.05$.**

Results: Table 1 shows the comparison of inflammatory cell response among the study groups. Absent or very few inflammatory cells were reported among 81.82%, 72.73% and 100% of the teeth in group 1, group 2 and group 3 respectively. Completely necrotic pulp was absent among the entire group whereas severe inflammatory lesion was revealed in 9.09% of the teeth among group 1 and group 2 respectively. The above finding suggest that both the materials showed absence or presence of mild inflammatory changes with marginally higher number of teeth in MTA than Biodentine, but the difference was statistically non-significant.

Table 1: Comparison of inflammatory cell response among the study groups

Inflammatory cell response	Group 1(n=11)		Group 2(n=11)		Control Group 3 (n=11)	
	n	%	n	%	N	%
Absent or very few inflammatory cells	9	81.82	8	72.73	11	100
Mild or average number < Inflammatory cells	1	9.09	2	18.18	0	0
Severe inflammatory lesion	1	9.09	1	9.09	0	0
Completely necrotic pulp	0	0	0	0	0	0
Fisher exact test	3.89					
p value	0.79					

Presence of a dentine bridge directly adjacent to some portion of the medicament interface 4 (36.36%) and 5 (27.27%) of 11 teeth in each MTA and Biodentine group respectively. Presence of a dentine bridge distant from the medicament interface observed in 7 (63.64%) and 6 (72.73%) of 11 teeth in each MTA and Biodentine group respectively. Above finding suggested that Presence of a dentine bridge formation directly adjacent the pulp-medicament interface was observed marginally higher in Biodentine group than MTA group. However, the difference between two experimental group for formation of dentine bridge was statistically non-significant (table 2).

Table 2: Comparison of dentine bridge formation among the study groups

Dentine bridge formation	Group1(n=11)		Group2 (n=11)		Control Group3(n=11)	
	n	%	n	%	n	%
1	4	36.36	5	27.27	11	100
2	7	63.64	6	72.73	0	0
3	0	0	0	0	0	0
Fisher exact test	3.45					

DOI: 10.69605/ijlbpr_15.2.2026.64

p value	0.38

Both the experimental groups show irregular hard tissue deposition in 3(27.27%) sample of each group. Thin layer of hard tissue deposition was observed in 1 sample (9.09%) of Group 2 (Biodentine). Above finding suggest that morphology of dentine bridge directly adjacent to portion of the medicament interface was observed marginally more in Group1 (MTA) than Group 2(Biodentine). However, the difference between two experimental group for morphology of dentine bridge was statistically non-significant (table 3).

Table 3: Comparison of morphology of dentine bridge among the study groups

Morphology of the dentinal bridge	Group1(n=11)		Group2 (n=11)		Control Group 3 (n=11)	
	N	%	n	%	n	%
Dentine or dentine associated with irregular hard tissue	8	72.73	7	63.64	11	100
Only irregular hard tissue deposition	3	27.27	3	27.27	0	0
Only a thin layer of hard tissue deposition	0	0	1	9.09	0	0
No hard tissue deposition	0	0	0	0	0	0
Fisher exact test	3.94					
p value	0.73					

Presence of Complete dentine bridge formation was observed in 7(63.64%) and 6(54.55%) of 11 teeth in each Group 1 (MTA) and Group-2 (Biodentine) respectively. Partial dentine bridge formation more than one half of the exposure site between pulp and material interface was observed in 4(36.36%) and 5(45.45%) of 11 teeth in each Group-1 (MTA) and Group2 (Biodentine) respectively. None of material from experimental groups shows formation dentine bridge less than one half of the exposure site. Above finding suggest that continuity of the dentinal bridge directly adjacent to the medicament interface was observed marginally more in Group-1 (MTA) than Group-2 (Biodentine). However, the difference between two experimental group for continuity of the dentinal bridge was statistically non significant (table 4).

Table 4: Comparison of continuity of the dentinal bridge among the study groups

Continuity of the dentinal bridge	Group1 (n=11)		Group2 (n=11)		Control Group3(n=11)	
	n	%	n	%	n	%
Complete dentine bridge formation	7	63.64	6	54.55	11	100
Partial dentine bridge formation (>one half of the exposure site)	4	36.36	5	45.45	0	0
Initial dentine bridge formation (<one half of the exposure site)	0	0	0	0	0	0
No dentine bridge formation	0	0	0	0	0	0
Fisher exact test	4.13					
p value	0.84					

Comparison of thickness of dentinal bridge more than 0.25 mm was observed in 5(45.45%) and 4(36.36%) of 11 teeth in each Group -1 (MTA) and Group -2 (Biodentine) respectively. It was observed 3(27.27%) and 4(36.36%) of 11 teeth in each group exhibited dentinal bridge formation having thickness between 0.1-0.25 mm respectively. Very thin dentine bridge less than 0.1 mm was observed in equal no of teeth 3 out of 11 teeth from both groups. Above finding suggest that thickness of dentinal bridge directly adjacent to the medicament interface was observed marginally more in Group-1 (MTA) than Group-2 (Biodentine). However, the difference between two experimental group for thickness of dentinal bridge was statistically non significant (table 5).

