Research Article

# Comparative Evaluation Of Pushout Bond Strength Of Three Root End Filling Materials In Teeth With Root Resection – An In Vitro Study

Dr. Kenchugonde Suresh Kumar[1], Dr. Surya Dahiya[2] , Dr. Rajan Dhawan[3], Dr. Aparna Singh[4], Dr. Robin Mathew James[5],Dr. D S S Vishnu Pavan[6]

[1]Post Graduate Student, Department of Conservative Dentistry & Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala kenchugondesuresh@gmail.com Orcid Id :- 0009-0006-3482-4763
[2]Professor, Department of Conservative Dentistry & Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala drsuryadahiya@gmail.com
[3]Professor and head, Department of Conservative Dentistry & Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala endorajan@gmail.com
[4]Post Graduate Student, Department of Conservative Dentistry & Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala aparnasingh.charu@gmail.com
[5]Post Graduate Student, Department of Conservative Dentistry & Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala robinmathewjames@gmail.com
[6] Assistant Professor, Department of Conservative Dentistry & Endodontics, Narayana Dental College and Hospital, Nellore vishnud2831@gmail.com

**Abstract**

**Background:** Achieving a hermetic seal between the pulp chamber and surrounding periodontal tissues is essential to prevent bacterial leakage during endodontic therapy. Despite advancements, obtaining an ideal seal remains challenging. Periapical surgery is indicated when non-surgical treatment fails, involving root-end resection, retrograde cavity preparation, and sealing to confine bacteria within the canal. The bond strength of root-end filling materials to radicular dentin plays a critical role in long-term clinical success. This in-vitro study aimed to evaluate and compare the push-out bond strength of three root-end filling materials in resected roots.
**Materials and Methods:** Sixty extracted teeth were prepared and obturated using gutta-percha and Bio Root RCS sealer with a single cone technique. Standardized root-end resection and retrograde cavity preparation were performed. Samples were randomly divided into three groups (n=20): Group I – Endo CEM MTA, Group II – Bio-C Repair, and Group III – Bio Structure MTA. Push-out bond strength was evaluated using a universal testing machine, and results were statistically analyzed.
**Results:** No statistically significant difference was observed among the groups ($p>0.05$). However, Endo CEM MTA exhibited the highest mean push-out bond strength ($5.00\pm4.144$), followed by Bio Structure MTA ($4.035\pm4.77$) and Bio-C Repair ($1.984\pm1.04$).
**Conclusion:** Within the limitations of this in-vitro study, all tested materials demonstrated comparable bond strength and can be considered suitable for use as retrograde filling materials.

**Keyword:** Endo CEM MTA, Bio-C Repair, Biostructure MTA, Pushout Bond Strength, BioRoot RCS, Apicectomy, Root-end filling, Root-end resection.

## Introduction:

Preservation of natural teeth is the main objective of the Endotherapy which tries to eliminate the main source of infection and this treatment also restores tooth in its functional state.[1] Also, from a biological perspective, natural teeth, when adequately maintained, does not possess a predetermined shelf life whereas artificial replacements such as implants are subject to material fatigue, mechanical complications and biological limitations over time. However, significant injury to the pulp chamber leads to inflammation that may further lead to pulp necrosis. Possible scenarios that can lead to periapical pathology are commonly initiated by caries, trauma or tooth wear. Microorganisms colonize pulpal tissue as soon as it loses its blood supply as a result of trauma resulting in periapical pathosis. The majority of periapical lesions heal subsequent to meticulous non-surgical root canal treatment. However, failure is possible after endodontic treatment due to different microbial and non-microbial factors.[2]

The most frequent cause of periapical pathosis, which results in periodontal inflammation and consequent pain and swelling in the area, is bacterial leakage from the pulpal, infection into the periodontal space. Periapical surgery is the considerable option for the conditions when traditional root canal treatment fails.[3]

The pulp chamber and the surrounding periodontal tissue must be sealed hermetically to avoid the spread of bacteria during the course of the endodontic therapy. Although there has been great improvement in endodontic procedures, it continues to be challenge to create a hermetic seal. The presence of bacteria in the area affects the rate at which a lesion heals or persist in teeth or periodontium.[4]

