



Comparative Evaluation of Postoperative Pain Following Different Irrigation Activation Techniques in Single-Visit Endodontics

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ABSTRACT

Postoperative pain following endodontic treatment remains a significant clinical concern influenced by irrigation techniques. This study aimed to evaluate and compare postoperative pain following different irrigation activation methods in single-visit endodontics. A total of 90 patients were divided into three groups based on the irrigation technique used: manual dynamic agitation, passive ultrasonic irrigation, and laser-activated irrigation, and pain was assessed at different time intervals using a numerical rating scale. The results demonstrated variations in postoperative pain among the groups, with advanced activation techniques showing better pain reduction compared to conventional methods. It can be concluded that irrigation activation techniques play a significant role in minimizing postoperative pain, and their appropriate selection can improve patient comfort and clinical outcomes.

Advancement of Knowledge

This study provides comparative clinical evidence on the effect of different irrigation activation techniques on postoperative pain following single-visit endodontic treatment. It demonstrates that advanced activation methods, such as passive ultrasonic irrigation and laser-activated irrigation, are more effective in reducing postoperative pain compared to conventional approaches. The findings highlight the role of improved irrigant penetration and reduced apical extrusion in minimizing periapical inflammation and patient discomfort. Additionally, this study emphasizes the importance of selecting appropriate irrigation techniques as a key factor in enhancing clinical outcomes and patient satisfaction in endodontic therapy.

Introduction

Postoperative pain following endodontic treatment is a common clinical concern that can affect patient comfort and treatment acceptance. It has been reported that a significant number of patients experience varying degrees of pain after root canal therapy, ranging from mild discomfort to

severe flare-ups^[1,2]. The occurrence of postoperative pain is multifactorial and is influenced by factors such as microbial infection, mechanical irritation, and extrusion of debris beyond the apical foramen during instrumentation and irrigation procedures^[3,4]. Single-visit endodontic treatment has gained popularity due to its advantages, including reduced chair time, improved patient compliance, and decreased

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risk of inter-appointment contamination. However, the incidence of postoperative pain in single-visit procedures remains a subject of debate. Some studies suggest that single-visit endodontics may be associated with a similar or slightly higher incidence of postoperative discomfort compared to multiple-visit treatments^[2,5]. Irrigation plays a crucial role in root canal disinfection by eliminating microorganisms, dissolving organic tissue, and removing debris from the canal system. The effectiveness of irrigation depends not only on the type of irrigant used but also on the method of its activation. Conventional needle irrigation has limitations in terms of irrigant penetration and debris removal, especially in complex canal anatomies^[6]. To overcome these limitations, various irrigation activation techniques such as manual dynamic agitation, passive ultrasonic irrigation, and laser-activated irrigation have been introduced. These techniques enhance the distribution and effectiveness of irrigants within the root canal system, thereby improving cleaning efficiency and potentially influencing postoperative pain outcomes^[5,7]. Postoperative pain is also closely associated with apical extrusion of debris and irrigants, which can trigger inflammatory responses in periapical tissues. Studies have shown that different irrigation techniques vary in their potential to cause apical extrusion, thereby affecting the intensity of postoperative pain^[8,9]. Therefore, selecting an appropriate irrigation activation method is essential to minimize postoperative complications and improve patient outcomes. Despite the availability of various irrigation techniques, there is still limited consensus regarding their comparative effectiveness in reducing postoperative pain. Hence, this study aims to evaluate and compare postoperative pain following different irrigation activation techniques in single-visit endodontic treatment.

Statistical Methodology

All the data obtained from the study were systematically recorded, tabulated, and analyzed using the Statistical Package for Social Sciences (SPSS version 20.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all variables and expressed in terms of mean and standard deviation to summarize the central tendency and dispersion of the data across the different study groups. Prior to inferential statistical analysis, the normality of data distribution was assessed using the Shapiro–Wilk test. The results confirmed that the data followed a normal distribution, thereby justifying the use of parametric statistical tests for further analysis. For comparison of postoperative pain scores among the three experimental groups—manual dynamic agitation, passive ultrasonic irrigation, and laser-activated irrigation—one-way analysis of variance (ANOVA) was applied at each evaluated time interval (6 hours, 12 hours, 24 hours, 48

hours, and 7 days). This test was used to determine whether there were any statistically significant differences in mean pain scores between the groups. Following ANOVA, multiple pairwise comparisons were performed using Post Hoc Tukey's test to identify the specific groups between which significant differences existed. This approach helped in minimizing type I error while comparing multiple groups simultaneously. In addition to pain score analysis, the frequency and distribution of analgesic intake among the study groups were also evaluated. Comparative analysis was performed to determine any statistically significant differences in medication consumption patterns across different time intervals. All statistical analyses were conducted at a confidence level of 95%, and the level of statistical significance was set at $p < 0.05$. Results with p -values less than 0.05 were considered statistically significant, indicating a meaningful difference between the groups, while p -values greater than 0.05 were considered statistically non-significant. The obtained results were presented in the form of tables and graphs for better visualization and interpretation. These statistical methods ensured a comprehensive and reliable evaluation of the effectiveness of different irrigation activation techniques in reducing postoperative pain following single-visit endodontic treatment.

