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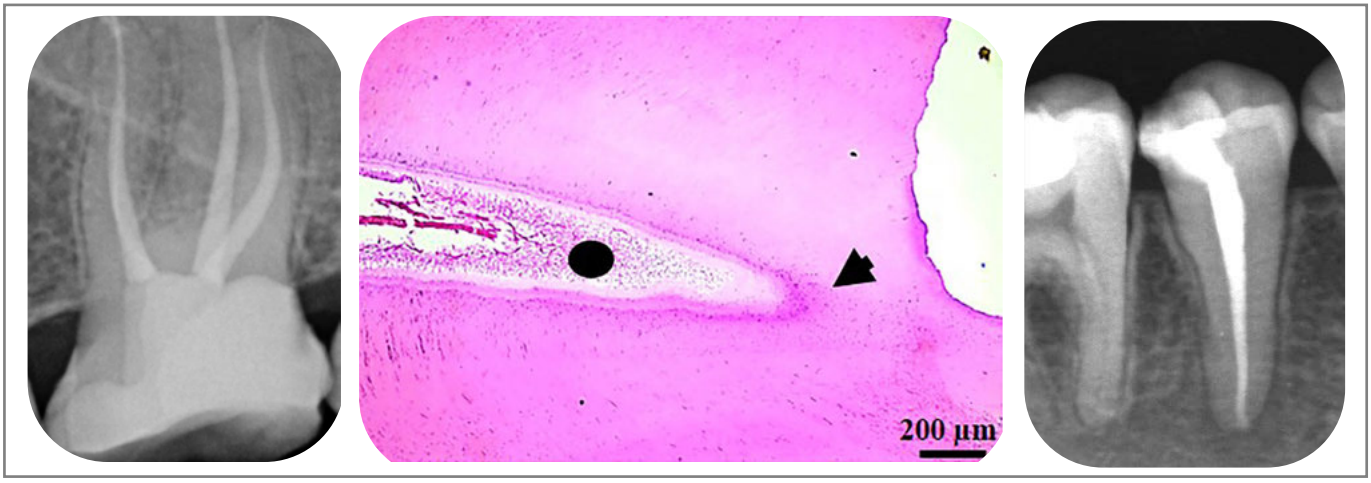

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REGISTRATION Court of Milan n° 89, 3 March 2009

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Editorial

Endodontics: A 40-year journey through evolution, innovation and time

Sandro Rengo
Editor-in-Chief
Giornale Italiano
di Endodonzia
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There are disciplines that advance slowly, and then there is endodontics - a clinical science that over the last 40 years included a profound and rapid evolution that has completely transformed the profession's identity. Today, at the end of a long academic and clinical journey, I look back with gratitude and wonder: what was considered cutting-edge a generation ago now appears almost rudimentary.

When I first began to take my steps in this discipline, biological concepts were already solid, but the instruments were limited and technology was more a desire than a certainty. Endodontics was art, manual skill and clinical sensitivity refined through experience. Materials were few, techniques often simple and the risk of failure was a constant partner.

Then came the time of innovation — not sudden, but persistent. First, nickel-titanium rotary instrumentation systems, which transformed endodontic biomechanics, then increasingly effective irrigants and ultrasonic and sonic activation systems capable of reaching and disinfecting spaces once thought inaccessible. Moreover, the rubber dam that advanced from a virtuous optional tool to an indispensable standard and digital radiology and CBCT which redefined our ability to prevent, plan and assess. Finally, the advent of bioceramic sealers, materials that have crossed the boundaries of biocompatibility and sealing ability, ensuring prognoses once unimaginable.

Of course, innovation is not only measured through devices or materials: it is also a cultural evolution. We moved from a technical approach to one biologically-related, conservative and predictable.

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We learned the importance of isolation, prevention and early diagnosis, and we discovered that treating a tooth means defending a part of the patient's quality of life rather than simply solving a problem.
Today, as this academic journey concludes, what remains is not only the memory of what has changed, but an inexhaustible enthusiasm for what is still to come. Endodontics has never stop evolving and it will continue with the advent of artificial intelligence, nanotechnology and pulp regeneration procedures as promising new revolution.
As I pass on a legacy of experience, I welcome the future with confidence, trusting in the hands of new generations, aware that the essence of endodontics does not lie in technology itself, but in the deeply human capacity to learn, improve and heal.

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ORIGINAL ARTICLE

Evaluation of postoperative pain in endodontic treatments, with sodium hypochlorite solution and gel as an auxiliary chemical substance

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ABSTRACT

Introduction: *Endodontic treatment aims to clean and fill the root canals to maintain periapical health and alleviate pain, with postoperative pain influenced by multiple clinical factors. Sodium hypochlorite irrigation, although effective, can cause debris extrusion, with gel being an alternative that reduces this risk while maintaining antimicrobial efficiency.*
Objective: *This study aimed to assess postoperative pain incidence in asymptomatic upper premolars with pulp necrosis and chronic periapical lesions undergoing endodontic intervention.*
Materials and Methods: *Sixty-six patients were divided into three groups (n=22): Group SHG/SS used 3% sodium hypochlorite (SH) gel and saline solution (SS). Group SHG/S employed 3% SH gel and 2.5% SH solution (S). Group SHS/S used 2.5% SH solution for both purposes. Procedures lasted 40 to 60 minutes, conducted by the same operator in a single session. Clinical data was recorded, and postoperative pain was evaluated at 24, 48, and 72 hours using a modified Numeric Rating Scale. Statistical analysis was applied to the collected data.*
Results: *Within the first 24 hours, auxiliary chemical substances significantly impacted postoperative pain ($p = 0.021$). SHS/S showed lower pain scores compared to SHG/S, while SHG/SS scores were intermediate. At 48 hours ($p = 0.548$) and 72 hours ($p = 0.127$), postoperative pain did not show statistical significance. SHS/S and SHG/SS did not significantly influence postoperative pain, but SHG/S had an impact.*
Conclusions: *Postoperative pain did not significantly differ at 48 and 72 hours. SHG/S and SHG/SS did not markedly influence postoperative pain. Notably, the use of 3% SH gel with 2.5% SH solution increased postoperative pain levels.*
Clinical Relevance: *The application of 3% sodium hypochlorite gel used as an auxiliary chemical associated with the 2.5% sodium hypochlorite solution used as an irrigant had an impact on postoperative pain, which resulted in higher levels of post-operative pain.*

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KEYWORDS *Chemical Substances, Endodontic Treatments, Gel, Postoperative Pain, Sodium Hypochlorite.*

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Introduction

Endodontic treatment Endodontic treatment aims to perform cleaning, shaping, and obturation of the root canal systems, with the goal of achieving and maintaining the health of the periapical tissues, as well as eliminating signs and symptoms associated with pain (1). In the postoperative period, pain is considered an undesirable perception, since its resolution constitutes one of the criteria for success in pulp therapy (2). Pain is frequently regarded as a negative experience, and its cessation represents an important indicator of success in endodontic treatment (3,4). Apical extrusion of infected debris into the periradicular tissues—including dentinal fragments, pulp tissue remnants, bacteria, and irrigating solutions—may occur during root canal instrumentation, triggering periapical inflammatory response and postoperative pain (5). As emphasized by Mahalakshmi, "postoperative pain results from a synergistic effect of the aforementioned causes and cannot be exclusively attributed to a single definitive cause" (6). During endodontic treatment, the irrigation stage is of fundamental importance, given that the instruments employed are unable to contact all canal walls or reach accessory or lateral canals. Thus, irrigation contributes to reducing friction between the instrument and dentin, promotes cooling of the file-tooth interface, and exerts antimicrobial and antibiofilm effects (7).
The apical third is recognized as a critical zone, where bacterial presence in the apical foramen, often organized in colonies, can extend into the extraradicular region (8). This characteristic poses challenges regarding the efficacy and safety of apical irrigation (7), making this step essential for the success of endodontic treatment (9). Sodium hypochlorite (NaOCl), at various concentrations, is the most widely used irrigant in endodontics due to its antimicrobial properties and ability to dissolve organic tissue (9). Its action consists of hydrolysis and oxidation of cellular proteins, resulting in clinically proven efficacy during biomechanical preparation of the canals (10). However, NaOCl exhibits potential toxicity, being highly irritating to periapical tissues, especially at higher concentrations (9). Its action is not limited to necrotic tissue, as it is a caustic and nonspecific agent, exhibiting cytotoxicity to all cells (10). Studies evaluating the gel form of sodium hypochlorite have reported significantly less debris extrusion compared to the conventional solution. The gel's viscosity restricts its presence to the interior of the root canal, reducing the risk of extrusion and its possible complications, while presenting antimicrobial efficacy comparable to the solution during canal treatment (11). Therefore, the present study aims to evaluate the incidence of postoperative pain in endodontic treatments of asymptomatic maxillary premolars diagnosed with pulp necrosis and chronic apical lesion, using two presentations of sodium hypochlorite: solution and gel. The null hypothesis adopted is that there will be no statistically significant difference between the evaluated groups.

Materials and methods

This was a randomized, prospective, parallel-type clinical trial, where the informed consent form was approved by the Research Ethics Committee of the Faculty of Dentistry, Faculty of Dentistry São Leopoldo Mandic, Campinas, São Paulo, Brazil (Clinical Trial Number CAAE: 43858321.6.0000.5374). This study was conducted in patients who needed endodontic treatment and who were referred to Centro de Especialidade Odontológicas (CEO) in Senhor do Bonfim city, Bahia, Brazil, from January 2021 to December 2022. All patients signed a consent form, informing about the procedure. 66 endodontic treatments of upper first and second premolars were performed. Only first and second premolars were included in this study, with two root canals, with one or two roots, asymptomatic teeth, diagnosed with pulp necrosis, and chronic periapical lesion presence, in one or both roots, performed in a single session, by a single endodontist. Vital teeth, necrotic teeth without injury and premolars with

a single canal, previous endodontic retreatment, teeth with open apex, internal and external root resorption, dental trauma, treatments not completed in a single session or in the procedure time were excluded from the study. between 40 to 60 minutes, and root canals, where it was not possible to patency the apical foramen. Patients with provoked or spontaneous painful symptoms, patients who used analgesic or anti-inflammatory medication in the last 30 days, patients with decompensated systemic diseases, such as heart disease, hypertension and diabetes, and those who refuse to participate in the study. Treatments in which the use of files using the R40 file was required.

Sample calculation

The sample calculation was based on an effect size of 0.185, obtained from pilot study data (n = 6). In order to reach a 80% test power and a 5% significance level, adopting the analysis of variance model for repeated measures, the G*Power 3.1.9.4 program indicated the need for 22 patients for each of the three proposed groups.

Endodontic treatment protocol

The treatment protocol carried out initially consisted of anamnesis, clinical examination, initial radiographic examination, vitality test, diagnosis, treatment planning and execution of endodontic treatment.

All cases were performed in a single session, by a single operator, during a period of 40 to 60 minutes. All patients were previously anesthetized with Lidocaine 2% with adrenaline 1:100,000 (DFL®, Taquara, Rio de Janeiro, Brazil), in the amount of one tube (1.8mL) for each tooth, using a supraperiosteal infiltration technique, through the vestibular and through the palate with a short needle, 30G (Procare, Labor Import Com. Imp. Exp Ltd, Osasco, SP, Brazil). The carious tissue and/or restorations were removed for later surgical access with high-speed diamond burs No. 1014 (KG Sorensen Ind. e Com. Ltda., São Paulo, SP, Brazil), under refrigeration in the treated dental element, following the convenience form with a high-speed diamond bur, n° 3081 (KG Sorensen Ind. e Com. Ltda., São Paulo, SP, Brazil), also under refrigeration.

After absolute isolation, the canal was flooded with 1mL of sodium hypochlorite - with respective presentation of each group and then with a C-Pilot #15 file (VDW, Bayerwaldstrabe, Munich, Germany), in the apparent length of the tooth (4 mm), the conduits were explored, subsequently, the cervical and middle third were instrumented using a Reciproc R25 file (VDW®, Bayerwaldstrabe, Munich, Germany), with 3 movements of penetration and traction of the file from inside the conduit and amplitude of 3 mm at each movement until reaching 4 mm less than the working length (WL). At this time, the conduits were flooded with sodium hypochlorite solution or gel, and every three pecking movements there was irrigation with 5 ml of the auxiliary substance, respectively from each group, using a 10 ml hypodermic syringe (Injex, Ourinhos, São Paulo, Brazil) with 24Gx3/4 -20 mm x 0.55 disposable needles (Labor Import, Osasco, São Paulo, Brazil) under pressure of 1mL/sec. Each time the file was removed from the canal, it was cleaned with sterile gauze. The apical third was explored with a #15 C-Pilot manual file (VDW®, Bayerwaldstraße, Munich, Germany) for progressive decontamination until patency was achieved. The real canal length was defined with an electronic apex locator - VDW GOLD (VDW®, Bayerwaldstraße, Munich, Germany), by withdrawing the patency instrument to the apical binding point. The initial anatomical file was defined by the hand instrument that best fit in the apical foramen, from the patency file (#10 and #15). And then the measurement was established up to the apical foramen (0.0). Afterwards, the instrumentation and modeling of the root canal were carried out with a reciprocating file R25 VDW®, (Bayerwaldstraße, Munich, Germany). The instrument was inserted into the root canal with penetration and traction movements (pecking) with a maximum amplitude of 3 mm each movement, until reaching the WL. 1mL of auxiliary chemical substance from each specific group was introduced into the conduits, and every three pecking

movements, the canal was irrigated with 5 mL of irrigating solution from each group, under pressure, followed by suction.

Irrigation Protocol
The irrigation protocol began with the flooding of the root canal with 1 mL of the designated auxiliary chemical substance—either 2.5% sodium hypochlorite solution or 3% sodium hypochlorite gel, depending on group allocation. Canal instrumentation was performed using Reciproc R25 files (VDW®, Munich, Germany) in a pecking motion with a maximum amplitude of 3 mm. After every three pecking movements, the canal was irrigated with 5 mL of the same assigned irrigant using a 10 mL disposable syringe (Injex®, São Paulo, Brazil) equipped with a 24G x 0.55 mm needle, at a controlled rate of 1 mL/sec. This irrigation sequence was repeated throughout the mechanical instrumentation, ensuring thorough chemical debridement. After reaching the full working length, apical patency was confirmed with a #15 K-file, and real canal length was established using an electronic apex locator (VDW GOLD®). The final irrigation phase consisted of 3 mL of 17% EDTA, delivered in three successive 1 mL portions, each activated with an Easy Clean® plastic tip (EASY, Belo Horizonte, Brazil) in reciprocating motion for 60 seconds per canal. This protocol aimed to optimize smear layer removal and enhance chemical decontamination prior to obturation.

Root canal obturation
With the aid of a silicone cannula (Capillary Tips; Ultradent, South Jordan, Utah, USA) and R25 Reciproc absorbent paper points (VDW, Munich, Bayerwaldstrabe Germany), the root canal was dried and the cone was locked. to 2 mm, short of the WL. For root canal obturation, AH Plus endodontic cement (Dentsplay Maillefer, Chemin du Verger, Ballaigues, Switzerland) was used in conjunction with the single cone obturation technique and hydraulic compression. The gutta-percha cone itself, which had already been disinfected by the auxiliary chemical solution, from each specific group, was used to insert the cement inside the root canal until it was completely filled. After positioning the gutta-percha cone at the locking site, vertical hydraulic compression followed, with a schilder presser foot (Golgran Indústria e Comércio Odontológico, São Caetano do Sul - São Paulo, Brazil). The cervical portion was sealed with temporary obturator cement (Coltosol -Vigodent®, Bonsucesso, Rio de Janeiro, Brazil) and a temporary restoration was performed with glass ionomer cement (Riva ® SDI Lt, Victoria, Australia). Then, the occlusal contacts were checked and adjusted and a final periapical radiograph was obtained.

Postoperative pain assessment
After endodontic intervention, patients received a modified Numerical Rating Scale - NRS (12,13) with numeric values from 0 to 10.

Classified as follows:
Score 1- Represented by 0, on the scale as without pain: the treated tooth has a normal appearance;
Score 2- Represented from 1 to 3, on the scale, as mild pain: the tooth involved hurt slightly for a while, regardless of the duration, but there was no need to take analgesics;
Score 3- Represented from 4 to 6, on the scale, as moderate pain: the involved tooth caused discomfort and/or tolerated pain. Analgesics stopped the pain;
Score 4- Represented from 7 to 9, on the scale as severe pain: the pain caused by the treated tooth had disturbed sleep and required narcotic analgesics;
Score 5- Represented with 10, on the scale, as unbearable pain: the pain caused by the treated tooth, hindered normal activities and sleep. Analgesics had no effect (12,13).

Postoperative pain assessment was performed in 3 periods: 24, 48 and 72 hours. For each period, a pain scale was created to be evaluated. All patients were contacted by a person who did not participate in the experiment. In moderate symptomatology cases, patients were instructed to take medication for pain control, the choice medication was Ibuprofen 400 mg, 1 tablet

Table 1

Medians and minimum and maximum pain values, according to the auxiliary chemical substance and postoperative time.

Auxiliary chemical substance	Postoerative time		
	24 hours	48 hours	72 hours
Sodium hypochlorite 3% gel + saline solution	1 (1; 3) ABa m.r. of this group in relation to other groups: 32.05	1 (1; 3) Aa	1 (1; 1) Aa
Sodium hypochlorite 3% gel + 2.5% solution	2 (1; 3) Bb m.r. of this group in relation to other groups: 41.23 m.r. of this group in 24 hours in relation to other times: 2.43	2 (1; 3) Aab m.r. of this group in 48 hours in relation to other times: 1.89	1 (1; 3) Aa m.r. of this group in 72 hours in relation to other times: 1.68
Sodium hypochlorite 2.5% solution + 2.5% solution	1 (1; 3) Aa m.r. of this group in relation to other groups 27.23	1 (1; 2) Aa	1 (1; 1) Aa

Source: original authorship.

Legend: m.r. = mean of ranks (provided to prove differences by multiple comparison tests when there was a significant effect of chemicals and time). Means followed by distinct capital letters within each column indicate a significant difference between groups. (comparisons within each column). Means followed by distinct lowercase letters indicate a significant difference in pain over time (comparisons within each line).

every 8 hours for up to 3 days, in which they were instructed to make notes on the record of the amount and time of the medicine ingested.
In severe symptomatology cases, patients were instructed to return to the office for control. The operator was always available to the patient for any assistance in any postoperative complications case.

Statistical analysis
The auxiliary chemical effect on postoperative pain over time was assessed using the Kruskal-Wallis and Friedman tests. For multiple comparisons, Student-Newman-Keuls tests were used. As for the pain association with gender and extravasation, Fisher's and G's exact tests were used.
Statistical calculations were performed using the SPSS 23 (SPSS Inc., Chicago, IL, USA) and BioEstat 5.0 programs (Mamirauá Foundation, Belém, Brazil) at a 5% significance level.

Results

At 24 hours, the Kruskal-Wallis test showed that auxiliary chemical substances significantly affected postoperative pain ($p = 0.021$), and when using 2.5% sodium hypochlorite solution and performing irrigation with sodium hypochlorite 2.5% solution, the pain score was statistically lower than that reported by research participants who received the combination of 3% sodium hypochlorite gel and 2.5% sodium hypochlorite solution (Table 1). When applying 3% sodium hypochlorite gel and saline solution, the indicated pain scores were shown to be intermediate, not significantly different from the other groups (Table 1). At 48 hours ($p = 0.548$) and 72 hours ($p = 0.127$), postoperative pain was not statistically influenced by auxiliary chemical substances. For the groups that received 3% sodium hypochlorite gel and saline solution ($p = 0.168$) or 2.5% sodium hypochlorite solution followed by application of 2.5% sodium hypochlorite solution ($p = 0.753$) there was no difference in the pain score when comparing the times 24, 48 and 72 hours (Table 1). On the other hand, for the group that had sodium hypochlo-

Table 2

Absolute (n) and relative (%) frequencies of pain scores, according to gender. For each auxiliary chemical substance and postoperative time.

	Postoperative time			p value
		Male	Female	
24 hours	Sodium hypochlorite 3% gel + saline solution			
	Score 1	8 (80.0%)	6 (50.0%)	0.025
	Score 2	2 (20.0%)	1 (8.3%)	
	Score 3	0 (0.0%)	5 (41.7%)	
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	4 (80.0%)	4 (23.5%)	0.024
	Score 2	1 (20.0%)	4 (23.5%)	
	Score 3	0 (0.0%)	9 (52.9%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	5 (100.0%)	12 (70.6%)	0.394
	Score 2	0 (0.0%)	3 (17.6%)	
	Score 3	0 (0.0%)	1 (5.9%)	
	Score 5	0 (0.0%)	1 (5.9%)	
48 hours	Sodium hypochlorite 3% gel + saline solution			
	Score 1	9 (90.0%)	9 (75.0%)	0.274
	Score 2	1 (10.0%)	1 (8.3%)	
	Score 3	0 (0.0%)	2 (16.7%)	
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	4 (80.0%)	11 (64.7%)	0.554
	Score 2	1 (20.0%)	4 (23.5%)	
	Score 3	0 (0.0%)	2 (11.7%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	5 (100.0%)	13 (76.5%)	0.510
	Score 2	0 (0.0%)	2 (11.8%)	
	Score 3	0 (0.0%)	1 (5.9%)	
	Score 4	0 (0.0%)	1 (5.9%)	
72 hours	Sodium hypochlorite 3% gel + saline solution			
	Score 1	10 (100.0%)	12 (100.0%)	$\frac{3}{4}$
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	5 (100.0%)	13 (76.5%)	0.315
	Score 2	0 (0.0%)	2 (11.8%)	
	Score 3	0 (0.0%)	2 (11.8%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	5 (100.0%)	15 (88.2%)	0.580
	Score 3	0 (0.0%)	1 (5.9%)	
	Score 4	0 (0.0%)	1 (5.9%)	

Source: original authorship.
Legend: The sum may fall short or in excess of 100.0% due to decimal approximations in the % calculation.

rite 3% gel as an auxiliary chemical solution and the irrigator was sodium hypochlorite 2.5% solution, there was a significant difference (p = 0.037) in pain scores at evaluation times (Table 1). For this group, postoperative pain was significantly higher at 24 hours than at the end of 72 hours, while at 48 hours the pain score was intermediate, not differing from that reported by the participants after 24 and 72 hours (Table 1). Whether using 3% sodium hypochlorite gel and saline solution (p = 0.025) or 3% sodium hypochlorite gel and 2.5% sodium hypochlorite solution (p = 0.024), within 24 hours, a significantly higher proportion of men than women had postoperative pain score 1 and only female patients reported pain score 3. When the combination of 2.5% sodium hypochlorite solution and 2.5% sodium hypochlorite solution was used (p = 0.394), there was no significant difference between men and women in postoperative pain terms felt within 24 hours. At 48 and 72 hours, as shown in Table 2, postoperative pain was not significantly affected by participant gender for any of the auxiliary chemical substances. Postoperative pain was also not associated with extravasation, either after 24, 48 or 72 hours and whether 3% sodium hypochlorite gel and saline solution, 3% sodium hypochlorite gel and 2.5% sodium hypochlorite were used solution or 2.5% sodium hypochlorite solution and 2.5% sodium hypochlorite solution (Table 3).

