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GIORNALE ITALIANO DI ENDODONZIA

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▸ Original Articles

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Editorial

Biological Endodontics: New Strategies for Tooth Preservation

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Endodontics is undergoing a period of profound conceptual and technological evolution. For many years, the primary objectives of endodontic treatment have been the removal of compromised pulp tissue, the cleaning and disinfection of the root canal system and its subsequent three-dimensional sealing. This approach has contributed to achieve significant clinical success, enabling the long-term retention of many teeth that might otherwise have required extraction.

Nowadays, however, the field of endodontics adopts a broader perspective: rather than merely treating pulpal and periapical disease, it should aim, whenever biologically feasible, to preserve the structural integrity, vitality and reparative potential of the tooth.

It is within this new paradigm that some of the most interesting innovations in contemporary endodontics are emerging. Vital Pulp Therapy (VPT), minimally invasive procedures, new techniques for managing and sealing the endodontic space, innovative obturation methods, including the wallpaper technique*, and, above all, the use of increasingly advanced biomaterials represent key components of a therapeutic philosophy focused on biological preservation. While VPT seeks to preserve tissue that still retains its biological potential, regenerative endodontics opens an even more ambitious perspective: creating the conditions for biologically active tissues to reform within a previously compromised endodontic space. This is arguably one of the most exciting developments shaping the future of our discipline. Regenerative*

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endodontics is based on the principles of tissue engineering and on the interaction of three fundamental components: stem cells, scaffolds and growth factors. Its aim is to promote the colonization of the root canal space by cells capable of contributing to new tissue formation through appropriately modulated biological microenvironments. Regenerative procedures offer a different therapeutic approach: rather than simply achieving apical closure, they aim to promote continued root maturation, increase dentinal wall thickness, and improve the structural strength of the tooth. This is particularly important in young patients, for whom the long-term preservation of the natural tooth is a primary therapeutic goal. The future objective will be to overcome the limitations of current revitalization procedures and progressively move towards the possibility of reconstructing a true dentin-pulp complex, endowed not only with reparative capacity but also with sensory, vascular, and immunological functions.

The topics and perspectives outlined above are explored in greater scientific depth in the articles featured in this issue of the Giornale Italiano di Endodonzia*, which provide an up-to-date overview of the latest advances and innovations in the field of biological preservation and regeneration of the tooth.*

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ORIGINAL ARTICLE

The buffy coat platelet-rich fibrin concentrate on chelated root dentin. An in-vitro model in regenerative endodontics

ABSTRACT

Aim *To characterize in scanning electron microscopy (SEM), the morphology and structural conformation of the buffy coat – platelet-rich fibrin concentrate on root dentin conditioned with different chelation schemes.*

Materials and methods *An in vitro study was conducted on 35 human hemi-sected roots, randomly assigned to 7 groups. The samples were immersed in different solutions as follows: G1 distilled water (DW); G2 17% EDTA+DW; G3 17% EDTA; G4 chitosan (CS)+DW; G5 Cs; G6 nanoparticulate chitosan (CSnp)+DW; G7 CSnp. A sample of human blood was collected by venipuncture, then centrifuged to obtain a PRF matrix from which the buffy coat was extracted and placed on dentin surfaces for SEM analysis. The Blood Element Adhesion Index (BEAI) categorised each sample according to the arrangement and number of essential scaffolding elements. The Kruskal-Wallis nonparametric and Dunn's multiple-comparisons tests established statistical significance.*

Results *Significant differences were observed between groups (p = 0.011). Group G1, showed a complete absence of fibrin-matrix formation, with cellular dispersion on the surface. In groups G2-G3 (EDTA), a weak interconnection between fibrin, cells, and dentin was observed. Groups G4-G5 (CS) exhibited the greatest cellular adhesion to a consolidated fibrin-matrix. Finally, the variability for G6 and G7 (CSnp) resulted in an adequate fibrin network and cellular dispersion. The final rinse decreased matrix consolidation in CS-CSnp.*

Conclusions *The chelating agent and final rinse protocol significantly influence the initial stability of the buffy coat platelet-rich fibrin. Chitosan enhanced the stability and interaction of the essential elements of the scaffold compared to EDTA.*

Clinical Relevance *An approach to regenerative treatments is to examine the role of chelation in dentin, which supports the stability of a solid matrix, such as the buffy coat, which contains bioactive factors and cellular elements essential for regeneration.*

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Introduction

Regenerative endodontic procedures (REPs) have been developed to integrate biological mechanisms that enable the physiological replacement of damaged dental tissues and the restoration of pulp–dentin complex function (1). In vital teeth, an initial inflammatory response activates cells and signalling molecules that promote angiogenesis and the formation of reparative dentin in the presence of a bioactive material (2–4). In contrast, regeneration in non-vital teeth relies on intracanal conditioning through disinfection and chelation, followed by the incorporation of a scaffold that supports cell adhesion, proliferation, nutrition, and signalling (5).

The use of low-concentration sodium hypochlorite (1%) in combination with intracanal medication has been established as a disinfection strategy (6). Chelation, as an adjunct, presents significant biological challenges in contemporary endodontics. The release of signalling molecules conserved in the dentin matrix, such as fossilized morphogens, following the use of chelating agents, activates pro-regenerative interaction mechanisms in immature teeth or, more recently, pro-reparative mechanisms in necrotic teeth with periapical pathologies and complete root formation (7). Regarding the use of 17% ethylenediaminetetraacetic acid (EDTA), considered the standard chelating agent in REPs, it acts by coordinating with Ca^{2+} ions in root dentin (8). However, its high affinity for dentin leads to residual chelating agent within the intracanal space (9), which may reduce collagen matrix exposure and the availability of calcium ions, thereby interfering with the adhesion of coagulation factors and platelets present in the scaffold (10,11).

Natural cationic polymers, such as chitosan (CS), either in solution or in nanoparticulate form (CSnp), constitute chemical structures containing amino and hydroxyl groups capable of forming covalent bonds with dentinal collagen through the establishment of mineral bridges with Ca^{2+} ions and phosphate groups present in dentin. These interactions allow chitosan to act as a bioactive, antimicrobial, and chelating agent in root dentin (9,12). Nevertheless, although dentin chelation is considered a key process in configuring the intracanal microenvironment prior to regeneration, the interaction between conditioned dentin and biological scaffolds in REPs may depend on the chelating agent's mechanism of action and the final irrigation protocol. These aspects remain unclear in the available evidence (13) and are not yet standardized in clinical practice (13,14).

The development of autologous scaffolds has progressed significantly. Although the induction of a blood clot through the apical foramen may provide a biological scaffold containing stem cells, fibrin, platelets, and coagulation factors (15), its clinical acquisition is unpredictable, leading to non-standardized variations in specific conditions such as bleeding volume and the morphology of the cellular and protein components that constitute the fibrin network (16). In this context, platelet concentrates, including platelet-rich fibrin (PRF), may represent an autologous leukocyte-based biomaterial that provides a stable fibrin network and a slow, sustained release of growth factors over 7 to 28 days (17–19). Choukroun et al. (2001) identified, within PRF, an intermediate layer that concentrates the highest number of platelets and leukocytes, termed the buffy coat. This layer, with a thickness of up to 2 mm, is considered the primary site of growth factor release, thereby enhancing its regenerative scaffold effectiveness (17, 20).

Given this background, understanding how different dentinal chelation protocols influence the morphology and structural organization of the buffy coat–PRF concentrate is a clinical need. Therefore, the aim of the present study was to characterize, by scanning elec-

tron microscopy, the morphology and structural organization of the buffy coat–platelet-rich fibrin concentrate on root dentin conditioned using different chelation protocols.
Ho: Dentinal chelation protocols used in regenerative endodontics do not produce significant changes in the morphology and structural organization of the buffy coat–platelet-rich fibrin concentrate.

Materials and methods

An in vitro, quantitative experimental study approved by the Ethics and Research Committee of the Faculty of Dentistry at the Universidad Nacional de Colombia (FOUN), (ACT No. 03-25). The study design complied with the ethical standards established in the Declaration of Helsinki and with the technical recommendations of ISO 15189:2022 regarding the handling of body fluid samples for laboratory testing.

Study unit and sample selection

A total of 18 human permanent single-rooted teeth were included. All specimens were healthy, with complete root formation and without developmental defects or fracture lines and were extracted for orthodontic reasons. The sample was obtained from donors aged 18 to 24 years who attended the oral surgery clinics of the FOUN. Dental integrity was confirmed by stereomicroscopic examination (SMZ1000, Nikon Corp., Tokyo, Japan). The teeth were individually stored in Eppendorf tubes containing 0.9% sodium chloride (NaCl) with 0.02% sodium azide (NaN_3) at 4 °C for a period not exceeding three months (9). Teeth that exhibited coronal or apical fractures during extraction or laboratory handling were excluded.

Processing of the study unit

The hemi-sected root was defined as the unit of analysis. Sectioning was performed using an IsoMet cutting system (Buehler Ltd., Lake Bluff, IL, USA), operated at low speed under continuous irrigation. Each tooth was decoronated at the cemento-enamel junction, and each root was standardized to a length of 12 mm. Subsequently, the roots were hemisected by a transverse cut perpendicular to the long

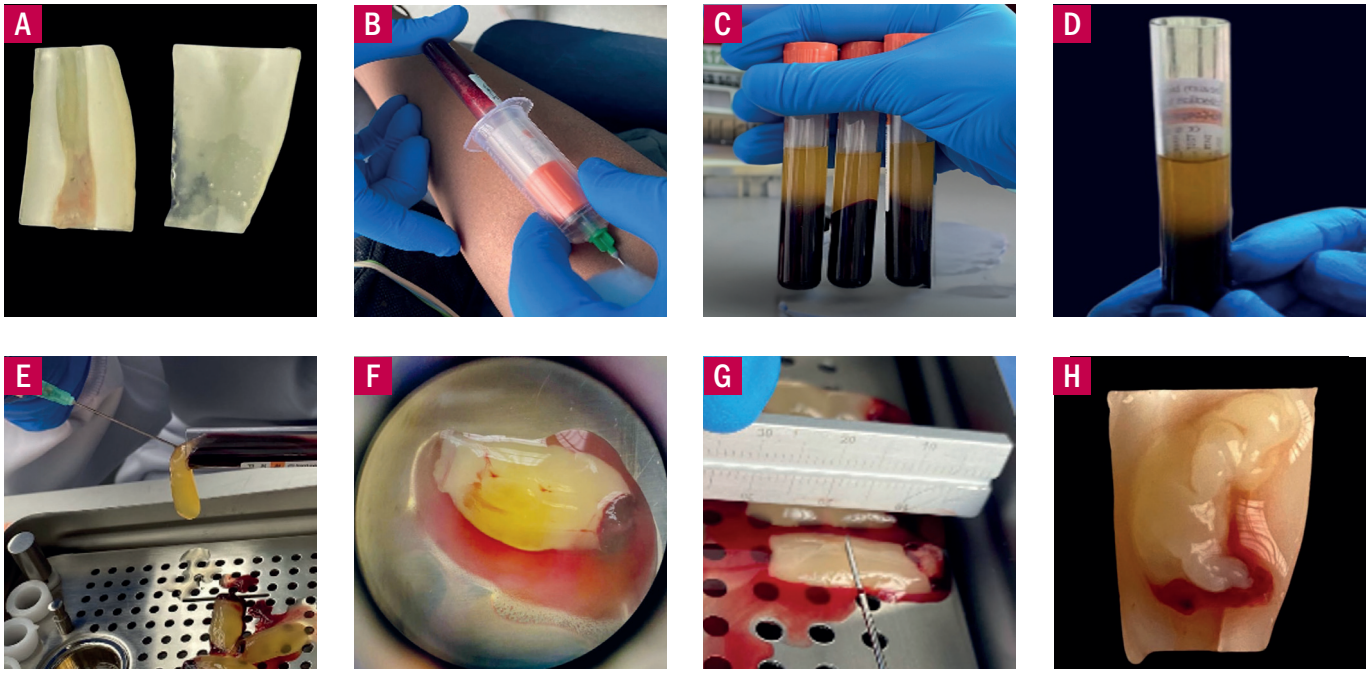


Figure 1
Sample preparation and buffy coat acquisition: **A** Decoronation and root hemisection; **B** Blood sample collection; **C** PRF obtained after centrifugation; **D** PRF maturation at body temperature; **E** Separation of PRF from the sediment; **F** Observation of the PRF clot formed by the fibrin yellow portion, constituting the main body, and a red portion located at the end of the clot. Between these two areas, a whitish layer called the ''buffy coat'' **G** Extraction of the buffy coat; **H** Application of the buffy coat onto conditioned root dentin.

axis of the root, in a buccal–palatal/lingual direction, until a total of 35 observational units (n = 35) (Figure 1A). Organic tissue remnants within the root canals were removed using a #25 K-flexofile (Dentsply Sirona, Maillefer, USA). The integrity of the dentinal surfaces was reconfirmed under stereomicroscopic examination. To eliminate residual smear layer, ultrasonic irrigation was performed for 8 minutes with distilled water using a Vita Sonic II for In-Ceram unit (Vita Zahnfabrik H. Rauter GmbH & Co. KG). The samples were subsequently stored under the same conditions previously described.

Chelating solutions

The chelating agents included 17% EDTA solution (Eufar®, Bogotá, Colombia) with a pH of 7.5 and a molecular weight of 292.24 g/mol; chitosan in solution (CS) with a pH of 3.2 and a molecular weight ranging from 50 to 190 kDa; and nanoparticulated chitosan (CSnp) with a pH of 4.58 and a nanoparticle size of 248.1 ± 4.07 nm. Chitosan-based solutions were prepared in the Department of Pharmacy at the Faculty of Sciences, Universidad Nacional de Colombia. Specifically, the CS was prepared by mixing 2 g of chitosan (Sigma-Aldrich, St. Louis, MO, USA) with 100.0 mL of 1% v/v acetic acid under magnetic stirring for 2 hours until a homogeneous, transparent solution was obtained. To obtain the nanoparticles, sodium tripolyphosphate (Sigma-Aldrich, St. Louis, MO, USA) was added to the CS at a concentration of 1 mg/1 mL using the ionic gelation dropwise method, followed by homogenization with an Ultra-Turrax® homogenizer (IKA, Staufen, Germany) at 5000 rpm for 15 minutes. Once prepared, the solutions were stored at 4 °C.

Seven experimental groups were established, each containing the study units (n = 5), and were assigned using Excel's randomization function (version 2412; Microsoft, Washington, USA). The groups were organized as follows: Group 1 (G1): distilled water (DW); Group 2 (G2): 17% EDTA with final irrigation using DW; Group 3 (G3): 17% EDTA without final irrigation; Group 4 (G4): CS with final irrigation using DW; Group 5 (G5): CS without final irrigation; Group 6 (G6): CSnp with final irrigation using DW; and Group 7 (G7): CSnp without final irrigation. Each specimen was placed in an Eppendorf tube to ensure complete immersion in 2 mL of each solution for 5 minutes at each step (14). Following the chelation protocol, the specimens were kept dry and immediately prepared for scaffold application.

PRF preparation

At the LIMACIB laboratory of the FOUN, a healthy adult volunteer under 30 years of age was recruited with informed consent. The volunteer had no history of comorbidities, no medication, and did not exhibit addictive behaviors, two weeks prior to sample collection. A total of 5 mL of blood was obtained by venipuncture of the median cubital and cephalic veins in the right and left forearms (Figure 1B). The sample was collected in orange-cap glass tubes, internally coated with silica as a procoagulant to reduce coagulation time during centrifugation (8 minutes at 1300 rpm and 223 relative centrifugal force (g) using an LC-04R centrifuge (Scientific, Zenith Lab, Jiangsu, China) (21) (Figure 1C). After centrifugation, the sample in the tube was exposed to ambient air for 10 minutes at 37 °C to allow stabilization (Figure 1D). Once stabilized, the PRF was extracted, and the scaffold components were identified by visual inspection. The basal portion containing red blood cells, identifiable by its color, was separated and discarded (Figure 1E). Subsequently, the buffy coat was identified as a slightly paler zone adjacent to the upper fibrin-rich portion (Figure 1F). A 5 mm-long section was then obtained (Figure 1G), which was divided into equal parts and immediately placed onto each previously chelated hemi-sected root (Figure.

1H). Each specimen was placed in a dry Eppendorf tube and stabilized in a Hygrobath (Whip Mix, Louisville, USA) for 15 minutes at 37 °C. The samples were then immediately prepared for SEM.

Preparation for SEM analysis

At room temperature, each specimen was fixed by immersion in 2.5% glutaraldehyde for 1 hour and subsequently rinsed with three changes of distilled water for 10 minutes each. Dehydration was performed through a graded ethanol series (70%, 75%, 80%, 85%, 90%, 95%, and 100%), with each step lasting 2 minutes. The process continued with gold coating of the specimens using the sputtering technique, applying a current of 8 mA for 150 seconds in a vacuum metallization unit (SPT-20, COXEM, South Korea; target: Au). All specimens were examined under SEM (EM-30AX PLUS, COXEM, South Korea), and micrographs were obtained at 2500× and 5000× magnifications at the Department of Physics, Faculty of Sciences, ?????.

Observational topographic analysis

To standardize the observations, the area at the interface between the buffy coat and dentin was selected. Topographically, four essential elements were identified: platelet conglomerates; the presence and morphology of leukocytes and erythrocytes; and the presence and density of the fibrin network (19,20).

Quantitative analysis

Two evaluators selected two representative images per group, ensuring one image for each magnification (2500× and 5000×). The observers recognize the four categories of the Blood Elements Adhesion Index (BEAI) proposed by Theodoro et al. (2006) (22) and classified the images according to the arrangement and number of essential elements observed, as follows: Category 0, absence of fibrin network and blood cells; Category 1, scarsely distributed fibrin network and/or blood cells; Category 2, a moderate number of blood cells and a thin fibrin network with poor interlacing; and Category 3, a dense fibrin network with rich interlacing and the presence of blood cells.

To standardize visualization conditions, an observation window of 1,280 µm × 960 µm was used in ImageJ version 1.52a (Wayne Rasband, National Institutes of Health, USA; Java 1.8.0_112 (64-bit)), under similar lighting and

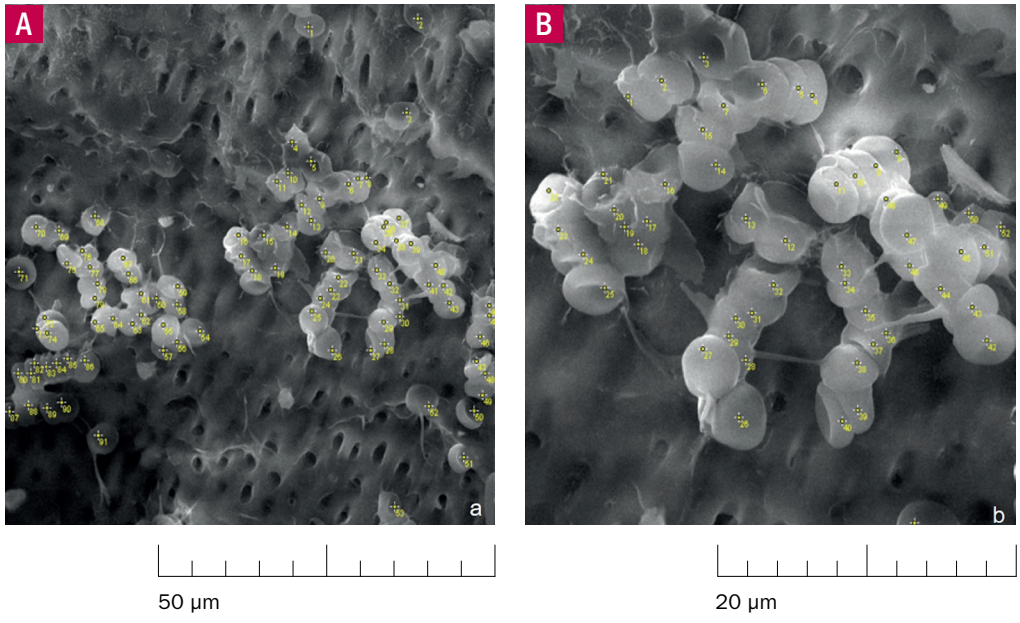


Figure 2
Observation windows for cell counting and fibrin network identification. **A** Field of view of 50 µm at 2500× magnification. **B** Field of view of 20 µm at 5000× magnification. Yellow dots indicate cell counts performed in ImageJ.

