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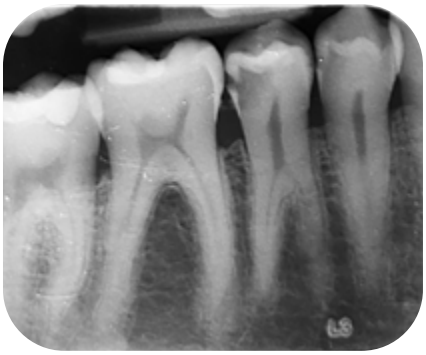

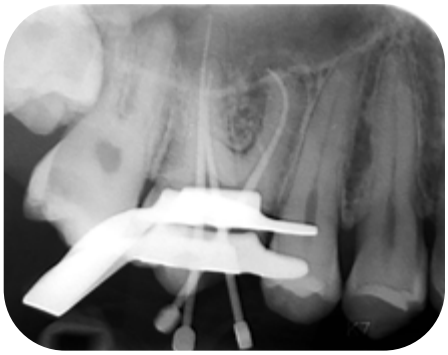

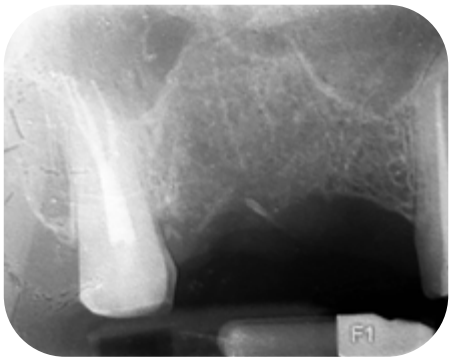

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*Investigating the Efficacy of the Metal Artifact Reduction Algorithm in Cone-Beam Computed Tomography Images for Endodontic and Restorative Materials*

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REGISTRATION Court of Milan n° 89, 3 March 2009

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# Editorial

## Nanoparticles: a promising tool in endodontics

**Sandro Rengo**
**Editor-in-Chief**
**Giornale Italiano di Endodonzia**
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*Effective disinfection of root canal system depends on different variables such as anatomy, proper shaping technique, correct penetration of irrigants and complete removal of pulp tissue and micro-organisms. The chance to obtain a correct canal disinfection strictly contributes to achieve clinical success and still remains a mayor challenging in the modern endodontics. Among different proposed strategies, use of nanoparticles has gained even more interest during the years in terms of root canal detersion. Nanoparticles are characterized by ultrasmall sizes, large surface area/mass ratio and increased chemical reactivity. Moreover, due to antibacterial features their role is promising in the removal of biofilm and microorganisms from the endodontic canal system. Different kind of nanoparticles can be incorporated within irrigant solutions, gels or even sealers to obtain and further maintain canals disinfection. The potential application of zinc oxide nanoparticles and their efficacy against bacteria are presented in the present issue of Giornale Italiano di Endodonzia, evaluating the possible enhancement of classic irrigation obtained by sodium hypochlorite. Further studies are warranted to support the use of nanoparticles in the prevention and treatment of dental infections and to establish the proper delivery systems.*

Peer review under responsibility of Società Italiana di Endodonzia.

10.32067/GIE.2025.39.02.01

ORIGINAL ARTICLE

# Zinc oxide nanoparticles and blue light enhance sodium hypochlorite disinfection against Enterococcus faecalis: an in vitro study


## ABSTRACT

**Aim:** *This study aimed to evaluate the antimicrobial efficacy of zinc oxide nanoparticles (ZnO NPs) and blue light, both individually and in combination, against* Enterococcus faecalis (E. faecalis) in vitro. *Their performance was compared to 1% sodium hypochlorite (NaOCl) to determine whether these adjuncts could enhance root canal disinfection.*

**Methodology:** *A laboratory investigation was conducted using eight experimental groups:* E. faecalis *with phosphate-buffered saline (control), 1% NaOCl, ZnO NPs, blue light, 1% NaOCl/ZnO NPs, 1% NaOCl/blue light, ZnO NPs/blue light, and 1% NaOCl/ZnO NPs/blue light. Standardized* E. faecalis *inocula were exposed to each treatment under controlled conditions. Bacterial cells were then recovered, serially diluted, and plated on agar to determine colony-forming units (CFU). Reductions in CFU, compared to the control, were analyzed using Mann-Whitney tests. Statistical significance was set at* $p<0.05$.

**Results:** *Most experimental groups exhibited significantly lower bacterial counts than the control (*$p=0.000$*), except for the blue light–only group, which was not statistically different. Among the single-agent treatments that reached significance, 1% NaOCl produced the greatest bacterial reduction, followed by ZnO NPs. When combined, dual treatments reduced bacterial counts more than single agents. The triple combination achieved the highest reduction overall.*

**Conclusions:** *This study highlights the potential of ZnO NPs and blue light as adjuncts to 1% NaOCl for more effective elimination of* E. faecalis *in planktonic cultures. The enhanced antimicrobial activity observed with combined treatments suggests that incorporating nanoparticles and photodisinfection could reduce the need for higher NaOCl concentrations while maintaining robust antibacterial efficacy.*



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**KEYWORDS** *Blue light, Enterococcus faecalis, Nanoparticles, Root canal, Sodium hypochlorite.*



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## Introduction

Effective root canal disinfection is critical for the success of endodontic treatments, particularly in eradicating Enterococcus faecalis (*E. faecalis*), a resilient pathogen associated with persistent infections. Sodium hypochlorite (NaOCl) has long been considered the gold standard irrigant due to its robust antimicrobial activity and ability to dissolve organic tissues, making it the most popular choice in endodontic therapy (1). Due to its cytotoxicity and potential to irritate periapical tissues, clinicians often opt for concentrations of NaOCl lower than the maximum 5.25%. However, the optimal concentration that balances efficacy and safety has yet to be determined, highlighting the need for alternative or adjunctive irrigation solutions that mitigate these side effects (2). Although highly effective, NaOCl presents several challenges, including reduced efficacy with prolonged exposure due to protein interaction, unpleasant odor and taste, and risks of severe tissue damage upon extravasation into periapical areas (3).

Recent advancements in nanotechnology and photodynamic therapy have opened new possibilities for enhancing root canal disinfection. Zinc oxide nanoparticles (ZnO NPs) exhibit potent antimicrobial activity, attributed to their size-dependent effects, disruption of bacterial membranes, and induction of reactive oxygen species (4,5). Meanwhile, blue light within the 400–500 nm spectrum is widely employed in dentistry for caries management, resin curing, and biofilm reduction, offering a safer alternative to ultraviolet radiation (6-8). Beyond its standalone antibacterial properties, blue light can augment nanoparticle-induced reactive oxygen species production, thereby amplifying bacterial elimination (9-11).

Despite these advancements, there is limited evidence on the combined application of ZnO NPs and blue light as adjuncts to NaOCl in root canal disinfection. To address this gap, this study evaluates the antimicrobial efficacy of ZnO nanoparticles and blue light, both individually and in combination, against Enterococcus faecalis, and benchmarks their performance against sodium hypochlorite to propose enhanced disinfection protocols for clinical endodontics.

## Materials and Methods

Ethical approval was obtained from the institutional ethics committee of Oman Dental College (Ref: ERIC-GS-2023-216), confirming that no human or animal subjects were involved. The study was conducted in accordance with the Declaration of Helsinki, ensuring adherence to recognized ethical standards. This laboratory investigation assessed the antibacterial properties of ZnO NPs and blue light under controlled experimental conditions. These were tested both individually and in combination against *E. faecalis*. Additionally, their efficacy was benchmarked against 1% NaOCl to determine any significant differences in bacterial reduction.

The study included eight experimental groups, detailed as follows:

- Group 1: Control (*E. faecalis* with phosphate-buffered saline (PBS))
- Group 2: *E. faecalis* with 1% NaOCl
- Group 3: *E. faecalis* with ZnO NPs
- Group 4: *E. faecalis* with blue light
- Group 5: *E. faecalis* with 1% NaOCl and ZnO NPs
- Group 6: *E. faecalis* with 1% NaOCl and blue light
- Group 7: *E. faecalis* with ZnO NPs and blue light
- Group 8: *E. faecalis* with 1% NaOCl, ZnO NPs, and blue light

*Cultivation and Inoculation of E. faecalis*

Strains of *E. faecalis* NCTC 12697 / ATCC® 29212 (TCS Biosciences, Buckingham, UK) were cultivated using broth overnight. Cultures were maintained on agar plates supplemented with 5% defibrinated horse blood (TCS Biosciences, Buckingham, UK) and sub-cultured weekly. For experimental purposes, single colonies were transferred to tryptone soy broth (Fisher Scien-

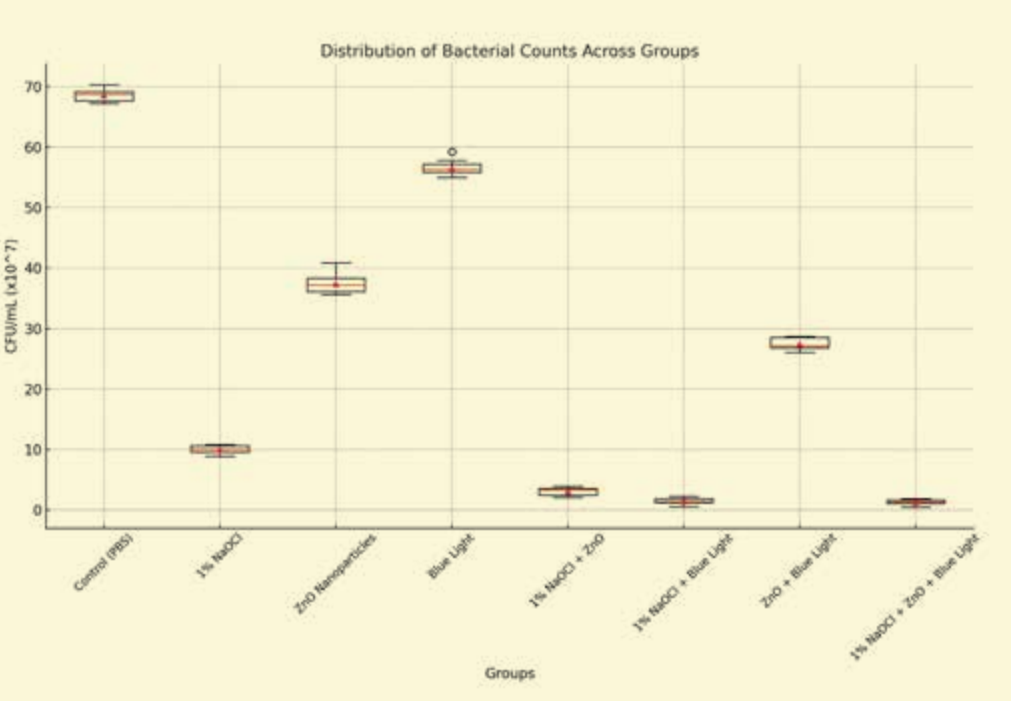


**Figure 1.**
Bacterial counts - Box plot showing the distribution of bacterial counts (CFU/mL) across experimental groups. The central line in each box represents the median, while the box bounds depict the interquartile range (IQR). Whiskers extend to the minimum and maximum non-outlier values, and individual data points indicate outliers. The mean is marked as a diamond in each group.

tific, Loughborough, UK) and incubated overnight at 37°C. Cell concentrations were standardized using McFarland turbidity standards and adjusted to an optical density (OD) of 0.2 using a diluphotometer.

*Preparation and Application of Experimental Solutions*

Sodium hypochlorite (5%, Fisher Scientific, Loughborough, UK) was diluted to 1%. A fresh working solution was prepared for each experiment. Each test involved mixing 1 mL of bacterial solution with 1 mL of 1% NaOCl for 10 seconds. The mixture was incubated for five minutes in a 6-well tissue culture plate before serial dilution and plating on blood agar.

Zinc oxide nanoparticles (particle size: <100 nm; Sigma-Aldrich, Poole, UK) were dispersed in water. A 1 mL dispersion of ZnO NPs was added to 1 mL of bacterial solution. The mixture was vortexed for 10 seconds and treated similarly to the NaOCl group.

Bacterial solutions were exposed to blue light emitted by a Bivar UV5TZ-405-30 LED (wavelength: 390-407 nm; irradiance: 120 mW/cm²; Digikey Electronics, Slough, UK) for 300 seconds. The light source was positioned at a fixed distance of 50 mm from the solutions. Serial dilutions were prepared immediately after exposure.

*Serial Dilution and Colony Counting*

Serial dilutions were performed to achieve countable colony numbers (30-300 colonies). Agar plates were prepared using trypticase soy agar (Oxoid Ltd., Cheshire, UK) and Iso-Sensitest agar (Oxoid Ltd., Cheshire, UK). Plates were incubated at 37°C for 24 hours. Bacterial colonies were manually counted using a Stuart® colony counter, with adjustments made based on the dilution factor to calculate colony-forming units (CFU) per milliliter.

*Data Analysis*

Bacterial counts were tabulated, and error bar graphs were generated to illustrate group comparisons. Statistical analyses were conducted using R (Version 4.4.0, R Core Team, R Foundation for Statistical Computing, Vienna, Austria). Mann-Whitney tests were employed to compare the control and experimental groups.

## Results

The intensity of blue light at a distance of 50 mm was measured using a spectropho-

**Table 1.**

**Summary of bacterial colony-forming units (CFU/mL), reductions compared to control, and statistical significance for each experimental group.**

| Group | Treatment | Mean CFU/mL ($x10^7$) (SD) | Median CFU/mL ($x10^7$) | Reduction vs Control ($x10^7$) | P-value* |
|---|---|---|---|---|---|
| 1 | Control (PBS) | 68.0 (1.5) | 68.0 | 0 | - |
| 2 | 1% NaOCl | 10.4 (0.8) | 11.0 | 57.6 | 0.000 |
| 3 | ZnO NPs | 38.2 (1.8) | 40.0 | 30.0 | 0.000 |
| 4 | Blue Light | 56.7 (1.4) | 58.0 | 12.0 | NS |
| 5 | 1% NaOCl+ZnO NPs | 3.4 (0.7) | 2.0 | 64.6 | 0.000 |
| 6 | 1% NaOCl+Blue Light | 1.6 (0.6) | 1.0 | 66.4 | 0.000 |
| 7 | ZnO NPs+Blue Light | 27.4 (1.2) | 28.0 | 41.0 | 0.000 |
| 8 | 1% NaOCl+ZnO NPs+BL | 1.1 (0.5) | 0.0 | 66.9 | 0.000 |

**Mann-Whitney U-tests indicates that median is significantly different to median of the control (group 1) (p=0.000). BL: blue light; CFU: colony-forming units; NaOCl: sodium hypochlorite; PBS: phosphate-buffered saline; ZnO NPs: zinc oxide nanoparticles; NS: not significant.*

tometer. The measured irradiance values were as follows: visible light, 3.17688 mW/cm²; total UV, 1.41556 mW/cm²; blue light, 1.14664 mW/cm²; and total output, 4.59244 mW/cm². The antibacterial efficacy of the experimental groups is summarized in Table 1, which presents the mean and median CFU/mL, reductions compared to the control group, and associated p-values for each treatment group.

The bacterial reductions across groups were statistically analyzed using Mann-Whitney U-tests, comparing each experimental group to the control. All experimental groups exhibited significantly lower bacterial counts than the control ($p$=0.000), with the combination treatments demonstrating the highest efficacy.

Group 8, combining 1% NaOCl, ZnO NPs, and blue light, achieved the greatest bacterial reduction. Among single-agent treatments, 1% NaOCl was the most effective, followed by ZnO NPs and blue light, respectively. Dual and triple combinations significantly enhanced bacterial reduction.

## Discussion

This study investigated the antimicrobial efficacy of ZnO NPs and blue light photodisininfection, both individually and in combination, against *E. faecalis* in planktonic cultures. The findings confirmed that 1% NaOCl alone is highly effective, consistent with its longstanding status as the gold standard in root canal irrigation (12,13). However, bacterial reduction was further enhanced when ZnO NPs and blue light were applied, either independently or along with NaOCl. These results highlight that while NaOCl remains indispensable, complementary methods can improve its antimicrobial activity and possibly minimize some of its drawbacks (14).

NaOCl's established role in endodontic disinfection arises from its robust antimicrobial properties and ability to dissolve organic tissue. Yet, it also presents significant limitations, such as restricted penetration into dentinal tubules and cytotoxic effects, which justify the need for adjuncts (12,14). Because no single agent has replaced NaOCl, current research focuses on identifying therapies that augment NaOCl and lower concentration-dependent side effects (9-11,15,16). The synergistic bacterial reduction noted in this study, particularly when NaOCl was combined with ZnO NPs or blue light, supports the wider trend in endodontics

to incorporate nanotechnology and photodynamic therapy.

Evidence shows that nanoparticles can enhance antimicrobial efficacy by disrupting bacterial membranes and generating reactive oxygen species (16-18). ZnO NPs, in particular, have low toxicity, favorable cost-effectiveness, and size-dependent antimicrobial properties against a diverse range of bacteria (4). Djearamane et al. (2022) reported that ZnO NPs inhibit *E. faecalis* by disrupting cell membranes and distorting bacterial cell structures (5). Other studies have shown that incorporating ZnO NPs into dental materials reduces bacterial adhesion and biofilm formation (19,20). The current findings, which demonstrated reduced bacterial counts following treatment with ZnO NPs, support prior reports that ZnO NP solutions can prevent *E. faecalis* adhesion and help disaggregate biofilm structures (21,22).