Discussion

The most used irrigant in endodontic treatments is sodium hypochlorite solution, as it has antimicrobial activity, with a wide range of activities against bacteria, gram positive and gram negative, it is antifungal and can destroy the microbial biofilm effectively, in addition to the tissue dissolution capacity (14). Due to its high pH, sodium hypochlorite causes biological damage to bacterial cells and the release of hydroxyl ions irreversibly alters the cytoplasmic membrane integrity (15). Sodium hypochlorite, although a very effective proteolytic solvent, is extremely cytotoxic and for this reason, it must be used judiciously and with caution in endodontic therapy (10). When NaOCl extravasation occurs, severe pain, immediate edema, profuse bleeding in the root canal, possible secondary infection and ecchymosis may occur (16). During mechanical instrumentation and irrigation with auxiliary chemical substances, which do not have biocompatibility, debris and irrigants extrusion may occur, in periradicular tissues, thereby increasing acute inflammation resulting in postoperative pain (9). There are few studies that use sodium hypochlorite gel to assess pain, one of them is Karatas et al. (17), which used teeth without periapical lesions, with vitality and in molars, so this article presents a new study proposal , with necrotic teeth and periapical lesion presence, to assess pain from using the gel. In the present study, the irrigations performed by the SHG/SS, SHG/S, SHS/S groups significantly affected postoperative pain (p = 0.021) in the first 24 hours, which agrees with Graunaite et al. and Machado et al. (18,19), who reported that pain, when it occurs, is more relevant during this period, when it can be justified by the inflammation presence in the periapical region (20), resulting from an immune response to the irrigant and microorganisms present in extruded debris (21). Pain begins within a few hours (22). In the SHS/S group, the postoperative score was lower than that reported by the participants who received irrigation with SHG/S, which is in agreement with the study results by Demenech et al. (23). In their study, no significant difference was observed in the postoperative pain presence during endodontic treatment when using sodium hypochlorite solution as an auxiliary and irrigating chemical substance, across different solution concentrations. The group that used SHG/S caused a higher pain score, among the other irrigations studied, a hypothesis for what happened would be the increase in pressure when inserting the solution to remove the gel, thus causing a greater amount of irrigant, both in the gel form, as in the solution form, in the periradicular tissues, which may have extravasated, causing

Table 3

Absolute (n) and relative (%) frequencies of pain scores, according to the occurrence of extravasation. for each auxiliary chemical substance and postoperative time.

	Postoperative time	Overflow		p value
		Yes	No	
24 hours	Sodium hypochlorite 3% gel + saline solution			
	Score 1	4 (44.4%)	10 (76.9%)	0.291
	Score 2	2 (22.2%)	1 (7.7%)	
	Score 3	3 (33.3%)	2 (15.4%)	
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	4 (44.4%)	4 (30.8%)	0.783
	Score 2	2 (22.2%)	3 (23.1%)	
	Score 3	3 (33.3%)	6 (46.1%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	8 (80.0%)	9 (75.0%)	0.393
	Score 2	1 (10.0%)	2 (16.7%)	
	Score 3	1 (10.0%)	0 (0.0%)	
	Score 5	0 (0.0%)	1 (8.3%)	
48 hours	Sodium hypochlorite 3% gel + saline solution			
	Score 1	7 (77.8%)	11 (84.6%)	0.921
	Score 2	1 (11.1%)	1 (7.7%)	
	Score 3	1 (11.1%)	1 (7.7%)	
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	6 (66.7%)	9 (69.2%)	0.102
	Score 2	1 (11.1%)	4 (30.8%)	
	Score 3	2 (22.2%)	0 (0.0%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	9 (90.0%)	9 (75.0%)	0.459
	Score 2	1 (10.0%)	1 (8.3%)	
	Score 3	0 (0.0%)	1 (8.3%)	
	Score 4	0 (0.0%)	1 (8.3%)	
72 hours	Sodium hypochlorite 3% gel + saline solution			
	Escore 1	9 (100.0%)	13 (100.0%)	¾
	Sodium hypochlorite 3% gel + 2.5% solution			
	Score 1	7 (77.8%)	11 (84.6%)	0.058
	Score 2	0 (0.0%)	2 (15.4%)	
	Score 3	2 (22.2%)	0 (0.0%)	
	Sodium hypochlorite 2.5% solution + 2.5% solution			
	Score 1	10 (100.0%)	10 (83.3%)	1.000
	Score 3	0 (0.0%)	1 (8.3%)	
	Score 4	0 (0.0%)	1 (8.3%)	

Source: original authorship.
Legend: The sum may fall short or in excess of 100.0% due to decimal approximations in the % calculation.

tissue irritation and greater inflammatory responses, this response being one of the main postoperative pain causes (21). Which in this case would become a study limitation, since it is not possible to measure the extruded debris amount. For this group, SHG/S, postoperative pain, was greater at 24 hours -score 2, than at the end of the observation period of the study, 72 hours - score 1, which is in line with Pak's study et al., who report that the pain prevalence decreased substantially over days immediately (24). In the SHG/SS group, the pain score was statistically intermediate, not significantly different from the other groups, which can be explained by the lower extrusion of sodium hypochlorite gel in relation to liquid sodium hypochlorite as an advantage of providing better control and prevent the adverse extravasation effects, especially in the periradicular tissues resulting in the reduction of apical extrusion of debris and irrigant, thus decreasing, the postoperative pain degree, along with the use of saline as an irrigant during system instrumentation (25). In the study by Karatas et al. (17), their results showed that the use of sodium hypochlorite gel caused less pain than the sodium hypochlorite solution use. However, this finding contradicts the present study, in which no difference in pain was observed during the evaluation of these two analyzed groups. As seen in Table 2, the values obtained are related to a study by Arias et al. (3), in which the female sex is associated with more pain compared to the male sex. EDTA was used as a final irrigant due to its chelating ability to remove the smear layer, thereby enhancing the penetration of sealers into dentinal tubules. This contributes to more effective disinfection of the root canal system and improved obturation (Zehnder, 2006). Although the Numerical Rating Scale (NRS) is commonly used to assess pain intensity, it has limitations. It is a unidimensional measure and does not account for the affective or qualitative aspects of pain. Moreover, variations in individual pain perception and interpretation can affect its reliability (Breivik et al., 2008). To the best of our knowledge, this is the first clinical trial comparing postoperative pain following the use of sodium hypochlorite in gel and solution forms in single-session endodontic treatments of necrotic upper premolars with chronic apical lesions. The null hypothesis of this study was rejected due to the presence of a statistical difference in pain between the studied groups. There are limited studies related to sodium hypochlorite gel, both in terms of its effectiveness and its impact on postoperative pain. Further studies are required to comprehensively explore this substance. Within the limitations of this study, it can be concluded that while the SHG/S group induced slightly more pain compared to the other groups, this pain was characterized as mild and diminished over time.

Conclusions

Postoperative pain did not significantly differ at 48 and 72 hours. SHG/S and SHG/SS did not markedly influence postoperative pain. Notably, the use of 3% SH gel with 2.5% SH solution increased postoperative pain levels.

Declarations section

Clinical Relevance

The application of 3% sodium hypochlorite gel used as an auxiliary chemical associated with the 2.5% sodium hypochlorite solution used as an irrigant had an impact on postoperative pain, which resulted in higher levels of post-operative pain.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Approval

Ethical approval was waived by the local Research Ethics Committee of Faculty of Dentistry, Faculty of Dentistry São Leopoldo Mandic, Campinas, São Paulo, Brazil (Ethics approval number CAAE: 43858321.6.0000.5374) in view of a randomized, prospective, parallel-type clinical

trial.

Author contribution

Ribeiro M.M., Queiroz E.L., Soares A.de J. and Frozoni M.R. conceived of the presented idea. Queiroz E.L., Soares A.de J. and Frozoni M.R. verified the analytical methods. Ribeiro M.M and Souza A.P.C. wrote the paper with input from all authors. All authors discussed the results and contributed to the final manuscript.

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ORIGINAL ARTICLE

Comparative Histological Analysis of Novel Bioceramic Materials with Adjunctive Diode Laser Therapy in Vital Pulp Therapy: An Experimental Study

Aim: *This study aimed to histologically evaluate dentin bridge formation and pulpal response following direct pulp capping using either mineral trioxide aggregate (MTA) or Well-Root PT, with and without adjunctive diode laser (DL) application, and to assess the independent effects of DL on pulpal tissues.*
Methodology: *Ninety-six teeth from eight healthy adult mongrel dogs underwent Class V cavity preparation with mechanical pulp exposure. Specimens were randomly assigned to three primary groups: Group I (control) with Teflon disc placement; Group II with MTA; and Group III with Well-Root PT. Each group was further subdivided based on the application or absence of an 810 nm DL pretreatment. Histological samples were collected at 2- and 8-weeks post-treatment to assess pulpal response and dentin bridge formation.*
Results: *Chi-square analysis showed statistically significant differences ($P < 0.05$) between the control group and both MTA and Well-Root PT groups at both time points. No significant differences ($P > 0.05$) were observed between the MTA and Well-Root PT groups, regardless of laser application. Similarly, DL pretreatment did not produce significant differences in histological outcomes within any group.*
Conclusion: *From a clinical perspective, Well-Root PT represents a viable alternative to MTA for direct pulp capping. However, the application of an 810 nm diode laser did not significantly enhance regenerative outcomes for either bioceramic materials.*

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Introduction

The dental pulp is a highly specialized connective tissue composed of nerve fibers, blood vessels, and immune cells, playing a vital role in maintaining pulpal homeostasis and exhibiting a remarkable regenerative capacity in response to external insults (1). This dynamic tissue serves as the vital core of the tooth, responsible for dentin formation, sensory function, and initiating defensive responses to pathological challenges (2).

Vital pulp therapy aims to preserve dental pulp health in cases of deep caries or trauma through pulp capping and pulpotomy techniques (3). It is commonly used in primary and immature permanent teeth and has more recently been applied to symptomatic mature permanent teeth to maintain vitality and potentially avoid root canal treatment, with the primary goal of preserving pulp vitality long term and preventing the need for non-surgical root canal therapy (3, 4). The success of vital pulp therapy depends on the protective material, as well as factors such as how long the pulp is exposed to the mouth, microbial level, root development stage, extent of pulp removal, and the restoration method used (5). Direct pulp capping represents a conservative vital pulp therapy that involves placing biocompatible materials directly onto exposed pulp tissue to prevent bacterial microleakage, stimulate reparative dentinogenesis, and maintain pulp vitality (6, 7). The quality of resulting reparative dentin, including its quantity, structural homogeneity, and presence of organized dentinal tubules, serves as a critical determinant for treatment success (8, 9).

The introduction of bioceramic materials has significantly enhanced the prognosis of direct pulp capping, with mineral trioxide aggregate (MTA) demonstrating high success rates of in clinical studies (10, 11). MTA exhibits superior biocompatibility, excellent sealing properties, and antimicrobial activity (12). However, conventional MTA presents challenges including prolonged setting time, difficult handling characteristics, and technique-sensitive mixing procedures (13, 14).

Recent advances have led to premixed formulations such as Well-Root PT (15). Well-Root PT is a ready-to-use bioceramic paste for root canal repair and pulp capping. It is composed mainly of calcium aluminosilicate, which forms the structural basis of the material and provides its bioactive properties, with zirconium oxide as a radiopacifier (16). The formulation also includes fillers and thickeners to improve consistency and handling. The material sets in the presence of moisture, ensuring chemical stability, and a durable, shrinkage-free seal (17). Moreover, Well-Root PT offer optimal biocompatibility, superior ease of application, reduced setting time, and potent antibacterial effects (18, 19). These next-generation bioceramics demonstrate comparable biological responses to conventional MTA while addressing practical limitations (20, 21).

Diode laser therapy (DL) has emerged as a promising adjunctive treatment that stimulates biological processes at the cellular level (22, 23). The 810 nm wavelength offers an optimal balance for dental applications, providing deep tissue penetration while minimizing thermal side effects, making it well-suited for procedures such as DL therapy (24). Previous studies have demonstrated that 810 nm diode laser irradiation can enhance pulpal healing responses and stimulate reparative dentin formation (25, 26).

Despite growing evidence supporting the individual efficacy of advanced bioceramic materials and DL therapy, limited research has explored their potential synergistic effects in direct pulp capping procedures. To our knowledge, no previous studies have evaluated the histomorphological effects of combining DL with Well-Root PT for this application. Therefore, this study was designed to assess pulpal response and reparative dentinogenesis following direct pulp capping using Well-Root PT compared to MTA, both with and without adjunctive 810 nm DL pretreatment, through histomorpho-

logical analysis in a mongrel dog model.

Material and Methods

Study design

The study was conducted at the Department of Surgery, Anesthesiology, and Radiology, Faculty of Veterinary Medicine, Suez Canal University, Egypt. Ethical approval was obtained from the Research Ethics Committee (REC) of the Faculty of Dentistry, Suez Canal University (Approval No. 529/2022). The study adhered to established ethical standards and animal research regulations and complied with the ARRIVE guidelines.
The study was designed as a randomized, controlled experimental trial. To determine the minimum number of dogs needed, a sample size calculation was performed using G*Power version 3.1.9.2 (27), based on data from previous research (28, 29). According to the sample size calculation, eight mature male mongrel dogs with intact dentition were included in this study. The dogs were between 12 and 24 months old and weighed between 14 and 17 kg. Prior to the start of the study, they were housed in the animal facility for a two-week acclimatization period, during which they were closely monitored for any signs of health issues through repeated physical examinations, including evaluation of the oral cavity and teeth. The dogs were fed a standard diet that met the nutritional requirements established by the National Research Council and were provided with unrestricted access to water. The incisor teeth of the eight dogs (n = 96) were randomly assigned to three groups (32 incisor teeth each) based on the pulp capping material used. Group I served as the control group and received Teflon discs only, while Group II underwent pulp capping with MTA, and Group III with Well-Root PT. Each group was further divided into two subgroups based on DL application: subgroups IA, IIA, and IIIA (without DL) and subgroups IB, IIB, and IIIB (with DL). Each subgroup was then evaluated at two time points: T1 (after two weeks) and T2 (after eight weeks), with eight teeth assessed at each interval.

Surgical Induction of Class V Cavities and Pulp Capping Procedures

Dogs were premedicated with an intramuscular injection of xylazine (0.5 mg/kg; Xyla-Ject, Adwia Pharmaceuticals, Egypt), nalbuphine HCl (1 mg/kg; Nalufin, Amoun Pharmaceutical Company), and atropine sulfate (0.04 mg/kg; Memphis Pharmaceutical). Following premedication, general anesthesia was induced via intravenous administration of propofol (2 mg/kg; Diprivan, AstraZeneca). Anesthesia was maintained using a combination of 2% isoflurane (IsoFlo, Zoetis) and oxygen. (30). The teeth were isolated using a rubber dam, and disinfected with 2% chlorhexidine. A Class V cavity was prepared on the cervical third of the labial surface using a high-speed contra-angle handpiece fitted with a 1.5 mm round bur (Figure 1). Pulpal exposure was achieved, and dentinal debris was removed by irrigation with normal saline. Hemostasis was obtained by applying cotton pellets moistened with 2.5% sodium hypochlorite (29). In group I, high-purity Teflon sheets (Chemours™, Wilmington, Delaware, USA) were used. These sheets were precision-cut into uniform discs measuring 0.5–1 mm in thickness and 1.5 mm in diameter to fit the prepared Class V cavities. The discs were sterilized by autoclaving and stored in sterile packaging to maintain aseptic conditions. In Group II, the pulp exposure sites were capped with MTA (Angelus, Londrina, Paraná, Brazil), prepared at a 3:1 powder-to-liquid ratio according to the manufacturer's instructions. After 30 seconds of mixing to achieve a sandy consistency, the MTA was applied using a specialized applicator to ensure proper coverage and sealing. Group III involved the application of Well-Root PT (Vericom Co., Ltd., Chuncheon, Korea) in premixed capsule form, using a dedicated applicator gun. A plastic instrument was used to apply a precise amount over the exposed pulp, ensuring adequate sealing and protection.

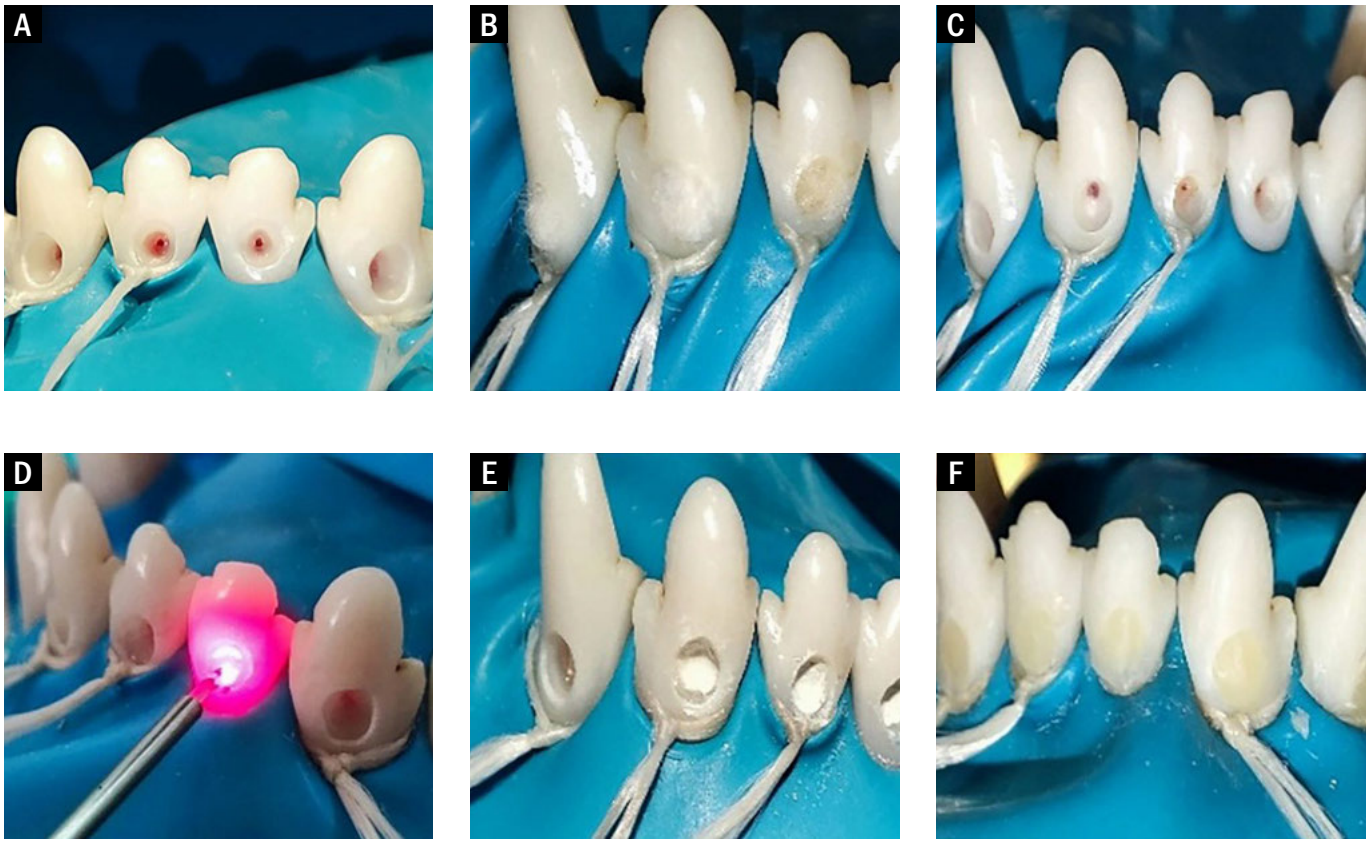

Figure 1
Clinical steps of the direct pulp capping procedure. (**A**) Cavity preparation; (**B**) application of sodium hypochlorite for disinfection; (**C**) bleeding control; (**D**) diode laser application; (**E**) placement of the capping material; and (**F**) restoration with glass ionomer cement.

Application of DL

In the subgroups designated to receive DL treatment, the exposed pulp areas were irradiated with the DL prior to the application of the capping material. The DL operated at a wavelength of 810 nm in continuous wave mode, delivering a power output of 20 mW. It was manually positioned approximately 2 mm from the exposure site to ensure precise targeting (Figure 1). Irradiation was performed for 150 seconds, covering a spot size of approximately 0.2 cm^2.
Considering an estimated 50% energy loss through the nozzle, the actual energy delivered to the tissue was calculated to be 1.5 J, resulting in an energy density of 7.5 J/cm^2. Following DL application, pulp capping was performed, and all cavities were then restored using a light-cured resin-modified glass ionomer cement (GC Fuji II, GC Corporation, Japan) (29).