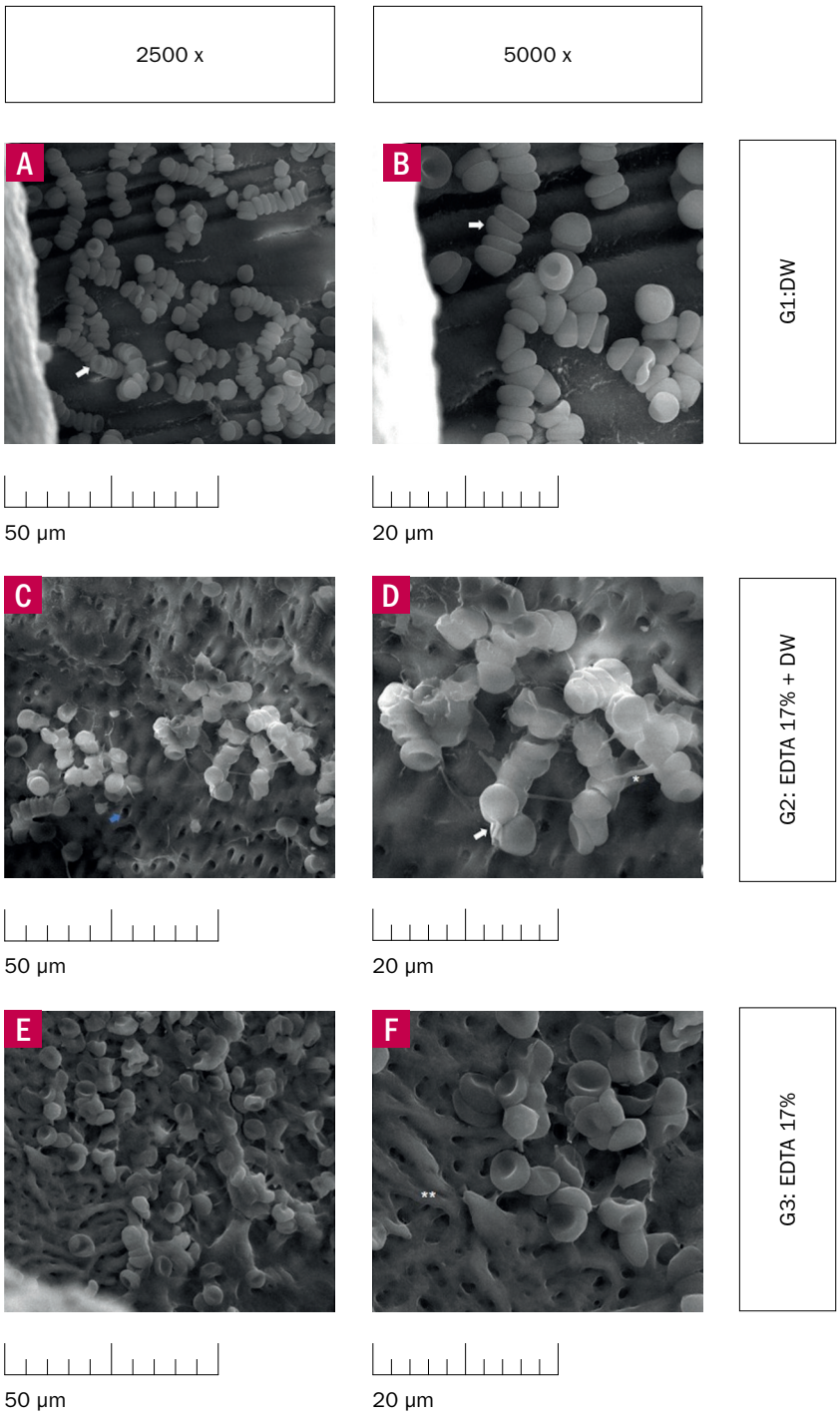


Figure 3 G1 – G3 fibrin network and cell layout. **A**. DW at 2500x, the white arrow indicates the conglomerate erythrocytes. **B**. DW at 5000x shows erythrocytes arranged on the root dentin without conditioning. **C**. EDTA 17% + final rinse at 2500x, the blue arrow denotes the exposed dentinal tubule. **D**. EDTA + final rinse at 5000x, the white arrow indicates conglomerate red blood cells, * Thin fibrin network interconnected with cells. **E**. EDTA 17% at 2500x cellular clusters superimposed on the fibrin network. **F**. EDTA 17% at 5000x,** thicker fibrin network.

timing conditions. For each field of view, a 50 µm grid was applied to micrographs acquired at 2500× magnification, and a 20 µm grid was applied to micrographs acquired at 5000× magnification (Figure 2A, 2B). According to the index, the objective was to categorize the fibrin mesh arrangement and the expected number of blood cells per field.

Statistical analysis

A descriptive analysis of the blood element adhesion index (BEAI) was performed by estimating position measures for each treatment or experimental group. The data were verified for normality using the Shapiro-Wilk statistic. Subsequently, a comparison of the BEAI between groups was performed with the nonparametric Kruskal-Wallis test. As a complement, a multiple-comparison analysis was performed using the Dunn test (with Benjamini-Hochberg correction). All tests were performed using IBM SPSS Statistics, version 27.0 (© 2020 IBM Corp., United States), with a significance level of $p < 0.05$.

Results

Morphological findings of three-dimensional architecture – SEM

Overall, the topographic description identified the presence of the four essential elements: cross-linked fibrin network scaffold, erythrocytes, platelets and leukocytes, representing the "buffy coat", an intermediate section between the fibrin network of the PRF and the red portion. Now standing, the SEM images revealed variability in the chelation patterns on the dentin surface as follows: In the control group with DW (G1), the absence of a chelating agent resulted in a smooth dentin surface without dentinal tubules and no evidence of fibrin deposition. Only biconcave erythrocytes in association with platelets were identified in clusters (Figure 3A, 3B). In the 17% EDTA (G2 and G3), dentinal tubules opened due to chelation. In G2, with a final rinse, a

scaffold characterised by a weak fibrin matrix and a cellular disposition similar to G1 was observed (Figures 3C and 3D). The G3 group, without a final rinse with DW, formed a denser fibrin network, showing some interaction with the cellular elements; however, the scaffold did not completely cover the chelated dentin surface (Figures 3E and 3F). In groups (G4 and G5), CS with and without a DW final rinse, a consolidated fibrin matrix was observed in close contact and significant interaction with the entire surface of the chelated dentin. A scaffold formed by fibrin filaments was observed, supporting the concentration of erythrocytes, platelets, and leukocytes with normal morphology (Figure 4A, B). In group G5 without a final rinse, the CS solution on the dentin surface promoted the formation of an extensive fibrin meshwork, enabling adequate accommodation of blood cells within the network and providing greater stability to the scaffold at all levels of the chelated dentin surface (Figure 4C, D). For CSnp (G6 and G7), variability in the results was observed. In general, high-density fibrin networks were identified, hindering the identification of the embedded cellular elements (Figures 5A and 5B). In the case of G7, without final washing, a denser scaffold was observed (Figures 5C and 5D). The comparison of group ranks showed significant differences between Groups 5 and 1 and 2 ($p = 0.011$), indicating variation in the distribution of BEAI values by treatment type (Figure 6). In group G1 (DW), fibrin network formation was not promoted, and some cellular elements were confirmed. In the four remaining groups, variable fibrin network formation was observed, confirming that dentin chelation is important for scaffold placement on the surface; however, scaffold and cell cluster stability is mediated by the chelating solution type and the final rinsing protocol. In this regard, the G4 and G5 (CS with and without final rinse) showed a blood component adhesion score of 3 (Figures 4A-D and 6). The presence of a dense fibrin network and trapped blood cells covering the dentin surface supports this result.

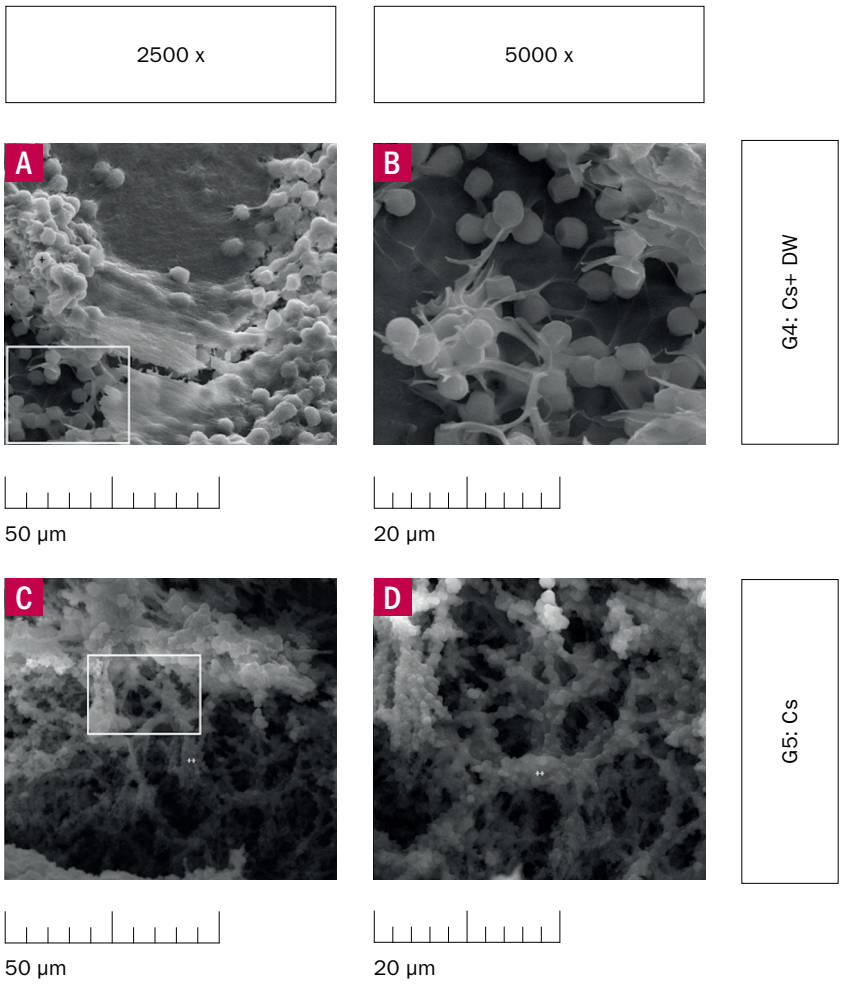


Figure 4
G4, G5 fibrin network and cell layout. **A**. Cs + final rinse at 2500x. + Presence of a leukocyte immersed in the fibrin network. **B**. Magnification at 5000x of the area indicated in image A. The marked interconnection of fibrin and blood cells is shown. **C**. Observation of Cs at 2500x, ++ Blood cells introduced into the fibrin network. **D**. Magnification to 5000x of the area indicated in the image C.

Figure 6 shows that the effect of 17% EDTA on buffy coat stability results in an insufficient fibrin network and/or blood cells, demonstrating great variability in findings within the same group (Score 1-2) (Figure 3A-F). Finally, for CSnp G6 and G7, the final wash made a difference, identifying moderate to high stability of the elements and the fibrin network for G7 CSnp without a final wash (Figure 5A-D), (Figure 6). Finally, for CSnp G6 and G7, the final wash made a difference, identifying moderate to high stability of the elements and the fibrin network for G7 CSnp without a final wash (Figure 5A-D), (Figure 6).

Discussion

In regenerative endodontics, the use of

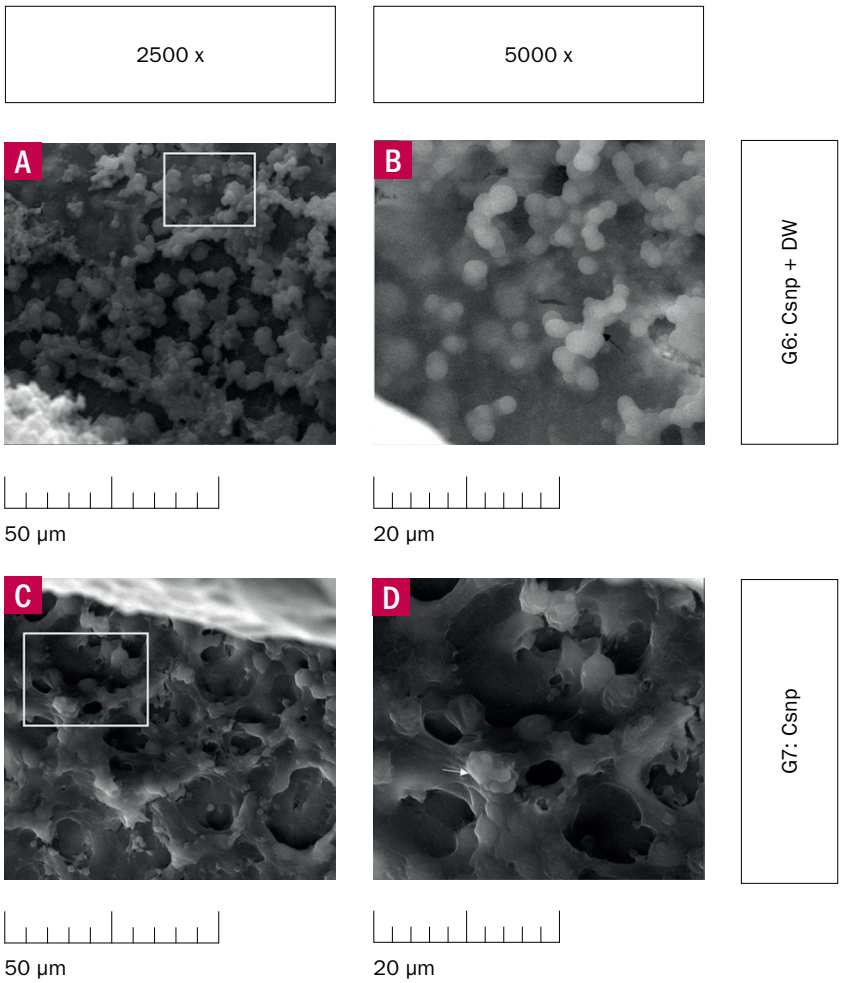
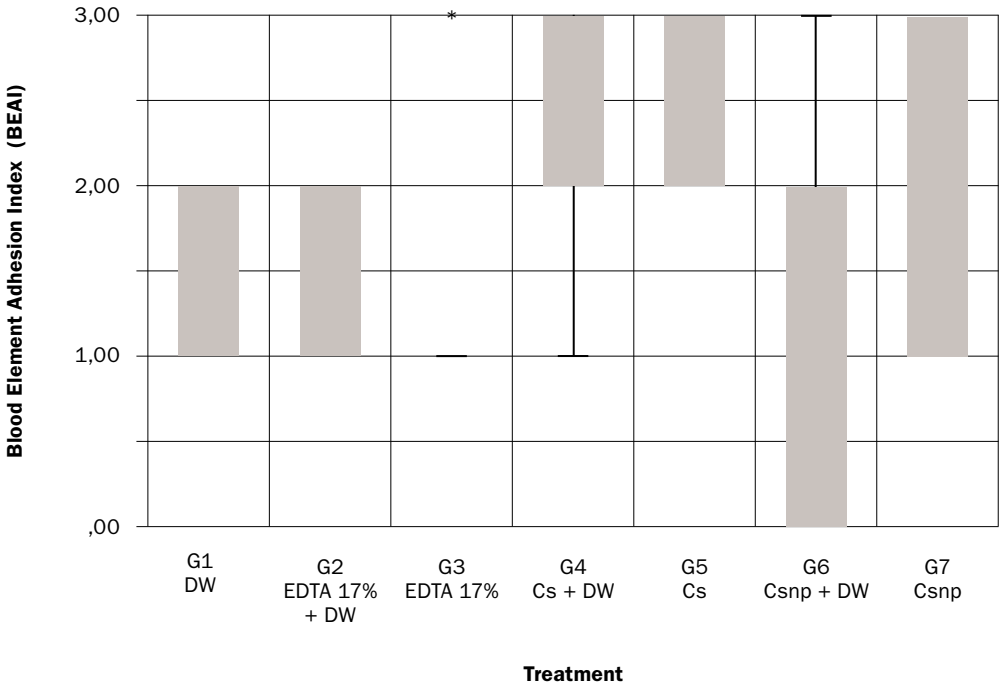


Figure 5
G6 and G7 fibrin network and cell layout. **A**. Csnp + final rinse (2500x), the black arrow indicates a large number of cells trapped within the fibrin network. **B**. Magnification of the area indicated in image a (5000x) reveals cells retained in clusters within the fibrin mesh. **C**. Csnp at 2500x, a thicker fibrin network is observed. **D**. Magnification of the area indicated in image C (5000x) shows that the thick fibrin network covers cells. The white arrow indicates the appearance of cell entrapment under the net.

autologous scaffolds is justified to facilitate interactions among essential elements and a chemically conditioned dentinal surface during disinfection and chelation (23 - 25). In the present work, the comparative analysis between the groups showed significant differences in the incorporation and distribution of platelets, leukocytes and erythrocytes within the fibrin meshwork architecture, with distributions and appearances that could be modified by the chelation protocol. In this regard, CS without a final rinse significantly promoted the adhesion of a dense fibrin network that integrates essential cellular elements to the dentinal surface, thereby allowing rejection of the null hypothesis.
The principle of intracanal chelation involves the formation of bridges between free electrons provided by a chelator and calcium-type metal ions of the dentinal inorganic substrate (26).

Figure 6
Blood element adhesion index (BEAI) for the different experimental groups.



The chelation process will expose the collagen fibers within the matrix, thereby modifying the surface energy of the dentin, promoting the initial stability of the scaffold (27). Three chelating solutions were analysed: 17% EDTA, CS and CSnp, which induced opening of the dentin tubules on the surface and scaffold attachment, with some variation depending on the chelating agent or final rinse (28). Dentinal conditioning increases the "biological acceptance" of the scaffold (29), in this regard, the negative control group (DW) showed a smooth dentinal surface, without tubular openings or structural modifications, and a limited or almost absent fibrin network, with the presence of small, morphologically conserved cell conglomerates, but without apparent adherence to the surface or a defined organizational pattern. This observation, consistent with the literature (29, 30), recognizes a determining role of the chelating agent in the initial scaffold stability as an early healing event.

The differences observed at the microscopic level between the analysed groups revealed how the nature of the chelating agent and the final rinse protocol affect the results. Clinical standards in endodontics recommend using EDTA as an adjunct to endodontic irrigation. However, the experimental results identified a weak fibrin conformation on the dentin, with low adhesion of blood elements, suggesting limited interaction between the buffy coat and the dentinal substrate; EDTA in the intracanal space increases the surface energy of the dentin substrate (12); however, its performance with respect to scaffold stability is limited (29, 31). Taweewattanapaisan et al. (2018) reported that the presence of residual EDTA increases the likelihood of trapping more Ca^{2+} ions, which are necessary for fibrin network stability and proper cell integration (32). The affinity of platelet aggregates for dentin collagen can be affected by poor scaffold adhesion, triggering premature platelet fragmentation (33). This aligns with the observation in G3 and supports the recommendation to perform a final rinse with a sterile solution after EDTA use in clinical practice (32).

In contrast, the results showed that the performance of chitosan in solution, without a final rinse, was significantly superior for forming a consistent fibrin network firmly adhered to the dentinal surface, capable of integrating blood elements and preserving their morphology and organization in clusters. From this perspective, the cationic nature of the CS polymer supports its chelating action on the anionic components of the mineral phase of dentin (9), exposing the dentin collagen after chelation without altering its integrity (34). Although evidence suggests that higher surface energy on a substrate may favor initial contact with biological fluids (14), the adhesion and stability of a less liquid matrix, such as buffy coat, appear to depend on the integrity of an organic matrix on the dentinal surface (27). In this regard, CS, as a dentinal conditioner, maintains the collagen structure and remains on the surface, protecting sites of collagen binding to fibrin in the buffy coat (35). Therefore, based on its cationic character, it is possible to suggest that the presence of CS on the dentinal surface could form electrostatic bonds with negatively charged components of the buffy coat, whose amphoteric behavior allows them to establish other surface-binding mechanisms to achieve the initial stability observed in this experimental group (36). This analysis, as a product of in vitro observation, raises hypotheses that must be confirmed.

In contrast, dentin chelation with CSnp resulted in weak adhesion of essential elements, which is explained by the arrangement of the nanostructured components. These components accumulate on exposed dentin collagen, interfering with the scaffold's interaction with the N-terminal domain of the dentin collagen triple helix (35).

The structural and rheological charac-

teristics of the consolidated fibrin networks and integrated cellular elements are directly influenced by the type of chelating agent and its specific effect on dentin (37).
In vivo studies have demonstrated that PRF production is a simple, rapid, and cost-effective procedure that does not require the addition of anticoagulants or exogenous activators that could interfere with healing and tissue regeneration. Physically, the three-dimensional PRF matrix exhibits mechanical properties that enable the retention of cellular elements and the progressive release of platelet-derived growth factors, which promote cell chemotaxis and angiogenesis (38). These biological events, in a clinical setting, determine dentin formation and increase root length by up to 50% (39), compared to blood clot (40). However, evidence supports promoting controlled microbleeding in the apical third to complement the process (41), so the chelating agent must prepare the intracanal space to receive scaffolds of varying consistencies. Finally, the role of leukocytes, identified in this study and integrated into the buffy coat, could be related to the regulation of the healing process, from promoting an initial inflammatory response to the stages of proliferation and tissue remodeling. Therefore, they are considered a key biological component that transcends the contributions of platelets and growth factors. Leukocytes could exert the antimicrobial and immunomodulatory effect needed to facilitate an orderly transition to more efficient repair phases (42).
In conclusion, the chelation, as the final complement to chemical conditioning in regenerative endodontics, must transcend the concept of "smear layer removal" and focus on chemically modifying the dentin substrate. The in vitro results obtained demonstrated that the initial adhesion of the scaffold depends on the protocol and the nature of the chelating agent used. Regarding, the preservation of the dentinal organic fraction promoted by chitosan, irrespective of the final rinse protocol, resulted in a more highly organized fibrin architecture and a greater abundance of cellular components compared to EDTA. Furthermore, the use of buffy coat as a biologically active fraction of PRF exhibited distinct structural advantages, supporting its efficacy as a robust scaffold.

Clinical relevance
This study is part of an ongoing research line focused on developing a safe microenvironment for regenerative endodontic procedures. Chelation is a critical step in endodontic treatment, and both previous evidence and our research experience indicate that chelating agents significantly influence the interaction between the dentin substrate and endogenous or exogenous components involved in regenerative processes.
In this context, the present manuscript investigates the interaction between autologous scaffolds and radicular dentin under the influence of different chelating agents. The study was conducted under strict methodological rigor, and the images presented accurately reflect the analyzed outcomes, which were interpreted in accordance with current scientific evidence.
The reported findings provide novel insights with potential clinical applicability, supporting the translational perspective emphasized by Giornale Italiano di Endodonzia and contributing evidence to advance knowledge to improve oral health.

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Data declaration
We certify that this work did not use any additional data, whether published or from other available sources. The

data used for the statistical analysis are shown in Figure 6. If sharing the data collection grids is required, we, as authors, are willing to provide them.

Author contribution declaration
The authors declare that they have participated sufficiently and voluntarily in the preparation of the work; therefore, we take public responsibility for the document's overall content. Authorship criteria are supported by contributions (C.G; L.F; S.Q) to the conception, design, analysis, critical revision of the intellectual content, (J.D; L.F; S.Q) verification of laboratory good practices, image evaluation, interpretation of the data, (C.G) and drafting and revising the entire document.
All authors declare no conflicts of interest, and the approval of the ethics committee of the Faculty of Dentistry guaranteed the development of this research under all the ethical and scientific integrity recommendations indicated by international and national regulations.