Table 5: Comparison of thickness of dentinal bridge among the study groups

Thickness of the dentinal bridge	Group1 (n=11)		Group 2(n=11)		Control Group 3 (n=11)	
	n	%	n	%	n	%
>0.25 mm	5	45.45	4	36.36	11	100
0.1-0.25 mm	3	27.27	4	36.36	0	0

DOI: 10.69605/ijlbpr_15.2.2026.64

<0.1 mm	3	27.27	3	27.27	0	0
Partial or absent bridge	0	0	0	0	0	0
Fisher exact test	3.67					
p value	0.52					

Discussion

Sixty-six intact human premolar teeth under age group of 15-25 years which were scheduled for extraction due to orthodontic reasons were selected for the purpose of this study. Existing Studies comparing response of these two materials on vital human healthy teeth are very few and observed that number of subjects (sample) recruited in those studies are very less. Therefore, in this study it was ensured that sufficiently large numbers of subjects (sample) were recruited. Informed legal consent form of the patients was obtained as per standardized protocol.

Half of the teeth from Group -1 and Group -2 total 11 each teeth respectively were extracted 15 days postoperatively. Remaining 22 teeth (11 from each experimental group) were extracted 65 days postoperatively. A time interval of 15 days was selected to study any inflammatory changes at the material pulp interface and time interval after 65 days was intended to study dentine bridge formation, morphology, continuity and thickness of dentine bridge formation. In accordance with **P. N. R. Nair et al (2008)[24], Accorinte et al (2008)[25], A Parolia et al (2010)[1], Alicja Nowicka et al (2013)**[26], **Laurent et al (2012)[27] and Jalan et al (2017)[28]** with these studies 15 days**,** 45 days, 60 days, 6 months and 1-year time interval were used to access the inflammatory changes, quality and formation of dentin bridge. So, we decided to use 15 days and 65 days' time interval to evaluate the inflammatory changes, quality and formation of dentin bridge experimental groups respectively.

Formation of the dentinal bridge at the interface between the pulp and pulp-capping material is a controversial issue because it can be a sign of healing or a reaction to irritation [28]. In the present study, formation of the dentinal bridge was interpreted as a positive reaction to stimulation and a sign of healing. The presence of inflammatory cells, dentine bridge formation, morphology, continuity and thickness of dentine bridge formation of the pulp are used as indicators of the outcome of vital pulp therapy **(Parirokh & Torabinejad 2010) [29].**

Absence of or presence of very few inflammatory cells was observed in 9 (81.82%) and 8 (72.73%) of 11 teeth in each MTA and Biodentine groups respectively. Mild or average number of Inflammatory cells was observed in 1(9.09%) and 2(18.18%) of 11 teeth in each MTA and Biodentine groups respectively. Both the experimental groups shows severe inflammatory response in single sample 1(9.09%) of each group. The above finding suggest that both the materials showed absence or presence of mild inflammatory changes with marginally higher number of teeth in MTA than Biodentine, but the difference was statistically non significant. Hence the performance of both the materials is similar in terms of absence or presence inflammatory changes.

With respect to pulpal response, the samples in Group-1 and Group-2 that were capped with MTA and Biodentine respectively, performed well in the current study This finding is in accordance with the study by **Alicja Nowicka et al (2013)**[30] in which they compared the human pulpal response to MTA and Biodentine and found no inflammation in their samples. It appears that, MTA and Biodentine has excellent sealing properties, prevents microleakage and pulpal inflammation by providing a predictable secondary barrier under the surface seal. **Jalan et al(2017)**[28] compared the pulpal response to calcium hydroxide and Biodentine in human premolars and found no inflammation in the samples of both materials. Similarly, the present study also demonstrated less pulpal inflammation in the Biodentine group.

Presence of a dentine bridge distant from the medicament interface observed in 7(63.64%) and 6(72.73%) of 11 teeth in each MTA and Biodentine group respectively. Above finding suggested that Presence of a dentine bridge formation directly adjacent the pulp-medicament interface was observed marginally higher in Biodentine group than MTA group. However, the difference between two experimental group for formation of dentine bridge was statistically non-significant, hence performance of both the materials is similar in terms of dentine bridge formation. In accordance with **Nowicka Wt al (2013)**[30] found similar response of pulp to dentine bridge formation in MTA and Biodentine group during the course of 6 months of study. **Tran et al (2012**)[31], **Abedi et al. (1996)**[32]and **Pitt Ford et al. (1996)**[33]found a significantly higher frequency of calcific bridge formation in MTA compared with calcium hydroxide in animal study during the course of 30 days, 3 months and 6 months of study.

