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Comparison of the difference in the intensity of post-operative pain between Laser irrigation technique and Ultrasonic irrigation technique in Endodontic treatment: A systematic review and meta-analysis

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INTRODUCTION

One of the cornerstones of endodontic treatment is the thorough cleaning and disinfection of the root canal system.[1] Effective debridement and disinfection depend on the ability of the irrigant to penetrate sufficiently, especially in the untreated portions of the root canal.[2] Mechanical debridement is, therefore, not effective in the complete removal of bacteria and necrotic tissue and approximately 35 % of the canal surface area remains unaltered following instrumentation. Therefore, irrigants are essential in combination with irrigant activating devices to achieve more complete microbial reduction within the root canal system.[3]

Ultrasonic and Laser activated irrigation has been used in Endodontics to assist mechanical action of files during root canal treatment by lubrication, removing of debris and microbes and preventing apical extrusion of debris[4]. Activated irrigation techniques exert various effects like mechanical effects through delivery of streaming forces to the root canal walls, chemical effects through exertion of specific effects of active components on the organic and inorganic remains and biological effects through inactivation of the microorganisms inside the canal.[5]

Postoperative endodontic pain (PEP) refers to any discomfort after initiation of endodontic therapy due to stimulation of nociceptors around the tooth, with a reported incidence between 3- 58 %.3 PEP is multifactorial in nature[6] and is linked to a periapical inflammatory response which could be secondary to mechanical, chemical and/or microbial injury to the peri-radicular tissues.[7,8,9,10] Use of various irrigants and irrigant activation devices are associated with pain.
The choice of irrigant and irrigant activation devices can influence the incidence and intensity of postoperative pain and healing, it is of utmost importance that clinicians have accurate knowledge in regards to recently published literature.
Accurate knowledge regarding pain after root canal treatment and related factors will enable clinicians to predict and effectively manage postoperative pain, which is an important patient-centred endodontic outcome.

The aim of this systematic review was to evaluate and collate existing evidence relating to the effect of LAI and UAI during primary root canal treatment on postoperative pain reported by patients at various time intervals following Endodontic Intervention.

MATERIALS AND METHODS

Protocol And Registration
The research protocol is designed according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta Analysis) guidelines 2009. The protocol for this systematic review was registered with the International Prospective register of Systematic Review (PROSPERO CRD42024584843).

Focused Question
Is there any difference in the intensity of post-operative pain when Laser Activated irrigation technique is used (intervention) when compared to Ultrasonic Assisted irrigation technique (comparator) in Endodontic treatment?

PICOS Format
Population (P)- adult patients with the need of Endodontic Treatment;
Intervention (I)- Laser Activated Irrigation (including PIPS, SWEEPS, Diode Laser);
Comparison (C)- Ultrasonic Assisted Irrigation;
Outcome (O)-Reduction in Intensity Post Operative Pain;
Study design (S) – randomized controlled clinical trials.

Eligibility Criteria:
The Inclusion Criteria were as follows:
(1) Publications were in English, with full text available in either soft or hard copy.
(2) Study designs included were randomized controlled trial;
(3) Studies that selected a population comprising of permanent teeth with Necrotic pulp, Irreversible pulpitis, Symptomatic Apical Periodontitis, Asymptomatic Vital/ Non- Vital Pulp;
(4) Studies that performed both Laser Activated Irrigation and Ultrasonic Irrigation with or without additional comparators
(5) Studies that measured the intensity of pain using the VAS Pain rating Scale

The Exclusion Criteria were as follows:
(1) in vitro or ex vivo studies, clinical trials;
(2) reviews (narrative or systematic);
(3) case reports;
(4) conference abstracts;
(5) studies that did not involve two groups of Laser and Ultrasonic Irrigation;
(6) studies that included Teeth with crown or root fracture, periapical cyst, resorption defects, periodontal problems, Endodontic Periodontal lesions, calcifications, incomplete root development, aberrant anatomy, sinus opening, previous evidence of endodontic treatment,
(7) studies on primary dentition;
(8) experiments carried out on animal subjects;
(9) Studies that included pregnant/lactating females and medically compromised patients.

No minimum follow-up period threshold was established for this systematic review and meta analysis, since Post Operative pain, which is very likely to occur in the first hours or days after the restorative procedure, was one of the main outcomes of interest.

Study Design:
All studies known were screened for by reading the printed title and abstract. Choice of articles for inclusion into the systematic review was decided by applying the inclusion and exclusion criteria given above. Then full texts of those studies were obtained, and reference lists contained in these were also reviewed to identify any other relevant articles which may have been missed during the initial search.

Study Selection:
Titles identified from the search were screened by one reviewer with a subsequent independent checking of their abstracts/full-texts retrieved by the electronic search against the eligibility criteria by another reviewer. Substantial agreement between reviewers in the study selection process was obtained. After the same reviewers independently reviewed the full-text articles of the previous included studies, and studies which did not present any of the exclusion criteria were selected. Additionally, all references of the selected studies were manually screened for potentially relevant additional studies. Inter-reviewer reliability was assessed with Cohen kappa (0.80). Any possible discrepancies encountered during this process that is, inclusion or exclusion criteria, were resolved by discussion between the reviewers who selected the included studies. If a disagreement persisted, the judgment of a third reviewer was considered decisive.