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ORIGINAL ARTICLE

Smoking as a Prognostic Modifier in Endodontic Care: A Mixed-Methods Study of the Evidence-Practice Gap

ABSTRACT

Aim: *This study aimed to evaluate the evidence-practice gap regarding smoking as a potential prognostic modifier in endodontic care, focusing on tobacco-use assessment, prognostic reasoning, risk communication, and reported clinical decision-making.*

Methodology: *A sequential mixed-methods study with a qualitative follow-up phase was conducted with dentists involved in endodontic care. In the quantitative phase, 201 dentists completed an online questionnaire. Associations between professional setting and clinical behaviours were analysed using Pearson's chi-square test, with Bonferroni and Benjamini–Hochberg corrections and Cramer's V effect sizes. All quantitative participants were subsequently invited to the qualitative follow-up; 30 accepted the invitation and completed the open-ended questions, which were analysed using reflexive thematic analysis. Integration occurred at the interpretative stage by examining qualitative themes alongside the aggregate quantitative response patterns.*

Results: *Among the 201 participants, 111 (55.2%) routinely asked about smoking status, whereas 57 (28.4%) assessed smoking frequency, 59 (29.4%) adapted case explanation according to smoking status, and 97 (48.3%) associated smoking with case prognosis. Only 56 (27.9%) reported prior awareness of the smoking–periapical healing relationship described in the questionnaire. No association between professional setting and clinical behaviour remained statistically significant after correction for multiple testing. The qualitative findings provided interpretative context for these quantitative patterns, showing variable depth of smoking-history assessment and inconsistent integration into prognostic reasoning and risk communication.*

Conclusions: *The findings indicate inconsistencies between documenting tobacco use and clinically interpreting this information in endodontic care. The principal evidence-practice gap concerned the depth of tobacco-use assessment, prognostic reasoning, and risk communication rather than the absence of a specific smoking-related technical modification to endodontic treatment. More consistent documentation and risk communication may be warranted, while the clinical implications of smoking-specific management strategies require further prospective investigation.*

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Introduction

Tobacco smoking remains an important determinant of oral morbidity and is associated with impaired tissue healing and less predictable outcomes in several areas of dentistry. It is also a well-established risk factor for periodontal disease and impaired tissue healing (1–2). In Endodontics, growing evidence suggests an association between tobacco use and a higher prevalence of periapical lesions and potentially less favourable outcomes following root canal treatment (3–7).

However, findings across endodontic studies remain heterogeneous, and causality has not been established (4–6,8–9). Smokers have been reported to be approximately 2.4 times more likely to present apical periodontitis or a history of endodontic treatment, although this association does not establish a causal relationship (4). Consequently, the recognition and incorporation of smoking as a potential prognostic factor in clinical endodontic practice remain insufficiently characterised (8).

This study did not aim to test biological outcomes directly. Instead, it examined how evidence on tobacco-related risks is recognised, interpreted, and incorporated into routine endodontic decision-making. Characterising this potential disconnect may help clarify how tobacco-related evidence is interpreted in clinical practice and identify barriers to more consistent history taking, risk communication, and evidence-informed decision-making in Endodontics (10).

Therefore, this study aimed to evaluate the evidence-practice gap regarding smoking as a potential prognostic modifier in endodontic care, focusing on how tobacco-use history is assessed and incorporated into prognostic reasoning, risk communication, and reported clinical decision-making.

Methods

Ethical considerations

The study was approved by the Research Ethics Committee of the University of Fortaleza (no. 6,482,408), in accordance with Resolution 466/2012 of the Brazilian National Health Council and the ethical standards laid down in the 1964 Declaration of Helsinki. All participants provided informed consent electronically before accessing the questionnaire.

Study design

The questionnaire was developed specifically for this study through an iterative consensus-based process involving five investigators with academic and/or clinical experience in Endodontics, led by the principal investigator, an endodontist. The proposed items were reviewed internally against the prespecified conceptual and clinical assumptions of the study, and wording was refined through discussion to enhance clinical relevance, clarity, and comprehensibility. No formal pilot testing, psychometric validation, or quantitative face/content-validity assessment was performed. Following the quantitative phase, all 201 respondents were invited to participate in a qualitative follow-up designed to provide additional interpretative depth regarding dentists' perceptions of the relationship between smoking and periapical disease and its relevance to clinical reasoning. Thirty participants accepted the invitation and completed the qualitative phase. Participants were not selected according to their previous quantitative responses or professional category. The qualitative questions explored the same prespecified conceptual domains in greater depth; participants were not informed of the quantitative findings, and integration of the two datasets occurred at the interpretative stage rather than through independent confirmation of one dataset by the other.

Sample characterisation
The quantitative sample comprised dentists involved in endodontic care in public and/or private clinical settings in Fortaleza, Ceará, Brazil, including public dental services, Specialised Dental Centres, university-based professionals with endodontic expertise, and clinicians working in private practice. The initial sample was recruited by invitation, targeting dentists actively involved in endodontic care. For the qualitative follow-up, all 201 quantitative respondents were invited, and 30 accepted and provided responses to the open-ended questions. The qualitative sample therefore reflected participation uptake rather than investigator selection according to quantitative responses. During analysis, the resulting dataset was considered by the research team to provide sufficient depth, diversity, and informational adequacy to address the qualitative aims, as additional interpretative categories were not required to account for the range of meanings present in the responses.

Data collection
Data were collected using an online form (forms.google.com). Given the relatively identifiable professional community under investigation, demographic variables such as age, sex, and years of experience were intentionally omitted to maximise anonymity and encourage candid reporting of clinical behaviours. This approach supported confidentiality and may have reduced prestige-related response bias, while limiting the assessment of individual-level influences. In the qualitative stage, the form included open-ended questions exploring participants' perceptions of the potential relationship between smoking and periapical lesions, their approach to investigating smoking habits, and their views on including tobacco-use assessment in endodontic anamnesis. Participants were not informed of the quantitative findings or of the response patterns observed in the first phase before completing the qualitative questions.

Sample size calculation
Sample size was calculated using R Studio (v. 2024.12.0+467; Posit Software, PBC). A chi-square test of independence with two degrees of freedom (df = 2), a type I error of 5% ($\alpha = 0.05$), and a statistical power of 80% ($1-\beta = 0.80$) were considered. An expected small-to-medium effect size ($w = 0.22$) was adopted, based on Cohen's theoretical parameters and Cramer's V values from similar studies. These assumptions yielded a minimum required sample size of 196 participants to ensure adequate statistical power.

Statistical analysis
Data analysis was performed using R Studio (v. 2024.12.0+467; Posit Software, PBC). Descriptive results were expressed as absolute and relative frequencies. Associations between professional category and questionnaire responses were assessed using Pearson's chi-square test. Bonferroni and Benjamini–Hochberg adjustments were applied to account for multiple testing, and Cramer's V was calculated as an effect-size measure. Statistical significance was set at an adjusted $p < 0.05$.
Qualitative data from the open-ended questions were analysed using reflexive thematic analysis following Braun and Clarke's six-phase framework (11): (i) familiarisation with the responses, (ii) generation of initial codes, (iii) development of candidate themes, (iv) reviewing themes, (v) defining and naming themes, and (vi) producing the final report. Analytical matrices were developed in Google Sheets (sheets.google.com) to organise responses, codes, preliminary themes, and interpretative notes. Initial coding was led by the principal investigator, an endodontist with academic research experience. Code interpretation and theme development were subsequently discussed iteratively by the full eight-member research team, which included researchers with backgrounds in Endodontics, Public Health, Medicine, and academic research. The multidisciplinary

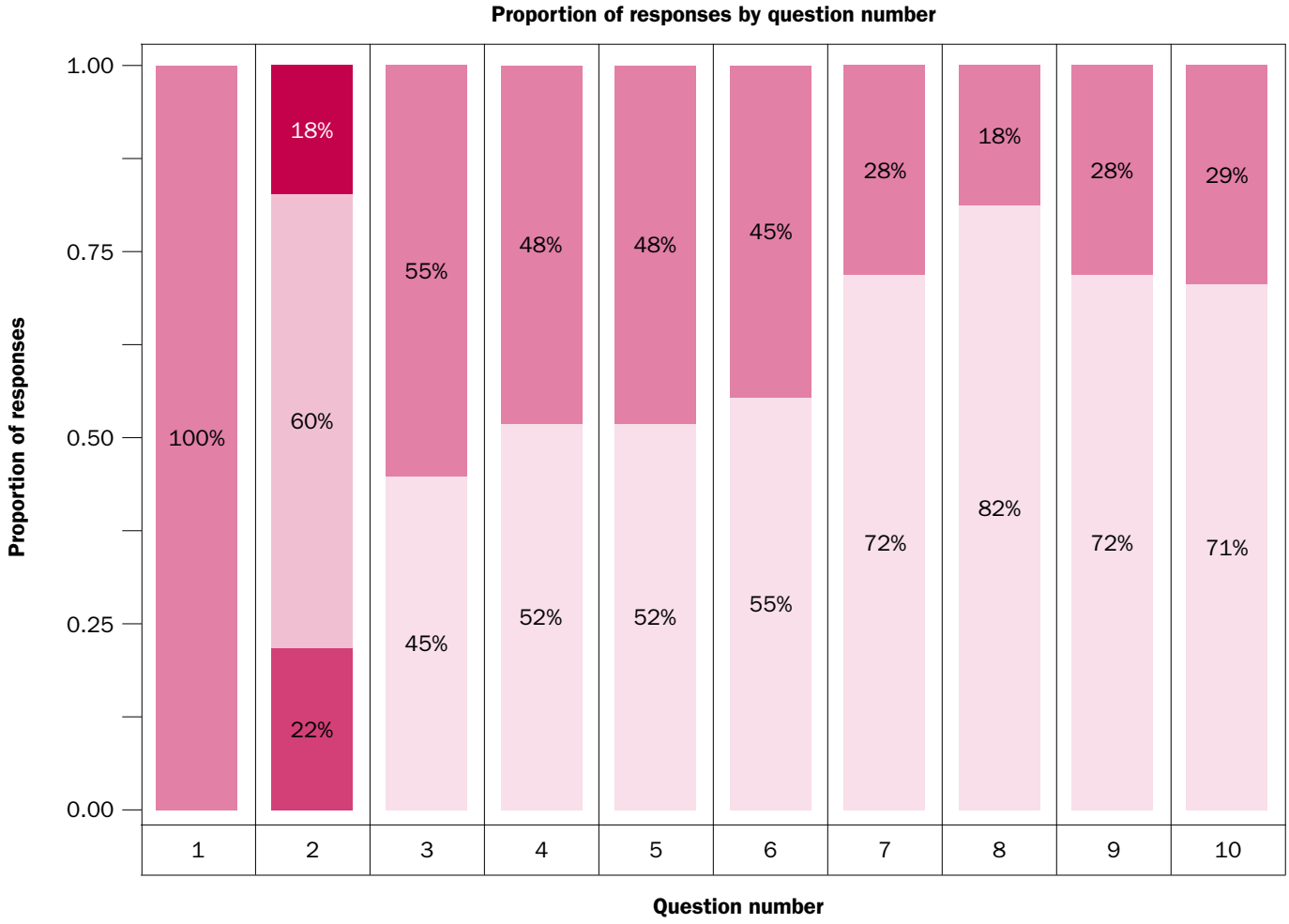


Figure 1
Distribution of responses across questionnaire items.

composition of the team broadened the interpretative perspective and helped challenge assumptions arising from a solely endodontic viewpoint. Different interpretations were discussed and used to refine code boundaries, thematic meanings, and relationships among themes rather than to establish inter-coder reliability, consistent with a reflexive thematic-analysis approach. The researchers recognised that prior clinical and academic familiarity with the smoking–endodontic literature could influence interpretation, and this positioning was considered throughout theme development and refinement.

Results

Responses from 201 dentists (100%) working across different service settings were analysed (Figure 1). The first two items referred to informed consent (Q1) and professional category (Q2), respectively. Q1 documented eligibility and consent, whereas Q2 was used for sample characterisation and as the grouping variable in the association analyses. All 201 participants (100%) confirmed having read and agreed to the informed consent form. Among respondents, 121 (60.2%) worked exclusively in private practice, 45 (22.4%) worked in both public and private sectors, and 35 (17.4%) worked exclusively in the public sector. Questions Q3–Q10 addressed clinical behaviours and perceptions related to smoking in endodontic contexts (Table 1).

Response distribution

Table 2 presents the absolute and relative

Code	Question
Q1	Have you read the informed consent form and do you agree to participate in the study?
Q2	Do you work in the public or private sector?
Q3	Before performing an endodontic treatment, do you inquire whether the patient is a smoker?
Q4	Do you ask about the patient's smoking frequency?
Q5	If the patient is an ex-smoker, do you inquire how long they have been abstinent?
Q6	If the patient is an ex-smoker, do you ask for how long they had smoked?
Q7	If the patient is a smoker, do you adopt different strategies in case explanation?
Q8	If the patient is a smoker, do you modify any aspects of the treatment?
Q9	If the patient is a smoker, do you associate smoking with case prognosis?
Q10	The scientific literature indicates that smoking negatively affects the healing of periapical lesions in endodontically treated teeth. Prior to completing this questionnaire, were you aware of this fact?
Note: Q8 and Q10 are reproduced verbatim as administered. Q8 did not specify the nature of treatment modification and was interpreted descriptively. Q10 described the smoking-periapical healing relationship more definitively than warranted by the heterogeneous evidence and referred to the relationship as a "fact"; this wording is acknowledged as a study limitation.	

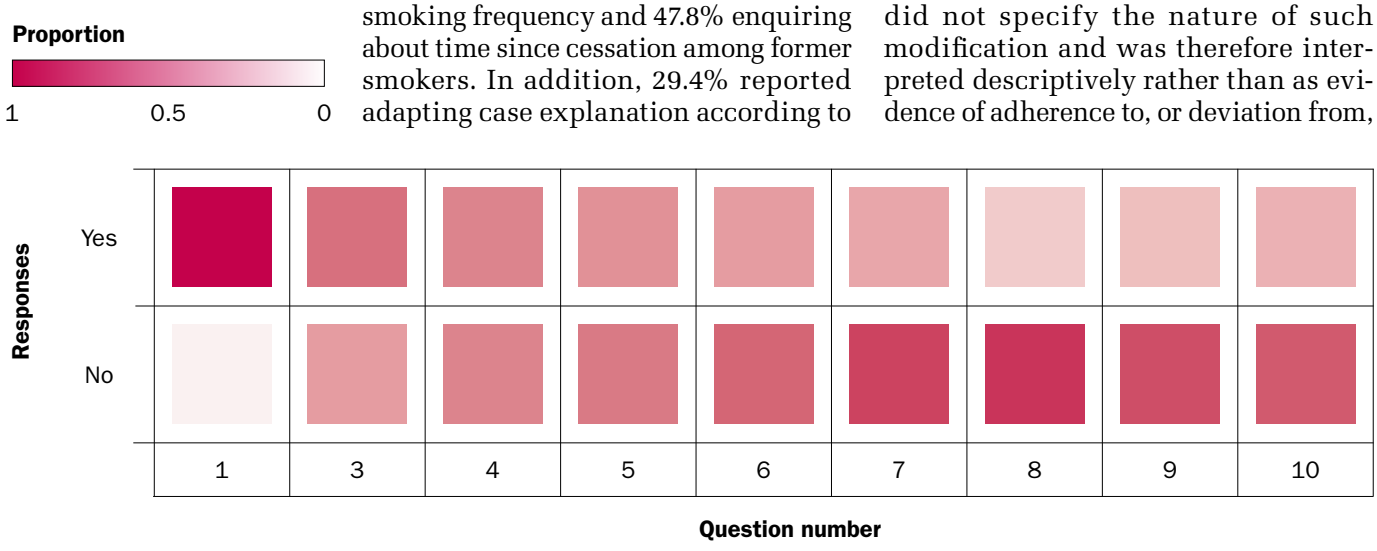
Table 1
Structure and content of the questionnaire items administered to participants

Table 2
SDistribution of responses to clinical items.

Figure 2
Heatmap of binary responses.

Question	No (n, %)	Yes (n, %)
Q3	90 (44.8%)	111 (55.2%)
Q4	144 (71.6%)	57 (28.4%)
Q5	105 (52.2%)	96 (47.8%)
Q6	110 (54.7%)	91 (45.3%)
Q7	142 (70.6%)	59 (29.4%)
Q8	164 (81.6%)	37 (18.4%)
Q9	104 (51.7%)	97 (48.3%)
Q10	145 (72.1%)	56 (27.9%)

frequencies of responses (Q3–Q10), also illustrated in Figures 1 and 2. Among participants, 55.2% reported routinely asking about smoking status before endodontic treatment. More detailed smoking assessment was less frequent, with 28.4% reporting assessment of smoking frequency and 47.8% enquiring about time since cessation among former smokers. In addition, 29.4% reported adapting case explanation according to smoking status, and 48.3% associated smoking with case prognosis. Only 27.9% reported prior awareness of the smoking–periapical healing relationship presented in Q10. Although 18.4% reported modifying some aspect of treatment according to smoking status, Q8 did not specify the nature of such modification and was therefore interpreted descriptively rather than as evidence of adherence to, or deviation from,



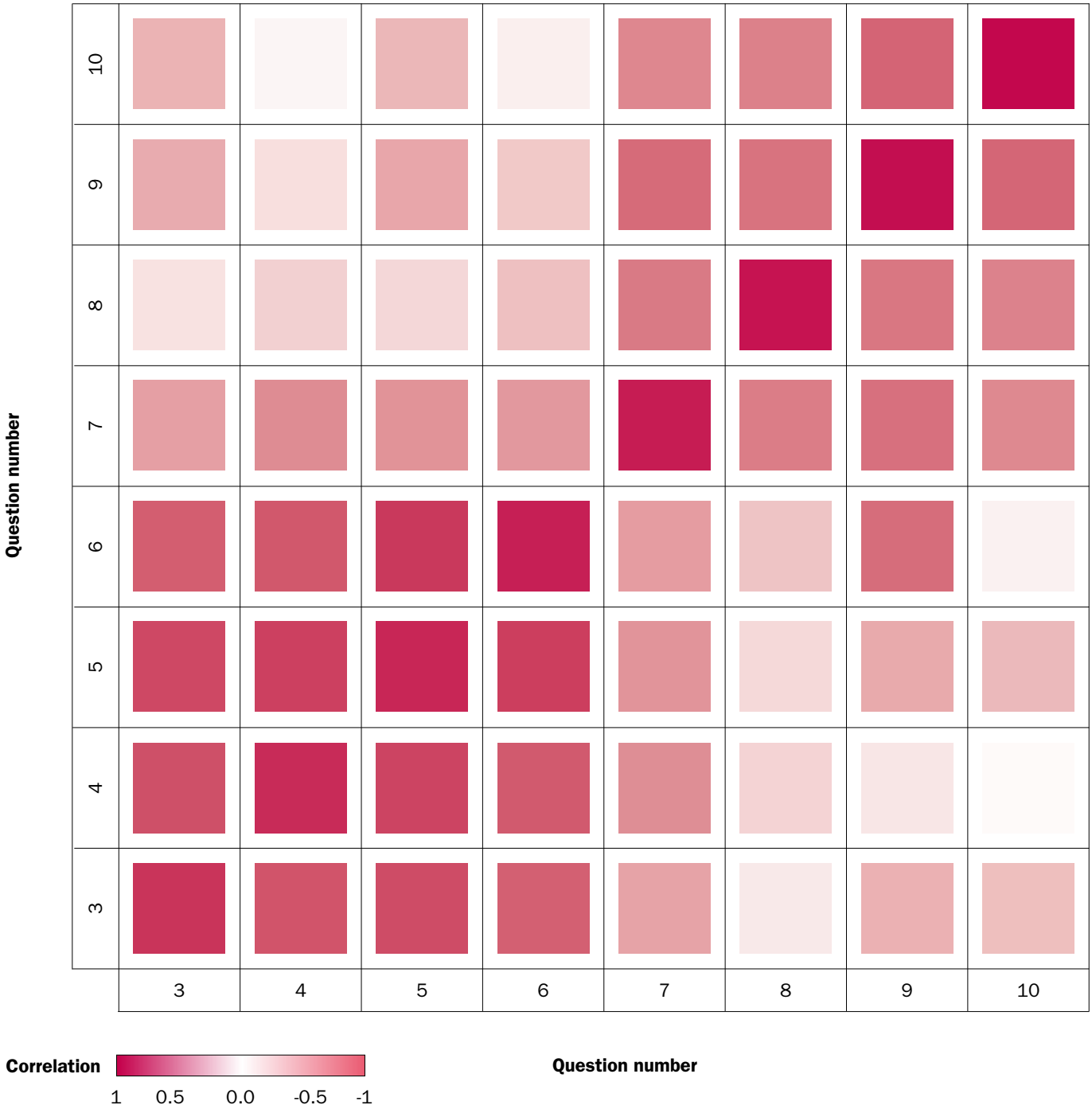


Figure 3
Correlation heatmap among questionnaire items (Q3–Q10).

an established smoking-specific treatment recommendation.

Associations

Table 3 details the associations between professional category and clinical behaviours. None of the associations remained statistically significant after correction for multiple testing using either the Bonferroni or Benjamini–Hochberg procedures (all adjusted $p \geq 0.058$). Cramer's V values ranged from 0.126 to 0.214, indicating small effect sizes. Accordingly, no differences between professional settings were inferred from these analyses.

Table 3
Association between professional category and clinical behaviours (Pearson's Chi-square test).

Question	X^2 (df=2)	p (original)	p (Bonferroni)	p (BH)	Cramer's V
Q3	4.64	0.098	0.787	0.112	0.152
Q4	7.23	0.027	0.215	0.058	0.190
Q5	7.09	0.029	0.231	0.058	0.188
Q6	7.07	0.029	0.234	0.058	0.188
Q7	3.19	0.202	1.000	0.202	0.126
Q8	6.34	0.042	0.336	0.066	0.178
Q9	6.01	0.050	0.396	0.066	0.173
Q10	9.19	0.010	0.081	0.058	0.214
Note: No association remained statistically significant after either Bonferroni or Benjamini-Hochberg correction. Cramer's V values ranged from 0.126 to 0.214.					

Thematic analysis

Qualitative responses from 30 dentists were analysed according to Braun and Clarke's six-phase framework (11). Participant-level characteristics, response summaries, and code assignments are presented in Supplementary Table S1. The analytical audit trail is detailed in Supplementary Table S2, and the initial codebook is presented in Supplementary Table S3. Exemplar extracts are provided in Supplementary Table S4, the progression from initial codes to candidate and final themes in Supplementary Table S5, and additional illustrative extracts supporting the final themes in Supplementary Table S6.

