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Effect of Low-Level Laser Therapy (LLLT) on Pain at Injection Site of Local Anesthetic Agent

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ABSTRACT

Background: Pain and anxiety associated with local anesthetic injection remain persistent challenges in dental practice, often deterring patients from seeking timely treatment. While various pharmacological and non-pharmacological approaches have been employed to mitigate injection-related pain, their effectiveness remains inconsistent. Low-level laser therapy (LLLT), a form of photobiomodulation, has demonstrated analgesic, anti-inflammatory, and tissue-healing properties in multiple clinical contexts, but its efficacy in reducing pain during anesthetic administration is inconclusive. Objective: This study aimed to evaluate whether pre-treatment with LLLT reduces pain intensity at the injection site of local anesthesia in adult patients undergoing endodontic procedures. Methods: A randomized controlled split-mouth trial was conducted on 30 adult patients requiring bilateral endodontic treatment. Each patient received LLLT (635 nm, 10 J/cm², 210 mW, four 25-second cycles) on one side before anesthetic injection, while the opposite side served as a control. Pain intensity was measured immediately after injection using a 10 cm Visual Analogue Scale (VAS). Data were analyzed with the Mann-Whitney U test for group comparisons and subgroup analyses by age and gender, with a significance threshold of $p<0.05$. Results: The mean VAS pain score was 6.80 ± 1.24 for the LLLT-treated side and 6.93 ± 1.46 for the control side, with no statistically significant difference ($p=0.612$). Female participants reported higher pain scores than males in both groups, and younger patients experienced more intense pain compared with older participants. No participant reported complete absence of pain. Conclusion: Pre-treatment with LLLT did not significantly reduce injection-site pain compared with standard practice. Age and gender appeared to influence pain perception, but these trends were not statistically significant. Larger, multicenter trials with optimized laser parameters and stratified analysis are recommended to further investigate the clinical utility of LLLT in dental pain management.

Keywords
Low-level laser therapy, photobiomodulation, injection pain, local anesthesia, endodontics, dental anxiety.

INTRODUCTION

When patients undergo invasive dental procedures, local anesthesia is essential to prevent pain, but its administration itself remains a significant source of discomfort and anxiety (1). The anticipation of a needle insertion into the oral mucosa often triggers strong fear responses across all age groups, leading to procedural avoidance, treatment delays, and heightened physiological stress (2). This anxiety is shaped by multiple factors, including previous traumatic dental experiences, negative social narratives, online media portrayals, and individual variations in pain sensitivity (3,4). Despite advances in anesthetic techniques, the initial injection remains one of the most distressing aspects of dental treatment, often rated as the most painful event during a dental visit (5).

Several strategies have been developed to mitigate injection-related pain, ranging from pharmacological approaches such as topical anesthetic gels and pre-injection nerve desensitization to non-pharmacological techniques like cryoanesthesia, vibration, distraction, and music therapy (6-9). While these interventions provide some relief, their efficacy is inconsistent and none has achieved universal acceptance in clinical practice. As a result, clinicians continue to seek reliable adjunctive methods that can enhance patient comfort without compromising procedural efficacy.

Low-Level Laser Therapy (LLLT), also known as photobiomodulation, has emerged as a promising adjunct for pain modulation in both medical and dental settings. LLLT delivers light of specific wavelengths (typically in the red to near-infrared spectrum) to biological tissues, where it is absorbed by mitochondrial chromophores and leads to increased ATP production, modulation of inflammatory pathways, and altered neural conduction (10,11). This photobiological cascade contributes to reduced nociceptor sensitivity, enhanced tissue repair, and modulation of neurogenic inflammation (12,13). Clinical studies have demonstrated the analgesic potential of LLLT in various dental applications, including the management of temporomandibular myofascial pain, reduction of dentinal hypersensitivity, and promotion of healing after surgical interventions (14-16).

Evidence regarding LLLT's efficacy specifically for injection-related pain, however, remains inconclusive. Munguia et al. reported significant pain reduction following LLLT in patients with temporomandibular myofascial pain, with sustained benefits weeks after treatment (14). Similarly, Jagtap and colleagues found that LLLT significantly decreased pain perception during local anesthetic injection before dental extractions (17). In contrast, Andrade et al. observed no significant analgesic effect of LLLT on root canal retreatment pain (18), while Ghaderi et al. found that pre-

injection laser therapy combined with benzocaine did not reduce needle insertion pain (1). Such discrepancies suggest that the analgesic efficacy of LLLT may be influenced by multiple factors, including laser wavelength, dosage, tissue type, anatomical site, and timing of application.