Periapical surgery is an endodontic treatment through surgical flap that focuses on removing the portion of root with anatomical complexities when a complete seal cannot be achieved through non-surgical approach. By sealing the root canal apically, removing the most apical and complex portion of the root canal, and removing the periapical lesion for additional histological analysis, the goal is to contain bacteria within the root canal. The

objective is to create the ideal environment for the attachment apparatus to regrow and the periapical tissue to repair.[2]
Since sealing the apical region is the primary goal of the treatment, the choice of root-end filling material affects how the outcomes turn out in the end. A variety of retrograde filling materials have been utilised, including silver amalgam, gutta percha, zinc oxide eugenol (SuperEBA), glass ionomer cement, composite resins, compomers, but Mineral Trioxide Aggregate remains the gold standard for this purpose.[5] MTA possesses a wide variety of practical advantages including superior biocompatibility, effective sealing ability, antibacterial efficacy, radiopacity and ability promote regeneration of pulp and peripheral root tissues.[6]
Despite favorable properties and long-term clinical success results, Conventional MTA has few drawbacks such as potential of discoloration, longer setting time and poor handling characteristics. To overcome these limitations, MTA is being constantly modified and marketed by different manufacturers.
Recently, a new variant of MTA, derived from pozzalan cement,
**EndoCEM MTA (Maruchi, Wonju, Korea)** has been introduced with faster setting time with advantage of being ready to use premixed injectable paste form maintaining chemical composition similar to commercially available MTA. Its composition include calcium oxide, silicon dioxide, aluminium oxide, bismuth oxide.[7]
Another ready to use bioceramic material,
**Bio-C Repair (Angelus, Brazil)** entered the market with the composition of tricalcium silicate, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, silicone dioxide and dispersing agent. [8]
**BioStructureMTA (SafeEndo, India)** is also another modification of conventional MTA with reduced setting time. It is available in powder and liquid form with improved mechanical resistance and decreased solubility and better biocompatibility.[9]
Bond strength of endodontic materials to radicular dentin is considered an important factor for long term clinical success. Any dislodgement forces applied during function are resisted by the material's adhesion to the surrounding dentin.[10]
Pushout test is widely use to evaluate the bond strength between the dentin and root-end filling material.[11]
The present in-vitro study was intended to assess and compare the pushout bond strength of three root-end filling material in teeth with root resection.

## MATERIALS & METHODS

**Sample size calculation**

- The sample size was calculated using G power analysis. For this study the effect size of 0.5 was kept setting alpha 0.05 and power of 80%.
- The total sample size achieved was 60, with 20 samples in each group.
- Single rooted teeth extracted for periodontal reasons, without root caries, cracks, root canal treated, root resorption, internal resorption, C-shaped canals were collected for the study.

**Sample Preparation**

Teeth were decoronated to obtain the standardized root length of 15mm and access to pulp chamber made with endoaccess bur. Glide path is achieved with 10# k-file and working length was measured 1mm short of file visible at the apex. Cleaning and shaping was done with Protaper Universal files till F3 and 2ml of 5% NaOCl is used as irrigant between each file. Final irrigation was done using 17% EDTA to remove smear layer, followed by 5%NaOCl for 1 minute and rinsing with saline. Canals were dried with paperpoints and obturated using single cone technique with Gutta Percha and BioRootRCS sealer and left undisturbed for one week at room temperature. Later 3mm root-end resection was done using diamond disc at perpendicular to long axis of the tooth under continuous water spray and root-end cavity of 3mm depth and 1.5mm diameter was made using ultrasonic tip.

**Sampling:**

- Sixty samples were divided equally into 3 groups with 20 samples in each.

- **Group – I:**

EndoCEM Premixed MTA material was directly dispensed into the cavity prepared from the syringe and then condensed with the endodontic plugger (RCP 50) followed by application of moist cotton pellet for 5 minutes for setting of the material.

- **Group – II:**

Bio-C Repair material was dispensed into the prepared cavity from the syringe and condensed with endodontic plugger (RCP 50). Then moist cotton pellet was placed over the restoration and tooth was temporised to maintain the moisture needed for setting of the material.

