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"Sealing the Deal: A Comparative Evaluation of Immediate and Delayed Post Space Preparation Techniques on Apical Microleakage- An In vitro Study"

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KEYWORDS

Apical microleakage, Post space preparation, Gutta-percha, Endodontic seal

ABSTRACT:

Background:

Successful endodontic therapy relies not only on proper cleaning, shaping, and obturation of the root canal system but also on maintaining a fluid-tight apical and coronal seal. Post space preparation, if not carefully executed, may disrupt the apical seal and compromise long-term success. This in vitro study compares the extent of dye microleakage following immediate and delayed post space preparation techniques.

Materials and Methods:

Eighty extracted human maxillary central incisors were decoronated and divided into four groups (n=20 each). Groups 1 and 2 underwent obturation with cold lateral condensation using gutta-percha and AH Plus sealer. Group 1 (IAC) had immediate post space preparation after obturation, while Group 2 (DAC) underwent delayed preparation after 48 hours. Group 3 served as the positive control (unobturated), and Group 4 as the negative control (fully sealed). Dye infiltration using Indian ink was assessed from apical to coronal direction after clearing and decalcification. Microleakage was measured under a stereomicroscope, and data were analyzed statistically using unpaired t-test and Mann-Whitney U-test.

Results:

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Mean dye penetration was 0.2000 mm in IAC and 0.2170 mm in DAC groups. Although Group DAC showed slightly higher leakage, the difference was statistically insignificant ($p > 0.05$).

Conclusion:

Both immediate and delayed post space preparation techniques preserved the apical seal effectively when 5 mm of gutta-percha was retained. Timing of post preparation had no significant impact on apical microleakage, emphasizing the importance of maintaining adequate apical filling regardless of technique.

Introduction:

Preserving natural teeth with function and esthetics is the central goal of endodontic and restorative dentistry. Following root canal therapy, the structural integrity of the tooth is compromised, necessitating reinforcement to restore function and prevent fracture.. A post and core system helps retain the final crown by anchoring to the remaining tooth structure, especially when substantial coronal loss is present.

While the post does not enhance the fracture resistance of an endodontically treated tooth, it serves to retain the core buildup that supports the definitive crown. Success depends not only on effective cleaning, shaping, and obturation but also on a well-executed restoration that integrates with the dental arch to restore function and prevent failure.[(1] Within endodontics, obturation is particularly significant, as it directly influences the prevention of microbial leakage and the prognosis of the treated tooth. Obliteration of the root canal space with an inert filling material, creation of fluid tight seal and elimination of any portal entry or exit to periapical tissues have been proposed as goals for successful endodontic treatment[2]

An adequate seal of the root canal is necessary to prevent ingress & accumulation of irritants which could cause biological breakdown of the attachment apparatus. Dennis Donley reported that nearly 60% of root canal failures were caused by incomplete obturation of the root canal system.[3]

As Schilder emphasized, the objective of root canal therapy is the complete three-dimensional filling of the root canal system, including accessory canals. Proper obturation plays a critical role in the long-term success of endodontic treatment.

The main purposes of obturation include:

1. Complete obliteration of the root canal space to prevent the entry of bacteria and body fluids.
2. Achieving a fluid-tight seal to avoid microleakage.
3. Obturation involves the complete filling of the prepared root canal system with an inert and biocompatible material to prevent microbial reinfection.
4. By sealing the canal space with a dimensionally stable, non-reactive material, obturation aims to eliminate potential pathways for bacterial ingress and ensure long-term periapical health.

The apical constriction is a crucial anatomical landmark, offering natural resistance and retention during obturation. Proper shaping and preservation of this region help resist the condensation forces and reduce the risk of material extrusion, even in cases of anatomical complexity or pathological resorption.[4]

Despite the availability of several obturating materials, gutta-percha continues to be the material of choice owing to its adaptability, inert nature, and proven clinical efficacy. Several techniques using gutta percha have been used in an attempt to achieve a three dimensional fluid tight seal. The cold lateral condensation method is still one of the most frequently used technique. Advancements in obturation techniques have led to the introduction of thermoplasticized gutta-percha systems, which are designed to provide superior sealing by better conforming to the internal anatomy of the root canal. Obturation system have been developed using heat softened gutta percha delivered via injection

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or with a carrier which delivers heat to cold gutta percha cones[5]