These inconsistencies underscore a critical knowledge gap regarding the role of LLLT in modulating acute pain specifically associated with local anesthetic injections in dental practice. Furthermore, most existing studies have been conducted in pediatric populations or under varying clinical conditions, limiting their generalizability to adult dental patients. There is therefore a clear need for controlled clinical trials evaluating the direct effect of pre-injection LLLT on acute injection-site pain under standardized conditions.

The present study aimed to address this gap by assessing whether pre-treatment with LLLT reduces pain intensity associated with local anesthetic injection during endodontic procedures in adult patients. We hypothesized that patients receiving LLLT prior to injection would report significantly lower pain scores on a visual analogue scale (VAS) compared to those receiving no laser therapy.

MATERIAL AND METHODS

This randomized controlled split-mouth clinical trial was designed to evaluate the effect of pre-treatment with low-level laser therapy (LLLT) on pain intensity associated with local anesthetic injection during endodontic procedures. The study was conducted in the Department of Endodontics at Fatima Jinnah Dental College and Hospital, Karachi, Pakistan. All data were collected from outpatients receiving bilateral endodontic treatment within a defined study period. The split-mouth design was selected to minimize inter-individual variability, as each participant served as their own control, thereby improving internal validity and reducing confounding from factors such as individual pain threshold or psychological predisposition.

Eligible participants were adults aged 18 to 50 years presenting for endodontic treatment in both quadrants of the mandible, requiring the same block anesthetic technique on both sides. Inclusion criteria required participants to have intact cognitive function and to provide informed written consent after receiving a complete explanation of the study purpose, procedures, risks, and benefits. Patients with active oral infections or abscesses at the injection site, cognitive impairments, or those not requiring nerve block anesthesia were excluded. A non-probability convenience sampling technique was used for recruitment due to the clinical setting and limited patient pool, which was acknowledged as a potential source of selection bias.

The sample size was calculated using OpenEpi software with a 90% power and a 5% significance level, assuming an effect size of 1 based on prior literature, yielding a total of 30 participants. In the split-mouth design, each participant contributed data for both the intervention and control conditions, effectively increasing statistical power without requiring a larger sample. All participants were fully informed about the study and provided written consent before inclusion. Ethical approval was obtained from the Institutional Ethical Review Committee (Reference: SEP-2022-OPR03), and the trial was registered under the identifier TCTR20250828003.

All participants underwent two separate local anesthetic injections in the same session — one on each side of the mandibular arch. The side to receive LLLT was determined randomly to minimize allocation bias. The intervention involved the application of LLLT to the injection site on one side before anesthetic administration. The laser used was a SMARTm PRO DiodeLX diode laser with a wavelength of 635 nm, delivering 10.0 J/cm² of energy at 210 mW. Treatment was applied in four cycles of 25 seconds each, targeting the mucosal site designated for injection. Patients and operators adhered to standard laser safety protocols, including the use of protective eyewear. Participants were blinded to the treatment condition; the laser produced no detectable heat, light, or sound, preventing them from discerning whether the site had been treated. The contralateral side served as the control, where the same anesthetic technique was performed without prior laser application.

Pain intensity was measured immediately after each injection using a 10 cm Visual Analogue Scale (VAS), where 0 represented “no pain” and 10 represented “worst imaginable pain.” Before the procedure, participants were instructed on how to use the VAS and mark their perceived pain level. The primary outcome variable was the difference in VAS scores between the LLLT-treated and untreated sides. Secondary variables included age and gender, which were analyzed as potential effect modifiers. All data were collected by a single calibrated investigator to minimize inter-observer variability.

To address potential sources of bias, a single-blind approach was implemented, and standardized injection techniques, needle gauge, and anesthetic agents were used across all participants. The split-mouth design controlled for inter-individual variability in pain perception, and uniform procedural timing further reduced confounding. The main limitation regarding external validity was the use of non-probability sampling, which was considered during interpretation.