Our findings support previous evidence that blue light is effective against *E. faecalis*, reinforcing its potential for endodontic disinfection when combined with ZnO nanoparticles (6,8). Other studies have also demonstrated that blue light can inhibit a broader range of pathogens, including *Staphylococcus aureus* and *Prevotella intermedia* (23,24). This effect arises from the excitation of microbial chromophores, such as flavins and porphyrins, leading to reactive oxygen species generation (25). Microorganisms do not develop resistance to blue light, making it a sustainable antimicrobial approach (26). Given its documented safety profile (27), blue light is a promising tool for root canal disinfection. The improved bacterial reduction noted in this study reflects its synergistic potential with other antimicrobials, as also reported previously in the literature (9-11, 28-30).

Recent investigations into light-activated nanoparticles affirm the synergistic effects observed in this study. Minhaco et al. (2023) found that curcumin-loaded polymeric nanoparticles activated by blue light significantly reduced bacterial viability in biofilm models (31). Afkhami et al. (2021) similarly reported that silver nanoparticles activated through passive ultrasonic irrigation and photon-induced photoacoustic streaming achieved over 90% bacterial reduction (32). These advances support the concept that combining nanoparticles with light-based activation methods can address limitations associated with conventional irrigation.

*E. faecalis* was selected due to its clinical importance in persistent endodontic infections and its ability to penetrate deeply into dentinal tubules (33). Its capacity for biofilm formation further complicates disinfection, which underscores the need to test novel antimicrobial strategies. Although using planktonic cultures facilitated a clear assessment of direct antimicrobial activity, this model does not fully capture the complexity of root canal biofilms (34). Future research should therefore employ biofilm and *ex vivo* models to better approximate clinical environments, particularly given that the dense extracellular matrix in biofilms can reduce antimicrobial penetration.

Clinically, integrating ZnO NPs and blue light into root canal disinfection protocols can enhance the penetration and effectiveness of antimicrobial agents in complex canal anatomies. This combination may be especially valuable in retreatment cases or infections involving resistant organisms such as *E. faecalis*. Lowering reliance on higher concentrations of NaOCl also offers a potential reduction in cytotoxicity to periapical tissues, which can increase patient safety and comfort. The broader shift in dentistry toward minimally invasive, targeted therapies aligns well with the development of light-activated antimicrobial protocols, which aim to optimize bacterial reduction while maintaining biocompatibility. Despite these promising results, a few limitations of this study must be acknowledged. Planktonic models do not replicate the protective matrix of biofilms or the variability of clinical conditions, including organic debris and irregular canal anatomy. Long-term biocompatibility and cytotoxicity data on ZnO NPs and blue light are also essential. Further research should evaluate these therapies using biofilm and ex vivo models and establish their safety profiles before wide-

spread clinical adoption. Additional studies on alternative photosensitizers and activation methods may further enhance the efficacy of this approach. By addressing these gaps, future investigations will provide deeper insights into the clinical potential of combining nanoparticles and photodisinfection for improved endodontic outcomes.

## Conclusion

This work highlights the potential of combining ZnO nanoparticles and blue light as a promising adjunct to sodium hypochlorite for root canal disinfection. The findings demonstrate that this combination enhances bacterial reduction and addresses some of the limitations of conventional irrigation methods. ZnO NPs offer effective antimicrobial and antibiofilm properties, while blue light adds a safe and widely available activation method. Together, they provide a synergistic approach that could improve the success rates of endodontic treatments, particularly in challenging cases involving resistant bacteria like *E. faecalis*. However, the translation of these results into clinical practice requires further validation in biofilm models, ex vivo systems, and safety studies. By bridging these gaps, this innovative approach has the potential to redefine modern endodontic therapy, aligning with the broader trend of minimally invasive and targeted dental treatments.

## Clinical relevance

Combining zinc oxide nanoparticles, blue light, and sodium hypochlorite significantly improved the elimination of Enterococcus faecalis in a laboratory model of root canal disinfection. This synergy may allow lower concentrations of irrigants, potentially reducing tissue toxicity and improving patient safety in endodontic therapy.

## Disclosures


- Acknowledgements: The authors thank Prof Paul Dummer for his guidance and support.
- Ethical Approval: The study was approved by the Ethics, Research, and Innovation Committee ERIC (Ref: ERIC-GS-2023-216).
- Authorship Contributions: Concept – G.S.; Design – G.S; Materials – G.S.; Data collection and/or processing – G.S., A.Q.; Data analysis and interpretation – G.S, A.Q.; Literature search – A.Q.; Writing – G.S., A.Q.; Critical review – G.S, A.Q.


## Conflict of Interest

All authors declared no conflict of interest.

## Financial Disclosure

Nothing to disclose.

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ORIGINAL ARTICLE

# Postoperative Pain Following Endodontic Treatment in Patients With Type 2 Diabetes Mellitus: A Prospective Non-Randomized Clinical Trial


## ABSTRACT

***Aim:*** *Diabetic patients may exhibit altered responses to nerve stimulation due to diabetes-related neurological damage. This prospective, non-randomized, parallel, blinded clinical trial evaluated postoperative pain following endodontic treatment by comparing two groups of patients—with and without type 2 diabetes mellitus (T2DM).*
***Methodology:*** *Eighty adult patients were included: 40 with T2DM and 40 without T2DM. At baseline, glycated hemoglobin (HbA1c) levels were recorded. Endodontic treatment was performed, and root canals were irrigated with 2.5% sodium hypochlorite solution. Postoperative pain was assessed by a blinded researcher at 6, 12, 24, and 72 hours using a Numerical Rating Scale (NRS, 0–10).*
***Results:*** *Within the first 6 hours, 19 patients in the T2DM group and 24 in the control group reported pain (p = 0.429). After 12 hours, 11 T2DM patients and 19 control patients experienced pain (p = 0.165). At 24 hours, 9 patients with T2DM and 11 in the control group reported pain (p = 0.930). After 72 hours, 5 patients from each group reported pain (p = 0.186). No significant differences in pain intensity were observed between the groups at 6 hours (p = 0.139), 12 hours (p = 0.169), 24 hours (p = 0.387), or 72 hours (p = 0.687). However, regression analysis revealed that patients with T2DM had lower odds of experiencing postoperative pain (OR = 0.19; 95% CI = 0.04–0.77), regardless of sex, age, preoperative pain, tooth type, treatment modality, or sealer extrusion.*
***Conclusions:*** *Although no statistically significant differences in pain intensity were observed between groups, patients with T2DM exhibited lower odds of reporting postoperative pain. These exploratory findings may indicate a trend toward reduced postoperative discomfort in this population, warranting further investigation through larger randomized trials.*



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## Introduction

Diabetes mellitus (DM) is a multifaceted metabolic disorder currently affecting over 537 million individuals worldwide, with projections indicating an increase to 783 million by 2045 (1). Type 2 DM (T2DM) is the most prevalent form, primarily associated with impaired insulin secretion from pancreatic beta cells or insulin resistance (2).

Diabetic patients may exhibit altered responses to nerve stimulation due to diabetes-induced neurological damage. The pathophysiological mechanisms affecting metabolic and intracellular signaling pathways remain underexplored(3-5).

Moreover, DM induces metabolic alterations in the dental pulp, compromising its vascular and sensory structures(6). As such, T2DM is considered a critical factor influencing pulpal and periapical pathology in terms of susceptibility, progression, healing, and even prevalence. It is thus regarded as a potential modulating factor in endodontic disease(7) .

Postoperative discomfort is observed in up to 60% of cases following endodontic procedures and is a major contributor to behavioral changes that negatively affect emotional well-being and daily functioning, including occupational tasks, household activities, sleep, eating habits, and verbal communication (8).

Factors associated with post-endodontic pain include age, sex, molar involvement, and the mandibular arch; however, the relationship between systemic health and postoperative discomfort has been rarely investigated in the literature (9). Studies indicate that pain intensity typically peaks within the first 24 hours after treatment and significantly subsides over the following three days (10, 11).

Given the high prevalence of postoperative pain, often reflecting an ongoing inflammatory process, identifying its underlying causes and predictive factors is essential for enabling clinicians to implement effective strategies to reduce its incidence and improve patient comfort. Therefore, the objective of this clinical trial was to evaluate and compare the incidence of postoperative endodontic pain in individuals with and without type 2 diabetes mellitus. The primary research hypothesis was that individuals with type 2 diabetes mellitus would exhibit a significantly different incidence and intensity of postoperative endodontic pain compared to non-diabetic individuals, possibly due to diabetes-associated neurological and inflammatory alterations.

## Materials and Methods

*Study design and population*

This prospective, non-randomized, parallel, blinded clinical trial was conducted at the Dental School Clinic of the Federal University of Amazonas, Manaus, Brazil, between November 2018 and November 2022. The study included patients requiring endodontic treatment. Ethical approval was obtained from the Research Ethics Committee of the Federal University of Amazonas (CAAE No. 97436918.0.0000.5020), and the trial was registered in the Brazilian Registry of Clinical Trials (REBEC) (UTN: U1111-1228-6794). The study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines(12) and complied with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

*Sample size calculation*

Sample size calculation indicated that a total of 80 patients (40 in each group) were required to detect a 30% difference between groups, assuming a significance level of $\alpha = 0.05$ and a power of 80%. The expected prevalence of postoperative pain was set at 60%, based on a previous clinical trial conducted at the same institution (10).

The study included adult men and women aged 18 years or older, with or without type 2 diabetes mellitus (T2DM), who required endodontic treatment for vital or necrotic permanent teeth without periapical lesions, excluding third molars (Table 1). Patients were excluded if they had periodontal disease, were pregnant, had hypersensitivity to or were using anti-inflammatory or antibiotic medications during treatment, were

**Table 1.**
**Clinical and demographic data of patients recruited (baseline).**

| Variable | Without diabetes (n= 40) | With diabetes (n=40) | p-value |
|---|---|---|---|
| Mean age | 32.7±12.63 | 54.53±10.68 | *<0.001 |
| Glycated hemoglobin | 5.07±0.61 | 7.98±2.46 | *<0.001 |
| **Gender** | | | |
| Women | 23 (57.5%) | 24 (60.0%) | 0.820 |
| Men | 17 (42.5%) | 16 (40.0%) | |
| **Arterial hypertension** | | | |
| Yes | 2 (5.0%) | 20 (50.0%) | ***<0.001 |
| No | 38 (95.0%) | 20 (50.0%) | |
| **Extrusion of filling material** | | | |
| Yes | 4 (10.0%) | 15 (37.5%) | ***0.041 |
| No | 36 (90.0%) | 25 (62.5%) | |
| **Maxillary teeth** | | | **0,002 |
| Molar | 13 (32.5%) | 12 (30.0%) | |
| Premolar | 2 (5.0%) | 2 (5.0%) | |
| Anterior | 2 (5.0%) | 5 (12.5%) | |
| **Mandibular teeth** | | | *<0,001 |
| Molar | 18 (45.0%) | 3 (7.5%) | |
| Premolar | - | - | |
| Anterior | 5 (12.5%) | 18 (45.0%) | |
| Preoperative pain (NRS) 3.95±3.82 | 3.37±3.61 | | *0.044 |
| **Pulp diagnosis** | | | |
| Vital | 27 (67.5%) | 12 (30 %) | **0.001 |
| Non-vital | 13 (32.5%) | 28 (70 %) | |

*p<0.05, Mann-Whitney test **p<0.05, Chi-square test ***p<0.05, Fisher's exact test

immunocompromised, or had teeth with periapical pathology or endodontic complications, such as canal calcifications, internal or external resorption, incomplete root formation, perforations, longitudinal or vertical root fractures, or cases that could not be completed in a single session. These exclusion criteria were implemented to eliminate confounding factors that could influence pain perception or interfere with the analysis of postoperative pain scores.
Patients using anti-inflammatory drugs were only included after a minimum wash-out period of 7 days. In case of postoperative pain, they were instructed to contact the research team, who would provide a standardized prescription if necessary. All medication use during the follow-up period was recorded.

*Group allocation procedure*
To determine the metabolic control status of the patients, glycated hemoglobin (HbA1c) levels were recorded prior to treatment. Patients were divided into two groups according to the criteria established by the American Association of Clinical Endocrinologists (AACE)(13). The experimental group consisted of individuals with a medical history of type 2 diabetes mellitus and an HbA1c level ≥ 6.5%, while the control group included participants with an HbA1c level < 6.5% (13).
A total of 130 patients were recruited. Of

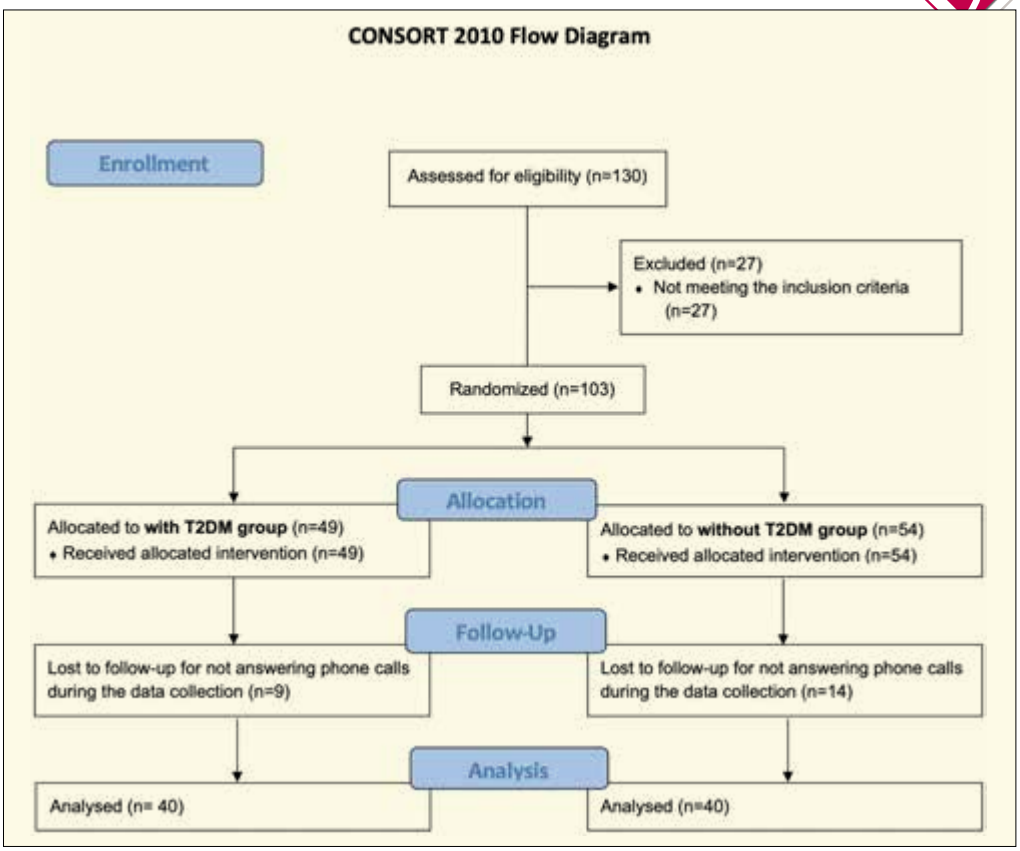


**Figure 1**
Flow diagram for clinical trials

these, 13 were excluded due to the presence of systemic disorders other than arterial hypertension, 10 were excluded because their teeth did not require endodontic treatment, and 4 were excluded due to endodontic complications. During the clinical trial, an additional 23 patients were excluded for failing to respond to telephone calls during outcome data collection (Figure 1).

*Treatment protocol*

The protocol was carried out in three phases. During the first phase, baseline and diagnostic data were collected, including glycated hemoglobin (HbA1c) levels to determine group allocation and preoperative pain assessment using the Numerical Rating Scale (NRS), ranging from 0 (no pain) to 10 (worst imaginable pain). Diabetic patients were instructed to adhere to their prescribed medications to maintain stable blood glucose levels. Eligible participants provided written informed consent. In the second phase, endodontic treatment was performed. All procedures were carried out in the morning. The third phase involved analysis of the outcome-related data. The endodontic protocol was standardized across both groups and performed by a certified endodontic specialist. Anesthesia was administered using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine (Alphacaine; DFL Indústria e Comércio Ltda., Rio de Janeiro, Brazil) via inferior alveolar nerve block for mandibular teeth or terminal infiltration for maxillary teeth. Following rubber dam isolation, access to the pulp chamber was performed, and the apical working length was determined using an electronic apex locator (Romiapex A-15; Romidan Ltd., Kiryat Ono, Israel) set to 0.0 mm from the apical foramen, with confirmation by periapical radiography. Root canal preparation was carried out using the WaveOne GOLD® system (Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer's instructions.

