



REVIEW ARTICLE

Patient-Centered Outcomes in Endodontics: Does the Irrigation System Impact Postoperative Pain?

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ABSTRACT

The importance of patient-centered outcomes in endodontics has been on the rise, and postoperative pain is considered to be among the most appropriate tools of measuring treatment success. The systems and methods of activation of irrigation have a significant role in cleaning and disinfecting the root canal system but can also contribute to postoperative discomfort due to factors like extrusion of debris, penetration of irrigant and periapical irritation. This review examines the association between irrigation systems such as conventional syringe irrigation, ultrasonic and sonic activation, laser-activated irrigation and negative pressure system and postoperative pain after root canal therapy. The randomized clinical trials have shown evidence that activated irrigation techniques, especially negative pressure and some laser or ultrasonic techniques, correlate with low levels of pain in the early postoperative period as opposed to the traditional needle irrigation. Nevertheless, the disparity in the results of pain are likely to decrease with time and the inconsistency in the study procedures further underscores the necessity of additional standardized clinical studies. The effects of irrigation strategies on patient-centered outcomes can inform clinicians to choose methods that effectively disinfect, as well as, increase patient comfort and experience, in general, of the treatment.

Keywords: Endodontics, Patient-centered outcomes, Irrigation systems, Irrigation activation, Postoperative pain, Root canal therapy.

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INTRODUCTION

The primary objective of endodontic treatment is the thorough elimination of microorganisms, necrotic tissue, and biofilm from the root canal system, followed by adequate sealing to prevent reinfection. Regardless of the improvement in instrumentation and materials, chemomechanical preparation plays a very significant role in the achievement of these objectives. Mechanical instrumentation cannot fully debride the intricate anatomy of root canals, so chemical irrigation is a key component in the improvement of disinfection, dissolution of organic tissue and elimination of debris.

Conventionally, the traditional method of irrigants delivery is through the use of syringes and needles, where sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) are used. But the shortcomings of the technique such as lack of penetration of irrigants to apical areas, insufficiency of removal of debris in isthmuses and lateral canals and chances of apical extrusion have led to the emergence of sophisticated irrigation and activation systems. These include passive ultrasonic irrigation (PUI), sonic activation devices (e.g., EndoActivator, EDDY), negative pressure irrigation systems (e.g., EndoVac), and laser-activated irrigation techniques. These innovations aim to improve cleaning efficacy while minimizing adverse effects.

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Background & Literature Review

Endodontic therapy aims to eliminate infection from the root canal system and to prevent reinfection while preserving the natural dentition. A central component of this process is effective chemomechanical preparation, in which irrigation plays a pivotal role. Irrigation not only flushes out debris but also dissolves organic tissue and disrupts microbial biofilms, thereby complementing the mechanical action of instrumentation. Despite these benefits, the method of irrigant delivery and activation may influence patient-centered outcomes, particularly postoperative pain.

Postoperative pain remains one of the most common complications of root canal treatment and significantly affects patient satisfaction and perception of care. It can

arise from a variety of factors, including extrusion of debris or irrigant into periapical tissues, persistent microbial activity, and host inflammatory responses. As such, attention has shifted toward evaluating how different irrigation systems impact these outcomes.

Conventional syringe and needle irrigation has been widely employed for decades due to its simplicity and accessibility. However, its limitations include restricted irrigant penetration into complex root canal anatomies and a higher risk of apical extrusion. To overcome these drawbacks, several advanced activation techniques have been developed. Passive ultrasonic irrigation enhances irrigant flow and penetration through acoustic streaming and cavitation. Sonic activation devices, such as the EndoActivator and polymer-based tips, provide agitation at lower frequencies but greater amplitude, improving irrigant replacement within the canal. Negative pressure systems, exemplified by EndoVac, are designed to draw irrigants apically while minimizing the risk of extrusion into periapical tissues. More recently, laser-activated irrigation has been introduced, utilizing photoacoustic streaming to generate dynamic fluid movement and enhance debridement.