Both the experimental groups show irregular hard tissue deposition in 3(27.27%) sample of each group. Thin layer of hard tissue deposition was observed in 1 sample (9.09%) of Group -2 (Biodentine). Above finding suggest that morphology of dentine bridge directly adjacent to portion of the medicament interface was observed marginally more in Group1 (MTA) than Group -2 (Biodentine). However, the difference between two experimental group for morphology of dentine bridge was statistically non-significant. Hence the performance of both the materials is similar in terms of dentine bridge formation. **Tran et al (2012)[31] and Alicja Nowicka et al (2013) [30]**found similar response of MTA and Biodentine for formation dentine bridge.

DOI: 10.69605/ijlbpr_15.2.2026.64

Morphology of Dentine Bridge of both the experiment groups shoes statistically none significant in their study.

Complete dentine bridge formation was observed in 7(63.64%) and 6(54.55%) of 11 teeth in each Group - 1 (MTA) and Group-2 (Biodentine) respectively. None of material from experimental groups shows formation dentine bridge less than one half of the exposure site. Above finding suggest that continuity of the dentinal bridge directly adjacent to the medicament interface was observed marginally more in Group1 (MTA) than Group -2 (Biodentine). However, the difference between two experimental group for continuity of the dentinal bridge was statistically non-significant. The findings of the current study are also in accordance with **Tran et al (2012)**[31] who showed that the reparative structures induced by both calcium silicate cements (MTA and Biodentine) were homogenous and in continuity with primary dentin. In contrast, the reparative tissue induced by calcium hydroxide had a porous organization. This porosity may eventually facilitate bacterial ingress into the pulp, leading to secondary inflammation of the pulp tissue and eventually failed maintenance of tooth vitality. Studies by **M. Aeinehchi et al (2002) [34], P. N. R. Nair et al (2008) [24], Ali Eskandarizadeh et al (2011) [35]** showed superior bridge formation of MTA with respect to Ca(OH)2 and the study by **Alicja Nowicka et al (2013)**[30] showed no significant difference with respect to the quality, continuity and thickness of bridge formation between Biodentine and MTA. Thus, these studies are in accordance with the present study.

Thickness of dentinal bridge directly adjacent to the medicament interface was observed marginally more in Group1 (MTA) than Group -2 (Biodentine). However, the difference between two experimental group for thickness of dentinal bridge was statistically non-significant. MTA has been compared with Ca(OH)2 in various animal studies **(Pitt Ford et al. 1996 [33], Faraco and Holland 2001 [36], Tziafas et al. 2002 [37], Till Dammaschke2010)**[38] and human studies **(Aeinehchi et al. 2002 [39], Nair et al 2008 [24], Accorinte et al 2008 [25], A Parolia et al 2010 [1], Ali Eskandarizadeh et al 2011) [35]**. These studies consistently demonstrated good quality of dentine bridge, more hard tissue bridge formation with MTA group when compared with the Ca(OH)2 control group which shows that MTA is clearly superior to Ca(OH)2 as a pulp capping agent. **Tran et al (2012) [31] and Alicja Nowicka et al (2013)** [30] found similar response of MTA and Biodentine for formation dentine bridge. Thickness of dentine bridge was found to be more in MTA group than Biodentine group, but the result was statistically non significant in their study.

Thus, after assessing the five histological criteria's for each of the 44 samples above finding suggested that, MTA and Biodentine shows acceptable response in terms of no pulpal inflammation and more predictable, uniform, thick and continuous hard tissue barrier formation at pulp medicament interface that completely seals the pulp tissue.

Limitations

Direct pulp capping is used in many situations like attrition, erosion, caries and traumatic injuries in which pulp is under the continuous stress, but in this study the selected teeth was healthy and carious free. Even though in the present study 65 days was used to study dentine bridge formation histologically, longer-time intervals at least 1 year could be examined to see the long-term thickness and quality of the bridge.

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The Effectiveness of Circumferential and Sectional Matrix Systems in Obtaining Optimum Proximal Contact in Class II Composite Restorations: A Systematic Review

Review began 05/14/2025
Review ended 05/26/2025
Published 05/28/2025

DOI: 10.7759/cureus.84967

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Abstract

This review aims to evaluate the effectiveness of circumferential matrix band (CMB) and sectional matrix band (SMB) systems in obtaining optimum proximal contact in class II composite restorations.

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and registered in PROSPERO (CRD42024556368). Electronic databases were searched from January 1990 to April 2024 for studies assessing the effectiveness of circumferential and sectional matrix systems in obtaining optimum proximal contact in class II composite restorations. Quality assessment or risk of bias assessment of included studies was performed using the Cochrane Risk of Bias (RoB) 2 tool for randomized controlled trials (RCTs) through its domains using Review Manager (RevMan) software version 5.3 (The Cochrane Collaboration, London, UK).