Postoperative management

All dogs received intramuscular meloxicam (0.2 mg/kg daily for 3 days) for postoperative pain management. Throughout the experiment period, the oral cavity was closely monitored for signs of inflammation, swelling, discharge, or restoration failure. Regular examinations were performed to ensure the integrity of the treated teeth.

Samples Preparation and Histological Evaluation

After two weeks, four dogs were humanely euthanized (31), followed by the remaining four after eight weeks. Vital perfusion was performed, and the teeth along with surrounding tissues were block-sectioned and fixed in 10% formalin. The samples were then decalcified using 17% EDTA over a period of six months and subsequently embedded in

paraffin. Using a microtome, the paraffin-embedded tissues were sectioned buccolingually into slices measuring 4–6 µm in thickness. The sections were stained with hematoxylin and eosin (H&E) for histological analysis and were coded for blinded evaluation.
For the interpretation of histopathological changes in the pulp tissue, each section was evaluated and graded according to criteria adapted from the scoring system proposed by Domínguez et al. (32). This system assessed four key outcomes: dentin bridge formation, the quality of the dentin within the bridge, the degree of pulpal inflammation, and the tissue response to the capping material as indicated in Table 1.

Statistical analysis

Statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The Shapiro–Wilk test was used to assess data normality. Associations between categorical variables were evaluated using the Chi-square test. Paired sample t-tests were applied for within-group comparisons over time, while one-way ANOVA followed by Bonferroni post hoc tests was used for comparisons between groups.

Results

Dentin Bridge Formation

At both the two-week and eight-week observation periods, dentin bridge formation was more evident in Group II (MTA) and Group III (Well-Root PT) compared to the control group (Group I). Statistical analysis revealed a significant difference between Group I and both Group II and Group III at the two-week interval ($P = 0.0018$), while no significant difference was observed between Group II and Group III ($P = 0.7212$) (Table 2). A calcific barrier covering more than 75% of the exposure site (grade 4) was observed in 62.5% and 87.5% of Group II and Group III, respectively. In contrast, 75% of Subgroup IA and 62.5% of Subgroup IB exhibited no dentin bridge formation (grade 0) (Figure 2). Similarly, at the eight-week interval, a significant difference was found between Group I and both Group II and Group III ($P = 0.0023$), with no

Table 1
Criteria and Scoring System Used for Histological Analysis

Criteria	Score	Description
Dentin bridge formation	0	Absence of dentin bridge formation
	1	Equal to 25%
	2	More than 25% and up to 50%
	3	More than 50% and up to 75%
	4	More than 75%
Quality of the dentin formed within the bridge	0	Absence of tubules
	1	Irregular tubules pattern
	2	Irregular tubules pattern
Pulpal inflammation	1	No inflammation
	2	Minimal inflammation
	3	Moderate inflammation
	4	Severe inflammation
	5	Abscess formation
	6	Tissue necrosis
Tissue reaction to the material	0	No macrophages and/or multinucleated giant cells adjacent to material.
	1	Mild-to-moderate infiltration of macrophages and/or multinucleated giant cells.
	2	Moderate infiltration of macrophages and/or multinucleated giant cells.
	3	Severe infiltration of macrophages and/or multinucleated giant cells.

Score	Experimental subgroups						P-value (between groups)	P-value (between Group II and III)
	IA	IB	IIA	IIB	IIIA	IIIB		
	n=8	n=8	n=8	n=8	n=8	n=8		
Dentin bridge formation								
0	75%	62.5%	0%	0%	0%	0%	0.0018**	0.7212
1	25%	12.5%	0%	0%	0%	0%		
2	0%	25%	0%	0%	0%	0%		
3	0%	0%	37.5%	25%	25%	12.5%		
4	0%	0%	62.5%	75%	75%	87.5%		
Intra-group comparison between DL and non-DL subgroups)	0.297		0.589		0.521			
Quality of formed dentin bridge								
0	75%	62.5%	0%	0%	0%	0%	0.0003**	0.5153
1	25%	37.5%	100%	87.5%	87.5%	75%		
2	0%	0%	0%	12.5%	12.5%	25%		
Intra-group comparison between DL and non-DL subgroups	0.589		0.301		0.521			
Pulpal inflammation								
1	0%	0%	0%	25%	12.5%	37.5%	0.017**	0.7153
2	0%	12.5%	12.5%	62.5%	75%	62.5%		
3	12.5%	25%	25%	12.5%	12.5%	0%		
4	12.5%	12.5%	12.5%	0%	0%	0%		
5	50%	37.5%	37.5%	0%	0%	0%		
6	25%	12.5%	12.5%	0%	0%	0%		
Intra-group comparison between DL and non-DL subgroups	0.770		0.716		0.351			
Tissue reaction to the capping material								
0	0%	0%	12.5%	25%	12.5%	37.5%	0.0011**	0.6846
1	0%	12.5%	62.5%	62.5%	75%	62.5%		
2	25%	25%	25%	12.5%	12.5%	0%		
3	75%	62.5%	0%	0%	0%	0%		
Intra-group comparison between DL and non-DL subgroups	0.579		0.716		0.351			
Significant level P<0.05								

Table 2
Percentage Distribution of Histologic Parameters in Each Experimental Subgroup at the Two-Week Observation Period

significant difference between Group II and Group III (P = 1.00) (Table 3). All samples in the MTA and Well-Root PT groups demonstrated complete calcific bridge formation (grade 4). In contrast, 75% of Subgroup IA and 62.5% of Subgroup IB still showed no evidence of dentin bridge formation (Figure 3). The application of DL had no statistically significant effect on dentin bridge formation in any of the subgroups at any observation period.

Dentin Bridge Quality

Atubular structure persisted in the major-

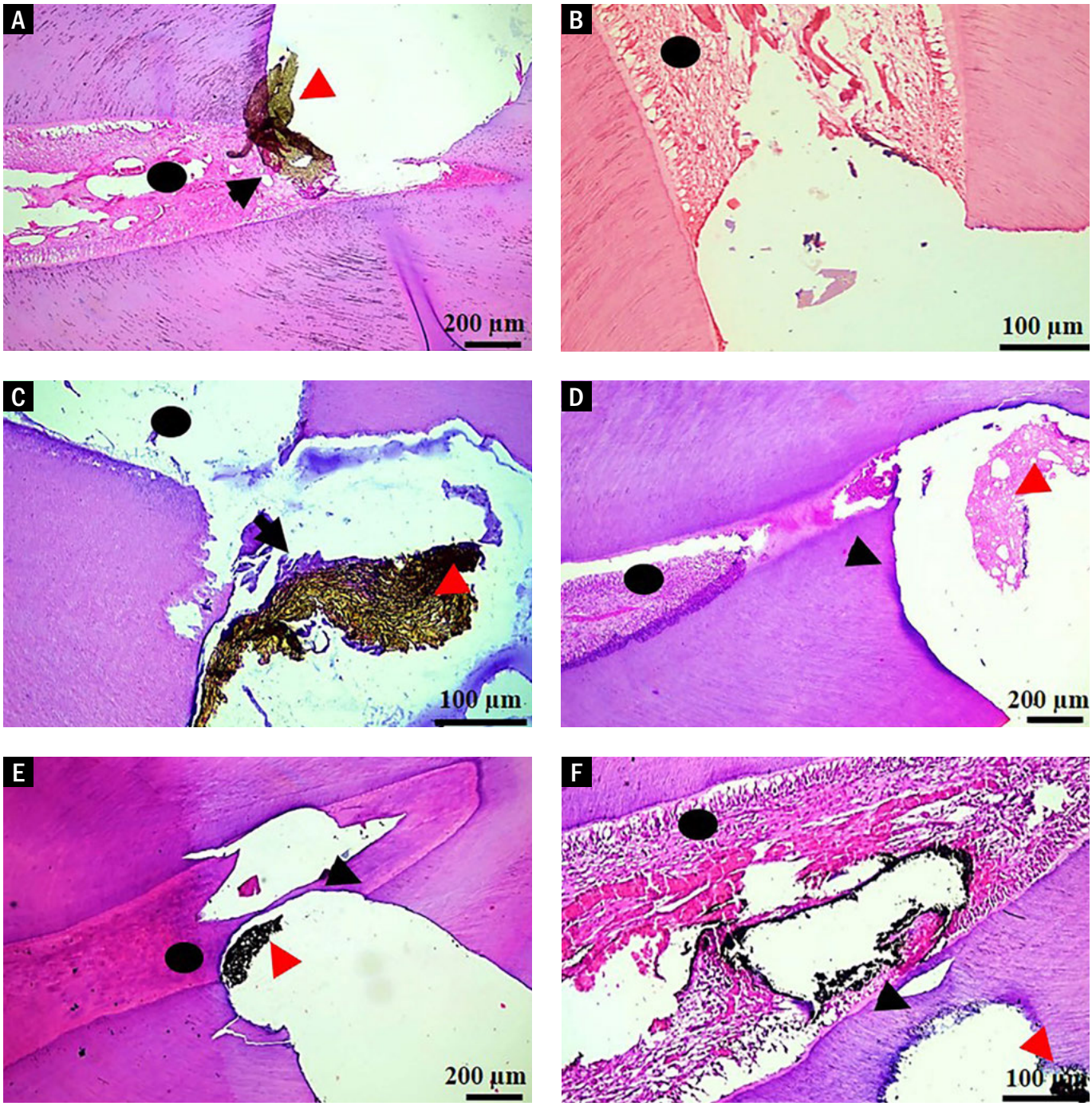

Figure 2
Representative microscopic images after two weeks of direct pulp capping. Figures A, C, and E correspond to subgroups IA, IIA, and IIIA, respectively, while figures B, D, and F represent subgroups IB, IIB, and IIIB, respectively. (**A**) showed degeneration of some odontoblasts, pus formation, and incomplete calcific barrier formation (<25%) associated with pulpitis. (**B**) revealed degeneration of pulp tissue with vasodilation. (**C**) demonstrated partial formation of a dentin bridge. (**D**) showed irregular dentin bridge formation accompanied by moderate pulpitis and calcific barrier formation. (**E**) revealed complete calcific barrier formation in the dentin bridge. (**F**) showed complete calcific barrier formation of a dentin bridge with impaction of Well-Root PT into the pulp tissue and the formation of a double bridge. The black circle represents the pulp tissue, the black arrow represents the dentin bridge, and the red arrow represents the capping material.

Score	Experimental subgroups						P-value (between groups)	P-value (between Group II and III)
	IA	IB	IIA	IIB	IIIA	IIIB		
	n=8	n=8	n=8	n=8	n=8	n=8		
Dentin bridge formation								
0	75%	62.5%	0%	0%	0%	0%	0.0023**	1
1	12.5%	12.5%	0%	0%	0%	0%		
2	12.5%	12.5%	0%	0%	0%	0%		
3	0%	12.5%	0%	0%	0%	0%		
4	0%	0%[a]	100%	100%	100%	100%		
Intra-group comparison between DL and non-DL subgroups)	0.779		1.00		1.00			
Quality of formed dentin bridge								
0	75%	62.5%	0%	0%	0%	0%	0.0012**	0.7212
1	25%	37.5%	87.5%	75%	75%	62.5%		
2	0%	0%	12.5%	25%	25%	37.5%		
Intra-group comparison between DL and non-DL subgroups	0.589		0.521		0.589			
Pulpal inflammation								
1	0%	0%	50%	87.5%	50%	87.5%	0.005**	0.3326
2	0%	0%	25%	12.5%	37.5%	12.5%		
3	0%	12.5%	25%	0%	12.5%	0%		
4	25%	25%	0%	0%	0%[b]	0%		
5	50%	37.5%	0%	0%	0%[b]	0%		
6	25%	25%	0%	0%	0%[b]	0%		
Intra-group comparison between DL and non-DL subgroups	0.766		0.206		0.244			
Tissue reaction to the capping material								
0	0%	0%	50%	87.5%	50%	87.5%	0.001**	0.3326
1	0%	12.5%[a]	25%	12.5%	37.5%	12.5%		
2	12.5%	37.5%	25%	0%	12.5%	0%		
3	87.5%	50%	0%	0%	0%	0%		
Intra-group comparison between DL and non-DL subgroups	0.244		0.206		0.244			
ignificant level P<0.05								

Table 3
Percentage Distribution of Histologic Parameters in Each Experimental Subgroup at the Eight-Week Observation Period

ity of control subgroups IA and IB (75% and 62.5%, respectively) at both two weeks and eight weeks, with no change over time. Meanwhile, irregular tubular patterns remained predominant in subgroups IIA, IIB, IIIA, and IIIB (87.5%, 75%, 75%, and 62.5%, respectively), although an increase in regular tubular dentin formation was observed (12.5%, 25%, 25%, and 37.5%, respectively) at the eight-week observation period.

Statistical analysis revealed significant differences between Group I and both Group II and Group III over time. The P-values (0.0003 at two weeks and 0.0012 at eight weeks) indicated that the scores were not randomly distributed across the groups. However, no significant differ-

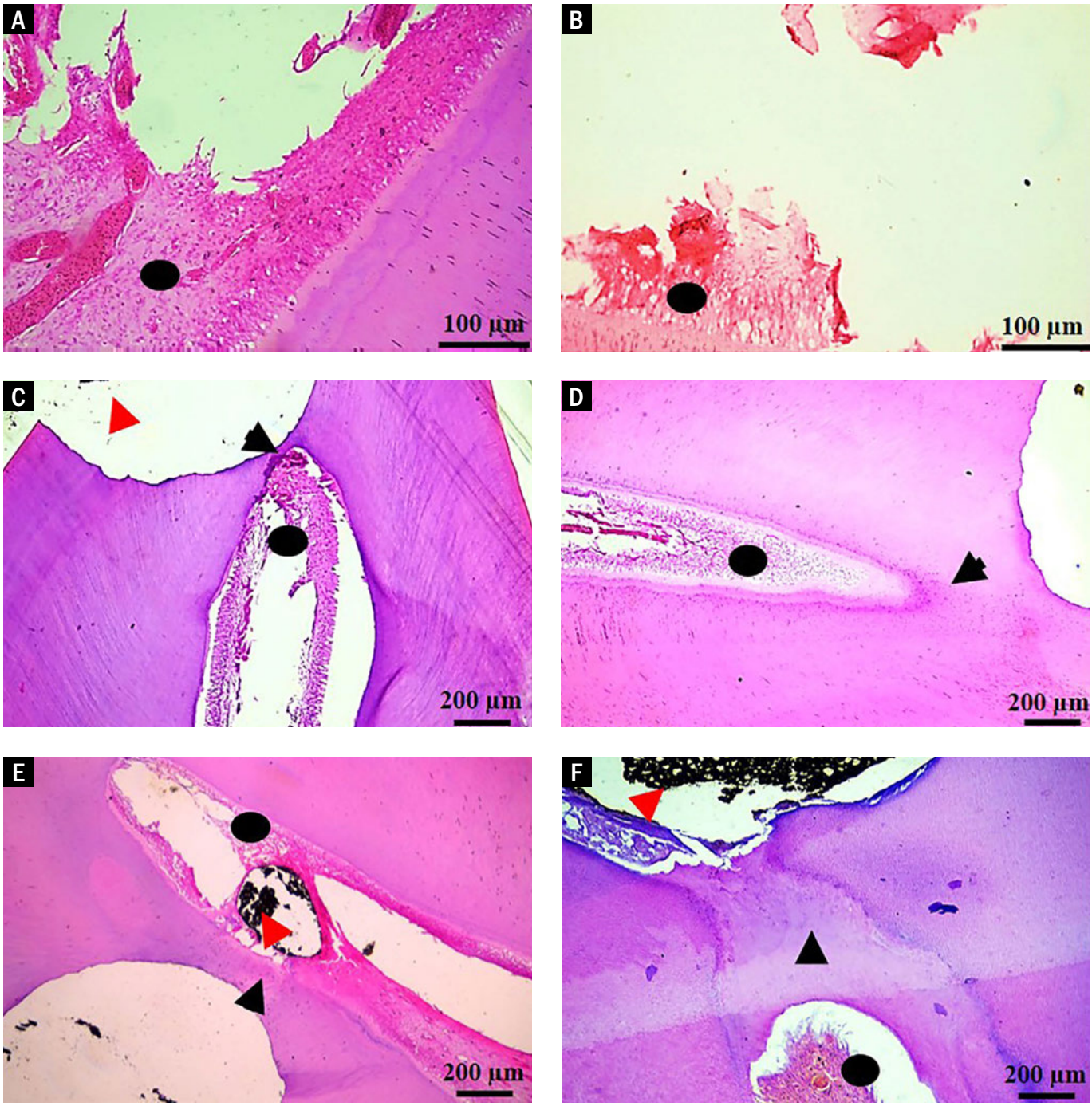

Figure 2
Representative microscopic images after eight weeks of direct pulp capping. Figures A, C, and E represent subgroups IA, IIA, and IIIA, while figures B, D, and F correspond to subgroups IB, IIB, and IIIB. (**A**) showed loose parts of the pulp, severe inflammation, and marked vasodilatation with the formation of granulation tissues. (**B**) revealed complete loss of pulp tissue. (**C**&**D**) demonstrated complete calcific barrier formation of the dentin bridge. (**E**) revealed complete calcific barrier formation of a dentin bridge with impaction of Well-Root PT into the pulp. (**F**) showed complete and thick calcific barrier formation of a dentin bridge with irregular dentin and Well-Root PT material. The black circle represents the pulp tissue, the black arrow represents the dentin bridge, and the red arrow represents the capping material.

ence was found between Group II and Group III (P = 0.5153).

Pulpal Inflammation and Tissue Reaction to the Capping Materials

At both the two-week and eight-week observation periods, statistically significant differences in pulpal inflammation were found between Group I and both Group II and Group III (P = 0.017 and 0.005, respectively). However, no significant differences were observed between Group II and Group III at the same time points (P = 0.3326 and 0.7153, respectively) (Table 2 and 3). Accordingly, the tissue response to the capping materials followed a consistent pattern, with statistically significant differences observed between Group I and both Group II and Group III at both time points (P = 0.0011 at two weeks and P = 0.001 at eight weeks). In contrast, no significant differences were found between Group II and Group III at either time point (P = 0.6846 and P = 0.3326, respectively).

At the two-week interval (Figure 2), mild pulpal inflammation (grade 1), accompanied by vasodilation of blood vessels, was observed in most samples from subgroups IIA, IIB, IIIA, and IIIB. Meanwhile, the control group (subgroups IA and IB) exhibited severe inflammatory responses, including pulp necrosis and degeneration of the odontoblast layer. Vasodilation and marked inflammatory cell infiltration were frequently observed in most cases (grades 4, 5, and 6). Granulation tissue formation was also significantly more pronounced in the control subgroups compared to Groups II and III ($P < 0.05$).

At eight weeks (Figure 3), the subgroups of Group II and Group III exhibited either no inflammation or only mild signs, with an absence of inflammatory infiltrates, macrophages, and multinucleated giant cells. Blood vessels were either mildly enlarged or appeared normal (grades 0 and 1). Conversely, the control group continued to exhibit a high incidence of pulpitis, with frequent observations of marked vasodilation, dense inflammatory cell infiltration, and granulation tissue formation. Marked pulpal necrosis was also evident, characterized by extensive odontoblastic degeneration, disorganization of the remaining degenerated cells, and significant narrowing of the pulp space.

Discussion

Direct pulp capping is a vital pulp therapy procedure designed to preserve the integrity and vitality of the pulp tissue. The present study demonstrated that dentin bridge formation was minimal in the absence of a pulp capping material, with less than 25% observed at two weeks and only a slight increase at eight weeks. This limited healing response can be attributed to the lack of bioactive stimulation and insufficient protection against microbial invasion (33, 34). On the other hand, the application of bioactive materials such as MTA and Well-Root PT significantly enhanced dentin bridge formation. Both MTA and Well-Root PT showed comparable efficacy, with more than 50–75% dentin bridge formation by two weeks and complete bridge formation in all samples by eight weeks. These materials are known to release calcium ions and stimulate odontoblastic differentiation, contributing to their regenerative potential (35, 36). Regarding DL application, the study found no statistically significant difference in dentin bridge formation between groups treated with and without laser use. This indicated that the primary role of DL may lie in its disinfection capability rather than direct stimulation of dentinogenesis (29). Meanwhile, Alharbi et al. (28) have reported improved regenerative outcomes with DL application, particularly when used in combination with EndoSequence Root Repair Material. These discrepancies may be attributed to differences in laser protocols, including wavelength, exposure time, and frequency. Overall, the present findings revealed the critical role of bioactive pulp capping materials in promoting dentinogenesis, while the adjunctive use of DL remains inconclusive.

Structurally, dentin bridges observed at

two weeks exhibited primarily irregular tubular patterns, with no significant differences between MTA and Well-Root PT or between laser-treated and non-laser-treated subgroups. However, by eight weeks, regular tubular structures became more evident across all groups. These results indicate that both materials support progressive dentinogenesis and mineralization in a controlled environment, aligning with prior findings (37, 38). The DL influence appeared to be limited to bacterial reduction rather than altering the structural characteristics of the dentin bridge, which may explain the absence of significant variation between laser-treated and non-treated samples (38).