- After setting time of 2 hours, temporisation and moist cotton pellet were removed.

- **Group – III:**

The Biostructure MTA material was mixed according to the manufacturer instructions. 1gm of powder is dispensed on sterile pad and mixed with 2ml liquid within 30-40 seconds, then the material was carried into the prepared cavity with MTA carrier and condensed with endodontic plugger (RCP 50). Then moist cotton pellet was applied over the restoration and temporisation was done to maintain the moisture needed for setting of the material.

- After 24 hours, the temporisation and cotton pellet were removed.
- All the samples were left undisturbed for 7 days.

**Bond strength testing:**

The samples were then embedded in the acrylic resin blocks and 3mm slices were made with diamond blade to measure the pushout bond strength of the materials using Universal Testing Machine.

- The bonding surface area was determined by conical frustrum formula:

**"Area=$\pi(R_1+R_2)\sqrt{(R_1-R_2)^2+H^2}$ "**

- Where,

$R_1$ = larger apical radius

$R_2$ = smaller coronal radius

H = slice thickness.

- Compressive pushout bond load was applied via Universal Testing Machine. Pushout bond strength was estimated using the formula:

$\mathbf{F}\boldsymbol{ailure\ load \div Bonding\ surface\ area.}$

**Statistical Analysis**

Data was collected compiled and entered into Microsoft excel 2016 , Data were analyzed using IBM SPSS version 20 software (IBM SPSS, IBM Corp., Armonk, NY, USA). Descriptive statistics and one-way analysis of variance (ANOVA) with Tukey's post hoc tests were done to analyze the study data. Simple bar graphs were used for data presentation. During the analysis the level of significance (p-value) was set at 0.05.

**Table 1** presents the comparison of mean pushout bond strength between the study groups. There was a no statistically significant difference between the study groups. It was noted that the mean pushout bond strength was highest in the EMTA group (5.00±4.144) followed by BMTA group (4.035±4.77), and the BCR group (1.984±1.04).

| Groups | Mean | Std. Deviation | Std. Error | fvalue | pvalue |
|---|---|---|---|---|---|
| **EMTA** | 5.0000 | 4.14423 | 1.31052 | 2.681 | 0.087(NS) |
| **BCR** | 1.9840 | 1.04104 | .32921 | | |
| **BMTA** | 4.4450 | 3.25206 | 1.02839 | | |

Oneway anova p<0.05* significant

**Table 1: Comparison of pushout bond strength (in MPa) among the study groups**

| Groups | | Mean Difference | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **BCR** | **EMTA** | -3.01600 | 1.38646 | .094(NS) | -6.4536 | .4216 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **BMTA** | -2.46100 | 1.38646 | .197(NS) | -5.8986 | .9766 |
| **EMTA** | **BMTA** | .55500 | 1.38646 | .916(NS) | -2.8826 | 3.9926 |

Posthoc tukey p<0.05* significant

**Table 2: Multiple comparison using posthoc tukey**

**Table 2** shows multiple pairwise comparisons revealed that the BCR group had no significant difference in pushout bond strength compared to EMTA and BMTA groups And no significant difference in pushout bond strength was seen between EMTA and BMTA

**Figure 1 shows the mean pushout bond strengths among the study groups**

The mean pushout bond strength among the BCR group was 1.984 MPa, EMTA group was 5 MPa and BMTA group was 4.44 MPa.