Four final themes were developed: (i) perceived biological and prognostic relevance of smoking to periapical healing, reflecting participants' perceptions that smoking may affect vascularisation, immune response, bone repair, lesion regression, and endodontic prognosis; (ii) smoking history as present in anamnesis but weakly integrated into endodontic reasoning, indicating that tobacco use was often recorded, but not consistently explored in terms

Table 4
Final themes from the thematic analysis.

Theme	Analytic meaning	Codes informing theme*	Illustrative evidence	Justification
(1) Perceived biological and prognostic relevance of smoking to periapical healing	Participants who articulated a specific link described smoking through vascular, immune, inflammatory, and repair pathways that they perceived as potentially relevant to lesion regression and endodontic prognosis.	C03, C04, C05	P03: reduced vascularisation, immune compromise, difficult bone healing and lesion persistence. P05: reduced vascularisation, reduced immune response and delayed healing. P09: reduced immunity, bone resorption and poorer healing.	This theme captures how participants perceived smoking as potentially relevant to periapical healing and endodontic prognosis.
(2) Smoking history is often present in anamnesis but weakly integrated into endodontic reasoning	Although many participants said that smoking was asked about during anamnesis, only a smaller subset described detailed investigation or explicit correlation with endodontic findings.	C06, C07, C08, C09	P08: detailed history and correlation with clinical/radiographic findings. P20: smoking is recorded but not associated. P29: only asks whether the patient smokes.	This theme captures the practice gap between recording tobacco use and using it as a prognostic variable.
(3) Anamnesis as risk communication, individualised care and professional accountability	Participants justified tobacco-related questions as a way to guide treatment planning, align expectations, educate patients and document risks that may affect outcomes.	C10, C11, C12	P03: individualising conduct and aligning expectations. P13: adjusting treatment plans and anticipating unfavourable prognosis. P16: health promotion and legal support.	This theme captures participants' views that smoking-related anamnesis may support risk communication, expectation alignment, individualised planning, and documentation.
(4) Knowledge gaps and structural constraints limit implementation	Limited awareness of the smoking–periapical lesion relationship, uncertainty about evidence and work-context barriers restricted the clinical use of tobacco history.	C01, C02, C13, C14	P15: lacks specific knowledge and does not address it in practice. P22: necessary but not realistic in public service. P24: important but no time.	This theme helps explain why knowledge and clinical behaviour were inconsistent, but the detailed participant-level evidence is better suited to supplementary material.
*Codes are defined in detail in Supplementary Table S3; their development into candidate and final themes is presented in Supplementary Table S5.				

of frequency, duration, previous exposure, cessation, or clinical implications; (iii) anamnesis as risk communication, individualised care, and professional accountability, showing that smoking-related questions were considered relevant for patient counselling, expectation alignment, treatment planning, and documentation of risk factors; and (iv) knowledge gaps and structural constraints limiting implementation, underscoring limited lesion-specific knowledge, broader non-endodontic framings of smoking-related harm, and practical barriers such as time pressure and service-context limitations (Table 4).

Integrated interpretive summary

The quantitative and qualitative findings together indicated variability in both the depth of smoking assessment and the clinical interpretation of tobacco-use history. Although 55.2% of respondents reported asking whether patients smoked, substantially fewer reported assessing smoking frequency or adapting case explanation according to smoking status. No association between these behaviours and professional category remained statistically significant after correction for multiple testing. The qualitative findings provided additional context for these aggregate patterns. Some participants described detailed investigation of smoking status, frequency, duration, quantity consumed, previous exposure, and cessation history, whereas others described only superficial yes/no inquiry, simple documentation without endodontic interpretation, or no smoking-related investigation. Participants also varied in how they perceived the potential biological and prognostic relevance of smoking. Overall, the integrated findings suggest that the principal gap concerned the depth and interpretation of tobacco-use information in prognostic reasoning and risk communication rather than the absence of a specific smoking-related technical modification to endodontic treatment.

Discussion

Smoking is a well-established risk factor for several systemic and oral conditions and has been associated with impaired tissue healing in multiple clinical contexts. In Endodontics, available evidence suggests associations between tobacco use, a higher prevalence of periapical disease, and potentially less favourable healing following root canal treatment (1,3,5–9). However, findings remain heterogeneous, and the available observational evidence does not establish causality. The present study did not evaluate biological or treatment outcomes directly; rather, it examined how tobacco-related evidence is recognised, interpreted, and incorporated into reported endodontic clinical reasoning.

Beyond the existing systematic reviews (3–6), epidemiological and prospective clinical studies have reported associations between tobacco use, periapical disease, and endodontic outcomes (12–14). Population-based investigations have suggested smoking as a possible modifying factor in periapical pathosis rather than a direct causal agent, while some prospective studies have reported lower healing rates or greater postoperative symptomatology among smokers (12–14). These findings should nevertheless be interpreted within the context of the methodological heterogeneity and residual uncertainty identified in the broader literature. In the present qualitative data, some participants similarly perceived smoking as potentially relevant to vascularisation, immune response, tissue repair, bone healing, lesion persistence, and prognosis, whereas others reported little lesion-specific knowledge or framed smoking mainly through broader oral-health outcomes.

Despite uncertainty in the available evidence, smoking may reasonably be considered a potential prognostic variable worthy of documentation and clinical consideration (3–6,12–14). The study-specific questionnaire was de-

signed to capture reported tobacco-related assessment and clinical reasoning through concise response options (Table 1). The findings suggest inconsistency between the documentation of smoking status and the depth with which this information is investigated and interpreted. The qualitative component provided interpretative depth by showing that tobacco use could be present as a formal anamnesis item without necessarily being incorporated into endodontic-specific prognostic reasoning. Similar gaps between theoretical knowledge and clinical application have been reported in previous surveys conducted in other populations (8).

Evidence from other areas of dentistry and wound healing provides biological plausibility for a potential association between smoking and impaired periapical repair, particularly through vascular, inflammatory, immune, and bone-healing pathways (15–16). However, such cross-disciplinary evidence cannot by itself establish a smoking-specific causal effect on endodontic healing. In the qualitative data, several participants invoked these mechanisms when explaining why they considered smoking potentially relevant to endodontic prognosis, whereas others framed smoking primarily through broader oral-health consequences. This variation further supports interpreting the qualitative findings as participants' clinical reasoning rather than as biological confirmation of the proposed mechanisms.

The principal evidence-practice gap identified in this study concerned the depth and clinical interpretation of tobacco-use information rather than the absence of a smoking-specific technical treatment modification. Although 55.2% of participants reported asking whether patients smoked, only 28.4% assessed smoking frequency, 29.4% adapted case explanation according to smoking status, and 48.3% associated smoking with case prognosis. The qualitative findings further showed substantial variation in smoking-history assessment, ranging from detailed investigation of frequency, duration, quantity, previous exposure, and cessation to simple yes/no recording without endodontic interpretation. Although only 18.4% reported modifying some aspect of treatment, Q8 did not define what such modification would entail, and current evidence does not establish a specific technical endodontic modification that should routinely be applied solely on the basis of smoking status. Accordingly, the Q8 finding should be interpreted descriptively rather than as evidence of failure to translate an established treatment recommendation into practice.

None of the associations between professional category and clinical behaviours remained statistically significant after either Bonferroni or Benjamini–Hochberg correction (Table 3). Cramer's V values ranged from 0.126 to 0.214 and were small. Therefore, the present data do not support inferential claims that smoking-related behaviours differed according to professional setting. The qualitative accounts of time pressure, service constraints, and workload should instead be interpreted as participant-reported contextual barriers rather than explanations for statistically demonstrated differences between professional groups (Supplementary Tables S1–S6).

This study has several limitations. Its cross-sectional design and invitation-based sampling restrict causal inference and may limit generalisability. The quantitative data were self-reported and may therefore be affected by recall or social-desirability bias. Demographic variables such as age, sex, years of experience, specialist training, and workload were intentionally omitted to preserve anonymity within a relatively identifiable professional community, limiting assessment of individual-level influences. The questionnaire was developed specifically for this study through internal expert discussion and did not undergo formal pilot

testing, psychometric validation, or quantitative face/content-validity assessment, which should be considered when interpreting the quantitative findings. Moreover, Q8 asked broadly whether participants modified any aspect of treatment without defining the nature of such modification; consequently, responses cannot be interpreted as adherence to or deviation from a specific evidence-based smoking-related endodontic protocol. Q10 also framed the smoking–periapical healing relationship more definitively than warranted by the heterogeneous literature and referred to this relationship as a "fact". Although participants in the qualitative phase were not informed of the quantitative findings or response distributions before providing their qualitative responses, they had previously been exposed to the wording of Q10. This exposure may have sensitised them to the hypothesised relationship and cannot be excluded as a potential influence on subsequent responses concerning mechanisms, prognosis, or clinical relevance. The qualitative participants were also self-selected from the quantitative sample by accepting the follow-up invitation, and open-ended responses varied in depth. Accordingly, the qualitative findings should be interpreted as providing explanatory and interpretative context rather than independent confirmation of the quantitative findings. Finally, the study did not assess whether smoking-specific modifications to endodontic treatment improve clinical outcomes. Longitudinal and prospective studies are needed to clarify both prognostic associations and the clinical utility of structured smoking-related assessment.

Overall, the combined quantitative and qualitative findings suggest that the principal evidence-practice gap lies not simply in whether smoking is recorded during anamnesis, but in the depth with which tobacco exposure is assessed and interpreted in relation to prognosis and patient communication. Smoking was often documented as a general health variable, whereas only a subset of participants described integrating this information into endodontic-specific reasoning. Importantly, these findings should not be interpreted as evidence that smokers require a specific technical modification of root canal treatment. Rather, they identify an area in which documentation, risk recognition, prognostic discussion, and patient communication remain inconsistent and warrant further investigation.

Conclusion

This study identified inconsistencies between the documentation of tobacco use and the depth with which this information is assessed and interpreted in endodontic care. The principal evidence-practice gap concerned detailed smoking-history assessment, prognostic reasoning, and patient communication rather than the absence of a specific smoking-related technical modification to treatment. Participant accounts also identified knowledge limitations and practical contextual barriers to more detailed assessment. The findings support more consistent documentation of tobacco-use history and risk communication, while the prognostic and management implications of smoking in Endodontics require further prospective investigation. Future studies should evaluate whether structured tobacco-use assessment or smoking-informed prognostic approaches improve clinical decision-making or patient outcomes.

Authors' contributions (credit)

Luiz Carlos Trevia Morais Correia Viana: Conceptualisation; Data curation; Formal analysis; Investigation; Methodology; Validation; Writing – original draft. Christina César Praça–Brasil: Conceptualisation; Data curation; Methodology; Project administration; Supervision; Writing – review & editing. José Evando da Silva-Filho: Conceptualisa-

tion; Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing. Juliana Carneiro Melo – Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing. Denise Nunes Oliveira – Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing. Bernardo Almeida Aguiar: Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing. Fábio Almeida Gomes: Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing. Eduardo Diogo Gurgel-Filho: Data curation; Formal analysis; Investigation; Methodology; Writing – review & editing.

Ethical considerations
The study was approved by the Research Ethics Committee of the University of Fortaleza (no. 6,482,408), in accordance with Resolution 466/2012 of the Brazilian National Health Council and the ethical standards laid down in the 1964 Declaration of Helsinki. All participants provided informed consent electronically before accessing the questionnaire.

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Generative AI and AI-assisted technologies in the writing process
The authors used ChatGPT (https://chatgpt.com/) to assist with the language refinement and readability of this manuscript. The tool was employed exclusively to enhance the language and readability of the text. Following its use, the authors thoroughly reviewed and edited the output as necessary, assuming full responsibility for the final content of the publication.

Declarations

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Competing interest
The authors deny any conflicts of interest.

Data availability
All data generated are presented within the manuscript. Supplementary materials and data are available by request to the authors.

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ORIGINAL ARTICLES

Apical sealing ability of matching single cone obturation technique compared to warm vertical and lateral compaction: an in vitro study

ABSTRACT

Objective *To evaluate the apical sealing ability of the matching single cone obturation technique and compare it to the warm vertical and cold lateral compaction techniques using dye penetration.*
Methodology *A total of 58 extracted single-rooted teeth were decoronated. Root canal preparation was performed using ProTaper Gold till size F4 with a standardized protocol. Four teeth served as control, and 54 teeth were randomly and equally divided into 3 groups according to the obturation technique (n=18). Calcium silicate-based sealer and gutta-percha points were used for obturation. Teeth were incubated for one week, then covered with nail polish except for the apical foramen. Teeth were placed in 0.1% rhodamine B dye for 24 hours. Longitudinal teeth sectioning was performed, and each half was examined using the dental operating microscope. Digital images were analyzed using ImageJ software. The maximum penetration depth of the dye was calculated as well as the percentage of penetration area. Data was statistically analyzed at a significance level of p<0.05.*
Results *Both maximum linear dye penetration (p=0.216) and percentage surface area leakage (p=0.077) failed to show statistically significant differences between the three obturation techniques.*
Conclusion *Within the limitations of this in vitro model, the single-cone obturation technique demonstrated comparable apical sealing ability to warm vertical compaction and cold lateral compaction when used with a calcium silicate-based sealer.*

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Introduction

Achieving an effective apical seal is a fundamental objective of root canal obturation and a critical determinant of long-term endodontic success. Inadequate sealing of the apical portion of the canal may permit the ingress of oral fluids, microorganisms, and their by-products, leading to reinfection and persistent apical periodontitis. Even after meticulous cleaning and shaping, residual microorganisms may remain within inaccessible areas of the canal system; therefore, the obturation material must create a fluid-tight barrier that prevents microbial leakage and entombs surviving bacteria. The ability of an obturation technique to establish and maintain an effective apical seal is consequently an important parameter for evaluating its clinical performance and prognostic value in endodontic treatment (1–4).

The single-cone (SC) obturation technique is a hydraulic filling method that utilizes a single master gutta-percha cone matched to the final preparation size and taper, in conjunction with a root canal sealer. The technique has gained considerable popularity because of its simplicity, reduced chair time, minimal technical sensitivity, and improved compatibility with contemporary nickel-titanium instrumentation systems. Unlike traditional compaction techniques, SC obturation relies primarily on the sealer to occupy irregularities and accessory spaces within the root canal system. Recent evidence suggests that when used with modern sealers, particularly bioactive calcium silicate-based materials, the SC technique can produce satisfactory sealing properties and clinical outcomes comparable to more complex obturation procedures (5–8).

Warm vertical compaction (WVC), originally described by Schilder, is widely regarded as a reference standard for three-dimensional root canal obturation. This technique involves the thermoplasticization of gutta-percha using heat and vertical compaction forces, allowing the filling material to adapt closely to canal irregularities, fins, isthmuses, and lateral canals. By enhancing the flow characteristics of gutta-percha, WVC aims to improve the homogeneity and density of the root filling while minimizing voids. Although the technique is more time-consuming and operator-dependent than other obturation methods, it is often recommended for teeth with complex canal anatomy because of its ability to achieve superior adaptation to the root canal system (6,9).

Cold lateral compaction (CLC) remains one of the most extensively taught and clinically utilized obturation techniques in endodontics. The procedure consists of placing a master gutta-percha cone coated with sealer followed by the insertion of accessory cones through lateral displacement using a finger or hand spreader. The technique is relatively inexpensive, requires minimal specialized equipment, and provides predictable control of working length. Consequently, it has long served as a benchmark against which newer obturation approaches are compared. However, concerns have been raised regarding the presence of sealer-rich areas, internal void formation, and limited adaptation of gutta-percha to canal irregularities, particularly in oval or anatomically complex canals (1,5).

The introduction of calcium silicate-based sealers has significantly influenced contemporary obturation concepts. These bioactive materials exhibit favorable physicochemical and biological properties, including biocompatibility, antibacterial activity resulting from alkaline pH, dimensional stability, slight expansion upon setting, and the capacity to form hydroxyapatite at the dentin-sealer interface. Unlike conventional sealers that primarily function as gap-filling materials, calcium silicate-based sealers actively contribute to the estab-

lishment of a biologically favorable seal. Consequently, a "sealer-based" obturation philosophy has emerged, with these materials being particularly recommended for use with the single-cone technique because the hydraulic condensation concept allows the sealer to penetrate dentinal tubules and anatomical irregularities while maintaining an adequate seal with minimal procedural complexity (10–14).

Despite the widespread use of single-cone, lateral compaction, and warm vertical compaction obturation techniques, the literature remains inconclusive regarding their relative ability to provide an effective apical seal. Previous studies have reported conflicting findings, particularly following the introduction of calcium silicate-based sealers, which have renewed interest in the single-cone technique and challenged the traditional assumption that thermoplasticized or compacted gutta-percha techniques provide superior sealing performance. Therefore, the aim of the present study was to compare the apical sealing ability of three root canal obturation techniques using a calcium silicate-based sealer. The null hypothesis tested is that no statistically significant difference in apical sealing ability among root canals obturated using the single-cone, cold lateral compaction, or warm vertical compaction techniques.

Methodology

Study Design and Ethical Consideration
This in vitro experimental comparative study was approved by the local IRB with the reference number: IRB-COD-STD-37-Sep-2025.

Sample Size Calculation
Sample size calculation was performed based on the results of Wang et al. (3). Based on an effect size of 0.40, a significance level (α) of 0.05, and a statistical power of 80%, a minimum sample size of 54 specimens (18 per group) was required for one-way analysis of variance among the three experimental groups.

Sample Preparation
A total of 58 teeth extracted for reasons not related to the current study were used. The included teeth were human permanent teeth with a single root and a single canal, fully formed apices, and intact root structure without fracture. Teeth showing root caries, internal or external root resorption, root fractures, cracks, or canal curvature more than 15 degrees were excluded.

Following extraction, teeth were cleaned of soft tissue remnants and calculus using an ultrasonic scaler. The specimens were disinfected in 0.1% thymol solution and subsequently stored in distilled water at room temperature until use.

Preoperative radiographs were obtained in the buccolingual and mesiodistal directions to verify the presence of a single canal and exclude anatomical variations. The anatomical crowns were removed using a water-cooled diamond disc to standardise root length to 12 mm.

Working length was established by introducing a size 10 K-file into the canal until its tip becomes visible at the apical foramen. The working length was determined by subtracting 1 mm from this measurement.

All canals will be prepared using the Protaper Gold rotary system (Dentsply Sirona, Ballaigues, Switzerland) according to the manufacturer's instructions up to file size F4, following the manufacturer's recommendations for speed and torque settings.

During instrumentation, each canal was irrigated with 2 mL of 3% sodium hypochlorite after the use of every rotary file using a 30-gauge side-vented irrigation needle.

Following completion of instrumentation, a final irrigation protocol was performed as follows: 5 mL of 3% sodium

hypochlorite for 1 minute, then 5 mL of saline for 1 minute, followed by 5 mL of 17% EDTA for 1 minute. A final rinse with 5 mL of saline for 1 minute was performed. The canals were left partially wet by applying only one matching paper point size F4 prior to obturation.

Four teeth served as a control; two teeth without obturation as a positive control, and two teeth with obturation and total coverage with nail polish as a negative control. The remaining 54 teeth were equally and randomly assigned into three experimental groups (n =18) according to the obturation technique used.

Group SC: C-Root SP bioceramic sealer (Beijing C-Root Dental Medical Devices Co., Ltd., Beijing, China) was delivered directly into the canal using the manufacturer's intracanal delivery tip. A single F4 gutta-percha cone corresponding to the final preparation size was coated with sealer and inserted passively to the full working length. Following confirmation of proper seating, excess gutta-percha was removed at the canal orifice using the heated plugger of BeeFill 2in1 (VDW GmbH, Munich, Germany).

Group WVC: C-Root SP bioceramic sealer was applied using a size 25 Lentulo spiral. An F4 gutta-percha master cone was fitted to the working length and verified clinically and radiographically. Down-packing was performed using a heated plugger positioned 3-5 mm short of the working length. Apical compaction was achieved through controlled application of heat and vertical pressure followed by a brief cooling period. The remaining canal space was backfilled using BeeFill 2in1 delivered in incremental layers. Excess material was removed and compacted coronally.

Group CLC: C-Root SP bioceramic sealer was applied to the canal walls using a size 25 Lentulo spiral operated at low speed. An ISO standardized gutta-percha master cone size 40 was fitted to the working length and verified clinically and radiographically. A finger spreader was then inserted alongside the master cone to create space for accessory cones. Accessory gutta percha cones were placed sequentially until the spreader can no longer penetrate beyond 2-3 mm into the canal. Excess gutta percha was removed using the heated plugger of BeeFill 2in1 and vertically condensed at the canal orifice.

Apical Sealing Ability Evaluation

Following obturation, all teeth were stored at 37°C and 100% humidity for seven days to allow complete setting of the sealer. The external root surfaces were then coated with two layers of nail varnish, leaving the apical 1 mm exposed. Each tooth was subsequently immersed in 0.1% rhodamine B dye solution for 24 hours at room temperature. Following dye exposure, the specimens were thoroughly rinsed under running water. Each root was then longitudinally sectioned in a buccolingual direction using a diamond disc under continuous water cooling. Both longitudinal halves of each specimen were examined under a dental operating microscope (Zumax Medical Co., Ltd., Suzhou, China) at 10× magnification. The half displaying the deeper dye penetration was selected for digital imaging and quantitative analysis.

High-resolution digital photographs were captured alongside a precision millimeter calibration ruler positioned at the same focal level and magnification. Image analysis was performed using ImageJ software (National Institutes of Health, Bethesda, Maryland, USA). Prior to measurement, spatial calibration was established for each photograph using the Analyze > Set Scale tool based on the physical millimeter ruler.

Maximum linear dye penetration was measured in millimeters along the root canal wall from the apical foramen to the most coronal point of dye ingress. To

Obturation Technique	Sample Size (n)	Maximum Linear Dye Penetration (mm)	Percentage of Surface Area of Dye Penetration (%)
Single Cone	18	2.55±0.86[a]	35.04±15.14[a]
Lateral Compaction	18	2.15±0.71[a]	30.83±11.65[a]
Warm Vertical Compaction	18	2.15±0.73[a]	25.40±10.10[a]
Statistical Analysis		$F_{(2,51)}$=1.58; p=0.216	$F_{(2,51)}$=2.70; p=0.077
Note: Identical superscript letters ([a]) within the same column indicate no statistically significant differences between techniques (p>0.05).			