Microorganisms can persist within dentinal tubules even after thorough chemomechanical preparation.[6] One important purpose of obturation is to block the migration of these microbes and their toxins from the oral cavity to periradicular tissues. An effective apical seal prevents residual microorganisms from reaching the periapical area and halts reinfection. To achieve this, the root canal must be tightly sealed using gutta-percha cones and endodontic sealers, effectively blocking dentinal tubules and accessory canals.[7]

Achieving a hermetic seal at both the apical and coronal ends of the root canal is a major goal of endodontic treatment. One of the most frequent causes of failure is leakage due to an inadequate apical seal.[8] This seal can be affected by factors such as obturation technique, sealer properties, and the presence of a smear layer.[6]

When the apical seal is insufficient, proteins, enzymes, and salts from the bloodstream may percolate into the canal, leading to periapical inflammation. To prevent this, the obturation must ensure a fluid-tight, dimensionally stable, and biologically inert seal at the apex.[8]

Root canal sealers, used with core materials like gutta-percha, serve to fill voids, ensure adhesion to canal walls, and form a tight seal.[8] Over time, different sealers have been evaluated for their sealing abilities. According to Grossman, ideal sealers should provide a hermetic seal, be non-irritating, insoluble in tissue fluids, allow sufficient working time, and be biologically compatible with periapical tissues.[8]

According to Timpawat et al., endodontic sealers are used to eliminate the interface between gutta-percha and dentinal walls.[6] However, leakage pathways can exist along the dentin–sealer interface, the sealer–gutta-percha interface, or through voids and defects within the sealer. Therefore, the overall quality of obturation largely depends on the sealing ability of the sealer.[6]

The effectiveness of post and core restorations is well supported in dental literature.[9,10] The process begins with the removal of gutta-percha from the root canal,[11] a step that can potentially affect the integrity of the apical seal. Critical factors influencing this outcome include post length, the amount of remaining gutta-percha, and the technique used for post preparation.[7] An ideal removal technique should be safe, efficient, and maintain both apical and coronal seals.[11]

Two common approaches to post space preparation are the immediate and delayed techniques. In the immediate method, gutta-percha is removed right after obturation using heated pluggers, whereas the delayed method involves removal after two days, allowing the sealer to set.[7]

Successful endodontic outcomes depend on the sealing capacity of obturation materials, which should remain unaffected by post preparation methods.[12] However, no material has proven completely resistant to apical leakage.[13] Whether from apical plasma seepage or coronal saliva contamination, leakage may lead to microbial colonization and eventual failure of treatment.[7] This study explores dye infiltration associated with both immediate and delayed post space preparation to assess their effect on apical-to-coronal sealing.

Aim:
To evaluate dye infiltration from apical to coronal using immediate and delayed post space preparation techniques.

Objective:
To compare apical-to-coronal dye infiltration between immediate and delayed post space preparation.

MATERIALS AND METHODS

The present in vitro study was conducted in the Department of Conservative Dentistry & Endodontics. The instruments and materials used are listed below:

The materials and instruments used in this study were categorized as follows: decoronation instruments included a wheel diamond disc and a straight handpiece. For access cavity preparation and biomechanical cleaning, an airotor and contra-angle micromotor handpiece were used along with burs, diamond points, K-files (sizes 15–80), Gates Glidden burs, barbed broaches, saline irrigation needles, 5.25% sodium hypochlorite, and 17% EDTA. Obturation was performed using a spatula, paper pad, lentulospiral, paper absorbent points, AH Plus sealer, finger spreader, plugger, and gutta-percha points. For tooth surface preparation and dye leakage assessment, materials like nail varnish, sticky wax, Indian ink dye, 11% nitric acid, and graded concentrations of ethyl alcohol (65% to 100%) along with methyl salicylate were used. Dye leakage evaluation was done using a stereomicroscope.

COLLECTION OF SAMPLES

A total of 80 extracted human maxillary central incisors were collected from the Department of Oral and Maxillofacial Surgery. All teeth were stored in **4% formalin** solution until use.

Inclusion Criteria

- Fully formed apices
- Straight root canals

Canal Preparation and Obturation:

All teeth were decoronated using a diamond disc under water cooling to standardize the root length to 15 mm. A #15 K-file was inserted until it reached the apical foramen and then withdrawn 1 mm to establish the working length.

Root canal instrumentation was performed using the step-back technique, enlarging up to #55 K-file at the apex. 5.25% sodium hypochlorite was used for irrigation throughout the procedure, replenished with each file change. Apical patency was confirmed by introducing a #15 K-file 1 mm beyond the apex after preparation.

