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Comparative Evaluation Of Apical Microleakage In Immediate And Delayed Postspace Preparation Using Different Root Canal Sealers: An In Vitro Study

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Abstract:
This study evaluated apical microleakage in root canals using two types of sealers— bioceramic (EndoSequence BC Sealer) and epoxy resin-based (Simpliseal™)—with immediate and delayed post-space preparation. Eighty single-rooted teeth were treated and assessed for dye penetration under a stereomicroscope. Results showed that EndoSequence BC Sealer had significantly lower microleakage than Simpliseal™, and immediate post-space preparation led to better sealing in both groups. The study concludes that both the choice of sealer and the timing of post-space preparation are critical to minimizing apical leakage and improving endodontic success.

Keywords: *Root canal sealers, apical microleakage, post-space preparation, bioceramic sealer, resin-based sealer, gutta-percha, endodontic treatment, bacterial infiltration, sealer-dentin adhesion, stereomicroscope analysis.*

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I. Rationale And Aim

This study was conducted to evaluate the apical sealing ability of two different root canal sealers—EndoSequence BC Sealer (bioceramic-based) and Simpliseal™ (epoxy resin- based)—following immediate and delayed post-space preparation. Given the clinical relevance of apical microleakage and the potential impact of post preparation timing on the integrity of the apical seal, this study aimed to provide comparative data that can guide clinicians in selecting appropriate materials and techniques to optimize endodontic outcomes.

II. Introduction

Root canal sealers are specialized materials used in endodontic therapy to aid in the obturation of the root canal system. Following the removal of infected or necrotic pulp tissue during root canal treatment, the canal space is filled with gutta-percha in combination with a sealing agent to achieve a hermetic seal and prevent microbial reinfection. The primary function of the sealer is to fill voids between the canal walls and the core filling material, forming a tight barrier to inhibit bacterial ingress and ensure the long-term success of treatment.1

Several types of root canal sealers are available, each with distinct physical and biological properties. Zinc oxide-eugenol (ZOE) sealers are recognized for their antimicrobial characteristics and ease of handling. Calcium hydroxide-based sealers are often utilized in cases of extensive infection due to their ability to promote healing. Bioceramic sealers offer excellent biocompatibility, bioactivity, and sealing ability, while epoxy resin-based sealers are known for their superior durability and sealing capacity, albeit with some limitations in handling.

Bioceramic sealers are formulated with bioactive materials such as calcium phosphate and bioinert constituents like zirconia or alumina. These components enhance bonding with surrounding dentin and promote periapical healing. Their hydrophilic nature, chemical stability, and potential for hydroxyapatite formation contribute to their favorable performance in clinical settings.2 Conversely, resin-based sealers are typically divided into epoxy resin-based and methacrylate-based types. Methacrylate sealers provide a fluid-tight seal but may exhibit polymerization shrinkage, while epoxy resin-based sealers demonstrate strong adhesion to dentin

and reliable apical sealing, contributing to long-term success.The setting behavior and working characteristics of sealers can also influence clinical performance. Bioceramic sealers exhibit minimal shrinkage and set rapidly, which can present handling challenges, particularly in moist environments where moisture sensitivity may interfere with optimal curing. Resin-based sealers offer more favorable flow properties and can cure effectively in the presence of moisture, providing versatility in diverse clinical scenarios. Both sealer types have inherent antimicrobial properties; bioceramic sealers release calcium hydroxide, while some resin-based formulations incorporate antimicrobial agents.3

Apical microleakage remains a key concern in endodontic treatment outcomes, as it may result in bacterial reinfection, periapical inflammation, and treatment failure. A critical factor in preventing microleakage is the integrity of the apical seal, which is influenced by the type of sealer used, obturation quality, and post-endodontic procedures, including post- space preparation.4

Post-space preparation is often necessary for the placement of an intra-radicular post to support coronal restoration. This procedure can be carried out either immediately after obturation (immediate post preparation) or after the sealer has set (delayed post preparation). Immediate post preparation is performed under the same aseptic conditions and by the same clinician, thus reducing the risk of procedural errors. Delayed preparation, on the other hand, may compromise the integrity of the sealer-dentin interface due to the disruption of the fully set sealer during instrumentation.5