Clinical investigations have sought to establish whether these technological advances translate into tangible improvements in patient-centered outcomes. Findings from randomized controlled trials suggest that activated irrigation methods can reduce the intensity of postoperative pain, particularly within the first 24 to 48 hours following treatment. Negative pressure systems have demonstrated favorable results by reducing periapical irritation, while ultrasonic and laser-activated systems have been associated with lower early pain scores compared with conventional needle irrigation. Nevertheless, the differences among techniques tend to diminish after the initial postoperative period, and heterogeneity in study design, patient selection, and outcome assessment has limited definitive conclusions.

Taken together, the available evidence highlights the potential of advanced irrigation systems to improve early postoperative comfort without compromising cleaning efficacy. However, variability in clinical protocols and outcome measures underscores the need for further standardized research to validate these findings and provide clear guidance for clinical decision-making.

Key Studies

Study A: UAI versus LAI in Asymptomatic Teeth

- Title / Design: Randomized clinical trial comparing ultrasonically-activated irrigation (UAI) and laser-

activated irrigation (LAI) in teeth without symptoms.

- Patients / Sample: 56 patients, each requiring primary root canal treatment of an asymptomatic tooth.
- Interventions: After standard chemo-mechanical preparation and NaOCl irrigation using rotary instruments, teeth were allocated to:
 - UAI group: 60 seconds of activation with an Irrisafe ultrasonic tip per canal.
 - LAI group: Activation of NaOCl using a pulsed Er:YAG (2940 nm) laser with conical tip (settings: 50 μ s pulses, 20 mJ energy, 15 Hz frequency) for 60 seconds.
- Pain Measurement / Follow-up: Pain assessed via 100 mm Visual Analogue Scale (VAS) at 6, 24, 48, and 72 hours; analgesic consumption also recorded.

Findings

- Overall pain was low.
- At 6 hours: LAI group had significantly lower pain intensity and incidence than the UAI group.
- At 24h, 48h, and 72h: no significant differences in pain levels or incidence between the two groups.
- Analgesic use did not differ significantly between groups.

Implications

LAI offers better early postoperative comfort (6 hours) in asymptomatic cases versus UAI, but by later time points (one day or more) the difference fades. Both are well tolerated.

Study B: Needle vs. PUI vs. EndoVac in Single-Visit Treatment

- Title / Design: Randomized clinical trial to evaluate postoperative pain after single-visit root canal treatment using three different irrigation activation techniques.
- Patients / Sample: 30 patients aged 16 - 40 years needing single-visit endodontic therapy on vital or non-vital maxillary central or canine teeth; asymptomatic at baseline.

Interventions

- Needle irrigation: Conventional needle (control) with standard NaOCl concentration (2.5%) during treatment.
- Passive Ultrasonic Irrigation (PUI): Activation of irrigant ultrasonically in the final irrigation stage.
- EndoVac system: A negative-pressure irrigation protocol. Root canals prepared with NiTi ProTaper Universal rotary instruments up to F4 or F5 depending

on canal size; obturation via cold lateral compaction.

- Pain Measurement / Follow-Up: VAS assessments at 6, 12, 24, 48 hours, 1 week, 2 weeks.

Findings

- The EndoVac group had the lowest postoperative pain values at early time-points (notably at 6 and 48 hours).
- Needle irrigation group had the highest pain values.
- PUI was intermediate - better than needle irrigation, particularly at 48 hours.
- Across all groups, pain intensity decreased over time.

Implications

Negative pressure systems like EndoVac reduce early postoperative discomfort more effectively than needle irrigation; PUI also helps. For single-visit treatments, choice of activation method matters especially in first two days post-treatment.