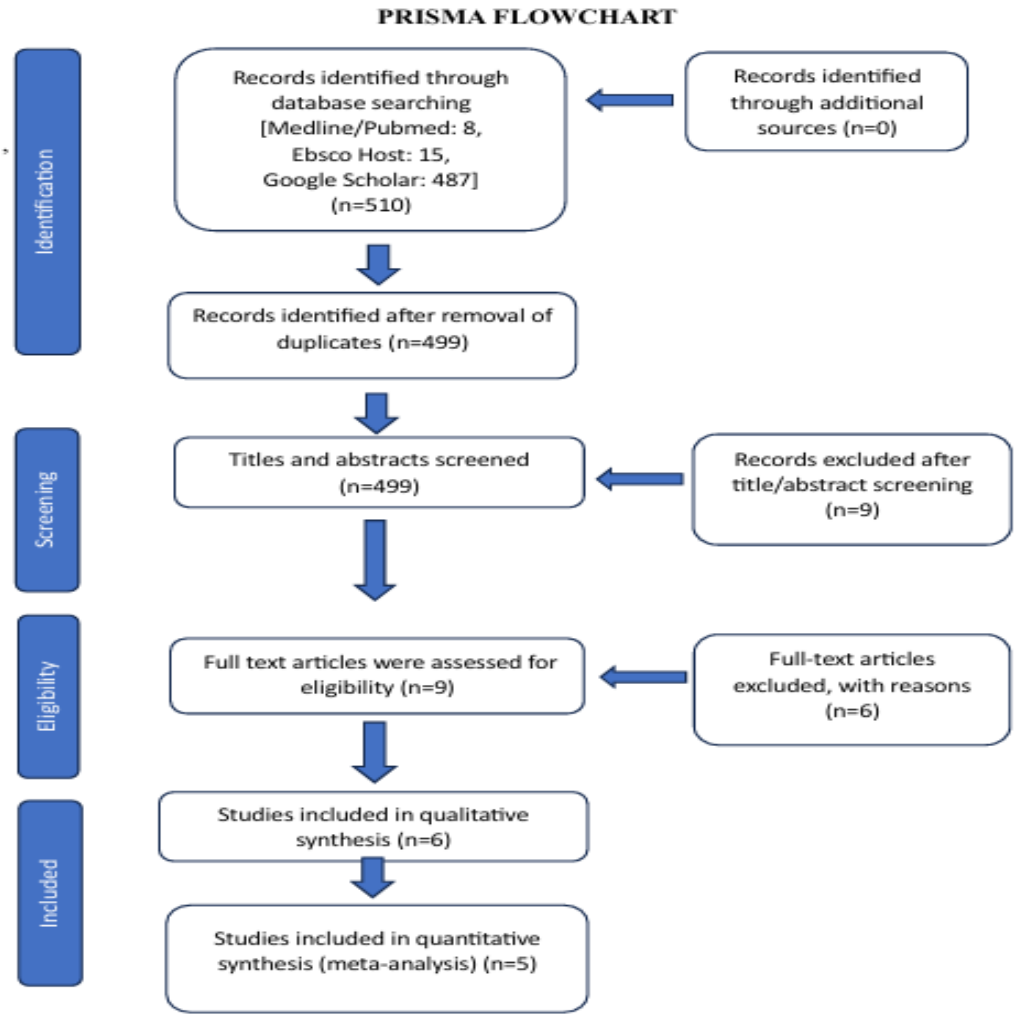
LITERATURE SEARCH

A comprehensive literature search was performed with no language restriction through several international and national databases. To identify relevant RCTs investigating the difference in the intensity of postoperative pain between Laser activated irrigation and ultrasonic irrigation in endodontic treatment, in PubMed [1990-2024], Ebsco Host [1990-2024], Cochrane [1990 2024] were explored. To identify potential previously published systematic reviews and relevant RCTs in the subject matter, as well as terms and synonyms associated to the key concepts of interest, preliminary searches of the aforementioned key sources were carried out (Postoperative pain, Laser Activated Irrigation, ultrasonic irrigation, Endodontic treatment). In order to maximize sensitivity, obtain an optimal search structure, and create and evaluate different information retrieval strategies, test searches were also used. Various combinations of previously identified free keywords, relevant controlled vocabulary terms (Medical Subject Headings — MeSH descriptors), Boolean, truncation, and proximity operators were used, depending on the database were searched.

Duplicate records were removed. Another search of the electronic databases for reports of outcome of medical procedure pretreatment was conjointly performed within the hope to not miss any potential reports that will be relevant to the present topic. Each prospective and retrospective clinical studies printed in English language were enclosed. The workflow followed the PRISMA checklist. All studies known were screened by reading the title and the abstract. Choice of articles for inclusion into the systematic review was done by applying the inclusion and exclusion criteria.

Then full texts of these studies were known, and reference lists contained in these were also reviewed to identify any other relevant articles which may have been missed during the initial search.
Search strategy applied to the current review.

DATABASE	SEARCH STRATEGY	N
PUBMED	(endodontic treatment OR root canal treatment) AND (pain OR postoperative pain OR discomfort OR analgesia) AND (laser activated irrigation OR laser assisted irrigation OR laser irrigation) AND (Ultrasonic Irrigation OR Ultrasonic activated irrigation OR Passive Ultrasonic irrigation) AND (randomized clinical trial OR Randomized control trial)	8
EBSCO HOST	(endodontic treatment OR root canal treatment) AND (pain OR postoperative pain OR discomfort OR analgesia) AND (laser activated irrigation OR laser assisted irrigation OR laser irrigation) AND (Ultrasonic Irrigation OR Ultrasonic activated irrigation OR Passive Ultrasonic irrigation) AND (randomized clinical trial OR Randomized control trial)	15
GOOGLE SCHOLAR	(endodontic treatment OR root canal treatment) AND (pain OR postoperative pain OR discomfort OR analgesia) AND (laser activated irrigation OR laser assisted irrigation OR laser irrigation) AND (Ultrasonic Irrigation OR Ultrasonic activated irrigation OR Passive Ultrasonic irrigation) AND (randomized clinical trial OR Randomized control trial)	487



Data Collection:
Characteristics of included trials and numerical data were extracted by two reviewers using predetermined and piloted extraction forms. Piloting of the forms was performed during the protocol stage until over 90% agreement was reached. Missing or unclear information was requested by the researchers.

