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An in Vitro Assessment of Various Success Parameters of Two Different Commercially Available Endodontic Sealers: A Scanning Electron Microscopy based Original Research Study

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KEYWORDS

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ABSTRACT:

Aim: This study aims to assess the various success parameters of two different commercially available endodontic sealers by Scanning Electron Microscopy (SEM) method.

Materials and Methods: The study assessed 60 extracted human single-rooted mandibular first premolars, free from caries and damage, and stored in saline. After cleaning, teeth with multiple foramina or prior treatments were excluded. Each root was encased in acrylic resin, and access cavities were created. The working length was set using a No. 15 K-file, and canals were prepared with ProTaper rotary files, rinsed with 2.5% sodium hypochlorite (NaOCl). The smear layer was removed using 17% EDTA, followed by rinses with 5.25% NaOCl and distilled water. Canals were dried with paper points. Obturations used either AH Plus Jet Root Canal Sealer or ZenSeal with gutta-percha. Teeth were stored in 100% humidity at 37°C for 7 days for sealer setting. Roots were sectioned for scanning electron microscopy (SEM) analysis, comparing sealants based on interfacial adaptation, dentinal tubule penetration, and microleakage prevention.

Statistical Analysis and Results: This study analysed 60 extracted human single-rooted mandibular first premolars to evaluate the success parameters of two endodontic sealants during obturation. The samples were divided into two groups: Group 1 included 30 teeth treated with gutta-percha and AH Plus Jet Root Canal Sealer, while Group 2 comprised 30 teeth treated with gutta-percha and ZenSeal from KERR CORPORATION™. The quality of the seal was assessed using scanning electron microscopy (SEM) to examine the interactions between the sealant and dental structures. Statistical significance for hydrophilic properties and material shrinkage was analysed using the Pearson Chi-Square test. A one-way ANOVA compared the performance of both sealants, revealing significant differences in their effectiveness. Detailed methodologies and statistical findings are provided in the tables.

Conclusion: The study found that ZenSeal outperformed AH Plus with better surface adaptation, enhanced dentin bonding, and deeper infiltration into dentinal tubules, thanks to its

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bio-ceramic composition. While AH Plus had good hydrophilic properties and lower shrinkage, it was less effective in penetration and adherence. Choosing the appropriate endodontic sealer is crucial for optimal clinical outcomes.

Introduction

Recent advancements in the management of dental caries have greatly enhanced patient care and improved treatment outcomes. Modern approaches to caries management emphasize essential components such as caries prevention, early detection of lesions, and risk-based diagnosis. By integrating these strategies with innovative techniques that focus on preserving healthy dental tissue and maintaining tooth pulp vitality, we can effectively minimize the need for invasive treatments and promote overall dental health. This holistic perspective not only addresses existing issues but also fosters a proactive approach to maintaining oral health.[1,2] Root canal therapy has emerged as one of the most effective solutions for addressing infected or damaged tooth pulp. This procedure involves a meticulous process where harmful bacteria and necrotic tissue are removed from the pulp chamber. Following this, the canal system is thoroughly cleaned and disinfected to ensure the elimination of any remaining pathogens. The final step involves sealing the tooth to protect against re-infection. Patients often report that the discomfort experienced during a root canal is comparable to that of receiving a dental filling, with any pain typically arising from the underlying infection prior to treatment. Success rates for root canal procedures range between 68% to 85%, with a substantial number of patients expressing satisfaction due to effective pain relief and the preservation of their natural tooth for the long term.[3,4]A crucial component of root canal therapy is the use of root canal sealers. These sealers are integral in establishing a fluid-tight seal within the treated tooth, thereby preventing the re-entry of bacteria and facilitating the healing process. Sealers fill in the microscopic gaps between core filling materials, such as gutta-percha, and the walls of the root canals, ensuring comprehensive sealing even in the tiniest of spaces. They are available in various forms, including pastes and powders, and comprise different materials such as zinc oxide eugenol (ZOE), calcium hydroxide, resin-based formulations, and modern bioceramic options. Each of these sealers possesses distinct properties that contribute to their effectiveness.[5,6] An ideal root canal sealer should meet several essential criteria: it must create a reliable fluid-tight seal, be radiopaque for visibility on radiographic images, exhibit antimicrobial properties to prevent infection, resist shrinkage during the setting process, and be non-staining and non-irritating to surrounding tissues. Additionally, it should be insoluble in tissue fluids and demonstrate biocompatibility to ensure patient safety and comfort.[7,8] Among the various options available, ZenSeal, a calcium silicate-based sealer, stands out due to its excellent flowability and strong adhesion capabilities with both dentin and gutta-percha. This enhances clinician confidence by ensuring a robust seal and optimal bonding within the root canal system. In contrast, the AH Plus Jet sealer is renowned for its reliable sealing abilities, complemented by an innovative delivery system that eliminates the need for manual mixing. This feature allows for precise placement and application of the sealer, further improving the efficacy of root canal treatments.[9,10] Additionally, Scanning Electron Microscopy (SEM) is a highly sophisticated imaging technique that utilises a focused beam of electrons to generate high-resolution images of a sample's surface. This powerful tool is invaluable in the field of dentistry, enabling researchers and clinicians to conduct a detailed examination of dental tissues and biomaterials. Through SEM, intricate surface structures and material integrity can be thoroughly analysed. It has become an important method in various dental research areas, where it is applied to study enamel wear patterns, assess the effectiveness of restorative materials, and explore forensic aspects of dental wear and damage. The evolution of dental caries management has led to more effective techniques that not only focus on the treatment of existing issues but also emphasise prevention and preservation, ultimately leading to better patient outcomes and experiences in dental care.[11-13] This study aims to assess the various success parameters of two different commercially available endodontic sealers by Scanning Electron Microscopy (SEM)

