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Comparative Evaluation Of Marginal Adaptation Of Two Root End Filling Materials And Micro Dentinal Crack Propagation In Root Using Diamond Points, Carbide Burs And Ultrasonics By Sem.

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Abstract:
Objective(s): *This study aimed to evaluate and compare the effects of three different root-end preparation techniques—ultrasonic tips, diamond burs, and carbide burs—on microcrack formation and marginal adaptation, using Mineral Trioxide Aggregate (MTA) and Biodentine as retrograde filling materials by SEM.*
Materials and Methods*: 120 Extracted human teeth were endodontically treated and resected apically. Root-end cavities were prepared using ultrasonic tips, diamond burs, or carbide burs, and retro filled with either MTA or Biodentine. Samples were assessed for microcrack formation using stereomicroscopy and for marginal adaptation using scanning electron microscopy (SEM). Quantitative data were statistically analyzed.*
Results*: Root-end preparation with ultrasonic tips resulted in significantly fewer microcracks compared to carbide and diamond burs. Biodentine showed superior marginal adaptation compared to MTA across all preparation techniques. However, microcrack formation was slightly higher in the Biodentine group, especially when used with rotary burs.*
Conclusion: *Ultrasonic root-end preparation minimizes microcrack formation, while Biodentine demonstrates better marginal adaptation than MTA. The ideal combination for optimal surgical endodontic outcomes may involve ultrasonic preparation with Biodentine retrofilling.*
Key Word: *Root-end preparation, Ultrasonic, MTA, Biodentine, Microcracks, Marginal adaptation, Endodontic surgery*

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I. Introduction

Endodontic treatment success depends on achieving a fluid-tight closure by sealing the root canal system in all three dimensions. Obturating a root canal is primarily done to create a complete hermetic closure between the peri radicular area and the pulp space.[1]

However, under certain clinical conditions the non-surgical procedure for periapical pathology clearance is inadequate. An orthograde filling cannot provide this hermetic seal; in these cases, a retrograde root filling is surgically placed hence preferred method of treatment is resection. When periapical pathology persists, overfilled canals, ledges, canal obstructions, separated instruments, apical transportation, and perforations occur, surgery is frequently recommended. [2]

Surgical endodontic treatment may be required if retreatment is not advised or if nonsurgical root canal therapy is unable to address periradicular lesions of endodontic origin.[3]

During peri radicular surgery, root-end preparation and filling are frequently used techniques (Gutmann & Harrison 1991). Their specific objectives are to seal the root canal system's apical terminus by creating a mechanically engineered chamber that can be filled. For root-end preparation, several methods and tools have been proposed (Gutmann & Harrison 1991)[4]

The steps involved in this treatment consist of three essential procedures to get rid of lingering endodontic pathogens:
1) surgically debriding the diseased periradicular tissue,
2) apicoectomy (root-end excision) to expose the affected apex, resect the root end and create a class I cavity
3) retrograde root canal obturation (root-end filling).[5]

Traditionally, root-end cavities are prepared with round or inverted cone burs, but this method has drawbacks. In the 1980s, alternatives like slot preparation with fissure burs and reverse instrumentation were introduced but remain uncommon in periradicular surgery. Ultrasound use began in 1957 with Richman's ultrasonic chisel for bone and apical tissue removal. Bertrand et al. first used modified ultrasonic inserts for root-end preparation after apicoectomy. Flath & Hicks documented sonic and ultrasonic tools, while Sultan & Pitt Ford experimentally compared hand-held and ultrasonic root-end preparations.

The availability of commercially manufactured microsurgical tips began in the early 1990s.[5] Ultrasonic retro tip root end preparation was introduced because of the high microleakage observed in conventional root end preparation employing microburs. Its benefits include the creation of a more centrally located, deep, smooth, and conservative cavity with a better form and a reduction in apical leakage due to less exposed dentinal tubules at the resected root surface.[2]

Wuchenich et al.'s (1993) assessment of this root end preparation method revealed that ultrasonically produced cavities had cleaner surfaces, deeper retention depths, more parallel walls, and preparations that followed the root canal's line.[4]

Root-end fillings main goal is to seal the apical region to prevent bacteria or their byproducts from infiltrating the root canal system from the periradicular tissues. Johnson described the possible correlation between long-term clinical success and three essential characteristics for choosing the best root-end filling material: biocompatibility, apical saleability, and their physical characteristics.[6]

