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Postoperative Quality of Life Following Conventional Endodontic Intracanal Irrigation Compared with Laser-Activated Irrigation: A Randomized Clinical Study

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Abstract

Objective: The aim of this randomized clinical study was to evaluate the effect of laser-activated irrigation using a photon-induced photoacoustic streaming (PIPS) technique on postoperative pain following completion of root canal obturation.
Methods: Fifty-six patients were enrolled in this randomized clinical trial. Fifty-six healthy premolars or molars with asymptomatic irreversible pulpitis, symptomatic irreversible pulpitis, or symptomatic pulpal necrosis, with or without apical periodontitis, were mechanically prepared for endodontic treatment and divided into two groups. Patients were randomly allocated to treatment groups. In the positive control group G1, the final irrigation with 2 cc of 5.25% sodium hypochlorite (NaOCl) was achieved using a 27G needle, introduced into the canal to a distance of 5 mm from the predetermined working length. In the experimental group G2, the root canals were irrigated with 17% ethyldiamine tetric acid (EDTA) and 5.25% NaOCl following the PIPS protocol, using an Er:YAG 2940 nm laser (LightWalker ATS®; Fotona, Slovenia) with a 600 μm diameter tip and operating parameters of 20 mJ per pulse, 15 Hz frequency, 0.3 W average power, and a 50-μs pulse duration. Postoperatively, the patients were advised to take a minor analgesic (ibuprofen 400 mg) in the event of pain perception. Postoperative pain levels were assessed after 24, 48, and 72 h and 7 days through the use of a Visual Analogue Scale questionnaire, completed by each patient. Data were analyzed using Kolmogorov–Smirnov, Fisher Exact, Chi square, Mann–Whitney test, and Friedman's test. The level of significance was set at $\alpha = 0.05$.
Results: There was no significant difference between the laser-irradiated group and the control group ($p < 0.5$). Laser activation of irrigating solutions did not increase postoperative pain.
Conclusions: The outcome of this investigation indicated that PIPS was as effective as conventional irrigation in relation to postoperative pain, making this activation technique interesting to use for supplementary root canal disinfection.

Keywords: debris, canal cleaning, irrigating solutions, laser activation, PIPS, postoperative pain

Introduction

The main purpose of endodontic treatment is the effective shaping, cleaning, decontamination, and/or elimination of the dentinal smear layer so that the canal can be effectively filled, thus minimizing the possibility of reinfection. The smear layer contains bacteria, their by-products, and necrotic tissue; bacteria may survive and multiply and can proliferate into the dentinal tubules, which may serve as a reservoir of microbial irritants.[1] Traditional endodontic techniques use mechanical instrumentation and chemical irrigation for shaping, cleaning, and decontamination of the endodontic system.

The effectiveness of debridement and bacterial elimination of the entire intraradicular space may be limited, due primarily to the anatomical complexity of the canal system and the limited penetration of the irrigating solutions within the lateral and apical ramifications of the canal. These ramifications often have differing dimensions and complex morphology as they split from the main canal, thus compromising complete root canal debridement.[2]

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Although the limitation in postoperative pain may be regarded as consequent upon the success of endodontic treatment, many clinical studies have reported varying degrees of pain, ranging from 25% to 40%.[3]

The etiology of postendodontic pain is linked primarily to microbial injury to the periapical area, due to the extrusion of irrigants during canal instrumentation. The development of a variable sensation—ranging from discomfort to frank pain—is one of the most common postendodontic complications. Many studies have been conducted to identify which factors are associated with this complication, and others have tried to find preventive measures that may be applied. Unfortunately, the results have been variable.[4]

Other possible causes of discomfort may include the result of insufficient cleaning of the canal system complex and expulsion of debris beyond the apex.[5,6]

Laser coherent photonic energy use has been recently proposed as an adjunct to conventional endodontic therapy. Different methods of application have been adopted to enhance the decontamination of the endodontic system through the use of near infrared wavelengths, such as diode-based lasers and the Nd:YAG laser (Neodymium-doped Yttrium Aluminum Garnet),[7] and also to increase the cleaning capacity and removal of debris and smear layer from the root canals using the Erbium laser family (Er:YAG—Erbium-doped Yttrium Aluminum Garnet and Er,Cr:YSGG—Erbium, Chromium-doped Yttrium Scandium Gallium Garnet).[3–8]

Different irrigation techniques have been developed for such application. Laser-activated irrigation is based on the activation of liquid irrigants by medium-infrared lasers (2780 nm Er,Cr:YSGG and 2940 nm Er:YAG). Two different techniques are suggested: the laser delivery tip is placed inside the root canal or located inside the pulp chamber only (''PIPS'' technique). Photon-induced photoacoustic streaming (PIPS) technique includes the Er:YAG laser. It uses a radial firing tip, stripped of outer amide coating at its distal end to allow a lateral emission of laser energy into intracanal irrigation liquids.