**Figure 1: Mean pushout bond strengths (in MPa) among the study groups**

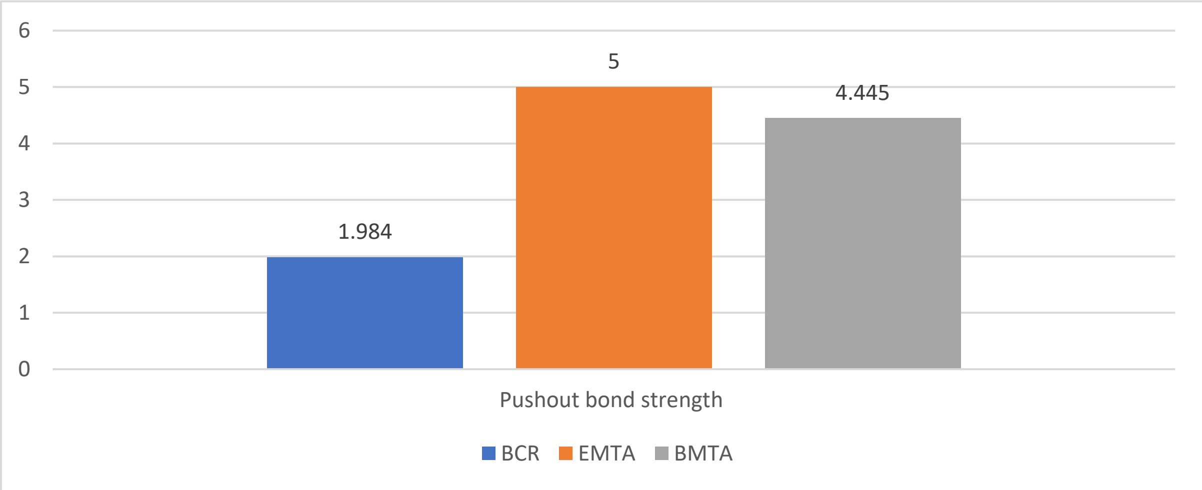


**Figure 2: Mean difference between the groups**

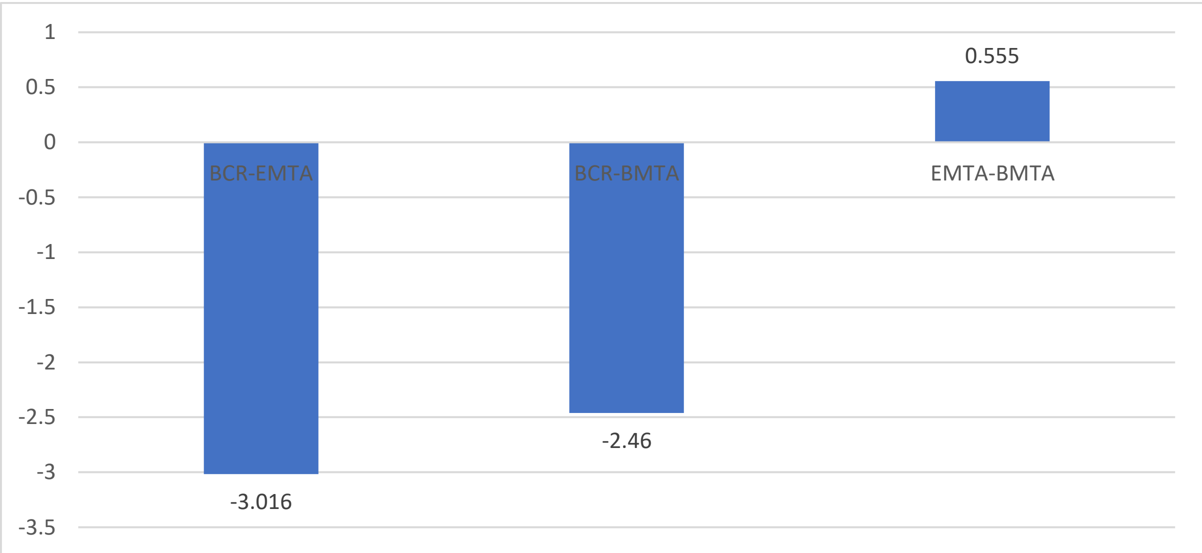


**Figure 2 shows the mean difference between the groups**

The mean difference in push out bond strength among the BCR and EMTA was -3.016, BCR and BMTA was -2.46 & EMTA and BMTA was 0.555.