Canals were finally irrigated with 5 ml of 5.25% sodium hypochlorite and dried using #55 paper points.60 teeth were obturated using AH Plus sealer and cold lateral condensation with gutta-percha. The coronal excess was removed using a heated burnisher.
All 80 samples were randomly divided into four groups of 20 each, as follows:

➢ **GROUP 1: Immediate Post Space Preparation (n=20)**

- Decoronated to 15 mm.
- Cleaned and shaped up to #55 using step-back technique.
- Obturated with AH Plus sealer and gutta-percha via cold lateral condensation.
- **Immediate post space preparation** was performed using **heated pluggers of decreasing diameters**, leaving **5 mm of apical gutta-percha**.
- Vertical condensation was done with the same pluggers.
- Samples were stored in **100% relative humidity at 37°C for 2 days** in an incubator.

➢ **GROUP 2: Delayed Post Space Preparation (n=20)**

- Decoronated to 15 mm.
- Cleaned and shaped up to #55 using step-back technique.
- Obturated as in Group 1.
- Stored for **2 days at 37°C in 100% relative humidity** to allow sealer setting.
- **Post space preparation** was performed after 48 hours using **heated pluggers**, maintaining **5 mm of apical gutta-percha**.

➢ **GROUP 3: Positive Control (n=20)**

- Decoronated to 15 mm.
- Cleaned and shaped up to #55 using step-back technique.
- **No obturation** performed.
- These served to confirm full dye penetration and acted as positive controls.

➢ **GROUP 4: Negative Control (n=20)**

- Decoronated to 15 mm.
- Cleaned and shaped up to #55 using step-back technique.
- Obturated as in Groups 1 and 2.
- **No post space preparation** was performed.
- Entire tooth surfaces including apical and coronal access were coated with **nail varnish** to prevent dye penetration.

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Experimental Groups Overview:

Group	Description	Post Space Preparation	Obturated	Storage Condition	Purpose
Group 1	Immediate Post Space Preparation	Immediately after obturation	Yes	2 days at 37°C, 100% humidity	Test group
Group 2	Delayed Post Space Preparation	2 days after obturation	Yes	2 days at 37°C, 100% humidity before post prep	Test group
Group 3	Positive Control (Unobturated)	Not applicable	No	Not specified (used for full dye penetration check)	Confirm dye penetration
Group 4	Negative Control (No post prep, sealed)	Not performed	Yes	Entire surface coated with nail varnish	Confirm no dye penetration

Dye Leakage Assessment (Apical to Coronal)

- **Group 1 (Immediate):**
  - Blue nail varnish applied 1 mm short of apex.
  - Suspended vertically in India ink using sticky wax.
  - Stored for 7 days at 37°C, 100% humidity.
- **Group 2 (Delayed):**
  - Red nail varnish applied 1 mm short of apex.
  - Suspended vertically in India ink using sticky wax.
  - Stored for 7 days at 37°C, 100% humidity.
- **Post-Dye Procedures (for both groups):**
  - Teeth rinsed and varnish removed with scalpel.
  - Decalcified in 11% nitric acid for 48 hours.
  - Pin passed to confirm complete decalcification.
  - Sequential dehydration in 65%, 75%, 85%, 95%, and 100% alcohol (1 hour each).
  - Cleared in methyl salicylate to make roots transparent.
- **Evaluation:**
  - Roots examined under stereomicroscope (4–40×).
  - Dye penetration measured by a single examiner.
  - Scores recorded and subjected to statistical analysis.

Original Values (mm) of Marginal Dye Leakage – Apical to Cervical:

No.	IAC (Immediate Post Space)	DAC (Delayed Post Space)
1	0.21	0.22
2	0.20	0.27
3	0.19	0.24
4	0.17	0.21
5	0.28	0.23
6	0.12	0.11
7	0.20	0.18
8	0.25	0.28
9	0.15	0.14
10	0.21	0.22
11	0.20	0.24
12	0.15	0.20
13	0.20	0.22
14	0.24	0.28
15	0.22	0.27
16	0.18	0.16