Laser emission energy of 20 mJ per pulse—below the ablation threshold of water—is delivered in a very short time (pulse duration of 50 μs) and produces a corresponding high-peak power value of 400 W, causing an explosion–implosion phenomenon within the irrigant solution. This results in a strong photoacoustic shock wave that generates irrigant streaming three-dimensionally throughout the entire root canal system.[9] Compared with other techniques, many studies reported better cleaning and more efficient smear layer removal using the PIPS technique.[10,11] Nevertheless, the possibility of decreasing the amount of debris expelled beyond the apex when using laser-activated irrigation still has no clear evaluation, and therefore, the reduction of postoperative pain when using PIPS remains debatable.

The purpose of this study was to evaluate the impact of the final activation of the irrigating solution using a PIPS protocol on the postoperative pain following endodontic treatment of teeth with pulpal and periradicular diseases.

Materials and Methods

This randomized clinical study was conducted in the endodontic department at the dental health center of the Saint Joseph University, Beirut. It followed the CONSORT guidelines and was approved by the University Ethics Committee and Review Board (reference no.: USJ-2016-34).

Sample selection

Fifty-six healthy patients having their premolar or molar teeth diagnosed with asymptomatic irreversible pulpitis, symptomatic irreversible pulpitis, or symptomatic pulpal necrosis with or without apical periodontitis (symptomatic or asymptomatic) were eligible for the study. A consent form was read and signed by all the patients enrolled in the study according to the principles of the Helsinki Declaration (WMA 2000).

Randomization

Only one clinician evaluated all patients. Following examination to satisfy the determinant criteria for inclusion in the study, the patients were randomly assigned to one of two groups. A random number table, and the endodontic treatment was carried out by an (experienced) clinician whose endodontic technique was calibrated for consistency. All treatments were carried out by this clinician to eliminate or minimize interpersonal variability. The study sample included 56 patients of both sexes, ranging from 19 to 73 years old. Patients were randomly assigned to two balanced groups: in the first group (G1), a final rinse with 5.25% of sodium hypochlorite solution (NaOCl) was done after shaping, using a 27G syringe at 5 mm from the working length. In the second group (G2), a final rinse with 5.25% of NaOCl[11] was completed using PIPS activation (as recommended by the manufacturer).

Root canal preparation

In each treatment, an access cavity was prepared using tapered diamond burs in a high-speed handpiece with water cooling and finished with an ultrasonic device (START X nos. 1 and 3; Dentsply DeTrey, Mantova, Switzerland) under microscope control (Zeiss, Oberkochen, Germany); rubber dam was placed and copious irrigation with 3% NaOCl during canal preparation and a final flush with sterile distilled water were performed.[12]

Shaping and irrigation protocol

All root canal treatments were performed in one session according to the following protocol: access cavity and localization of canal entry were confirmed using a DG16 probe, followed by rubber dam isolation. Using a stainless steel ISO 10 C-PILOT File (VDW, Munich, Germany), a glide path to the working length was created. Continuous irrigation of NaOCl (3%) using a 2 cc syringe and 27G needle was maintained. Root canals were prepared using Reciproc (VDW, Munich, Germany): a Reciproc R25 (25/0.08) unit was used with the reciprocating settings of VDW motor (VDW, Munich, Germany) until the working length was reached through slight movements of back and forth vertical pecking motion.[13]

Final irrigation

In G1, each canal received 10 mL of NaOCl (5.25%) followed by 5 mL of 17% ethyldiamine tetric acid (EDTA) for 3 min and a final rinse with distilled water.