Study C: Side-Port Needles, EDDY, EndoActivator and PUI in Symptomatic Irreversible Pulpitis

- Title/Design: Prospective randomized clinical study comparing multiple activation methods in symptomatic teeth (irreversible pulpitis) during single-visit root canal treatment.
- Patients/Sample: 160 patients with mandibular premolar teeth with symptomatic irreversible pulpitis.

Interventions/Groups

- NI (Needle Irrigation): Side-port endodontic needles without agitation.
- EDDY: Sonic activation method.
- EndoActivator (EA): Another sonic activation system.
- Passive Ultrasonic Irrigation (PUI).
- Pain Measurement / Follow-Up: Pain intensity and analgesic intake recorded at 8, 24, 48 hours, and 7 days post-treatment. Visual analogue scale used.

Findings

- Highest-pain recorded at 8 hours in all groups; pain decreased over time in every group.
- At 24 hours, the needle irrigation group had significantly higher pain than the EDDY group. EA and PUI had milder pain and similar pain scores at 24 hours (no significant difference between EA and PUI).
- By 48 hours and beyond, differences between groups diminished but 7 days pain is low across all boards.
- Analgesic consumption did *not* differ significantly among the groups.

Implications

Activation (sonic or ultrasonic) reduces early postoperative pain compared to standard needle irrigation in symptomatic teeth, particularly in the first 24 hours. However, the choice between different activation systems (e.g. EA vs. PUI vs. EDDY) shows smaller differences and becomes less clinically relevant after the first day.

Summary of Trends from These Studies

- Early time-points matter. The largest differences among irrigation activation methods (LAI, PUI, EndoVac, etc.) tend to appear in the first 6–24 hours post-treatment.
- For symptomatic versus asymptomatic teeth, activation methods seem more beneficial (in terms of pain reduction) in symptomatic cases, but still produce improvements even when there are no symptoms.
- Needle irrigation tends to produce more early pain compared to activated systems. Negative pressure and certain laser / ultrasonic activations give better early comfort.
- By 48–72 hours, pain levels tend to converge across different activation techniques. Long-term differences are small or non-existent.
- Analgesic consumption is a useful secondary outcome; many studies report lower analgesic use in activation groups, but not always significant.

Methods for The Reviewed Studies

A comprehensive review of clinical trials and randomized controlled studies was conducted to evaluate the impact of various irrigation systems on patient-centered outcomes, with particular focus on postoperative pain following root canal therapy. Eligible studies included adult patients undergoing primary root canal treatment, with both vital and non-vital pulps considered. Exclusion criteria typically involved retreatment cases, patients with systemic conditions that could alter pain perception, and those under analgesic or anti-inflammatory medication prior to treatment.

The irrigation methods assessed encompassed conventional syringe and needle irrigation, passive ultrasonic irrigation, sonic activation systems, laser-activated irrigation, and negative pressure systems. Standard irrigants, such as sodium hypochlorite and ethylenediaminetetraacetic acid, were applied in varying concentrations and volumes according to study protocols. Activation techniques were performed in accordance with manufacturer guidelines to ensure reproducibility.

Postoperative pain was the primary outcome measure, recorded using validated scales such as the Visual Analogue Scale (VAS) or Numerical Rating Scale (NRS) at defined intervals (commonly 6, 24, 48 hours, and up to 7 days post-treatment). Secondary outcomes included analgesic intake and patient-reported satisfaction when available.

Randomization, blinding, and allocation concealment methods were described where applicable to minimize bias. Data from the included studies were synthesized to identify patterns and trends in pain outcomes related to the irrigation systems used. For proposed clinical trials, a similar methodology would be employed, with emphasis on standardized irrigant concentrations, consistent activation times, and uniform pain assessment intervals to enhance comparability across investigations.