## Discussion

The golden statement by MM Devan: "Perpetual preservation of what remains is more important than meticulous replacement of what is missing." This statement depicts the importance of tooth retention rather than its replacement which cannot completely compensate the natural integrity.[12]

Root canal treatment is a well-established conservative modality designed to eliminate infection from root canal system, thereby preserving the natural tooth, maintaining its form, function and esthetics. When performed under ideal conditions, conventional endodontic therapy demonstrate a high success rate ranging from 73.8% to 85.2%. Despite this high success rate, certain clinical situations may present with persistent periapical pathology even after adequately performed root canal therapy. In such situations, endodontic surgical intervention becomes a viable treatment option to retain the natural tooth rather than opting for extraction.[13]

Surgical intervention is mainly advisable when the infection persists even after the available non-surgical procedures done.[14] Indications for periapical surgery include symptomatic cases, irretrievable materials in the root canal, procedural errors, exploratory surgery, and anatomical complexities of the root canal system that hinder thorough cleaning, shaping, and obturation of the root canal system through coronal access. Apical surgery, involving resecting the apical third of the root followed by root-end cavity preparation and filling it with an appropriate material is undertaken to eliminate apical source of infection and establish an effective seal at the root end. The proposed length for root-end resection was minimum of 3mm to encompass apical ramifications and lateral canals along with preserving 7-9mm of remaining root length to maintain structural integrity and stability.[14,15]

A study by Rahbaran S et al. evaluated overall success rate of root-end resection and revealed clinical success rate of 79.5%.[16] While the earlier study provided clinical insight, broader evidence from a systematic review by Tsesis I et al. further supports the favourable outcomes of surgical endodontic treatment with a reported success rate of 89% at one year follow-up.[17]

Retro-filling is an important predictor of treatment outcome. The long-term outcome of surgical intervention is significantly influenced by the type of retrograde filling material used as well as presence or absence of root-end filling material.[2,17]

MTA, a biologically active cement, first acquainted by Torabinejad M et al. in 1993, received approval for endodontic applications from US Food and Drug Administration in 1998. MTA undergoes setting by hydration reaction forming silicate gel and calcium hydroxide. It has initial pH of 10.2 which rises to approximately 12.5 after three hours.[67] Therefore, in its unset state, the material exhibits antibacterial properties, whereas upon complete setting, it is biocompatible and even bioactive.[18]

EndoCEM is a MTA derived pozzolan cement. The tiny particles of pozzolan cement increases the surface contact and facilitates faster setting. This pozzolan cement is a watery mixture of calcium silicate hydrate. Pozzolanic reaction uses calcium hydroxide to create calcium silicate hydrate and calcium aluminate hydrate products, primarily responsible for the beneficial effects of pozzolan addition in terms of compressive strength and durability. These reduce the permeability of the binder by filling up the pores and reducing their size.[7]

Kang YT et al. conducted a comparative study to evaluate the physico-chemical and mechanical properties as well as the cytotoxicity of four different root-end filling materials, namely EndoCEM MTA, Dia-Root Bio MTA, RetroMTA, and ProRoot MTA and concluded that EndoCEM MTA exhibited clinically acceptable physico-chemical characteristics and biocompatibility, suggesting its potential as an alternative to conventional MTA for retrograde filling.[19] Choi et al. compared the washout resistance of EndoCEM and ProRoot MTA and concluded that EndoCEM sets faster and is more resistant to washout in retrograde filling model.[20]

Bio-C Repair, another ready to use bioceramic material offers improved handling and insertion along with saving time.[8] This material exhibits biocompatibility and biomineralization properties comparable to those of conventional MTA. In periodontal ligament stem cells, Bio-C Repair demonstrated greater cell viability and enhanced cell adhesion indicating its bioactive potential.[21]

Biostructure MTA pioneered as root repair material has been recommended to be used for root-end filling, perforation repair and cavity liners. It has diminished setting time of 16 minutes as endorsed by manufacturer and has an additional advantage of optimal biocompatibility. Moreover, it provides good apical seal, better radiopacity with reduced cost. A case report by Rudranaik S et al. revealed good periapical healing and appreciable apical seal when Biostructure MTA was used for retrofilling.[9]

In order to minimize various anatomical complications and to standardize the length of the canal, this study used single rooted teeth with single canal.[4] Root-end preparation using ultrasonic tips has been shown to contribute to an increase success rate of endodontic surgery.[11] Moreover, according to Shokouhinejad N et al. the bond strength of retrograde filling material to dentin is greater in root-end cavities prepared ultrasonically.[22] Therefore in this study, ultrasonic tip was used for retrograde cavity preparation.