Contrary to the present findings, Sivadas et al. (39) reported improved dentin bridge quality following DL application, which may be attributed to variations in the pulp capping materials used. Some studies have suggested that DL enhanced dentin bridge formation (28, 40), while others, such as Al-Agele et al. (41), emphasized its role in pulp healing rather than mineralization. These conflicting outcomes highlight the variability in experimental designs, laser parameters, and material-laser interactions. Overall, the results of this study support the notion that the type of pulp capping material plays a more critical role in dentin bridge formation and structure than adjunctive laser therapy. Concerning the pulpal status, the absence of a capping material resulted in severe inflammation, abscess formation, and progressive pulp necrosis over time. Conversely, both MTA and Well-Root PT significantly reduced inflammation and showed mild to moderate levels at two weeks and minimal or absent inflammation at eight weeks. These effects can be attributed to the materials' alkaline pH, calcium ion release, and sealing ability, all of which contribute to pulp healing and reduced bacterial colonization (42). In this study, no significant differences were observed between MTA and Well-Root PT in terms of pulpal response, further supporting existing evidence that Well-Root PT is a viable alternative to MTA. The use of DL was associated with a slight reduction in pulpal inflammation prior to capping; however, these effects were not statistically significant. The photobiomodulatory effects of DL can stimulate cellular activity and tissue repair, variability in laser parameters may influence their clinical outcomes (43). Consistent with the observed pulp status, the tissue reaction to the capping materials was characterized by the presence of macrophages and multinucleated giant cells during the first two weeks following pulp capping, with their numbers decreasing significantly by eight weeks. No significant differences were observed between MTA and Well-Root PT, regardless of DL application. In contrast, the control group exhibited persistent inflammation, pus formation, and, in many cases, complete pulp loss. The reduction in immune cell presence over time reflects the natural healing process and is consistent with the known biocompatibility of both MTA and Well-Root PT (44). These findings align with previous studies that reported minimal long-term inflammatory responses when using bioactive capping materials, further reinforcing their critical role in promoting pulp repair and healing (45, 46). The limitations of the current study include a relatively small sample size and a limited observation period of eight weeks, which may not reflect long-term outcomes such as the stability of the dentin bridge and sustained pulp vitality. Additionally, the use of a single DL protocol limits the understanding of how different laser settings might influence healing. Future research should include longer follow-up periods, larger sample sizes, and clinical trials to validate these findings. Further studies should also explore various DL parameters and compare newer bioceramic materials to determine the most effective approach for long-term pulp regeneration.

Conclusion

This study concluded that Well-Root PT is an effective and clinically comparable alternative to MTA for direct pulp cap-

ping, showing similar efficacy in promoting dentin bridge formation and preserving pulp vitality. The use of DL did not significantly improve treatment outcomes, indicating that its primary role may be limited to disinfection rather than directly enhancing tissue regeneration. These findings emphasize that the choice of a biocompatible, bioactive capping material is the most critical factor in the success of direct pulp capping, outweighing any additional benefit from DL application.

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Conflict of interest statement
We declare that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Author Contributions
Mo'men A. Salama: writing – review and editing, writing – original draft, validation, methodology, investigation, formal analysis, data curation, and conceptualization. Dalia M. Fayyad: writing – review and editing, writing – original draft, validation, supervision, investigation, and conceptualization. Mohamed I. Rabie: writing – review and editing, writing – original draft, validation, supervision, investigation, and conceptualization. Manar A. A. Selim: writing – review and editing, supervision, investigation, and conceptualization. Mahmoud F. Ahmed: writing – review and editing, methodology, validation, supervision, investigation, resources, and conceptualization.

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ORIGINAL ARTICLE

Antibacterial Efficacy of N-Acetyl Cysteine Combined with Two Photodynamic Therapy Protocols Against Enterococcus faecalis in Infected Root Canals: An In Vitro Study

Aim: *Enterococcus faecalis (E. faecalis) is a resilient endodontic pathogen associated with persistent root canal infections. The objective of this investigation was to assess and compare antibacterial efficacy of N-acetyl cysteine (NAC) alone and in combination with two photodynamic therapy (PDT) protocols utilizing methylene blue (MB) and indocyanine green (ICG) as photosensitizers.*

Methodology: *Seventy-eight extracted human mandibular premolars were instrumented, sterilized, and inoculated with E. faecalis (MTCC 439). After 14 days of incubation, samples were randomly divided into 3 groups (n = 26 each): Group I – NAC alone; Group II – NAC + PDT with ICG (1 mg/mL, 810 nm diode laser); Group III – NAC + PDT with MB (20 µg/mL, 660 nm diode laser). Bacterial samples were collected before and after disinfection using sterile paper points, and quantified via colony-forming unit (CFU) analysis on Brain Heart Infusion (BHI) agar. Data were log_{10}-transformed and analyzed using paired t-tests and one-way ANOVA with Tukey's post hoc test (P<0.05).*

Results: *All groups demonstrated significant CFU reduction post-treatment (P<0.0001). Mean CFU reductions were: Group I – 0.84 ± 0.29, Group II – 1.52 ± 0.54, and Group III – 1.35 ± 0.47. Group II & III showed significantly greater reductions than Group I (P < 0.0001 and P=0.0003, respectively). No significant difference was observed between Group II & Group III (P=0.3554).*

Conclusion: *NAC combined with either MB- or ICG-mediated PDT significantly improved disinfection of E. faecalis-infected root canals compared to NAC alone. This combination offers a promising adjunctive approach for managing persistent endodontic infections.*

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Introduction

Endodontic infections are polymicrobial in nature and are closely associated with the development of robust biofilms within the complex root canal anatomy (1). E. faecalis is one of most persistent and clinically significant microorganisms implicated in the failure of root canal therapy. It is frequently isolated from refractory endodontic lesions and persistent apical periodontitis, owing to its ability to survive under harsh conditions, invade dentinal tubules, and resist conventional antimicrobial strategies (2). Mechanical instrumentation and chemical irrigation are fundamental to root canal debridement. However, anatomical challenges such as lateral canals, isthmuses, and deep dentinal tubules often limit the thorough elimination of microbial biofilms. Smear layer produced during instrumentation can further block dentinal tubules, thereby reducing efficiency of irrigants as well as intracanal medicaments (3). E. faecalis was shown to penetrate dentinal tubules up to 1200 µm, while most irrigants typically reach only 60–150 µm. Scanning electron microscopy (SEM) has confirmed widespread bacterial colonization in these difficult-to-access areas, highlighting the necessity for additional disinfection strategies beyond standard protocols (4), more in particular with oval and irregular round canals (5).

To improve root canal disinfection, ongoing research focuses on developing novel antimicrobial methods that can disrupt biofilm architecture and enhance bacterial removal. N-acetyl cysteine (NAC), a thiol-based derivative of L-cysteine, has gained interest due to its ability to degrade extracellular polymeric substances and interfere with bacterial protein structures through disruption of disulfide bonds. It has shown antimicrobial activity against both planktonic and biofilm forms of Enterococcus faecalis (E. faecalis) and Streptococcus mutans. Despite its potential, NAC alone may be insufficient to achieve complete biofilm eradication within complexities of root canal system (6).

Photodynamic therapy (PDT) was explored as an adjunctive disinfection approach (7). PDT employs a photosensitizer that, upon activation by light of specified wavelength in presence of oxygen, generates ROS (reactive oxygen species), encompassing singlet oxygen as well as free radicals. Such ROS disrupt microbial membranes, nucleic acids, and proteins, leading to bacterial cell death. Unlike high-power laser techniques, PDT exerts a photochemical effect with minimal heat production, reducing the risk of periradicular tissue injury. Its selective antimicrobial action, absence of microbial resistance, and biocompatibility support its application in endodontic therapy (8,9). Commonly studied photosensitizers such as Methylene blue (MB) and tolonium chloride are cationic dyes known for their broad-spectrum antimicrobial effects. MB, a phenothiazine compound with an absorption peak between 500 and 700 nm, has demonstrated strong antimicrobial efficacy even under less-than-ideal light conditions (8,10). However, its use may result in undesirable staining of dental structures. To overcome this limitation, Indocyanine green (ICG), an anionic dye with peak absorption at 810 nm, has been introduced. ICG primarily functions through photothermal activity and has demonstrated a favourable safety profile along with antimicrobial potential (11).

Effective photodynamic therapy requires that the wavelength of the light source closely corresponds to the absorption spectrum of the photosensitizer in order to optimize the generation of ROS. Diode lasers are commonly employed due to their portability, optical fibre delivery, and ease of clinical use. In the current study, MB (20 µg/mL) was activated utilizing 660nm diode laser, and ICG (one mg per mL) was activated using 810nm diode laser,

both following NAC irrigation (12). The rationale for this study stemmed from the need to enhance intracanal disinfection by combining the biofilm-disrupting properties of N-acetyl cysteine (NAC) with the antimicrobial capabilities of photodynamic therapy (PDT). This in vitro investigation was designed to assess and compare the antibacterial efficacy of NAC alone and in combination with two distinct PDT protocols using methylene blue (MB) with a 660 nm diode laser and indocyanine green (ICG) with an 810 nm diode laser against E. faecalis in infected root canals. Bacterial viability has been evaluated using colony-forming unit (CFU) quantification to determine whether these combined approaches provide synergistic antimicrobial effects that can provide synergistic antimicrobial effects in vitro. The tested hypothesis was that NAC combined with PDT (MB or ICG) will show greater reduction in E. faecalis compared to NAC alone.

Materials and Methods

Ethical Approval

This in vitro study has been performed using extracted human teeth collected in accordance with ethical guidelines for research involving human biological material. Ethical approval has been obtained from the Institutional Human Ethics Committee (IHEC) of KLE VK Institute of Dental Sciences, under approval number EC/NEW/INST/2021/2435/427, before commencement of study. All specimens were anonymized, and no identifiable patient information was used. The current study was drafted according to PRILE guidelines (13).

Sample Size Calculation

Sample size has been computed utilizing G*Power version 3.0.10 software (Heinrich Heine University, Düsseldorf, Germany). According to data from earlier similar research (14), having an effect size 0.904, an alpha error probability 5 percent, and statistical power (1–β) of 90%, the estimated sample size was 26 specimens per group. Accordingly, for three groups, the total required sample size was 78 specimens. Teeth with single straight canals and fully developed apices were included, confirmed by radiographs and canal patency with a #10 K-file. Teeth with cracks, resorption, caries, previous treatment, or open apices were excluded. All teeth have been cleaned of soft tissue and calculus with an ultrasonic scaler and preserved in a 0.1 percent thymol solution until utilized.

Specimen Preparation

Decoronation of the specimens was done utilizing a diamond disc (Komet, USA) under water cooling to obtain root segments of length 14 mm. Working length has been described by inserting size 10 K-file (MANI, Japan) until it is observable at apical foramen, followed by a subtraction of 0.5 mm. Biomechanical preparation was performed utilizing ProTaper Universal rotary system (Dentsply Sirona, USA) up to size F3. Canals were irrigated using 5 ml of 3% sodium hypochlorite (NaOCl) (Vishal Dental Care, India) and 2 ml of 17% EDTA (Canal Large, India) throughout instrumentation. Final irrigation included 2 mL of 17% EDTA for 60s, followed by 5 mL of 3% NaOCl for 60 s, and 5 mL of sterile distilled water for 60 s. All specimens were autoclaved at 121 °C, 15 psi, for 20 minutes for sterilization. The apical foramina of all specimens were sealed with composite resin (Filtek Z350 XT, 3M). Sterility was confirmed by paper-point sampling of random specimens into BHI broth, which showed no growth after 72 h.

Contamination Protocol

The Enterococcus faecalis strain MTCC 439 was used for bacterial inoculation. Colonies have been suspended in Brain heart infusion broth (BHI) (TM Media, India) as well as incubated for 24 hrs to reach turbidity equivalent to 0.5 McFarland standard (~1×10^8 CFU per mL). Each root specimen has been

RATIONALE/JUSTIFICATION
The study explores the antibacterial efficacy of N-acetyl cysteine (NAC) alone and in combination with two photodynamic therapy (PDT) protocols using methylene blue (MB) and indocyanine green (ICG) against Enterococcus faecalis in infected root canals.

↓

AIM
The study aimed at evaluating and comparing the antibacterial efficacy of NAC alone and when combined with PDT protocols using MB or ICG photosensitizers activated by diode lasers in root canals infected with E. faecalis.

↓

ETHICAL APPROVAL
EC/NEW/INST/2021/2435/427

↓

SAMPLES
Seventy-eight freshly extracted single-rooted human mandibular premolars.

↓

EXPERIMENTAL AND CONTROL GROUPS, INCLUDE INDEPENDENT VARIABLES
Group I – NAC irrigation only (n = 26)
Group II – NAC + ICG-mediated PDT (n = 26)
Group III – NAC + MB-mediated PDT (n = 26)

↓

OUTCOME(S) ASSESSED, INCLUDE DEPENDENT VARIABLES AND TYPE
Reduction in E. faecalis bacterial load quantified as colony-forming units (CFUs) before and after treatment.

↓

METHOD USED TO ASSESS THE OUTCOME(S) AND WHO ASSESSED THE OUTCOME(S)
Microbiological sampling with sterile paper points —> Culturing on BHI agar —> Manual CFU counting after 72-hour incubation.

↓

RESULTS
All groups showed significant CFU reduction post-treatment ($P < 0.0001$). NAC combined with PDT (Groups II and III) achieved significantly greater bacterial reduction than NAC alone ($P < 0.0001$ and $P = 0.0003$, respectively). No significant difference was observed between MB- and ICG-mediated PDT groups ($P = 0.3541$).

↓

CONCLUSION(S)
Combining NAC with PDT (either MB or ICG) significantly improves antibacterial efficacy compared to NAC alone, suggesting a promising adjunctive disinfection protocol in endodontics.

↓

FUNDING DETAILS
The research did not receive any specific grant from funding agencies.

↓

CONFLICT OF INTEREST
None

Figure 1
PRILE 2021 Flowchart

placed in sterile microcentrifuge tube containing 1 mL of BHI broth. A 50 µL aliquot of the bacterial suspension was inoculated into each canal under aseptic conditions in a laminar airflow hood. To confirm culture purity, 5 µL of the bacterial broth was sub-cultured on BHI agar. The specimens have been incubated at 37 ± 1°C for 14 days to allow mature biofilm development.

Intervention

Subsequently, all samples were randomly allocated into three experimental groups, each corresponding to a specific disinfection strategy implemented after the contamination phase. This randomization was achieved using a computer-generated sequence with concealed allocation to ensure unbiased assignment.

Group 1: N-acetylcysteine (NAC) only (Control) [n=26]
The specimens were irrigated with 5 mL of NAC solution (200 mg/mL), prepared by dissolving 0.2 g of NAC powder (MOLYCHEM, India) in 1 mL of sterile distilled water, and adjusting the pH to 11. This was followed by a final flush with 4 mL of sterile distilled water.

Group 2: NAC + Indocyanine Green (ICG)-mediated PDT [n=26]
Following NAC irrigation, indocyanine green (ICG) solution (1 mg/mL; AUROGREEN, India) was introduced into the canal and retained for 5 minutes. Photodynamic activation was performed using an 810 nm diode laser (INDILASE, India) at a power output of 0.1 W, delivered through a 200 µm optical fibre. Irradiation was applied for a total of 60 seconds, consisting of 10-second cycles with 10-second rest intervals after every 20 seconds. The fibre-optic tip was positioned 1 mm short of the working length and moved helically from apical to coronal

Group 3: NAC + MB-mediated PDT [n=26]
Following NAC treatment, a 20 µg/mL methylene blue (MB) solution (ISOCHEM, India) was introduced into the canal and retained for 5 minutes. Photodynamic activation was performed using a 660 nm diode laser (INDILASE, India) at an output of 0.1 W, delivered through a 200 µm optical fibre. Irradiation was applied for a total of 90 seconds in 10-second bursts with 30-second rest intervals. The fibre-optic tip was positioned 1 mm short of the working length and moved in a helical motion from apical to coronal.

Outcome Measures

Microbiological sampling was performed before and after disinfection using sterile size 20 paper points, which had been inserted into canal for one minute. Paper points have been transferred into Eppendorf tubes comprising 10 µL of sterile saline and vortexed briefly. The resulting suspension was streaked onto BHI agar plates using sterile spreaders. Plates have been incubated for 72 hrs at 37°C. Colony forming units (CFUs) were enumerated using an automated colony counter and recorded to assess bacterial viability. Figure 1 illustrates the PRILE flowchart outlining the methodology followed in the study.

Statistical Analysis

Data were entered in Microsoft Excel 2021 and analyzed using GraphPad Prism for Windows, Version 10.1.2 (GraphPad Software, La Jolla, California, USA). CFU values were $\log_{10}$-transformed to normalize distribution and reduce variability, aiding interpretation across groups. Normality was confirmed via the Shapiro-Wilk test and visual assessments of histograms. Descriptive statistics included mean and standard deviation. Intra-group comparisons used paired t-test; inter-group comparisons employed one-way ANOVA with Tukey's post-hoc test.

Results

Table 1 and Figure 2 depict mean CFU values before and after treatment across the study groups. All groups showed statistically significant decrease in CFU following treatment (P < 0.0001), (Figure 1). Group I had the least reduction (0.84 ± 0.29), while Groups II and III demonstrated greater reductions of 1.52 ± 0.54 and 1.35 ± 0.47, respectively. The inter-group comparison of mean CFU reductions revealed statistically significant difference (P < 0.0001). Pairwise comparisons showed that the reductions in Groups II & III have been significantly greater than in Group I (P < 0.0001 and P=0.0003, respectively), whereas difference between Groups II & III have not been statistically significant (P = 0.3554). These findings indicate that although all interventions were effective, those in Groups II and III produced a more substantial reduction in CFU than Group I (Table 2 and Figure 3).

Table 1
Mean (±standard deviation) and comparisons between pre-treatment and post-treatment colony-forming unit values for all the groups

Study Groups/Time Points	Pre-treatment	Post-treatment	Difference	P value†
Group I (n=26)	2.72±0.08	1.88±0.25	0.84±0.29	<0.0001*
Group II (n=26)	2.72±0.08	1.21±0.56	1.52±0.54	<0.0001*
Group III (n=26)	2.72±0.07	1.37±0.48	1.35±0.47	<0.0001*
P value§			<0.0001*	

n: sample size per study group
SD: Standard deviation
§: Inter-group comparisons (between the study groups for the mean difference/reduction); ‡: intra-group comparisons (pre-treatment versus post-treatment within each study group)
**: statistically significant (P ≤0.05)*

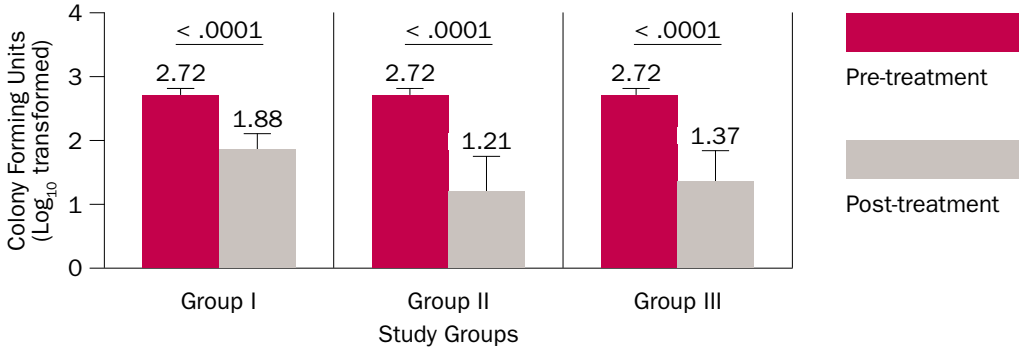

Figure 2
Mean and standard deviation of the pre-treatment and post-treatment colony-forming unit values for all the groups. Horizontal bars above the columns represent intra-group comparisons that were statistically significant as determined by a paired t-test.

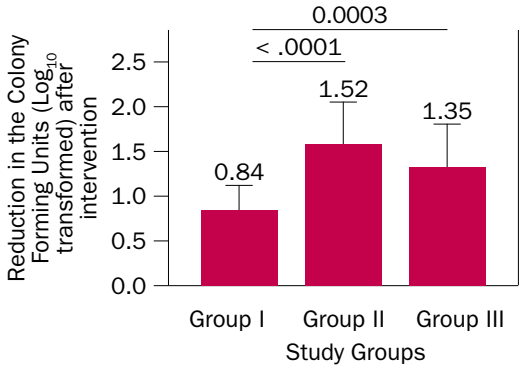

Figure 3
Mean and standard deviation of the reduction in colony-forming unit (CFU) values following treatment across the study groups. Horizontal bars above the columns represent pairwise group comparisons that were statistically significant as determined by Tukey's post-hoc test.

Table 2
Pairwise comparisons of colony-forming unit (CFU) reduction between groups post-treatment relative to pre-treatment

Pairs	Mean Difference	Adjusted P value
Group I vs. Group II	-0.6807	<0.0001*
Group I vs. Group III	-0.5100	0.0003*
Group II vs. Group III	0.1707	0.3554NS
Group III (n=26)	2.72±0.07	1.37±0.48

NS: not significant (P >0.05),
**: statistically significant (P <0.05)*

Discussion

Effective disinfection of root canal system remains cornerstone of successful endodontic therapy. E faecalis, known for its ability to penetrate dentinal tubules and form resilient biofilms, is frequently implicated in persistent infections and endodontic treatment (15). The present in vitro study assessed antibacterial efficacy of NAC, both alone and in combination with PDT, using MB and ICG as photosensitizers, against E. faecalis in contaminated root canals. The results demonstrated that NAC alone exhibited limited antimicrobial activity, while its combination with either PDT protocol significantly enhanced bacterial reduction (16). Hence, the aim of this study was to evaluate whether the combination of NAC with PDT (using either MB or ICG) would result in a greater reduction of E. faecalis compared to NAC alone.

NAC has recently gained attention as potential endodontic irrigant because of its biofilm-disrupting capabilities, attributed to the cleavage of disulfide bonds in the extracellular polymeric substance (EPS) matrix. Compared to traditional agents like NaOCl, NAC is biocompatible, anti-inflammatory, and safer for use near periapical tissues, especially in open apices or immature teeth (17,18,19). However, in our study, NAC alone at 200 mg/mL, the concentration recommended in earlier studies (Group I), showed the least bacterial reduction (mean CFU reduction: 0.84 ± 0.29). This is consistent with previous reports indicating that NAC monotherapy is insufficient for the complete eradication of mature E. faecalis biofilms (20,21).