Data Extraction And Data ITEMS:
Information on authors' names, year of publications, study design, preoperative pulpal and periapical diagnosis, type of teeth included, groups of intervention, follow-up period, material used for activating irrigants, materials used for root canal therapy, method of pain assessment, method for assessing long term success rates and the result was independently extracted by two reviewers. Data regarding the included studies was also independently extracted by the reviewers based on a previously defined protocol in a specific form in the Microsoft Office Excel 2007 software (Microsoft Corporation, Redmond, WA, USA)

SR. NO.	AUTHOR	JOURNAL	YEAR OF PUBLICATION	SAMPLE SIZE	AGE GROUP	INTERVENTION PROCEDURE
1.	D. Liapis et al.	IEJ	2021	56	18-71 19-78	Ultrasonic Activated Irrigation Laser Activated Irrigation (PIPS)
2.	Neelam Mittal et al.	J of Cons Dent	2023	60	18-44	Conventional Needle Irrigation Passive Ultrasonic Irrigation Laser Activated Irrigation (PIPS) Laser Activated irrigation (SWEEPS)
3.	Erhan Erkan et al	Odontology	2022	200	17-80	Laser Activated Irrigation (PIPS) Laser Activated Irrigation (SWEEPS) Passive Ultrasonic Irrigation Sonic Irrigation (EDDY) Manual Dynamic Irrigation
4.	Swarna Mathevanan et al.	J Clin Exp Dent	2023	75	18-65	Passive Ultrasonic Irrigation (Irrisafe) Laser Activated Irrigation (Er, Cr: YSGG) Conventional Needle Irrigation
5.	Mohammad Tamer Abbara et al.	Clin and Exp Dent Res	2023	60	25-44	Passive Ultrasonic Irrigation XP-Endo Finisher file activation Laser Activated Irrigation (Diode - 810 mm)
6.	Karishma Krishnakumar et al.	Endodontology	2023	63	18+	Continous Ultrasonic Irrigation Laser Activated Irrigation (Diode Laser) Laser Irradiation (Diode Laser)

SR. NO.	AUTHOR AND YEAR	TYPE OF STUDY	GENDER	TYPE OF TEETH	PULPAL STATUS	ASMPTOMATIC/ SYMPTOMATIC	PERIAPICAL LESION	STUDY GROUPS
1.	D. Liapis et al. (2021)	RCT	M=18, F=10 M=13, F=15	Non Molar- 26 Molar- 30	Vital/ Necrotic Pulp	Asymptomatic	-	Ultrasonic Activated Irrigation Laser Activated Irrigation (PIPS Tips)
2.	N Mittal et al. (2023)	RCT	M= 28 F=32	Molars	-	Symptomatic	-	Conventional Needle Irrigation Passive Ultrasonic Irrigation Laser Activated Irrigation (PIPS) Laser Activated Irrigation (SWEEPS)
3.	Erhan Erkan et al. (2022)	RCT	M= 24, F=16 M= 22, F= 18 M= 22, F= 18 M= 22, F= 18 M= 24, F=16	Single Rooted Manibular Premolars	Irreversible Pulpitis	Symptomatic	-	Laser Activated Irrigation (PIPS) Laser Activated Irrigation (SWEEPS) Passive Ultrasonic Irrigation Sonic Irrigation (EDDY) Manual Dynamic Irrigation
4.	Swarna Mathevanan et al. (2023)	RCT	m=13, F=12 M=14, F=11 M=11, F=14	Mandibular First Molars	Irreversible Pulpitis	Symptomatic	Absent	Passive Ultrasonic Irrigation (Irrisafe) Laser Activated Irrigation (Er, Cr: YSGG) Conventional Needle Irrigation

			M=32, F=28					
5.	Mohammad Tamer Abbara et al. (2023)	RCT	M=32, F=28	Maxillary Incisors	Apical Periodontitis	Asymptomatic	Large-sized periapical lesions, >5 mm	Passive Ultrasonic Irrigation XP-Endo Finisher file activation Laser Activated Irrigation (Diode - 810 mm)
6.	Karishma Krishnakumar et al. (2023)	RCT		Maxillary central incisors (25) Maxillary lateral incisors (19) Maxillary canines (4) Mandibular canines (7) Mandibular central incisors (4) Mandibular first premolars (4)	Necrotic Teeth	Symptomatic	Periapical RL<= 2mm	Continous Ultrasonic Irrigation Laser Activated Irrigation (Diode) Laser Irradiation (Diode)

SR. NO.	AUTHOR AND YEAR	PAIN RATING SCALE	ANALGESIC CONSUMPTION	LOCAL ANESTHESIA	RUBBER DAM ISOLATION	ROTARY FILE SYSTEM	*IRRIGATION*	IRRIGANT ACTIVATION PROTOCOL
1.	D. Liapis et al. (2021)	VAS	YES	4% articaine with 1:100,000 epinephrine	YES	ProTaper Next, Dentsply Sirona	*2 ml of 3% NaOCl* *2 ml of 17% EDTA*	2mL of 3% NaOCl for 2 cycles of 30 sec
2.	N Mittal et al. (2023)	VAS	YES	2.5 ml of 2% Lignocaine with 1:80,000 Adrenaline	YES	Hyflex EDM (Coltene)	*10% EDTA* *15% Carbamide Peroxide* *2 ml Saline with 2% Povidone Iodine* *NaOCl, EDTA* *2% Chlorhexidine*	1 mL of 3% NaoCL activated in 3 cycles of 20 secs 2mL of 17% EDTA activated for 1 min
3.	Erhan Erkan et al. (2022)	VAS	YES	4% Articaine with 1:200,000 Epinephrine	YES	ProTaper Next; Dentsply-Sirona	*15 ml of 15% NaOCl* *3 ml of 3% NaOCl* *2 ml 17% EDTA* *Saline*	1 mL 3% NaOCl activated in three cycles of 20 s 2 mL of 17% EDTA activated for 1 min
4.	Swarna Mathevanan et al. (2023)	VAS	YES	1.8 ml 2% Lidocaine with 1:200,000 Epinephrine	YES	ProTaper Gold, Dentsply Maillefer	*2 ml 3% NaOCl* *2 ml Saline Intermittently* *3 ml 17% EDTA*	3 mL of 3% NaoCl for 30 sec (2 cycles)
5.	Mohammad Tamer Abbara et al. (2023)	VAS	YES	Lidocaine HCl	YES	Plex V ORODEKA rotary files	*2 ml of 5.25% NaOCl* *normal saline* *2 ml of 17% EDTA*	2 mL of 5.25% NaOCl for 45 secs 2mL of 17% EDTA for 15 secs
6.	Karishma Krishnakumar et al. (2023)	VAS	YES		YES		*3% NaOCl*	3% NaOCl