Six studies fulfilled the eligibility criteria and were included in the qualitative synthesis. Quality assessment revealed a presence of moderate to low risk of bias. It was observed that sectional matrix band systems were superior and provided better results as compared to circumferential matrix band systems with regard to the parameters assessed.

This study found the sectional matrix band system to be more effective than the circumferential system in achieving optimal proximal contact in class II posterior composite restorations. Sectional matrices with separation rings produced significantly tighter contacts. Although operator satisfaction was similar for both systems, the sectional matrix was deemed easier to use. Overall, the sectional matrix system is preferred for achieving stronger, more consistent proximal contacts in clinical settings.

Categories: Dentistry
Keywords: circumferential matrix band system, class ii cavity, class ii composite restoration, composite filling, composite restoration, conservative dentistry and endodontics, dental cavities, matrix band system, proximal contact, sectional matrix band system

Introduction And Background

Since its existence, mankind has been affected by various diseases, including oral and dental conditions, with dental caries being the most prevalent. Dental caries are mainly categorized into pit and fissure caries and smooth surface caries. Among smooth surface caries, class II lesions are the most frequent, as the interdental space naturally fosters bacterial colonization and poses challenges in maintaining effective cleanliness [1].

Caries progression pattern in smooth surface caries impacts the wider area of proximal contact, leading to more damage in the proximal contact area [2]. When caries disrupts the natural tooth contacts, it can lead to several issues, including periodontal diseases, tooth shifting, food impaction, and compromised dental arch stability. Therefore, restoring proper proximal contact and contour is crucial for maintaining an optimal stomatognathic system and achieving a well-balanced functional occlusion [3].

Among all smooth surface carious lesions, class II cavities require adequate clinical skills and knowledge, and achieving ideal proximal contact is a known challenge in class II direct composite restorations. Various restorative techniques and matrix systems have been proposed to overcome these restoration challenges to produce natural contours and embrasures [4].

Establishing proximal contact areas relies heavily on matricing and tooth separation techniques. Various systems of matrix bands have been utilized to restore cavities with missing walls. For class II cavity restorations, the circumferential matrix band (CMB) system has traditionally been favored owing to its stability and user-friendly nature. In traditional circumferential matrix systems, such as with stainless steel

bands, the thickness ranges from 0.038 mm to 0.05 mm. This system is particularly recommended for cases involving missing adjacent teeth or misaligned dentitions. However, a circumferential matrix band system is not without its drawbacks. These include poor adaptation to neighboring teeth, challenges in recreating natural anatomical contours, and an increased likelihood of developing marginal overhangs [5,6]. Over time, the matrix band system evolved, and newer systems are designed to be less challenging to use and to compensate for the shortcomings and complexity of the earlier versions [7].

Although the sectional matrix band (SMB) system has drawbacks, such as technique sensitivity, concave contact formation, and placement distortion, it is a relatively recent innovation. It has been shown to create tight proximal contact points (PCPs), facilitate faster tooth separation, and enhance the anatomical emergence [8].

Currently, there is a lack of comprehensive research that combines qualitative and quantitative analyses to compare the efficacy of circumferential and sectional matrix systems in establishing the optimal proximal contact for class II composite restorations. Therefore, this systematic review aimed to assess and compare the performance of these matrix systems in restoring appropriate proximal contact in class II composite restorations.

Review

Materials and methods

This systematic review was performed in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. It was also documented in the PROSPERO database (Prospective Registration of Systematic Reviews) under the identification number CRD42024556368.

The study was structured using the PICO format, with the following criteria: population, teeth affected by proximal caries, intervention, circumferential matrix system, comparison, sectional matrix system, outcome, clinical effectiveness in achieving proximal contact, study design, randomized controlled trials (RCTs), clinical trials, and in vivo studies.

The inclusion criteria were studies that evaluated posterior teeth with proximal caries, comparative analyses of circumferential and sectional matrix systems, randomized controlled trials, clinical trials, in vivo publications from January 1990 to April 2024, and studies written in English. The exclusion criteria comprised studies centered on non-interproximal cavities and comparisons involving alternative matrix systems, as well as literature reviews and abstracts, letters to the editor, editorials, in vitro studies, case series, case reports, and animal studies.

Search Strategy

A thorough electronic search was performed from January 1990 to April 2024 using PubMed, Google Scholar, and cross-referencing. Additionally, a manual search was conducted in endodontic journals, including the International Endodontic Journal, Journal of Endodontics, Saudi Endodontic Journal, and Journal of Conservative Dentistry. The search was refined using keywords and Medical Subject Headings (MeSH) terms combined with Boolean operators (AND/OR): ("Matrix Band"[MeSH] OR "matrix system" OR "sectional matrix" OR "circumferential matrix") AND ("Composite Resins"[MeSH] OR "composite restoration" OR "resin restoration" OR "Class II restoration") AND ("Dental Contacts"[MeSH] OR "proximal contact" OR "contact point" OR "proximal contact tightness" OR "contact quality") AND ("Effectiveness" OR "clinical outcome" OR "contact accuracy" OR "restoration quality").