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Materials and Methods

This study involved a total of 60 extracted human single-rooted mandibular first premolars that were devoid of caries, apical resorption, root surface resorption, and cracks. To ensure the preservation of moisture in the dentinal tubules, the teeth were stored in a saline solution. Residual soft tissue and calculus were meticulously removed using a scaler. Each tooth was extracted for reasons related to periodontal concerns. To maintain the integrity of our findings, strict inclusion criteria were implemented, excluding any teeth that displayed multiple foramina, signs of dilation, indications of infection, or those that had previously undergone endodontic treatment. All root surfaces of the selected specimens were encased in acrylic resin for appropriate handling. In the preparation phase, the occlusal surfaces of the selected teeth were flattened utilising diamond rotary cutting instruments. Uniform access cavities were established in all samples, and the working length was determined. The working length assessment was conducted using a No. 15 K-file, ensuring it was maintained 1 mm short of the actual length discernible at the major diameter of the apical foramen. The preparation of the root canals was executed employing ProTaper rotary files, following the single-length technique up to F3 (30/0.09). Between each file application, the canals were rinsed with 3 mL of 2.5% sodium hypochlorite (NaOCl). Upon completing the instrumentation, 1 mL of 17% ethylene-diamine-tetra-acetic acid (EDTA) (Prime Dental Products, India) was utilised for 1 minute to eliminate the smear layer, followed by a rinse with 3 mL of 5.25% NaOCl. The final rinse was conducted with 5 mL of distilled water, after which the canals were thoroughly dried using paper points. The obturation of the roots was randomly allocated into two groups, each filled with one of two sealers: AH Plus Jet® Root Canal Sealer (Dentsply Sirona™) or ZenSeal (KERR CORPORATION™), in conjunction with gutta-percha, utilising the lateral condensation filling technique. In the AH Plus group, the sealer was combined in equal volumes (1:1) of pastes A and B (epoxide and amine pastes) on a mixing pad until a homogeneous consistency was achieved. The pre-mixed sealer was then introduced into the canal with a syringe, with additional sealer dispensed on the mixing paper pad to coat the master cone. For the ZenSeal group, the premixed sealer was similarly placed into the canal and on the mixing paper pad. A standard #30 master cone was selected and confirmed through radiographic evaluation. The coated cone was introduced into the apical region, and the obturation process was continued using the lateral compaction technique in both groups. To facilitate the complete setting of the sealer, all teeth were stored in 100% humidity at 37°C for duration of 7 days. Subsequently, the roots were transversely sectioned using a 200 µm-thick diamond blade, with a total sample thickness of 2 mm. The distance from the first cut to the coronal surface and from the last cut to the apex tip was standardised at 1.5 mm. The cut sections were dehydrated for observation via scanning electron microscopy (SEM). This investigation examines a total of 60 extracted mandibular first premolars, focusing on the effectiveness of obturation procedures performed using two different types of sealants. The samples were divided into two distinct groups for comparison. Group 1 utilized AH Plus Jet® Root Canal Sealer, a product from Dentsply Sirona™, known for its reliable sealing properties. In contrast, Group 2 employed ZenSeal in combination with gutta-percha for the obturation process. The evaluation of these two sealants was conducted with careful attention to several critical parameters. These included the degree of interfacial adaptation, the extent of dentinal tubule penetration, and the capacity to prevent microleakage. Each parameter was meticulously assessed by qualified clinicians using scanning electron microscopy, a highly detailed imaging technique that provides insights into the microscopic interactions between the sealants and the dental structures. The primary objective of this study is to thoroughly evaluate and compare the various success parameters associated with these two commercially available endodontic sealers, employing scanning electron microscopy as a means of obtaining precise and reliable results.