SR. NO.	AUTHOR AND YEAR	SEALER	OBTURATION	SINGLE/ MULTIPLE VISIT	FOLLOW UP	RESULTS
1.	D. Liapis et al. (2021)	Epoxy resin based (AH Plus) Sealer	Continuous wave compaction technique	Single Visit	6, 24, 48 72 Hours	UAI > LAI (6 hrs) Rest Not statistically significant
2.	N Mittal et al. (2023)	Zinc Oxide Eugenol based Sealer	Single Cone Obturation	Single Visit	24, 48 hours	SWEEPS < PIPS< PUI< CNI
3.	Erhan Erkan et al. (2022)	Epoxy resin based (AH Plus) Sealer	Cold Lateral Compaction	Single Visit	8, 24, 48 Hours, 7 days	PIPS=SWEEPS< PUI, Sonic< MDI
4.	Swarna Mathevanan et al. (2023)	Epoxy resin based (AH Plus) Sealer	Cold Lateral Compaction	Single Visit	6, 24, 48 hours	CNI> LAI> PUI
5.	Mohammad Tamer Abbara et al. (2023)	Epoxy resin based (AH Plus) Sealer	Warm vertical compaction technique	Single Visit	1, 3, 7, 14 days	XP Endo > PUI> Diode Laser
6.	Karishma Krishnakumar et al. (2023)	-	-	Multiple Visit	1, 2, 7 Days	No Statistical Difference

RESULTS

Assessment of methodological Quality of included studies The risk of bias assessment was conducted using the Cochrane RoB 2 revised tool, which evaluates bias in randomized trials. The included studies were generally comparable in methodological quality but exhibited low to high risk of bias across various domains. The highest risk was associated with the randomization process and bias in the measurement of the outcome. One study, Krishnakumar K et al, showed high risk of bias as there was bias due to deviations from the intended interventions. Only one study had loss to follow-up after the delivery of interventions. However, all studies reported outcomes as outlined in their analysis plans, leading to a low risk of bias in that aspect. Two studies indicated some concerns in overall risk of bias, but only one of them was reported to have high risk of bias. The findings are illustrated in Figures 1 and 2.

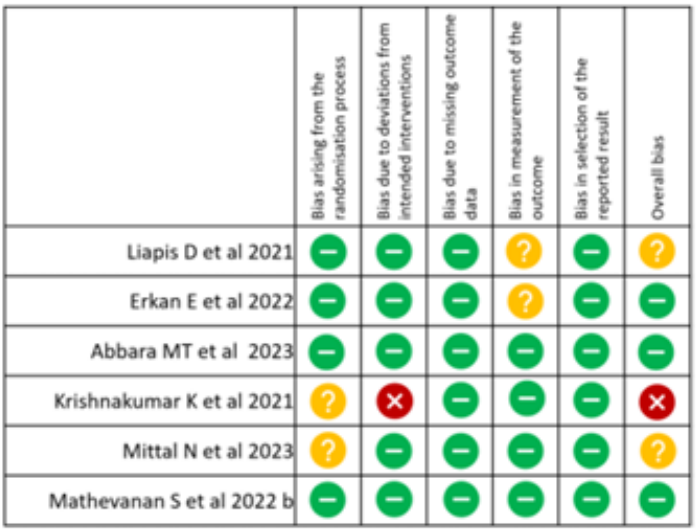


Figure 1: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

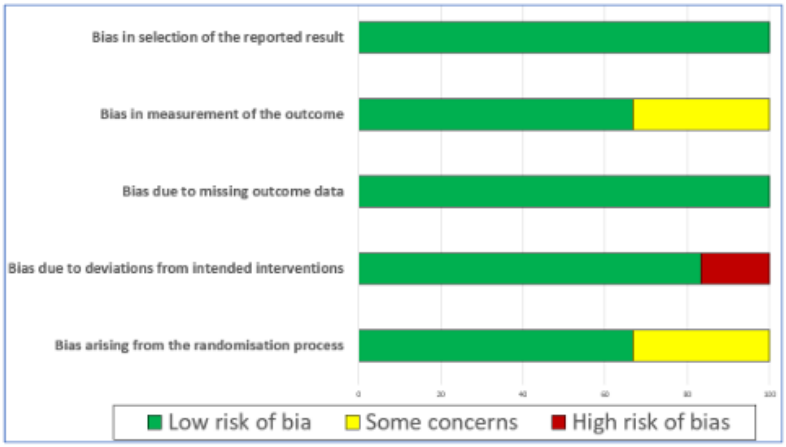


Figure 2: Risk of bias summary: review authors' judgments about each risk of bias item for each included study.

Statistical analysis Data collection:
Characteristics of included trials and numerical data were extracted by two reviewers using predetermined and piloted extraction forms. Piloting of the forms was performed during the protocol stage until over 90% agreement was reached. Missing or unclear information was requested by the researchers.

Data extraction and data items:
Information on authors' names, year of publications, study design, type of teeth included, groups of intervention, follow-up period, method of pain assessment, type of sealer used, method for assessing long-term success rates and the result was independently extracted by two reviewers. Data regarding the included studies was also independently

extracted by the reviewers based on a previously defined protocol in a specific form in the Microsoft Office Excel 2007 software (Microsoft Corporation, Redmond, WA, USA).

Statistical analysis:

STATA version 17 was used for statistical analysis. The primary outcome was measured as standardised mean difference (SMD) for the mean pain level. However, dichotomous data related to the presence of pain were expressed as odds risks (ORs) at 95% confidence intervals (CIs). Heterogeneity was assessed by the Q test, for $p < 0.1$, as well as by the I2 test. An I2 statistic below 30% was considered as not important, between 30% and 60% was considered as moderate heterogeneity, between 50% and 90% as substantial heterogeneity, and over 75% was considered as considerable heterogeneity. Random-effect models were adopted for all meta-analyses, due to the methodological heterogeneity of the studies. A p-value of less than 5% was considered significant.

Results:

A. Laser Activated Irrigation versus Ultrasonic Activated Irrigation

A total of 6 studies were identified that compared Laser Activated Irrigation (LAI) and Ultrasonic Activated Irrigation (UAI) technique for pain assessment at different time points during the post-operative period. These studies contained data on approximately 328 samples, of which of which half samples were treated by UAI and other half were treated by LAI (PIPS, SWEEPS, Diode laser). Most studies reported pain assessment using mean scores and standard deviations on various pain scales, as well as the number of participants reporting pain at each time point. In some studies, multiple LAI techniques were evaluated, and all comparisons were included in the analysis.