For the other groups, the concentrations of MB (20 µg/mL) and ICG (1 mg/mL) were chosen in accordance with established PDT protocols reported in the endodontic literature (22,23). The results show that the addition of PDT significantly improved disinfection outcomes both MB- and ICG-mediated PDT (Groups II and III) showed superior antibacterial efficacy (1.52 ± 0.54 and 1.35 ± 0.47, respectively), with statistically significant differences compared to NAC alone ($P < 0.0001$ and $P = 0.0003$). This supports existing literature suggesting that PDT enhances antimicrobial activity when used adjunctively with irrigants, with no superiority among them (8,11). The enhanced antibacterial action seen with PDT can be explained by its photochemical mechanism. PDT involves activation of a photosensitizer by a specific light wavelength in presence of oxygen, leading to ROS generation, including singlet oxygen and free radicals. Such ROS damage to microbial membranes, nucleic acids, and proteins leads to bacterial death (24). MB, a phenothiazine dye, binds well to bacterial biofilms and is efficiently activated by red light (660 nm), while ICG, an anionic dye, absorbs light in the near-infrared spectrum (810 nm) and primarily acts via photothermal mechanisms. Although MB may stain dental tissues, it was included due to its well-established photochemical efficacy and to allow direct comparison with ICG, which has less staining potential. In the current study both photosensitizers achieved comparable antimicrobial efficacy, underscoring their suitability for endodontic disinfection protocols (25). The observed synergistic effect between NAC and PDT is likely due to NAC's ability to weaken the biofilm matrix, allowing deeper photosensitizer penetration and enhanced ROS-mediated killing. This aligns with previous evidence supporting the combination of biofilm-disrupting agents with antimicrobial therapies for improved efficacy (26).

A key strength of this study is the use of a standardized and clinically relevant E. faecalis biofilm model with a 14-day incubation period, which simulates persistent root canal infections (27). Furthermore, diode lasers were chosen for PDT activation due to their clinical accessibility and fiber-optic

compatibility, enabling precise delivery within root canals (28). Nonetheless, this study has limitations. The colony-forming unit (CFU) quantification method, while widely accepted, primarily reflects planktonic or loosely adherent bacteria from the main canal. This may underestimate the actual residual bacterial load, especially within dentinal tubules.

Advanced techniques, including CLSM (confocal laser scanning microscopy) or SEM, could provide more comprehensive insights into biofilm disruption and residual intratubular bacteria. More research should also focus on understanding the role of effective root canal disinfection strategies (29,30), improvising the fluid dynamics (31) without altering the instrument surface (32) and thereby focussing on effective pain control strategies (33,34). Future focus is needed more on understanding the complex root canal anatomy (35) and its intricate relation to the periodontium (36) and also on bioactive strategies (37,38,39) for improvising the overall outcomes.

The findings of this study support the adjunctive use of PDT with NAC as an effective disinfection strategy in endodontics. Given the comparable antibacterial performance of MB and ICG, clinicians may consider other factors such as staining potential, cost, and laser compatibility when selecting a photosensitizer. Further studies using polymicrobial biofilms, digital devices (40), regenerative models (41), or immature teeth and its application in vital pulp therapies (42) are needed to validate the clinical applicability of these protocols and assess their long-term effects on root dentin (43) and periapical healing (44,45).

Conclusion

Within the limitations of this in vitro study, NAC + PDT (MB or ICG) showed greater antibacterial activity than NAC alone. Further studies comparing these protocols to NaOCl + EDTA are required before clinical recommendations can be made. Both MB and indocyanine green performed similarly when used with PDT, suggesting either photosensitizer may be effective. This combination may thus serve as a biocompatible adjunct for enhanced root canal disinfection in persistent infections.

Clinical Relevance

This study shows that combining N-acetyl cysteine (NAC) with photodynamic therapy (PDT) using either methylene blue or indocyanine green significantly enhances disinfection of E. faecalis compared to NAC alone. The synergistic effect suggests that NAC + PDT may represent a safe and effective adjunct for managing persistent root canal infections, with the choice of photosensitizer guided by clinical considerations such as staining potential and laser availability.

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CASE SERIES

Management of Intraoperative Endo-Sinus Communications in Maxillary Posterior Teeth: A 15-Case Series

ABSTRACT

Background: *The anatomical relationship between posterior maxillary teeth and the maxillary sinus may predispose to intraoperative complications during endodontic treatment. While sodium hypochlorite extrusion into the sinus has been sporadically reported, no case series has described direct intraoperative endo-sinus communications.*

Methods: *Fifteen cases of intraoperative endo-sinus communication were documented during root canal treatment or retreatment of maxillary premolars and molars. Clinical signs included profuse bleeding synchronous with respiration, the presence of nasal mucus in the pulp chamber, disappearance of sodium hypochlorite solution, and contamination of paper points. In all cases, a Valsalva maneuver was performed and confirmed the presence of communication. Management strategies included immediate obturation when the canal could be dried or hemostasis achieved, or provisional sealing with Teflon and IRM with or without calcium hydroxide dressing when immediate obturation was not possible. Patients were followed clinically and radiographically..*

Results: *In 4 cases (26.7%), endodontic obturation was completed in a single visit, while in 11 cases (73.3%) obturation was postponed. Among the latter, 4 cases received calcium hydroxide dressing and 7 had no intracanal medicament. In all cases, the communication resolved spontaneously within one week. At a mean follow-up of 3.9 years (range: 1–10 years), no patient developed persistent sinonasal symptoms or radiographic evidence of sinus pathology.*

Conclusions: *This case series provides the first clinical description of intraoperative endo-sinus communications. When promptly recognized and appropriately managed, these events do not appear to compromise the long-term prognosis of endodontic treatment. Careful preoperative radiographic assessment, accurate working length determination at the first appointment, and controlled instrumentation are essential to prevent recurrence. Different obturation techniques may be successfully applied, with bioceramic sealers offering potential advantages in postoperative comfort.*

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Introduction

The maxillary sinus is the largest of the paranasal sinuses, with development beginning in the third month of fetal life and continuing throughout adolescence. Its morphology and degree of pneumatization are highly variable, and in the posterior maxilla, close anatomical relationships often exist between the sinus floor and the roots of premolars and molars (1). While first premolars are usually distant from the sinus, the second premolars and molars frequently present close proximity. CBCT studies report that up to 15–25% of second premolars and 40–45% of molar roots protrude into the sinus cavity, with the mesiobuccal root of the second molar and the palatal root of the first molar most commonly involved (2–5). Such anatomical variability underscores the clinical importance of accurate preoperative assessment (Fig. 1).

In oral and maxillofacial surgery, several complications have been associated with sinus involvement. Extractions of posterior maxillary teeth may result in oroantral communications (OAC), displacement of root fragments, or subsequent development of chronic sinusitis (6). Implant surgery also presents challenges, particularly in the atrophic posterior maxilla where sinus augmentation is often required to achieve adequate bone volume (7–10).

Endodontic procedures can also involve the maxillary sinus. The intimate anatomical relationship between posterior maxillary teeth and the sinus floor means that endodontic pathoses and treatments may have direct consequences for sinus health (11). Extrusion of filling materials or irrigants beyond the apical foramen may lead to sinus involvement, foreign body reactions, or acute sinusitis (Fig. 2). Although sodium hypochlorite (NaOCl) accidents are rare, isolated case reports have documented its accidental extrusion into the maxillary sinus with severe inflammatory consequences (12–14).

Intraoperative complications may also occur during endodontic procedures when overinstrumentation leads to perforation of the Schneiderian membrane. In such cases, a positive Valsalva maneuver can be observed, often accompanied

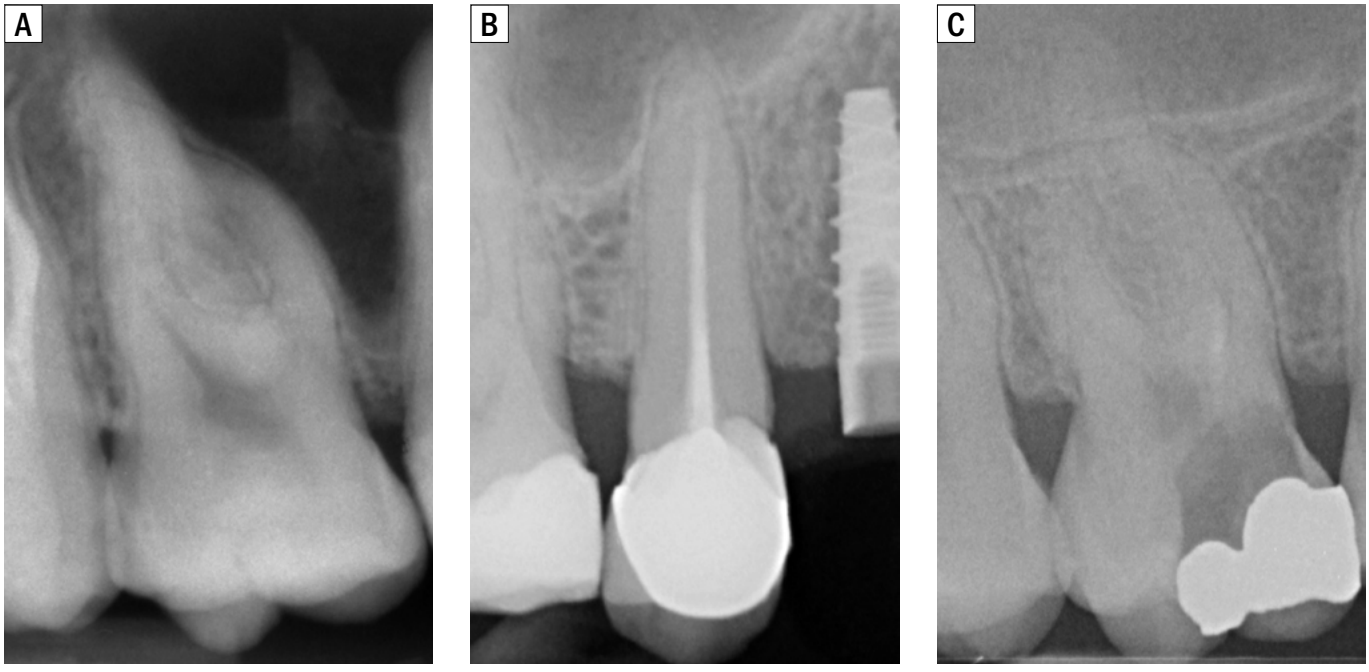


Figure 1
Periapical radiographs of maxillary posterior teeth showing different anatomical relationships with the maxillary sinus. **(A)** First maxillary molar with a very pneumatized sinus, in close contact with the root apices. **(B)** Maxillary premolar with minimal penetration into the sinus cavity. **(C)** Maxillary molar in which the palatal root shows direct relationship with the sinus floor.

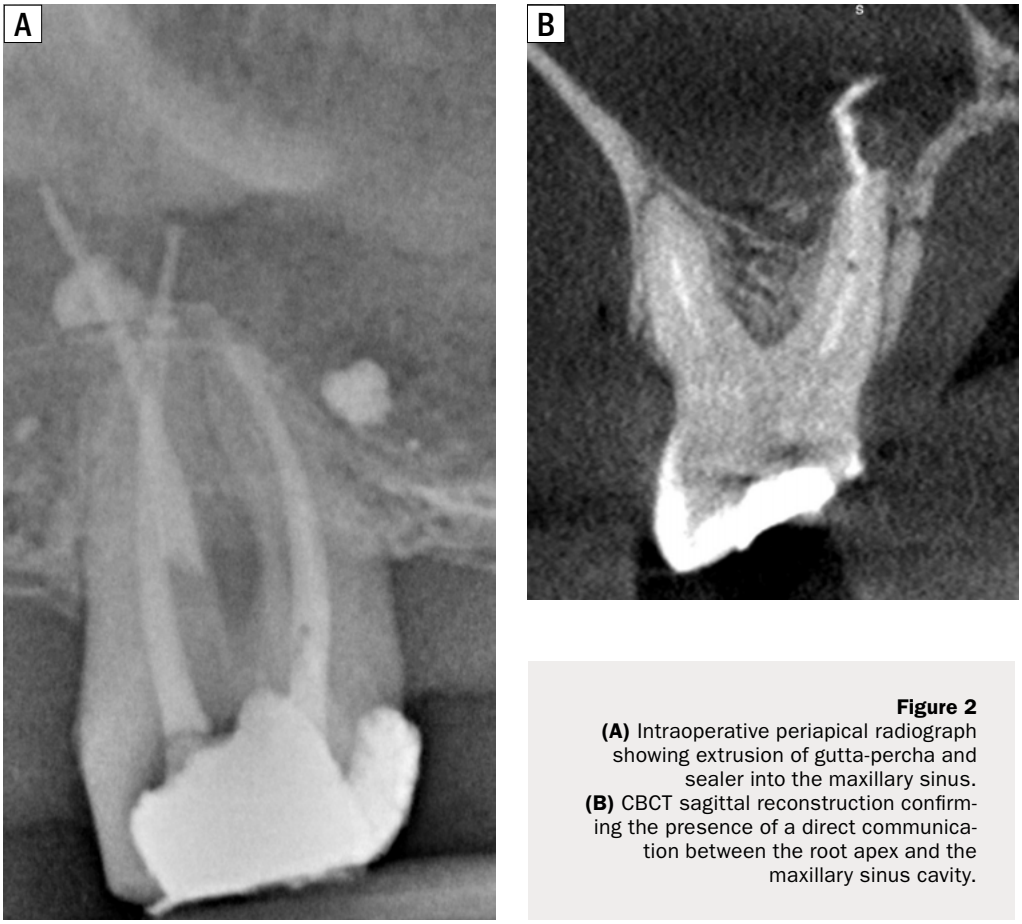


Figure 2
(A) Intraoperative periapical radiograph showing extrusion of gutta-percha and sealer into the maxillary sinus.
(B) CBCT sagittal reconstruction confirming the presence of a direct communication between the root apex and the maxillary sinus cavity.

by bleeding and the leakage of nasal mucus into the operative field (15). This clinical scenario represents a direct communication between the root canal system and the maxillary sinus. At present, no intraoperative endo-sinus communications have been reported in the literature, and consequently no clinical guidelines are available on how to manage this complication. The present case series is the first to describe and document the management of such endo-sinus communications.

This study addresses a current gap in the literature, as no systematic case series on intraoperative endo-sinus communications has yet been reported. The objective of the present work was therefore to document the clinical presentation, management strategies, and outcomes of 15 such cases, with the aim of providing practical guidance for clinicians confronted with this rare but clinically significant complication.

Management of Cases

All patients included in this series presented with a maxillary premolar or molar requiring endodontic treatment or retreatment due to extensive carious destruction, prosthetic needs, or persistent periapical pathology. Each patient provided written informed consent before undergoing endodontic therapy. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

All patients signed written informed consent for treatment and for the use of anonymized images. Preoperative periapical radiographs revealed a close anatomical relationship between the treated roots and the maxillary sinus floor. In

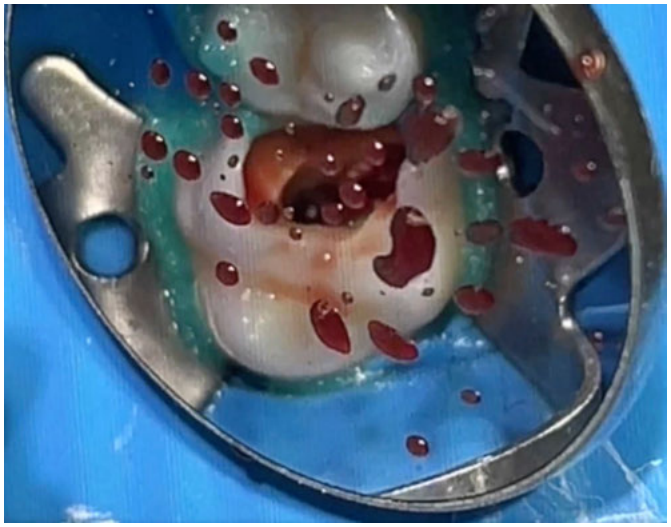
some patients, cone-beam computed tomography (CBCT) was performed and confirmed the proximity.
Cone-beam computed tomography (CBCT) examinations were acquired when necessary with a Carestream 8100 unit (Carestream Health, USA), using a limited field of view (5 × 5 cm) and a voxel size of 0.2 mm.
Endodontic procedures were initiated with a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) to establish the working length. The working length was determined using the Morita TriAuto ZX2 apex locator integrated with endodontic motor (J. Morita Corp., Osaka, Japan) and confirmed radiographically only in doubtful cases. Canal patency was maintained with a size 10 K-file.
Canal shaping was carried out with the ProTaper Gold system (Dentsply Maillefer, Ballaigues, Switzerland), used according to the manufacturer's instructions, and completed once the instrument flutes were filled with clean dentin debris.
Irrigation was performed with 5.25% sodium hypochlorite (Niclor; Ogna, Muggiò, Italy), delivered in three aliquots of 5 ml each using dedicated irrigation cannulas (IrriFlex; PD Produits Dentaires, Vevey, Switzerland) positioned 2 mm short of the root apex.
When an intraoperative communication was suspected, NaOCl irrigation was discontinued and replaced by the iVac negative pressure system. A final rinse with 10% EDTA (Tubuliclean; Ogna, Muggiò, Italy) was then performed.
During or towards the end of canal preparation, four different intraoperative findings were observed:.

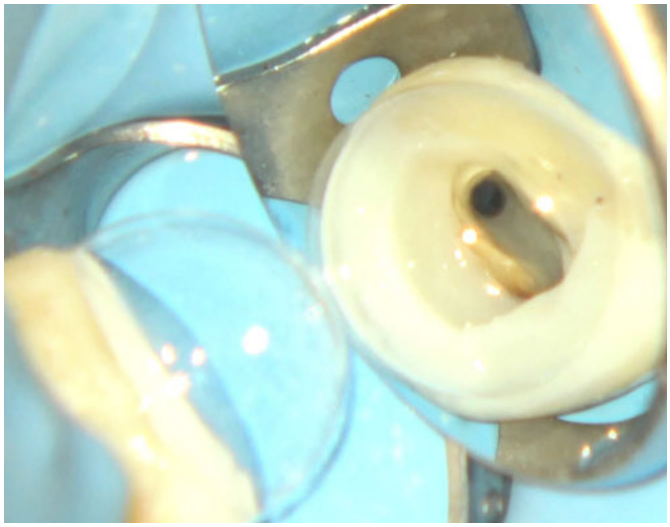
1. Profuse bleeding into the pulp chamber, which, being synchronous with respiration, was cyclically re-aspirated into the canal system (Fig. 3).
2. Presence of nasal mucus in the pulp chamber, clearly of paranasal origin (Fig. 4).
3. Disappearance of sodium hypochlorite solution from the pulp chamber during irrigation.
4. Paper points contaminated with blood or nasal mucus during canal drying.

In all 15 cases, a Valsalva maneuver was performed intraoperatively to confirm Schneiderian membrane perforation. The maneuver was positive in every patient, demonstrating the presence of an iatrogenic communication between the endodontic space and the maxillary sinus.
Following confirmation of endo-sinus communication, the management strategy was adapted to the intraoperative conditions of the canal system. When the canal could be adequately dried, or hemostasis was obtained with the aid of topical hemostatic agents (10), endodontic obturation was completed in the

Figure 3
Clinical image extracted from an intraoperative video during the Valsalva maneuver. The palatal canal shows an endo-sinus communication with profuse bleeding. The blood outflow, synchronous with respiration, was so intense that it splashed against the mouth mirror.

Figure 4
Clinical image extracted from an intraoperative video during the Valsalva maneuver. Nasal mucus from the sinus extrudes through the palatal canal, forming a visible bubble at the canal orifice, confirming the presence of an endo-sinus communication.





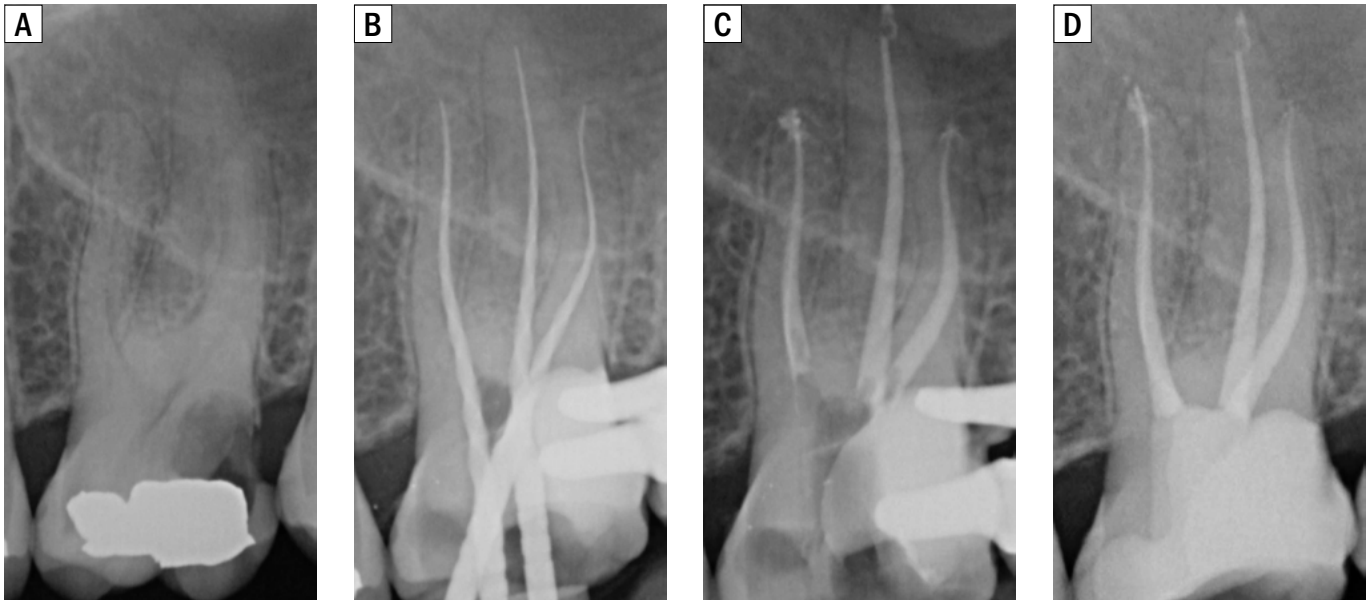


Figure 5
Case of endo-sinus communication involving the mesial root, managed in a single visit.
(A) Preoperative periapical radiograph.
(B) Working length radiograph.
(C) Postoperative radiograph after endodontic Coneless obturation.
(D) Three-year follow-up radiograph showing complete healing and absence of sinus involvement.

same visit. Conversely, when persistent bleeding or nasal mucus prevented satisfactory drying, obturation was postponed. In these cases, the canals were provisionally sealed with teflon and temporary restorative material. At the operator's discretion, an inter-appointment dressing with calcium hydroxide was placed, while in other cases no intracanal medicament was used.