Multiple methods are available for post-space creation, including the use of heated instruments, Gates Glidden drills, Peeso reamers, hand files, and solvents.6 Regardless of the technique, maintaining a minimum apical plug of gutta-percha—typically 4–5 mm—is recommended to preserve the apical seal. Studies have consistently shown that leakage decreases with increased residual obturation material, with 5 mm being considered the optimal minimum.7

Various techniques have been employed to evaluate apical microleakage, including dye penetration, fluid filtration, bacterial leakage, and isotope tracing. Among these, dye penetration remains one of the most commonly used and sensitive methods for detecting microleakage. Longitudinal sectioning of specimens and measuring dye infiltration in millimeters provides a quantitative assessment of sealing ability.8-11

The effect of post-space preparation timing on apical microleakage remains controversial. Some authors suggest that immediate preparation does not significantly compromise the apical seal, while others advocate for delayed preparation to allow the sealer to fully set.

Likewise, while bioceramic and resin-based sealers have been independently studied, direct comparisons of their sealing performance in relation to post-space preparation timing are limited.12-14

III. Methodology:

Sample Selection:

Inclusion criteria:

- Intact, freshly extracted teeth
- Straight, single canals with fully developed apices

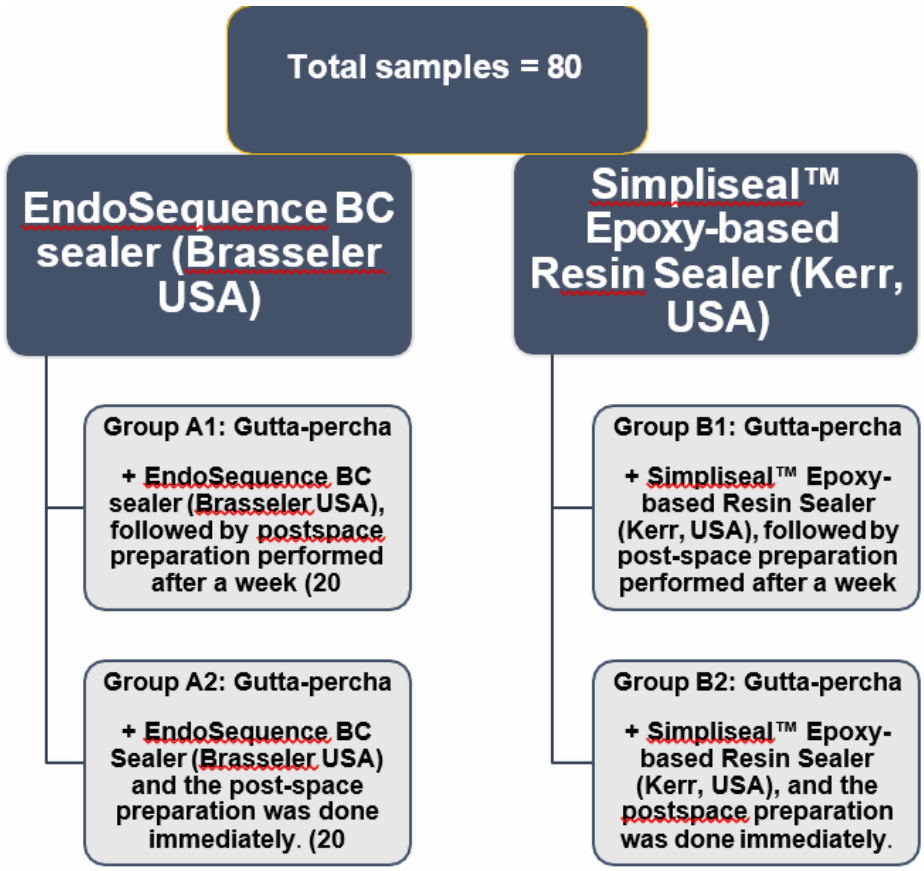
Exclusion criteria:

- Teeth with caries affecting the root
- Teeth with a history of attrition, abrasion, restoration, or surface cracks/defects
- Teeth with bifurcated canals
- Teeth exhibiting extreme calcification
- Teeth with incompletely formed apices
- Teeth with curved canals

Sampling including sample size calculation:

- Experimental groups based on sealer and post-space preparation timing:

Fig.1: Sampling



Formula:

$$U_x = N_x.N_y + \frac{N_x(N_x + 1)}{2} - \Sigma r_x$$

Where, U_x is the Mann Whitney calculation for sample X

N is number in the samples

Σr_x is the sum of ranks for sample X.