Meta-analysis for the presence of pain during the post-op period:

The meta-analysis was conducted for post-operative time intervals of 6 hours, 24 hours, and 48 hours, comparing the intervention (LAI) with the control (UAI) groups. Absence of pain at the time of assessment was defined as success (No pain group), while patient reported pain was considered a treatment failure (pain present group). There was no significant difference in the risk of pain occurrence at 6 hours (RR: 1.84; 95% CI = 1.04–3.25; p = 0.24; I2 = 36.2%), at 24 hours (RR: 1.05; 95% CI = 0.80–1.39; p = 0.19; I2 = 0.0%) and two days (RR: 2.45; 95% CI = 0.57–10.58; p = 0.03; I2 = 96.7%). RR more than one represents results favouring the Laser Activated Irrigation i.e. more effective in pain reduction among patients undergoing the treatment. Among all the included studies, Liapis D et al 2021 had highest weightage at the overall pooled estimate while the lowest weightage was observed for Erkan et al 2023 at the pooled estimate.

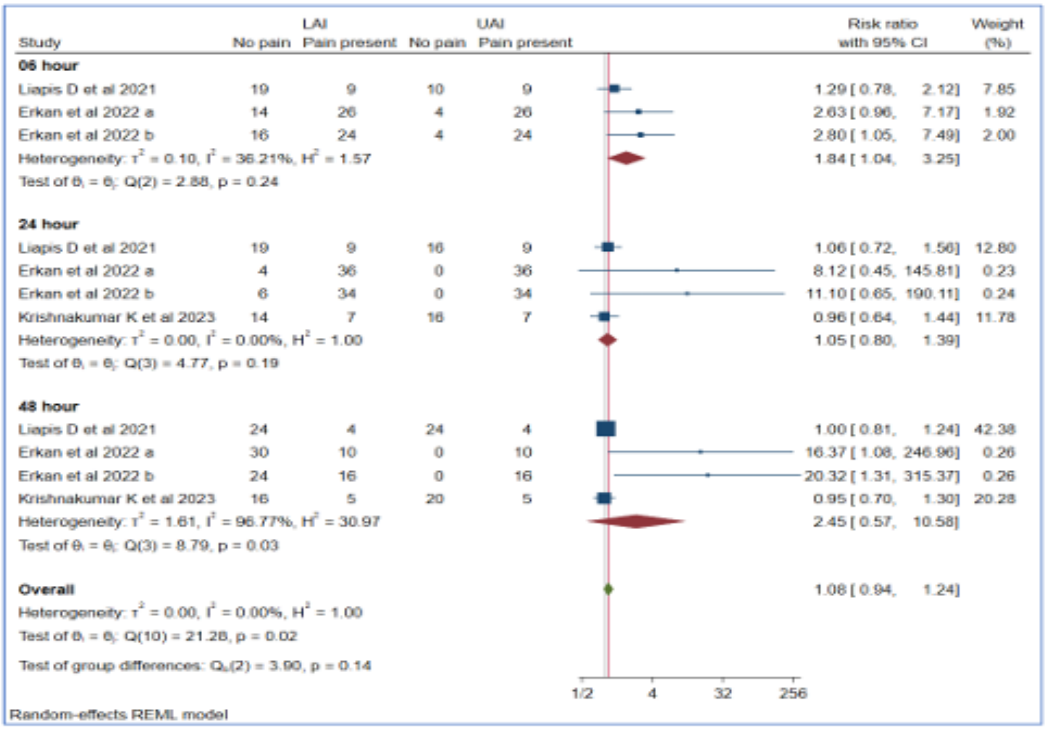


Figure 3: Forest plot showing comparisons of risk of occurrence of pain between LAI and UAI after 6, 24 and 48 hours post-operation

Meta-analysis for the intensity of pain during the post-op period:
Only four studies presenting data as mean and standard deviation were included in the meta- analysis of continuous data, leading to the exclusion of a few studies from the initial meta- analysis. Meta-analysis for postoperative pain intensity (mean ± standard deviation) was performed at 6 hours, 24 hours, 48 hours and 7 days. Additionally, studies presenting zero values were not considered due to potential computational issues. Since this outcome was provided as continuous variables and the scales used for pain assessment varied across the studies, the effect measure was the standardised mean difference (SMD). SMD less than zero represents results favouring the LAI i.e. more effective in pain reduction among patients undergoing the treatment. Significant differences were verified for the overall effect [P = <0.05; SMD = -0.69; 95% CI: -1.17 to -0.21; I2 = 87.41%]. Subgroup analysis showed significant difference only at 24 hours but not in all times evaluated, as illustrated in Figure 4.

Among all the included studies, Mittal N et al 2023 had highest weightage at the overall pooled estimate while the lowest weightage was observed for Mathevanan S et al 2023 at the pooled estimate.