For single-rooted teeth, instrumentation was performed up to size 45.05 (Large file); for bi-rooted teeth, up to size 35.06 (Medium file). In multi-rooted teeth (e.g., molars), instrumentation varied according to canal complexity and curvature: mesial canals were generally prepared to size 25.07 (Primary file), and distal canals to size 35.06. Files were introduced into the canals with short reciprocating strokes (3–4 mm) until

complete preparation of the cervical, middle, and apical thirds was achieved.
Apical patency was confirmed using a #10 K-file at the established working length. All instrumentation was performed with the XSmart Plus® motor (Dentsply Maillefer, Ballaigues, Switzerland) in reciprocating motion.
Throughout instrumentation, the canals were irrigated with 20 mL of 2.5% sodium hypochlorite solution (Asfer; São Caetano do Sul, São Paulo, Brazil), ensuring continuous presence of the irrigant within the canals. Irrigation was delivered using a Max-i-Probe 30-G needle (Dentsply Maillefer, Ballaigues, Switzerland) positioned 3 mm short of the working length, as measured with a silicone stop.
Prior to obturation, the canals were irrigated with 2 mL of 17% EDTA (Fórmula e Ação; São Paulo, Brazil), followed by 2.5% sodium hypochlorite. Final irrigation was enhanced using passive ultrasonic irrigation (PUI) for 1 minute with an E2 Irrisonic® ultrasonic tip (Helse, Brazil) attached to an ultrasonic unit (Altsonic Ceramic II; ALT Equipamentos, Ribeirão Preto, São Paulo, Brazil).
The canals were dried using absorbent paper points corresponding to the final instrument size used in apical preparation (WaveOne GOLD® system). For obturation, gutta-percha cones from the same system were coated with AH Plus sealer (Dentsply Maillefer, Ballaigues, Switzerland) and placed 5 mm short of the apical foramen. Thermoplasticized obturation was then performed using a McSpadden compactor (Dentsply Maillefer, Ballaigues, Switzerland), positioned 5 mm short of the working length.
The teeth were restored with glass-ionomer restorative cement, and a final radiograph was obtained. At the end of the procedure, patients were instructed on how postoperative pain would be monitored through follow-up telephone calls. They were also provided with printed instructions and a copy of the Numerical Rating Scale for reference.

*Pain assessment*
Postoperative pain was assessed via telephone calls at 6, 12, 24, and 72 hours after endodontic treatment by an evaluator blinded to group allocation. Pain intensity was measured using the Numerical Rating Scale (NRS), ranging from 0 (no pain) to 10 (worst imaginable pain). While a specific Minimal Clinically Important Difference (MCID) for the NRS was not pre-defined for this exploratory study, a reduction of 2 points or a 30% decrease from baseline is generally considered clinically meaningful in pain research(14).
Patients were allowed to contact the researcher at any time if they had questions or concerns. No rescue medication was required for the management of severe pain.
Statistical analysis
The frequency of patients reporting postoperative pain was analyzed using the Chi-square test and Fisher's exact test. Comparisons of pain scores between the two groups at each time point were performed using the Mann–Whitney U non-parametric test. Multiple logistic regression analysis was used to examine the association between covariates and the occurrence of postoperative pain, estimating odds ratios (OR) and 95% confidence intervals (95% CI). Variables with $p<0.20$ in the bivariate analyses were included in the multiple model. The final multiple model was estimated using backward selection process, retaining the variables with $p<0.20$. All statistical analyses were conducted using Stata® SE, version 17 (StataCorp LLC, Texas, USA), with the significance level set at 0.05.

## Results

Of the 130 patients initially considered eligible for the study, 27 were excluded for not meeting the inclusion criteria, and an additional 23 were excluded for not responding to the NRS questionnaire during follow-up (9 in the diabetes group and 14 in the non-diabetic group), as shown in Figure 1. These participants were lost to follow-up despite multiple contact attempts and were not included in the final analysis. No imputation methods were applied; thus, the results are based on complete case analysis. A total of 80 patients were included in the study, with 40 in each group.
In the diabetes group, the prevalence of postoperative pain was reported by 19 pa-

**Table 2.**

**Descriptive analysis of postoperative pain in both groups at the four-time intervals assessed, mean ± SD (median, IQR).**

| NRS | 6h | 12h | 24h | 72h |
|---|---|---|---|---|
| Without diabetes | 2.25±2.27 (1, 4.5) | 1.43±2.14 (0, 2.5) | 1.00±2.15 (0, 1) | 0.30±0.91 (0, 0) |
| With diabetes | 1.65±2.23 (0, 3) | 0.85±1.55 (0, 2) | 0.58±1.36 (0, 0) | 0.18±0.59 (0, 0) |
| | p =0.139 | p =0.169 | p = 0.387 | p = 0.687 |

**p<0.05, Mann-Whitney test.*

**Table 3.**

**Measures of association between the independent variables and the occurrence of postoperative pain. Logistic regression for estimation of OR (95% CI).**

| Variable | Crude OR | Model 1 | Model 2 |
|---|---|---|---|
| Diabetes (ref.: no) | 0.29 (0.11-0.79)* | 0.05 (0.01-0.56)* | 0.19 (0.04-0.77)* |
| Gender (ref.: women) | 0.51 (0.19-1.32)[a] | 0.31 (0.09-1.09)b | 0.31 (0.10-0.99)* |
| Age | 0.99 (0.96-1.02) | 1.04 (0.98-1.10) | - |
| Extrusion of filling material (ref.: no) | 1.19 (0.42-3.40) | 2.39 (0.54-10.54)[a] | - |
| Glycated hemoglobin | 0.94 (0.77-1.14) | 1.39 (1.01-1.95)* | 1.26 (0.94-1.70)[a] |
| Preoperative pain (NRS) | 1.37 (1.14-1.65)** | 1.38 (1.11-1.72)** | 1.39 (1.14-1.69)** |
| Treatment (ref.: necro) | 1.99 (0.79-5.05)[a] | 1.11 (0.29-4.29) | - |
| Hypertension (ref.: no) | 0.99 (0.36-2.76) | 1.04 (0.21-5.04) | - |

*a p<0.20; b p<0.10; * p<0.05; ** p<0.01*
*Model 1: initial multiple model including all variables*
*Model 2: final multiple model estimated using backward selection process, retaining variables with p<0.20*

tients (47.5%) within the first 6 hours, 11 patients (27.5%) at 12 hours, 9 patients (22.5%) at 24 hours, and 5 patients (12.5%) at 72 hours.

In the non-diabetic group, postoperative pain was reported by 24 patients (60%) within 6 hours, 19 patients (47.5%) at 12 hours, 11 patients (27.5%) at 24 hours, and 5 patients (12.5%) at 72 hours.

Postoperative pain intensity, measured using the Numerical Rating Scale (NRS), is presented in Table 2. No statistically significant differences were observed in pain intensity between the groups at any of the assessed time intervals.

The effects of the independent variables—sex, age, extrusion of filling material, glycated hemoglobin level, preoperative pain, and pulp diagnosis—on postoperative pain were evaluated using multiple logistic regression analysis. The odds of experiencing postoperative pain were significantly lower in patients with diabetes mellitus (OR = 0.19; 95% CI: 0.04–0.77), regardless of the other covariates included in the model. Variables with p<0.20 in the bivariate analyses were included in the multiple model. The final multiple model was estimated using backward selection process, retaining the variables with p<0.20. (Table 3).

## Discussion

Previous endodontic clinical studies have focused on evaluating treatment success through apical healing(15, 16), which is a

recognized complication among diabetic patients (17, 18). The presence of postoperative symptoms in this population, particularly pain, also warrants attention, as it affects more than half of patients(10, 11) and remains a concern for clinicians(8).

In the control group, nearly half of the patients reported postoperative pain within the first 6 hours after treatment. Similar results were reported in studies with comparable designs conducted in the same geographic region(10, 11). In the experimental group, fewer diabetic patients reported pain at 6 hours, which may be related to altered nerve response in individuals with DM(4). This outcome differs from that of Ali et al. (19), who attributed increased postoperative pain during the first 12 hours to diabetes-related nerve damage, which can either exacerbate pain or cause an absence of symptoms. The age disparity between groups in the present study aligns with findings by Cho et al. (20), who analyzed global diabetes prevalence. Their study found that most individuals with type 2 diabetes were older, with the highest prevalence in the 60–79 age group in high-income countries and 55–64 years in low-income countries. Age was included as a covariate in the multiple logistic regression model to account for its potential confounding effect. The association between T2DM and reduced postoperative pain remained significant after adjustment, suggesting that age did not substantially influence this relationship.

Given the well-established association between type 2 diabetes mellitus and hypertension(21), hypertension was not considered an exclusion criterion. The frequent coexistence of these conditions is due to shared pathophysiological mechanisms, particularly those involving obesity and insulin resistance(22). Epidemiological data highlight a high prevalence of hypertension among patients with type 2 diabetes, as well as increased risks of resistant hypertension and cardiovascular complications. According to the Framingham Heart Study, type 2 diabetes is associated with a two- to fourfold increased risk of hypertension, peripheral arterial disease, and myocardial infarction(23).

Regression analysis in this study indicated that systemic arterial hypertension did not influence patients' pain experience, although previous studies(24, 25)have shown that patients using angiotensin-converting enzyme (ACE) inhibitors may exhibit an increased pain threshold.

In our study, most participants in both groups were women, despite global data showing a higher prevalence of diabetes among men, with approximately 231.7 million male cases reported(20). A possible explanation is that women tend to seek healthcare services more frequently than men. According to the 2019 Brazilian National Health Survey(26), women reported accessing medical care more often than men. In a prospective clinical trial, Ali et al.(19) evaluated 270 patients and found a positive correlation between preoperative and postoperative endodontic pain—patients who experienced pain before treatment were more likely to report pain afterward. This was also observed in the present study.

Diabetes mellitus has a direct impact on the structural integrity of dental pulp, causing histological changes in vascular and neural components. In diabetic patients, peripheral nerve glycosylation results in neurotoxicity, further aggravated by endoneurial microangiopathy. Increased intracellular glucose promotes mitochondrial oxidant release, reducing membrane potential and impairing energy production, which diminishes nerve conduction. Clinically, this manifests as reduced sensitivity to stimuli in the dental pulp and peripheral tissues(27), potentially explaining the lower average pain scores among diabetic patients observed in this study.

In cases of poorly controlled or long-standing diabetes, pulpal blood flow is significantly reduced due to vascular basement membrane thickening and diminished collateral circulation. Elevated levels of inflammatory mediators, such as kallikrein-nitrite, along with a reduced leukotactic response, contribute to pulpal inflammation and irreversible damage, including necrosis. These vascular changes also decrease oxygen saturation, creating an anaerobic environment conducive to bacterial proliferation(28). In an in vitro study, Alsamahi et al.(6) found morphological differences in pulp tissue

from diabetic patients, including reduced cell density, fewer blood vessels, thicker vascular walls, increased calcification, and enhanced collagen deposition.

All dental groups were included in the study due to the difficulty in pairing patients by tooth type. Diabetic patients were found to have fewer teeth than controls, consistent with previous studies reporting that poorly controlled diabetes is associated with significant tooth loss due to increased caries and aggressive periodontal disease(29).

In the non-diabetic group, most treated teeth were molars, whereas in the diabetic group, the majority were incisors or canines. This discrepancy may explain the higher incidence of material extrusion in the diabetic group (37.5%) compared to the non-diabetic group (10.0%), likely due to the larger apical diameters of anterior teeth(30). The lack of statistically significant differences in postoperative pain between diabetic and non-diabetic patients undergoing single-session endodontic treatment was also reported by Anagha et al. (31). The results of this study should be interpreted considering its methodological limitations. Despite adjusting for potential confounding factors, challenges in matching groups due to population heterogeneity and the impossibility of randomization remain key limitations. Randomization is essential in clinical trials to ensure equal allocation and comparability between groups. However, because systemic condition was the main distinguishing factor, randomization was not feasible in this study.

The results of this study suggest a trend toward reduced postoperative pain in individuals with type 2 diabetes mellitus (T2DM). This observation may be associated with the neuropathic changes linked to T2DM. Diabetic neuropathy is a common complication of diabetes and can lead to altered pain perception, resulting in hypoalgesia or even analgesia in some cases(32, 33). Studies have indicated that diabetic neuropathy may affect the nerve fibers responsible for pain transmission, leading to decreased pain sensitivity(34). Furthermore, central mechanisms such as descending pain modulation may also be altered in patients with T2DM, contributing to variability in pain perception(35). It is important to note that the presence or absence of pain in patients with diabetic neuropathy can vary significantly, and factors such as the duration of diabetes, glycemic control, and the presence of other comorbidities may influence this perception(34). Therefore, although our findings suggest a potential reduction in postoperative pain among patients with T2DM, further studies are required to fully understand the underlying mechanisms and confirm these results.

From a clinical perspective, the observed trend toward reduced postoperative pain in patients with type 2 diabetes mellitus (T2DM) following endodontic treatment has meaningful implications for treatment planning and patient management. Specifically, these patients may require less analgesic intervention in the postoperative period. However, this diminished pain perception—likely influenced by diabetic neuropathy—should not be misinterpreted as an indication of improved healing. Instead, it underscores the need for careful postoperative follow-up to monitor healing progression and detect potential complications that may otherwise go unnoticed due to altered pain sensitivity. Diabetic patients constitute a heterogeneous group with diverse systemic characteristics, and currently, no specific endodontic protocol exists for this population. Anagha et al.(31) also demonstrated that one- or two-session endodontic treatment did not influence postoperative pain in diabetic patients. Therefore, future studies should aim to identify the most effective techniques, instruments, and materials for endodontic treatment in patients with diabetes to reduce postoperative pain and enhance clinical outcomes.

## Conclusion

Considering the limitations of this study, individuals with type 2 diabetes mellitus may experience reduced postoperative pain following endodontic treatment compared to non-diabetic individuals. However, these findings should be interpreted with caution, as the study was exploratory in nature and may be limited by its statistical power.

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## Declarations

*Ethical approval*
The study was approved by the Research Ethics Committee of the Federal University of Amazonas (CAAE n° 97436918.0.0000.5020) and registered in the Brazilian Registry of Clinical Trials (REBEC) (UTN: U1111-1228-6794).

*Informed consent*
Written informed consent to participate was obtained from all individual participants included in the study.

*Data availability*
No datasets were generated or analyzed during the current study.

*Conflict of interest*
All the authors report no conflicts of interest related to this study.

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ORIGINAL ARTICLE

# Comparison of debris removal efficiency of different endodontic file systems


## ABSTRACT

***Aim:*** *The aim of this study was to compare 4 different NiTi endodontic file systems [ProTaper Next (PTN), ProTaper Ultimate (PTU), VDW.Rotate (VR), and XP-Endo Shaper (XPS)] in terms of their instrumentation time (IT) and material removal capacity using standardized transparent acrylic root canal blocks (TABs).*

***Methods:*** *A total of 80 standardized TABs with canals of 17 mm length, a constant taper of 2%, and a curvature of 30 degrees were used. The root canals were randomly assigned to 4 experimental groups (n = 20 each), each of which used one of the tested file systems. All the instrumentation procedures were performed by a single operator following manufacturers' protocols using a torque-controlled endodontic motor. The weight of each TAB was measured before and after instrumentation using a precision scale, and the percentage of material loss was calculated. IT was also recorded using a digital stopwatch. Data was analyzed using one-way ANOVA, Kruskal-Wallis test, and Pearson correlation, with a significance level set at P < 0.05.*

***Results:*** *XPS demonstrated the highest material loss, significantly greater than PTN and VR (P < 0.001), while VR exhibited the most conservative material removal. XPS also showed the shortest IT, whereas PTU exhibited the longest (P < 0.001). A moderate positive correlation was found between IT and material loss (r = 0.579, P < 0.001).*

***Conclusions:*** *Endodontic file systems differ significantly in shaping efficiency and dentin preservation. The XPS offered superior time efficiency but removed more material, while VR preserved dentin more effectively. These findings may guide clinicians in selecting endodontic file systems based on clinical priorities. Future studies using natural teeth are recommended to validate these findings.*



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## Introduction

In contemporary endodontics, nickel–titanium (NiTi) endodontic files have revolutionized root canal instrumentation procedures. Compared to manual techniques, these systems facilitate the creation of more consistent tapered preparations, thereby enhancing treatment efficacy. In addition, they contribute to increased operator efficiency by reducing fatigue and shortening procedure time, which in turn improves patient comfort (1,2). The mechanical capabilities of endodontic file systems allow for efficient canal preparation in less time, resulting in both time and labor savings. Consequently, these advantages have made this instrumentation an indispensable component of modern endodontic practice (3).

NiTi endodontic file systems differ considerably in terms of their NiTi alloy composition, cross-sectional geometry, taper design, and kinematics. For instance, ProTaper Next (PTN) (Dentsply Maillefer, Ballaigues, Switzerland) is manufactured from M-Wire alloy and features a variable taper with an off-centered rectangular cross-section, a configuration designed to reduce contact points within the canal and minimize instrument fatigue (3,4). In contrast, the XP-Endo Shaper (XPS) (FKG Dentaire, LaChaux-de-Fonds, Switzerland) is a single-file system made from MaxWire alloy, which exhibits phase transformation properties. While in a narrow martensitic form at room temperature, it transitions to an expanded semi-circular shape with an approximate 0.04 taper at body temperature (~35 °C) due to its shape memory effect (5). This dynamic behavior enables the file to adaptively contact more canal walls while maintaining high flexibility (6). The VDW.Rotate (VR) (VDW, Munich, Germany) system comprises files with small tapers (e.g. 0.04 and 0.05) and incorporates an adaptive S-shaped cross-section. This design prioritizes dentin preservation in narrow canals and facilitates effective debris removal (7). Moreover, newer systems such as ProTaper Ultimate (PTU) (Dentsply Maillefer) utilize advanced thermally treated “gold” NiTi alloys, offering enhanced flexibility and improved resistance to cyclic fatigue (8).