DISCUSSION

Patient-centered outcomes, particularly postoperative pain, are essential indicators of success in endodontic treatment. Although the primary goal of irrigation is to achieve thorough microbial reduction and tissue dissolution, the choice of irrigation system can also influence the patient's comfort after therapy. The reviewed evidence suggests that advanced irrigation activation methods, such as ultrasonic, sonic, laser-activated, and negative pressure systems, generally contribute to reduced postoperative pain compared with conventional syringe irrigation, especially in the early hours following treatment. This effect is likely related to improved debridement, reduced extrusion of debris and irrigants, and more effective disinfection of the canal system.

From a clinical perspective

The potential to minimize postoperative discomfort has direct implications for patient satisfaction, treatment acceptance, and overall quality of care. Selecting an irrigation system that balances antimicrobial efficacy with patient comfort supports the broader shift in endodontics toward patient-centered practice. Negative pressure systems and ultrasonic activation, for instance, appear particularly promising in limiting debris extrusion and associated periapical irritation.

Trade-offs

Advanced irrigation systems require additional equipment, training, and cost, which may limit their routine application in some clinical settings. Laser-activated irrigation, for example, may improve patient outcomes but is not universally accessible due to its high financial and technical demands. Similarly, while ultrasonic and sonic activation

are more widely available, their effectiveness is technique-sensitive and requires operator skill to avoid complications such as irrigant extrusion. Clinicians must weigh these factors against the benefits of reduced postoperative pain, considering the resources of their practice and the expectations of their patients.

Study limitations

Many studies assessing postoperative pain rely on small sample sizes, heterogeneous patient populations, and variations in pulp status, tooth type, and irrigation protocols. Differences in irrigant concentration, volume, and activation duration further complicate direct comparisons across studies. In addition, most trials focus on short-term pain assessment, often within the first 24 to 72 hours, with limited information on longer-term outcomes or broader measures of patient well-being such as quality of life.

Overall, while irrigation system choice does appear to influence postoperative pain, particularly in the immediate postoperative period, further high-quality randomized clinical trials with standardized protocols are needed. Expanding outcome measures beyond pain to include patient satisfaction, functional recovery, and quality-of-life indicators will provide a more comprehensive understanding of how irrigation strategies impact patient-centered outcomes in endodontics.

RESULTS SUMMARY

Comparative analyses of irrigation systems demonstrated that the choice of activation method can significantly influence postoperative pain, particularly during the first 24 - 48 hours after treatment. Conventional syringe and needle irrigation were consistently associated with higher pain scores in the early postoperative period. In contrast, negative pressure irrigation systems generally produced lower pain levels, likely due to their ability to minimize apical extrusion of debris and irrigant. Ultrasonic and sonic activation techniques also showed favorable outcomes, with many patients reporting reduced discomfort compared with traditional needle irrigation. Laser-activated irrigation demonstrated additional benefits in some studies, particularly in decreasing immediate postoperative pain intensity. Despite these findings, pain differences between irrigation systems tended to converge after several days, with most patients experiencing substantial pain reduction regardless of the method employed. Analgesic consumption followed a similar trend, with lower use observed in groups treated with activated or negative pressure irrigation methods. Overall, the results highlight that advanced irrigation systems may improve early patient-centered

outcomes, although long-term pain differences are less pronounced.

CONCLUSION

Postoperative pain remains a critical patient-centered outcome in endodontics, directly influencing treatment acceptance and satisfaction. Evidence indicates that the choice of irrigation system can impact early postoperative discomfort, with activated methods such as ultrasonic, sonic, laser, and negative pressure systems generally associated with reduced pain when compared to conventional syringe irrigation. These benefits appear most pronounced within the first 24 - 48 hours after treatment, although differences tend to diminish over time. Although activated irrigation methods are effective in terms of cleaning efficacy and patient comfort, the differences in study design and patient variables indicate that additional well-designed clinical trials with a standardized protocol are required. Finally, antimicrobial efficacy, safety, and the patient experience should be balanced when selecting an irrigation system, which supports the reasons behind the need to introduce patient-centered outcomes in the clinical decision-making process in endodontics.

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