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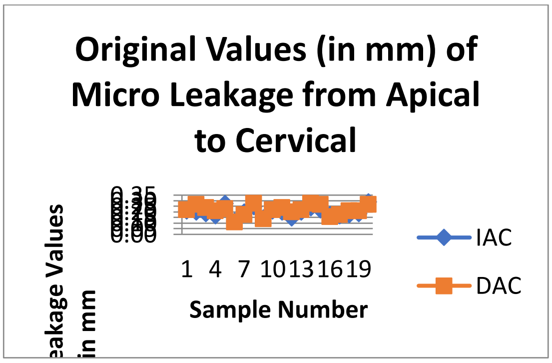
17	0.17	0.18
18	0.18	0.21
19	0.19	0.21
20	0.29	0.27

GRAPH I



GRAPH II

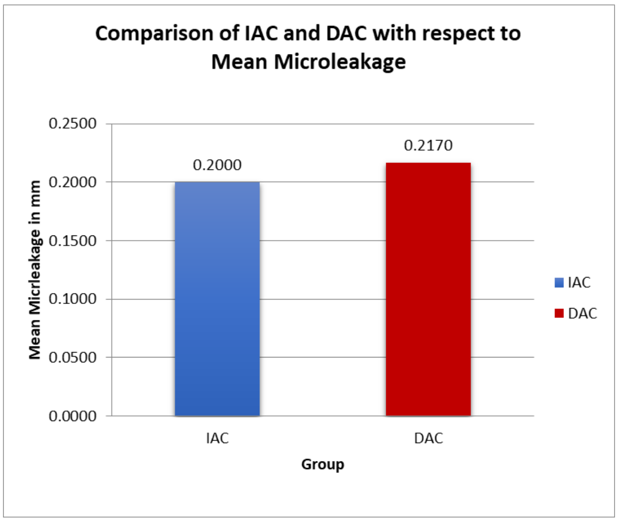


Table 2: Summary Statistics – Dye Leakage (mm):

Summary	IAC (Immediate)	DAC (Delayed)	Total
Mean	0.2000	0.2170	0.2085
Standard Deviation	0.0419	0.0467	0.0446
Standard Error (SE)	0.0094	0.0104	0.0071
Coefficient of Variation (CV)	20.95%	21.52%	21.39%

Table 3: Comparison of Microleakage Between IAC and DAC Using Unpaired Student's t-Test

Group	n	Mean	SD	t-value	p-value	Significance
IAC	20	0.2000	0.0419	-1.212	0.233	NS
DAC	20	0.2170	0.0467			

Interpretation: There was no statistically significant difference in dye microleakage between immediate (IAC) and delayed (DAC) post space preparation techniques ($p > 0.05$).

Table 4: Comparison of Microleakage Between IAC and DAC Using Mann-Whitney

Group	Rank sum	U-value	Z-value	p-level	Significance
IAC	354.50	144.50	-1.507	0.132	NS
DAC	465.50				

Interpretation: The Mann-Whitney U-test also showed no statistically significant difference in microleakage values between IAC and DAC groups (*p > 0.05*).

RESULTS

This in vitro study aimed to evaluate apical-to-coronal dye infiltration following different post space preparation techniques.

A total of **80 extracted maxillary central incisors** were divided into four groups:

- **Group 1 (IAC)** and **Group 2 (DAC)** – 20 samples each
- **Group 3 (Positive control)** – 20 samples (unobturated)
- **Group 4 (Negative control)** – 20 samples (fully sealed, no post space preparation)

Original microleakage values for Group 1 (IAC) and Group 2 (DAC) were recorded (Table 1; Graphs 1 & 2). **Group DAC** showed slightly higher leakage values compared to IAC.

The **mean leakage** for IAC was **0.2000 mm**, and for DAC was **0.2170 mm**. The **standard deviations** were **0.0419** and **0.0467** respectively (Table 2; Graph 3).

Statistical analysis using **Student's unpaired t-test** revealed **no significant difference** between IAC and DAC groups (**p=0.233**) (Table3).

Similarly, **Mann-Whitney U-test** also showed **no statistically significant difference**

(**p = 0.132**) (Table 4).

DISCUSSION

According to Weine, root canal filling is essential to preserve periapical health. While healing begins with adequate cleaning and shaping, failure to obturate the canal space allows irritants and microbes to re-enter, potentially causing lesion recurrence.[4]

An effective apical seal is influenced by many factors, including the presence or absence of a smear layer. Since the smear layer can harbor bacteria and facilitate microleakage, it was removed in this study using 5.25% sodium hypochlorite and 17% EDTA. This is supported by studies highlighting the smear layer as a medium for bacterial growth within dentinal tubules.