In G2, a laser-activated irrigation PIPS protocol was applied for final flushing using a solid-state free-running-pulse 2940 nm Er:YAG laser (LightWalker ATS®; Fotona,

Table 1. Laser Parameters

Intrinsic properties		*Adjustable parameters*		*Calculated parameters*	
Laser manufacturer	Fotona	Pulse width	50 μs	Average power	0.30 W
Model	LightWalker	Energy per pulse	20 mJ	Peak power	400 W
Typo	Er:YAG	Pulse repetition rate	15 pps	Tip area	0.0028 cm^2
Wavelength nm	2940	Tip diameter	600 μm	Spot diameter at tissue	0.0600 cm
Delivery system	Contact tip	Tip-to-tissue	0 mm	Spot area at tissue	0.0028 cm^2
Emission mode	Free running pulse	Beam divergence	12.7 degrees	Peak power density	141,471 W/cm^2
Energy distribution	Gaussian	Water	0 mL/min	Average power density	106 W/cm^2
		Air	None	Total energy	9 J
		Length of treatment	30 sec	Energy density with movement	3183 J/cm^2
		Speed of movement	0 mm/sec	Average energy density	3183 J/cm^2

Slovenia). All laser safety measurements were respected and followed. The power settings of the PIPS disinfection were 20 mJ, 15 Hz, 50 μs pulse width. A radial stripped PIPS tip of 600 μm diameter and 9 mm length (600/9) was placed inside the pulp chamber and kept stationary for 30 sec at each application. The tip was attached to a 90° handpiece with integrated air/water nozzle (H14-N). Water and air on the laser system were turned off. The laser photonic energy was delivered through an articulated-arm delivery system (Optoflex®). The power density applied was 107 W/cm^2, and the average energy density was 3183 J/cm^2 (Table 1). During laser activation, the tip was submerged in irrigant that was continuously applied by syringe (double-side vent Luer Lock 27-G needle). The irrigation protocol was as follows[14]:

1. Three milliliters of EDTA, PIPS activation for 30 sec, and a rest for 30 sec.
2. Three milliliters of distilled water, PIPS activation for 30 sec, and a rest for 30 sec.
3. Three cycles of 3 mL of 5.25%[10] NaOCl, PIPS activation for 30 sec, and a rest of 30 sec between each cycle.
4. Three milliliters of distilled water and PIPS activation for 30 sec.

Obturation

Specimens in both groups were obturated in the same session with nonstandard medium gutta-percha cones and the continuous wave condensation technique with System B and medium plugger (Analytic Technologies, Redmond, WA) at 220°C and Pulp Canal Sealer EWT (Kerr, Orange, CA). They were backfilled with Obtura (Spartan) gutta-percha gun and the access cavity sealed with glass ionomer cement, Ketac Cem (3M ESPE). An appointment for percussion test was fixed after 7 days.

No postoperative systemic medication was prescribed; patients were advised to take a minor analgesic (400 mg of ibuprofen) in case of pain perception and to record such event. Ibuprofen has a dose-dependent activity and its analgesic effect disappears completely after 8 h.[15]

Patient's questionnaire

Each participant undertook (self-completed) a questionnaire for evaluation of pain perception [Visual Analogue Scale (VAS)], determination of frequency of use of analgesics, and the quality of life after the endodontic treatment. The questionnaire was filled at 24, 48, and 72 h and 7 days postoperatively. The pain was graded on a scale of 0–10; from absent, to mild (no analgesic needed), to moderate (relieved by analgesic), to severe (not relieved by analgesic). The questionnaire information was collected via phone call by an anonymous nonclinical support staff member. Patient assignment by grouping was not known to the assistant, and the questionnaire was completed and returned a week later by the patient. Tooth percussion and palpation tests were recorded clinically on day 7.

The results of clinical evaluation and questionnaire data were compared with the results of the clinical examination and forwarded for statistical evaluation.

Statistical analysis

The null hypothesis tested was that postoperative VAS score when using PIPS is not significantly different to postoperative VAS score when using conventional irrigation.

Statistical analysis was performed using a software program (SPSS for Windows; Version 18.0, Chicago, IL). The level of significance was set at $\alpha = 0.05$. Normality distribution was assessed using the Kolmogorov–Smirnov test. Fisher's exact test and chi-square test were used to compare percentages. The Mann–Whitney test was performed to compare VAS between the two methods of irrigation for each evaluation day. The Friedman test was used to compare the VAS in each group within the time frame (Fig. 1).

Results

Across the entire patient cohort, the status of each pulp was determined as healthy (26.8%), presented inflammation (37.5%), or necrosis (25%). The distribution of pulp status was not significantly different between groups before the

Table 2. Visual Analogue Scale Score Within Time for Each Group

VAS	*Syringe G1* (N = *31*)	*Laser G2* (N = *25*)
D0	1.12 ± 1.943	0.71 ± 1.296
D1	1.32 ± 1.773	1.32 ± 1.869
D2	0.88 ± 1.563	0.97 ± 1.663
D3	0.52 ± 1.085	0.61 ± 1.453
D4	0.32 ± 0.852	0.23 ± 0.617
D5	0.12 ± 0.600	0.10 ± 0.396
D6	0.00 ± 0.00	0.00 ± 0.00
D7	0.00 ± 0.00	0.00 ± 0.00

VAS, Visual Analogue Scale; D, day.