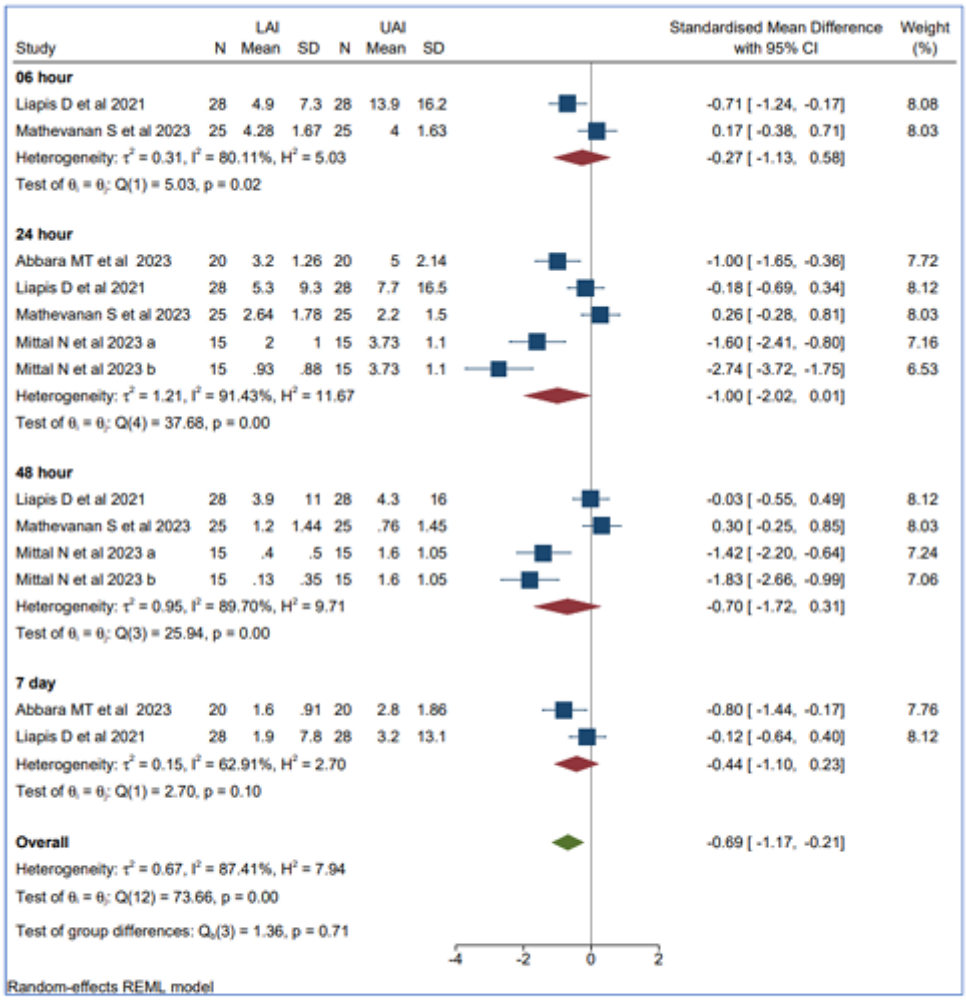


Figure 4: Forest plot of the postoperative pain intensity between LAI and UAI at 6 hours, 24 hours, 48 hours and 7 days.

Assessment of publication bias
Publication bias was not assessed for this comparison as only 6 studies were identified providing comparison of the two groups.

B. PIPS versus UAI
Only two studies, Liapis D et al and Erkan et al, were identified that compared PIPS and UAI for pain assessment at three time points: 06 hours, 24 hours, and 48 hours post- treatment.

The meta-analysis was conducted for post-operative time intervals of 06 hours, 24 hours, and 48 hours, comparing the intervention (PIPS) with the control (UAI) groups. Absence of pain at the time of assessment was defined as success (No pain group), while patient-reported pain was considered a treatment failure (Pain group). There was significant

difference in the risk of pain occurrence at 6 hours and 48 hours, but it can be attributed to the heterogeneity among the studies and small sample size. Overall also results are statistically significant (RR: 1.99; 95% CI = 0.99–3.99; p = <0.05; I2 = 8.53%) but clinical significance may not be observed in practice. (Figure 5)

Meta-analysis was also performed for the intensity of pain during the post-operative pain between PIPS and UAI group. Though statistically significant, clinical significance cannot be established. (Figure 6)

Publication bias was not assessed for this comparison as only two studies were identified providing comparison of the two groups.

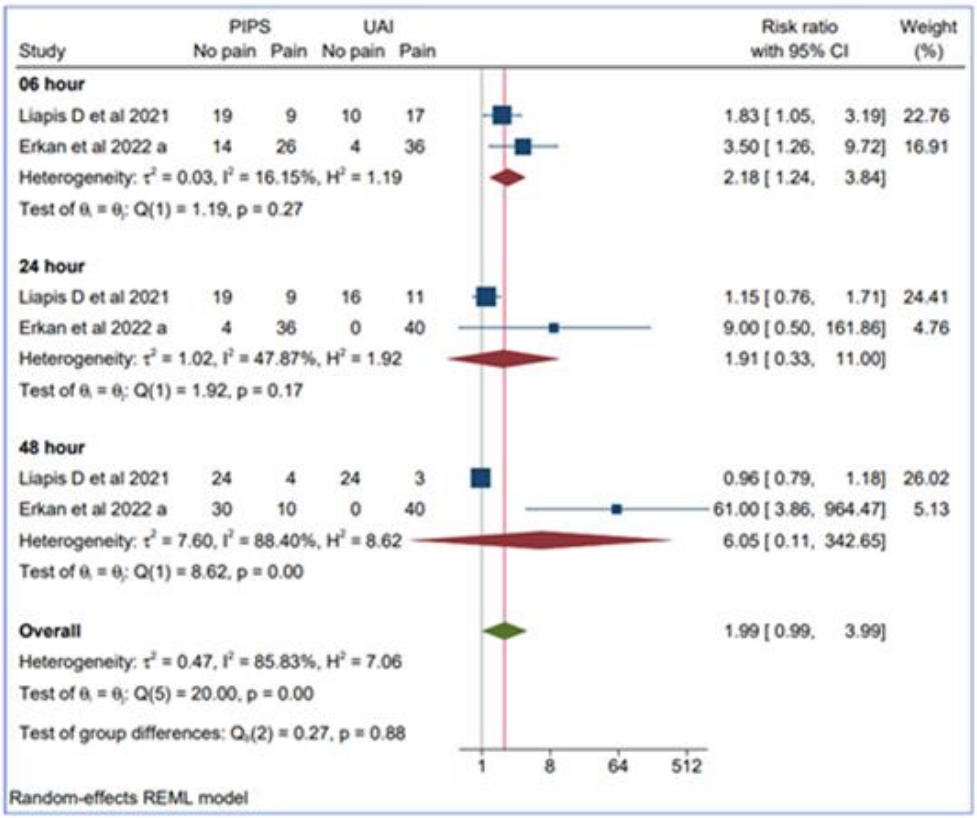


Figure 5: Forest plot showing comparisons of risk of occurrence of pain between LAI and UAI after 6, 24 and 48 hours post-operation