Screening Process

Search and screening were performed by two independent investigators following a two-phase selection process. In the first phase, titles and abstracts were reviewed, and studies that did not meet the inclusion criteria were excluded. In the second phase, full-text articles were independently assessed. Corresponding authors were contacted for additional information when necessary.

Study Selection

After duplicate removal and screening of reference lists, 116 studies were excluded. The remaining full-text articles were assessed for eligibility, and six studies that met the inclusion criteria were included in the qualitative synthesis (Figure *1*).

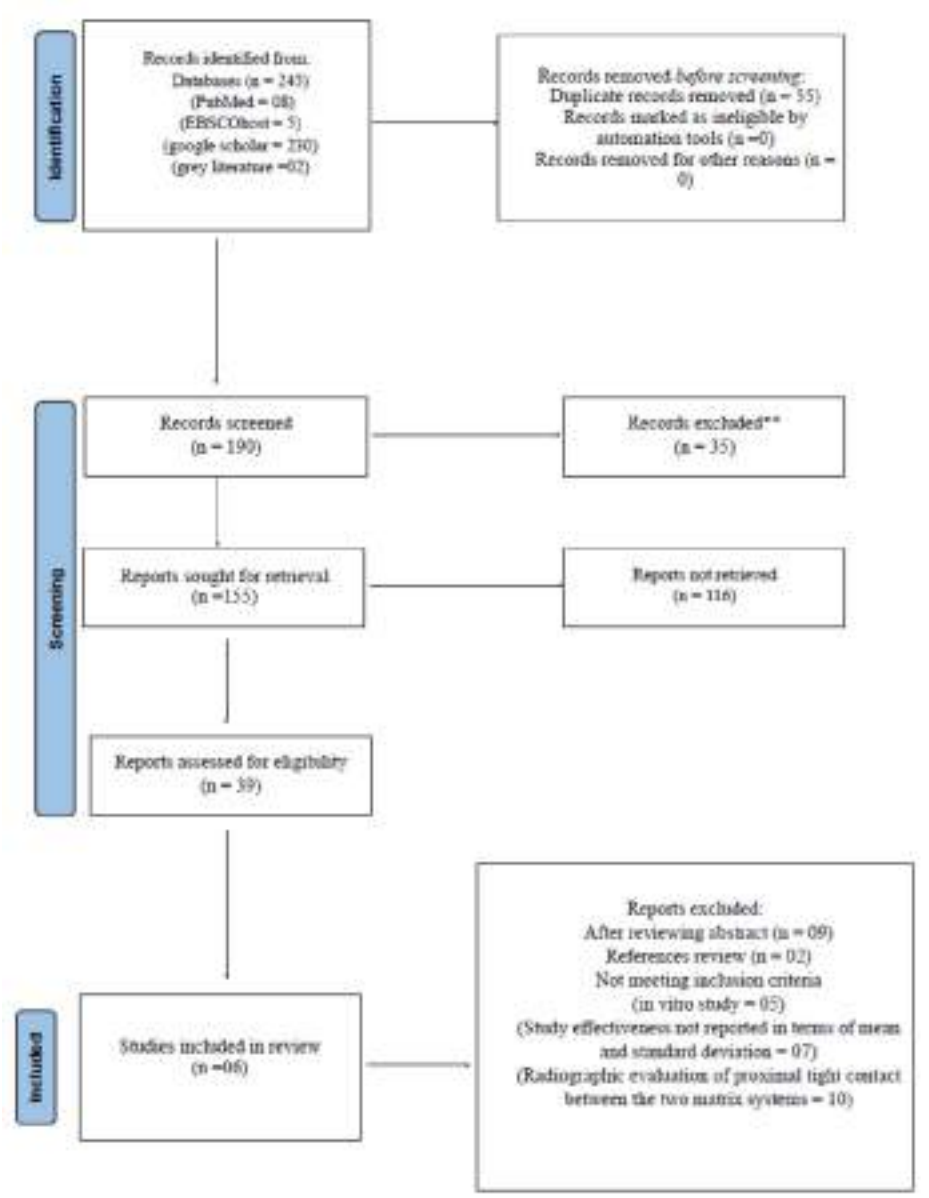

FIGURE 1: PRISMA flowchart

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Data Extraction

Two independent reviewers extracted descriptive details from all included studies using customized data extraction forms in Microsoft Excel. The forms contained headings for author(s), country of study, year of study, sample size, study design, outcome assessed, and conclusion.