Material Required And Armamentarium To Be Used
5.25% sodium hypochlorite (NaOCl): for irrigation between each file change
17% EDTA gel
0.9% saline
Sealers: EndoSequence BC sealer (Brasseler USA), o Simpliseal™ Epoxy-based Resin Sealer (Kerr, USA)
2% aqueous solution of Methylene Blue dye
Contra-angle handpiece and diamond disk
15 K-file (Dentsply Maillefer)
Rotary file: HyFlex CM files (Coltene/Whaledent, Switzerland)
Paper points
Gutta Percha points
Peeso reamer (Mani, Japan)
Aqueous solution of Methylene Blue dye
Stereomicroscope

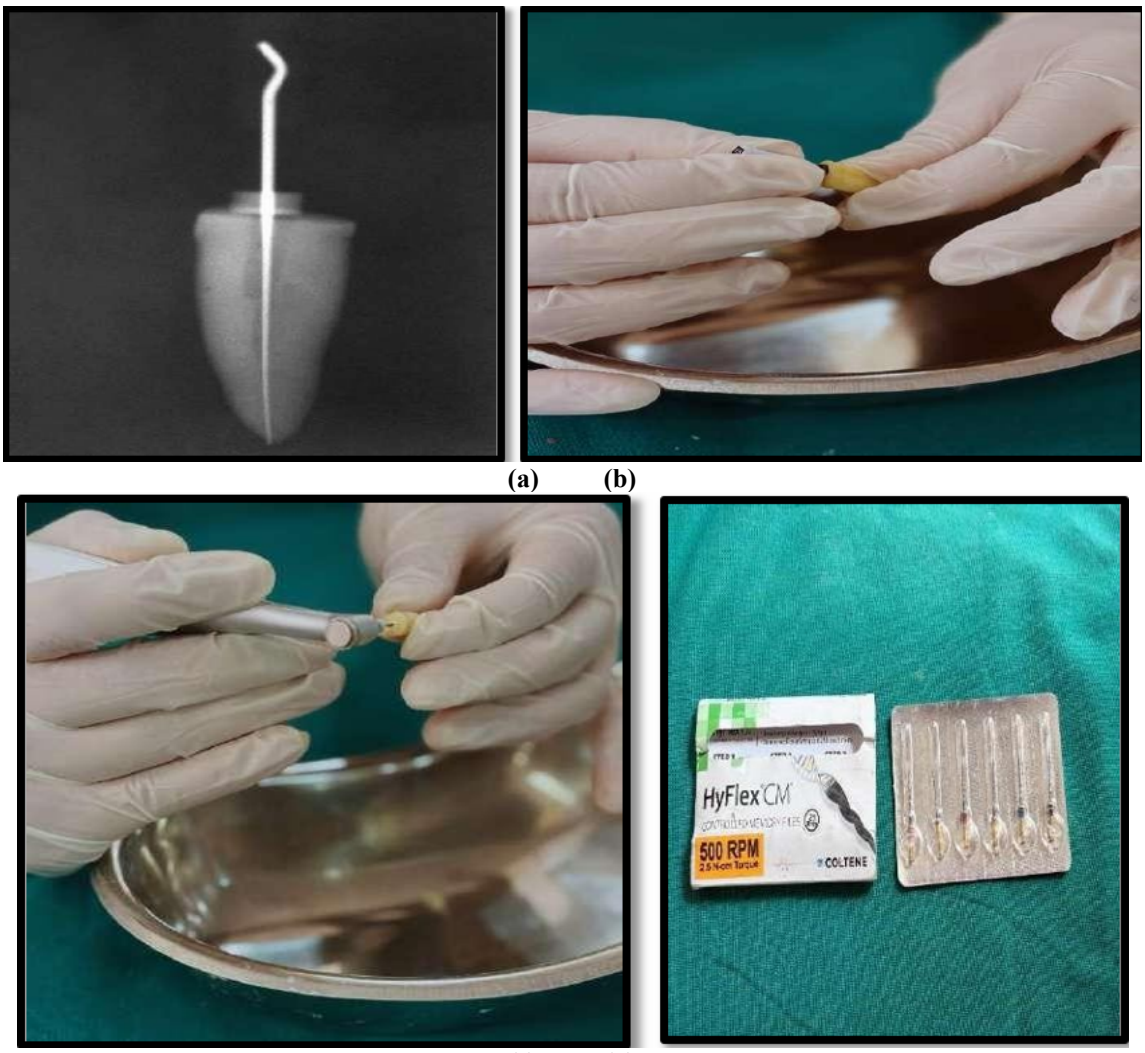
Eighty non-carious, single-rooted teeth were selected and stored in normal saline. To remove surface organic debris, the teeth were immersed in 5.25% sodium hypochlorite for 8 hours. The crowns were removed at the cementoenamel junction using diamond discs under water cooling.