Statistical Analysis and Results

SPSS software version 29.0 was used for all Statistical Analysis. The study's findings were analyzed using ANOVA test to compare gap widths across different experimental groups. Tukey's test was used for pair wise comparisons, while the Kruskal-Wallis test evaluated the dentine-sealer interface. Donn's test was also applied for pair wise comparisons among the groups. To determine the significance of our findings,

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we meticulously applied the chi-square test, which excels in evaluating differences in proportions among various groups. This robust method enabled us to conduct thorough comparisons of categorical data, ensuring our results faithfully represent the critical trends and relationships within the dataset, thereby enhancing the reliability of our conclusions.

Results

This investigation was designed to deliver an in-depth analysis of 60 human single-rooted mandibular first premolars that were carefully extracted. The primary focus of the study was to examine and compare the effectiveness of two distinct types of endodontic sealants utilized during the obturation procedures. By exploring the properties and performance of these sealants, the research aimed to shed light on their roles in ensuring successful endodontic treatment outcomes for the affected teeth. Table 1 shows the study involved meticulously categorising the extracted samples into two distinct groups to facilitate a comparative analysis of the sealant performance. Table 2 shows Group 1, which consisted of 30 single-rooted mandibular first premolars; the teeth underwent a standard extraction protocol followed by root canal treatment. These canals were filled with gutta-percha in conjunction with the AH Plus Jet Root Canal Sealer, a well-established product manufactured by Dentsply Sirona™. This particular sealer is recognised in the dental field for its reliable sealing properties, making it a popular choice among practitioners. After the obturation process, the quality of the seal achieved using this material was rigorously evaluated through scanning electron microscopy (SEM). This sophisticated imaging technique allowed researchers to achieve a detailed visualisation of the microscopic interactions between the sealer and the dental structures, essential for understanding the efficacy of the material. To ensure the robustness of the findings, a detailed statistical analysis was conducted using the Pearson Chi-Square test. This was particularly aimed at evaluating the significance of observed hydrophilic properties and the incidence of material shrinkage within the sealed canals. Conversely, Table 4 Group 2 also included 30 extracted mandibular first premolars that underwent similar extraction and obturation processes. In this group, the root canals were filled with gutta-percha in combination with ZenSeal. Like the first group, this sealant was subjected to evaluation through SEM, allowing for a comparative assessment of the quality of obturation achieved. The analysis specifically concentrated on several key parameters: the degree of interfacial adaptation between the sealer and the dentin, the extent to which the sealant permeated into the dentinal tubules, and its effectiveness in preventing microleakage, an important factor in the long-term success of endodontic therapy. As in Group 1, the statistical significance of the findings for Group 2 was determined using the Pearson Chi-Square test, paying particular attention to the superior surface adaptability and bonding capabilities of ZenSeal to the dentin. To synthesise the results across both groups, a one-way ANOVA (Analysis of Variance) was conducted. This statistical approach enabled the researchers to compare the performance of the two different sealants on a wider scale, facilitating the identification of any statistically significant differences in their effectiveness in achieving optimal obturation. The accompanying tables in the study provide a detailed overview of the categorisations of the samples, the specific methodologies employed for each group, and the statistical findings that arose from these investigations. Each table offers essential insights into how the different sealants performed in terms of sealing capability and compatibility, contributing to the overall understanding of their efficacy in endodontic practices.