The choice of root end filing material with advantageous qualities like biocompatibility, good strength, optimal sealing ability, promote healing, radiopacity, ease of manipulation, and resistance to moisture is one of the prerequisites for the success of surgical endodontics[1]

Amalgam has been used as a root-end filling material but has drawbacks like microleakage, poor adhesion, and mercury content. Alternatives include glass ionomer, calcium hydroxide, gutta-percha, composite resins, and zinc oxide eugenol-based cements. Mineral trioxide aggregate (MTA) is preferred for its sealing ability, biocompatibility, moisture setting, and radiopacity, but its long setting time, handling difficulty, and high cost drive the search for substitutes.

Researchers have created a brand-new active calcium silicate-based substance called Biodentine (Septodont), which promises advantageous qualities like superior sealing ability, biocompatibility, and good dimensional stability. Biodentine also has the added benefit of being a root end filling material with a quick setting time, enhanced mechanical strength, and ease of use.[6]

II. Material And Methods

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Jaipur Dental College and Hospital, Jaipur collaboration with Sophisticated Analytical Instrumentation Facility, Punjab University, Chandigarh.

Study Design: In-vitro study

Sample size: 120.

Sample size calculation: A power analysis was established by G*power, version 3.1.9.2 (Franz Faul university at, Kiel, Germany). A sample size of 120 subjects (20 in each group) would yield 81% power to detect significant differences, with effect size of 0.34 and significance level at 0.05.

Inclusion criteria:
The selected teeth should be intact, extracted for periodontal reasons and non-carious and fully mature apices.

Exclusion criteria:
The selected teeth should not have root caries or restorations, open apices, calcifications, fractures, or craze lines.

Procedure methodology

A total of 120 non-carious, single-rooted extracted teeth with similar buccolingual and mesiodistal dimensions were selected. Post-extraction, teeth were rinsed to remove blood, scaled to eliminate periodontal tissue, plaque, and calculus, and then immersed in 5% sodium hypochlorite (NaOCl) for 2 hours for surface disinfection and soft tissue dissolution. Preoperative radiographs ensured exclusion of teeth with root caries, restorations, open apices, calcifications, fractures, or craze lines.

To standardize the samples, each tooth was sectioned using a flexible diamond disk (Novo Dental Products, Mumbai, India) in a slow-speed handpiece with copious water coolant, and the root length was standardized to 14 mm from apex to CEJ.

Standard access cavities were prepared in each tooth using a high-speed diamond bur under continuous water cooling. The crowns of the teeth were sectioned at the cementoenamel junction to obtain a standardized root length. Working length was established 1 mm short of the apical foramen using a #10 K-file and verified radiographically.

Cleaning and shaping were performed using ProTaper rotary files (up to F3) driven by an X-Smart endomotor. Throughout instrumentation, the canals were irrigated with 3% sodium hypochlorite, and a final rinse with 17% EDTA was performed to remove the smear layer, followed by a final flush with distilled water.

After drying with paper points, the canals were obturated with gutta-percha and AH Plus resin sealer using the lateral compaction technique. The access cavities were sealed with temporary restorative material, and the teeth were stored at 37°C in 100% humidity for seven days to allow complete sealer setting.

Apical resection was performed 3 mm from the apex, perpendicular to the long axis of the tooth, using a water-cooled diamond disc in a high-speed handpiece to simulate clinical root-end resection.

The samples were then randomly divided into three groups (n = 40 each) based on the root-end preparation technique:
Group I – ultrasonic retro tips
Group II – diamond burs
Group III – carbide burs

Each of these groups was further subdivided into two subgroups (n = 20 each) based on the retrograde filling material used:
Subgroup A: MTA (Angelus)
Subgroup B: Biodentine (Septodont)
Resulting in six experimental groups in total.

Root-end cavities were prepared to a depth of 3 mm using the assigned instruments. Ultrasonic retro tips (Woodpecker) were used under continuous water spray at medium power setting, while diamond burs (ISO 012) and carbide burs (ISO 012) were used in high-speed and straight handpieces, respectively, under copious irrigation to minimize heat generation.

Root-end cavities were filled with either MTA and Biodentine, mixed according to manufacturer’s instructions and applied. Samples were then stored at 37°C and 100% humidity for 48 hours to ensure complete setting.