Table 1
Apical sealing ability of the three obturation techniques measured by maximum linear dye penetration and percentage of surface area of dye penetration (Values are presented as Mean ±Standard Deviation).

evaluate the percentage of surface area of dye penetration, the dye-stained region within the apical 6 mm zone was manually delineated using the Polygon Selection tool, and its area was calculated (mm²). The total surface area of the apical 6 mm root canal space was delineated in the same manner. The percentage of surface area leakage was determined using the following formula (1):

Percentage of surface area of dye penetration = surface area of dye penetration/ surface area of the apical 6 mm of the root.

Measurements were performed independently by the second and third authors, who were fully blinded to group allocation. The mean of their independent measurements was recorded for statistical analysis.

Statistical Analysis

Statistical analysis was performed using R statistical software. Continuous data for maximum linear dye penetration depth (mm) and the percentage of surface area of dye penetration (%) were first evaluated for normal distribution using the Shapiro-Wilk test. Upon confirming that the data met the assumption of normality across all experimental groups (p>0.05), parametric testing was implemented. A One-Way Analysis of Variance was conducted to determine statistically significant differences in sealing ability among the three obturation techniques. Pairwise post-hoc comparisons were subsequently evaluated using Tukey's Honestly Significant Difference (HSD) test to isolate specific group differences. For all statistical analyses, the level of significance was established at p<0.05.

Results

Maximum Linear Dye Penetration

The maximum linear dye penetration depth across the three experimental groups is summarized in Table 1. The WVC demonstrated the numerically lowest mean penetration depth (2.15±0.73 mm), followed closely by the CLC (2.15±0.71 mm), while the SC technique exhibited the highest level of linear leakage (2.55±0.86 mm). However, One-Way Analysis of Variance revealed that these differences in linear penetration depth among the obturation methods were not statistically significant, p=0.216. Pairwise comparisons via Tukey's HSD post-hoc test confirmed no significant differences between any of the individual groups (p>0.05), Figure 1 and Figure 2.

Percentage of Surface Area of Dye Penetration

Regarding the total percentage of dye penetration surface area within the apical 6 mm zone, the WVC group showed the highest sealing ability with the lowest mean leakage area (25.40%±10.10%), followed by the CLC (30.83%±11.65%), and the SC technique (35.04±15.14%). The One-Way ANOVA indicated that the effect of the obturation technique on the

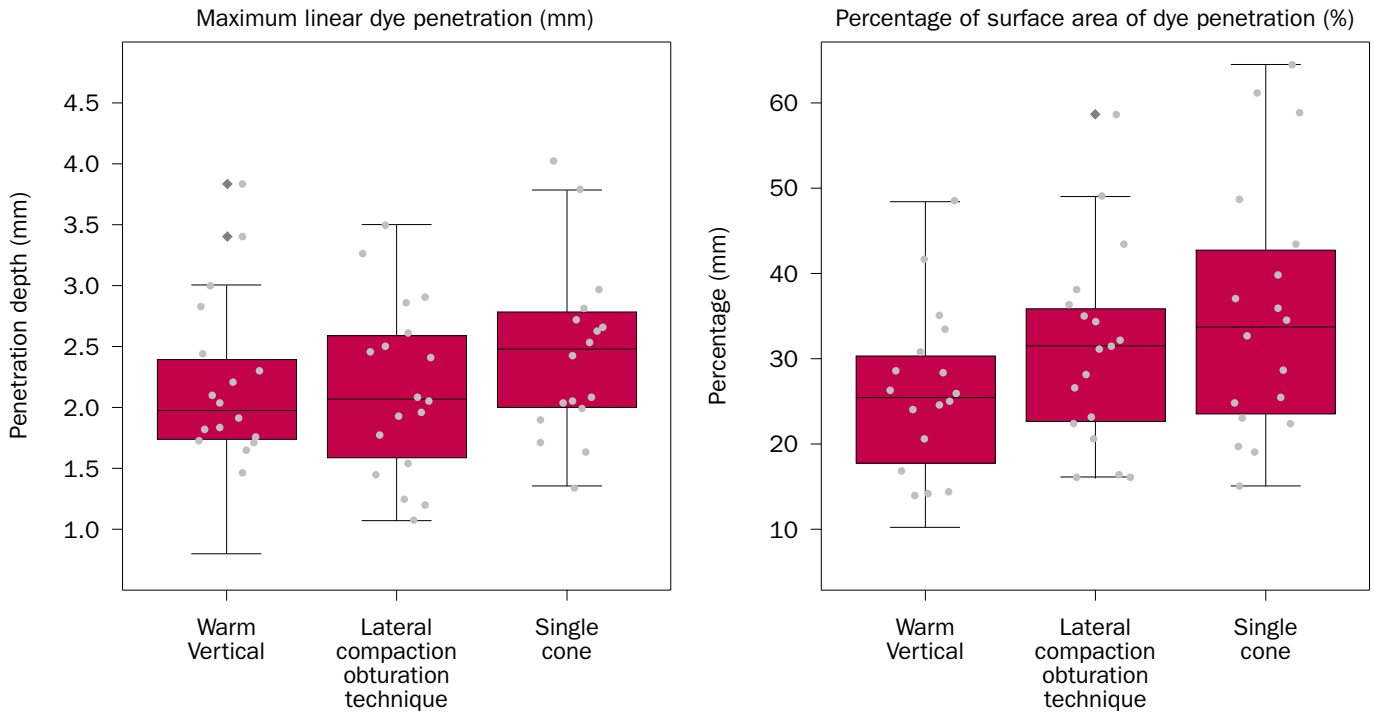


Figure 1
Boxplot comparison of apical sealing ability among Single Cone, Lateral Compaction, and Warm Vertical Compaction; a) Maximum linear dye penetration depth (mm), b) total percentage area of dye penetration (%) within the apical 6 mm zone.

percentage of leakage area did not reach full statistical significance at the conventional 95% confidence level (p=0.077). Tukey's HSD post-hoc analysis similarly revealed no statistically significant pairwise differences between any of the groups (p>0.05), Table 1, Figure 1, and Figure 2.

The positive control group (unobturated teeth) showed complete dye penetration throughout the canal, whereas the negative control group (completely sealed with nail varnish) demonstrated no dye penetration at all (0%), confirming the technical validity and reliability of the dye penetration methodology.

Discussion

Thorough chemomechanical preparation constitutes the biological foundation of successful endodontic therapy. Effective shaping using modern Nickel–Titanium (NiTi) rotary instruments, combined with rigorous irrigation protocols, is essential for reducing the intracanal microbial load, removing debris, and opening dentinal tubules. The mechanical performance and resistance to procedural errors of continuous rotation NiTi files ensure predictable canal enlargement, while advanced irrigation dynamics facilitate deep irrigant penetration and thorough cleaning of complex root anatomy. Together, these preparation procedures establish the prerequisite biological environment and spatial conditions required for optimal, three-dimensional root canal obturation. Once adequate cleaning and shaping are achieved, the primary goal of obturation is to create a complete, fluid-tight seal that entombs residual microorganisms and prevents fluid ingress into periapical tissues. The present study evaluated the apical sealing ability of the SC technique compared to WVC and CLC using a bioactive calcium silicate-based sealer (15,16).

The primary goal of root canal obturation is to create a complete, three-dimensional fluid-tight seal that prevents the ingress of microorganisms and their by-products into the periapical tissues. The present study evaluated the apical sealing ability of the SC technique com-

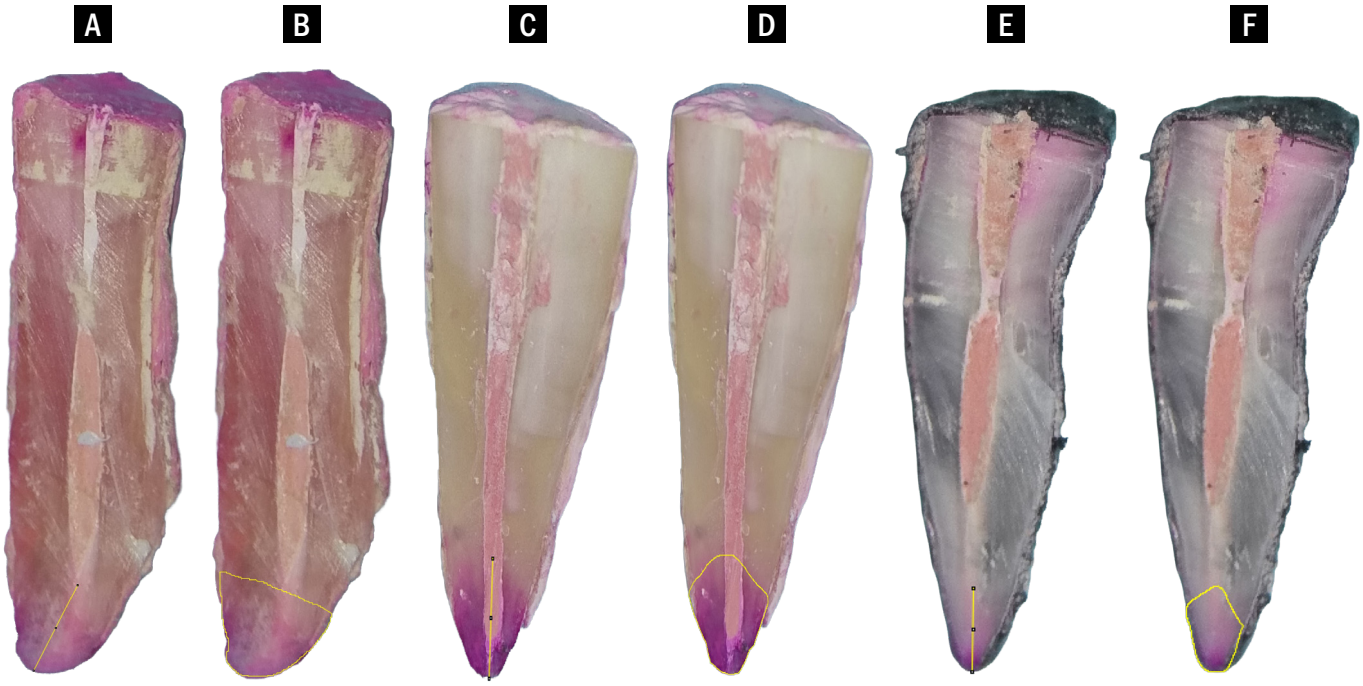


Figure 2
Digital photographs under magnification showing dye penetration analysis where the yellow line indicates the maximum linear dye penetration depth and the yellow outlined area indicates the surface area of dye penetration; **(A, B)** teeth obturated using the cold lateral compaction technique; **(C, D)** teeth obturated using the warm vertical compaction technique; **(E, F)** teeth obturated using the matching single cone technique.

pared to the WVC and CLC techniques using a calcium silicate-based sealer.

Based on our statistical findings, the null hypothesis, that no significant difference exists in apical sealing ability among the three techniques, was accepted. Both maximum linear dye penetration (p=0.216) and percentage surface area leakage (p=0.077) failed to show statistically significant differences at the established significance level. These results align with a growing body of endodontic literature suggesting that contemporary bioceramic sealer-based obturation concepts can provide a reliable apical barrier regardless of the compaction method utilized (6,7,17–22).

Linear dye penetration has long served as a standard methodology for evaluating apical microleakage due to its sensitivity in tracking fluid pathways along the root canal filling. In this study, the maximum linear penetration depths were remarkably similar between WVC (2.15±0.73 mm) and CLC (2.15±0.71 mm), while the SC technique exhibited a numerically higher but statistically non-significant value (2.55±0.86 mm). This equivalence indicates that the primary linear pathway for apical fluid ingress remains uniform when root canals are prepared using contemporary standardized protocols. Our findings corroborate previous studies reporting that modern obturation techniques perform comparably regarding linear apical microleakage when procedural variables are strictly controlled (5,21,22).

Measuring the percentage of surface area of dye penetration offers a two-dimensional assessment of apical leakage by accounting for structural gaps and anatomical variations. Although numerical differences were noted, with WVC exhibiting lower mean percentage leakage (25.40%±10.10%) than SC (35.04%±15.14%), these differences did not reach statistical significance (p=0.077). The lower numerical leakage in the WVC group may be attributed to the thermoplasticization and vertical compaction of gutta-percha, which facilitates adaptation to anatomical recesses. Conversely, the SC technique relies on hydraulic forces to push sealer

into spaces, which may lead to thicker sealer regions in irregular canals. Nevertheless, under the conditions of this study, both techniques provided comparable overall sealing performance.

Conversely, the SC technique relies entirely on the hydraulic force of a single master cone to distribute the sealer into accessory spaces. In wide or slightly oval canals, this mechanism can result in a thicker, less uniform layer of sealer, potentially increasing the total area susceptible to micro-gaps or incomplete adaptation (1,7).

The introduction of calcium silicate-based bioactive materials has altered the traditional paradigm that mechanical gutta-percha compaction is mandatory to achieve a tight seal. Calcium silicate-based sealers possess outstanding physicochemical properties, including slight expansion upon setting, high dimensional stability, and excellent dentinal tubule penetration via an alkaline hydraulic reaction. Furthermore, their biocompatibility and ability to induce mineralized nodule formation at the dentin interface contribute to a tight physical and chemical bond (10,13,23,24). This advanced biochemical behavior explains why the SC technique, despite relying on a non-compacted, thicker layer of sealer, achieved a maximum linear seal and total leakage area statistically comparable to the more labor-intensive CLC and WVC methods. This supports the clinical validity of a "sealer-based" obturation philosophy when utilizing modern calcium silicate materials.

Methodologically, this study utilized an in vitro dye penetration model with rhodamine dye combined with ImageJ software analysis, a combination known for high contrast and reproducible measurement accuracy. However, in vitro leakage models carry inherent limitations. While dye penetration effectively screens sealing capability, it lacks the dynamic fluid pressures, complex microbial flora, and continuous moisture conditions present in vivo. Additionally, longitudinal sectioning only exposes a single plane, which may under- or overestimate three-dimensional void distribution. Future studies utilizing high-resolution micro-computed tomography are recommended to provide detailed three-dimensional insights into the volumetric breakdown of voids and sealer thickness across these obturation techniques.

Within the limitations of this in vitro study, the single-cone, cold lateral compaction, and warm vertical compaction techniques demonstrated comparable apical sealing abilities when used in combination with a bioactive calcium silicate-based root canal sealer. Although warm vertical compaction showed lower numerical leakage values, no statistically significant differences were observed among the three techniques for either maximum linear dye penetration or percentage surface area of leakage. These findings indicate that a sealer-based single-cone approach yields sealing performance comparable to compacted gutta-percha techniques under these experimental laboratory conditions.

Ethical Statement

This study was approved by the local institutional review board with registration no. IRB-COD-STD-37-Sep-2025.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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CASE REPORT

Vital pulp therapy as a minimally invasive approach for root fracture in a mature maxillary central incisor: a case report

ABSTRACT

Aim *To describe the management of a horizontal root fracture in a mature maxillary central incisor with pulpal complications using vital pulp therapy as a conservative approach aimed at preserving pulp sensibility.*

Summary *A 22-year-old patient presented with a horizontal root fracture and symptomatic pulpitis of a mature maxillary central incisor following dental trauma. Initial emergency management included repositioning of the coronal fragment and stabilization with a flexible splint. As symptoms worsened, a full coronal pulpotomy was performed to remove the inflamed coronal pulp tissue, and a bioceramic material was placed over the remaining radicular pulp. During the three-year follow-up period, the tooth remained asymptomatic. Radiographic findings were consistent with a favorable healing pattern at the fracture site, indicating successful preservation of pulp sensibility and favorable tissue repair.*

Key learning points:

- *Pulpotomy may represent a conservative treatment option for selected mature teeth with horizontal root fractures and pulpal complications.*
- *Vital pulp therapy may allow preservation of the radicular pulp as an alternative to conventional root canal treatment of the coronal fragment.*
- *Preservation of vital radicular pulp tissue may be associated with favorable healing patterns in horizontal root fractures.*

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KEYWORDS *Biodentine; dental trauma; horizontal root fracture; mature permanent teeth; vital pulp therapy.*

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Introduction

The prognosis of traumatized permanent teeth depends largely on pulp vitality and the quality of subsequent treatment (1). The dental pulp provides nutrition, immune defense, sensory function and continuous dentin formation throughout the tooth's lifespan (2). Traumatic injuries can compromise pulp integrity, leading to pulpitis or necrosis and, ultimately, tooth loss if inadequately managed. Endodontic management plays a crucial role in the long-term prognosis of traumatized permanent teeth.

Horizontal root fractures are relatively uncommon but clinically significant injuries (3). Their prognosis depends on fracture location (apical, middle, or coronal third; subcrestal vs supracrestal), the degree of fragment displacement, and patient-related factors such as age (4). In many cases, the apical fragment remains vital, whereas the coronal segment may develop necrosis.

Conventional treatment typically involves root canal treatment (RCT) of the coronal fragment usually with gutta-percha or a bioceramic material as an apical barrier (5). However, preservation of pulp vitality may play a critical role in the biological healing of root fractures.

Pulpotomy is a vital pulp therapy that removes only the inflamed coronal pulp tissue, while preserving the remaining radicular pulp under a biocompatible capping material. Traditionally indicated for immature permanent teeth to allow continued root development, recent evidence supports pulpotomy as a definitive treatment for irreversible pulpitis in mature permanent teeth. When appropriate case selection and strict aseptic techniques are employed, reported success rates exceed 90% (6). However, the use of pulpotomy in mature teeth with horizontal root fractures has rarely been described in the literature (7).

This report describes the management of a mature maxillary central incisor with a horizontal root fracture and symptomatic pulpitis, treated with pulpotomy, resulting in favorable clinical and radiographic outcomes over a 3-year follow-up.

This case report was prepared in accordance with the PRICE guidelines, and the corresponding PRICE checklist was completed (8).

Report

A healthy 22-year-old male patient with a non-contributory medical history sustained oro-facial trauma to the upper anterior region, involving the maxillary incisors. Extraoral clinical examination revealed a laceration involving the upper and lower left lip associated with painful swelling (Figure 1A). Intraorally, tooth 22 showed grade 2 mobility and tooth 21 extrusive coronal displacement and grade 3 mobility (Figure 1B, C). Thermal and electric pulp tests were negative for both teeth. Transillumination revealed no enamel infractions. No relevant findings were detected for the other teeth in the second sextant.



Figure 1
Initial clinical presentation **(A)** Initial clinical appearance following trauma showing soft tissue injuries of the upper lip. **(B)** Frontal view demonstrating extrusive displacement of tooth 21 associated with soft tissue injuries of the surrounding oral mucosa. **(C)** Occlusal view of the area.

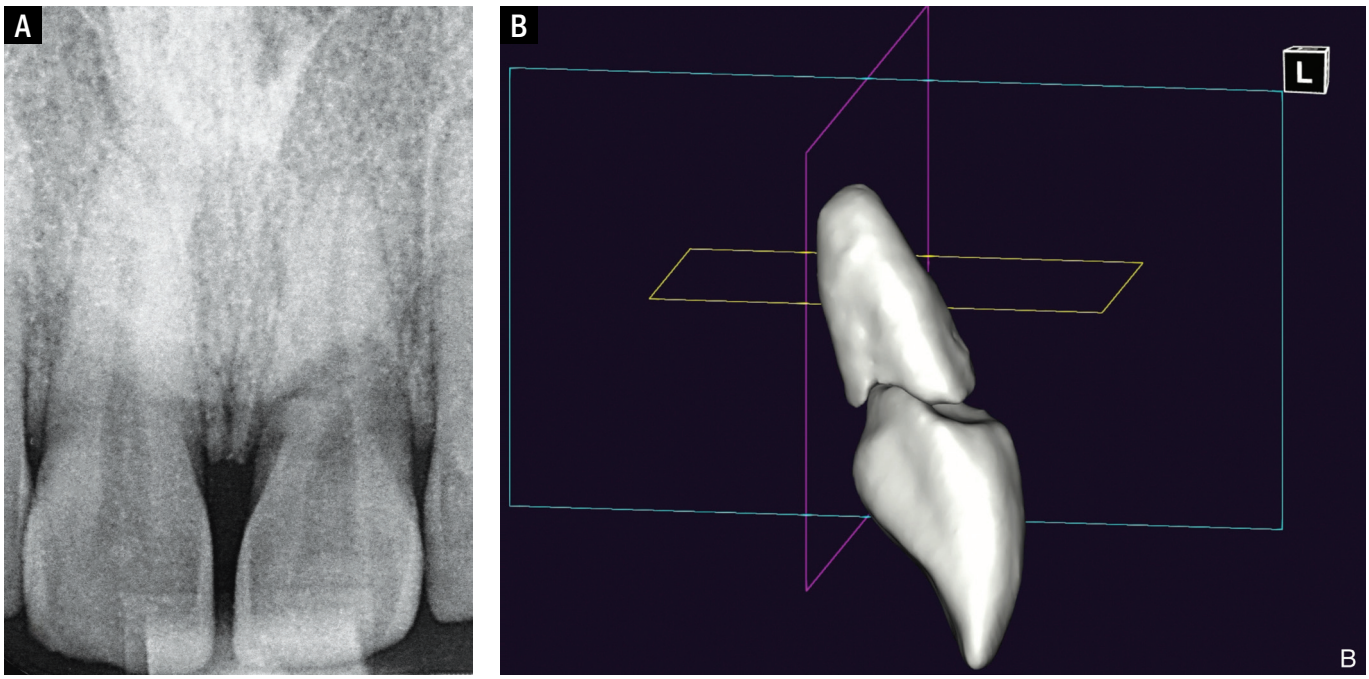


Figure 2
Radiologic assessment of the root fracture **(A)** Periapical radiograph of tooth 21. **(B)** Three-dimensional CBCT reconstruction showing a horizontal root fracture of tooth 21, with approximately 2 mm separation between the coronal and apical fragments.