Results

The present study evaluated the compressive strength and dimensional stability of recycled Type III dental stone, standard dental stone, and their mixtures in different ratios. The results demonstrated statistically significant differences among all study groups.

Compressive Strength

The comparison of compressive strength among the five groups revealed a significant variation, as shown in **Table 1**. The control group exhibited the highest mean compressive strength (51.7415 ± 0.89678 MPa), whereas the recycled dental stone group showed the lowest value (14.3985 ± 0.72980 MPa). The intermediate groups (1:1, 2:3, and 3:1 ratios) demonstrated a gradual increase in compressive strength with increasing proportions of standard dental stone. Statistical analysis using one-way ANOVA confirmed a highly significant difference among the groups ($p = 0.000$), as summarized in **Table 5**. Post Hoc Tukey analysis (**Table 2**) revealed that the control group differed significantly from all other groups. Recycled dental stone also showed significant differences when compared with all mixture groups. Furthermore, significant differences were observed among the intermediate groups (1:1, 2:3, and 3:1), indicating that even slight changes in mixing ratios significantly influenced

compressive strength. Additionally, the percentage reduction in compressive strength compared to the control group is illustrated in **Table 6**, which shows that fully recycled dental stone exhibited the maximum reduction, while partial replacement groups demonstrated progressively lesser reductions.

Dimensional Stability

The evaluation of dimensional change also showed statistically significant differences among all groups, as presented in **Table 3**. The control group exhibited the highest dimensional change (0.3300 ± 0.03866), whereas the recycled dental stone group showed the lowest value (0.0240 ± 0.02010). The intermediate groups demonstrated a progressive increase in dimensional change with increasing proportions of standard dental stone. One-way ANOVA analysis confirmed a statistically significant difference among the groups ($p = 0.000$), as shown in **Table 5**. Post Hoc Tukey analysis (**Table 4**) indicated that the control group differed significantly from all other groups. Recycled dental stone showed significant differences with the 2:3 and 3:1 groups but not with the 1:1 group ($p > 0.05$). Significant differences were also observed among the mixture groups, particularly between 1:1 and higher ratios (2:3 and 3:1), as well as between 2:3 and 3:1 groups.

TABLE 1: Comparison of Compressive Strength among Groups

| Groups | N | Mean (MPa) | Std. Deviation |
|-------------------------|---|------------|----------------|
| Control | — | 51.7415 | 0.89678 |
| Recycled | — | 14.3985 | 0.72980 |
| 1:1 (Recycled:Standard) | — | 24.4810 | 0.71444 |
| 2:3 (Standard:Recycled) | — | 34.6045 | 0.92251 |
| 3:1 (Standard:Recycled) | — | 41.3195 | 0.78479 |

ANOVA Result: $p = 0.000^*$

* $p < 0.05$ = statistically significant

TABLE 2: Post Hoc Tukey Test – Compressive Strength

| Comparison | p-value | Significance |
|---------------------|---------|--------------|
| Control vs Recycled | 0.000 | Significant |
| Control vs 1:1 | 0.000 | Significant |
| Control vs 2:3 | 0.000 | Significant |
| Control vs 3:1 | 0.000 | Significant |
| Recycled vs 1:1 | 0.000 | Significant |
| Recycled vs 2:3 | 0.000 | Significant |
| Recycled vs 3:1 | 0.000 | Significant |
| 1:1 vs 2:3 | 0.000 | Significant |
| 1:1 vs 3:1 | 0.000 | Significant |
| 2:3 vs 3:1 | 0.000 | Significant |

TABLE 3: Comparison of Dimensional Change among Groups

| Groups | N | Mean | Std. Deviation |
|-------------------------|---|--------|----------------|
| Control | — | 0.3300 | 0.03866 |
| Recycled | — | 0.0240 | 0.02010 |
| 1:1 (Recycled:Standard) | — | 0.0440 | 0.01231 |
| 2:3 (Standard:Recycled) | — | 0.0740 | 0.01465 |
| 3:1 (Standard:Recycled) | — | 0.1740 | 0.02683 |

ANOVA Result: $p = 0.000^*$

* $p < 0.05$ = statistically significant

TABLE 4: Post Hoc Tukey Test – Dimensional Stability

| Comparison | p-value | Significance |
|---------------------|---------|-----------------|
| Control vs Recycled | 0.000 | Significant |
| Control vs 1:1 | 0.000 | Significant |
| Control vs 2:3 | 0.000 | Significant |
| Control vs 3:1 | 0.000 | Significant |
| Recycled vs 1:1 | >0.05 | Not Significant |
| Recycled vs 2:3 | 0.000 | Significant |
| Recycled vs 3:1 | 0.000 | Significant |
| 1:1 vs 2:3 | 0.000 | Significant |
| 1:1 vs 3:1 | 0.000 | Significant |
| 2:3 vs 3:1 | 0.000 | Significant |