(a) (b)

Fig.2: (a) Contra-angle handpiece and diamond disk, (b) Decoronated teeth at the cementoenamel junction.

Working length was established by inserting a size 15 K-file until visible at the apical foramen, then subtracting 1 mm. Root canals were prepared with HyFlex CM files (up to size #30, 0.04 taper) using a step-down technique. 17% EDTA gel was used as a lubricant,

and canals were irrigated with 5% NaOCl between files, followed by a final rinse with sterile saline and drying with paper points.



(a) (b)

(c) (d)

Fig.3: (a), (b) Working length radiograph; (c) Root canals were prepared with HyFlex CM files (up to size #30, 0.04 taper) using a step-down technique; (d) HyFlex CM files (Coltene/Whaledent, Switzerland).

Samples were randomly divided into two main groups, each with two subgroups based on the type of sealer and timing of post-space preparation:

- Group A1: Gutta-percha + EndoSequence BC Sealer; post-space prepared after 1 week
- Group A2: Gutta-percha + EndoSequence BC Sealer; immediate post-space preparation
- Group B1: Gutta-percha + Simpliseal™ Epoxy-based Sealer; post-space prepared after 1 week
- Group B2: Gutta-percha + Simpliseal™ Epoxy-based Sealer; immediate post-space preparation

Sealers were prepared per manufacturer instructions. Obturation quality was verified with radiographs. For delayed post preparation, samples were stored in 0.9% saline at 37°C for one week. Post-space was created using Peeso reamers (sizes 1–3) at 4000 rpm, preserving 5 mm of apical gutta-percha. Sticky wax sealed the coronal portion, and two layers of clear nail polish covered the root, leaving the apical 2 mm exposed.