Table 1: The total number of teeth has been categorised into two distinct groups

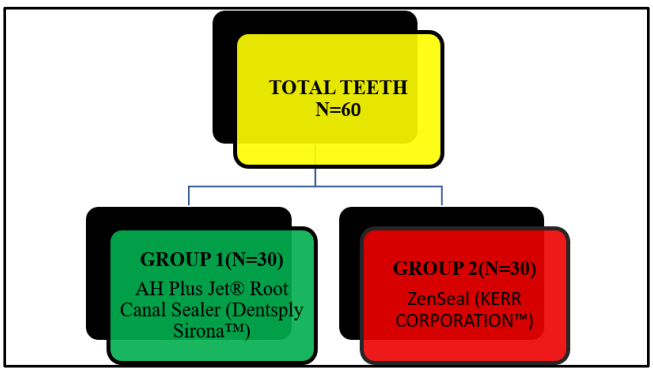

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Table 2: Group 1 (N=30) underwent extraction of mandibular first premolars. The root canals of these teeth were then filled with gutta-percha in conjunction with the AH Plus Jet® Root Canal Sealer (Dentsply Sirona). The obturation quality was evaluated using scanning electron microscopy (SEM). Additionally, a statistical analysis was conducted, employing the Pearson Chi-Square test to determine the significance of the results

Parameters	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Surface adaptations	7	2.26	2.035	2.053	2.34	2.25	1.2	0.01*
Dentin bond	5	2.24	2.025	2.024	2.33	2.18	1.0	0.06
Tubules penetration	4	2.20	2.020	2.017	2.28	2.09	1.0	0.05*
Hydrophilic properties	9	2.30	2.245	2.083	2.54	2.56	1.3	0.02*
Shrinkage	7	2.26	2.035	2.053	2.34	2.25	1.2	0.01*
*p<0.05 significant								

Table 3: Group 2 (N=30) underwent extraction of mandibular first premolars. The root canals of these teeth were then filled with gutta-percha in conjunction with the ZenSeal (KERR CORPORATION™). The obturation quality was evaluated using scanning electron microscopy (SEM). Additionally, a statistical analysis was conducted, employing the Pearson Chi-Square test to determine the significance of the results

Parameters	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Surface adaptations	9	2.30	2.245	2.083	2.54	2.56	1.3	0.02*
Dentin bond	7	2.26	2.035	2.053	2.34	2.25	1.2	0.01*
Tubules penetration	5	2.24	2.025	2.024	2.33	2.18	1.0	0.06
Hydrophilic properties	4	2.20	2.020	2.017	2.28	2.09	1.0	0.05*
Shrinkage	5	2.24	2.025	2.024	2.33	2.18	1.0	0.06
*p<0.05 significant								

Table 4: Estimation amongst all studied groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares ∑	Mean Sum of Squares m∑	F	Level of Sig. (p)
Between Groups	2	1.352	1.801	1.2	0.01*

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Within Groups	16	2.224	1.423	_
Cumulative	110.10	07.644	*p<0.05 significant	