To assess both marginal adaptation and microcrack formation, the samples were sectioned longitudinally using a diamond disc under water cooling to expose the interface between the retrograde filling material and dentinal walls.

Each specimen was examined under a **Scanning Electron Microscope (Nova NanoSEM 450) at 500× and 1000× magnifications.** High-resolution digital micrographs were obtained for each specimen.

Marginal adaptation was evaluated by measuring the maximum and minimum gaps (in micrometers) between the filling material and the surrounding dentinal wall at four predetermined quadrants using **ImageJ software** calibrated to the microscope’s scale.

Similarly, microcrack formation was assessed by visually identifying and recording the presence of any linear discontinuities in dentin radiating from the cavity margins or apical resection plane. Microcracks were defined as distinct lines or fractures in the dentinal structure that were not visible prior to instrumentation, as confirmed by pre-operative imaging and visual inspection.

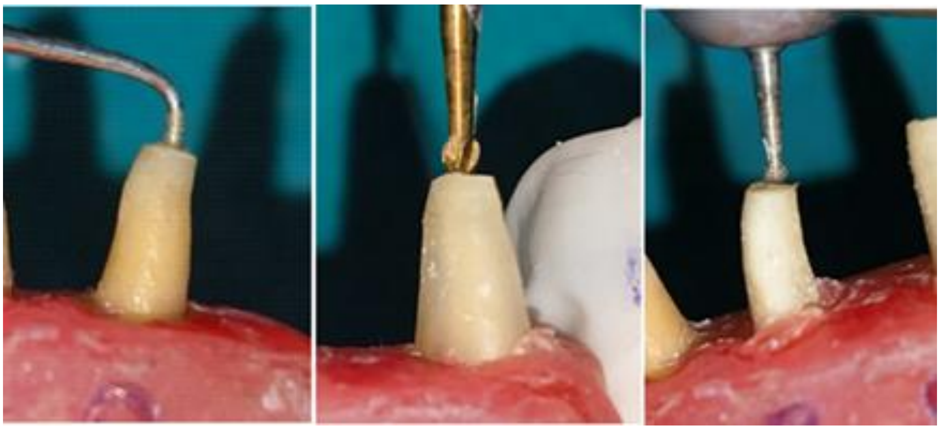


Figure 1: Retro cavity preparation using Ultrasonic retro tip carbide bur and diamond points

Figure 2: Retro cavity filling

Statistical analysis

All observations were independently evaluated by two calibrated examiners blinded to the experimental groups. In cases of disagreement, a third senior examiner was consulted to reach a consensus. Data obtained were subjected to statistical analysis using SPSS software version 21.0 (IBM Corp., USA).

Two-way Analysis of Variance (ANOVA) was used to assess differences in marginal gap width and microcrack prevalence among the various preparation techniques and filling materials. Tukey's post hoc test was applied for pairwise comparisons between groups. A p-value less than 0.05 was considered to indicate statistical significance.

III. Result

This study aimed to evaluate the influence of different root-end preparation techniques—ultrasonic tips, diamond burs, and carbide burs—on the formation of microcracks and the marginal adaptation of two retrograde filling materials: Mineral Trioxide Aggregate (MTA) and Biodentine, using Scanning Electron Microscopy (SEM) as the sole evaluation tool. All results were statistically analyzed and interpreted with respect to both quantitative metrics and clinical relevance.

The extent of dentinal damage, as observed under SEM, differed substantially based on the instrumentation technique. A five-point grading scale was used to classify dentinal microcracks: Grade 0 for no cracks, Grade 1 for incomplete cracks, Grade 2 for complete cracks, Grade 3 for severe cracks, and Grade 4 for gross fragmentation.

In the Ultrasonic group, 75% of samples showed intact dentin (Grade 0), while 25% had minor internal microcracks (Grade 1) with no external propagation. No severe cracks were observed. SEM images revealed smooth cavity margins and minimal surface damage, indicating ultrasonic instrumentation is relatively conservative and less traumatic to root-end structures.

In the Diamond Bur group, only 5% of samples were crack-free. Incomplete cracks appeared in 7.5%, complete cracks in 55%, severe cracks in 25%, and 7.5% showed gross fragmentation with structural damage. SEM images highlighted significant dentinal disruption caused by the vibratory and thermal stresses of high-speed rotary instruments.