Assessment of Study Quality

The Cochrane Risk of Bias (RoB) 2 tool was employed to evaluate the methodological quality of the included studies. This tool examines various domains, including random sequence generation, allocation concealment, blinding of personnel and equipment, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases. The assessment was conducted using Review Manager (RevMan) software version 5.3 (The Cochrane Collaboration, London, UK). Based on the domains and criteria, individual studies were classified as having low, moderate, or high overall risk. A study was deemed low risk only if all domains were assessed as low risk. High risk was assigned if one or more domains were found to be at high risk. Moderate risk was given to studies with one or more uncertain domains and no high-risk domains.

Data Analysis

For continuous outcomes, the standardized mean difference (SDM) with 95% confidence interval (CI) was computed. When heterogeneity was absent ($p > 0.05$ or I-squared ⩽ 24%), a fixed effects model (Mantel-Haenszel method) was employed; otherwise, a random effects model (DerSimonian-Laird method) was utilized. RevMan software version 5.3 (The Cochrane Collaboration, London, UK) was used for all statistical analyses. Statistical significance was determined at $p < 0.05$.

Evaluation of Methodological Quality in Included Studies

Figure *2* and Figure *3* illustrate the risk of bias in the included studies as assessed through the Cochrane Risk of Bias (RoB) 2 tool [9-13]. The methodological quality of all included studies was largely comparable. Each study exhibited a moderate to high risk of bias across all relevant domains. The highest risk of bias was observed in random sequence generation (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), and selective reporting (reporting bias). Among the studies, Durr-E-Sadaf et al. (2018) [10] and Shaalan et al. (2021) [11] demonstrated the highest risk of bias compared to others. Asif et al. [12] showed minimal risk of bias. Almushayti and Arjumand (2021) [13] showed the lowest risk of bias. The allocation concealment (selection bias) and other bias domains were assigned the lowest risk.

FIGURE 2: Risk of bias graph: review of authors' judgements on each risk of bias item presented as percentages across all included studies