Apical periodontitis exerts a direct influence on stress state of the affected tooth owing to resorption of surrounding alveolar bone which also has detrimental effect on future preservation and restoration of tooth.[23] Therefore, an ideal retrograde filling material should exhibit adequate adhesion to root-end cavity walls and withstand dislodging forces generated during static and functional situations and also during surgical procedures.[24] Also, in the apical region the diameter and number of dentinal tubules are comparatively lower than in middle and coronal third which makes the adhesion highly challenging. Pushout test indicates the adherence between retrograde filling material and radicular dentin to withstand the aforementioned dislodging forces.[25] Hence this study evaluated a crucial prognostic factor i.e., pushout bond strength of retrograde filling materials namely. EndoCEM MTA, Bio-C Repair and Biostructure MTA.

The mean push-out bond strength values obtained in this study were 1.984MPa for Bio-C Repair (BCR), 5.00MPa for EndoCEM MTA (EMTA), and 4.44Mpa for BioStructure MTA (BMTA). Although numerical differences were observed among the three groups, statistical analysis using one-way ANOVA revealed no statistically significant difference in push-out bond strength ($p = 0.087$). This indicates that the observed variations in mean values were not large enough to represent true differences in bonding performance and may be attributed to sample variability.

EMTA demonstrated the highest mean push-out bond strength among the three materials evaluated. This higher numerical value indicates that EMTA exhibited greater resistance to dislodging forces under the conditions of this study which is in aligment with the study conducted by Silva et al.[7] This finding may be attributed to the presence of pozzolanic cement, which increases the surface area available for interaction and thereby enhances the reactivity of calcium silicate particles with water, leading to the formation of compounds with cementitious properties. This process is followed by a pozzolanic reaction, resulting in a favourable and gradual reduction in the amount of free calcium hydroxide. Since excess calcium hydroxide is known to have detrimental effects on the mechanical strength and durability of the material, its controlled reduction contributes to improved material performance. During this reaction, additional calcium silicate hydrate and calcium aluminate hydrate phases are formed, which crystallize into stable structures. The formation of these stable reaction products enhances the mechanical strength and durability of the cement.[7]

BMTA exhibited a mean push-out bond strength value of 4.44MPa which was lower than that of EMTA but higher than that of BCR. This intermediate value suggests that BMTA demonstrated bonding performance comparable to EMTA. The absence of a statistically significant difference between BMTA and EMTA indicates that BMTA was equally effective in resisting dislodging forces. The overlap of confidence intervals between these two groups further supports the finding that the difference in mean values does not represent a true difference in performance. The results suggest that BMTA provides a level of bond strength similar to that of EMTA under standardized conditions.

BCR demonstrated the lowest mean push-out bond strength value among the three groups. However, statistical analysis showed that this difference was not significant when compared with EMTA and BMTA. This finding indicates that although BCR exhibited slightly lower numerical values, its resistance to dislodging forces was comparable to that of the other materials which contradicts the findings of Hammadi FR et al.[26] However, the controversy among different reported results may be attributed to variations in the test methodology employed in such studies.

The results of present study suggest that the bonding performance of BCR falls within the same range as EMTA and BMTA and that the observed difference may be attributed to normal experimental variation rather than an inherent deficiency in bonding ability.

Post hoc Tukey multiple comparison analysis revealed no statistically significant difference between any of the pairwise comparisons, including BCR–EMTA, EMTA–BMTA, and BCR–BMTA. This confirms that none of the materials demonstrated a statistically superior or inferior push-out bond strength. The lack of significant differences in pairwise comparisons reinforces the finding that all three materials performed similarly in terms of resistance to dislodgement. The relatively high p value obtained in this study ($p = 0.087$) indicates a strong acceptance of the null hypothesis, suggesting that there is no statistically significant difference in push-out bond strength among the tested materials. Such a high p value implies that the variability within each group was greater than the variability between the groups. This may be attributed to inherent differences in dentinal substrate among samples, variations in canal anatomy and minor inconsistencies during specimen preparation all of which can influence bond strength outcomes.