In addition to mechanical instrumentation, chemical debridement constitutes a fundamental component of root canal treatment. The complex anatomy of the root canal system often harbors residual tissue, bacteria, and smear layer that cannot be completely eliminated by instrumentation alone. Therefore, the irrigation phase plays a pivotal role in achieving optimal disinfection and cleanliness of the canal system (9). Effective irrigation enhances the removal of organic and inorganic debris, aids in smear layer elimination, and improves the penetration of intracanal medicaments and sealers (9). Recent studies (15,16) have highlighted the importance of both irrigant activation and temperature in enhancing debridement efficacy. Penukonda et al.(10) demonstrated that activation systems such as Ultra-X and XP-Endo Finisher significantly improve smear layer removal, suggesting that mechanical agitation complements chemical irrigants in cleaning complex canal anatomies. Similarly, Abdellatif et al. (11) reported that using Dual Rinse HEDP at elevated temperatures significantly improved bovine pulp tissue dissolution, underscoring the relevance of temperature-controlled irrigation protocols. These findings emphasize that root canal instrumentation is not solely dependent on the file system used, but also on the adjunctive irrigation strategy implemented, which ultimately affects clinical outcomes.

Technological differences among the NiTi file systems have a direct impact on 2 critical parameters: instrumentation time (IT) and material removal (12). Single-file systems like the XPS tend to reduce IT due to fewer file changes, unlike multi-file systems such as PTN, PTU, and VR (13,14). Moreover, the file’s taper and cross-sectional area are key determinants of how much dentin is removed; larger tapers typically result in more extensive tissue removal, which may compromise root strength (15). In contrast, conservative designs with minimal taper are aligned with minimally invasive endodontic

principles and help preserve root dentin. Cross-sectional geometry and motion type also influence shaping efficacy; for example, S-shaped cross-sections improve debris removal, while thermomechanically adaptive designs like that of XPS enhance wall contact. Clinically, shorter ITs are advantageous in managing pediatric or anxious patients, while preserving dentin is essential for maintaining long-term structural integrity and reducing the risk of root fracture (15,16). Therefore, selecting a file system that balances efficiency with dentin conservation is crucial in endodontic practice.

Considering these factors, it becomes evident that comparative evaluations of NiTi endodontic file systems are of significant importance. Although several studies (10,11,17) have researched individual file systems or performed pairwise comparisons (such as XPS versus PTN or VR versus ProTaper Gold) (13,14,17) comprehensive evaluations directly comparing XPS, PTN, PTU, and VR in terms of both IT and dentin preservation remain limited in the current literature. Accordingly, the aim of this study was to systematically compare the time efficiency and material removal performance of these four file systems, thus addressing the current gap in the literature. The null hypothesis tested in this study is that there is no significant difference among the XPS, PTN, PTU, and VR file systems in terms of IT and the amount of material removed from transparent acrylic blocks (TABs).

## Materials and Methods

*Sample Selection and Standardization*

As this was an in vitro study involving no human or animal subjects, ethical approval was not required. The sample size was calculated using G*Power 3.1 (Heinrich Heine University, Düsseldorf, Germany), assuming a significance level (α) of 0.05, a power (1–β) of 0.80. The analysis indicated that a minimum of 19 samples per group were required to achieve adequate statistical power.

A total of 80 TABs (Dentsply Maillefer) with simulated single root canals were used. All the root canals were approximately 17 mm in length and had a 2% constantly increasing taper with a curvature of 30 degrees. The TABs were inspected using a stereomicroscope (Stemi 508, Zeiss, Oberkochen, Germany) to ensure the absence of manufacturing defects or deformities. The root canals were initially scouted with a size 10 K-type file until its tip was visible at the apical foramen, and the working length (WL) was set 0.5 mm shorter. Before the instrumentation, a glide path was established with a #15 K-file to the WL for each root canal.

*Instrumentation Protocol*

The TABs were then randomly assigned to 4 groups (n = 20) based on the used NiTi file systems PTN, PTU, VR, and XPS.

- PTN group: Glide path was prepared using a ProGlider file after confirmation with a size 15 K-file (Mani Inc., Tochigi, Japan). Instrumentation was initiated with X1 (17/.04), followed by X2 (25/.06), and completed with X3 (30/.07). All files were operated in continuous rotation at 300 rpm and 2 Ncm torque.
- PTU group: Glide path was prepared using the Slider (16/.02) file. Instrumentation was performed using the Shaper (20/.04), Finisher F1 (20/.07), Finisher F2 (25/.06), and Finisher F3 (30/.09). All files were operated in continuous rotation at 400 rpm and 4.0 Ncm torque.
- VR group: Glide path was prepared using VR 15/.04. Instrumentation was performed with VR 20/.05, 25/.04, and 30/.04 files. All files were operated in continuous rotation at 350 rpm and 2.0 Ncm torque.
- XPS group: Glide path was confirmed with a size 15 K-file. Instrumentation was performed using a single XPS file (30/.01). The file was operated in continuous rotation at 800 rpm and 1 Ncm torque. In this group, the TAB were immersed in a water bath at 35 °C to simulate intracanal conditions and ensure optimal performance of the XPS

file. At this temperature, the file undergoes a phase transformation from martensite to austenite, resulting in controlled expansion. This transformation facilitates a consistent preparation taper of 4% along the entire length of the root canal.

All instrumentation procedures were carried out by a single experienced operator, who is a certified endodontist with more than 5 years of clinical experience in the field, in accordance with the manufacturers' protocols using a torque-controlled endodontic motor (X-Smart Plus, Dentsply Sirona, Ballaigues, Switzerland). During the procedures, the TABs were stabilized using modeling wax (Polywax, Bilkim Co. Ltd., Istanbul, Türkiye) to ensure consistent positioning and prevent displacement.

Each canal was prepared up to the final file recommended for that system, and the instrumentation was performed with distilled water irrigation delivered using a 30-gauge side-vented needle (EndoArt, Inci Dental, Istanbul, Türkiye). The volume of irrigant was standardized across all samples (10 mL per canal). After preparation, each canal was rinsed with 5 mL of distilled water and dried with paper points.

*Weight Measurement and Material Loss Calculation*

Before instrumentation, each TAB was individually weighed using a precision analytical balance (XB 220A; Kunz Precisa, Zofingen, Switzerland). After instrumentation and irrigation, the TABs were rinsed, dried, and reweighed using the same balance under identical environmental conditions. The percentage of material loss was calculated using the formula:

$$\textit{Material Loss (\%)} = (\textit{Initial Weight} - \textit{Final Weight}) / \textit{Initial Weight} \times 100$$

*Time Measurement*

The total IT was measured using a digital stopwatch (Neval Digital Stopwatch, Istanbul, Türkiye) operated by an independent observer. The timer was started when the shaping file entered the canal and stopped once it was fully removed. Only the time during which the shaping file was actively engaged within the canal was included. Irrigation, patency checks, and drying steps were excluded from the time calculation to ensure standardization.

*Statistical Analysis*

All data were statistically analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. One-way ANOVA was used for normally distributed variables (e.g., instrumentation time), while the Kruskal-Wallis test was employed for non-normally distributed variables (e.g., material loss in the XP-Endo Shaper group). Post-hoc pairwise comparisons were conducted with Tukey's or Dunn's tests as appropriate. A Pearson correlation analysis was performed to evaluate the relationship between preparation time and material loss. Statistical significance was set at $P < 0.05$.

## Results

For each group, the IT (min) and percentage of weight loss were calculated as mean ± standard deviation (SD). Normality was assessed using the Shapiro-Wilk test. IT showed normal distribution across all groups, while the percentage of weight loss in the XPS group did not follow a normal distribution ($p = 0.014$).

*Weight Loss*

The Kruskal-Wallis H test showed significant differences in the percentage of weight loss among groups ($H = 42.685$, $df = 3$, $P < 0.001$). Pairwise comparisons using the Mann-Whitney U test with Bonferroni correction ($\alpha = 0.0083$) revealed that the XPS group was significantly different from both PTN (Adj. Sig. = 0.000) and VR (Adj. Sig. = 0.001). However, the difference between XPS and PTU was not statistically significant after adjustment (Adj. Sig. = 0.080). Pairwise comparisons with Bonferroni correction are shown in

**Table 1**
**Tukey HSD post-hoc results for preparation time.**

| Groups | Mean Difference ± SE | p-value |
|---|---|---|
| PTU vs. PTN | 2.88 ± 0.65 | <0.001 * |
| PTU vs. VR | 10.81 ± 0.65 | <0.001 * |
| PTU vs. XPS | 21.11 ± 0.65 | <0.001 * |
| PTN vs. VR | 7.93 ± 0.65 | <0.001 * |
| PTN vs. XPS | 18.23 ± 0.65 | <0.001 * |
| VR vs. XPS | 10.30 ± 0.65 | <0.001 * |

** Statistically significant at P < .05.*

**Table 2**
**Pairwise comparisons between endodontic file systems (Mean Differences ± Std. Error, Bonferroni-adjusted p-values).**

| Groups | Mean Difference ± SE | Adjusted p-value |
|---|---|---|
| XP vs. PTU | 19.48 ± 7.35 | 0.080 |
| XP vs. VDW | 28.38 ± 7.35 | 0.001 * |
| XP vs. PTN | 42.45 ± 7.35 | 0.000 * |
| PTU vs. VDW | –8.90 ± 7.35 | 1.000 |
| PTU vs. PTN | 22.98 ± 7.35 | 0.018 * |
| VDW vs. PTN | 14.08 ± 7.35 | 0.554 |

** Statistically significant (P < .05, Bonferroni-adjusted)*
***Note:*** *Mean differences represent the score of Group A minus Group B.*

detail in Table 2. A significant difference was also found between PTU and PTN (Adj. Sig. = 0.018), whereas no significant differences were observed between PTU and VR or VR and PTN. According to the results shown in Table 3, a moderate positive and statistically significant correlation was found between preparation time and weight loss (r = 0.579, P < 0.001).

*Instrumentation Time*
A one-way ANOVA was performed to evaluate differences in IT among groups. The analysis revealed a statistically significant difference (P < 0.001). Tukey HSD post-hoc test results are summarized at Table 1. The PTU group demonstrated a significantly longer IT compared to all other groups (P < 0.001). Conversely, the XPS group exhibited the shortest IT, which was statistically significantly different from all other groups (P < 0.001).
A positive correlation between IT and material loss was observed.

## Discussion

In this study, different NiTi endodontic file systems were compared in terms of their IT and material removal capacity. Standardized canal instrumentation was performed using TABs to evaluate the impact of each system's technological design on shaping efficiency. The findings suggest that the structural and technological differences among the systems may lead to clinically significant outcomes.

**Table 3**

**A moderately positive and statistically significant correlation was shown between time and weight loss.**

| Variable 1 | Variable 2 | Correlation Coefficient (r) | p-value |
|---|---|---|---|
| Time | Weight Loss | 0.579 | <0.001 |

The performance of NiTi endodontic file systems is directly influenced by their metallurgical composition and geometric design. In this context, the structural and technological characteristics of the systems compared in this study demonstrated notable differences in terms of IT and material removal capacity. PTN features a variable taper and an off-centered rectangular cross-section. It is manufactured using M-Wire, a heat-treated NiTi alloy, which enhances flexibility and reduces the risk of file fracture (18,19). PTU is a multi-file system in which each file is fabricated from a distinct proprietary alloy (M-Wire, Gold, Blue NiTi). With its parallelogram-shaped cross-section and a maximum flute diameter limited to 1 mm, the system aims to balance cutting efficiency and flexibility. Due to its R-phase crystalline structure, it offers superior flexibility compared to previous generations (8,20). VR comprises three files and incorporates an adaptive S-shaped cross-section that closely follows the natural root canal anatomy. The use of a newly developed heat-treated NiTi alloy improves the system's flexibility and fracture resistance. Additionally, the file's cross-section is designed with a central offset, which enhances debris removal and cleaning efficiency (17). XPS is a single-file system characterized by highly dynamic thermomechanical behavior. Made from MaxWire alloy, the file is in the martensitic phase at room temperature and transforms into the austenitic phase within the canal, expanding into a semi-circular shape upon exposure to body temperature (6). During rotation, it forms 6 cutting edges due to its booster tip design, allowing the file to expand from an initial ISO size 15 with a 0.01 taper to approximately ISO size 30 with a 0.04 taper. This structural adaptability enables the file to make extensive contact with canal walls and perform effective shaping, particularly in oval and irregularly shaped canals (6,21).

Considering their distinct design philosophies, the 4 systems were purposefully selected to encompass a wide spectrum of contemporary endodontic instrumentation approaches. PTN was chosen based on its well-documented clinical efficacy and widespread adoption, serving as a reference multi-file system characterized by M-Wire technology and an off-centered design that collectively enhances shaping efficiency and file flexibility (18,19). PTU and VR, as relatively recent advancements in multi-file instrumentation, were included owing to their sophisticated metallurgical properties and minimally invasive design concepts (17,20). It was aimed to evaluate these file systems that aim to increase dentin protection with these features. In contrast, the XPS was incorporated for its distinctive thermomechanical properties and capacity to achieve complete canal preparation using a single file, enabling direct comparison with conventional multi-file systems (6).

Moreover, in order to standardize apical preparation across all groups, files corresponding to a final apical size of ISO 30 were selected. This decision was driven by the fact that XPS offers a fixed apical diameter of 30 as part of its design, thereby necessitating the use of size 30 files in the other systems to ensure consistency and comparability in shaping outcomes.

In terms of dentin removal, systems with a conservative design, such as VR, generally tend to preserve more root canal structure by removing less tissues. This finding is supported by the study of Piț et al. (17) where VR exhibited the lowest material removal among the evaluated systems. In contrast, the XPS, due to its expanding geometry and adaptive design, increases the canal volume and the number of contacted canal walls. Azim et al.

(14) demonstrated that XPS removed significantly more dentin than Vortex Blue, particularly in the coronal and middle thirds. Similarly, Poly et al. (13) found that repeated activation of the XPS file, performed 25 times, resulted in greater dentin removal in the coronal third compared to the PTN X3 instrument. In a study (22) XPS was shown to remove more dentin and achieve larger canal wall preparation compared to PTN, especially at multiple root levels, like previous findings in literature. Consistent with these findings, our study also showed that XPS exhibited the highest amount of dentin removal among the tested systems, particularly due to its expanding file design and enhanced wall contact, while VR removed the least amount of material, likely owing to its conservative cross-sectional architecture. Based on the findings of our study, the null hypothesis was also rejected in terms of the amount of material removed from the TABs, given the significant variability in shaping outcomes across the tested systems. In multi-file systems such as PTN, the increased number of shaping steps generally results in longer ITs. In contrast, the single-file XPS can shape the canal in a shorter period due to its reduced number of procedural steps and adaptive design. In a micro-CT study by Poly et al. (13) the mean IT for XPS was reported as approximately 90 ± 7 sec, while PTN X3 required about 112 ± 9 sec. Similarly, in an in vitro study by Pi̦t et al. (17) TruNatomy showed the shortest IT (14 sec), followed by VR (~40 sec), Reciproc Blue (~53 sec), and ProTaper Gold (~63 sec). VR was found to require significantly less time compared to the four-step ProTaper Gold sequence. These findings suggest that, in general, systems using fewer and finer files tend to reduce the overall procedure time, whereas multi-step protocols are associated with longer shaping durations. In our study, a similar trend was observed in accordance with the existing literature. The significantly longest IT was recorded in the PTU group, which utilizes a multi-file system, whereas the XPS group, employing a single-file approach, demonstrated the shortest IT in a statistically significant manner. In the light of the findings of our study the null hypothesis was rejected with respect to IT, as statistically significant differences were observed among the file systems evaluated.

The differences in IT and dentin removal are clinically significant. The use of NiTi endodontic file systems can enhance treatment efficiency by reducing the duration of canal shaping procedures, thereby facilitating the process for both the clinician and the patient (23). Shorter ITs are particularly advantageous in pediatric patients or individuals with limited cooperation, contributing to increased comfort and improved treatment outcomes. On the other hand, the amount of residual dentin is critically important for root fracture resistance. Previous studies have demonstrated that instrumentations preserving more dentin are associated with a reduced risk of root fractures (24–26). Therefore, in selecting NiTi endodontic file systems, a balance must be maintained between effective disinfection and canal enlargement while preserving as much sound dentin as possible. In this regard, systems that optimize efficiency without causing unnecessary structural loss are essential for long-term clinical success.

In our study, the XPS demonstrated significantly greater dentin removal compared to the other systems evaluated. This finding may be attributed to several key design features of the file. The adaptive expansion capability of its MaxWire alloy allows the file to increase both its diameter and taper from an initial 0.01 to approximately 0.04 at body temperature, enabling it to contact canal surfaces that are typically untouched by conventional files (21). Additionally, its booster tip design, characterized by a tapered shape and 6 cutting edges, facilitates efficient material removal across broader areas through helical motion. Azim et al. (14) also reported that XPS exhibited low untouched wall percentages and produced more extensive canal preparations. Furthermore, the application of extended activation time has been shown to enhance its shaping performance (13). Collectively, these factors support the observation that XPS may

operate more aggressively within the canal. Although various irrigants (e.g. sodium hypochlorite, EDTA, and chlorhexidine) are widely used in clinical endodontics for their antimicrobial and tissue-dissolving effects, distilled water was chosen in the present study to avoid the potential confounding influence of these chemically active agents on TABs. Prior studies (27,28) have shown that such irrigants may alter the physical properties of synthetic materials, potentially compromising the integrity of simulated canals and leading to inaccurate evaluation of instrumentation performance. Thus, the use of distilled water provided a controlled environment and maintained the standardization necessary for valid comparisons among instrumentation systems.