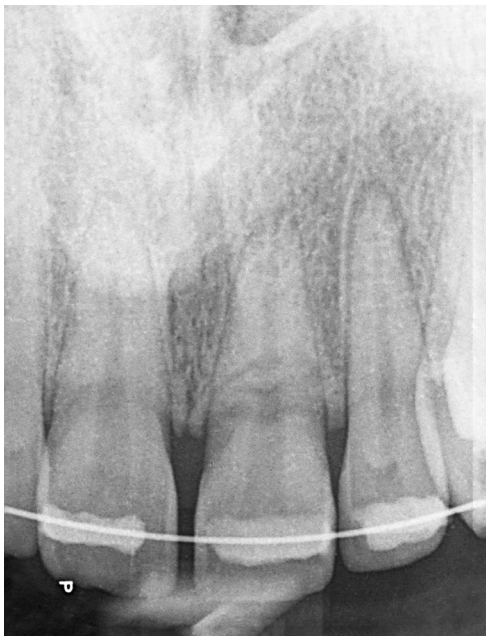
Figure 3
Stabilization of the traumatized teeth. Immediate postoperative view showing stabilization with a composite splint extending from canine to canine in the maxillary arch.

Figure 4
Radiologic findings at six-week follow-up. Periapical radiograph showing a moderate periapical radiolucency associated with tooth 21.

2D and 3D imaging confirmed a horizontal root fracture of tooth 21 (Figure 2). Following local anesthesia, gentle repositioning of the coronal fragment was performed, and a flexible splint was applied from the left to the right maxillary canine using light-cured composite resin on the labial surfaces (Figure 3). Once stabilized, the coronal fragment exhibited no pathological mobility. The splint was left in place for four weeks.

The patient missed the scheduled 4 week follow-up and returned at six weeks with severe spontaneous pain in tooth 21. The patient reported severe spontaneous pain. Clinical examination showed normal gingival appearance, no pathological probing, but intense response to cold testing that persisted after removal of the stimulus before subsiding, together with tenderness to percussion. A new periapical radiograph also revealed a moderate periapical radiolucency (Figure 4). Although transient apical breakdown was considered in the differential diagnosis of the periapical radiolucency, the clinical findings, including severe spontaneous pain, an intense and lingering response





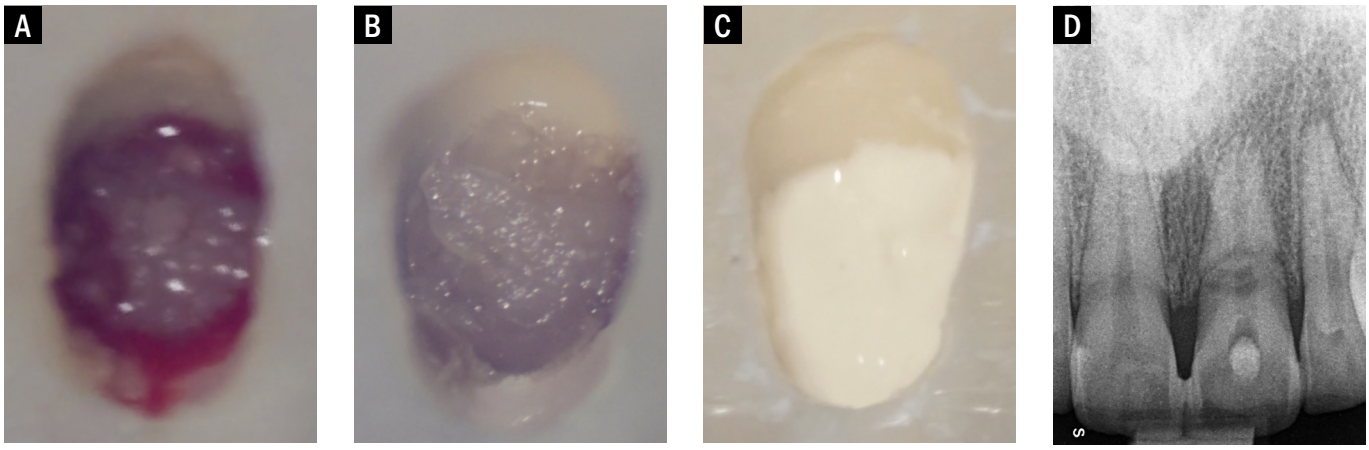


Figure 5
Vital pulp therapy procedure. **(A)** Intraoperative view under magnification following access cavity preparation and removal of the inflamed coronal pulp tissue prior to vital pulp therapy. **(B)** Hemostasis of the pulp stump achieved under magnification. **(C)** Intraoperative view showing coronal pulpotomy and direct pulp capping with Biodentine® (Septodont, Saint-Maur-des-Fossés, France) over the pulp exposure site. **(D)** Radiographic control at 1-week follow-up after placement of the pulp capping material and sealing of the access cavity.

to cold testing, and tenderness to percussion, supported a clinical diagnosis of symptomatic irreversible pulpitis with associated apical symptoms. The decision to access the pulp chamber under local anesthesia was therefore based on the overall clinical presentation rather than on the radiographic finding alone.
The treatment plan, including the option to attempt pulp preservation via pulpotomy, was discussed with the patient, and informed consent was obtained. After anesthetizing the region, the tooth was isolated with a rubber dam properly disinfected with 5% sodium hypochlorite. The roof of the pulp chamber was removed to gain access. Under magnification, a ceramic round bur under copious irrigation was used to remove the entire coronal pulp to the level of the root canal orifice (Figure 5A). Visual inspection of the remaining pulp tissue revealed no visible areas of necrosis. Hemostasis was achieved within five minutes using sterile cotton pellets soaked in 2% sodium hypochlorite. Both the clinical appearance of the tissue and its bleeding characteristics supported the decision to preserve the remaining radicular pulp and proceed with vital pulp therapy. These findings were considered compatible with clinically viable pulp tissue but could not establish the histological extent of inflammation (Figure 5B).
Thus, a full coronal pulpotomy was completed, preserving the radicular pulp. A bioceramic material (Biodentine®, Septodont, Saint-Maur-des-Fossés, France) was applied over the radicular pulp, followed by temporary restoration with a glass ionomer cement (EQUIA Forte®, GC Corporation) (Figure 5C). Tooth 22 underwent conventional RCT based on persistent negative responses to pulp sensibility testing and tenderness to percussion since the initial examination, together with a periapical radiolucency at the six-week visit. At the 7-day follow-up, the patient was asymptomatic, and a periapical radiograph confirmed an adequate coronal seal (Figure 5D). Definitive composite restoration and palatal fiber-reinforced splinting of teeth 21–22 were completed for long-term stabilization, because of slight residual mobility of tooth 21 and the cervical location of the root fracture. The diastema was simultaneously closed for esthetic purposes. At 3 months, the patient remained symptom-free, with no tenderness on percussion or palpation. Tooth 21 was non-responsive to both electric and cold testing. The radiographic examination showed a visible fracture line without signs of periapical pathology.
By 1 year, pulp sensibility had recovered, periodontal probing depths were within normal limits, and percussion and palpation tests were negative.. No clinically detectable mobility was observed with the palatal splint in place. The splint was not removed during follow-up; therefore, the independent mobility of tooth 21

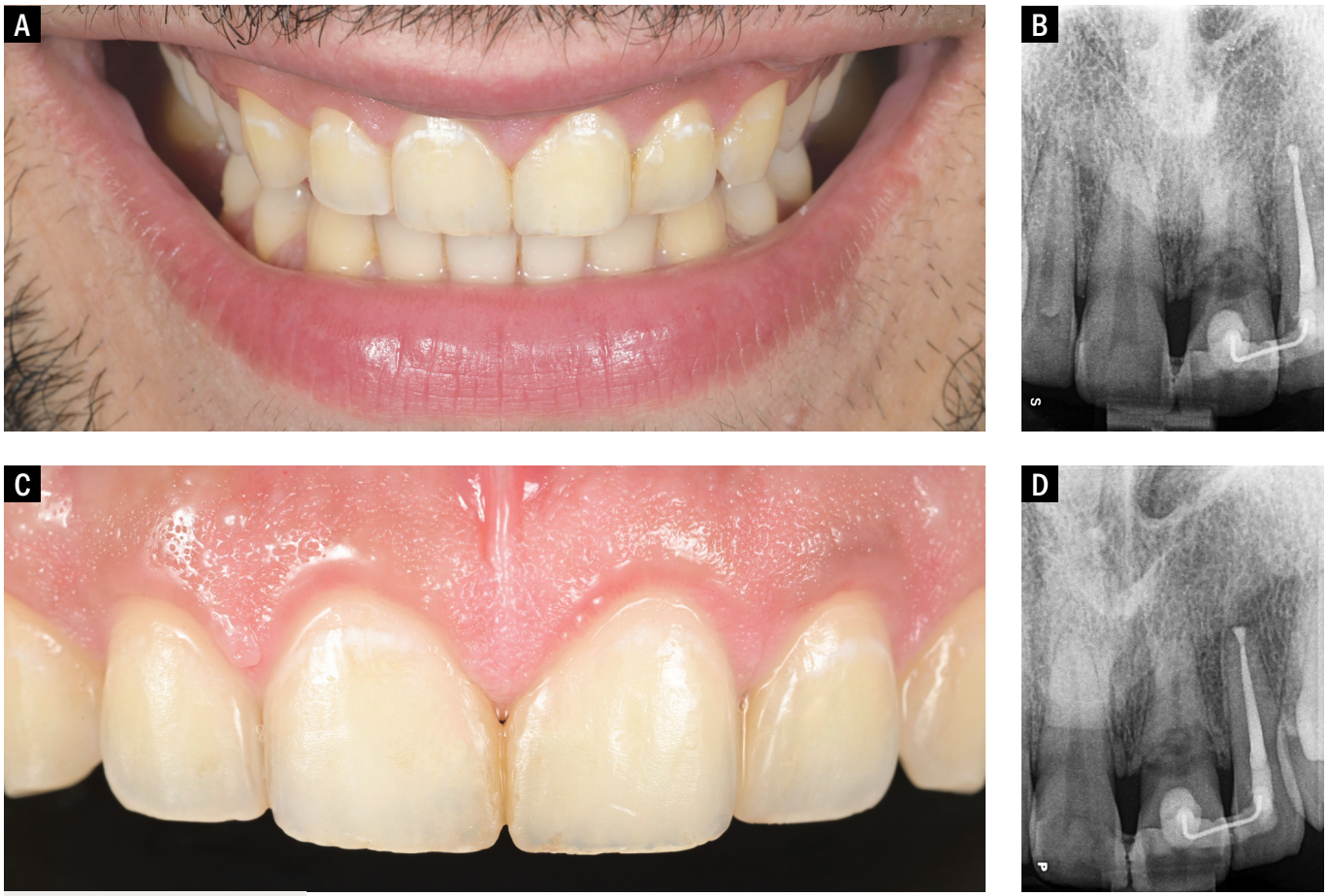


Figure 6 Long-term clinical and radiographic follow-up. **(A)** Clinical photograph at 1-year follow-up showing palatal fiber-reinforced stabilization and simultaneous closure of the diastema using composite resin for esthetic purposes. **(B)** Periapical radiograph at the 2-year follow-up demonstrating absence of periradicular radiolucency and stable healing of the horizontal root fracture. **(C)** Clinical appearance at the 3-year follow-up showing satisfactory esthetic integration and healthy periodontal tissues. **(D)** Periapical radiograph at 3-year follow-up confirming maintained healing of the root fracture and absence of periradicular pathology.

could not be assessed (Figure 6A). At 2 and 3 years, tooth 21 remained vital, functional, and asymptomatic, with stable periodontal parameters. Radiographic examination showed no apical radiolucency and a persistent radiolucent line at the fracture site, consistent with connective-tissue healing although the tissue type could not be confirmed histologically (Figure 6B-D).

Discussion

Approximately 20–44% of horizontally fractured teeth ultimately require RCT (9). Pulp pathosis may develop months or years after trauma, highlighting the need for long-term follow-up. Current International Association of Dental Traumatology guidelines recommend repositioning of displaced fragments, flexible splinting for at least four weeks in cases of horizontal root fracture, and careful clinical and radiographic monitoring over time to detect possible complications and assess healing patterns (10).

In most cases of root fracture associated with necrosis of the coronal pulp, treatment consists of RCT of the coronal segment, with obturation up to the fracture line using gutta-percha or a bioceramic apical barrier. Although this approach is well established and generally effective, it presents certain limitations, including the risk of overfilling into the fracture space, the need for multiple appointments, and the potential for reinfection over time. In contrast, pulpotomy aims to selectively remove the irreversibly inflamed coronal pulp tissue while preserving the vitality of the remaining radicular tissue.

In the present case, full coronal pulpotomy was performed in a mature perma-

nent tooth with horizontal root fracture, symptomatic pulpitis and periapical radiolucency. Transient apical breakdown should be considered in the differential diagnosis of a periapical radiolucency following dental trauma. This phenomenon has been described after luxation injuries and may resolve without endodontic intervention (11). In the present case, the radiographic finding alone was not considered conclusive evidence of an infected root canal system. The decision to perform vital pulp therapy was based on the overall clinical presentation, including severe spontaneous pain, an intense, lingering response to cold testing, and tenderness to percussion. Nevertheless, a transient post-traumatic contribution to the radiographic changes cannot be excluded, and the subsequent resolution following treatment does not establish their original aetiology.

Conventionally, pulpal complications in such cases are managed with RCT of the coronal fragment. However, maintaining pulp vitality may promote more favorable biological healing at the fracture interface by preserving odontoblastic activity, vascular supply and the local immune defense mechanisms. Additional potential advantages include shorter treatment time, maintenance of proprioception, preservation of tooth structure and long-term mechanical integrity (12). Preservation of functional pulp tissue may have biological relevance to repair; however, its contribution to fracture healing cannot be determined from this case. In this report, preservation of radicular pulp following full coronal pulpotomy was associated with favorable clinical and radiographic outcomes over a three-year follow-up period. Furthermore, the recovery of pulp sensibility observed at the one-year follow-up is consistent with the preservation of functional pulp tissue and suggests a capacity for pulpal healing even in mature teeth. However, these findings do not establish a causal relationship between the procedure and fracture healing or demonstrate superiority over conventional root canal treatment.

Previous studies have reported high success rates of pulpotomy in mature permanent teeth with irreversible pulpitis. However, its application in mature teeth with horizontal root fractures remains scarcely documented. To the best of our knowledge, only one case report has previously described pulpotomy as a treatment option in this specific clinical context, highlighting the novelty and potential clinical relevance of the present approach. The present report adds clinical documentation of a biologically conservative approach to managing pulpal complications in a mature permanent tooth with a horizontal root fracture, using a different operative protocol. Its contribution complements the previously published case without establishing treatment predictability or superiority over conventional root canal treatment.

Conclusion

In this case, the three-year follow-up showed that the patient remained asymptomatic, with no evidence of tooth mobility, pathological probing depths, or periapical alterations. Radiographic findings were consistent with a favorable healing pattern at the fracture site, supporting successful preservation of pulp sensibility and favorable tissue repair. When symptoms are promptly identified and appropriately managed, vital pulp therapy may represent a biologically oriented alternative to conventional RCT in selected cases of horizontal root fracture in mature teeth. Although further studies are required, this minimally invasive approach appears promising and may contribute to refining future treatment recommendations.

This report has inherent limitations, as it describes a single clinical case and therefore cannot establish causal relationships or generalizable clinical recommendations. Nevertheless, the favorable outcomes observed suggest that preserva-

tion of pulp sensibility may promote favorable healing patterns in root fractures. Further clinical studies are needed to clarify the potential role of vital pulp therapy in the management of horizontal root fractures in mature teeth.

Conflict of interest
The authors declare no conflicts of interest.

Funding
The authors received no specific funding for this work.

Ethical statement
This case report was conducted in accordance with the principles of the Declaration of Helsinki.

Patient consent
Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Data Availability Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Image acquisition
All clinical photographs were obtained using a digital camera (Nikon Z5, Nikon Corporation, Tokyo, Japan) equipped with a 105-mm macro lens under standardized photographic conditions (ISO 100, shutter speed 1/125 s, aperture f/32) with bilateral lateral flash illumination (Godox, Shenzhen, China).
Periapical radiographs were obtained using a digital intraoral radiographic system with standardized exposure parameters and paralleling technique. Cone-beam computed tomography (CBCT) imaging was performed using an ORTHOPHOS XG unit (Sirona Dental Systems GmbH, Bensheim, Germany) to evaluate the location of the root fracture and the spatial relationship between the coronal and apical fragments because conventional periapical imaging did not adequately delineate the precise configuration of the root fracture. The acquisition parameters, including field of view, voxel size, tube voltage, tube current, and exposure time, could not be retrieved retrospectively.

Clinical and radiographic images were acquired and included to document the initial traumatic injury, support the diagnosis and treatment planning, illustrate the treatment procedures, and assess clinical and radiographic healing during follow-up.

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SYSTEMATIC REVIEW AND META ANALYSIS

Endodontic Microsurgery or Single-Tooth Implant after Root Canal Failure? A Narrative Review and Clinical Decision Framework

ABSTRACT

Persistent apical periodontitis after root canal treatment requires a cause-directed assessment of whether to retain or replace the tooth. This structured narrative review compares endodontic microsurgery (EMS) with extraction and single-implant replacement and proposes a clinical decision framework. A focused PubMed search covering 1 January 2005 to 30 August 2026, repeated on 13 September 2026, retrieved 15 records. Six publications informed the core synthesis; one broader comparative study was retained as contextual evidence and eight records were excluded. Purposive supplementation produced 58 cited publications overall. Both pathways can achieve favourable outcomes, but survival, radiographic healing and freedom from complications are distinct endpoints. Separate-arm pooled proportions cannot establish treatment superiority or equivalence. EMS outcomes vary with follow-up, periodontal support, structural integrity, defect morphology and root-end management. Implant survival must be distinguished from crown survival and peri-implant health. Economic findings depend on the clinical scenario, time horizon and assumptions about replacement and reintervention. The proposed sequence first establishes whether active treatment is indicated, then assesses restorability, periodontal maintainability, orthograde retreatability, surgical feasibility, patient and site risks, and informed preference. EMS is a reasonable tooth-retention option when the tooth can be durably restored and the cause of failure is surgically manageable. Extraction and implant assessment are appropriate when retention is not predictable or the informed patient chooses replacement. The framework supports shared decision-making but is not a validated prediction tool.

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Introduction

Persistent or recurrent apical periodontitis after root canal treatment is most often sustained by intraradicular infection within anatomically inaccessible areas, but extraradicular infection, foreign-body reactions and cystic pathology may also contribute. Structural failure can compromise prognosis or mimic an endodontic presentation. Contemporary guidance places diagnosis and cause-directed treatment before tooth replacement. Orthograde retreatment is generally considered when disinfection can be improved without disproportionate structural damage; the European Society of Endodontology (ESE) S3 guideline states that apical surgery may be considered when non-surgical treatment or retreatment is impractical. This is a conditional clinical pathway, rather than proof that one intervention is universally more effective (1–3).

When orthograde treatment has failed or is not appropriate, the clinician may retain the tooth by endodontic microsurgery (EMS) or extract it and provide a single-tooth implant. Both are established treatments with different biological consequences. EMS retains the tooth and periodontal ligament and may preserve existing hard- and soft-tissue architecture, although recession, scarring and local bone loss can occur. Implant therapy replaces the tooth with an osseointegrated implant and prosthetic crown. Extraction is irreversible; implant placement may remain possible after failed EMS, but persistent infection, tissue loss and additional procedures can make subsequent rehabilitation more complex. Microsurgery should not be used to postpone extraction when durable tooth retention is not achievable (4–6).

The apparent simplicity of comparing percentages is misleading. Endodontic studies usually define success through both symptoms and radiographic healing, whereas implant studies often report survival of an implant that remains in function despite peri-implant inflammation, prosthetic repair or aesthetic compromise. Moreover, implant cohorts frequently use selective site and patient criteria, while EMS is often offered to previously treated teeth with an established lesion and complex restorative history. Comparisons that ignore these differences risk favouring the treatment assessed with the less demanding endpoint (7–9).

This narrative review aims to: (i) appraise current evidence on the effectiveness, complications and prognosis of EMS and single implants after unsuccessful endodontic treatment; (ii) identify clinically important differences in outcome definition and patient burden; and (iii) translate the evidence into a sequential decision framework. The emphasis is not on declaring a universally superior procedure, but on identifying the circumstances in which retaining or replacing a particular tooth is the more defensible choice. The question begins after root canal treatment and therefore excludes earlier tooth-preserving interventions such as vital pulp therapy in selected mature teeth (10).

Review approach

The preparation and reporting of this structured narrative review were informed by SANRA, a quality-assessment scale for narrative reviews, including justification of the topic, a focused clinical question, a described literature search, appropriate referencing and scientific reasoning (11). The review integrates heterogeneous clinical, biological, restorative, economic and patient-reported evidence. It was not prospectively registered and is not a systematic review; SANRA does not substitute for systematic-review methods or formal assessment of certainty.

A focused PubMed search was repeated on 13 September 2026 using the publication-date interval 1 January 2005 to 30 August 2026. The complete

query, including the date restriction, is reproduced in Table 1. Core eligibility required explicit consideration of apical surgery or EMS and implant replacement as alternative strategies. Systematic reviews, meta-analyses, comparative clinical studies and clinical decision reviews were eligible. Broader studies of non-surgical endodontic treatment and implants were considered contextual evidence because they cannot directly estimate the comparative effectiveness of EMS. Case reports and small case series without a relevant comparison, laboratory studies, implant-pathology reports without alternative-treatment evidence, combined procedures and publications addressing a different clinical question were outside the core scope.