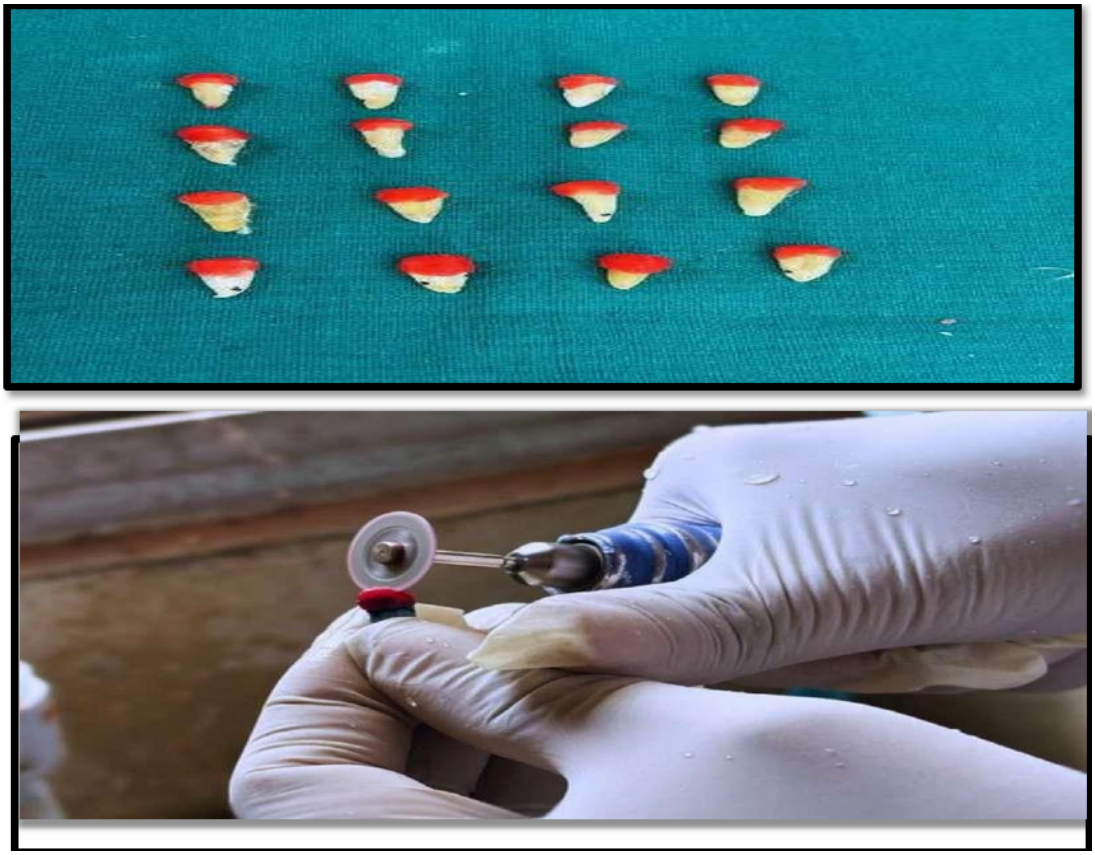


Fig.4:
(a) Placement of sticky wax on the coronal opening,
(b) The samples were cut longitudinally at a high speed with a diamond disc

Dye Penetration:

Specimens were suspended in 2% methylene blue (pH 7) for 24 hours, then rinsed and cleaned. Nail varnish was removed with a scalpel.

Microscopic Examination:

Samples were longitudinally sectioned using diamond discs under water cooling. Final cuts were made at low speed without water to expose internal structures. Dye penetration from the apex was assessed under ×20 magnification using a stereomicroscope, and the maximum dye penetration value was recorded for analysis

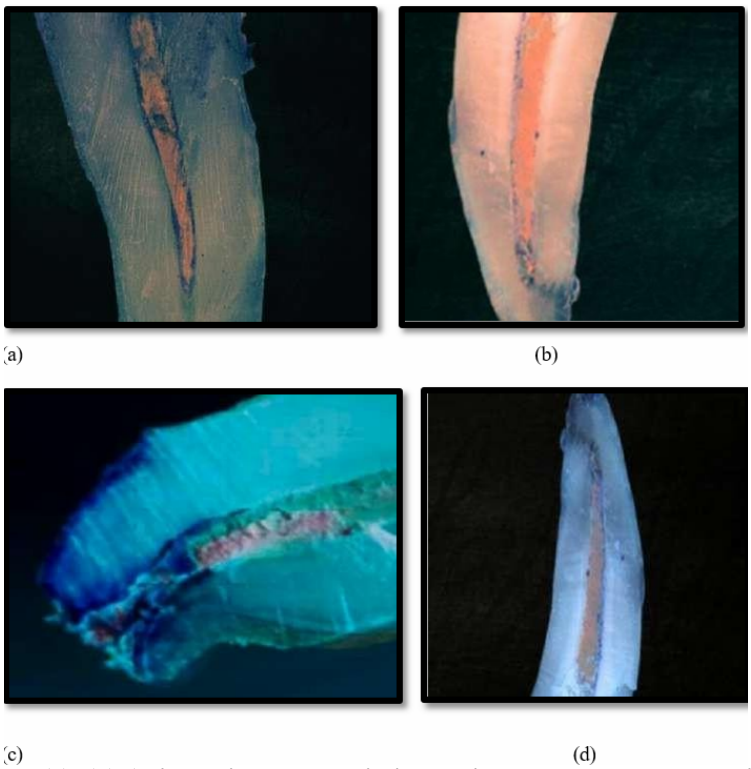


Fig.5: (a), (b) Apical microleakage in immediate post-space preparation (Simpliseal™ Epoxy-based Resin Sealer, Kerr, USA); (c), (d) Apical microleakage in delayed post-space preparation (Simpliseal™ Epoxy-based Resin Sealer, Kerr, USA)