Data were entered and analyzed using SPSS version 25. The Shapiro-Wilk test was applied to assess normality of continuous variables. As the VAS data were not normally distributed, non-parametric tests were used. Descriptive statistics, including mean and standard deviation for continuous variables and frequencies and percentages for categorical variables, were calculated. The Mann-Whitney U test was used to compare differences in VAS scores between the intervention and control groups. Subgroup analyses stratified by gender and age group were conducted to explore potential modifiers of treatment effect. A two-sided p-value of <0.05 was considered statistically significant. Data integrity was ensured through double-entry verification, and all procedures adhered to institutional ethical standards and international research guidelines.

RESULTS

A total of 30 patients participated in the study, comprising 12 males (40%) and 18 females (60%), with a mean age of 31.86 ± 8.98 years (range: 18–57). The sample was stratified into four age categories: 18–27 years (n = 11), 28–37 years (n = 9), 38–47 years (n = 9), and 48–57 years (n = 1). The Shapiro-Wilk test indicated that VAS pain scores were not normally distributed in either the LLLT intervention group ($p = 0.001$) or the control group ($p = 0.031$), confirming the suitability of non-parametric tests for group comparisons.

The primary outcome analysis revealed no statistically significant difference in pain scores between the LLLT-treated side and the control side. The mean pain score for the intervention group (left side with LLLT) was 6.80 ± 1.24, while the control group (right side without LLLT) reported a slightly higher mean pain score of 6.93 ± 1.46 ($p = 0.612$). The negligible effect size (Cohen’s $d = 0.09$) suggests a clinically insignificant difference between the two conditions.

Further subgroup analysis based on gender indicated that female participants consistently reported higher pain scores compared to males in both the intervention and control groups. In the control group, males reported a mean rank of 13.88, while females had a mean rank of 16.58 ($p = 0.390$).

Similarly, in the LLLT group, males reported a mean rank of 12.58 compared to 17.44 among females (p = 0.126). Although the differences were not statistically significant, the trend suggests that gender may influence pain perception irrespective of laser intervention.

Age-stratified analysis demonstrated that younger patients (18–27 years and 38–47 years) reported relatively higher pain scores even after receiving LLLT, while older patients (48–57 years) reported comparatively lower pain levels. This inverse relationship between age and reported pain intensity suggests a potential moderating effect of age on pain perception, though the sample size in the older age group was insufficient for robust statistical testing.

Table 1. Descriptive statistics of pain intensity with and without LLLT

Study Group	n	Mean VAS ± SD	Minimum	Maximum	95% CI (Mean)	p-value	Cohen's d
With LLLT (Intervention)	30	6.80 ± 1.24	5	10	6.33 – 7.27	0.612	0.09
Without LLLT (Control)	30	6.93 ± 1.46	5	10	6.38 – 7.48	—	—

Table 2. Comparison of VAS pain scores between male and female participants

Group	Gender	n	Mean Rank	Sum of Ranks	Mann-Whitney U	p-value	95% CI of Difference
Pain without LLLT	Male	12	13.88	166.50	88.50	0.390	-0.72 – 1.14
	Female	18	16.58	298.50	—	—	—
Pain with LLLT	Male	12	12.58	151.00	73.00	0.126	-0.94 – 1.25
	Female	18	17.44	314.00	—	—	—

Table 3. Age-wise distribution of pain scores with LLLT (Intervention)

Age Group (years)	n	Mean VAS ± SD	95% CI (Mean)	Kruskal-Wallis H	p-value
18–27	11	7.10 ± 1.22	6.28 – 7.92	4.283	0.233
28–37	9	6.70 ± 1.31	5.79 – 7.61	—	—
38–47	9	6.89 ± 1.18	6.04 – 7.74	—	—
48–57	1	5.00	—	—	—

Despite theoretical mechanisms suggesting that LLLT could modulate nociceptive pathways, the present trial demonstrated no significant reduction in immediate injection-site pain following laser pre-treatment. Pain intensity remained in the moderate range across all groups, and demographic factors such as gender and age showed trends but no statistically significant interactions. These results indicate that while LLLT is safe and feasible, its clinical efficacy for reducing acute anesthetic injection pain remains unsubstantiated in this study population. Larger, multicenter trials with optimized dosing parameters and stratified analyses are recommended to further explore its potential role in dental pain management.