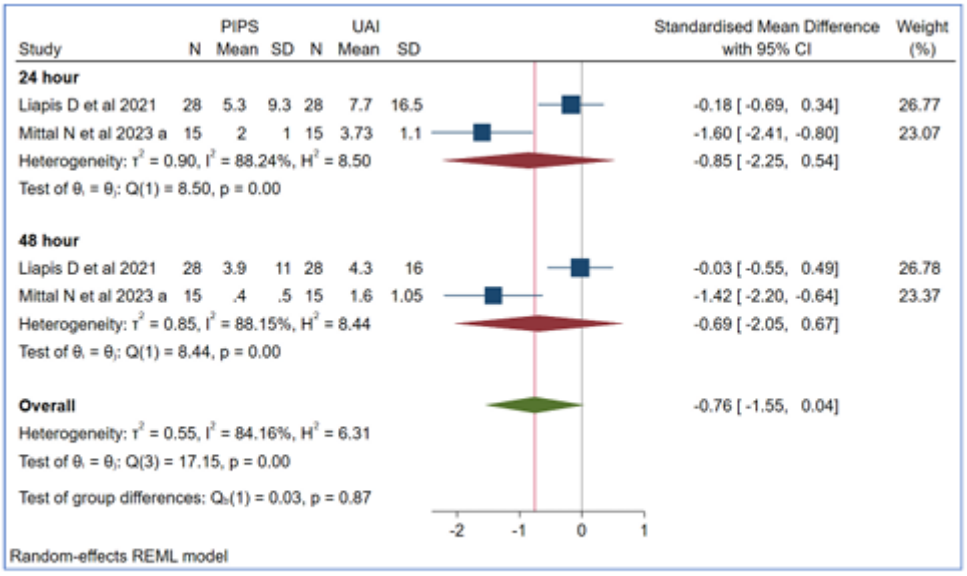


Figure 6: Forest plot of the postoperative pain intensity between PIPS and UAI at 6 hours, 24 hours and 48 hours.

DISCUSSION

Post endodontic pain is multifactorial and can be attributed to mechanical, chemical and microbial causes, of which microbes are conceivably the prime aetiologic agents. Thus, complete eradication of microbial population from the root canal system or at least its significant reduction is essential for successful management of endodontically involved teeth.[11] Post-endodontic pain (PP) can occur within a few hours or a few days after endodontic treatment.[12] Thus, pain control both during and after root canal treatment, poses a huge challenge to the clinician and hence is an integral part of endodontic management.

Instrumentation of the root canal system must always be supported by effective irrigation. Irrigation is regarded as one of the most important aspects of root canal procedure. Activation of the endodontic irrigant appears to be a necessary step in the more complete cleaning of the root canal system. Activation of irrigants via ultrasonic and laser devices has shown great improvement in the cleaning and disinfection of the root canal system and should be considered an important fundamental step in non- surgical endodontic therapy.[13]

Number of studies have been performed to evaluate the effectiveness of different irrigation techniques in reducing the postoperative pain, however, a systematic analysis of the quality of these randomized controlled trials needs to be evaluated using well defined criteria like those used in the risk of bias assessment. Thus, a systematic review is a viable way of analysing the effectiveness of various methods of irrigation activation techniques in reducing postoperative pain.

Variables such as age, gender, psychological factors contribute to the perception of pain by the patients. In the current study, in which age and gender were also evaluated, it was seen that the differences in these demographic characteristics between the groups did not have a significant effect. All studies showed that there were no significant differences between sex, age distribution, and baseline pain scores between the two groups owing to adequate sample size.
The majority of the studies reported the presence of symptomatic teeth[14,15,16,18]. The selected studies included both single and multirooted teeth, of which two studies focused on molars (Mittal et al.[14], Mathevanan et al[16]).
Postoperative pain was assessed at various time intervals (6, 8, 24, 48, 72 hours and 7, 14 days); however, the most frequently implemented observation periods from the selected studies were 24, 48 hours (Liapis et al.[19], Mittal et al.[14], Erkan et al.[15], Mathevanan et al.[16]).

Laser-assisted agitation techniques included PIPS, SWEEPS, Diode laser and Er, Cr: YSGG Laser techniques. Endodontic treatment is indicated whenever the pulp is irreversibly pathologically involved or the sequalae of the pulpal diseases have involved the periapical area. Teeth with necrotic pulps and chronic apical periodontitis were included as previous reports have suggested that pre-operative pulpal and periapical status have a significant bearing on pain experienced following treatment. However, non-vital teeth may also have cementum resorption or periapical resorption where the apical constriction is lost and various studies have shown the extrusion of debris and violation of the working length in such cases[19]. Also, cases with pre-existing periapical pathology have a higher possibility of exacerbation of pre-existing periapical inflammation which is clinically presented as increased pain after cleaning and shaping procedures.

The present systematic review aimed to compare the effect of Ultrasonic (Passive Ultrasonic Irrigation and Laser Activated irrigation with needles on postoperative pain. The component studies were Randomized Control trials and included ultrasonic and Laser (Diode Laser, Er, Cr: YSGG Laser, Er: YAG Laser, PIPS AND SWEEPS) activation techniques.

Another factor determining the inclusion criteria was the method of post-operative pain measurement. The studies evaluated postoperative pain using Visual Analog Scale at regular intervals post treatment. This helped in close monitoring of the patients and helped in determining the effectiveness of the treatment modalities. Thus, the relevance of the case selection thus plays an important role in determining the incidence of postoperative pain based on whether cases with pathology restricted to only pulp were included in the study or cases with preexisting periapical pathology were included in the study. Out of the six articles reviewed for this systematic review, four articles (Erkan et al.[15], Mathevanan et al.[16], Krishnakumar et al.[18], Mittal at al.[14]) have included symptomatic teeth and other two articles have included asymptomatic teeth (Liapis et al.[19], Abbara et al.[17]) in the randomised clinical trial. In the two studies that assessed asymptomatic teeth, greater reduction of post operative pain was observed, thus presence of preoperative symptoms is considered an important confounding factor among the studies. So, selection criteria should be well defined and specific with respect to the preoperative pulpal and periapical status as they may influence the occurrence and intensity of postoperative pain.