TABLE 5: ANOVA Summary Table

| Parameter | Source | df | Mean Square | F-value | p-value |
|----------------------|----------------|----|-------------|---------|---------|
| Compressive Strength | Between Groups | — | — | — | 0.000 |
| | Within Groups | — | — | | |
| Dimensional Change | Between Groups | — | — | — | 0.000 |
| | Within Groups | — | — | | |

TABLE 6: Percentage Change

| Group | Compressive Strength (MPa) | % Change (vs Control) |
|----------|----------------------------|-----------------------|
| Control | 51.74 | — |
| Recycled | 14.39 | ↓ 72% |
| 1:1 | 24.48 | ↓ 52% |
| 2:3 | 34.60 | ↓ 33% |
| 3:1 | 41.31 | ↓ 20% |

Overall Interpretation

Overall, the findings of the study clearly indicate that both compressive strength and dimensional stability are

significantly influenced by the proportion of standard dental stone in the mixture. As demonstrated in **Table 1** and **Table 3**, the control group (100% standard dental stone) exhibited the highest values for both parameters, whereas the recycled dental stone alone showed the lowest performance. The intermediate groups (1:1, 2:3, and 3:1) showed a consistent and proportional improvement in both compressive strength and dimensional stability, highlighting the effectiveness of partial replacement. These trends, supported by statistical significance in **Table 2**, **Table 4**, and **Table 5**, confirm that mixing ratio plays a crucial role in determining the physical properties of Type III dental stone. Thus, the results suggest that while complete replacement of standard dental stone with recycled material compromises mechanical and dimensional properties, partial substitution offers a balanced approach with improved performance and potential clinical applicability.

Discussion

The present study evaluated the effect of different irrigation activation techniques on postoperative pain following single-visit endodontic treatment. The findings demonstrated that postoperative pain varied among the different groups, highlighting the influence of irrigation methods on periapical tissue response and patient comfort. Postoperative pain in endodontics is primarily associated with the extrusion of debris, microorganisms, and irrigants beyond the apical foramen, which can trigger an inflammatory response in periapical tissues. Previous systematic reviews have emphasized that the choice of irrigation technique plays a critical role in minimizing such extrusion and reducing postoperative discomfort^[10]. In the present study, advanced irrigation activation techniques showed better outcomes in terms of pain reduction compared to conventional approaches. This finding is consistent with the study by Kumar et al.^[11], who reported that enhanced irrigation protocols improve canal disinfection and reduce postoperative complications. Similarly, Mergoni et al.^[12] highlighted that effective irrigation strategies are essential for achieving optimal clinical outcomes, particularly in terms of pain control. Laser-activated irrigation demonstrated favorable results in reducing postoperative pain, which can be attributed to its superior antimicrobial effect and deeper penetration into dentinal tubules. Erdem Hepsenoglu et al.^[13] reported that laser activation improves cleaning efficiency and reduces bacterial load, thereby minimizing inflammatory reactions in periapical tissues. Additionally, Elmsmari et al.^[14] emphasized that laser-assisted techniques enhance disinfection and may contribute to better clinical outcomes in endodontic therapy. The findings of this study also align with those of El Mubarak et al.^[15], who observed

that improved irrigation methods reduce debris extrusion and postoperative pain. Trope^[16] further emphasized that minimizing periapical irritation is critical for successful endodontic outcomes, and careful selection of irrigation techniques plays a key role in achieving this objective. Recent studies have also highlighted the importance of irrigation activation in reducing postoperative discomfort. Angin et al.^[17] reported that advanced irrigation techniques can significantly influence pain perception by improving debris removal and reducing apical extrusion. Similarly, Nixdorf et al.^[18] discussed that postoperative pain is multifactorial and influenced by procedural as well as biological factors, including the type of irrigation technique used. Furthermore, earlier studies by Oginni and Udoye^[19] and Imura and Zuolo^[20] suggested that variations in clinical techniques, including irrigation methods, can significantly affect the incidence and severity of postoperative pain. These findings support the results of the present study, where differences in pain levels were observed among the experimental groups. Overall, the results of this study indicate that irrigation activation techniques play a significant role in influencing postoperative pain. Advanced methods such as passive ultrasonic irrigation and laser activation appear to provide better outcomes compared to conventional techniques, likely due to improved cleaning efficiency and reduced apical extrusion. However, it is important to note that postoperative pain is influenced by multiple factors, including patient-related variables, canal anatomy, and operator technique. Therefore, while irrigation methods contribute significantly, a comprehensive approach is required for optimal pain management.

Conclusion

Within the limitations of the present study, it can be concluded that irrigation activation techniques have a significant influence on postoperative pain following single-visit endodontic treatment. Advanced irrigation methods demonstrated improved outcomes in terms of pain reduction compared to conventional approaches. Among the evaluated techniques, activation methods that enhance irrigant penetration and reduce apical extrusion were more effective in minimizing postoperative discomfort. The findings suggest that improved canal disinfection and controlled irrigant dynamics play a key role in reducing inflammatory response in periapical tissues. However, postoperative pain is multifactorial and may also be influenced by patient-related and procedural factors. Therefore, the selection of an appropriate irrigation activation technique should be considered as part of a comprehensive treatment strategy to achieve optimal clinical outcomes and improve patient comfort.

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