The Carbide Bur group showed the highest dentinal damage, with no crack-free samples. Complete cracks occurred in 12.5%, severe cracks in 50%, and gross fragmentation in 37.5%. SEM images revealed multidirectional cracks, irregular cavities, and structural collapse, indicating that carbide burs caused the most mechanical trauma among all techniques.

The difference was statistically highly significant ($p = 0.001$). Post hoc comparisons confirmed that ultrasonic tips produced significantly fewer microcracks than both diamond and carbide burs ($p < 0.05$), and carbide burs caused significantly more cracks than diamond burs ($p < 0.05$). These findings clearly indicate that the choice of preparation instruments plays a crucial role in preserving dentinal integrity, with ultrasonics being the most favorable.

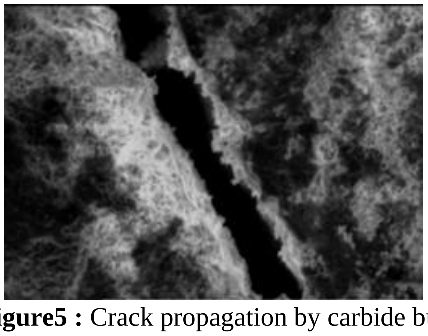


Figure5 : Crack propagation by carbide bur

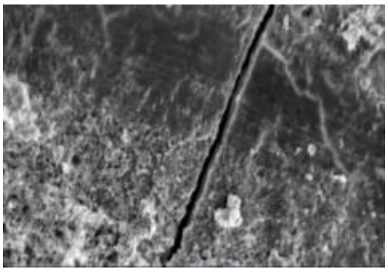


Figure 6 : Crack propagation by diamond bur

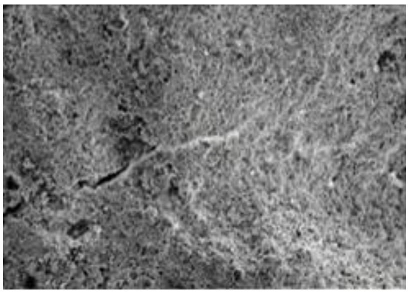
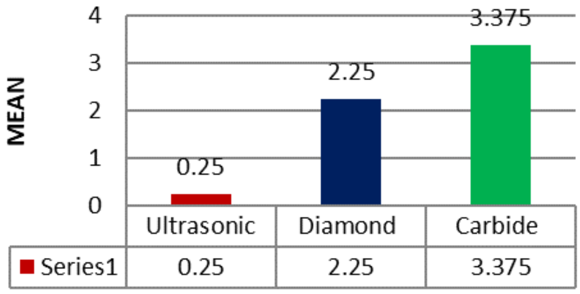
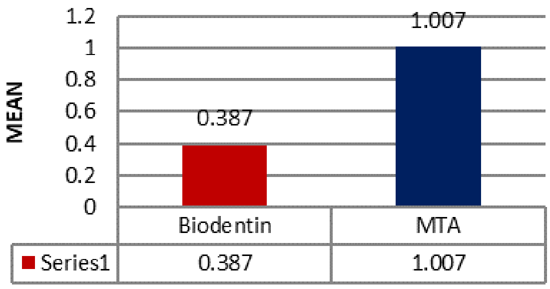


Figure 7: Crack propagation by ultrasonic retro tips



Graph 1: intergroup comparison of mean cracks between the groups

SEM was used to evaluate marginal adaptation of retrograde filling materials by measuring the maximum interfacial gap at four dentin quadrants, assessing material adherence and the impact of preparation techniques on seal quality. Biodentine showed significantly better marginal adaptation than MTA, with a mean gap of 0.387 ± 0.032 µm versus 1.007 ± 0.147 µm ($p = 0.001$). It also demonstrated more consistent performance. SEM images revealed close dentin contact, no visible gaps, and hydroxyapatite-like crystal formation, indicating Biodentine's superior sealing and bioactivity. MTA-filled cavities often showed interfacial gaps, especially in rotary-prepared sites. SEM images revealed visible separations, granular surfaces, and material detachment, likely due to MTA's long setting time, moisture sensitivity, and slight contraction during setting, resulting in poorer adaptation.