Cohen and Burns emphasized that regardless of obturation technique, achieving an apical seal is critical for treatment success. Without a dense, well-adapted filling, the prognosis can be compromised.[1] Microleakage, defined as the ingress of fluids and bacteria into microscopic gaps, can undermine root canal therapy.[60] Methods to assess microleakage include dye penetration, radioisotope and bacterial penetration, electrochemical methods, and fluid transport models.[61]

Crown and obturation deficiencies permit bacterial migration, leading to periapical inflammation.[55] This study used Indian ink as the leakage marker due to its strong visual contrast and ability to detect microdefects despite its particle size (10 µm) theoretically being too large to enter dentinal tubules.[59]

The complex anatomy of root canals—fins, cul-de-sacs, and accessory canals—makes complete obturation difficult. An ideal obturation material should be biocompatible, dimensionally stable, radiopaque, insoluble, non-toxic, and impervious to moisture. Gutta-percha, derived from *Palaquium* species, meets most of these criteria. It exists in alpha and beta forms, the latter being used clinically. Chemically, it is 1,4-trans-polyisoprene.

Cold lateral condensation of gutta-percha continues to be the most widely employed obturation technique owing to its predictability, simplicity, and minimal requirement for canal enlargement. Nevertheless, its limitations include the formation of a non-homogeneous mass, presence of

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internal voids, and suboptimal adaptation to complex canal anatomies. In the present study, cold lateral condensation was performed using AH Plus sealer, with 5 mm of apical gutta-percha retained—an amount supported by previous investigations demonstrating a significant increase in apical leakage when ≤3 mm of material remains.[56–58] Gutta-percha removal in both immediate and delayed post space preparation groups was achieved using heated pluggers. Existing literature indicates that when 5 mm of apical filling is preserved, techniques employing Peeso reamers, heated pluggers, or chloroform-softened files do not adversely affect the integrity of the apical seal.[21,25] In fact, Gates Glidden drills and thermoplastic instruments have been associated with superior sealing outcomes.

In this investigation, no statistically significant difference in apical microleakage was observed between immediate and delayed post space preparation protocols. These findings are in concordance with earlier studies by Madison & Zakariasen (1984), Bourgeois & Lemon (1981), and Abramovitz et al. (2000). Conversely, other research, including that by Portell et al. (1982), Fan et al. (1999), and Kwan & Harrington, reported reduced microleakage when the post space was prepared immediately following obturation.

A possible explanation for the current findings is that 5 mm of gutta-percha was retained apically in both groups. Also, heated pluggers used immediately after obturation may provide better vertical compaction before the sealer sets, preventing displacement or cracking of the material—problems more likely in delayed techniques.

Torabinejad et al. noted that only 18.1% of inadequately obturated and poorly restored teeth lacked periapical reactions.[24] This emphasizes the combined importance of both endodontic and coronal seal integrity.

Although linear dye penetration is commonly used, it only shows the length of leakage, not the volume of voids. Quantitative volumetric methods may provide better comparison among obturation systems.[59] From a clinical standpoint, evaluating coronal-to-apical leakage could offer more relevant insights.[7]

In this study, positive control samples showed extensive dye leakage, whereas negative controls showed none, confirming the method's validity. The observed differences between immediate and delayed techniques, though present, were statistically insignificant.

CONCLUSION

This in vitro study evaluated apical-to-coronal microleakage following immediate and delayed post space preparation techniques using dye penetration analysis. Preservation of 5 mm of gutta-percha at the apex resulted in effective apical sealing in both techniques, aligning with previously established guidelines in the literature.

Although the **delayed post preparation group** (DAC) exhibited slightly greater dye leakage than the **immediate group** (IAC), the difference was **not statistically significant**. These findings suggest that **either technique can be employed clinically without compromising the apical seal**, provided that the remaining obturating material is adequate.

The results are consistent with several earlier studies, reinforcing the importance of maintaining sufficient apical filling and adopting a careful post space preparation technique. The use of heated pluggers, particularly in immediate post preparation, may contribute to better compaction and sealing properties.

Further clinical studies and volumetric leakage analyses are recommended to substantiate these findings and determine their relevance in long-term outcomes.

Limitations of the Study

1. This was an **in vitro study**, and although care was taken to simulate clinical conditions, the oral environment is far more complex and dynamic.
2. The use of **dye penetration** allowed only a linear assessment of leakage; volumetric leakage and microbial infiltration were not evaluated.
3. The study was limited to a **short observation period** of 7 days, so long-term sealing ability was not assessed.

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