The use of TABs offers significant advantages in experimental endodontic research by providing standardized canal dimensions, shapes, and curvatures, while eliminating the risk of biological contamination. Their transparency allows for real-time visualization of instrumentation, facilitating more immediate detection of canal morphology changes compared to natural dentin. Moreover, the ability to define canal curvature and diameter mathematically ensures high reproducibility and enables direct comparison between different files or instrumentation protocols under consistent conditions (29).

Despite their advantages, the use of TABs in endodontic research is associated with notable limitations. One major concern is the potential softening of the acrylic material due to the heat generated by rotary files during instrumentation. This softening may lead to the file embedding into the acrylic and increase the risk of file separation. Such effects are partly due to the mechanical and thermal properties of acrylic, which differ significantly from natural dentin - TABs typically have approximately half the hardness of human dentin and markedly distinct thermal conductivity. Furthermore, the canal configurations in TABs are often uniform and simplified, lacking the anatomical complexity and variability encountered in clinical cases (30,31). As a result, instrumentation outcomes observed in TABs may not accurately reflect file performance in natural root canals. Therefore, caution is warranted when extrapolating findings from acrylic-based simulations to real clinical scenarios. These results contribute to clinical decision-making in selecting endodontic file systems according to specific procedural needs.

In addition, the fact that all instrumentation procedures were performed by a single human operator constitutes an inherent limitation of the study. Human-dependent techniques are subject to intra-operator variability, including factors such as differences in applied pressure, motion consistency, and tactile feedback. Unlike automated or robotic systems that offer high levels of standardization and reproducibility, manual instrumentation introduces an element of subjectivity, which may influence the uniformity and comparability of the results.

## Conclusion

Within the limitations of this in vitro study, it can be concluded that the evaluated NiTi endodontic file systems demonstrated significant differences in both IT and material removal. The XPS exhibited the shortest IT and the highest material removal, likely due to its single-file design and thermomechanical adaptability. In contrast, PTU required the longest IT, while VR was the most conservative in terms of material removal. These results underscore the importance of choosing an endodontic file system that balances shaping efficiency and dentin preservation for optimal clinical outcomes.

## Author Contributions

K.E. designed the study; D.E. and A.D. contributed to data collection and performed statistical analysis; Y.E.Ç., Z.Ç. and O.P.B. drafted the manuscript; A.M.P. and K.E. critically revised the article for important intellectual content. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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ORIGINAL ARTICLE

# Investigating the Efficacy of the Metal Artifact Reduction Algorithm in Cone-Beam Computed Tomography Images for Endodontic and Restorative Materials


## ABSTRACT

***Aim:*** *This study aimed to assess the effectiveness of metal artifact reduction (MAR) algorithms in cone-beam computed tomography (CBCT) images, specifically for various common dental materials. Metal restorations, posts, and gutta-percha frequently cause artifacts due to their high density, impacting image quality.*
***Methodology:*** *Researchers used 11 extracted human mandibular teeth with different dental materials (amalgam, metal posts, porcelain-fused-to-metal (PFM) crowns, gutta-percha) and three intact teeth. CBCT scans were performed using a Galileos scanner on a mandible in water to simulate soft tissue. Images were acquired both with and without MAR activation across various tooth positions. Contrast-to-noise ratio (CNR) was calculated at multiple distances and angles. Statistical analysis was conducted using the Wilcoxon test.*
***Results:*** *The study found that activating the MAR algorithm had no significant impact on reducing metal artifacts across any of the evaluated dental materials, regardless of tooth type, position, or angle.*
***Conclusion:*** *The MAR algorithm, as tested, does not significantly reduce metal artifacts caused by dental materials like amalgam, metal posts, PFM crowns, or gutta-percha in CBCT images. In this context, clinical application of these algorithm does not provide justifiable added benefits.*



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## Introduction

Cone-beam computed tomography (CBCT) is the main three-dimensional imaging modality for maxillofacial structures based on reconstruction from two-dimensional images (1). CBCT is a valuable tool in dental diagnosis and treatment planning (2-5). Previous evidence has shown that the presence of materials with high density and high atomic number leads to artifacts in the reconstructed images (6). A variety of restorative and endodontic materials are used in modern dentistry (7, 8), most of which contain radiopacifier agents to allow visualization in dental radiographs (9). Materials such as metal posts, metal restorations, dental implants, and metal crowns cause the formation of artifacts. These artifacts appear as shadows and lines on the adjacent structures (10, 11), thereby reducing the diagnostic utility of CBCT images (12). Metal artifact reduction (MAR) algorithms and image processing methods, developed with the aim of reducing potential image distortions, have been introduced to enhance the quality of CBCT images (13). However, significant variability in the results obtained by using these algorithms under different imaging conditions, such as variations in the type of material and its placement, has been observed, which calls into question the true interpretability of the images (14). Therefore, evaluating the effectiveness of MAR under different conditions appears to be essential. Different studies have focused on investigating the quantitative performance of MAR algorithms in CBCT images with controversial findings. Khosravifard et al. (15), using the Canny edge detection technique to quantify the amount of artifacts, found that MAR algorithms of their Vatech CBCT scanner significantly decreased the amount of artifacts arising from a titanium implant and a stainless steel intracanal post. Bechara et al. (16) used a phantom incorporating three metallic beads and three epoxy resin-based bone substitutes to simulate bone next to metal and concluded that MAR increased the contrast-to-noise ratio (CNR) in the presence of metal objects. Contrasting these results, Soltani et al. (17) reported that MAR algorithm of Genoray CBCT scanner was not successful in reducing the artifacts surrounding ceramic brackets and coated archwires. Queiroz et al. (6) concluded that while there was a significant reduction in artifacts surrounding dental alloys with MAR, no difference was detected in the artifacts around gutta-percha, regardless of MAR use (14). These findings reflect the diversity in the results of different studies performed on quantification of metallic artifacts arising from various dental materials. To the authors' knowledge, no study has been previously performed to investigate the efficacy of the native MAR algorithm of the Galileos CBCT scanner in reducing metallic artifacts surrounding a variety of different dental materials and in different conditions. Therefore, this study aimed to evaluate the efficacy of the MAR algorithm in CBCT images for various dental materials.

## Material and Methods

*Study Design and Setting*

This ex-vivo study was performed on extracted human mandibular teeth. The study was ethically approved by the Research Ethics Committee, Isfahan University of Medical Sciences (#IR.MUI.RESEARCH.REC.1401.240). A sample size of 18 regions of interest (ROIs) was determined for this study. With this number of images, there is an 80% probability of detecting a difference equivalent to d = 0.93 (i.e., 0.93 times the standard deviation (SD)) between the mean CNR and SD values for the different materials at a significance level of $\alpha$=0.05. Inclusion criteria were intact crowns without fracture, caries, or morphological abnormalities. The teeth were excluded if unnecessary loss of dental structures occurred during preparation. These teeth, five left first molars (36), five right first molars (46), and four left central incisors (31).

*Sample Preparation*

For each dental material, two posterior

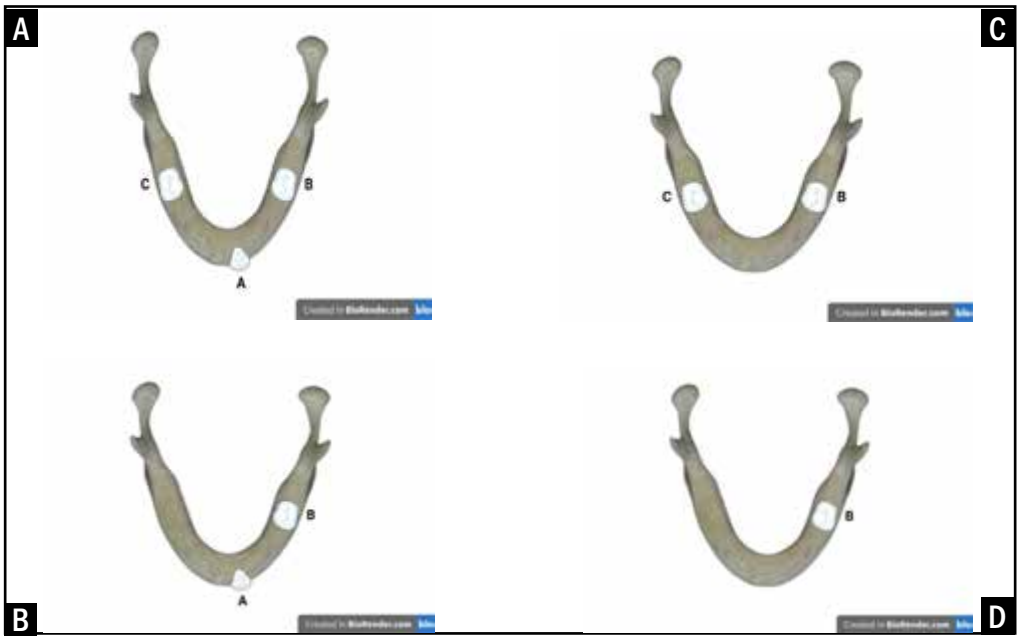


**Figure 1**
Schematic demonstration of positions of teeth in the mandible for CBCT imaging: (a) ABC position; (b) AB position; (c) BC position; and (d) B position (Created in https://BioRender.com).

teeth and one anterior tooth were selected, except for amalgam, for which only two posterior teeth were chosen. Initially, all teeth were disinfected in 70% alcohol, and any carious lesions were removed. Subsequently, each tooth was prepared for the application of the tested materials:

*Gutta Percha:* two left first molars, two right first molars, and two central incisors were selected. The canals of these teeth were instrumented to the appropriate length and width (18). The teeth were then obturated with gutta-percha points (Meta Biomed, Chungcheongbuk-do South Korea), using the lateral condensation technique. Three of the obturated teeth (36, 31, and 46) were chosen for the evaluation of the gutta-percha material.

*Intracanal post:* another three obturated teeth (36, 31, and 46) were designated for post placement. In the distal canals of teeth 36 and 46, as well as in the canal of tooth 31, the root canal filling material was removed first using Piezo #2 and then with Piezo #3 (Dentsply Maillefer, Ballaigues, Switzerland) up to a depth corresponding to two-thirds of the canal length. Following this, post-space impressions were taken and sent to the laboratory for the fabrication of cast posts. The cast posts were subsequently inserted into the corresponding canals, and the fit of the posts was verified using periapical radiography.

*Porcelain fused to metal (PFM) crowns:* an additional three teeth (31, 36, and 46) were selected for preparation for the placement of PFM crowns.

The incisal edge of the anterior tooth was reduced by 2 mm, and its labial and lingual surfaces were reduced by 1.2 mm and 0.8 mm, respectively. In the posterior teeth, the functional cusps were reduced by 2 mm, while the non-functional cusps were reduced by 1.5 mm.

The buccal and lingual surfaces of these posterior teeth were also reduced by 1.2 mm and 0.8 mm, respectively. After taking impressions, the crowns were cast and porcelain-fused-to-metal restorations were fabricated in the laboratory. The crowns were then placed on the respective teeth, and the adaptation of the crown margins to the teeth was evaluated using periapical radiography and a probe.

*Amalgam restoration:* lastly, an MOD cavity was prepared on two posterior teeth (36 and 46) and restored with amalgam (Cinalux, Tehran, Iran).

The mandible was fixed at the bottom of a plastic container using wax; to simulate soft tissue conditions, the container was then filled with a mixture of water and oil.

*CBCT Image Acquisition:* the mounting positions are schematically shown in Fig-

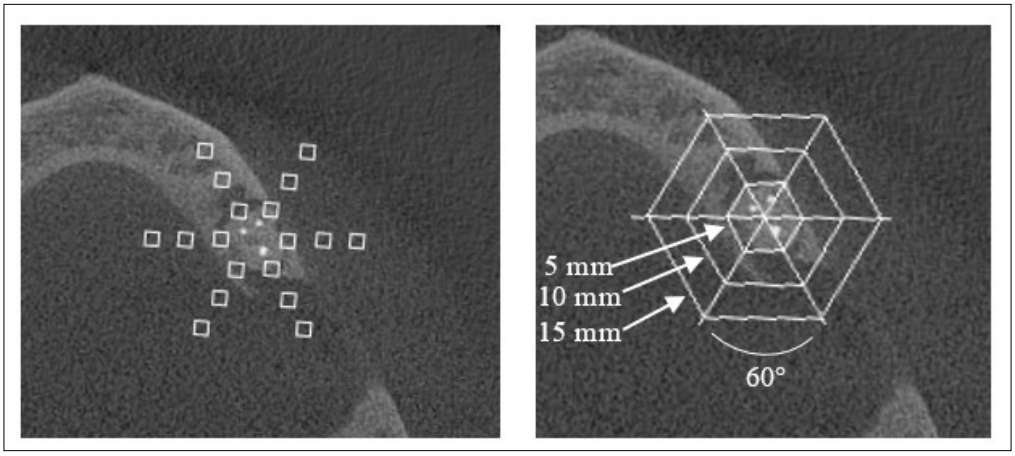


**Figure 2**
ROIs and their position in the CBCT axial image

ure 1. For gutta-percha, posts, PFM crowns, and the intact teeth, CBCT scans were performed in three positions:
**ABC Position:** All three teeth were present.
**AB Position:** Only teeth 31 and 36 were present.
**B Position:** Only tooth 36 was present.
For amalgam, scans were performed in two positions:
**BC Position:** Both teeth 36 and 46 were present.
**B Position:** Only tooth 36 was present.
For each material in each position, four CBCT images were acquired. The procedure involved taking two images without activating the MAR algorithm, and then two images with activation of the MAR. The CBCT scan was repeated twice to address any variability in image acquisition. All images were acquired using the Galileos CBCT scanner (Sirona, Bensheim, Germany) with exposure parameters set at 85 kVp and 21 mAs, voxel size 280 micrometers, and field of view 15 cm×15 cm.

*CBCT Image Analysis*
The DICOM files generated from the CBCT scans were imported into ImageJ software (NIH, Bethesda, MD, USA). In a preselected axial image, 18 square-shaped ROIs with dimensions of 2 mm × 2 mm were created. This was achieved by dividing the area surrounding each tooth into six segments using lines drawn at 60-degree intervals. Additionally, three circular sections with radii of 5, 10, and 15 mm were drawn centered on the tooth, and the intersection points of these lines and circles were designated as the ROIs (Figure 2). For each ROI, the mean and SD of the gray values were calculated.
To calculate the CNR, an ROI of similar size was selected in the water surrounding the mandible, and the mean and SD of the gray value were recorded as a control. The CNR was calculated as follows:

$$NR = \frac{|Mean - Mean_{control}|}{\sqrt{SD^2 + SD^2_{control}}}$$

Data analysis was performed using the Wilcoxon test ($\alpha$=0.05) by the Statistical Package for the Social Sciences (SPSS, version 26, IBM Statistics, Armonk, NY, USA).

## Results

For each dental material, two posterior teeth and one anterior tooth were selected, except for amalgam, for which only two posterior teeth were chosen. Additionally, four CBCT images were obtained in each of the positions (two with and two without activation of MAR). For the amalgam restoration, when only one posterior tooth was present (position B), there was no significant difference between CNR values in the MAR activated and deactivated conditions, at distances of 5 mm (P=0.248), 10 mm (P=0.248), and 15 mm (P=0.463) from the center of the tooth (overall P=0.679). Similarly, when two posterior teeth were present (position BC), there was no significant difference between CNR

**Table 1**

**Mean (SD) of CNR values of teeth in the presence of amalgam restorations.**

| Position | Distance | MAR | Number | Mean (SD) | P-value |
|---|---|---|---|---|---|
| B | 5 mm | Off | 6 | 1.571 (0.763) | 0.248 |
| | | On | 6 | 1.390 (0.812) | |
| | 10 mm | Off | 6 | 27.374 (6.274) | 0.248 |
| | | On | 6 | 27.392 (6.286) | |
| | 15 mm | Off | 6 | 19.733 (5.565) | 0.463 |
| | | On | 6 | 19.718 (5.271) | |
| | Total | Off | 18 | 16.226 (11.969) | 0.679 |
| | | On | 18 | 16.167 (12.514) | |
| BC (for left molar) | 5 mm | Off | 6 | 1.446 (0.669) | 0.172 |
| | | On | 6 | 1.464 (0.647) | |
| | 10 mm | Off | 6 | 24.857 (4.635) | 0.248 |
| | | On | 6 | 24.839 (4.717) | |
| | 15 mm | Off | 6 | 21.964 (6.347) | 0.463 |
| | | On | 6 | 21.969 (6.318) | |
| | Total | Off | 18 | 16.895 (11.481) | 0.711 |
| | | On | 18 | 16.913 (11.465) | |

values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.172), 10 mm (P=0.248), and 15 mm (P=0.463) from the center of the left molar (overall P=0.711) (Table 1).