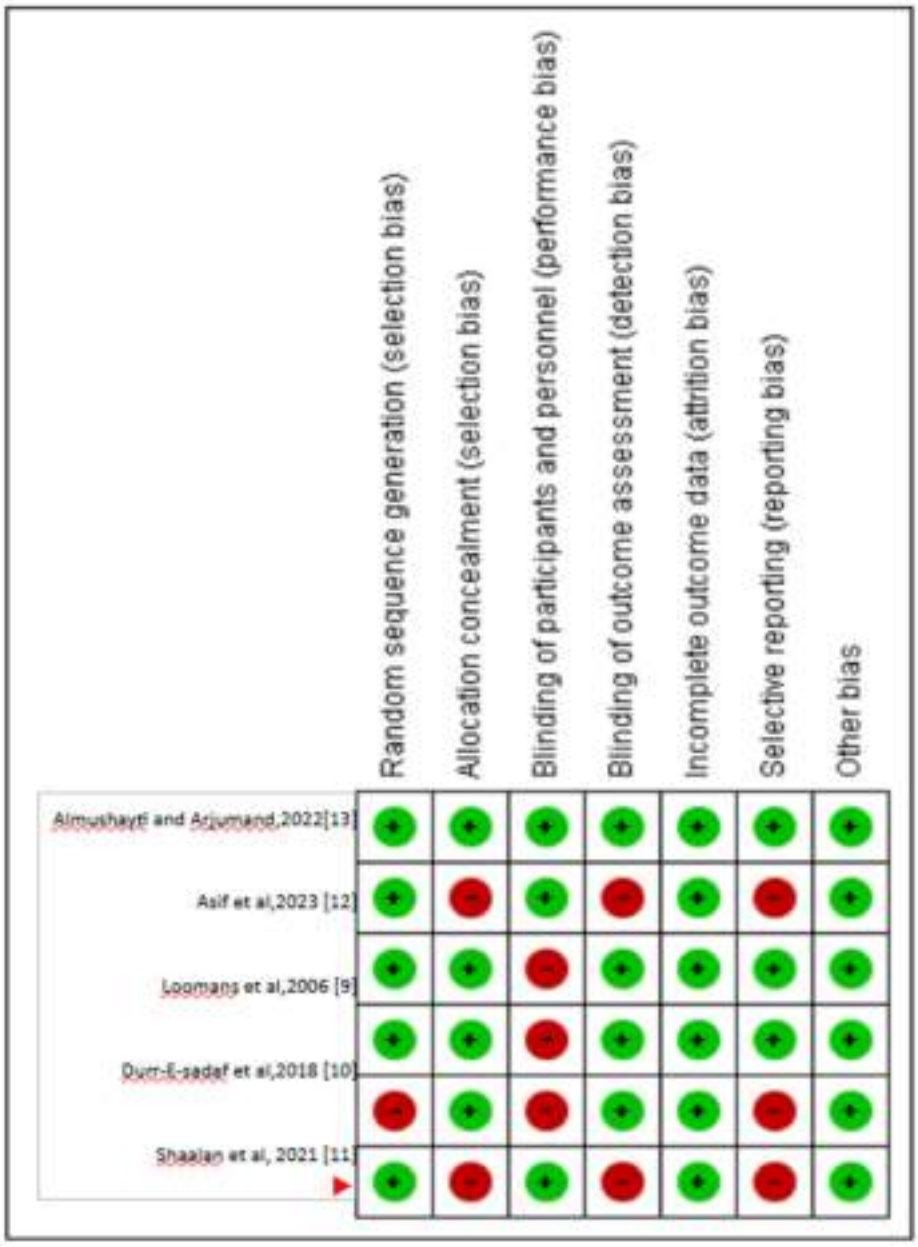

FIGURE 3: Risk of bias graph

Results

As presented in Table *1*, data from six studies of the 245 studies screened were analyzed, encompassing a total of 1,720 class II cavities requiring composite restorations, where the effectiveness of sectional and circumferential matrix band systems in achieving optimal proximal contact was assessed. All included studies followed a randomized clinical trial (RCT) design. Geographically, two studies were conducted in Pakistan, two in Saudi Arabia, and two in Egypt. Each study evaluated the ability of both matrix systems to achieve better proximal contact. The findings indicated that sectional matrix band systems were generally superior, providing better outcomes compared to circumferential matrix band systems in most studies.

Journal name	Author and publication year	Study design	Parameters assessed	Experimental group	Control group	Outcome evaluated	Summary
						To investigate the influence of cavity preparation	The use of the sectional matrix system

Journal of Dentistry	Wirsching et al. (2011) [5]	RCT	Effect of two matrix systems on the proximal contact tightness of direct posterior composite restorations	Circumferential matrix system	Sectional matrix system	(MO/DO/MOD) and type of matrix system on the proximal contact tightness of direct posterior composite restorations	in two-surface class II cavities resulted in statistically significantly tighter proximal contacts than the use of the circumferential matrix system.
Journal of Dentistry	Loomans et al. (2006) [9]	RCT	Clinical changes in proximal contact strength using a circumferential and sectional matrix system with separation rings	Circumferential matrix system	Sectional matrix system	Clinical changes in proximal contact strength after inserting class II composite resin restorations	Class II posterior composite resin restorations placed with a combination of sectional matrices and separation rings resulted in a stronger proximal contact than when a circumferential matrix system was used.
Indian Journal of Dental Research	Durr-E-Sadaf et al. (2018) [10]	RCT	Effect of matrix system on the proximal contact points and contours in posterior teeth with class II cavities	Circumferential matrix system	Sectional matrix system	To compare the effects of two matrix band systems, the circumferential matrix system and the sectional matrix system	The sectional matrix band system has been found to be superior to the circumferential matrix band system.
Journal of International Oral Health	Shaalan et al. (2021) [11]	RCT	Use of two different matrix systems for the reproduction of proximal contact	Circumferential matrix system	Sectional matrix system	To assess the influence of different matrixing techniques, either a sectional matrix or a circumferential matrix, on obtaining proper proximal contacts	Optimum contact points were highly associated with the sectional matrix system.
Journal of Ayub Medical College Abbottabad	Asif et al. (2023) [12]	RCT	Contact tightness	Circumferential matrix system	Sectional matrix system	To compare the contact tightness achieved with two matrix band systems	The sectional matrix band system was statistically superior to the circumferential matrix band system.
Cureus	Almushayti and Arjumand (2022) [13]	RCT	Operators' comfort and satisfaction were evaluated according to their assessment of the contact points they reproduced and the emergence profiles of restorations, using a circumferential matrix system and a sectional matrix system	Circumferential matrix system	Sectional matrix system	To investigate the operators' ease, satisfaction, and comfort in using a circumferential matrix system and a sectional matrix system on the proximal contact points	Circumferential and sectional matrix band systems showed no significant differences in operators' satisfaction, but it was easier to use the sectional matrix band system than the circumferential matrix band system.

TABLE 1: Descriptive characteristics of the included studies

RCT: randomized controlled trial

Discussion

Proximal contact is a dynamic physiological feature influenced by multiple factors, including tooth type, position, mastication, and restorative procedures. It plays a crucial role in preserving and stabilizing the dental arch. The absence of proximal contact can result in food impaction, periodontal diseases, proximal caries, tooth displacement, and, ultimately, loss of dental arch integrity [9,10].

There are several matrix systems available on the market that are specifically intended for posterior direct composite restorations. The two most frequent ones are the circumferential matrix band (CMB) and sectional matrix band (SMB) systems [11]. Circumferential matrix systems, such as the Tofflemire system, were first introduced in 1946 by Dr. Joseph Tofflemire [12]. Circumferential matrix systems are easy to use and minimize time, but they can replicate a single point of contact rather than an entire area [13]. To address these issues, traditional matrix systems were transformed into a novel sectional matrix system for the restoration of class II composite resin. To achieve proximal contact, a matrix band is used to restore the contact area. Its primary function is to replace the missing wall, contain excess restorative material, and simplify the process of restoring the proximal contact area [14,15].