Table 3. Percussion at Day 7 in Different Groups

Percussion at D7	*Syringe G1* (N=*31*) (%)	*Laser G2* (N=*25*) (%)	*Total* (%)
Positive	12 (38.7)	13 (52.0)	25 (44.6)
Negative	19 (61.3)	12 (48.0)	31 (55.4)

endodontic treatment ($p=0.629$). The mean VAS scores of pain perception in each group are presented in Table 2.

For G1, the VAS score did not significantly change between D0 (Day 0) and D1 ($p=0.739$). The VAS score decreased significantly between D1 and D2 ($p=0.002$), D2 and D3 ($p=0.020$), D3 and D4 ($p=0.025$), and D4 and D5 ($p=0.039$). However, the pain score did not significantly change between D5, D6, and D7 ($p=0.368$). For G2, the VAS score did not significantly change between D0 and D1 ($p=0.593$). The VAS score decreased significantly between D1 and D2 ($p=0.003$), D2 and D3 ($p=0.008$), D3 and D4 ($p=0.046$), and D4 and D5 ($p=0.015$). However, the pain score did not significantly change between D5, D6, and D7 ($p=0.135$). It was noticed that the VAS pain was not significantly different between the two groups on the day of endodontic treatment, D1 ($p=0.812$), D2 ($p=0.978$), D3 ($p=0.949$), D4 ($p=0.949$), D5 ($p=0.720$), D6 ($p=1.000$), and D7 ($p=1.000$).

At D7, 52% of the teeth irrigated with laser and 38.7% of teeth irrigated without activation had a positive response; however, the difference was not significant between groups ($p=0.320$) (Table 3).

Pain during mastication occurred in 16% of participants in G2 and in 22.6% in G1; the difference was not significant ($p=0.737$). Four percent of participants in the PIPS group (G2) and 9.7% of participants in G1 took analgesic or NSAIDs (nonsteroidal anti-inflammatory drugs) after the root canal treatment; the difference was not significant ($p=0.620$).

Discussion

Minimizing postoperative pain in endodontic therapy is one of the subjects that have been widely discussed in the literature, making this topic a main issue that is debated for every innovative endodontic technology. In this context, PIPS is defined as a freshly introduced treatment procedure that promises high success; from this perspective, it deserves to be observed through a wide range of clinical criteria and this constitutes the purpose of our study.

In the present study, seeking to minimize all possible causes of postoperative discomfort was considered imperative. Therefore, sample selection was restricted to patients in good general health and who needed an endodontic treatment on any premolar or molar. Teeth with large apical foramina were excluded from the study, in recognition of previous research articles stating that the enlargement of the apical foramen during root canal treatment increased the incidence and intensity of postoperative pain.[16] Pulpal diseases were not included as criteria in the study considering that the prevalence of postoperative pain did not differ between vital and nonvital teeth,[4] but the distribution of the pulp status before the endodontic treatment was not significantly different between the two groups.

Other studies showed that the endodontic failures were mostly observed in maxillary and mandibular first molars as these are the first teeth to erupt, so more prone to caries and pulpal pathology and are subjected more often to endodontic treatment[17] and due to the complex morphology and anatomy of their root canals. Curved, narrow, and the presence of additional root canals make these teeth difficult to treat, and in need of additional cleaning method,[17] thus explaining our choice for bicuspids and molars inclusion.

Locating any extra canals was achieved under the dental operating microscope and adopting and following a meticulous aseptic protocol was mandatory to avoid the risk of residual microorganism exacerbation or to introduce the bacteria into the periradicular tissues. Our approach to endodontics was to complete the required therapy in a single visit since many clinical trials provided evidence of the reliability of single-visit endodontics.[18–20] Based on studies concluding that occlusal reduction helped in reducing postoperative pain in patients undergoing endodontic treatment of posterior teeth,[21] occlusal reduction was performed on all teeth included in the study. Using a unified instrument and protocol for all patients limits the difference of extruded debris and noncleaned zones between all teeth. Topcu et al. stated that the debridement efficiency of Reciproc files was ~91.21%.[22] In the study conducted by Tinoco et al., the quantification of the mean value of extruded debris and bacteria was significantly lower with the reciprocating single-file systems than the conventional multifile rotary system.[23] According to that the Reciproc file was considered the instrument of choice in this study. Pain is a subjective parameter that is difficult to quantify. Most clinical studies used a numerical scale to measure it. The scale is considered a reliable and reproducible tool for clinical pain trials.[24–26]