The standard deviation values observed across all groups indicate considerable dispersion of bond strength values within each material group. This variability is expected in studies involving dentin as a bonding substrate due to its heterogeneous nature. Factors such as tubule density, orientation, and degree of mineralization can influence the resistance of the material–dentin interface to dislodgement. As a result, even when mean values differ numerically, statistical significance may not be achieved if intra-group variability is high. When the results of all three materials are compiled, it is evident that BCR, EMTA and BMTA demonstrated comparable push-out bond strength values under the conditions of the present study. Although EMTA showed the highest mean value, followed by BMTA and BCR, these differences were not statistically significant. This indicates that all three materials exhibited similar bonding behaviour and resistance to dislodging forces.

Overall, the findings of the present study demonstrate that BCR, EMTA, and BMTA exhibit similar push-out bond strength values with no statistically significant differences among them. The null hypothesis stating that there is no difference in push-out bond strength among the tested materials is therefore accepted. These results indicate that all three materials are capable of providing comparable resistance to dislodging forces at the root end under the conditions evaluated in this study.

Despite the valuable insights provided by the present study, certain limitations must be acknowledged. Being an in vitro study, it does not fully replicate the complex biological and mechanical environment present in vivo. Factors such as blood contamination, periodontal ligament simulation, thermal cycling, and long-term functional loading were not evaluated and may influence material performance. Additionally, bond strength was assessed at a single time point, and changes over time were not investigated.

Future studies should evaluate the push-out bond strength of these materials under simulated clinical conditions and assess their long-term performance following aging and mechanical loading. Clinical studies correlating in vitro findings with treatment outcomes would further enhance the understanding of the clinical relevance of push-out bond strength.

## References:


1. Clark D, Levin L. In the dental implant era, why do we still bother saving teeth? Dent Traumatol. 2019;35:368–375.
2. Karamifar K, Tondari A, Saghiri MA. Endodontic Periapical Lesion: An Overview on the Etiology, Diagnosis and Current Treatment Modalities. Eur. Endod. J. 2020;2:54-67.
3. Berman LH, Hargreaves KM. Cohen’s Pathways of the Pulp: South Asia Edition E-Book. Elsevier Health Sciences; 2021.p.439-442.
4. Garg I, Goyal V, Kaur P, Tomar A. An in-vitro comparison of bond strength of three different root end filling materials with Universal testing machine. IP Indian J Conserv Endod. 2023;8(4):221-225.
5. Syam N, Shetty SV, Shetty KH. RETROGRADE FILLING MATERIALS AND RECENT ADVANCES: A LITERATURE REVIEW. Int. J. Adv. Res. 2018;6(12):255-261.
6. Joshi S, Gandage D, Thakare E, Mahagaonkar PA, Gadda R, Palekar AU. A Comparative Evaluation of the Fracture Resistance of Mineral Trioxide Aggregate (MTA) Plus and MTA Angelus: An In Vitro Study. Cureus 2023;15(6):e40385.
7. Silva EJNL, Carvalbo NK, Guberman MMrCL, Prado M, Senna PM, Souza EM, De-Deus G. Push-out Bond Strength of Fast-setting Mineral Trioxide Aggregate and Pozzolan-based Cements: ENDOCEM MTA and ENDOCEM Zr. J, Endod. 2016;43(5):801-804
8. Campi LB, Rodrigues EM, Torres FFE, Reis JMSN, Guerreiro-tanomaru JM, Tanomaru-Filho M. Physiochemical properties, cytotoxicity and bioactivity of a ready-to-use bioceramic repair material. Braz. Dent. J. 2023;34(1):29-38.
9. Rudranaik S, Krishnegowda SsssC, Jaganath BM, Harnad AB. Biodentine v/s biostructure mta- the better root end filling material- clinical case report. Int. J. Adv. Res. 2023;11(10):114-117.
10. Rahoma A, AlShwaimi E, Majeed A. Push-out bond strength of different types of mineral trioxide aggregate in root dentin. Int. J. Health. Sci. 2018;12(5):66-69.
11. Vivan RR, Guerreiro-Tanomaru JM, Martelo RB, CostaBC, Duarte MAH, Tanomaru-Filho M. Push-out Bond Strength of Root-end Filling Materials. Braz Dent J. 2016;27(3):332-335.
12. Ravichandran R, Kumar D, K HK, Nair VV. Preservation of residual alveolar ridge using tooth supported overdenture prosthesis- a case report. Int. J. Adv. Res. 2022;10(04):345-350.
13. Miryala G, Dasari AK, Patil SR, Alam MK. Comparative Analysis of Treatment Outcomes and Patient Experiences: Single-Visit versus Multiple Visit Root Canal Treatment. Int. J. Health Sci. Res. 2023;13(7):1-6.
14. Setzer FC, Kratchman SI. Present status and future directions: Surgical endodontics. Int. Endod. J. 2022;55(4):1020–1058.
15. Rotstein I, Ingle JI. Ingle’s Endodontics 7: $50^{th}$ Anniversary edition. PMPH USA 2019;p801-818.
16. Rahbaran S, Gilthorpe MS, Harrison SD, Gulabivala K. Comparison of clinical outcome of periapical surgery in endodontic and oral surgery units of a teaching dental hospital: A retrospective study. Oral Surg.