Graph 2: intergroup comparison of mean distance between MTA and Biodentin

IV. Discussion

Endodontic surgery is a dental operation that has a lengthy history. In the late 19th and early 20th centuries, several physicians presented the ideas of apical surgery. The goal was to eliminate diseased periapical tissues and necrotic apex sections. [7]

However, the existence of intra-radicular infection was not considered in these methods. Following the publications of Partsch and Faulhaber and Neumann, root-end resection attracted even more attention.[9 10]

Retreatment, either nonsurgical or surgical, is a treatment option for recurring or chronic apical periodontitis. When a new final restoration is planned or when the first root canal treatment is inadequate and there are unidentified canals, nonsurgical retreatment is seen to be the best course of action. Adequate nonsurgical retreatment should be beneficial for most periapical lesions, such as abscesses, cysts, and granulomas. [13]

Immature root development (>1.5 mm in apical diameter), extreme (>30°) or s-shaped root curvatures, root canal bifurcations in the middle or apical third, excessively long roots (>25 mm), or severe calcifications are examples of natural anatomical challenges that may lead to a decision for surgical retreatment. [14]

Levers, transportation, perforations, internal and external resorptions, or separated instruments are examples of changes to the original anatomy of the root canal system that may be challenging to overcome. These changes may leave behind microorganisms near the apical constriction or apical foramen because of insufficient biomechanical disinfection. [15]

Periapical lesions are primarily inflammatory pathoses according to histology. Nair et al. 63 reported that 15% of lesions were pocket or true cysts, 35% were periapical abscesses, and 50% were granulomas. While genuine cysts are not dependent on the root, pocket cysts are directly related to the diseased root canal system. [16]

Furthermore, endodontic surgery may be required for extra-radicular infections, which can manifest as biofilms on an external root surface or as colonies of Actinomyces and Propionibacterium within asymptomatic lesions. [17]

The European Society of Endodontology guidelines indicate apical surge is warranted for:

apical periodontitis with obstructed, unremovable canals; persistent apical periodontitis or symptoms due to extruded material; persistent disease after root canal treatment when retreatment isn't feasible; and pulp chamber or root perforations unsuitable for internal treatment. [18]

The term "endodontic microsurgery" refers to a technique that uses new micro instruments appropriately in conjunction with the magnification and lighting that a microscope provides. [19]

Endodontic microsurgery removes the presumptions present in conventional surgical techniques and can be carried out with accuracy and predictability. Microsurgery offers advantages such as smaller osteotomies, minimal bone loss, and easier root apex identification. High magnification reveals complex root anatomy, while microscopes and ultrasonic devices allow for precise, conservative root-end preparations that meet surgical standards. [20]

Microsurgery allows for minimal osteotomy—just 3–4 mm—preserving bone while still accommodating ultrasonic tips. Unlike traditional techniques that required a 45–60° bevel for access, microsurgery reduces or eliminates beveling, improving outcomes and conserving root structure. [21]

Gilheany et al. recommend removing a minimum of 2 mm to reduce the number of bacteria that leaks from the canals. According to our anatomical analysis of the root apex, 98% of the apical ramifications and 93% of the lateral canals can be eliminated by removing at least 3 mm of the root end. [22]

To rule out the possibility of air emphysema or air embolism behind the flap in the soft tissues, a high-speed handpiece with no air leaving the working end, as the Palisades Dental Impact Air 45 handpiece (Star Dental, Lancaster, PA, USA), should be utilized. A typical highspeed handpiece should never be used because of these factors.[23]

According to Bonfield & Li, there was an irreversible bone deformation at temperatures between 1501C and 901C because of both a reorientation of the collagen's structure and a weakening of the links that hold it to hydroxyapatite. These results are in line with the idea that burn injuries cause protein denaturation. [24]

Eriksson et al. observed that as blood flow increased over 401C, hyperemia developed. After one minute of a heat stimulus between 50 and 531 degrees Celsius, blood flow stalled, and the vascular network eventually died within two days. When bone was heated to 601C or higher, tissue necrosis and a permanent stop in blood flow occurred. [25]

This study used #2 round carbide burs (SS White) for precise, smooth root-end preparation with minimal vibration and microcrack risk, ensuring infection control. Additionally, #2 round diamond burs (Mani) were employed for retrograde cavity preparation, offering efficient cutting and smooth walls but requiring irrigation to prevent heat damage and microcracks.

According to this study Diamond burs showed moderate results, while carbide burs led to the highest microcrack formation and comparatively poorer adaptation.