Discussion

Schwendicke F et al reviewed in their study that dental caries management has significantly improved, emphasising early detection and intervention through evidence-based strategies. These modern approaches focus on prevention and timely treatment, leading to better patient outcomes. By identifying carious lesions early and using risk-based diagnosis, dental professionals can minimize invasive procedures and enhance oral health. This proactive approach not only addresses current dental issues but also promotes the preservation of healthy dental tissue and tooth pulp vitality.[14] Simon S et al included in their study that individualised risk assessments help tailor preventive measures, ensuring a focused strategy in dental care. Overall, these advancements encourage a culture of oral health awareness among both practitioners and patients. Furthermore, the promotion of remineralisation techniques for non-cavitated lesions serves to reinforce the notion that early signs of decay can be successfully addressed and potentially reversed when given timely intervention. This strategic focus on prevention and early management is enhancing patient care and improving overall oral health outcomes.[15] Giacaman RA et al showed in their study that traditional restorative procedures often compromise the structural integrity of teeth by removing significant amounts of tooth structure, which can inadvertently initiate a cycle of constant restorations. Consequently, modern dentistry now emphasises minimally invasive techniques centred on repairs instead of replacements whenever possible. This paradigm shift not only preserves healthy tissue but also enhances the overall longevity and resilience of the tooth.[16]Labib M E et al reviewed in their study that in instances where pulp exposure occurs due to the progression of caries, conservative management strategies, such as vital pulp treatments (VPT), should be favoured over the more invasive full pulpectomy procedures. VPT aims to maintain the vitality of the pulp while addressing the infection or damage without resorting to the complete removal of the pulp tissue. While certain practitioners may still depend on traditional methods that are more invasive, a broader acceptance of less invasive, patient-centred approaches is increasingly recognised as crucial for achieving better clinical outcomes and patient satisfaction.[17,18] Schwendicke F et al included in their study that root canal therapy serves as a specialised procedure designed to thoroughly clean, disinfect, and hermetically seal the root canal system. This is accomplished through both biomechanical debridement—where instruments carefully remove infected pulp and debris—and chemical disinfection processes aimed at eliminating infectious microorganisms. The complexity of root canal anatomy necessitates skilled manipulation of endodontic instruments, as the intricate structure can vary significantly from one tooth to another.[19] Hülsmann M et al showed in their study that a key component of successful root canal therapy lies in the proper application of sealers, which are imperative for achieving a fluid-tight seal between the dentinal walls and the core filling materials used in endodontic treatments. Effective sealing not only prevents leakage of fluids and bacteria but also extends into any potential lateral canals within the root system. Although some sealers can exhibit toxicity before setting, meticulous application techniques can help avert extrusion into the surrounding periapical tissues, which could lead to transient inflammation yet would not impede the healing process.[20,21] Küçükkaya Eren S et al reviewed in their study that there exists a variety of sealer types for clinicians to choose from—each with unique properties and benefits—such as zinc oxide eugenol (ZOE), calcium hydroxide, glass ionomer, resin-based materials, and bioceramic options. Among these, ZenSeal is notable for its ability to significantly reduce product waste; while AH Plus Jet® offers an innovative double-barrel syringe design that ensures precise mixing of the sealer components to optimise performance. In research and clinical practice, Scanning Electron Microscopy (SEM) emerges as an invaluable tool, providing high-resolution imaging that enhances our understanding of dental structures at a microscopic level. By utilising a focused beam of electrons, SEM is capable of revealing intricate details with resolutions below one nanometer, far exceeding the capabilities of

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traditional optical microscopy.[22-24] Fischer ER et al showed in their study that in the field of endodontics, SEM is critical for assessing bacterial leakage, observing biofilm formations, and identifying fracture patterns of filling materials. Its capacity to evaluate the gaps between filling materials and dentin walls is indispensable for discerning between genuine defects and artefacts from the imaging process. The application of replicas can further aid in this differentiation, ensuring accurate assessments. Ultimately, SEM not only enriches our understanding of root and dentin structures but also continues to play an essential role in advancing both dental research and practice, pushing the boundaries of restorative dentistry towards improved patient outcomes.[25]

Conclusion

In this study, the author thoroughly examined various success parameters associated with two commercially available endodontic sealers, namely ZenSeal and AH Plus. The investigation employed Scanning Electron Microscopy (SEM) to analyse the performance characteristics of these materials in a detailed manner. The results indicated and concluded that both ZenSeal and AH Plus Jet function effectively as root canal sealants; however, ZenSeal demonstrated superior performance overall. Specifically, it exhibited enhanced surface adaptation, improved dentin bonding capabilities, and greater penetration into dentinal tubules when compared to AH Plus Jet. This advantage is primarily attributed to the bioceramic composition of ZenSeal, which facilitates superior integration with the tooth structure. Conversely, AH Plus Jet, an epoxy resin-based sealer, displayed notable hydrophilic properties and minimised shrinkage during the setting process. Although these attributes are commendable, the data suggest that AH Plus Jet is comparatively less effective in terms of dentinal tubule penetration and adherence than its bioceramic counterpart. The SEM evaluations clearly illustrate that ZenSeal, with its distinctive chemical properties associated with bioceramics, generally provides better adaptation and penetration within the dental substrate. This fundamental distinction in material composition accounts for the observed performance differences between the two sealers. Overall, the findings of this study underscore the significance of selecting appropriate endodontic sealers based on their specific properties and anticipated clinical outcomes.