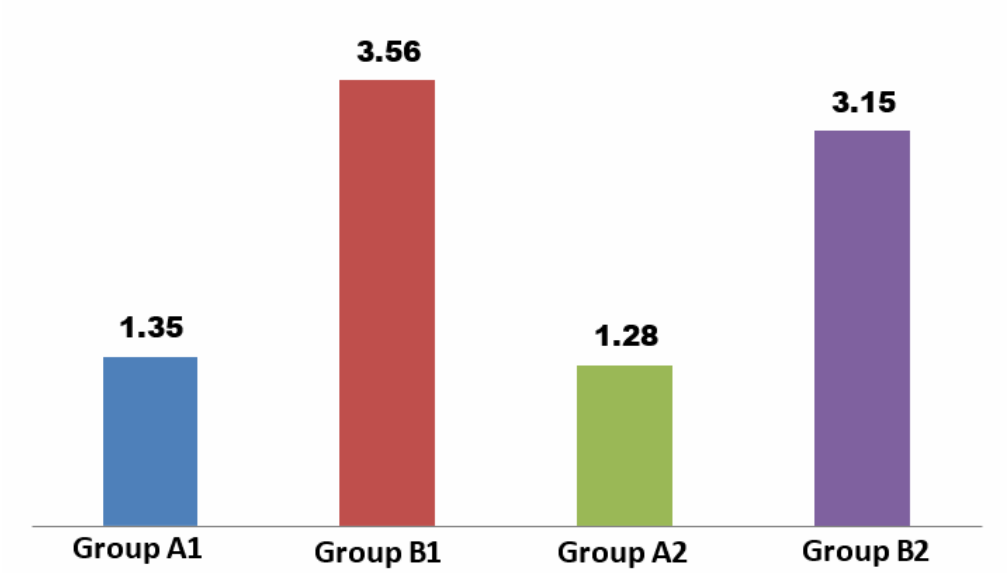
Fig.6: (a), (b) Apical microleakage in immediate post-space preparation ((EndoSequence BC Sealer, Brasseler USA); (c), (d) Apical microleakage in delayed post-space preparation ((EndoSequence BC Sealer, Brasseler USA)

IV. Results:

Table 1: Mean microleakage among Study groups

Group	N	Minimum	Maximum	Mean	Standard Deviation (SD)	Std Error
Group A1	20	1.03	1.90	1.3500	0.24000	0.080
Group B1	20	3.01	4.01	3.5600	0.31000	0.010
Group A2	20	0.60	2.00	1.2800	0.45000	0.015
Group B2	20	2.70	3.69	3.1500	0.27000	0.090

Graph 1: Mean microleakage among Study groups



The study revealed that both the sealer type and the timing of post-space preparation significantly influenced microleakage. EndoSequence BC Sealer consistently showed lower microleakage than Simpliseal™, regardless of timing.

- Group A1 (delayed post-space with EndoSequence): Mean microleakage 1.35
- Group B1 (delayed with Simpliseal™): Significantly higher microleakage at 3.56

- Group A2 (immediate with EndoSequence): Slightly lower mean (1.28), but more variable
- Group B2 (immediate with Simpliseal™): Mean microleakage reduced to 3.15, but still high

These results suggest EndoSequence BC Sealer offers superior sealing, and that immediate post-space prep has less negative impact, especially with Simpliseal™.

Statistical Analysis

The data for the present study was entered in the Microsoft Excel 2007 and analyzed using the SPSS statistical software 23.0 Version. The descriptive statistics included mean, standard deviation frequency and percentage. The level of the significance for the present study was fixed at 5%.

The intergroup comparison was done using the Mann Whitney U test The Shapiro–Wilk test was used to investigate the distribution of the data and Levene's test to explore the homogeneity of the variables.

Mean
X X
N

Where:
X = the data set mean
∑ = the sum of
X = the scores in the distribution
N = the number of scores in the distribution

Range
range Xhighest Xlowest

Where:
Xhighest = largest score
Xlowest = smallest score

Variance
SD2 (X X)2
N

The simplified variance formula
(X)2
X 2

Where:
SD2 = the variance
∑ = the sum of
X = the obtained score

SD2 N
N

X = the mean score of the data
N = the number of scores

Standard Deviation (N)
SD

The simplified standard deviation formula
SD

Where:
SD = the standard deviation
∑ = the sum of
X = the obtained score
X = the mean score of the data

Mann–Whitney U Test

The Mann–Whitney U test, also referred to as the Wilcoxon rank-sum test or the Wilcoxon–Mann–Whitney test, is a non-parametric statistical method used to compare differences between two independent groups. It evaluates the null hypothesis that the probability of a randomly selected observation from one group being greater than a randomly selected observation from the other group is equal to 0.5. In other words, it assesses whether the two groups originate from the same distribution.