Haiyang Yu et al concluded in study that to enhance the quality of the finish line preparation, it is advised to utilize tungsten steel burs with tip sizes and shapes that match the design. Using top-notch cutting equipment is also advised to lessen iatrogenic harm to the periodontium and tooth pulp.[26]

Majd et al. found that diamond burs significantly reduced dentin strength, especially fatigue strength, more than tungsten carbide burs. The greatest weakening occurred when cutting was perpendicular to primary stress. Damage from abrasive grains and stress concentration around grooves likely caused this strength reduction. [27]

Wuchenich et al. compared ultrasonic and bur root-end preparations, finding that ultrasonic tips produced deeper, more parallel cavities and better followed the canal path. SEM analysis showed cleaner cavity walls with ultrasonic tips compared to bur-prepared surfaces.[28]

In this study, Woodpecker ultrasonic tips were used for root-end preparation. Designed for apicoectomy, they offer precise, conservative cutting with minimal dentinal damage and fewer microcracks. Their fine, angled design ensures good access and visibility, making them ideal for microsurgical techniques and improving adaptation of materials like MTA and Biodentine.

According to this study Ultrasonic technique resulted in fewer microcracks and better marginal adaptation compared to diamond and carbide burs.

In 1957, Richman used a modified ultrasonic periodontal chisel scaler for root canal debridement and apicoectomy, marking the first time ultrasonics was used in endodontics. [29]

Retrotips made especially for root-end cavity preparation during endodontic surgery were eventually presented by Carr. When employing ultrasonic retrotips instead of micro handpieces, some writers later observed better operator control and a lower risk of perforation due to an increased capacity to stay focused in the canal. [30]

Wuchenich et al. conducted a SEM investigation to examine the root-end cavities made in cadavers using ultrasonic tips and traditional handpieces. They discovered that using ultrasonic tips also resulted in deeper and cleaner root-end cavity preparations, which helped to disinfect by eliminating contaminated dentin and aid in the retention of the root-end filling material. [28]

In this study, MTA Angelus, a calcium silicate-based cement, was used for its biocompatibility, sealing ability, and moisture setting. SEM studies show it offers better marginal adaptation than Super EBA and Vitremer, though Super EBA may slightly outperform it in apical leakage resistance.[31]

MTA Angelus is favored clinically for its ease of handling, varied formulations, and proven success in root-end fillings. Biodentine (Septodont), a bioactive dentin substitute with tricalcium silicate and calcium chloride, offers excellent biocompatibility, fast setting (~12 minutes), and strong sealing, making it popular in endodontics and restorative dentistry.

Several studies have compared the marginal adaptation of MTA and Biodentine as root-end filling materials using various microscopic techniques. Kumbhar et al. conducted a scanning electron microscope (SEM) study comparing MTA, Biodentine, and Geristore, and found that Biodentine exhibited the smallest marginal gaps at both 1 mm and 2 mm levels, suggesting better adaptation to the dentinal walls than MTA and Geristore. [34]

This study confirms that Biodentine offers superior marginal adaptation over MTA due to its finer particles, chemical bonding, and faster setting, enhancing sealing and biomineralization. Among preparation methods, ultrasonic tips showed the best outcomes with clean, conservative cavities and minimal damage, while diamond burs performed moderately and carbide burs caused the most microcracks, supporting existing literature favoring ultrasonics for apical surgery.

V. Conclusion

The present study evaluated the marginal adaptation of MTA Angelus and Biodentine, alongside the influence of ultrasonic tips, diamond burs, and carbide burs for retrograde cavity preparation, with a focus on microcrack formation and marginal leakage. Within the limitations of this research, Biodentine exhibited superior marginal adaptation compared to MTA Angelus, attributed to its enhanced bioactivity, favorable handling characteristics, and faster setting time, making it a reliable choice for achieving an effective apical seal. Ultrasonic retro-tips emerged as the most effective preparation method, enabling conservative, centrally positioned cavity preparations with minimal dentinal damage, thereby reducing the risk of microcrack formation and improving material adaptation. The results also highlight the critical importance of strict moisture control during placement, as both materials are sensitive to contamination, and optimal sealing is dependent on maintaining ideal clinical conditions. Furthermore, operator expertise plays a pivotal role in treatment success, underscoring the need for continuous training in advanced preparation techniques, particularly the use of ultrasonic tips, and proficiency in handling bioactive root-end filling materials to ensure predictable, long-term outcomes in endodontic microsurgery.

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