When required, hemostasis was achieved with 38% ferric sulfate (galenic preparation) applied using paper points at working length.

When intracanal medicament was inserted, a calcium hydroxide paste (Stomidrox; Stomygel SRL, Rome, Italy) was placed for 1–2 weeks until the subsequent appointment.

Obturation was performed with different techniques. In cases of single-cone or warm vertical compaction, ProTaper Gold conform-fit gutta-percha cones (Dentsply Maillefer, Ballaigues, Switzerland) were used. In cases of coneless obturation, the Obtura III Max device (Obtura Spartan, Algonquin, IL, USA) was employed. A bioceramic sealer (Ceraseal; Meta Biomed, Cheongju, Republic of Korea) was applied in all cases. No collagen barrier was placed. Temporary sealing was standardized using Teflon tape followed by IRM (Dentsply Sirona, Charlotte, NC, USA). All patients were subsequently recalled for completion of endodontic treatment and were monitored both clinically and radiographically to assess healing and exclude persistence of sinus-related symptoms.

Postoperative instructions included informing patients about the possibility of mild nasal bleeding, advising against Valsalva maneuvers or nose blowing. No antibiotics were prescribed, and analgesics were recommended only as needed.

Results

A total of 15 cases of intraoperative endo-sinus communication were documented. All patients presented with a positive Valsalva maneuver, confirming the presence of a communication between the root canal system and the maxillary sinus.

In 4 cases (26.7%), the canals could be adequately dried, or hemostasis was achieved with the aid of topical hemostatic agents, and endodontic obturation was completed in a single visit. (Fig. 5)

In the remaining 11 cases (73.3%), pro-

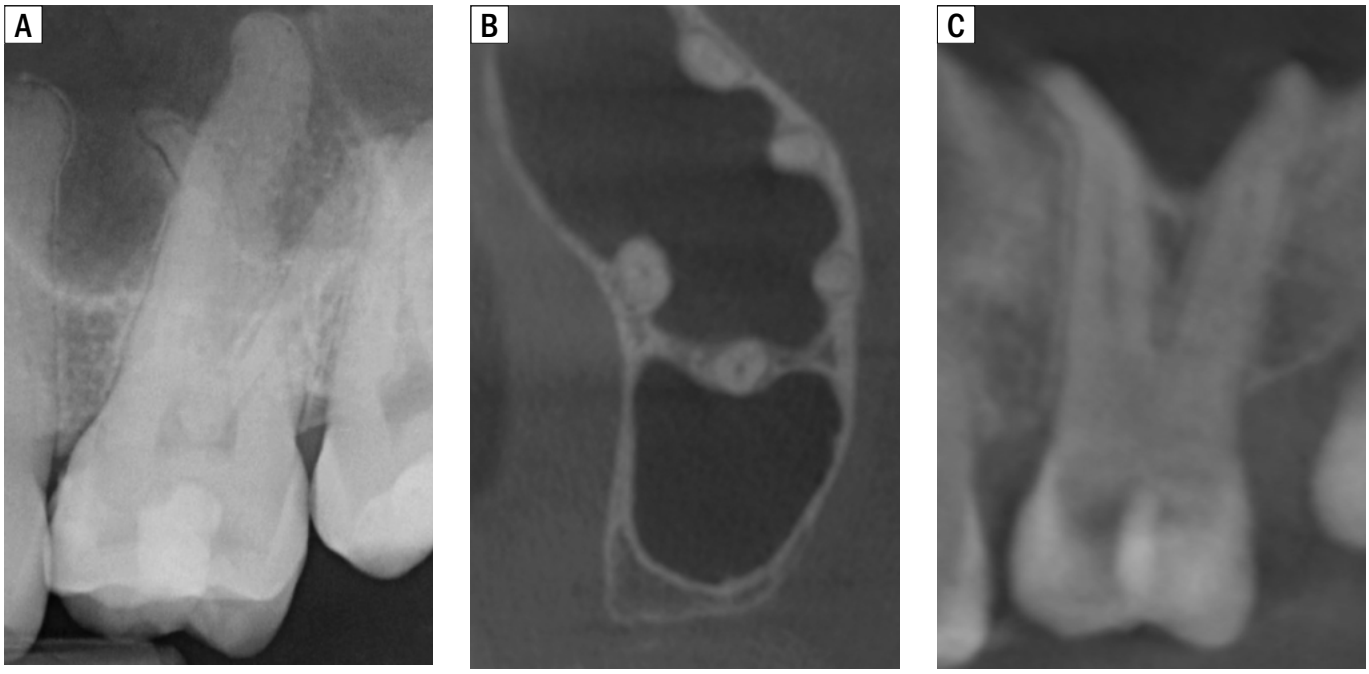


Figure 6 Preoperative assessment of a maxillary molar scheduled for endodontic treatment due to pulpitis. The complex root anatomy and suspected sinus involvement prompted a CBCT evaluation prior to therapy. **(A)** Periapical radiograph showing a close relationship between root apices and the maxillary sinus floor. **(B)** CBCT axial slice confirming apical protrusion into the sinus cavity. **(C)** CBCT coronal view demonstrating the protrusion of all root apices into the sinus.

fuse bleeding or nasal mucus prevented immediate obturation. These cases were managed with a two-visit approach, sealed provisionally with Teflon and IRM. Among them, 4 cases (26.7%) received an interappointment dressing with calcium hydroxide, while in 7 cases (46.7%) no intracanal medicament was placed (Fig. 6,7).

All patients were recalled for comple-

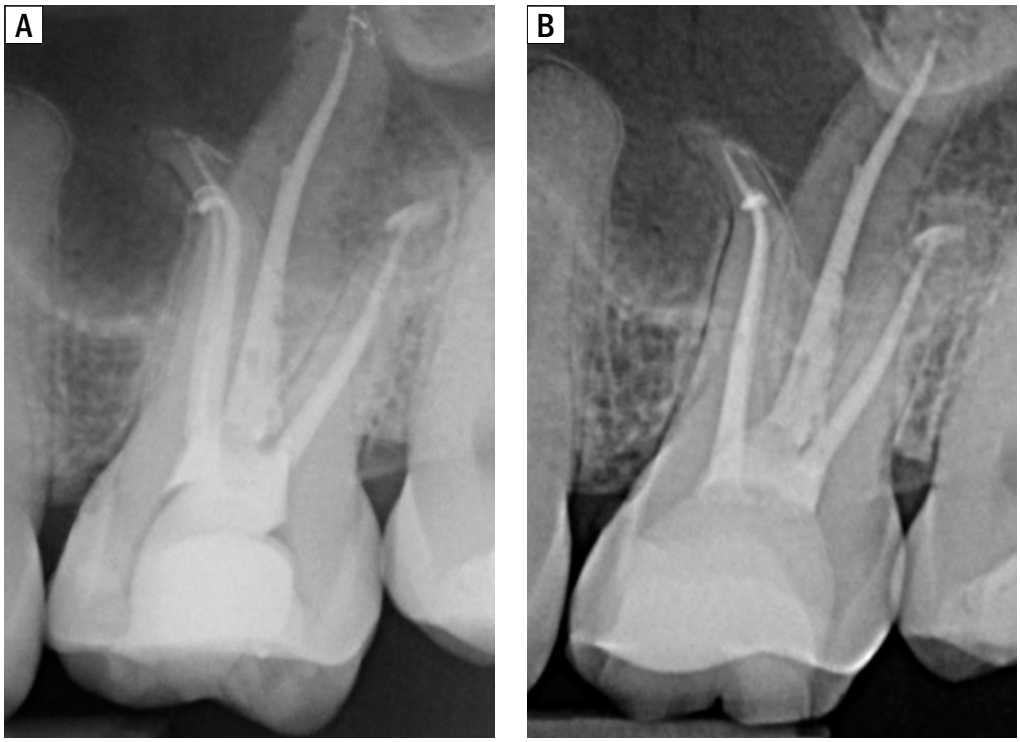


Figure 7 Same case as in Figure 6, managed in two visits. The tooth was obturated using the coneless endodontic technique. **(A)** Postoperative periapical radiograph after completion of root canal treatment. **(B)** Four-year follow-up radiograph showing stable periapical healing and absence of sinus-related complications.

Case	Age/Sex	Tooth	Root involved	Intraoperative findings	Management	Follow-up
1	M	17	P	Paper points contaminated with blood/mucus	Immediate obturation	4 Y
2	M	16	D	Paper points contaminated with blood/mucus	Immediate obturation	3 Y
3	M	16	M	Disappearance of NaOCl	Immediate obturation	4 Y
4	F	26	P	Nasal mucus in pulp chamber	Immediate obturation	10 Y
5	M	15	P	Paper points contaminated with blood/mucus	$Ca(OH)_2$ (Stomidrox)	1 Y
6	M	26	P	Profuse bleeding synchronous with breathing	$Ca(OH)_2$ (Stomidrox)	2 Y
7	M	27	M	Paper points contaminated with blood/mucus	$Ca(OH)_2$ (Stomidrox)	5 Y
8	F	16	D	Paper points contaminated with blood/mucus	$Ca(OH)_2$ (Stomidrox)	3 Y
9	M	16	M	Paper points contaminated with blood/mucus	No medication	4 Y
10	M	26	P	Disappearance of NaOCl	No medication	1Y
11	M	26	P	Profuse bleeding synchronous with breathing	No medication	4 Y
12	M	16	M	Profuse bleeding synchronous with breathing	No medication	6 Y
13	F	17	P	Profuse bleeding synchronous with breathing	No medication	3 Y
14	M	27	P	Profuse bleeding synchronous with breathing	No medication	7 Y
15	M	16	P	Disappearance of NaOCl	No medication	1 Y

Table 1
Summary of 15 cases of intraoperative endo-sinus communication

tion of endodontic treatment and were followed clinically and radiographically. The mean follow-up period was 3.9 years (range: 1–10 years). No patients reported persistent sinonasal symptoms or complications during the observation period.
Clinical details of 15 cases of intraoperative endo-sinus communication, including tooth, root involved, intraoperative findings, management, and follow-up are shown in Table 1.

Discussion

In this case series, we report 15 instances of intraoperative endo-sinus communication that occurred during root canal treatment or retreatment of maxillary posterior teeth in close proximity to the sinus floor. All patients presented with a positive Valsalva maneuver, confirming the presence of a direct communication between the endodontic space and the sinus cavity. To our knowledge, this is the first case series describing such a complication, as the literature to date has reported only three isolated cases of sodium hypochlorite extrusion into the maxillary sinus (12–14).
The distribution of affected teeth and roots in our sample was consistent with previous CBCT studies investigating the anatomical relationships between posterior maxillary teeth and the sinus. Large radiological investigations have shown that only 1–2% of first premolars and up to 15–25% of second premolars are in contact with or protrude into the sinus, whereas the prevalence increases markedly for molars, with 40–45% of first molar roots and up to 45% of second molar roots projecting into the sinus cavity (2–5). Root-specific analyses confirm that the mesiobuccal root of the second molar and the palatal root of the first molar are most frequently involved, with frequencies ranging from 30–40% in different populations (3,6). These anatomical data explain why, in our series, the majority of endo-sinus communications occurred in molars, while only a few premolars were affected.
Furthermore, studies have demonstrated that younger individuals tend to present shorter distances between apices and the sinus floor, with a higher prevalence of root protrusion into

the sinus cavity (4,7,8). Although age distribution was not a primary focus of our series, this factor may represent an additional risk variable when planning endodontic treatment in the posterior maxilla.

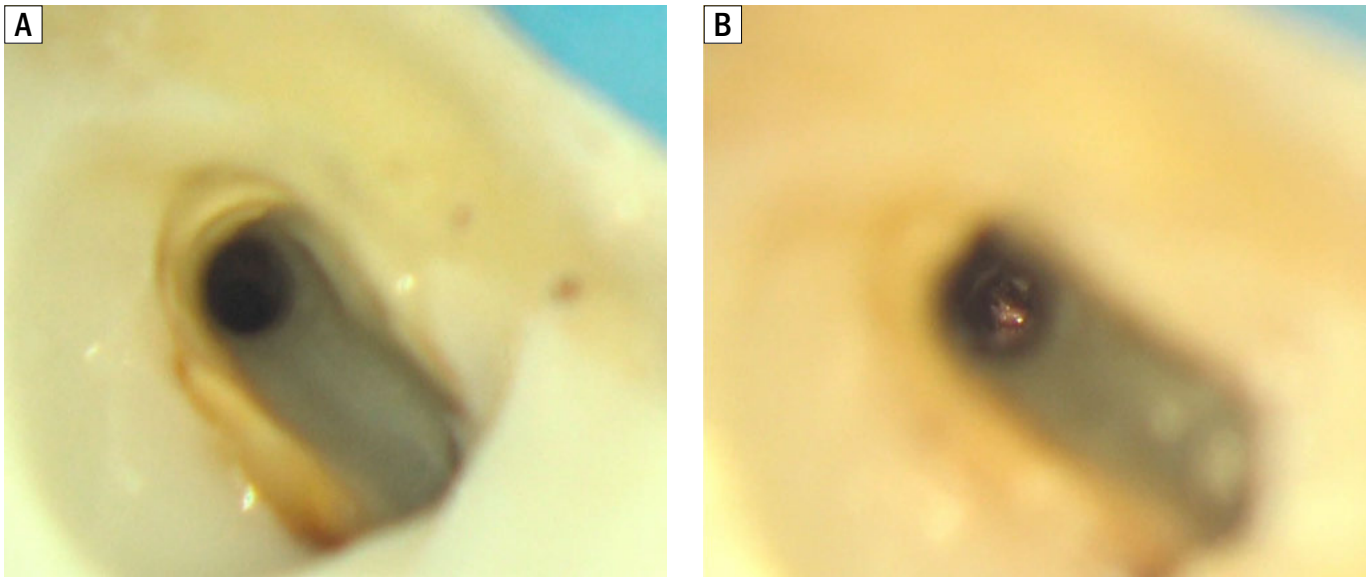
Intraoperative signs observed in our series included profuse bleeding synchronous with respiration, the presence of nasal mucus in the pulp chamber, disappearance of sodium hypochlorite, and contamination of paper points with blood or mucus. In all cases, the Valsalva maneuver confirmed the presence of communication, underscoring its utility as a simple intraoperative diagnostic tool (15).

Management depended on the possibility of drying the canal and controlling bleeding. In four cases (26.7%), obturation was completed in a single visit. In the remaining eleven cases (73.3%), definitive obturation was postponed, with provisional sealing using Teflon and IRM. Among these, four cases received calcium hydroxide as an interappointment dressing, while seven had no intracanal medicament. Importantly, in all cases the communication resolved spontaneously within one week, (Fig. 8) and no differences were observed in clinical outcome between teeth that received calcium hydroxide and those that did not.

At follow-up (mean: 3.9 years; range: 1–10 years), none of the patients developed persistent sinonasal symptoms or radiographic evidence of chronic sinusitis. These findings indicate that, when promptly recognized and managed, intraoperative endo-sinus communications may have a benign course and do not compromise the long-term prognosis of endodontic treatment.

Another relevant clinical aspect is the determination of working length (WL) in maxillary posterior teeth. Electronic apex locators are widely considered reliable, but their accuracy may be compromised when root apices are in contact with the sinus cavity. An ex vivo study demonstrated that the Root ZX apex locator significantly overestimated the real WL in palatal roots communicating with the sinus, while no error was observed in roots without such relationship (17). This finding is crucial, as inaccurate WL determination in these cases may increase the risk of overinstrumentation, extrusion of irrigants, or debris into the sinus. For this reason, in clinical practice, WL determination should always be confirmed radiographically when treating teeth in close proximity to the sinus floor.

Figure 8
Endo-sinus communication involving the palatal root (apical size #50). **(A)** Intraoperative microscopic view showing the communication as a dark area, resembling the appearance of post-extraction sockets with sinus opening. **(B)** One-week recall without interappointment dressing: the sinus membrane can be visualized at the apical level. In such cases, particular caution is required to avoid patency filing or overinstrumentation, which could recreate the communication.



In addition, shaping of curved canals with NiTi rotary systems can progressively modify canal curvature, leading to WL changes. An in vitro study showed that overinstrumentation in curved canals resulted in canal straightening and a mean WL variation of 0.4–0.5 mm (18). This highlights the importance of frequent WL reassessment during shaping procedures to prevent inadvertent overinstrumentation and possible perforation of the sinus floor.

Accurate preoperative radiographic assessment is also essential in preventing and recognizing endo-sinus communications. While CBCT provides the most precise evaluation of root–sinus relationships, periapical and panoramic radiographs remain the first-line diagnostic tools in daily practice. Importantly, clinicians should not only look for the apparent projection of the root apex into the sinus cavity, but also for indirect radiographic signs that may indicate close anatomical contact. These include interruption of the cortical outline of the sinus floor, absence of the periodontal ligament space, apical darkening of the root, and upward curving of the sinus floor enveloping the apex. The presence of multiple signs significantly increases the likelihood of true root protrusion into the sinus, as confirmed by CBCT (19). Careful evaluation of these features on preoperative radiographs may therefore provide an early warning and help prevent inadvertent intraoperative complications.

An important aspect of case management is the chemomechanical cleaning phase. Adequate irrigation protocols, combined with negative pressure delivery—particularly when communication is suspected—are crucial to minimize the risk of extrusion into the sinus and to ensure effective microbial control. This is consistent with recent evidence emphasizing both the safety and efficacy of optimized irrigation strategies (20).

Limitations

A precise assessment of maxillary sinus involvement was limited by the use of non-standardized imaging. Ideally, a baseline preoperative CBCT (limited field of view, low-dose) and a follow-up CBCT would be required to objectively document the extent of Schneiderian membrane involvement and to demonstrate healing versus persistence (e.g., resolution of mucosal thickening or closure of the communication). Reliance on intraoperative signs (such as a positive Valsalva maneuver) and periapical radiographs alone may lead to misclassification. Future prospective studies should incorporate standardized CBCT protocols, while maintaining adherence to the ALARA principle to minimize radiation exposure. Where feasible, adjunctive outcome measures—such as ENT evaluation or sinonasal symptom scoring—should also be included.

Conclusions

This case series documents, for the first time, intraoperative endo-sinus communications during root canal treatment of maxillary posterior teeth. These events, although rare, can be promptly recognized through characteristic clinical signs and confirmed by the Valsalva maneuver.

The communication resolved spontaneously within one week in all cases, and no differences were observed between teeth medicated with calcium hydroxide and those managed without interappointment dressing. Endodontic treatment was successfully completed in all patients without subsequent sinonasal complications.

An important aspect not to be underestimated is the accurate determination of working length at the first appointment, in order to avoid tearing the sinus membrane again at a subsequent visit. Once the communication has been controlled, different obturation techniques can be employed successfully. Recent evidence indicates that bioceramic sealers, in particular, may reduce pos-

toperative discomfort while ensuring long-term success rates comparable to conventional methods (21).
Careful radiographic assessment, accurate and repeatedly verified working length determination, and controlled canal instrumentation are therefore essential to minimize the risk of this complication and ensure favorable long-term outcomes. These findings are in line with previous clinical reports that emphasize the challenges posed by anatomical variability of root canal systems and the importance of meticulous radiographic and clinical evaluation (22).

Conflict of Interest and Funding

The authors declare that they have no conflicts of interest related to this study. No external funding was received for the conduct of this research or for the preparation of this manuscript.

Authors' Contributions

C. B. and **F. C.** conceived the study, performed the clinical treatments, collected data, and contributed to manuscript drafting.
F. S. assisted in the clinical management of cases and data collection.
E. N. S. carried out the radiographic analysis and contributed to case documentation.
S. H. and **A. S.** contributed to data interpretation and critically revised the manuscript for important intellectual content.
E. P. supervised the study design and contributed to the final revision of the manuscript.