This test is particularly useful when the assumptions of normality are not met, as it does not require the data to follow a normal distribution. It is applicable under the following conditions: (1) the observations in each group are independent, (2) the dependent variable is ordinal or continuous, and (3) the two groups being compared are independent of each other.

Under the null hypothesis (H), the distributions of the two populations are assumed to be equal. The alternative hypothesis (H) posits that the distributions differ. The Mann–Whitney U test is thus appropriate for determining whether there is a statistically significant difference in the central tendencies or distributions of two independent samples.

V. Discussion

The findings of this study demonstrate that both the type of endodontic sealer and the timing of post-space preparation significantly influence apical microleakage. Among all groups, specimens obturated with EndoSequence BC Sealer and subjected to immediate post-space preparation (Group A2) exhibited the lowest mean microleakage (1.2800 mm), suggesting that immediate intervention may preserve the integrity of the apical seal.

Conversely, the highest mean microleakage (3.5600 mm) was recorded in Group B1, where post-space preparation was delayed by one week following obturation with Simpliseal™, an epoxy resin-based sealer.

The statistically significant differences observed between immediate and delayed post-space preparation in both sealer types ($P < 0.05$) highlight the critical role of timing in maintaining the apical seal. Notably, EndoSequence BC Sealer consistently exhibited significantly lower microleakage compared to Simpliseal™, irrespective of timing. These findings align with previous studies by Fan et al., Solano et al., and Karapanou et al., which report increased leakage associated with delayed post preparation due to potential disruption of the sealer- dentin interface.

The superior performance of the bioceramic sealer may be attributed to its bioactivity, capacity to form hydroxyapatite, and chemical bonding with dentin. The setting mechanism involves the hydration of calcium silicates, forming calcium silicate hydrate and calcium hydroxide, which subsequently react with phosphate ions to produce hydroxyapatite. This contributes to a stable, biologically integrated seal. Additionally, the fine particle size and high flowability of bioceramic sealers facilitate penetration into dentinal tubules and accessory canals, improving adaptation and sealing efficacy.

In contrast, epoxy resin-based sealers such as Simpliseal™ may be more prone to leakage due to slower polymerization, dimensional changes during setting, and potential disruption during delayed post-space preparation. Studies have also shown that the incorporation of non-reactive additives like chitosan nanoparticles can further prolong setting times, potentially affecting the sealer's performance.

The importance of sealer flowability is underscored by ISO 6876 guidelines, which specify a minimum flow diameter to ensure adequate canal adaptation. Bioceramic sealers meet these criteria while minimizing extrusion risk. Previous studies have reported that excessive or insufficient flow can compromise the apical seal either by promoting overextension or by limiting sealer distribution.

Although in vitro studies, including dye penetration techniques, have limitations in clinical extrapolation, they remain a standard for comparative analysis. The results of this study are consistent with existing literature emphasizing the benefits of immediate post-space preparation and the superior sealing ability of bioceramic materials. Given the increasing emphasis on evidence-based endodontics, these findings provide valuable guidance for optimizing post-endodontic restoration protocols.

VI. Conclusion:

This study underscores the significant impact of root canal sealer type and the timing of post-space preparation on apical microleakage. EndoSequence BC Sealer demonstrated superior sealing ability compared to Simpliseal™ epoxy resin-based sealer, exhibiting consistently lower microleakage values under all experimental conditions. Immediate post- space preparation was associated with reduced apical leakage relative to delayed preparation, suggesting that performing the procedure prior to complete sealer setting may help preserve the integrity of the apical seal. These findings highlight the clinical importance of both sealer selection and the timing of post-space preparation in enhancing the long-term success of endodontic treatment. Further research with larger sample sizes and in vivo validation is warranted to support these results and inform evidence-based clinical guidelines.

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