In the current study, pain intensity gradually decreased in both groups. Being a common postoperative complication

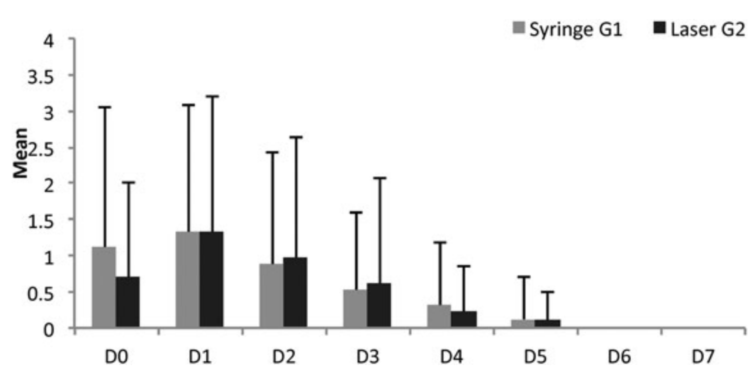

FIG. 1. VAS score within time for each group. VAS, Visual Analogue Scale.

after debridement, pain regression recorded day after day was logical and expected. No patient reported any increase in pain nor any other symptoms or complications such as postoperative swelling or paresthesia. These facts underline and reflect the atraumatic treatment protocols and the level of care that was provided.

It is very difficult to differentiate which factor causes pain and it is difficult to determine whether single or multiple factors elicit pain. Many studies linked the apical extrusion of irrigating solution in root canal treatment to postoperative complications, such as periapical tissue damage, burning sensation, and pain.[27,28] Laser-assisted irrigation is a very delicate technique that may be associated with apical irrigant extrusion. PIPS technique produces a high-peak power of 400 W, causing cavitation phenomena within the irrigant solution along the length of the root canal. The result is a strong photoacoustic shock wave that induces irrigant streaming three-dimensionally throughout the entire root canal system.

However, Arslan et al. reported that PIPS activation of irrigation solutions resulted in similar apical extrusion compared with conventional irrigation and ultrasonic irrigation,[28] and Snjaric reported that all LAI and PIPS regimens showed lower apical extrusion compared with conventional irrigation methods.[29] The photoacoustic streaming produced with applied energy of 20 mJ (subablative to both water and host tissue) in a very short pulse width of 50 μs did not generate any direct laser irradiation on the dentin and consequently unwanted thermal effects.[9–30] These observations were reflected in our study by the absence of any postoperative complications or unbearable pain following the laser procedure.

In our investigation, pain during mastication occurred in 16% of G2 participants, whereas 22.6% of G1 participants felt pain; these outcomes exhibited a slight advantage for the PIPS protocol but statistically the difference was not significant ($p = 0.737$). This result was confirmed by the fact that 4% of participants in the PIPS group had to use analgesics after the root canal treatment in comparison to 9.7% of participants in the G1. In addition, percussion test at day 7 was positive in 52% of the G2 teeth and 38.7% of G1, resulting in a little numeric gain using the PIPS activation but statistically insignificant.

In our study, we used 56 teeth divided in the two groups, and therefore, the number of cases involved was relatively small. Despite this limited sample size, the result of our study confirms some data from previous studies evoking similar outcomes between PIPS and conventional irrigation protocols.[28–31] In addition, to the best of our knowledge, it is the first time that a postoperative pain evaluation following PIPS irrigation activation has been conducted in vivo.

In keeping with other authors in any in vivo model, the presence of periapical tissues (periodontal and granulation) and residual pulp tissues may serve as a physical barrier that limits apical extrusion of debris and irrigant.[32] That could present an explanation of the statistical insignificance of the results.

Conclusions

Within the limitations of this study, the two irrigation protocols gave satisfactory results without any significant difference noticed with PIPS as a final irrigation technique. PIPS and conventional irrigation had similar outcomes related to postoperative pain. The results of this investigation indicate that PIPS was as effective as conventional irrigation concerning the reduction of postoperative pain, making it interesting to use for supplementary root canal disinfection. This in vivo study may be beneficial for further evaluation with larger number of patients, teeth with open or large foramina with periapical lesions, and advanced laser applications.

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Author Disclosure Statement

No competing financial interests exist.

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