For the gutta-percha material, when all three teeth were present (position ABC), there was no significant difference between the CNR values of the left anterior incisor in active and inactive MAR conditions at distances of 5 mm (P=0.753), 10 mm (P=0.172), and 15 mm (P=0.463) from the center of the tooth (overall P=0.982). Similarly, for the left molar, when all three teeth were present (position ABC), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.600), 10 mm (P=0.916), and 15 mm (P=0.753) from the center of the tooth (overall P=0.810). The same results were found in AB position for the left central incisor (P=0.753, P=0.753, P=0.600, and P=0.982 for 5-, 10-, and 15-mm distances and overall, respectively) and left molar (P=0.345, P=0.248, P=0.172, and P=0.420 for 5-, 10-, and 15-mm distances and overall, respectively). In presence of the left molar (position B), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.463), 10 mm (P=0.248), and 15 mm (P=0.916) from the center of the tooth (overall P=0.878) (Table 2).

For the PFM crowns, when all three teeth were present (position ABC), there was no significant difference between the CNR values of the left anterior incisor in active and inactive MAR conditions at distances of 5 mm (P=0.600), 10 mm (P=0.175), and 15 mm (P=0.753) from the center of the tooth (overall P=0.472). Similarly, for the left molar, when all three teeth were pres-

**Table 2**

**Mean (SD) of CNR values of teeth in the presence of gutta-percha.**

| Position | Distance | MAR | Number | Mean (SD) | P-value |
|---|---|---|---|---|---|
| ABC (for left central incisor) | 5 mm | Off | 6 | 17.957 (4.706) | 0.753 |
| | | On | 6 | 17.940 (4.681) | |
| | 10 mm | Off | 6 | 19.844 (2.143) | 0.172 |
| | | On | 6 | 19.824 (2.415) | |
| | 15 mm | Off | 6 | 22.612 (3.595) | 0.463 |
| | | On | 6 | 22.628 (3.597) | |
| | Total | Off | 18 | 19.850 (4.108) | 0.982 |
| | | On | 18 | 19.849 (4.103) | |
| ABC (for left molar) | 5 mm | Off | 6 | 13.127 (3.963) | 0.600 |
| | | On | 6 | 12.603 (3.405) | |
| | 10 mm | Off | 6 | 17.788 (1.784) | 0.916 |
| | | On | 6 | 17.800 (1.762) | |
| | 15 mm | Off | 6 | 15.453 (3.757) | 0.753 |
| | | On | 6 | 15.452 (3.738) | |
| | Total | Off | 18 | 15.456 (3.680) | 0.810 |
| | | On | 18 | 15.285 (3.635) | |
| AB (for left central incisor) | 5 mm | Off | 6 | 22.935 (3.243) | 0.753 |
| | | On | 6 | 22.945 (3.325) | |
| | 10 mm | Off | 6 | 22.270 (2.884) | 0.753 |
| | | On | 6 | 22.179 (2.918) | |
| | 15 mm | Off | 6 | 22.121 (1.453) | 0.600 |
| | | On | 6 | 22.107 (1.377) | |
| | Total | Off | 18 | 22.352 (2.375) | 0.982 |
| | | On | 18 | 22.351 (2.379) | |
| AB (for left molar) | 5 mm | Off | 6 | 1.963 (3.339) | 0.345 |
| | | On | 6 | 1.646 (3.136) | |
| | 10 mm | Off | 6 | 15.315 (2.636) | 0.248 |
| | | On | 6 | 15.297 (2.649) | |
| | 15 mm | Off | 6 | 18.691 (3.617) | 0.172 |
| | | On | 6 | 18.709 (3.621) | |
| | Total | Off | 18 | 14.700 (4.673) | 0.420 |
| | | On | 18 | 14.690 (4.688) | |
| B | 5 mm | Off | 6 | 1.539 (2.247) | 0.463 |
| | | On | 6 | 1.552 (2.214) | |
| | 10 mm | Off | 6 | 15.504 (1.913) | 0.248 |
| | | On | 6 | 15.488 (1.894) | |
| | 15 mm | Off | 6 | 17.116 (2.650) | 0.916 |
| | | On | 6 | 17.124 (2.671) | |
| | Total | Off | 18 | 14.386 (3.594) | 0.878 |
| | | On | 18 | 14.388 (3.586) | |

**Table 3**

**Mean (SD) of CNR values of teeth in the presence of PFM restorations.**

| Position | Distance | MAR | Number | Mean (SD) | P-value |
|---|---|---|---|---|---|
| ABC (for left central incisor) | 5 mm | Off | 6 | 17.813 (4.598) | 0.600 |
| | | On | 6 | 17.825 (4.605) | |
| | 10 mm | Off | 6 | 2.854 (4.264) | 0.175 |
| | | On | 6 | 2.827 (4.830) | |
| | 15 mm | Off | 6 | 17.637 (2.522) | 0.753 |
| | | On | 6 | 17.634 (2.513) | |
| | Total | Off | 18 | 18.767 (3.894) | 0.472 |
| | | On | 18 | 18.762 (3.884) | |
| ABC (for left molar) | 5 mm | Off | 6 | 1.320 (0.655) | 0.463 |
| | | On | 6 | 1.307 (0.648) | |
| | 10 mm | Off | 6 | 2.239 (4.552) | 0.753 |
| | | On | 6 | 2.251 (4.507) | |
| | 15 mm | Off | 6 | 18.826 (7.372) | 0.600 |
| | | On | 6 | 18.830 (7.156) | |
| | Total | Off | 18 | 13.462 (9.959) | 0.810 |
| | | On | 18 | 13.462 (9.957) | |
| AB (for left central incisor) | 5 mm | Off | 6 | 17.827 (4.425) | 0.248 |
| | | On | 6 | 17.796 (4.393) | |
| | 10 mm | Off | 6 | 18.294 (5.287) | 0.600 |
| | | On | 6 | 18.309 (5.320) | |
| | 15 mm | Off | 6 | 18.424 (3.585) | 0.753 |
| | | On | 6 | 18.425 (3.601) | |
| | Total | Off | 18 | 18.182 (4.223) | 0.743 |
| | | On | 18 | 18.177 (4.230) | |
| AB (for left molar) | 5 mm | Off | 6 | 1.479 (1.246) | 0.753 |
| | | On | 6 | 1.494 (1.203) | |
| | 10 mm | Off | 6 | 18.376 (6.645) | 0.248 |
| | | On | 6 | 18.392 (6.663) | |
| | 15 mm | Off | 6 | 17.885 (5.703) | 0.916 |
| | | On | 6 | 17.888 (5.691) | |
| | Total | Off | 18 | 12.580 (9.396) | 0.327 |
| | | On | 18 | 12.591 (9.394) | |
| B | 5 mm | Off | 6 | 1.232 (1.155) | 0.463 |
| | | On | 6 | 1.228 (1.128) | |
| | 10 mm | Off | 6 | 18.577 (5.487) | 0.753 |
| | | On | 6 | 18.579 (5.496) | |
| | 15 mm | Off | 6 | 17.364 (6.582) | 0.463 |
| | | On | 6 | 17.379 (6.539) | |
| | Total | Off | 18 | 12.391 (9.390) | 0.711 |
| | | On | 18 | 12.395 (9.386) | |

ent (position ABC), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.463), 10 mm (P=0.753), and 15 mm (P=0.600) from the center of the tooth (overall P=0.810). The same results were found in AB position for the left central incisor (P=0.248, P=0.600, P=0.753, and P=0.743 for 5-, 10-, and 15-mm distances and overall, respectively) and left molar (P=0.753, P=0.248, P=0.916, and P=0.327 for 5-, 10-, and 15-mm distances and overall, respectively). In presence of the left molar (position B), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.463), 10 mm (P=0.753), and 15 mm (P=0.463) from the center of the tooth (overall P=0.711) (Table 3). For the intracanal posts, when all three teeth were present (position ABC), there was no significant difference between the CNR values of the left anterior incisor in active and inactive MAR conditions at distances of 5 mm (P=0.600), 10 mm (P=0.248), and 15 mm (P=0.600) from the center of the tooth (overall P=0.248). Similarly, for the left molar, when all three teeth were present (position ABC), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.600), 10 mm (P=0.916), and 15 mm (P=0.115) from the center of the tooth (overall P=0.111). The same results were found in AB position for the left central incisor (P=0.248, P=0.248, P=0.753, and P=0.943 for 5-, 10-, and 15-mm distances and overall, respectively) and left molar (P=0.463, P=0.345, P=0.345, and P=0.844 for 5-, 10-, and 15-mm distances and overall, respectively). In presence of the left molar (position B), there was no significant difference between CNR values of MAR activated and deactivated conditions, at distances of 5 mm (P=0.248), 10 mm (P=0.345), and 15 mm (P=0.916) from the center of the tooth (overall P=0.947) (Table 4).

## Discussion

The present study investigated the effectiveness of the MAR algorithm in CBCT images for dental materials, including amalgam, metal posts, PFM crowns, and gutta-percha, and it was observed that there was no significant difference in the mean CNR between the two conditions (MAR activated and deactivated) for any of the dental materials or at any of the evaluated distances and positions.

In 2020, Fontenele et al. (1) performed CBCT scans on a human mandible—once with a zirconia implant and once without—under three MAR conditions (no MAR, MAR before exposure, and MAR after exposure). Artifacts in the ROIs were measured at various distances and angles relative to the implant using SD and CNR. They concluded that both MAR conditions reduce the amount of artifacts in CBCT images, particularly when artifact effects are more pronounced. This finding contrasts with the present study's results; the discrepancy may be due to differences in the material type under investigation.

Kim et al. (19), in 2020, used four phantoms fitted with prostheses made of amalgam, gold, zirconia, and PFM. They acquired CBCT images both with and without MAR activation, as well as under different settings: kVp values of 100 and 70, and voxel sizes of 0.2 mm and 0.3 mm. They concluded that the MAR algorithm reduces the extent of streaked artifacts, but its effect depends on the device settings and the type of prosthesis. The differences in results can be attributed to the fact that the present study did not consider the role of exposure settings. In 2022, Farias-Gomes et al. (20) investigated the effect MAR algorithm in various regions of teeth restored with different posts, and they found that for nickel-chromium and chrome-cobalt posts, these algorithms do not lead to a significant reduction in artifact levels in the different regions. In general, the findings of that study are consistent with those of the present study. The present study aimed to evaluate the effectiveness of the MAR algorithm in CBCT images for various dental materials. The findings of this study, regarding lack of significant efficacy of Galileos scanner's native MAR algorithm, prompts further consideration of several factors that may influence both artifact formation and the efficacy of artifact reduction algorithms. A critical factor that may account for the lack

**Table 4**

**Mean (SD) of CNR values of teeth in the presence of intracanal post restorations.**

| Position | Distance | MAR | Number | Mean (SD) | P-value |
|---|---|---|---|---|---|
| ABC (for left central incisor) | 5 mm | Off | 6 | 16.519 (2.414) | 0.600 |
| | | On | 6 | 16.523 (2.394) | |
| | 10 mm | Off | 6 | 17.694 (4.192) | 0.248 |
| | | On | 6 | 17.902 (4.158) | |
| | 15 mm | Off | 6 | 17.873 (3.943) | 0.600 |
| | | On | 6 | 17.883 (3.912) | |
| | Total | Off | 18 | 17.154 (3.432) | 0.248 |
| | | On | 18 | 17.165 (3.413) | |
| ABC (for left molar) | 5 mm | Off | 6 | 6.525 (3.865) | 0.600 |
| | | On | 6 | 6.523 (3.842) | |
| | 10 mm | Off | 6 | 16.698 (4.182) | 0.916 |
| | | On | 6 | 16.701 (4.200) | |
| | 15 mm | Off | 6 | 14.801 (3.228) | 0.115 |
| | | On | 6 | 14.775 (3.239) | |
| | Total | Off | 18 | 12.675 (5.767) | 0.111 |
| | | On | 18 | 12.666 (5.068) | |
| AB (for left central incisor) | 5 mm | Off | 6 | 19.297 (3.174) | 0.248 |
| | | On | 6 | 19.557 (3.089) | |
| | 10 mm | Off | 6 | 16.829 (5.861) | 0.248 |
| | | On | 6 | 16.814 (5.848) | |
| | 15 mm | Off | 6 | 17.927 (3.002) | 0.753 |
| | | On | 6 | 17.921 (2.964) | |
| | Total | Off | 18 | 17.933 (4.652) | 0.943 |
| | | On | 18 | 17.930 (4.668) | |
| AB (for left molar) | 5 mm | Off | 6 | 8.497 (5.163) | 0.463 |
| | | On | 6 | 8.505 (5.161) | |
| | 10 mm | Off | 6 | 16.255 (1.610) | 0.345 |
| | | On | 6 | 16.274 (1.639) | |
| | 15 mm | Off | 6 | 14.866 (6.960) | 0.345 |
| | | On | 6 | 14.850 (6.117) | |
| | Total | Off | 18 | 13.206 (5.622) | 0.844 |
| | | On | 18 | 13.211 (5.629) | |
| B | 5 mm | Off | 6 | 6.518 (3.430) | 0.248 |
| | | On | 6 | 6.533 (3.421) | |
| | 10 mm | Off | 6 | 16.952 (3.527) | 0.345 |
| | | On | 6 | 16.802 (3.510) | |
| | 15 mm | Off | 6 | 14.412 (3.201) | 0.916 |
| | | On | 6 | 14.411 (2.964) | |
| | Total | Off | 18 | 12.341 (5.312) | 0.947 |
| | | On | 18 | 12.341 (5.292) | |

of significant differences in our study is the role of exposure parameters. Our investigation maintained fixed exposure settings (85 kVp and 21 mAs), similar to other studies where such conditions remained constant. In contrast, it is revealed that variations in kVp, mAs, and even voxel sizes can alter artifact production, thereby affecting the performance of MAR algorithms (19). This brings into focus the importance of optimizing exposure settings combined with MAR activation to potentially enhance image quality. The rapid development of new radiology programs, along with the fast-paced advancement in image processing techniques, has led to an increased demand for customizable image analysis software. ImageJ is a free image processing software capable of handling DICOM format images and is supported by the National Institutes of Health. This software serves as a powerful platform for image processing, offering users a wide range of tools for comprehensive image analysis (21). Among the limitations of the present study is its laboratory-based nature. The findings of this study should be further examined in subsequent stages using CBCT images acquired from patients. In addition, employing only one MAR algorithm in this study makes direct comparison between different algorithms difficult. As an integral part of digital dentistry, CBCT imaging is an ever-evolving field (22). With the rapid improvements in the field of artificial intelligence (AI), a promising avenue for further research is applying AI-based approaches for correcting metallic artifacts and improving the image quality in CBCT images. Therefore, further research investigating the effects of these modern AI-driven methods on the amount of artifacts caused by different endodontic and restorative materials is recommended.

## Conclusion

The activation of the MAR algorithm does not significantly reduce metal artifacts for dental materials such as amalgam, metal posts, PFM crowns, and gutta-percha. In this context, clinical application of these algorithm does not provide justifiable added benefits.

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CASE REPORTS

# Next Generation Workflow for Apical Control in Endodontics: three case reports


## ABSTRACT

***Aim:*** *This report proposes a new, step-by-step workflow designed to safely manage the apical extent of root canal preparation. It utilizes advanced, motor-driven endodontic technology, specifically the enhanced Optimum Apical Stop (OAS2) function, to streamline and expedite traditional root canal procedures.*

***Summary:*** *In this case series, three patients underwent endodontic treatment, using a motor-driven protocol with the Morita Tri Auto ZX2+ device (J. Morita Corp., Osaka, Japan) and its OAS2 function activated. Root canal shaping was initiated with VDW.ROTATE instruments (VDW GmbH, Munich, Germany), followed by refinement using ProTaper Ultimate F2 and F3 files (Dentsply Sirona, Charlotte, NC, USA), and obturation with conform fit gutta-percha cones. Postoperative assessments included clinical evaluation, periapical radiographs, and patient-reported outcomes at 1, 3, 6, and 12 months. Outcome measures included pain, swelling, tooth function, need for reintervention, adverse effects, and radiographic signs of periapical healing.*

*Immediate postoperative radiographs showed high-quality apical preparation and obturation. At one-year follow-up, all three cases demonstrated complete symptom resolution and radiographic absence of periapical radiolucency.*

***Key learning points:***

- *The OAS2 function allows controlled, minimal, and reproducible apical preparation.*
- *The workflow reduces chair-time and technical variability.*
- *Outcomes are successful regardless of operator experience.*
- *Radiographic healing and patient satisfaction are consistently achieved.*
- *The combined use of VDW.ROTATE and ProTaper Ultimate files supported effective and conservative canal shaping.*



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**KEYWORDS** *Apical foramen, Apical preparation, Endodontic motor, Integrated motor.*



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## Introduction

The accurate maintenance of the apical limit during cleaning, shaping, and filling procedures has been closely associated with successful outcomes (1, 2). Accurate apical control during root canal preparation has been closely associated with reduced risk of complications such as over-instrumentation (3), extrusion of root canal filling materials beyond the apex, and damage to periapical tissues (4). During mechanical preparation, the three-dimensional shape and pathways of root canals are modified, which can cause slight variations in total canal length (5). Therefore, continuous monitoring of the working length (WL) is essential for preventing over-instrumentation and ensuring precise preparation (3, 6-9). Recent innovations in endodontic technology have provided innovative solutions to address the challenges of maintaining precise apical control (5). Endodontic motors with integrated electronic apex locator have been developed with the intention of simplifying and accelerating root canal treatment (6). These advanced systems provide numerous options for motions, angles, speeds, and apical control functions, while continuously monitoring and maintaining the apical limit during the mechanical preparation (10). This precision minimizes the risk of over-instrumentation and associated complications, fostering predictable treatment outcomes (1, 2). One useful apical function is the auto apical reverse technology (AAR) which automatically stops and reverses the rotation upon reaching the specified apical limit (6, 11, 12). This function has been deeply tested and its precision have been demonstrated ex-vivo on several endodontic motors (6, 10, 13). A recent innovation is the improved version of the Optimum Apical Stop (OAS2) technology which automatically perform twice reciprocating rotations of ± 180° before stopping the motion at a pre-set apical level, disengaging the flutes of the endodontic instrument, thereby preventing jamming or tip lock.