Loomans et al. conducted a randomized controlled trial to examine the proximal contact of posterior composites utilizing CMB (with wooden wedge and hand instrument) and SMB (separation ring), with contralateral teeth serving as a control. A tooth pressure meter was used to conduct the evaluation. They discovered that class II posterior composite restorations applied with a mix of section matrices and separation rings provided better proximal contact than a circumferential matrix system. This result was attributable to the stronger separating effect of the ring when compared to the usage of hand instruments [9].

Wirsching et al. (2011) also conducted a randomized controlled trial to evaluate the tightness of proximal contacts in posterior composite restorations involving two and three surfaces. They utilized a tooth pressure meter device for their assessment. Their findings revealed that in two-surface class II cavities, the use of a separating ring led to tighter proximal contacts. However, when examining three-surface cavities, the study found no statistically significant difference between the two matrix systems employed. This is due to the fact that the two rings and matrices arranged simultaneously both medially and distally provide a separation effect in the opposite direction, which reduces their effect in the contact area [5]. Durr-E-Sadaf et al. (2018) [10] evaluated the effectiveness of CMB and SMB in repairing two-surface cavities in posterior teeth. The proximal contact point (PCP) was measured by passing a dental floss. They discovered that CMB had more overhanging proximal borders and defective contact points than SMB. Despite higher results with SMB, a considerable majority of students favored CMB due to its ease of use and the lack of training required for SMB [16].

Shaalan et al. (2021) [11] discovered that regardless of the operator's experience, optimum contact sites were more closely connected with SMB than CMB. They discovered that pre-contoured section matrices with an interdental separation ring caused a significant increase in total contact tightness, whereas the flat CMB produced a significant decrease in contact tightness. As a result, the thickness and shape of the matrix band may influence the contact tightness. Similarly, inadequate separation caused by wedge insertion could be the etiology of the open contact in CMB [17].

The aim of the study by Almushayti and Arjumand [13] was to analyze the ease with which operators could use matrix band devices to restore class II cavities. Of the students, 48.6% believed that CMB's difficulty stemmed from the need for extra time for placement. Additionally, 57.1% of students thought that the difficulty of SMB stemmed from a lack of training or expertise. The study's overall outcome was that the ease and convenience of using both systems do not differ statistically significantly [18].

Asif et al. (2023) conducted a randomized controlled trial to compare the contact tightness of CMB (Tofflemire) and SMB (Palodent) for class II composite repair. The evaluation was performed with dental floss and the FDI World Dental Federation clinical rating standards of contacts. They discovered that the SMB Palodent contact outperformed the Tofflemire matrix method solely in men. There was no statistically significant difference between the two systems in women. Male teeth are often larger than female teeth, which explains this. This implies that the contact point is generally larger and more difficult to construct [12].

A review of the existing information reveals a severe dearth of research comparing sectional and circumferential matrix band systems in terms of clinical outcomes. Although a comprehensive and unrestricted search was conducted based on the established eligibility criteria, only a limited number of studies qualified for qualitative analysis, with just six being included in this systematic review. To develop a more robust and evidence-based repository, it is strongly recommended that well-designed randomized controlled trials and clinical studies be undertaken.

Limitations

The study had a limited sample size, which may affect the generalizability of the results. Additionally, variability in operator experience and technique could have influenced the outcomes. The scarcity of

randomized controlled trials on this topic highlights the need for further high-quality research to confirm these findings. Future studies should incorporate larger sample sizes, diverse clinical settings, and long-term follow-ups to provide more comprehensive evidence on the effectiveness of sectional and circumferential matrix band systems in restorative dentistry.

Conclusions

The findings of this study indicate that the sectional matrix band system is superior to the circumferential matrix band system in achieving optimal proximal contact in class II posterior composite resin restorations. The use of sectional matrices combined with separation rings resulted in significantly tighter proximal contacts compared to the circumferential matrix system. Additionally, while no significant differences were observed in operator satisfaction between the two systems, the sectional matrix band system was considered easier to use. Given these advantages, the sectional matrix system appears to be the preferred choice for achieving stronger and more consistent proximal contacts in clinical practice.

However, an important limitation in the reviewed studies is the lack of consideration for operator competency and experience, which could have influenced clinical outcomes, especially given the technique-sensitive nature of matrix placement. Furthermore, this review focused solely on traditional circumferential matrices and did not account for recently introduced thin, pre-contoured anatomical circumferential matrix bands, which may offer improved adaptation and contact formation. Future studies should consider evaluating these modern anatomical circumferential matrices in comparison to both traditional circumferential and sectional systems to better understand their clinical effectiveness in achieving optimal proximal contacts.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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