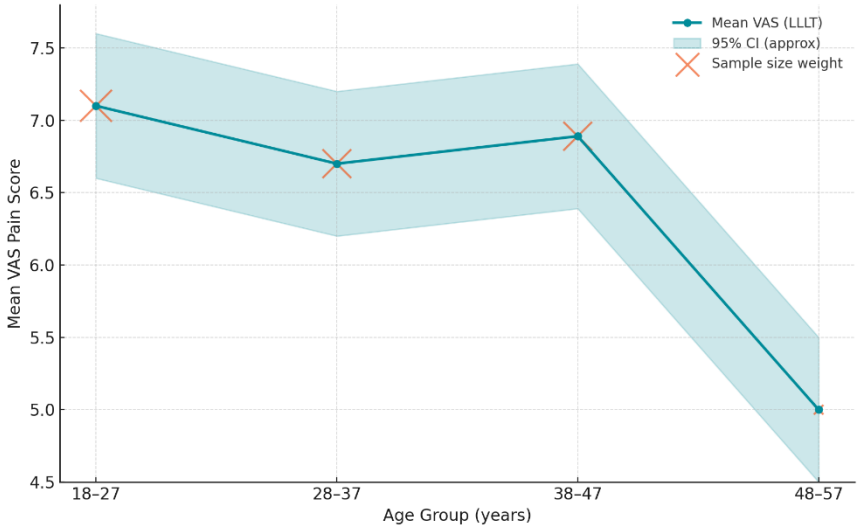

Figure 1 Pain Intensity with LLLT Across Age Groups

Visualization demonstrates the relationship between age and reported pain intensity following low-level laser therapy (LLLT) before anesthetic injection. The line trend reveals that younger patients (18–27 years) experienced the highest pain intensity (mean VAS ≈ 7.10), followed by those aged 38–47 years (≈ 6.89) and 28–37 years (≈ 6.70), while the oldest group (48–57 years) reported the lowest pain level (VAS = 5.00).

Figure 2 Age-wise pain severity shows persistent moderate-to-severe pain, slightly lower in older adults.

Bubble sizes, proportional to group sample sizes, emphasize that most data originated from younger cohorts. The declining slope with increasing age suggests an inverse association between age and pain perception, indicating that older adults may derive slightly greater analgesic benefit from LLLT. However, the wide confidence range in the smallest age group underscores variability and limited statistical power, highlighting the need for larger stratified samples to validate age-related effects on LLLT efficacy.

The paired graphs illustrate the distribution of pain severity across age categories with and without low-level laser therapy (LLLT) prior to local anesthetic injection, highlighting patterns in patient response. In the LLLT group, severe pain remained the most frequently reported category in younger adults (18–27 years: n=7; 28–37 years: n=4; 38–47 years: n=6), while moderate pain responses were less frequent across all ages, and "worst" pain was rare, occurring only once in the 28–37 age group. Interestingly, the oldest patients (48–57 years) reported exclusively moderate pain (n=1), suggesting a potential age-related decline in pain perception even with laser pre-treatment. In contrast, the control group (without LLLT) demonstrated a higher prevalence of moderate pain in younger patients (18–27 years: n=6; 28–37 years: n=5), with severe pain most frequent in the 38–47 group (n=5). A small number of participants reported "worst" pain in all age groups except the oldest, and no participants in the 48–57 group reported severe or worst pain. Overall, both graphs reveal that LLLT did not eliminate pain, with severe pain persisting across all age groups, but they also hint at reduced pain severity and fewer "worst" pain reports among older adults, indicating that age may modulate pain response more significantly than the intervention itself.

DISCUSSION

Laser-assisted analgesia has gained increasing attention in dentistry as a potential adjunctive tool to improve patient comfort during invasive procedures, particularly injection administration. In this randomized controlled split-mouth trial, however, pre-treatment with low-level laser therapy (LLLT) did not produce a statistically significant reduction in injection-related pain compared with standard care. The mean VAS scores in both the intervention and control groups remained in the moderate range, and the small numerical difference between them lacked clinical significance. These findings align with previous research reporting inconsistent analgesic outcomes for LLLT in similar contexts (18,19).