A recent ex-vivo study evaluated the performance of two endodontic motors in controlling the apical extent of root canal preparation compared to the visual determination of WL (3). The findings demonstrated that OAS or AAR functions successfully prevented over-instrumentation, maintaining precise control over the apical extent. The original OAS system improved root canal preparation with controlled reversing movements to prevent over-instrumentation, but depended on the cutting direction of the file, therefore limiting versatility. The OAS2 system advanced this concept with bidirectional reciprocation (+180°/-180°), enhancing control, safety, and compatibility with modern endodontic file systems. Despite these promising findings, to the best of our knowledge, no data exist on the reproducibility of WL measurements and the safety and success of the improved OAS2 function during routine clinical practice. Furthermore, no standardized protocol has been proposed for clinicians to incorporate this function into a simplified workflow to optimize shaping of the apical third.

Thus, this study aimed to introduce a protocol that leverages advanced motor-driven endodontic technology to simplify and accelerate traditional procedures by integrating an automated apical control function (i.e., OAS2) with contemporary instrumentation systems and compatible obturation materials. The purpose of this report is to propose a technique to lay the groundwork for future validation through more extensive research.

## Case Report Informations

The present report was conducted in accordance with the 2020 Preferred Reporting Items for Case Reports in Endodontics (PRICE) guidelines (14).

Three consecutive patients who presented with the need for endodontic treatment were treated by an experienced endodontist in a private dental office in Milan, Italy, using a novel, simplified protocol for root canal shaping.

The affected teeth were a mandibular right first premolar (4.5; Case A; Figure 1), a maxillary right first molar (1.6; Case B; Figure 2), and an upper third molar (1.8; Case C; Figure 3). Case A was affected by "irreversible pulpitis", Case B was affected by "symptomatic apical periodontitis", while Case C was a previously initiated therapy (15).

*Patient Evaluation*

Upon obtaining informed consent for further evaluation, a review of the patients' non-contributory medical histories was conducted. The three referred patients were a 28-year-old female (A), a 32-year-old male (B), and a 52-year-old male.

Comprehensive oral and dental examinations were performed after gathering dental histories. The clinical examination revealed no abnormal extraoral findings, and all the neighboring teeth exhibited normal responses to cold [using 1,1,1,2-tetrafluoroethane (Endo-Ice; Coltène/Whaledent Inc, Cuyahoga Falls, OH)], percussion, and palpation tests, except for the tooth scheduled for treatment. Pre-operative periapical radiographs were taken using the long cone paralleling technique with a film holder and a beam-aiming radiographic unit (Nomad Pro 2; KavoKerr, Biberach, Germany) operating at 60 kV and 7 mA. Case A presented with pain and swelling in the area of interest, along with a positive, painful response to cold stimuli, and showed a slight enlargement of the periodontal ligament space without periapical radiolucency (Figures 1 and 3), confirming the diagnosis of "irreversible pulpitis." (15). Case C presented with pain and swelling in the area of interest, as well as a positive, painful response to cold stimuli. There was a slight enlargement of the periodontal ligament space without periapical radiolucency. Treatment was previously initiated; however, due to the complexity of the case, the patient was referred to the clinic to finalize the therapy. The tooth was temporarily sealed with Cavit (3M ESPE, Seefeld, Germany) by the previous dentist.

In contrast, case B, which presented a history of intermittent pain, pain on percussion, and a negative response to the cold test, showed slight periapical radiolucency in the mesial root (Figure 6), confirming the diagnosis of "symptomatic apical periodontitis" (15).

*Procedure*

The endodontic treatments were executed under local anesthesia (lidocaine 2% with epinephrine 1:100.000) with rubber dam isolation (Swedent, medium, Stockholm, Sweden). The whole procedure was conducted under magnification (Leica M320, Leica Microsystems, Wetzlar, Germany) at x8 magnification level. The access cavity was prepared with a high-speed round diamond bur (Komet Dental, Lemgo, Germany) and refined using an ultrasonic tip Start-X #3 (Dentsply Sirona, York, PA, USA). Afterwards, root canal instrumentation was conducted using the Morita Tri Auto ZX2+ motor, featuring the apical stop function OAS2 technology.

Root canal instrumentation was performed with the Tri Auto ZX2+ motor, setting the apical function OAS2 and the optimum torque reverse (OTR) motion selecting the following parameters on the meter display: speed at 300 rpm, "auto start" on, "auto stop" off, a rotation angle of 180°, and trigger torque at 0.2 N·cm and the "0.5" position.

Root canal shaping began with VDW. ROTATE sequence (VDW GmbH, Munich, Germany) with instruments of sizes 15, 20, and 25, advanced slowly inside each canal until the motor's apical action stopped the motion (3). This was followed by refinement using ProTaper Ultimate F2 and F3 instruments (Dentsply Maillefer, Ballaigues, Switzerland) to conclude the shaping process.

To evaluate instrument fit, the flutes of the final rotary file were examined for debris, ensuring conformity to the canal's shape and dimensions. Debris-filled flutes indicate a proper match between the instrument and the canal's dimensions, indicating no need for a larger instrument to achieve further canal shaping.

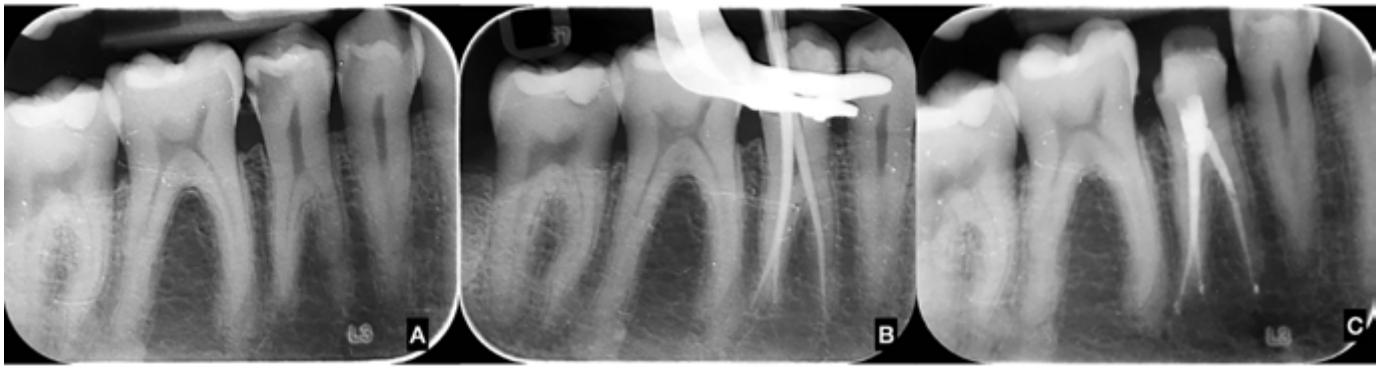


**Figure 1.**
A 28-year-old female patient pre-operatory X-ray. The patient presented with throbbing pain to the lower right quadrant. Clinical examination found no abnormal extraoral findings. All lower arch teeth responded normally to diagnostic tests, except for the right mandibular second premolar, which exhibited sensitivity to cold stimuli. **A)** The periapical radiograph shows a deep distal caries and a slight enlargement of the periodontal ligament space without periapical radiolucency, confirming the diagnosis of "irreversible pulpitis". **B)** Intra-operatory X-ray. **C)** Post-operatory X-ray showing the precision of the technique.

Each canal was irrigated with 20 mL of 5.25% sodium hypochlorite (NaOCl; Ultradent Products, South Jordan, UT, USA) over five minutes using an irrigating needle (IrriFlex; PD Produits Dentaires, Switzerland) positioned approximately 1 mm from the root apex and activated with an ultrasonic activator (EndoActivator, Dentsply Sirona, York, PA, USA). Final irrigation was performed using 5ml of 17% EDTA (CanalPro; Coltene-Endo, Cuyahoga Falls, OH, USA) to remove the smear layer, followed by 5ml of 5.25% NaOCl (2).

The canals were dried with sterile paper points (VDW GmbH, Munich, Germany). Before obturation, an intra-operative X-ray was taken to confirm the precision of apical preparation and the adequacy of the apical seal (Figure 4).

Root canal obturation was achieved performing a single cone technique using ProTaper Ultimate gutta-percha cones conform fit (Dentsply Maillefer, Ballaigues, Switzerland) in combination with a hydraulic calcium silicate-based materials (BioRoot RCS, Septodont, Saint-Maur-des-Fossés, France), ensuring a hermetic seal.

*Postoperative Results*

Post-operative results were assessed through a combination of clinical evaluation, periapical radiographs, and patient-reported outcomes (e.g., post-operative comfort and functionality) at 1, 3, 6 months, and 1 year.

For Cases A and C (irreversible pulpitis and previously initiated therapy), the primary outcome measure was identified as the patient-reported outcome measure of 'tooth survival'(2). Additional critical outcomes included 'pain, tenderness, swelling, and need for medication (analgesics)', 'tooth function' (assessed through fracture and restoration longevity), 'need for further intervention', and 'adverse effects' (such as exacerbation, restoration integrity issues, and allergy). Clinician-reported outcome measures included 'evidence of emerging apical radiolucency' and 'presence of sinus tract' (16).

For Case B (Apical Periodontitis), the most critical outcome measure was identified as 'tooth survival'(2). Other critical outcomes included 'pain, tenderness, swelling, and need for medication (analgesics or antibiotics)', as well as radiographic outcomes, using loose and strict criteria, such as 'evidence of reduction in apical lesion size' (using loose criteria) and 'normal periodontal ligament space' (using strict criteria) (16). Precisely, the term loose criteria refers to a partial radiographic healing, defined as a reduction in the size of the apical radiolucency compared to baseline, while strict criteria require complete resolution of the radiolucency and restoration of a normal periodontal ligament space. These definitions are consistent with the recommendations of the European Society of Endodontology (ESE) (16). Additionally, other important outcomes were noted, including 'tooth function' (evaluated through fracture and restoration longevity), 'need for further intervention', 'adverse effects' (such as exacerbation, restoration integrity issues, or allergy), and the 'presence of a sinus tract'.

The ESE recommended observation pe-

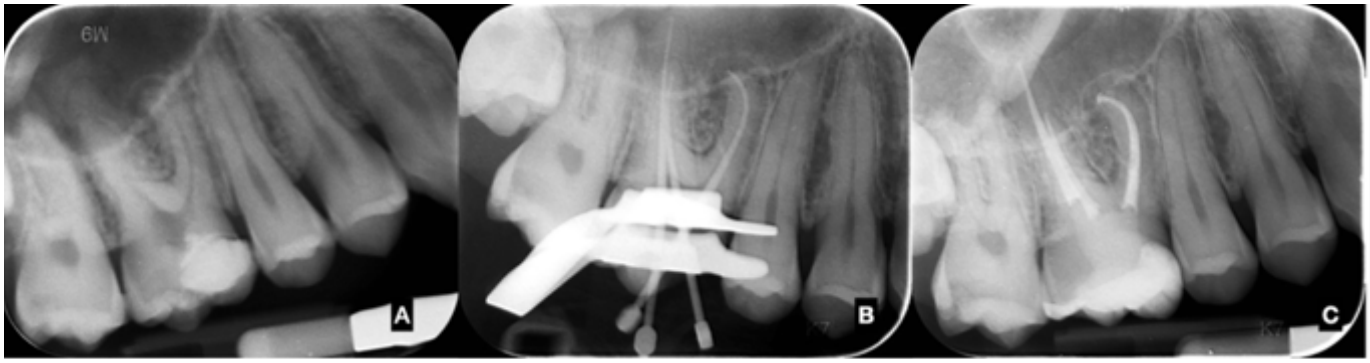


**Figure 2.**
**A)** 32 years old patient with symptomatic apical periodontitis with a history of intermittent pain, pain on percussion, and a negative response to the cold test, showed slight periapical radiolucency in the mesial root. **B)** Intra-operatory radiograph and **C)** post-operatory radiograph showing the positive radiographic outcome.

riods for these outcomes. For all outcomes except 'pain, tenderness, swelling, and need for medication (analgesics)', a minimum follow-up of 1 year and a maximum of 'as long as possible' was advised. For 'pain, tenderness, swelling, and need for medication (analgesics)', the observation period was set to a minimum of 7 days and a maximum of 3 months (16).
Overall, the chair time was 53,3 ± 6.2 minutes. Postoperative radiographs confirmed precise apical seals with no signs of over-instrumentation.
For all the cases, the primary patient-reported outcome measure of 'tooth survival' was fully met. Postoperative evaluations conducted at 1, 3, 6 months and 1 year revealed complete healing in all three cases (Case A, Case B, and Case C), as evidenced by the successful achievement of all defined outcomes. Additionally, all critical outcomes were satisfied, including the absence of sinus tract, pain, tenderness, swelling, or need for medication (analgesics), and presence of restored 'tooth function' (with no fractures or issues with restoration longevity) (Figure 9). For Case A and B clinician-reported outcomes confirmed the absence of 'evidence of emerging apical radiolucency'. For Case C radiographic assessments demonstrated complete resolution of apical lesions, meeting both 'evidence of reduction in apical lesion size' (loose criteria) and 'normal periodontal ligament space' (strict criteria) (17).
Overall, the findings align with the recommendations of ESE regarding the observation periods for these outcomes. The absence of clinical symptoms and radiographic evidence of pathology at the final follow-up underscores the efficacy of the treatments across all three cases.

## Patient Perspective

All three patients reported a positive overall experience with the treatment protocol. They appreciated the streamlined nature of the procedure, particularly the reduced chair-time and minimal post-operative discomfort. Notably, none of the patients experienced post-operative pain at any point, and all reported immediate comfort following the procedure. The clarity of communication regarding each treatment step, combined with the use of advanced technology, contributed to a heightened sense of trust and confidence in the clinical process. Patients noted significant improvement in symptoms shortly after the procedures and expressed satisfaction with the functional and aesthetic outcomes. At follow-up visits, all patients emphasized their comfort during the interventions and reported a high level of satisfaction with both the treatment experience and the clinical results.

## Discussion

The present study introduces a novel and simplified protocol for root canal shaping, highlighting the effective integration of the OAS2 apical function of the Morita Tri Auto ZX2+ motor, the ProTaper Ultimate system, and conform fit gutta-percha cones in order to achieve precise apical preparation and obturation. This strategy seeks to streamline procedures, reduce

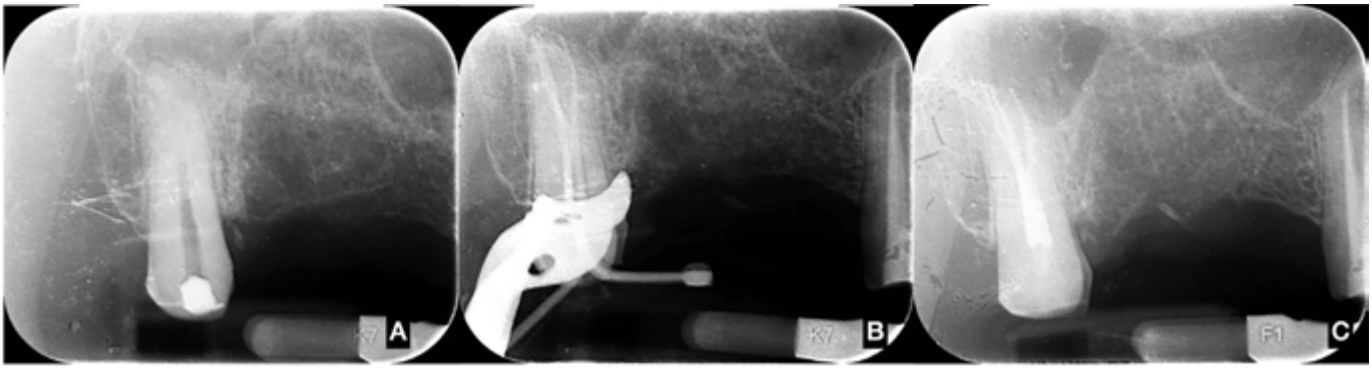


**Figure 3.**
A 52-year-old male patient with a previously initiated therapy on the upper right third molar **A)** Pre-operatory periapical radiograph of the the tooth showing Cavit (3M ESPE, Seefeld, Germany) and a partial endodontic therapy, requiring further treatment. **B)** Intra-operatory periapical radiograph showing a complex anatomy with three canals. **C)** Postoperative periapical radiograph demonstrating a favorable immediate radiographic outcome.

treatment time, and minimize the risk of over-instrumentation. To the best of our knowledge, this represents the first report to integrate the use of OAS2 to offer an easily applicable workflow to implement in everyday practice, posing the bases for further research.

These results support the clinical viability of the proposed workflow and should be interpreted within the context of existing evidence. The patients reported no postoperative complications. A six-month follow-up showed complete resolution of symptoms, confirming the success of the treatment protocol.