The search retrieved 15 unique PubMed records. Eight were excluded from the core synthesis: three case reports or case series without a relevant comparison, two implant-pathology or site-effect reports, one combined-treatment study, one odontogenic-sinusitis cost model and one review of dynamic oral surgery outside the decision question. A further record, Hannahan and Eleazer (12), concerned non-surgical endodontic treatment and was retained only as contextual evidence. Six core publications remained: three systematic reviews or meta-analyses, two narrative or clinical decision reviews, and one retrospective comparative cohort (4,7–9,13,14). Table 1 provides

Table 1
Core search and disposition of retrieved records

Component	Specification
Design and scope	Structured narrative review informed by SANRA. No systematic-review or exhaustive-search claim.
Source and dates	PubMed; search repeated 13 September 2026. Publication-date interval: 1 January 2005 to 30 August 2026.
Complete core query	("endodontic microsurgery"(Title/Abstract) OR "apical surgery"(Title/Abstract) OR "periradicular surgery"(Title/Abstract) OR apicoectomy(Title/Abstract)) AND ("dental implant"(Title/Abstract) OR implants(Title/Abstract)) AND (outcome*(Title/Abstract) OR success(Title/Abstract) OR survival(Title/Abstract) OR cost*(Title/Abstract) OR "quality of life"(Title/Abstract) OR decision*(Title/Abstract)) AND ("2005/01/01"(Date - Publication) : "2026/08/30"(Date - Publication))
Records retrieved	15 unique PubMed records; uniqueness checked by PMID. A single database does not itself prove absence of duplicate publications.
Core eligibility	Explicit evaluation of EMS/apical surgery and implants as alternatives; clinical comparative studies, systematic reviews/meta-analyses and clinical decision reviews.
Excluded records n = 8	Case reports/series without a relevant comparison: PMIDs 40532150, 39619062, 20545551 (n = 3). Implant pathology/site effects: 36548276, 32452035 (n = 2). Combined treatment: 37279227 (n = 1). Other clinical questions: 34418111, 41598823 (n = 2).
Contextual reclassification n = 1	PMID 18928836, Hannahan and Eleazer: non-surgical endodontic treatment versus implants, not an EMS comparison (12).
Core publications n = 6	PMIDs 25306305, 39979225, 24065635, 28343928, 26778004, 42282368. Three systematic reviews/meta-analyses, two narrative/decision reviews and one retrospective comparative cohort.
Context and synthesis	Six core plus 52 contextual/methodological publications = 58 references. The latter include the reclassified cohort. Supplementation was purposive; overlapping primary studies were not counted as independent replications.
Critical appraisal	Descriptive appraisal of design, directness, outcomes and reporting. No independent duplicate screening, formal risk-of-bias scoring, new meta-analysis or certainty grading.

Abbreviations: EMS, endodontic microsurgery; PMID, PubMed identifier; SANRA, Scale for the Assessment of Narrative Review Articles. Publication-date limits are distinct from the date on which the search was repeated.

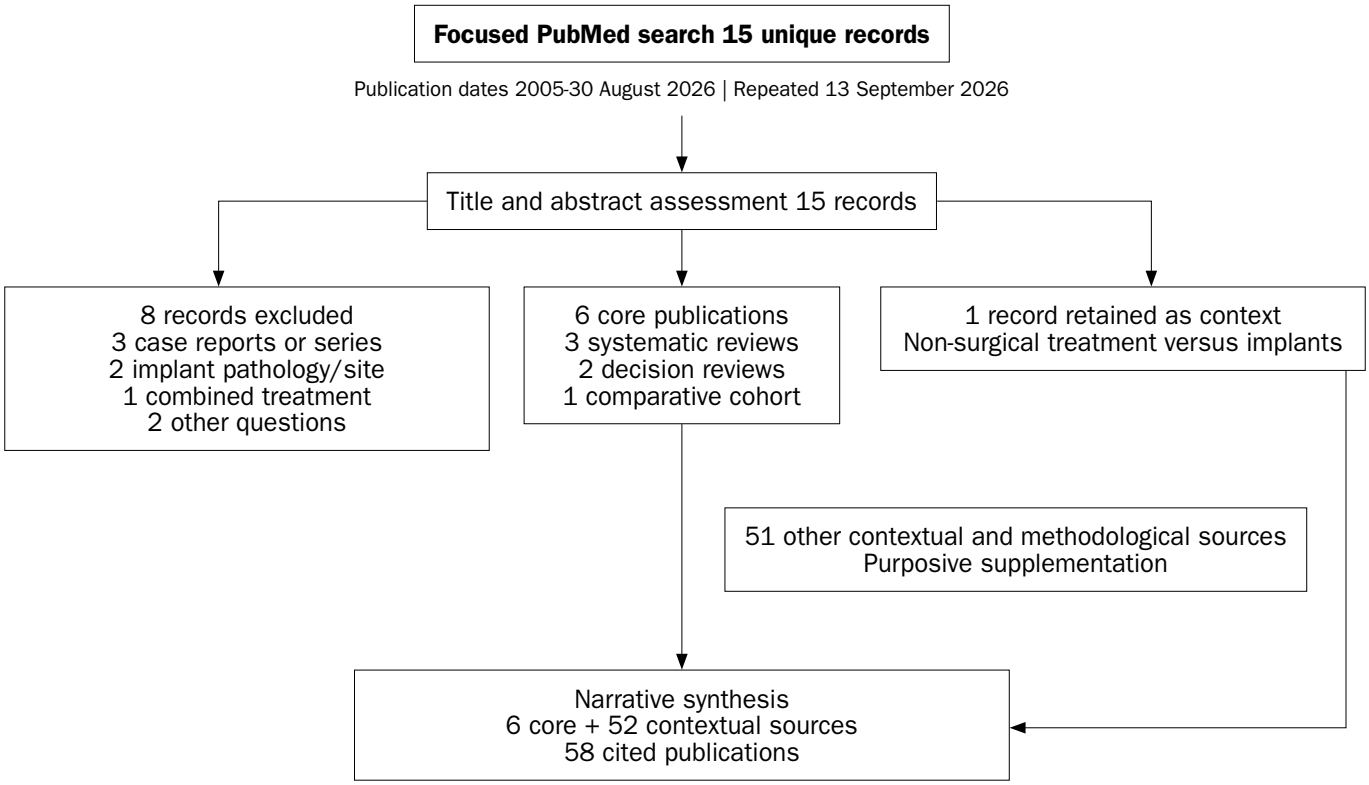


Figure 1
Evidence identification and selection. The figure distinguishes the six core publications from broader contextual and methodological references. The 58 cited publications are not 58 independent primary studies. The diagram describes a structured narrative review and is not a PRISMA flow diagram.

the disposition of the retrieved records with PubMed identifiers; Table 2 summarises the core evidence and Figure 1 shows the selection process.
Targeted topic searches and reference checking supplied contextual evidence on EMS outcomes and prognosis, implant survival and complications, outcome definitions, imaging, patient-reported outcomes and economics. These included randomised comparisons of navigation approaches and clinical evidence addressing restorability and diagnosis in root-filled teeth. In total, the manuscript cites 58 publications: six core publications and 52 contextual or methodological sources, including the broader comparative study identified by the core search. The supplementary selection was purposive rather than exhaustive; these counts describe cited publications, not independent primary studies or a complete census of eligible evidence.
Screening was not performed independently in duplicate, a formal risk-of-bias instrument was not applied, and no de novo meta-analysis or certainty-of-evidence grading was undertaken. Evidence was appraised descriptively for design, directness, follow-up, analysed sample, outcome definitions and reporting limitations. Estimates are attributed to individual studies or published syntheses, with confidence intervals where available. Related reviews may contain overlapping primary studies and should not be interpreted as independent replications. The narrow search terms and single-database core search limit sensitivity, and purposive supplementation does not eliminate selection or interpretation bias.

Clinical sequence before the microsurgery and implant decision

A persistent radiolucency is not, by itself, an indication for extraction or immediate reintervention. Diagnosis should integrate symptoms, time since treatment, serial radiographs, restora-

Publication and design	Scope and directness	Principal finding	Main limitation
Torabinejad et al. 2015 (7) Systematic review PMID 25306305	EMS and single implants in separate evidence sets.	High survival in both; higher implant survival at 4–6 years.	No direct comparison; success definitions incompatible.
Ko et al. 2025 (8) Systematic review and meta-analysis PMID 39979225	22 EMS and six implant studies; separately pooled proportions.	At ≥5 years: EMS 80% (95% CI 71–86%); implants 78% (70–85%).	Implant success reconstructed; no head-to-head estimate or equivalence test.
Chércoles-Ruiz et al. 2017 (13) Systematic review PMID 28343928	Initial treatment, retreatment and apical surgery versus implants.	Both retention and replacement can be valid options.	Broad interventions and heterogeneous comparative studies; indirect for modern EMS.
Setzer and Kim 2014 (9) Narrative review PMID 24065635	Endodontically treated teeth, EMS and implants.	Clarifies survival, success and complications.	Clinical context; no independent comparative estimate.
Torabinejad and White 2016 (4) Clinical decision review PMID 26778004	Options after unsuccessful initial root canal treatment.	Supports assessment of retreatment, surgery and other retention options.	Narrative clinical guidance, not a comparative trial.
Anand et al. 2026 (14) Retrospective cohort PMID 42282368	Microsurgical periapical surgery versus extraction and implants.	Reported success: 89.7% versus 92.3% at 24 months.	Clinical allocation; abstract/table sample discrepancy; limited endpoint definition and unclear blinding.

Abbreviations: CI, confidence interval; EMS, endodontic microsurgery; PMID, PubMed identifier. The reviews are not independent datasets and may contain overlapping primary studies. Hannahan and Eleazer is contextual evidence and is not included in this core table.

Table 2
Core publications and their relevance to the comparison

tion quality, periodontal probing and mobility. An asymptomatic lesion that is reducing, or a stable appearance compatible with scar healing after surgery, may warrant continued review. New symptoms, an enlarging lesion or evidence of structural failure require reassessment. Limited-field cone-beam computed tomography (CBCT) is justified when it can resolve a specific diagnostic or planning question; it should not be used routinely simply to demonstrate complete radiographic repair (2,15–17).

The clinician should investigate missed anatomy, inadequate canal disinfection, coronal leakage, obstruction, extruded material, perforation, resorption and possible root fracture. A cyst or extraradicular biofilm cannot be diagnosed reliably from lesion size or CBCT appearance alone; atypical lesions require specialist assessment and, where indicated, histopathological examination. Orthograde retreatment is often the initial retention option when the canals can be renegotiated and disinfection improved safely. Computational and laboratory studies suggest that irrigation protocols can change apical fluid exchange and cleaning of complex canal anatomy, but these surrogate findings do not establish improved clinical healing after retreatment (18,19). Historical comparisons suggest different early and later outcome patterns after retreatment and surgery, but their heterogeneity and older surgical methods limit application to current EMS (1–3,6). A post, bonded restoration or procedural blockage may favour surgery when coronal dismantling carries substantial fracture or perforation risk. In mandibular first molars, CBCT measurements of thin mesial-root dentine near the furcation further support case-specific assessment of perforation risk during re-instrumentation (20).

EMS is most rational when the tooth is restorable, periodontal support is maintainable, orthograde access is unsafe or unlikely to resolve the cause, and the

apical pathology can be addressed surgically. Extraction should be considered for a root fracture that prevents predictable retention, non-restorable tissue loss or perforation, hopeless periodontal support, or an unacceptable surgical risk after specialist assessment. Active periodontal disease requires treatment and reassessment; it does not automatically favour implantation. In selected multirooted teeth, root resection may preserve the remaining tooth, although this lies outside the principal comparison. Intentional replantation may be considered in selected cases when conventional access is impractical. Replacement options also include fixed or removable prostheses, autotransplantation in suitable patients, orthodontic space management or no replacement (2,4,5).

Modern endodontic microsurgery

Modern EMS differs materially from traditional apical surgery. The operating microscope, microsurgical instruments, ultrasonic root-end preparation and calcium silicate-based root-end filling allow treatment of the apical anatomy with less bevel and less tissue removal. Resection of approximately 3 mm of the root end is commonly used to remove most apical ramifications and lateral canals; inspection of the resected surface under magnification helps identify isthmuses, missed canals and cracks. A preparation centred on the long axis of the canal and an adequate root-end filling are essential for controlling the apical pathway of infection (6).

The shift to microsurgical technique is reflected in pooled outcomes. A meta-analysis of traditional and microsurgical approaches reported weighted success of approximately 59% and 94%, respectively; another synthesis favoured microsurgical techniques with higher magnification (21,22). An updated meta-analysis estimated success at approximately 89% for modern surgery (23). These are study-defined outcomes, commonly combining absence of symptoms with complete or incomplete radiographic healing. They should not be presented as rates of strict complete healing or as controlled estimates of the effect of a microscope alone (24). Case selection, co-interventions and predominantly short- to medium-term follow-up also influence these figures.

Longer follow-up yields more variable estimates. A systematic review reported pooled success of 91.3% in randomised trials and 78.4% in prospective cohorts over 2–13 years, with survival ranging from 79% to 100% (25). The trials compared aspects of EMS, not EMS with implants, and the design-specific pooled values are not directly comparable. Pallarés-Serrano et al. reported lower healing in the 5–9-year than the 1–4-year follow-up cohort, partly associated with vertical root fractures; this should not be described as a within-tooth decline without paired longitudinal data (26). Yoo et al. analysed 309 of 721 EMS-treated teeth and reported 80.5% estimated 10-year survival and 63.4% study-defined success at the final assessment, conducted 10–17.5 years after treatment (27). Eligibility and follow-up selection limit generalisability. Sperou et al. reported 82.8% radiographic healing in 128 teeth at a median of 41.5 months, and 86.6% survival without reintervention in a separate analysis of 186 teeth at a median of 37.5 months (28). Periodontal involvement and shallower root-end fillings were associated with poorer outcomes; these observational associations are not validated individual prediction rules.

Root-end materials and regenerative adjuncts may influence selected cases. Calcium silicate-based materials are supported by clinical studies and a network meta-analysis, but comparative rankings do not establish a universally superior material (29). A randomised trial found no statistically detectable difference in 12-month healing between mineral trioxide aggregate and TotalFill,

or from adding a bone graft to small-to-medium lesions (30). Regenerative procedures may be considered for selected apicomarginal or through-and-through defects; the evidence is heterogeneous, and not all pooled comparisons show a clear benefit (31). Routine grafting of contained defects is therefore not justified by these findings.
CBCT and computer-assisted navigation can assist planning and localisation in anatomically demanding sites. Static guides constrain the planned osteotomy, whereas dynamic systems permit real-time tracking and adjustment. Systematic reviews and prospective clinical evidence support technical feasibility, but accuracy is a surrogate for clinical benefit (32–34). Recent randomised trials have compared static with dynamic navigation for early patient-reported outcomes and operative accuracy (35,36). These studies do not establish superior long-term healing or tooth survival compared with conventional EMS. Device cost, registration error, restricted access, radiation exposure and the learning curve should be weighed against a specific anticipated benefit.

Single tooth implants effectiveness and complications

Single implants can provide predictable replacement of teeth that cannot be retained. In a systematic review, estimated survival of implants supporting single crowns was 97.2% at 5 years (95% confidence interval (CI) 96.3–97.9%) and 95.2% at 10 years (95% CI 91.8–97.2%); the corresponding crown-survival estimates were 96.3% and 89.4% (37). Fixture and prosthesis survival must therefore be reported separately. A selected cohort of 511 implants in partially edentulous patients reported 98.8% implant survival at 10 years, but was not restricted to single-tooth replacement after failed endodontic treatment (38). Similarly, a 20-year series of older titanium plasma-sprayed implants reported 89.5% survival and 75.8–89.5% success depending on the definition (39). This illustrates endpoint dependence rather than providing a contemporary single-crown benchmark. Immediate placement and loading in the aesthetic zone also involve selected patients and sites (40).
Implant survival does not capture the full treatment complex. Biological, prosthetic and aesthetic complications may affect the fixture, surrounding tissues, abutment, screw or crown. A systematic review estimated peri-implantitis prevalence at 19.5% of patients and 12.5% of implants, with substantial variation in case definitions (41). A later synthesis restricted to World Workshop definitions estimated 25.0% at patient level (95% CI 21.1–29.3%) and 18.0% at implant level (95% CI 15.8–20.5%); most included studies had moderate or high risk of bias (42). These cross-sectional prevalence estimates concern heterogeneous implant populations, not the prospective risk for a newly placed single implant, and should not be compared directly with an EMS failure rate. Periodontal history, plaque control and supportive care are relevant to risk assessment, while the evidence for individual modifiers varies. Longitudinal diagnosis of peri-implant disease requires baseline probing and radiographic information (43).
The comparison with EMS should include the implant crown and surrounding tissues rather than osseointegration alone. A functioning implant may remain a survivor after prosthetic repair or treatment of peri-implant disease. Likewise, a retained tooth can require further treatment despite survival. Stable incomplete healing compatible with a surgical scar may be classified as success under established endodontic criteria, whereas strict complete-healing endpoints exclude it. Table 3 distinguishes these outcomes and summarises representative evidence.

Why direct comparison remains difficult

Endodontic healing is commonly clas-

Endpoint	Definition	Representative evidence	Interpretation
Complete healing after EMS	No clinical disease and complete radiographic repair.	Complete, incomplete, uncertain and unsatisfactory categories (15,16).	Do not equate complete healing with all study-defined success.
Study-defined EMS success	Often includes complete or stable incomplete healing without symptoms.	Published modern pooled estimates approximately 89–94% (21–23).	Different imaging, definitions and follow-up; not a direct implant comparison.
Tooth survival after EMS	Tooth remains present; specify whether reintervention is allowed.	80.5% estimated survival at 10 years in the Yoo cohort (27).	Separate from 63.4% success at the final 10–17.5-year assessment.
Survival without reintervention	Tooth retained without further treatment during observation.	86.6% of 186 teeth, median follow-up 37.5 months (28).	Different denominator from the study's radiographic-healing analysis.
Implant-fixture survival	Implant remains in situ; biological/prosthetic complications may coexist.	Single-crown implants: 97.2% at 5 years and 95.2% at 10 years (37).	Does not demonstrate survival of the original crown or healthy peri-implant tissues.
Implant-crown survival	Original implant-supported crown remains in service.	96.3% at 5 years and 89.4% at 10 years (37).	Report crown replacement separately from fixture loss.
Comprehensive success and patient outcomes	Biological health, prosthetic integrity, symptoms, function, aesthetics and patient experience.	Criteria remain heterogeneous across pathways (44–47).	Use explicit domains and common observation periods; distinguish prevalence from incidence.

Abbreviations: CI, confidence interval; EMS, endodontic microsurgery. These rows illustrate endpoint differences; they are not a head-to-head comparative analysis. Study-defined success must not automatically be relabelled as complete radiographic healing.

Table 3
Outcome definitions and representative evidence.

sified on periapical radiographs as complete, incomplete, uncertain or unsatisfactory (15,16). Clinical signs and symptoms must be considered alongside imaging. Complete and incomplete healing are often grouped as success; uncertain or unsatisfactory healing should be reported separately, with follow-up appropriate to the clinical course. CBCT can reveal residual defects not visible on two-dimensional imaging, reducing the proportion judged completely healed without necessarily demonstrating clinically important persistent disease. Implant success criteria have also evolved to include biological, prosthetic, soft-tissue, aesthetic and patient-reported domains (44,45). Even when both arms report 'success', the underlying events and surveillance may differ. Randomisation between preservation and extraction can be ethically and practically challenging because it requires clinical equipoise and informed patient acceptance; it is not intrinsically impossible. Most relevant evidence nevertheless comes from separate or non-randomised cohorts. Treatment selection is influenced by restorability, periodontal status, lesion severity, patient preference and clinician expertise, creating confounding by indication. Implant and EMS studies may both select favourable patients. Differences in eligibility, missing follow-up and outcome assessment can therefore bias either pathway. Starting observation at implant loading also omits extraction, augmentation and pre-loading failures unless the complete pathway is explicitly followed.

The 2015 systematic review found higher implant survival at 4–6 years, but no direct treatment comparisons and incompatible success definitions (7). Ko et al. pooled 22 EMS and six single-implant studies without a direct comparison (8). At at least 5 years, EMS success was 80% (95% CI 71–86%) and

reconstructed implant success was 78% (95% CI 70–85%). The overall EMS estimate of 89% largely reflected shorter follow-up. These separate-arm estimates neither prove superiority nor establish equivalence. Hannahan and Eleazer compared implants with non-surgically treated teeth and provide indirect evidence only (12). Anand et al. reported 89.7% versus 92.3% success at 24 months (14). However, its abstract reports 166 patients while its tables contain 78 per group, the implant endpoint lacks a comprehensive prosthetic and peri-implant definition, and the claimed assessor blinding is inadequately explained. These reporting limitations, clinical allocation and imprecision substantially limit inference; a non-significant difference is not evidence of equivalence.

Broader systematic reviews of endodontically treated teeth and implant-supported prostheses report mixed survival findings and frequent additional interventions in implant pathways, with generally favourable patient satisfaction after both treatments (46,47). Their applicability to EMS is indirect because they include non-surgical treatment, retreatment and different restorative situations. Repeated inclusion of the same primary cohorts in several reviews also limits the apparent breadth of independent evidence. Overall, the literature does not establish a universally superior pathway, and raw survival percentages are insufficient for individual treatment planning.

Prognostic determinants and case selection

Restorability is the first treatment-selection gate. Assessment should include remaining supracrestal dentine, ferrule potential, crack pattern, root form, the anticipated crown-to-root relationship after resection, and the biological cost of crown lengthening or extrusion. Evidence supports the contribution of ferrule and residual dentine to restoration performance, but combines clinical, laboratory and finite-element studies and does not establish a universal threshold for extraction (48). A sound coronal seal and a maintainable definitive restoration are essential. EMS cannot compensate for an unrestorable coronal defect.

Periodontal support is equally important. Attachment loss, apicomarginal defects and lesion morphology are associated with EMS outcome, although findings are not uniform across studies (31,49,50). Defect size alone should not determine extraction. Mobility, deep isolated probing and a halo-like radiolucency warrant investigation for root fracture but are not individually diagnostic. Evidence from clinically assessed root-filled teeth indicates imperfect CBCT sensitivity and specificity; artefacts from filling materials or posts can complicate interpretation, and direct inspection may be required (51).

Anatomical and technical feasibility should be assessed on limited-field CBCT where the result is likely to alter management. Relevant features include cortical thickness, root inclination, lesion size and extension, maxillary sinus involvement, proximity to the inferior alveolar or mental nerve, access to palatal roots and the amount of root remaining after resection. Mandibular molars and palatal roots are not absolute contraindications, but the risk–benefit ratio and operator expertise differ. Guided access may convert a difficult site into a manageable one, although it cannot correct poor restorability or periodontal prognosis.