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CASE REPORT

P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root canal Lumen): presentation of a case report

ABSTRACT

Aim: *This study aimed to introduce and clinically validate a novel conservative technique, P.E.A.R.L. (Periapical Exudate Aspiration via Root canal Lumen), designed to manage acute periapical abscesses with associated facial swelling. The technique allows for direct aspiration of periapical exudate via the root canal system, potentially eliminating the need for surgical drainage or systemic antibiotic therapy.*

Materials and Methods: *A clinical case involving a necrotic mandibular second premolar (tooth 4.5) presenting with acute facial swelling was treated using the P.E.A.R.L. technique. After establishing the working length, the canal was gently instrumented and irrigated. Apical patency was achieved with a small manual file to stimulate periapical exudate release. When exudate was not initially present within the canal, a fine endodontic suction tip (Ø 0.30 mm) was connected to high-vacuum suction and positioned slightly beyond the apical foramen to allow negative pressure drainage. No systemic antibiotics were administered. Root canal obturation was performed in the same session.*

Results: *Facial swelling and associated symptoms resolved within 36 hours following treatment. No postoperative complications occurred, and clinical and radiographic follow-up confirmed the infection's resolution. The case demonstrated successful management of an acute periapical abscess in a single visit without surgical incision or pharmacological support.*

Conclusions: *The P.E.A.R.L. technique offers a conservative, efficient, and minimally invasive approach for managing periapical abscesses. It may reduce or eliminate the need for mucosal incision and antibiotic therapy, shorten treatment duration, and allow definitive root canal therapy to be completed in a single session. Further clinical studies are recommended to validate its broader applicability and long-term outcomes.*

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Introduction

Endodontic therapy is a fundamental component of modern dental practice, aiming to preserve teeth affected by pulpal and periapical pathologies (1). The success of root canal treatment depends on several critical factors, including accurate diagnosis, effective microbial control through chemomechanical instrumentation, disinfection, and hermetic three-dimensional obturation of the canal system (2). When executed properly, endodontic treatment can yield high long-term success rates (3). However, treatment failures occur and may be attributed to various causes such as missed canals, inadequate disinfection, persistent or secondary microbial contamination, or procedural errors (4).
One of the most common clinical outcomes of pulp necrosis is the development of periapical lesions, which represent the body's immune response to bacterial invasion and byproducts exiting through the apical foramen (5). These lesions can manifest in a spectrum of clinical presentations ranging from chronic, asymptomatic apical periodontitis to acute apical abscesses with systemic involvement (6). While chronic lesions may remain clinically silent for long periods, acute infections can progress rapidly and present with severe pain, purulent discharge, and, in some cases, significant facial swelling due to the spread of the infection to adjacent fascial spaces (7).
Facial swelling associated with endodontic infections is both a clinical challenge and an emergency, often causing considerable patient discomfort, aesthetic concern, and functional impairment (8). The standard management protocol typically involves systemic antibiotic administration to reduce inflammation, followed by incision and drainage procedures when indicated, and delayed completion of endodontic therapy once the acute phase has subsided (9). Although effective in many cases, this approach has notable limitations (9). The reliance on antibiotics contributes to global concerns regarding antimicrobial resistance (10), while surgical drainage procedures are invasive, may lead to postoperative complications such as scarring, and can cause patient apprehension (11, 12).
In this context, there is a growing need for minimally invasive and more efficient strategies to manage acute endodontic infections presenting with facial swelling. Recent advances in endodontic techniques and instrumentation have opened new possibilities for conservative management of exudative periapical lesions directly through the root canal system.
This article introduces and describes a novel approach termed the P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root canal Lumen), which facilitates the aspiration of periapical exudate through the root canal using negative pressure. This technique aimed to achieve effective drainage and symptom resolution without the need for mucosal incision or systemic antibiotics, thereby enabling the completion of endodontic therapy in a single visit.
A clinical case involving a necrotic mandibular second premolar (tooth 4.5) with associated facial swelling is presented to demonstrate this technique's application, advantages, and outcomes in a real-world setting.

Materials and Methods

This case report was prepared and reported in accordance with the PRICE 2020 guidelines (Preferred Reporting Items for Case reports in Endodontics) to ensure transparency, completeness, and clinical relevance

Case presentation

A 19-year-old male patient in good general health with no relevant medical history presented to our dental centre with a chief complaint of facial swell-

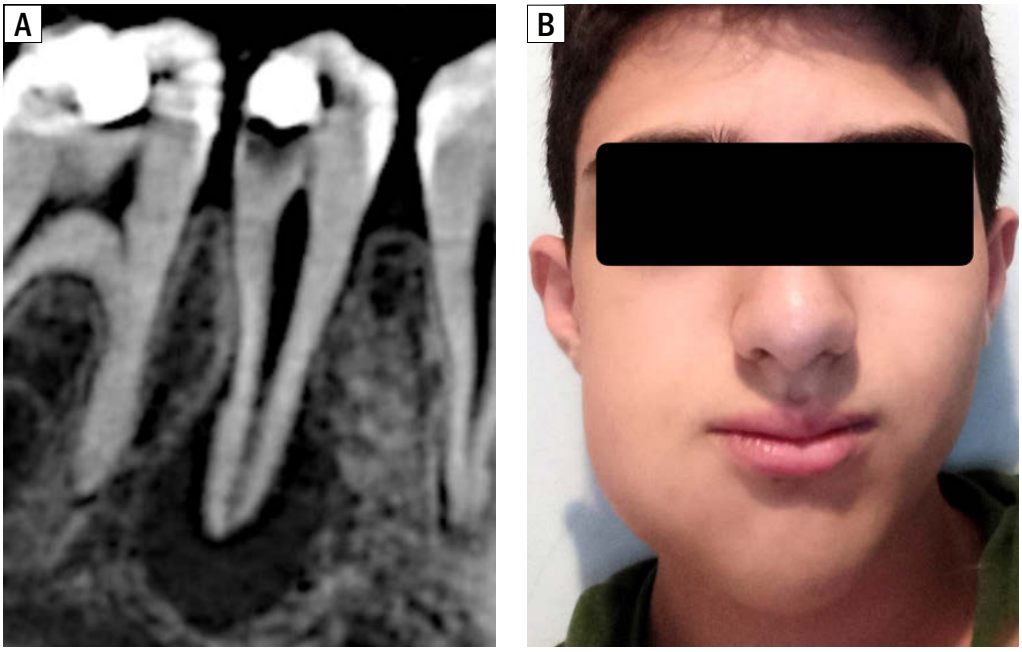

Figure 1
A: CBCT image showing the periapical lesion of tooth 4.5, **B:** Swelling on the lower right side of the face.

ing localized to the lower right side associated with spontaneous throbbing pain. Clinical examination revealed composite restorations on teeth 4.5 and 4.6, with no evidence of recurrent caries, pathological tooth mobility, or periodontal pocketing. Pulp sensibility testing (cold test) was physiologic on teeth 4.4 and 4.6 but negative on 4.5. Percussion testing elicited a positive response only on tooth 4.5.

The patient independently underwent a cone beam computed tomography (CBCT) scan one day prior to presentation. Radiographic analysis revealed a defective composite restoration on tooth 4.5 with carious infiltration approaching the pulp chamber and an extensive periapical radiolucency. A diagnosis of pulpal necrosis with symptomatic apical periodontitis and acute facial swelling was established. After informed consent was obtained, orthograde root canal treatment was initiated immediately (Figure 1).

Due to the pulp's necrotic status, local anaesthesia was not required. Rubber dam isolation was applied, and a conservative access cavity was prepared through the existing restoration under an operating microscope. Carious tissue was removed, and the root canal was located. Irrigation was initially performed with 5.25% sodium hypochlorite (NaOCl) (Canal Pro, Coltene/Whaledent AG, Switzerland). Coronal flaring was accomplished, and working length was established with a size 10 K-file (MicroMega, Coltene/Whaledent AG, Switzerland) using an electronic apex locator (Morita, Japan).

At this stage, the canal was dry with no apparent purulent exudate. Therefore, the P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root canal Lumen) was employed. This technique stimulates periapical exudate by enlarging the apical diameter without visible drainage within the canal. Apical enlargement was performed using the HyFlex EDM rotary system (Coltene/Whaledent AG, Switzerland), with final instrumentation achieved using a 30/0.04 file to full working length.

A 0.30 mm diameter endodontic suction tip (30G NaviTip needle, Ultradent Products, Inc., South Jordan, UT, USA), connected to high-vacuum suction (Luer Vacuum Adapter, Ultradent, Salt Lake City, UT, USA), was carefully positioned slightly beyond the apical foramen. Negative-pressure aspiration

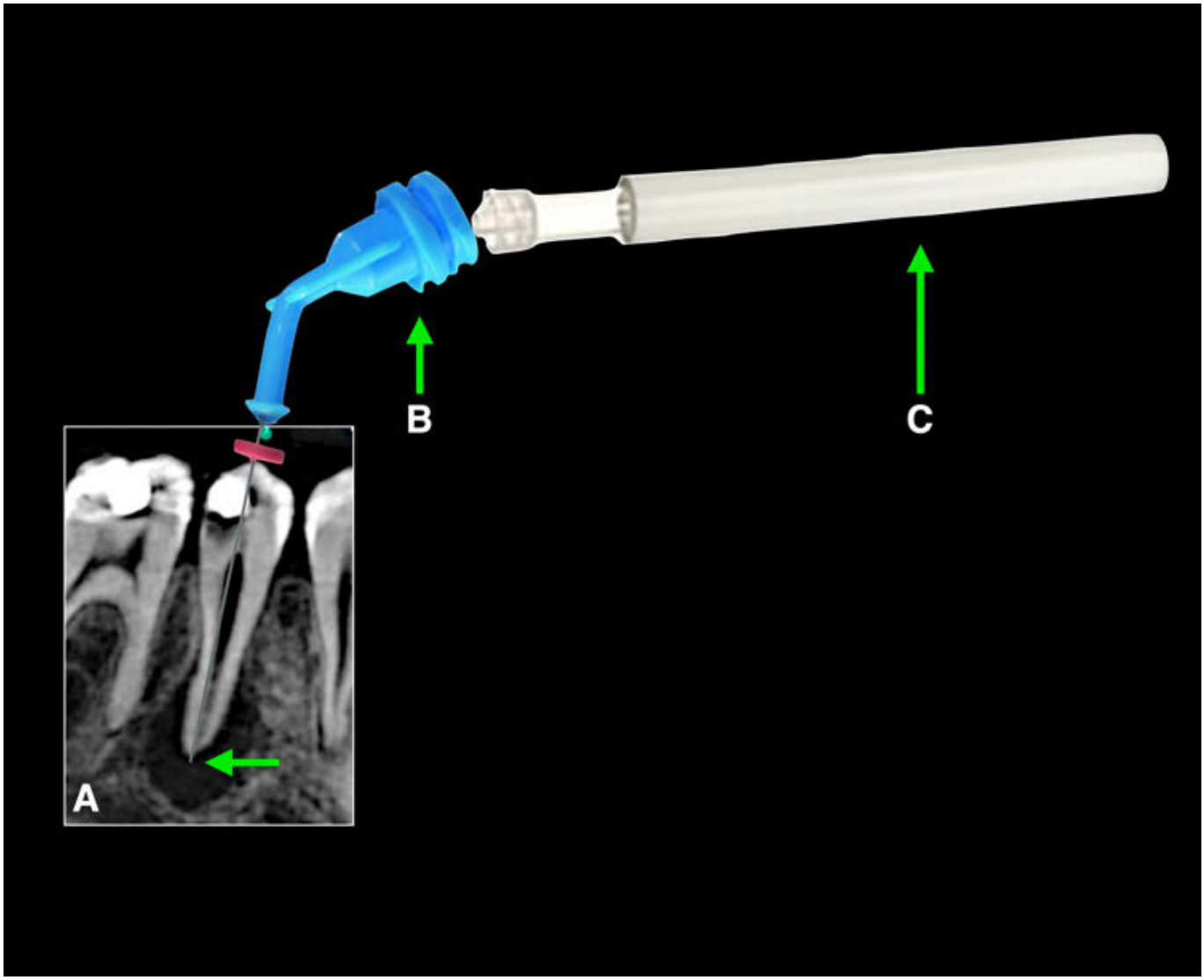

Figure 2
P.E.A.R.L. Technique:
A: Needle positioned beyond the apex,
B: Endodontic needle,
C: Luer vacuum adapter.

of the periapical exudate was initiated and maintained for approximately 20 minutes. Exudate flow was monitored visually through the transparent connector of the aspiration needle. Once no further exudate was observed, canal disinfection and cleaning protocols were initiated (Figure 2).

The canal was irrigated with 17% EDTA (Canal Pro, Coltene/Whaledent AG, Switzerland) for one minute to remove the smear layer, followed by a 5.25% NaOCl (Canal Pro, Coltene/Whaledent AG, Switzerland) rinse to inactivate any residual chelating agent. Final irrigation was carried out using the 3D Cleaning Technique, including controlled internal heating of sodium hypochlorite with a thermal plugger and a 20-second ultrasonic activation (13). This activation cycle was repeated three times, each with fresh NaOCl.

Following final irrigation, the canal was dried with sterile paper points (Coltene/Whaledent AG, Switzerland) and obturated using a single-cone gutta-percha (Coltene/Whaledent AG, Switzerland) technique with bioceramic sealer (Bioseal, Coltene/Whaledent AG, Switzerland). The tooth was then definitively restored with composite resin and a postoperative periapical

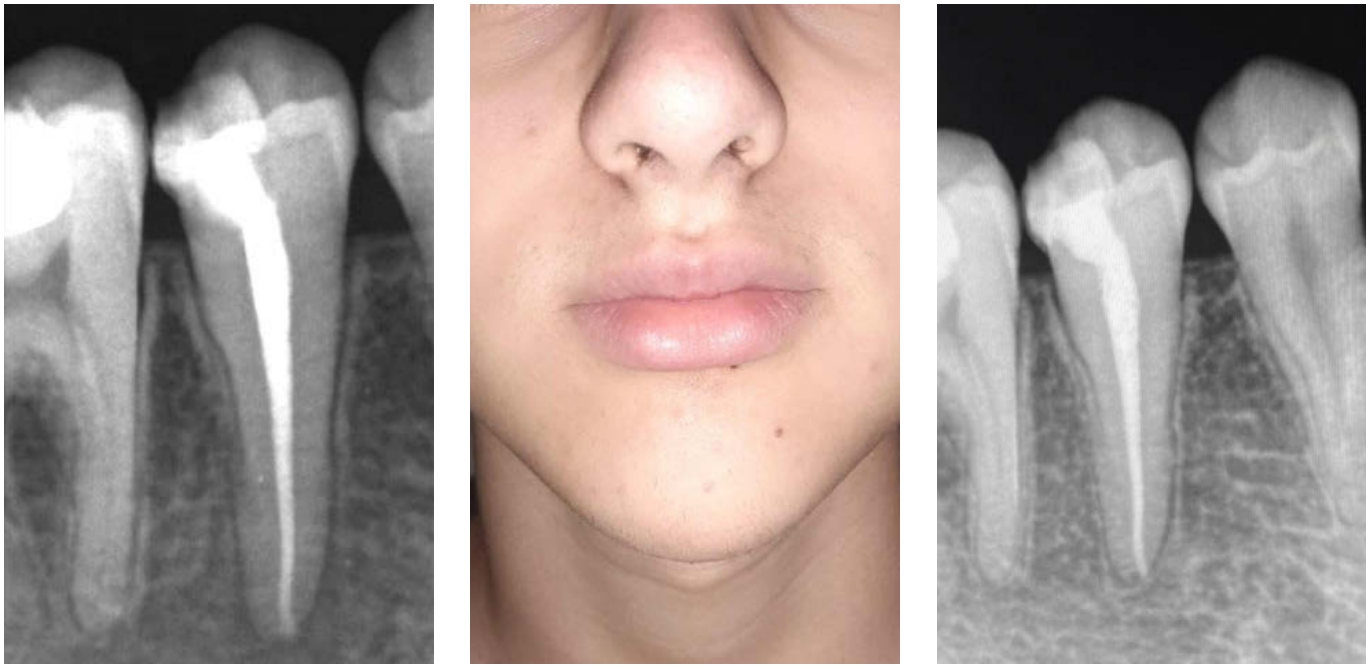

Figure 3
A: Postoperative radiograph
B: Absence of facial swelling after 36 hours
C: One-year follow-up radiograph showing periapical healing.

radiograph was obtained to confirm the quality of the obturation (Figure 3A). The patient reported a marked reduction in discomfort within hours of treatment. At 36 hours, the facial swelling had completely resolved (Figure 3B). At the 12-month follow-up, the patient remained asymptomatic, and radiographic evaluation demonstrated substantial periapical healing (Figure 3C).

Description of the P.E.A.R.L. Technique

The P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root canal Lumen) is a conservative, nonsurgical approach designed to manage periapical abscesses and associated facial swelling by applying negative pressure within or just beyond the root canal system. This technique can be adapted to two primary clinical scenarios:

1. When purulent exudate is present within the root canal:

Negative-pressure aspiration is initially performed using a high-vacuum suction tip (e.g., Surgi Tip Endo) introduced into the canal. However, the procedure should also include aspiration beyond the apical foramen to ensure complete and effective drainage. A fine endodontic aspiration needle (Ø 0.28 mm or Ø 0.30 mm) is gently inserted slightly beyond the apex to evacuate any residual periapical exudate that has not yet entered the canal. During this phase, manual external massage of the swollen facial area is recommended to facilitate the directional flow of the exudate toward the apical foramen, enhancing the efficacy of suction.

2. When the canal appears dry, but facial swelling is evident:

Apical patency is confirmed, and the foramen is enlarged—typically to at least size 30 with a 0.04 taper. A fine suction needle (Ø 0.28 mm or Ø 0.30 mm) is then advanced slightly beyond the apex and connected to high-vacuum suction. Negative-pressure drainage is applied while simultaneously massaging the extraoral swollen region to mobilize trapped exudate and promote its evacuation through the apical path-

way. This technique eliminates the need for surgical incision and systemic antibiotics in both scenarios, facilitates effective canal drying, and enables definitive root canal obturation in a single visit. The addition of external facial massage serves as a mechanical aid to promote fluid mobilization and optimize drainage, especially in cases of soft-tissue accumulation and limited canal exudate flow.

Discussion

Endodontic therapy remains the cornerstone of conservative dental treatment aimed at preserving natural dentition in the presence of irreversible pulpal damage or periapical pathology (14). The primary goal is to eliminate intracanal infection and prevent reinfection using thorough biomechanical debridement, disinfection, and three-dimensional obturation of the root canal system (15,16). When executed correctly, these procedures demonstrate high success rates (17). Nevertheless, treatment failures still occur due to anatomical complexities, missed canals, biofilm persistence, or procedural deficiencies such as inadequate irrigation or incomplete obturation (18).
In cases where primary root canal therapy fails, retreatment becomes necessary. Nonsurgical orthograde retreatment is typically the first choice and can effectively resolve persistent periapical inflammation or infection, provided the canal system can be fully re-instrumented and disinfected (19). Surgical intervention may be required in more complex cases, although this introduces higher morbidity and patient discomfort (20).
One of the most critical complications of untreated or unsuccessfully managed necrotic pulps is the development of periapical lesions (5). These lesions vary from chronic granulomas or cysts to acute apical abscesses characterized by suppurative inflammation (21, 22). Acute abscesses may rapidly expand into adjacent fascial planes, leading to localized or diffuse facial swelling, a clinical situation requiring prompt attention due to the risk of systemic involvement and compromised airway function (23).
Standard clinical protocols for managing facial swelling secondary to periapical infection often include systemic antibiotic therapy to control infection and reduce inflammation before proceeding with definitive endodontic treatment (9). Surgical incision and drainage are also performed in severe cases to evacuate purulent exudate (9). While these measures are generally effective, they are not without drawbacks (10,11). Systemic antibiotics, although essential in certain medical risk categories (such as patients with cardiac conditions, endocarditis history, or prosthetic heart valves), are often overprescribed in otherwise healthy individuals (24). This practice contributes to the global crisis of antibiotic resistance (9). Furthermore, incision and drainage can result in postoperative scarring, increased patient morbidity, and psychological discomfort (11, 12).
In this context, the P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root Canal Lumen) offers a novel, minimally invasive alternative. By enabling the drainage of periapical exudate directly through the root canal using negative pressure, either within the canal or just beyond the apical foramen this technique addresses the pathophysiological cause of facial swelling without needing systemic pharmacologic or surgical intervention.

The advantages of the P.E.A.R.L. Technique are significant

Avoidance of surgical incision: The technique allows for the evacuation of exudate without soft tissue trauma, reducing the risk of postoperative scarring and improving patient comfort.
No preoperative antibiotic therapy is required. In healthy patients, eliminating the infection source through me-

chanical and negative-pressure drainage may be sufficient to resolve the inflammatory response.
Single-visit treatment: By achieving effective drainage and allowing thorough drying of the canal system, definitive endodontic therapy can be completed in the same session, streamlining clinical workflow and improving patient compliance.
Precise and conservative approach: The use of fine endodontic aspiration needles beyond the apex allows targeted intervention without compromising periapical tissues or anatomical structures.
Clinical efficiency: As demonstrated in the presented case, facial swelling resolved within 36 hours, and long-term radiographic follow-up confirmed periapical healing, highlighting the therapeutic potential of this protocol.
However, it is important to underline that antibiotic therapy remains essential for certain patient populations. These include children with systemic involvement, immunocompromised individuals, elderly patients with cardiac comorbidities, and those at risk for infective endocarditis. Antibiotic prophylaxis or adjunctive therapy must be considered according to current clinical guidelines in these scenarios.
Nevertheless, for otherwise healthy patients presenting with localized abscesses and extraoral swelling, the P.E.A.R.L. Technique may offer a safer, faster, and more comfortable alternative to traditional protocols.
The routine prescription of systemic antibiotics for the management of endodontic infections particularly those without signs of systemic involvement has been extensively debated in the endodontic literature (24). Current evidence-based guidelines emphasize that antibiotics do not significantly contribute to pain relief or the resolution of swelling in cases of localized apical pathosis in otherwise healthy patients (24). Systematic reviews have concluded that antibiotic therapy should not be prescribed solely for symptomatic irreversible pulpitis or localized acute apical abscesses unless systemic symptoms are present (25, 26).
A Cochrane review found no significant benefit of antibiotics in reducing pain in irreversible pulpitis (25). Similar conclusions were drawn by Matthews et al. and Aminoshariae & Kulild (27, 28), who emphasized that systemic infection, fever, or compromised immunity are prerequisites for considering antibiotic use. In practice, this means that most endodontic infections, particularly those with localized swelling or drainage should be managed through mechanical means alone, such as drainage, debridement, and disinfection of the root canal system (24).
The overprescription of antibiotics, particularly in dental settings, contributes to the alarming rise in antimicrobial resistance, a concern recognized globally by health authorities (10). Dental and endodontic infections are typically polymicrobial and often managed empirically, which may lead to the indiscriminate use of broad-spectrum antibiotics even when not clinically indicated (24). This misuse exposes patients to unnecessary side effects and contributes to developing resistant strains within the oral microbiome (10).
In the context of localized odontogenic infections without systemic signs, the primary therapeutic goal should be the mechanical removal or drainage of the infectious source (24). The P.E.A.R.L. technique enables direct periapical exudate aspiration via the root canal and addresses this condition efficiently and conservatively. As demonstrated in the presented case, the technique permitted complete drainage and resolution of swelling without systemic pharmacologic intervention.
However, it is crucial to recognize the patient groups in whom systemic antibiotic therapy remains essential. Immunocompromised individuals, pediatric patients, elderly individuals with chronic conditions, and patients with specific cardiovascular risks (e.g., pros-

thetic heart valves, history of infective endocarditis, recent joint prostheses) may require prophylactic or adjunctive antibiotics to prevent systemic complications (24). The clinician must follow current medical guidelines to determine the appropriate regimen. First-line options often include amoxicillin alone or with clavulanic acid due to its effective absorption and favourable safety profile (24). In patients with a confirmed penicillin allergy, clindamycin remains the antibiotic of choice (24). In summary, antibiotics should be reserved for cases where the infection is not self-limited, there is systemic spread, or when host defences are compromised. The P.E.A.R.L. Technique reinforces this therapeutic philosophy by offering an evidence-based, mechanical alternative to pharmacologic overreliance, consistent with modern principles of antimicrobial stewardship and patient-centred care. Recent perspectives in endodontics are progressively embracing regenerative and non-obturation-based concepts for managing apical pathosis, highlighting the evolving understanding of apical healing mechanisms (29)
Further research, including larger case series and controlled studies, is warranted to assess this approach's reproducibility and standardize clinical parameters such as aspiration duration, apical diameter preparation, and suction device specifications.