Oral Med. Oral Path. 2001;91(6):700-709.
17. Tsesis I, Rosen E, Taschieri S, Strauss YT, Ceresoli V, Fabbro MD. Outcomes of Surgical Endodontic Treatment Performed by a Modern Technique: An Updated Meta-analysis of the Literature. J. Endod. 2013;39(3):332–339.
18. Debelian G, Trope M. The use of premixed bioceramic materials in endodontics. Giorn. Ital. Endod. 2016;30:70-80.
19. Kang T-Y, Choi J-W, Seo K-J, Kim K-M, Kwon J-S. Physical, Chemical, Mechanical, and Biological Properties of Four Different Commercial Root-End Filling Materials: A Comparative Study. Materials 2021;14:1693.
20. Choi Y, Park S-J, Lee S-H, Hwang Y-C, Yu M-K, Min K-S. Biological Effects and Washout Resistance of a Newly Developed Fast-setting Pozzolan Cement. J. Endod. 2013;39(4):467–472.
21. Ghilotti J, Sanz JL, Lopez-Garcia S, Guerrero-Girones J, Pecci-Lloret MP, Lozano A. Comparative Surface Morphology, Chemical Composition, and Cytocompatibility of Bio-C Repair, Biodentine, and ProRoot MTA on hDPCs. Materials 2020;13:2189.
22. Shokouhinejad N, Razmi H, Fekrazad R, Asgary S, Neshati A, Assadian H. Push out bond strength of two root-end filling materials in root-end cavities prepared by Er,Cr:YSGG laser or ultrasonic technique. Aust Endod J. 2012;38:113-117.
23. Chen S, Ye Z, Hong X, Chen L, Wu L, Wong Y. The effect of periapical bone defects on stress distribution in teeth with periapical periodontitis: a finite element analysis. BMC Oral Health. 2023;23:980.
24. Chaudhari PS, Chandak MG, Jaiswal AA, Ikhar A. Comparative evaluation of push out bond strength of three retrograde filling materials in teeth with root apices resected at 900: Mineral trioxide aggregate Angelus, Zirconomer and Bioactive bone cement. J Conserv Dent. 2022 Nov-Dec;25(6):605-609.
25. Marques JHS, Silva-Sousa YTC, Rached-Junior FJA, Macedo LMD, Camilleri J, Sousa-Neto MD. Push-out bond strength of different tricalcium silicate-based filling materials to root dentin. Braz. Oral Res. 2018;32:e18.
26. Hammadi FR, Abdul-Ameer ZM. Evaluation Of The Push-out Bond Strength Of The Bio-C Repair And Compare It With The Mineral Trioxide Aggregate And Amalgam When Used As Root-end Filling Material: An In Vitro Study. Dent Hypotheses 2023;14(2):62-65.