References

1. European Society of Endodontology (ESE), Duncan H. F., Galler K. M., et al. European Society of Endodontology position statement: management of deep caries and the exposed pulp. International Endodontic Journal2019;52:923–934.
2. Lennon S., Duncan H. F. Minimally invasive endodontics – pulp fact or pulp fiction? Journal of the Irish Dental Association 2020;66:135–138.
3. Barrett B., O'Sullivan M. Management of the deep carious lesion: a literature review. Journal of the Irish Dental Association 2021;67:36–42.
4. Deery C. Caries detection and diagnosis, sealants and management of the possibly carious fissure. British Dental Journal2013;214(11):551–557.
5. Innes N. P. T., Frencken J. E., Bjørndal L., et al. Managing carious lesions: consensus recommendations on terminology. Advances in Dental Research2016;28(2):49–57.
6. Kidd E., Fejerskov O., Nyvad B. Infected dentine revisited. Dental Update2015;42(9):802–809.
7. Glickman GN, Gluskin AH, Johnson WT, Lin J. The crisis in endodontic education: Current perspectives and strategies for change. J Endod 2005; 31(4): 255-61.
8. Peters O, Peters C. Cleaning and shaping of the root canal system.Cohen's Pathways of the Pulp 10th ed. 2010; 283-348.
9. Lambrianidis T. Ledging and blockage of root canals during canal preparation: Causes, recognition, prevention, management, and outcomes. Endod Topics 2006; 15(1): 56-74.
10. Alsofi L. Bioactivity and Element Composition of Three Endodontic Root Canal Sealers. J Contemp Dent Pract. 2025 Jan 1;26(1):62-70.
11. Álvarez-Vásquez JL, Erazo-Guijarro MJ, Domínguez-Ordoñez GS, Ortiz-Garay ÉM. Epoxy resin-based root canal sealers: An integrative literature review. Dent Med Probl. 2024 Mar-Apr;61(2):279-291.

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www.jchr.org

JCHR (2025) 15(5), 2227-2234 | ISSN:2251-6727

12. Kwak SW, Koo J, Song M, Jang IH, Gambarini G, Kim HC. Physicochemical Properties and Biocompatibility of Various Bioceramic Root Canal Sealers: In Vitro Study. J Endod. 2023 Jul;49(7):871-879.

13. Fischer ER, Hansen BT, Nair V, Hoyt FH, Dorward DW. Scanning electron microscopy. Curr Protoc Microbiol. 2012 May;Chapter 2:Unit 2B.2.

14. Schwendicke F, Walsh T, Lamont T, Interventions for treating cavitated or dentine carious lesions. Cochrane Database of Systematic Reviews . 2021;7

15. Simon S, Perard M, Zanini M, Should pulp chamber pulpotomy be seen as a permanent treatment? Some preliminary thoughts. International Endodontic Journal . 2013;46(1):79–87.

16. Giacaman RA, Muñoz-Sandoval C, Neuhaus KW, Fontana M, Chalas R. Evidence-based strategies for the minimally invasive treatment of carious lesions: review of the literature. Advances in Clinical and Experimental Medicine . 2018;27(7):1009–1016.

17. Labib M E, Hassanein O E, Moussa M, Yassen A, Schwendicke F. Selective versus stepwise removal of deep carious lesions in permanent teeth: a randomised controlled trial from Egypt-an interim analysis. BMJ Open . 2019;9 .

18. Dorri M., Dunne S. M., Walsh T., Schwendicke F. Micro-invasive interventions for managing proximal dental decay in primary and permanent teeth. Cochrane Database of Systematic Reviews. 2015;2015(11).

19. Schwendicke F, Splieth CH, Bottenberg P. How to intervene in the caries process in adults: proximal and secondary caries? An EFCD-ORCA-DGZ expert Delphi consensus statement. Clinical Oral Investigations. 2020;24(9):3315–3321.

20. Hülsmann M, Peters O, Dummer P. Mechanical preparation of root canals: Shaping goals, techniques and means. Endod Topics 2005; 10(1): 30-76.

21. Murray CM, Chandler NP. Undergraduate endodontic teaching in New Zealand: Students' experience, perceptions and self-confidence levels. Aust Endod J 2014; 40(3): 116-22.

22. Küçükkaya Eren S. Clinical applications of calcium silicate-based materials: a narrative review. Aust Dent J. 2023 Jun;68 Suppl 1:S96-S109.

23. Yang X, Zheng T, Yang N, Yin Z, Wang W, Bai Y. A Review of the research methods and progress of biocompatibility evaluation of root canal sealers. Aust Endod J. 2023 Sep;49 Suppl 1:508-514.

24. Silva EJNL, Cardoso ML, Rodrigues JP, De-Deus G, Fidalgo TKDS. Solubility of bioceramic- and epoxy resin-based root canal sealers: A systematic review and meta-analysis. Aust Endod J. 2021 Dec;47(3):690-702.

25. Fischer ER, Hansen BT, Nair V, Hoyt FH, Schwartz CL, Dorward DW. Scanning Electron Microscopy. Curr Protoc. 2024 May;4(5):e1034.