Conclusions

The P.E.A.R.L. Technique (Periapical Exudate Aspiration via Root canal Lumen) represents a significant step forward in the conservative management of acute periapical abscesses with facial swelling. This minimally invasive protocol enables rapid symptom resolution, reduces or eliminates the need for antibiotics and surgical intervention, and allows for single-visit endodontic treatment in appropriately selected patients. As antibiotic stewardship and patient-centred care gain increasing importance in clinical practice, the P.E.A.R.L. Technique may offer a valuable addition to the therapeutic arsenal of modern endodontics.

Conflict of interest
The authors declare no conflicts of interest related to the materials, methods, or findings presented in this case report.

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Lettera DEL PRESIDENTE

Cari colleghi,
siamo ormai giunti alle soglie del 40o Congresso Nazionale che si svolgerà a Verona dal 20 al 22 novembre prossimi e sarà caratterizzato da diversi e significativi aspetti innovativi. Tra questi il format congressuale del Clinical Match in cui due relatori con opinioni differenti si confronteranno su di uno stesso argomento apportando la propria esperienza clinica ed arricchendo di vivacità il dibattito scientifico. Anche nella scelta dei relatori abbiamo voluto bilanciare il binomio tradizione/innovazione, un valore che solo una società scientifica di lunga data come la SIE può vantare ed offrire.
Abbiamo voluto arricchire il momento culturale con ospiti stranieri di fama mondiale come il Prof. S. Kim dell'Università di Pennsylvania che aprirà il Congresso con una Lectio Magistralis il venerdì mattina e sarà inoltre coinvolto nel Clinical Match di Microchirurgia Endodontica del sabato esponendo le ultime novità in questo settore. Abbiamo voluto dare visibilità ai giovani Soci Attivi della SIE nella sessione "Talenti in prima fila" del sabato mattina. I giovani colleghi verranno inoltre valorizzati mediante l'assegnazione dei Premi Garberoglio, Riitano-Lavagnoli ed il premio Mangani istituito per onorare la memoria del Maestro ed Amico recentemente scomparso. Il Congresso prevederà inoltre le consuete tavole cliniche nonché il Corso per Igienisti ed Aso. Il momento sociale del Congresso sarà rappresentato quest'anno dal Cocktail Party Dress to Impress, in un'atmosfera rilassata ed informale ci si potrà divertire al sound condotto dai famosi dj Michele Mainardi e Loribi DJ di Deejay Set.
A nome di tutto il Consiglio Direttivo, che ha tanto lavorato per la corretta realizzazione dell'evento, vi saluto e vi aspetto numerosi a Verona.

Cordialmente,
Francesco Maggiore

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Socio Onorario
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Spina Dott. Vincenzo
Socio Onorario
Zerosi Prof. Carlo
Socio Onorario

COME DIVENTARE SOCIO ATTIVO/AGGREGATO

Scaricabile dal sito **www.endodonzia.it**

SOCIO AGGREGATO

Per avere lo status di Socio Aggregato si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo "status" di Socio Aggregato: i punti saranno attribuiti in base al tipo di documentazione presentata. Possono accedere alla qualifica di Socio Aggregato tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda dovrà essere firmata da un Socio Attivo, in regola con la quota associativa per l'anno in corso, il quale è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO AGGREGATO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Aggregato. Un meccanismo a punti è stato introdotto per valutare il candidato: un minimo di 80 punti è richiesto per divenire Socio Aggregato.
La documentazione clinica per ottenere la qualifica di Socio Aggregato dovrà presentare almeno sei casi, di cui non più di tre senza lesione visibile nella radiografia preoperatoria e non più di uno di Endodonzia Chirurgica Retrograda.
Nella domanda non potranno essere presentati casi la cui somma superi i 120 punti per la qualifica di Socio Aggregato.
L'aspirante Socio Aggregato potrà presentare la documentazione clinica in più volte, con un minimo di 40 punti per presentazione, in un arco massimo di tre anni. Il mancato rinnovo della quota associativa, anche per un solo anno, annulla l'iter di presentazione dei casi.

SOCIO ATTIVO

Per avere lo status di Socio Attivo si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso documentazione scientifica e casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo status di Socio Attivo: i punti saranno attribuiti in base al tipo di documentazione clinica e scientifica presentata. Possono accedere alla qualifica di Socio Attivo tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda di ammissione allo status di Socio Attivo rivolta al Presidente della SIE dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO ATTIVO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Attivo. Il Socio Aggregato che volesse presentare la documentazione scientifica e clinica a integrazione di quella clinica già approvata dalla CAS per lo status di socio Aggregato, potrà farlo già dall'anno successivo all'ottenimento della sua qualifica.
Un meccanismo a punti è stato introdotto per valutare il candidato a Socio Attivo. Un minimo di 200 punti è richiesto per divenire Socio Attivo.
Nella domanda non potranno essere presentati casi la cui somma superi i 240 punti per la qualifica di Socio Attivo.
La documentazione scientifica potrà essere presentata, a completamento della documentazione clinica, solo per la domanda per divenire Socio Attivo e non potrà superare i 80 punti.
La documentazione clinica dovrà presentare un minimo di sei casi, di cui almeno 4 di molari pluriradicolati con delle precise tipologie: tra questi casi almeno uno deve essere un ritrattamento con lesione visibile nella radiografia preoperatoria e dei restanti tre almeno due devono avere una lesione visibile nella radiografia preoperatoria.
La documentazione clinica non deve presentare più di un caso di Endodonzia Chirurgica Retrograda con immagini e non più di uno senza immagini.
La documentazione scientifica non potrà presentare più di due articoli come coautore.

MODALITÀ DI DOCUMENTAZIONE DEI CASI CLINICI

Criteri e modalità per la valutazione dei casi clinici idonei ad accedere alle qualifiche di Socio Aggregato e di Socio Attivo sono espressi nell'apposita sezione del Regolamento

della Società Italiana di Endodonzia (SIE) all'indirizzo web: www.endodonzia.it.

CRITERI DI VALUTAZIONE

I casi clinici verranno valutati nel loro complesso, coerentemente con gli scopi e fini della SIE, e devono essere presentati dai Candidati considerando non solo l'aspetto clinico, ma anche quello formale della documentazione presentata.
La documentazione scientifica verrà valutata considerando la classificazione ANVUR delle Riviste Scientifiche, i documenti scientifici dovranno essere tutti di pertinenza endodontica.

ADEMPIMENTI DEL CANDIDATO

La domanda di ammissione allo status di Socio Aggregato/Attivo, rivolta al Presidente della SIE, dovrà pervenire, insieme alla documentazione di seguito elencata, alla Segretaria della SIE con un anticipo di 20 giorni sulle date di riunione della CAS, sufficiente per poter organizzare il materiale dei candidati. Le date di scadenza saranno rese note sul sito. La domanda dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

PRESENTAZIONE DEI CASI ALLA COMMISSIONE

La presenza del Candidato è obbligatoria durante la riunione della CAS; è altresì consigliabile la presenza del Socio presentatore.

LA COMMISSIONE ACCETTAZIONE SOCI

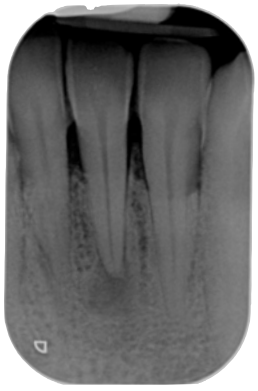
La CAS (Commissione Accettazione Soci) è formata cinque Membri di indiscussa esperienza clinica, quattro Soci Attivi con almeno cinque anni di anzianità in questo ruolo eletti a ogni scadenza elettorale dall'Assemblea dei Soci Attivi e Onorari e uno dei Past President della Società incaricato dal CD a ogni riunione. Compito della CAS è quello di esaminare e valutare la documentazione presentata dagli aspiranti Soci Aggregati e Soci Attivi. Per rispetto del lavoro dei Candidati e per omogeneità di giudizio, in ogni riunione CAS verranno valutati non più di 12 candidati a Socio Attivo; resta libero, invece, il numero dei candidati a Socio Aggregato valutabile in una singola riunione. Il Consiglio Direttivo (CD) incaricando la Commissione Accettazione Soci (CAS) la rende responsabile dell'applicazione delle regole descritte nell'articolo 2 del regolamento. Il giudizio della CAS è insindacabile.

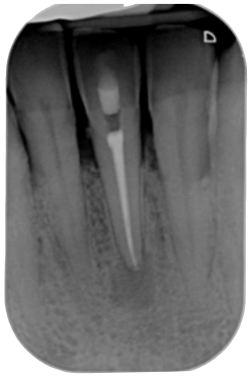
MEMBRI DELLA COMMISSIONE ACCETTAZIONE SOCI BIENNIO 2025-26

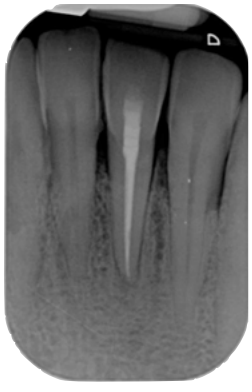
Francesco Riccitiello
Maurizio Boschi
Marco Colla
Claudia Dettori
Giuseppe Multari

Ceraseal

Obturation is a Fundamental Pillar in Endodontic Success







Courtesy of Dr Claudio Farnararo

1 Y

A tridimensional obturation is one of the key final steps for a successful endodontic therapy. Filling as much as possible of the intricate endodontic anatomy and achieving a stable apical seal are essential for long-term prognosis.

Ceraseal: The Next Generation of Bioceramic Sealers

In modern endodontics, the choice of root canal sealers is crucial for long-term treatment success. Ceraseal, a pre-mixed bioceramic sealer, stands out due to its bioactivity, biocompatibility, and superior sealing properties. Its advanced formulation enhances biological response and long-term stability.

Superior Bioactivity

Ceraseal actively promotes healing and tissue regeneration. Upon contact with moisture, it releases calcium ions, stimulating hydroxyapatite formation. This strengthens the bond with dentinal walls and fosters periapical healing, making it particularly beneficial in apical periodontitis or retreatment cases.

Unmatched Biocompatibility

Unlike traditional sealers that may cause inflammation, Ceraseal is highly biocompatible and does not irritate surrounding tissues. Its calcium-silicate composition enhances tissue tolerance, reducing post-operative complications. In cases of accidental extrusion, it integrates naturally with periapical tissues, minimizing risks and promoting healing.

Hermetic Sealing & Dimensional Stability

Ceraseal's formulation ensures an excellent seal, preventing microleakage and bacterial reinfection. Unlike some conventional sealers that shrink, it maintains dimensional stability for long-term durability. Its flowable consistency allows deep penetration into lateral canals, isthmuses, and dentinal tubules, further enhancing its sealing capabilities.

User-Friendly and Efficient Application

As a pre-mixed, ready-to-use sealer, Ceraseal eliminates complex mixing procedures, reducing errors and ensuring consistent application. It can be delivered with a disposable tip for precision and efficiency while minimizing material waste.

Conclusion

Ceraseal is revolutionizing endodontic sealing materials, offering bioactivity, biocompatibility, ease of use, and superior sealing properties. Its innovative formula enhances treatment predictability and promotes healing while preventing reinfections. For practitioners seeking a high-performance bioceramic sealer, Ceraseal represents a state-of-the-art solution in modern endodontic therapy.

EdgeEndo®:
una Evoluzione nell'Endodonzia

L'attesa è finita: EdgeEndo® presenta la nuova Linea EdgePower, una nuova fase nell'endodonzia con un portfolio di prodotti pensato per soddisfare — e anticipare — le esigenze cliniche quotidiane, puntando a ottimizzare efficienza e precisione e a semplificare i flussi di lavoro: un motore endodontico cordless, un localizzatore apicale un dispositivo di otturazione della guttaperca e un condensatore.

Protagonista di questa evoluzione è EdgeApex HP™, il nuovo motore endodontico cordless con localizzatore apicale integrato.

Progettato per offrire massima libertà di movimento e precisione operativa, garantendo flessibilità e performance in ogni trattamento con opzioni di movimento a rotazione continua e reciprocante compatibile con la maggior parte delle sistematiche esistenti. Il dispositivo include un controllo intelligente e torque dinamico.

A supporto di un approccio completo e affidabile, EdgeEndo propone inoltre:

EDGEAPEX™
combina un localizzatore apicale e un test di vitalità pulpare in un unico strumento. Dotato di un ampio display a colori di facile lettura, fornisce un feedback visivo e acustico.

EDGEPACK™
un dispositivo di otturazione della guttaperca wireless progettato per un'otturazione precisa e costante, design ergonomico e ambidestro con tempo di riscaldamento ultrarapido.

EDGEFLOW™
un condensatore di guttaperca wireless progettato per fornire un'elevata fluidità e garantire un riempimento uniforme e privo di bolle per una sigillatura ottimale. Un display intuitivo per monitorare al meglio la guttaperca rimanente.

Con queste soluzioni, EdgeEndo non vuole offrire semplicemente file endodontici, ma essere un partner affidabile per accompagnare il clinico a 360° verso risultati di alto livello, unendo funzionalità, precisione e semplicità d'uso.

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GUIDELINES FOR AUTHORS

Giornale Italiano di Endodonzia (GIE) was founded in 1987 and is the official journal of Società Italiana di Endodonzia, SIE (Italian Society of Endodontics) https://www.endodonzia.it/

It is a peer-reviewed journal, only available in electonic format and publishes original scientific articles, reviews, clinical articles and case reports in the field of Endodontology. Scientific contributions dealing with health, injuries to and diseases of the pulp and periradicular region, and their relationship with systemic well-being and health. Original scientific articles are published in the areas of biomedical science, applied materials science, bioengineering, epidemiology and social science relevant to endodontic disease and its management, and to the restoration of root-treated teeth. In addition, review articles, reports of clinical cases, book reviews, summaries and abstracts of scientific meetings and news items are accepted. Please read the instructions below carefully for details on the submission of manuscripts, the journal's requirements and standards as well as information concerning the procedure after a manuscript has been accepted for publication in Giornale Italiano di Endodonzia. Giornale Italiano di Endodonzia is indexed in Scopus, Science Direct, Embase and published online by Tecniche Nuove, Milan, Italy and hosted by PAGEPress, Pavia, Italy. All articles are available on www.giornaleitalianoendodonzia.it.

We publish, monthly, new articles in the Early View section while the full Journal is issued twice a year, in June and November.

Authors are encouraged to visit www.giornaleitalianoendodonzia.it for further information on the preparation and submission of articles and figures.

Ethical guidelines

Giornale Italiano di Endodonzia adheres to the below ethical guidelines for publication and research.

Authorship and Acknowledgements

Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Giornale Italiano di Endodonzia. Giornale Italiano di Endodonzia adheres to the definition of authorship set up by The International Committee of Medical Journal Editors (ICMJE). According to the ICMJE, authorship criteria should be based on 1) substantial contributions to conception and design of, or acquisiation of data or analysis and interpretation of data, 2) drafting the article or revising it critically for important intellectual content and 3) final approval of the version to be published. Authors should meet conditions 1, 2 and 3. It is a requirement that all authors have been accredited as appropriate upon submission of the manuscript. Contributors who do not qualify as authors should be mentioned under Acknowledgements.

Manuscript preparation

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rtf) files (not write-protected) plus separate figure files: TIF, EPS, JPEG files are acceptable for submission.

The text file must contain the **abstract, main text, references, tables and figure legends**, but no embedded figures or title page. The title page should be provided as a separate file. In the main text, please reference figures as for instance **figure 1, figure 2** etc to match the tag name you choose for the individual figure files uploaded.

Please note that **manuscripts must be written in English**. Authors whose native language is not English are strongly advised to have their manuscript checked by a language editing service or by a native English speaker prior to submission.

Manuscript Types Accepted

Original Scientific Articles must describe significant and original experimental observations and provide sufficient detail so that the observations can be critically evaluated and, if necessary, repeated. Original Scientific Articles must conform to the highest international standards in the field.

Systematic Review Articles reconsider and bring previously published systematic reviews up to date. This allows authors to present changes to the review while avoiding unwarranted duplication in the literature. A guiding principle for an update is that it is an event that is discrete and distinct from the conduct and reporting of the original systematic review (or previously updated review). This means that at a minimum the search for studies will have been brought up to date and that any changes to the results and conclusions of the original review (or a previously updated review) are described. Systematic review updates will not usually warrant publication of a new full-length article. However, any published update will be an independent publication. It will not be part of the original review publication (or previously updated review).

We encourage authors to be innovative in how they report and present systematic review updates. Systematic review updates are not appropriate for corrections/errata. Authors must clearly acknowledge and reference any previously-published work they are updating.

Review Articles are accepted for their broad general interest; all are refereed by experts in the field who are asked to comment on issues such as timeliness, general interest and balanced treatment of controversies, as well as on scientific accuracy. Reviews should generally include a clearly defined search strategy and take a broad view of the field rather than merely summarizing the authors´ own previous work. Extensive or unbalanced citation of the authors´ own publications is discouraged.

Mini Review Articles are accepted to address current evidence on well-defined clinical, research or methodological topics. All are refereed by experts in the field who are asked to comment on timeliness, general interest, balanced treatment of controversies, and scientific rigor. A clear research question, search strategy and balanced synthesis of the evidence is expected. Manuscripts are limited in terms of word-length and number of figures.

Clinical Articles are suited to describe significant improvements in clinical practice such as the report of a novel technique, a breakthrough in technology or practical approaches to recognised clinical challenges. They should conform to the highest scientific and clinical practice standards.

Case Reports or **Case Series** illustrating unusual and clinically relevant observations are acceptable, but they must be of sufficiently high quality to be considered worthy of publication in the Journal. On rare occasions, completed cases displaying nonobvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

Case reports should be written using the **Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 guidelines.** A PRICE checklist and flowchart (as a Figure) should also be completed and included in the submission material. The PRICE 2020 checklist and flowchart can be downloaded from: http://pride-endodonticguidelines.org/price/. It is recommended that authors consult the following papers, which explains the rationale for the PRICE 2020 guidelines and their importance when writing manuscripts:

- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Setzer FC, Sunde PT, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: a consensus-based development.* Int Endod J. 2020 Feb 23. Doi: 10.1111/iej.13285. https://onlinelibrary.wiley.com/doi/10.1111/iej.13285.
- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: Explanation and elaboration.* Int Endod J. 2020 Mar 28. Doi: 10.1111/iej.13300. https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13300.

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The **official language** of the publication is **English**. It is preferred that manuscript is professionally edited. All services are paid for and arranged by the author and use of one of these services does not guarantee acceptance or preference for publication.

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Structure
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Results: give the main results of the study, including the outcome of any statistical analysis.
Conclusions: state the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

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Abstract for Review Articles should be non-structured, no more than 250 words giving details of what was done including the literature search strategy.

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Key learning points: provide up to five short, bullet-pointed statements to highlight the key messages of the report. All points must be fully justified by material presented in the report.

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THE STRUCTURE

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Conclusions should contain a summary of the findings.

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Main Text of Review Articles
should be divided into Introduction, Review and Conclusions.
The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical subsections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

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should be divided into Introduction, Review and Conclusions; please note that the Conclusions section should present clear statements/recommendations and suggestions for further work. The manuscript, including references and figure legends, should not normally exceed 4,000 words.

Main Text of Case Reports and Case series
should be divided into Introduction, Report, Discussion and Conclusion. They should be well illustrated with clinical images, radiographs, diagrams and, where appropriate, supporting tables and graphs. However, all illustrations must be of the highest quality.

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Examples of correct forms of reference follow.
Standard journal article
(1) Somma F, Cammarota G, Plotino G, Grande NM, Pameijer CH. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. J Endod 2008;34:466-9.

Corporate author
British Endodontic Society - Guidelines for root canal treatment. Giornale Italiano di Endodonzia 1979;16:192-5.

Journal supplement
Frumin AM, Nussbaum J, Esposito M. Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). Blood 1979;54 (Suppl. 1):26a.

Books and other monographs
Personal author(s)
Gutmann J, Harrison JW. Surgical Endodontics, 1st edn Boston, MA, USA: Blackwell Scientific Publications, 1991.

Chapter in a book
Wesselink P. Conventional rootcanal therapy III: root filling. In: Harty FJ, ed. Endodontics in Clinical Practice, (1990), 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper
DuPont B. Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; (1974), pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication
Ranofsky AL Surgical Operations in Short-Stay Hospitals: United States-1975 (1978). DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.

Dissertation or thesis
Saunders EM. In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis) (1988). Dundee, UK: University of Dundee.

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