By using controlled reversing movements to avoid over-instrumentation, the original OAS technique significantly facilitate root canal preparation. When it reaches the apical endpoint, the motor reverses 180° to 360° in the cutting direction before stopping, reducing apical binding and limiting risks of file overextension. Although efficient, this mechanism was depended on the cutting direction of the file, limiting its versatility. Additionally, the single reversal motion, although suitable for many cases, may not be able to handle more complex root canal anatomies, such as curved or narrow canals. In light of these limitations, the OAS2 system introduced a refined mechanism that employs bidirectional reciprocating movements to enhance control and safety. Before stopping, the motor performs two alternating rotations of +180° clockwise and -180° counterclockwise. This bidirectional reciprocation is independent of the file's cutting direction, making the system compatible with a broader range of file designs and clinical scenarios. The repeating motion of OAS2 reduces the possibility of instrument separation by more equally distributing mechanical stress along the file in addition to more successfully disengaging the file from apical binding. These features provides significant benefits. In addition to increasing flexibility in curved or calcified canals, the alternating action lowers the possibility of procedural mistakes like over-instrumentation or debris extrusion. Additionally, by eliminating the dependence on cutting direction, OAS2 facilitates integration with modern file systems, increasing versatility and efficiency in clinical practice. In summary, OAS2 refines the capabilities of OAS, moving from basic reversing movements to advanced reciprocating motions, thus improving safety, precision, and compatibility for modern endodontic treatments.

To the best of our knowledge, no studies have evaluated the efficacy of OAS2. However, a previous investigation (2) demonstrated that the combination of OTR motion and OAS achieved remarkable apical accuracy, with 75% of cases falling within the highly precise 0.0 to -0.5 mm range from the apical foramen. This level of accuracy surpassed other combinations, such as OTR with AAR, or the use of continuous rotation with AAR or OAS, which yielded success rates below 50%. This closer approximation to the apical foramen with OTR motion and OAS may be attributed to the algorithm controlling the instrument tip position which triggers the apical function and the torque control mechanism initiating reciprocating motion (3). An-

other ex-vivo study compared the precision of the electronic apex locator and automatic apical stop (AAS) function capabilities of Morita Tri Auto ZX+ and another cordless apex locator in determining WL. The results indicated consistent and accurate measurements with neither device exceeding nor falling short of the critical 1 mm margin crucial for successful endodontic treatments (10).

In contrast to AAS, which primarily halts movement based on WL, OAS2 not only stops the file but actively disengages it from apical binding through its reciprocating action. This lowers the chances of file separation and guarantees safer operation, especially in difficult situations involving curved or narrow canals. Moreover, OAS2 is not affected by the cutting direction of the file, therefore it is more adaptable and compatible with a wider range of file systems.

Furthermore, following the use of any NiTi systems, refining canal preparation with ProTaper Ultimate F2 and F3 instruments offers geometric advantages (5), such as a progressive taper design that improves canal shaping consistency and makes cleaning and debris removal easier. The instruments' cross-sectional design and cutting efficiency improve dentinal debris removal, enhance irrigation efficacy, and reduce the risk of canal transportation (18). The precise tip sizes and tapers of F2 and F3 instruments ensure a tight apical seal, minimizing apical leakage. In the end, using dedicated ProTaper Ultimate conform fit gutta-percha cones improves obturation quality even more and ensure a reliable seal that effectively prevents reinfection.

It is well known that the WL can vary across different stages of chemo-mechanical preparation (19). Traditionally, the WL was determined manually, leading to errors such as inaccurate length identification, lack of parallelism during measurements, and extended chair-time. In contrast, integrating EALs into endodontic motors allows continuous monitoring of file position throughout treatment, eliminating the need for recalibration (3). It has been demonstrated that when the therapeutic procedures were shorter than 2 mm from or past the radiographic apex, the success rate for infected canals was approximately 20% lower than that when the procedures terminated at 0 to 2 mm (20). Furthermore, a large body of evidence demonstrated that it is clinically preferable to fall slightly short of the actual length rather than exceed it, as the latter is more likely to lead to unfavorable outcomes (2, 6, 8, 13, 21). The present protocol eliminates the chances of over-instrumentation. In accordance with previous studies, in this workflow all measurements were performed using the "0.5" display mark to determine working length, with manufacturers claiming that this displays mark indicate the position of the apical constriction, which in reality it is an arbitrary indicator of the apical position of the file (6, 22, 23). An important clinical observation across all three cases was the complete absence of postoperative pain, as reported by the patients during follow-up. This favorable outcome may be attributed not only to the precise apical control achieved through the OAS2-guided instrumentation, which minimizes apical extrusion and tissue trauma, but also to the use of a hydraulic calcium silicate-based sealer which have been shown to possess excellent biocompatibility, anti-inflammatory properties, and the ability to promote periapical healing. Their low cytotoxicity and excellent sealing ability may significantly reduce the incidence of immediate postoperative discomfort as demonstrated in a previous study (24). Therefore, the combination of a conservative, controlled preparation technique and the use of a hydraulic calcium silicate-based materials likely contributed to the patients' immediate postoperative comfort and absence of pain.

This simplified approach to root canal treatment seeks to drastically cut down on treatment time compared to traditional methods. These new sophisticated features automate critical steps in canal preparation, reducing the need for manual adjustments and recalibrations. This automation not only improve accuracy, but also saves chair-time.

The present protocol presents several limitations, particularly concerning the accuracy of electronic apex locators, which can be influenced by factors such as cervical flaring, tooth length, instrument size, anatomical variations, irrigating solutions, and canal contents. Furthermore, previous research has highlighted that integrated motors like the Tri Auto ZX2+ may be affected by variables such as the presence of gutta-percha (25), the use of 0.9% saline as an irrigating solution (26), and the choice of the apical mark (26, 27). Another limitation is that all cases were performed by a single expert operator, without accounting for different levels of operator experience. Further research is necessary to fully assess how different conditions, such as variations in shaping instruments, motor settings, operator expertise, and tooth anatomical variations, may affect the performance of this motor system. Moreover, future studies should rigorously examine the clinical effectiveness of this new shaping protocol across a range of clinical scenarios and analyze and comprehend its performance under controlled conditions.

## Conclusions

This protocol has the potential to accelerate and streamline endodontic procedures, resulting in reduced chair time and enhanced procedural simplicity. Further research is needed to investigate its benefits across larger sample sizes and test different operator experience levels.

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# SIE 2025 - CADAVER LAB PLUS

## TRA ISTMI, CANALI E RADICI

*Un Viaggio nella Microchirurgia Endodontica*

- 19-20 Settembre 2025
  Mikros Srl
  Milano - Viale Thomas Alva Edison, 621, 20099 Sesto San Giovanni

- 10-11 Ottobre 2025
  Università degli Studi di Siena
  Reparto di Otorinolaringoiatria

40° CONGRESSO NAZIONALE

Società Italiana di Endodonzia

# CLINICAL MATCH POINT

## IDEE, SFIDE, CAMBIAMENTI

20/22 NOVEMBRE 2025
VERONA

# READY TO WORK

## CONSULENTE CERTIFICATO SIE

Conoscenze, abilità e competenze:
tutto ciò di cui hai bisogno per lavorare.

**CORSO CERTIFICATO** il tuo migliore biglietto da visita

## Il corso che mancava e di cui hai assolutamente bisogno

- 5 incontri di 1 giorno e mezzo
- 3 sedi (nord, centro e sud)
- certificazione rilasciata da un Ente Esterno
- +50% di HANDS ON
- 13 webinar
- "What if?" e "Good to know" : le sessioni che ti insegneranno a risolvere problemi e difficoltà

# Lettera DEL PRESIDENTE

Cari Soci e Care Socie,
è con grande piacere che vi scrivo per condividere con voi i risultati del nostro recente Closed Meeting, un evento che ha saputo coniugare momenti di crescita associativa, impegno culturale e scientifico, e momenti di condivisione professionale e personale.
Il Venerdì mattina abbiamo dato il via ai lavori con un incontro particolarmente significativo che ha visto riuniti tutti i componenti delle nostre commissioni. La riunione plenaria è stato un momento di scambio vivace e costruttivo, che ha dimostrato quanto sia prezioso il contributo di ciascuno di voi alla vita della nostra Società.
Nel pomeriggio del Venerdì si è svolta l'Assemblea Straordinaria, momento particolarmente atteso e durante la quale abbiamo: - Completato il nostro Consiglio Direttivo con l'elezione dell'ottavo membro nella persona del Prof. Michele Simeone. - Nominato il quarto componente della Commissione Accettazione Soci, Dott. Gennaro Ferraioli. - Approvato importanti modifiche statutarie illustrate in modo dettagliato dal consulente giuridico Dottor E. Montefiori collegato via zoom con l'assemblea, modifiche che rendono la nostra Società più efficiente e dinamica.
Non sono mancati i momenti di relax in piscina o in spa che si sono alternati ai momenti di lavoro nel corso della giornata. La sera del Venerdì si è conclusa con l'elegante cena presso l'hotel Silva Splendid, bellissima location immersa nella cornice della città dei Papi.
La giornata del Sabato si è aperta con le sessioni culturali, interventi di alto livello, dove si sono potute approfondire sia tematiche strettamente cliniche nonché argomenti di gestione dello studio professionale di grande attualità ed interesse per la nostra attività.
Particolarmente interessante, il Sabato pomeriggio, è stata senza dubbio l'escursione al Monastero di Trisulti, un'oasi di pace e cultura che ci ha permesso di staccare la spina e apprezzare la bellezza e la storia del territorio.
Indimenticabile la Cena Sociale del Sabato sera tenutasi presso il Casale VerdeLuna un esclusivo Wine Resort immerso nella natura, tra le colline e la bellezza dei vigneti di Piglio, dove nasce il vino Cesanese DOCG del Lazio. In un'atmosfera di autentica convivialità e aggregazione, apprezzando la gastronomia locale, abbiamo potuto scambiare idee, esperienze, proposte che saranno oggetto di ispirazione per eventi societari futuri. Un grazie particolare a tutti coloro che erano presenti a Fiuggi ed hanno reso speciali i vari momenti del nostro Closed Meeting. Desidero ancora ringraziare tutti i componenti del Consiglio Direttivo e la Segreteria esterna MV per l'organizzazione e la cura nella gestione professionale di tutti i dettagli dell'assemblea elettiva. Questo Closed Meeting ci ha dimostrato come quando una comunità scientifica sa unire competenza professionale e valori umani, si possono raggiungere significativi risultati. Colgo l'occasione per condividere con voi alcuni dei prossimi eventi formativi che la SIE ha ideato per rispondere alle vostre esigenze professionali.
Il percorso per Consulente Certificato SIE, iter formativo avanzato, rivolto soprattutto ai giovani professionisti, che combina teoria e pratica clinica e disponibile in tre sedi del nord, centro e sud Italia. Il corso avrà inizio ad Ottobre. Al termine del percorso, i partecipanti otterranno una certificazione di eccellenza riconosciuta, un vero e proprio sigillo di qualità per la carriera professionale.
Altro evento innovativo è il Cadaver Lab Plus SIE che si articolerà in due momenti distinti ma complementari: il 19-20 Settembre a Milano sarà dedicato all'uso del microscopio operatorio in endodonzia chirurgica in tutti i suoi aspetti pratici, per arrivare quindi preparati al Cadaver Lab vero e proprio che si terrà a Siena il 10-11 Ottobre. Il corso unico nel suo genere è dedicato a chi desidera avvicinarsi o perfezionarsi nelle tecniche di microchirurgia endodontica. Un'esperienza pratica di altissimo livello, pensata per chi cerca l'eccellenza nella pratica clinica.
Vi invito quindi a partecipare numerosi al Congresso Nazionale SIE, che si terrà a Verona il 21-22 Novembre e che esordirà in un format congressuale innovativo, quello del Clinical Match, con relatori di fama internazionale e sessioni interattive che trasformeranno il classico congresso in un'esperienza coinvolgente e dinamica.
Sarà l'occasione perfetta per confrontarci sulle ultime frontiere dell'endodonzia, crescere insieme come professionisti e rafforzare il senso di appartenenza alla nostra comunità La SIE è la vostra Società, e ogni vostra proposta costruttiva e innovativa sarà preziosa per renderla sempre più rappresentativa e al servizio di tutti.
Con l'augurio di rivederci presto, invio un caro saluto.

Il Presidente della Società Italiana di Endodonzia,
**Francesco Maggiore**

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# COME DIVENTARE SOCIO ATTIVO/AGGREGATO

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

## SOCIO AGGREGATO

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

### DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO AGGREGATO

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

## SOCIO ATTIVO

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

### DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO ATTIVO

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

## MODALITÀ DI DOCUMENTAZIONE DEI CASI CLINICI

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

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

## CRITERI DI VALUTAZIONE

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

## ADEMPIMENTI DEL CANDIDATO

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

## PRESENTAZIONE DEI CASI ALLA COMMISSIONE

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

## LA COMMISSIONE ACCETTAZIONE SOCI

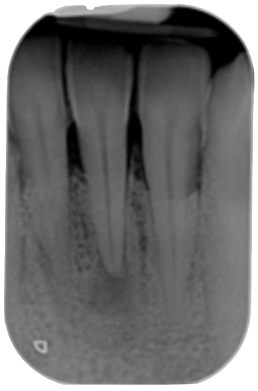
La CAS (Commissione Accettazione Soci) è formata cinque Membri di indiscussa esperienza clinica, quattro Soci Attivi con almeno cinque anni di anzianità in questo ruolo eletti a ogni scadenza elettorale dall'Assemblea dei Soci Attivi e Onorari e uno dei Past President della Società incaricato dal CD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

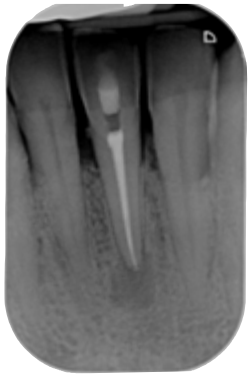
## MEMBRI DELLA COMMISSIONE ACCETTAZIONE SOCI BIENNIO 2025-26

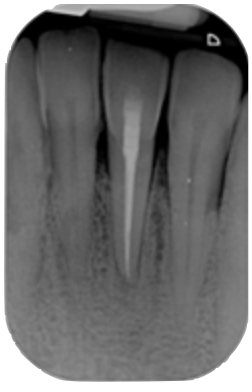
**Francesco Riccitiello**
**Maurizio Boschi**
**Marco Colla**
**Claudia Dettori**
**Giuseppe Multari**

# Ceraseal

## Obturation is a Fundamental Pillar in Endodontic Success







Courtesy of Dr Claudio Farnararo

1 Y

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

### Ceraseal: The Next Generation of Bioceramic Sealers

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

### Superior Bioactivity

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

### Unmatched Biocompatibility

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

### Hermetic Sealing & Dimensional Stability

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

### User-Friendly and Efficient Application

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

### Conclusion

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

# EdgeEndo®:

## *una Evoluzione nell'Endodonzia*


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

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

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

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

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


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

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

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

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# GUIDELINES FOR AUTHORS

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

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

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

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

## Ethical guidelines

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

## Authorship and Acknowledgements

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

## Manuscript preparation

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

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

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

## Manuscript Types Accepted

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

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

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

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

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

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

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

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

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

## 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.
Technical **jargon** should be avoided as much as possible and clearly explained where its use is unavoidable. **Abbreviations** should also be kept to a minimum, particularly those that are not standard. Giornale Italiano di Endodonzia adheres to the conventions outlined in *Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors.* If abbreviations are used in the text, authors are required to write full name+abbreviation in brackets [e.g. Multiple Myeloma (MM)] the first time they are used, then only abbreviations can be written (apart from titles; in this case authors have to write always the full name). If names of equipments or substances are mentioned in the text, brand, company names and locations (city and state) for equipment and substances should be included in parentheses within the text.
The **background** and **hypotheses** underlying the study, as well as its main conclusions, should be clearly explained.
Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

**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.
Title Page should bear:

I. Title, which should be concise as well as descriptive (no more than 150 letters and spaces);
II. Initial(s) and last (family) name of each author;
III. Name and address of department, hospital or institution to which the work should be attributed;
IV. Running title (no more than 30 letters and spaces);
V. Three to five key words (in alphabetical order);
VI. Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence (Corresponding Author).

**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.

**Abstract for Systematic Review Articles** should be divided into Aim, Methodology, Result, Conclusion.
**Aim**: Provide an explicit statement of the main objective(s) or question(s) the review addresses.
**Methodology**: Specify the inclusion and exclusion criteria for the review, the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched. Specify the methods used to assess risk of bias in the included studies and the methods used to present and synthesis of studies.
**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.

**Abstract for Case Reports** and **Case Series** 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.
**Summary:** describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and analysis if any.
**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.
**Introduction**: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.
**Material and Methods** must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.
*(I) Clinical Trials: should be reported using the CONSORT guidelines available at www.consort-statement.org A CONSORT checklist and flow diagram (as a Figure) should also be included in the submission material.*
*(II) Experimental Subjects:* experimentation involving **human subjects** will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used. When **experimental animals** are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations. All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.
*(III) Suppliers* of materials should be named

and their location (Company, town/city, state, country) included.
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British Endodontic Society - Guidelines for root canal treatment. Giornale Italiano di Endodonzia 1979;16:192-5.

*Journal supplement*
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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.

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