Mandibular molars were selected in the randomized control trial by Mittal et al.[14] as these teeth have been reported to have the highest incidence of post-operative pain due to dense bone[20]. Mandibular posterior teeth also have a complex anatomy, with a number of lateral canals and apical ramifications[15] making the canals difficult to clean and challenging

to treat endodontically. The cross-sectional shape of the roots of molars may be oval or long oval or ribbon shaped which is challenging to treat, clean and disinfect as compared to the wider canals of the anterior teeth. Thus, inclusion of single rooted anterior teeth and multirooted posterior teeth need to be evaluated separately as such a diverse sample population owing to such vast confounding factors may lead to variable results causing misinterpretation of the data.
In the randomized clinical trial by Erkan et al.[15], Abbara et al.[17] and Krishnakumar et al.[18]only teeth with single canal were incorporated to reduce the confounding effect of complex root canal anatomy, to minimize the risk of iatrogenic errors because of missed or complicated root canal anatomy and to make sure the same amount of irrigation solution would pass by each canal. Larger/ wider canal diameters in single rooted teeth facilitate the easy removal of debris through the canal orifice during irrigation, thereby reducing the debris extrusion into the periapical area. Multi-rooted teeth were significantly more susceptible for postoperative pain due to complex anatomy.[14,16]

Erkan et al.[16] reported that the amount of debris and solution extruding from the apex and postoperative pain formation were minimal in laser-assisted irrigation activation. Irrigation of root canals using a laser source has also been found to be very effective in the elimination and disinfection of Enterococcus faecalis in infected root canals. In a study examining changes in the pressure of liquids in the canal caused by laser activation, Peters and De Moor showed that the intra-canal pressure occurred was too low to exceed the central venous blood pressure of 5.88 mmHg. According to Jezeršek et al., the pressure generated does not exceed 0.89 mmHg. In this systematic review, the lower pain prevalence, and scores of the groups in which laser activation methods (SWEEPS and PIPS) were used considered to be due to the low amount of liquid extruding from the apical region because of the low liquid pressure created by the laser tip placed in the access cavity.

Post-operative pain after single visit endodontics has been shown to be less than multi visit endodontic treatment according to the studies done by Krishnakumar et al.69 Krishnakumar et al.[18] had performed multi visit endodontic treatment as it offers numerous advantages like complete eradication of microorganisms; using calcium hydroxide, it could reevaluate the tissue responses, and its disadvantages include, prolonged number of visits, interappointment flare ups, and patient fatigue. Hence, in the rest of the included studies (Erkan et al.[15], Liapis et al.[19], Abbara et al.[17], Mathevanan et al.[16], Mittal et al.[14]), all teeth were instrumented and obturated in one session to eliminate intracanal medication as another possible factor for postoperative pain. However, the importance of multi visit endodontic treatment in case of necrotic, non-vital teeth with periapical pathology or retreatment cannot be completely overviewed. Single visit endodontic treatment can be performed in all the conditions where the disease is restricted to pulpal space or when the periapical lesion is asymptomatic.[14-17,19] The advantages of single visit include, lesser number of appointments, less stress for an anxious patient and no risk of inter-appointment leakage, ease of orientation to internal anatomy for the operator. Hence, this is an important factor which contributes to post- operative pain.

Premedication has been known to suppress or reduce post endodontic pain. Administration of NSAIDs before endodontic therapy can suppress post endodontic pain, before it begins. This can be explained by the action of NSAID to block COX pathway inhibiting prostaglandin synthesis by decreasing the activity of cyclo-oxygenase enzyme and pain sensation is blocked before it begins[21]. Thus, only patients without a contributing medical history who did not take analgesic medication recently were included in all six studies, so that no other pain source or drug interaction could interfere with pain resulting from therapy. All studies included in the systematic review included patients without a non-contributing history who did not take analgesic medication recently so that no other pain source or drug interaction could interfere with the pain resulting from endodontic therapy.

Erkan et al.[15], Liapis et al.[19], Abbara et al.[17], Mathevanan at al.[16], and Mittal et al.[14] prescribed analgesics in the event of significant unbearable pain. Erkan et al.[15] and Liapis et al[19] mentioned that there was no difference between the groups in terms of analgesic use. Thus, the VAS score results may not be true representation of pain control as effect of analgesics was not excluded.

All the studies included in this systematic review considered endodontic treatment as primary endodontic treatment and any cases of retreatment or incomplete root canal treatment were excluded from the study. This was done to avoid the confounding effect of multiple factors of retreatment on the final outcome. Multiple factors of retreatment like the time taken to remove all the gutta percha material, the extent of removal of sealer, additional enlargement and disinfection that is required in retreatment cases and the type of microbiota present in failed root canal can all affect the final outcome of the treatment. All the studies included in the present systematic review performed primary endodontic treatment procedure.

VAS score was considered as the main outcome for pain parameter. VAS was chosen for determination of pain as it is a simple, sensitive and easily administrable method of pain assessment with well-established reliability. Comparisons of VAS score was done after 8 hours, 24 hours,48 hours and 7 days using mean difference (MD) for VAS score between Ultrasonic Irrigation and Laser activated Irrigation. VAS score was less in laser activated irrigation group as compared to Ultrasonic Irrigation group. This difference in VAS score among two groups was statistically significant in all the four-time intervals, thus statistically proving the effectiveness of irrigation in reducing pain as compared to conventional needle irrigation.

Post-operative pain was measured over a period of one week at regular intervals 6-8hrs and the results of all the six studies showed that as able to achieve better pain relief as compared to routine non-surgical endodontic therapy.
At the end of this systematic review, we can conclude that mature teeth with symptomatic irreversible pulpitis can be successfully treated with partial or complete pulpotomy. With the use of correct diagnostic methods, meticulously followed treatment protocol and the application of newer biomaterials it is possible to preserve the vitality of the tooth and maintain its natural state with the additional benefit of reducing treatment time, post-operative pain and overall armamentarium. Thus, partial or complete pulpotomy is a highly effective alternative to routine non-surgical endodontics and can help bring about a paradigm shift in the speciality in the coming future.

CONCLUSION

Within the limitations of the present study, it can be concluded that laser activated irrigation reduces postoperative pain compared to ultrasonic irrigation. The subgroup meta-analysis showed that laser activated irrigation was more effective than ultrasonic irrigation in reducing postoperative pain. This systematic review of six articles and subsequent meta - analysis confirmed that laser activated irrigation reduces postoperative pain compared with ultrasonic irrigation as depicted in the forest plot. Thus, laser activated irrigation techniques should be considered an important fundamental step for management of postoperative pain following root canal treatment in non-surgical endodontic therapy.

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Conflicts of Interest
There are no conflicts of interest.

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