Patient-level factors modify both pathways. Diabetes control, smoking, immune status, antiresorptive or antiangiogenic medication, previous head-and-neck radiotherapy, bleeding risk, blood-pressure responses to local anaesthesia (52), capacity for plaque control and adherence to maintenance should be reviewed (2,5,17). Their implications are treatment-specific: factors affecting implant healing do not necessarily carry the same magnitude of risk for EMS, while surgical risks may affect

Domain	Features supporting retention or EMS	Features requiring reassessment or replacement planning
Restorability (5,48)	Maintainable coronal seal, residual dentine and achievable restoration.	Non-restorable tissue loss or fracture; excessive biological cost of reconstruction.
Periodontal support (31,49,50)	Disease can be controlled and attachment can be maintained.	Hopeless support or advanced furcation destruction. Active disease requires control before implant assessment.
Cause and access (2,4,6)	Surgically manageable apical cause when orthograde correction is impractical.	Persistent cause cannot be addressed safely. Consider alternative retention options and referral.
Anatomy (6,17)	Safe access and sufficient root structure after resection.	Unacceptable anatomical risk or inadequate residual support; lesion size alone is not decisive.
Implant site (5,40)	Retention may avoid augmentation or a difficult aesthetic reconstruction.	Assess prosthetic position, tissue volumes and augmentation; a suitable site does not itself justify extraction.
Patient and care (2,17,53,54)	Informed preference for retention; acceptable burden and maintenance.	Discuss medical risk, prior experiences, affordability and alternative preferences. Both pathways need continuing care.
Operator and access (17,32–34)	Appropriate training, magnification and root-end management.	Seek specialist input before declaring EMS infeasible; technology does not correct a poor biological prognosis.

Abbreviations: EMS, endodontic microsurgery. This is a qualitative framework, not a validated score. No single row establishes an absolute indication for extraction or an implant.

Table 4
Prognostic considerations for treatment selection.

both. These factors require individual assessment rather than blanket exclusion rules and may warrant liaison with the treating physician. Active oral disease should be stabilised before elective surgery or implant rehabilitation where feasible.

Implant-site assessment includes bone and soft-tissue volume, prosthetically appropriate three-dimensional positioning, smile line, neighbouring roots and the need for augmentation (5,40). A high implant-survival probability does not ensure an acceptable aesthetic result, particularly in a thin phenotype or high smile line. Conversely, severe structural compromise may favour extraction when retention would require disproportionate treatment. Operator competence matters for both pathways. Referral should be considered before a tooth is declared unsuitable for EMS, and access to technology cannot overcome poor restorability or periodontal prognosis (17). Key determinants are synthesised in Table 4.

Patient experience and economic value

Patients value pain control, function, appearance, treatment time, cost, predictability and the possibility of retaining their own tooth. Studies comparing non-surgical endodontic treatment or retreatment with implants generally report favourable satisfaction, but are indirect evidence for EMS (53,54). The five-year study was cross-sectional at recall and therefore cannot by itself demonstrate a longitudinal change in quality of life or an EMS-specific benefit (54). Consent should address both expected outcomes and uncertainty, including symptoms, further procedures and maintenance, rather than describing an implant as permanent or microsurgery as an inevitable final attempt.

Treatment burden differs. EMS often retains the tooth in function and may involve one surgical episode followed by healing review and restorative care. It can nevertheless cause pain, swell-

Dimension	Endodontic microsurgery	Extraction and single-implant replacement
Biological effect	Retains the tooth and periodontal ligament; local tissue change remains possible.	Removes the tooth and periodontal ligament; replaces function with implant and crown.
Pathway	Surgical assessment and EMS, followed by healing review and restorative care.	Extraction, possible augmentation, implant placement/healing and prosthetic restoration.
Burden and complications	Pain, swelling, recession/scarring and site-related surgical risks; recurrent disease or structural failure.	Surgical and aesthetic risks, implant loss, peri-implant disease and prosthetic repair or replacement.
Time	May be shorter when the existing restoration is maintainable.	Variable; immediate protocols are selective and augmentation may extend the pathway.
If treatment fails	Reassess cause and structure; further retention or extraction may be appropriate. Later implantation is not guaranteed.	Assess infection and tissue loss; further surgery, a replacement implant or another prosthesis may be needed.
Maintenance	Long-term periodontal/restorative care and review of healing.	Long-term peri-implant and prosthetic care, including baseline and serial records.
Economics	Some models favour EMS; the result depends on tooth/site, fees and subsequent care.	Some scenarios favour implant replacement; assess full pathway costs and uncertainty.

Abbreviations: EMS, endodontic microsurgery. Treatment duration and costs depend on the individual case and healthcare setting; both pathways require long-term maintenance.

Table 5
Patient-relevant comparison of complete treatment pathways.

ing, recession, scarring, sinus-related complications or sensory disturbance, depending on the site; persistent disease, fracture or other structural failure may require reintervention (6,17). Implant rehabilitation may involve extraction, augmentation, placement, healing, provisionalisation and a definitive crown. Immediate protocols shorten selected pathways but are not suitable for every site (40). Both teeth and implants require continuing maintenance. Failed EMS may leave an implant option, but the feasibility, tissue requirements, time and cost must be reassessed.

Economic evidence is scenario-dependent. A US decision model for a failed first molar ranked EMS as the most cost-effective option (55). In contrast, a UK lifetime model for a maxillary incisor favoured implant replacement over surgical retreatment after orthograde retreatment had failed (56). A Swedish one-year cohort found extraction more cost-effective than initial root canal treatment when subsequent replacement was uncommon; it did not compare EMS with a complete implant pathway (57). These findings cannot support a universal economic advantage for either strategy. Current fees, reimbursement, perspective, restoration and augmentation needs, time horizon, maintenance and subsequent interventions must be specified, and older models may not represent contemporary techniques. Methodological appraisal of dental economic studies reinforces the need to examine assumptions and uncertainty (58). Table 5 summarises the practical comparison without presenting context-dependent cost estimates as general treatment effects.

A sequential clinical decision framework

The proposed framework (Figure 2) starts by confirming diagnosis and whether active intervention is indicated, then applies six treatment-selection steps. A stable or improving asymptomatic finding can enter a moni-

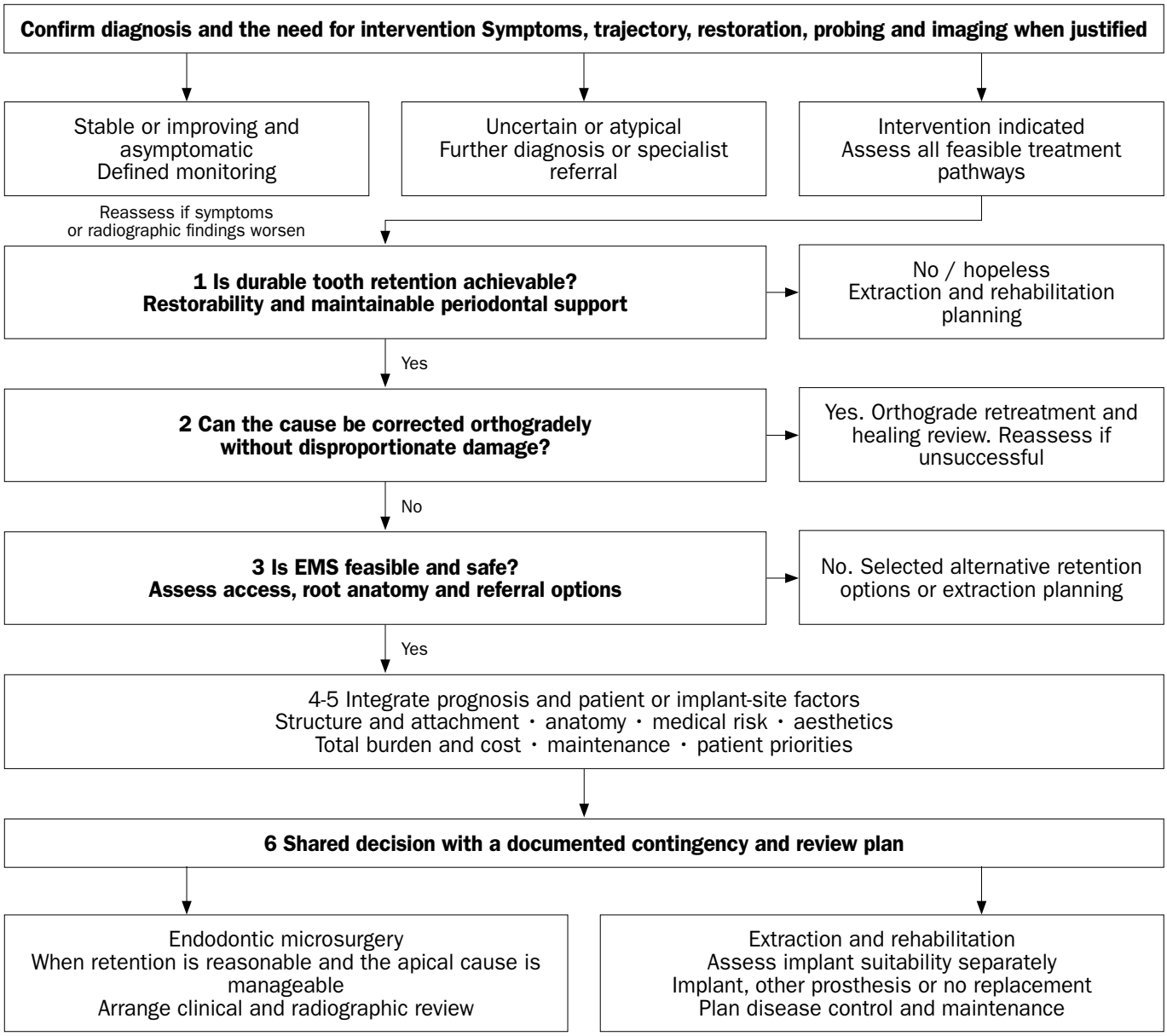


Figure 2
Therapeutic decision framework after unsuccessful root canal treatment. Diagnosis and the need for intervention precede treatment selection. Patient preferences, medical risks and maintenance requirements apply throughout. Persistent or worsening disease after retention treatment prompts renewed diagnosis and planning. EMS, endodontic microsurgery; CBCT, cone-beam computed tomography. This framework has not been externally validated.

toring pathway with defined review and escalation criteria. Acute symptoms and atypical findings require appropriate assessment before elective treatment selection. The framework is a cognitive aid, not a validated prediction model or a compulsory treatment sequence.

Step 1—restorability and periodontal maintainability. Establish whether a durable restoration and maintainable periodontal support can be achieved,

including after disease control. Non-restorable tissue loss, a root fracture incompatible with retention or hopeless attachment loss favours extraction. Diagnostic uncertainty or potentially reversible periodontal disease warrants assessment and reassessment before an irreversible decision.

Step 2—cause and orthograde accessibility. Consider orthograde retreatment when a missed canal, inadequate disinfection, coronal leakage or removable obstruction can be corrected without disproportionate damage. Assess subsequent healing before escalating treatment. When access is unsafe or unlikely to resolve the cause, consider surgical assessment; an apparently adequate filling alone does not prove an extraradicular source.

Step 3—technical feasibility of EMS. Evaluate surgical access, root length after resection, adjacent anatomy and the ability to identify, prepare and seal the relevant root-end anatomy. Consider navigation or referral when they address a defined limitation. If safe, meaningful surgery cannot be achieved, discuss selected alternatives such as intentional replantation or extraction and rehabilitation.

Step 4—tooth- and site-specific prognosis. Integrate mobility, attachment, defect morphology, root structure and restorative quality. A large lesion or unfavourable crown-to-root relationship is a prognostic consideration rather than an isolated validated contraindication. Multiple adverse factors should reduce confidence in retention and be explained to the patient.

Step 5—patient and implant-site modifiers. Assess medical and periodontal risks, plaque control, bone and soft-tissue anatomy, aesthetics, previous treatment experience, time, total cost and capacity for maintenance. The same critical assessment should be applied to retention and replacement; uncontrolled periodontal disease is not an argument for immediate implantation.

Step 6—shared decision and contingency planning. Present realistic outcomes, uncertainties, complications and subsequent options. For a restorable tooth with maintainable support and surgically manageable apical disease, EMS is a reasonable option to discuss before extraction. Implant replacement may be selected when retention is unpredictable or the informed patient chooses it after balanced counselling and assessment of implant suitability. Document why orthograde retreatment was or was not selected and arrange review. Extraction does not commit the patient to an implant: other prosthetic options or no replacement may be appropriate. Table 6 summarises the sequence.

Controversies and research priorities

Several scenarios remain contentious. A tooth with a cast post and apical lesion may be an excellent EMS candidate because surgery avoids destructive post removal, but only if the crown and root remain restorable. A deep mandibular molar apex may become accessible through static or dynamic navigation, although technology cannot eliminate neurovascular risk. Suspected vertical root fracture demands diagnostic restraint: unnecessary extraction should be avoided, but repeated surgery on a fractured root is equally inappropriate. Future comparative studies should enrol patients for whom both pathways are clinically feasible and define a common starting point at treatment allocation. Prospective registries can capture treatment selection, baseline restorability, periodontal status and patient preference, although adjustment cannot remove all residual confounding. Outcomes should distinguish radiographic healing, tooth or fixture survival, crown survival, survival without reintervention, complications, patient-reported outcomes and total costs. Long-term follow-up, ideally extending to 10 years or more, should report the number at risk, losses and reasons for censoring, with analyses accounting for multiple

teeth or implants within patients. Navigation studies should assess clinical benefit, radiation exposure, learning curves and cost alongside accuracy. The proposed framework requires external evaluation of feasibility, reproducibility and patient understanding before any claim of clinical validation.

Strengths and limitations

This review integrates evidence across treatment outcomes, prognosis, patient experience and economics while making endpoint asymmetry explicit. The PubMed core search and record disposition are reproducible as documented, but the narrow search has limited sensitivity and supplementary selection was purposive. Screening and study weighting were not independently duplicated; risk of bias and certainty were not formally graded, and no new pooled estimate was calculated. Several reviews contain overlapping primary studies. Few studies directly compare EMS with implant replacement in patients eligible for both, and the recent comparative cohort has material reporting limitations. Older implant surfaces, historical surgical techniques, specialist settings and selective follow-up restrict applicability. The decision framework is evidence-informed and unvalidated; it supports specialist assessment and shared decision-making rather than estimating an individual probability of success.

Conclusion

Modern EMS and single-tooth implant replacement can both achieve favourable outcomes. The available literature does not establish general superiority or equivalence because populations, outcome definitions and follow-up differ. A cause-directed sequence is clinically reasonable: establish whether intervention is required, assess restorability and periodontal maintainability, consider orthograde retreatment when feasible, and discuss EMS when the tooth has a defensible retention prognosis and the cause is surgically manageable. This sequence is a clinical synthesis consistent with tooth-preservation principles, rather than a treatment hierarchy proven by direct comparative trials.
Extraction and rehabilitation are appropriate when predictable retention cannot be achieved or an informed patient chooses replacement. Implant suitability, other replacement options and the option of no replacement require separate consideration. Decisions should reflect the complete treatment pathway, including biological and prosthetic complications, reintervention, time, cost, maintenance and patient priorities.

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Francesco Maggiore
Presidente della Società Italiana di Endodonzia

Lettera DEL PRESIDENTE

Cari Soci e Amici,

al termine del 41° Congresso Nazionale SIE di Verona e del mio mandato biennale, desidero rivolgervi un sentito ringraziamento per la fiducia, il sostegno e la vicinanza che avete dimostrato in questi due anni.

Il biennio 2025-2026 è stato un periodo di intenso lavoro e di importanti risultati: abbiamo consolidato la stabilità societaria, rilanciato con forza le attività culturali e formative, ampliato la nostra presenza sul territorio nazionale e rafforzato il confronto con l'Università. Sono particolarmente orgoglioso del successo del Corso Certificato "Ready to Work", della crescita della nostra rivista, il Giornale Italiano di Endodonzia, e della rinnovata collaborazione con ANDI. Il Congresso di Verona, con il suo programma scientifico di alto livello, ha rappresentato la sintesi migliore di questo percorso.

Il 2027 sarà caratterizzato dal Congresso ESE, che si terrà a Roma dall'8 all'11 settembre e sarà ospitato congiuntamente da SIE e AIE. La presenza del Congresso ESE in Italia comporta d'altro canto la mancata organizzazione del Congresso Nazionale SIE 2027. Gli eventi SIE 2027 saranno pertanto due appuntamenti gemelli e complementari, Expo Endo e Focus Endo, entrambi accomunati dalla stessa anima e da percorsi fortemente hands-on, pensati per far provare ai professionisti i protocolli clinici più innovativi.

Guardando al futuro, posso affermare che questo biennio ha creato le basi per una Società rinnovata, aperta e vicina ai bisogni dei propri Soci. Il lavoro svolto è stato intenso, ma i risultati ottenuti ci danno la giusta carica per affrontare le prossime sfide. Queste non sono poche, ma la nostra Società Scientifica ha le energie, le competenze e la coe-

sione necessarie per affrontarle, trasformandole in opportunità e restando fedele al proprio ruolo di guida scientifica e punto di riferimento per tutti gli endodontisti italiani.

È stato un privilegio guidare la SIE in un periodo così intenso e ricco di soddisfazioni, e se abbiamo raggiunto questi risultati è merito della passione, della competenza e dello spirito di collaborazione che contraddistinguono la nostra comunità. La SIE continuerà a credere nella formazione, nella divulgazione, nel dialogo con Università, Libera Professione e Aziende, con l'obiettivo di guidare i propri soci attraverso le nuove, entusiasmanti frontiere, con la competenza e lo spirito critico che ci hanno sempre contraddistinto. Ci riusciremo, come sempre, lavorando insieme.

Grazie di cuore a tutti voi e arrivederci ai prossimi eventi del 2027.

Con affetto e stima,
Il Presidente
Dott. Francesco Maggiore



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COME DIVENTARE SOCIO ATTIVO/AGGREGATO

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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.
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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

ITALIAN SOCIETY OF ENDODONTICS · 2027–2028

Endodontics, hands-on

Two events built around clinical practice and two courses that take you step by step from your first cases to advanced work: the SIE training programme for 2027 and 2028.



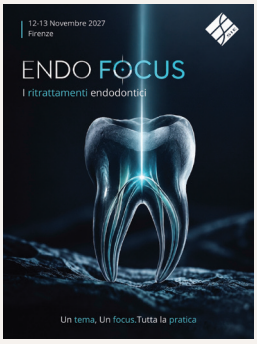
Expo Endo

Where endodontics meets practice

On Friday, 17 hands-on clinical tables with 12 seats each, to try instruments and materials first-hand. On Saturday, "SIE invites AIC": endodontics and restorative dentistry together.

5–6 February 2027

Rome
Holiday Inn Parco dei Medici



Endo Focus

Non-surgical retreatment: one topic, one focus

Friday is entirely hands-on, with 15 clinical tables on retreatment techniques and instruments. On Saturday, a multidisciplinary plenary on when and how a tooth can be saved.

12–13 November 2027

Florence
Radisson



Ready to Work

The path to becoming an SIE-certified consultant

5 residential meetings and 13 webinars, with more than half of the time hands-on. Certification by an external body and a place in a national network of certified consultants.

From April 2027

5 meetings
Friday and Saturday



Level Up

Ready to Advance: the next step after Ready to Work

4 meetings of a day and a half, two speakers each: theory, clinical case discussion and hands-on sessions at every meeting.

September 2027 – January 2028

Sesto San Giovanni (Milan)
Mikros

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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.

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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.

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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).

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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.

Manuscript Format

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.

Authors should pay special attention to the **presentation** of their research findings or clinical reports so that they may be communicated clearly.
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Structure
All manuscripts submitted to Giornale Italiano di Endodonzia should include Title Page, Abstract, Main Text, References, Clinical Relevance, Conflict of Interest, Acknowledgements, Tables, Figures and Figure Legends as appropriate.
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III. Name and address of department, hospital or institution to which the work should be attributed;
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Abstracts should be no more than 250 words giving details of what was done.

Abstract for Original Scientific Articles should be no more than 250 words giving details of what was done using the following structure.
Aim: give a clear statement of the main aim of the study and the main hypothesis tested, if any.
Methodology: describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.
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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Results: Give the total number of included studies and participants and summarise relevant characteristics of studies. Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).
Conclusion: Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision) and a general interpretation of the results and important implications.

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

Abstract for Mini Review Articles should be non-structured of no more than 250 words, including a clear research question, details of the literature search strategy and clear conclusions.

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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.

Abstract for Clinical Articles should be no more than 250 words using the following structure.
Aim: give a clear statement of the main aim of the report and the clinical problem which is addressed.
Methodology: describe the methods adopted.
Results: give the main results of the study.
Conclusions: state the primary conclusions of the study.

THE STRUCTURE

Main text for Original Scientific Articles should include Introduction, Materials and Methods, Results, Discussion and Conclusion.
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Results should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.
Discussion may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.
Conclusions should contain a summary of the findings.

Main Text of Systematic Review Articles
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In the case of systematic reviews, whether with or without meta-analyses, strict adherence to the PRISMA guidelines (http://www.prisma-statement.org/) is mandatory. Additionally, authors must submit a PRISMA checklist (http://www.prisma-statement.org/PRISMAStatement/Checklist.aspx) and flowchart (http://www.prisma-statement.org/PRISMAStatement/FlowDiagram) along with the manuscript.

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.

Main Text of Mini Review Articles
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.

IMPORTANT TO KNOW

Manuscript that do not conform to the general aims and scope of the Journal will be returned immediately without review. All other manuscripts will be reviewed by experts in the field (generally two referees). Giornale Italiano di Endodonzia aims to forward referees´ comments and to inform the corresponding author of the result of the review process. Manuscripts will be considered for fast-track publication under special circumstances after consultation with the Editor. Giornale Italiano di Endodonzia uses **double blinded review** which menas that the names of the reviewers will thus not be disclosed to the author submitting a paper and the name(s) of the author(s) will not be disclosed to the reviewers. To allow double blinded review, please submit your main manuscript and title page as separate files.
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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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Once the review process is completed (*i.e.* all the assigned Reviewers have provided their comments and recommendations on the paper), the authors will be notified via email by the editors of the editorial decision: **Accepted, Rejected, Decline Submission, Minor revisions, Major revisions.**
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If the editor's decision is to resubmit for review (=Major revisions or Minor revisons), the revised paper may undergo a "second round" of peer-review.
Once a paper is accepted for publication, the authors will be notified via email and their paper is moved to the "Copyediting phase", where it is improved by the work of a copyeditor. Authors can be given the opportunity to review the copyedits.
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