Several possible explanations may account for the lack of significant pain reduction observed. First, laser wavelength, power density, and application duration are critical determinants of photobiomodulation efficacy, and suboptimal parameter selection could diminish its analgesic effects. While the 635 nm wavelength used in this study falls within the therapeutic range, its shallow tissue penetration may have limited its interaction with deeper nociceptors and peripheral nerves (20). Second, the timing of LLLT relative to injection might influence efficacy. Some studies suggest that repeated preconditioning or post-procedural irradiation enhances outcomes, while single-dose pre-treatment may be insufficient to achieve significant neuromodulation (21). Additionally, the split-mouth design, while effective in controlling inter-individual variability, may have introduced a carry-over effect if systemic or central sensitization occurred after the first injection, potentially reducing observable differences between sides.

Our findings are consistent with those of Uçar et al., who reported no significant reduction in injection pain among pediatric patients pretreated with diode laser therapy (22). Similarly, Andrade et al. observed no analgesic benefit of LLLT in patients undergoing root canal retreatment (18). These null results contrast with studies by Jagtap et al. and Sharifi et al., which demonstrated significant pain reduction when LLLT was applied prior to anesthetic injection (17,23). Such discrepancies likely reflect heterogeneity in study populations, laser dosimetry, methodological designs, and pain assessment timing. In particular, Jagtap's trial applied laser parameters with higher energy density, while Sharifi's work involved a different anatomical site and infiltration technique — factors that can critically influence pain modulation outcomes.

Beyond treatment efficacy, this study revealed secondary findings with clinical relevance. Female participants reported consistently higher pain scores than males in both treatment arms, a trend supported by previous research suggesting that hormonal fluctuations, psychosocial factors, and heightened pain sensitivity may contribute to sex-related differences in nociception (24). Age also appeared to influence pain perception, with older patients reporting lower VAS scores following LLLT. This pattern may reflect age-related changes in peripheral nerve function or altered central pain processing, though the small sample size limits definitive conclusions. These demographic variations underscore the importance of individualized pain management strategies and warrant targeted exploration in future research.

Methodologically, the trial's design strengthened internal validity by using a split-mouth approach and standardized procedural techniques, thereby reducing confounding from patient-level variables. However, the limited sample size, non-probability sampling, and single-blind design restricted statistical power and generalizability. Furthermore, pain was assessed only immediately after injection, precluding evaluation of longer-term analgesic or anti-inflammatory effects that LLLT may exert post-procedure. Future investigations should consider larger, multicenter randomized trials with stratified recruitment by age and gender, optimized laser parameters, and multiple dosing regimens to elucidate the full therapeutic potential of photobiomodulation in injection-related pain management.

From a clinical perspective, the current results suggest that while LLLT is a safe, feasible, and non-invasive adjunct, its use solely for reducing injection-site pain may offer limited benefit under standard conditions. Nonetheless, its demonstrated efficacy in other dental applications — such as enhancing tissue healing, modulating inflammation, and improving postoperative comfort — supports its continued integration into comprehensive patient care protocols. Its potential synergistic role alongside pharmacological anesthesia or behavioral interventions should also be explored, as multimodal approaches may yield more meaningful analgesic outcomes.

In summary, the findings of this study contribute to the growing body of evidence that the analgesic effectiveness of LLLT in reducing acute injection-related pain remains inconsistent and context-dependent. By addressing methodological limitations and refining clinical application protocols, future research can better define the patient populations and procedural conditions under which LLLT may achieve optimal clinical utility.

CONCLUSION

The present study demonstrated that pre-treatment with low-level laser therapy did not produce a statistically significant reduction in pain intensity associated with local anesthetic injection during endodontic procedures. Pain scores in both the intervention and control groups remained in the moderate range, indicating that LLLT, under the parameters applied in this trial, does not substantially alter the immediate nociceptive response to needle insertion. Gender- and age-related trends were observed, with female participants consistently reporting higher pain scores and older patients demonstrating slightly lower pain perceptions, suggesting that individual patient factors may influence analgesic outcomes.

While the findings do not support the routine use of LLLT as a standalone analgesic adjunct for injection-related pain, the therapy remains a promising non-invasive modality with broader clinical applications. Its potential efficacy may depend on specific laser parameters, dosing protocols, and patient characteristics. Larger, adequately powered randomized controlled trials with optimized treatment protocols, longer follow-up periods, and stratified analyses are warranted to clarify the clinical utility of LLLT and explore its role as part of a multimodal pain management strategy in dental practice.

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