

IN VITRO COMPARISON OF SHEAR BOND STRENGTH OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.

Dr. Bobbin Gill¹, Dr. Shruti Atul Kamanwar², Dr. Deepika Sharma³, Dr. Kalyani Karwa⁴, Dr. Harshita Tilayacha², Dr. Chandrashekhar Sharma²

¹Department of Conservative Dentistry and Endodontics, Vyas Dental College And Hospital, Jodhpur, Rajasthan.

²Department of Conservative Dentistry and Endodontics, Vyas Dental College And Hospital, Jodhpur, Rajasthan.

³Department of Med Tech , AIIMS JODHPUR, IIT-JODHPUR, Rajasthan

⁴Department of Pediatric dentistry, Saraswati Dhanwantari Dental College and hospital, parbhani, Maharashtra.

Head Of Department (Dr. Bobbin Gill) | Email: bobbinsandhu@yahoo.co.in

Postgraduate student (Dr. Shruti Atul Kamanwar) | Email: shrutikamanwar44093@gmail.com

Postgraduate student in medical technology (Dr. Deepika Sharma) | Email: deepikasharma22102@gmail.com

Associate professor (Dr. Kalyani Karwa) | Email: kalyanikarwa8711@gmail.com

Postgraduate student (Dr. Harshita Tilayacha) | Email: harshitatilayacha@gmail.com

Postgraduate student (Dr. Chandrashekhar Sharma) | Email: cschandan58@gmail.com

*Corresponding Author: Dr. Shruti Atul Kamanwar, Postgraduate student of Department of Conservative Dentistry and Endodontics, Vyas Dental College And Hospital, Jodhpur, Rajasthan.
| Email: shrutikamanwar44093@gmail.com

Received: 6th August , 2026; Revised: 8th September 2026;

ABSTRACT

Background: Vital pulp therapy aims to preserve the health and function of the dental pulp, and the long-term success of these procedures depends considerably on the integrity of the interface between the pulp-capping material and the definitive restorative material. Mineral trioxide aggregate (MTA) is widely used for pulp capping; however, its handling characteristics and prolonged setting time have prompted interest in alternative bioactive materials. Bioactive glass (BG) has demonstrated favorable biocompatibility, antimicrobial activity, and potential for hard-tissue regeneration.

Aim: To evaluate and compare the shear bond strength and failure modes of MTA and bioactive glass when bonded to a nanohybrid composite resin.

Materials and Methods: Twenty cylindrical acrylic resin specimens containing standardized cavities were prepared and randomly divided into two groups (n = 10) , Group1: MTA and Group2: bioactive glass. The respective pulp-capping materials were placed according to the manufacturers' instructions. Following their cutting, cavity was restored with nanohybrid composite resin .Samples were stored in distilled water and incubated for 24hrs. Shear bond strength was evaluated using a universal testing machine at a crosshead speed of 1 mm/min. Following debonding, the specimens were examined under a stereomicroscope at 20× magnification to determine the mode of failure. Data was assessed using independent T test .

Results: The mean shear bond strength was higher for group 2 i.e. bioactive glass (4.59 ± 0.57) than for group 1 i.e MTA (4.24 ± 0.89), although the difference was not statistically significant. A statistically significant difference was observed in the distribution of failure modes between the two materials, with MTA showing a greater predominance of adhesive failures, whereas bioactive glass demonstrating a higher proportion of cohesive failures.

Conclusion: Within the limitations of this in vitro study, bioactive glass demonstrated slightly higher and more consistent shear bond strength to nanohybrid composite resin than MTA. The significantly different failure patterns, with a greater tendency toward cohesive failure in the bioactive glass group than MTA group, suggest favorable interfacial behavior. Bioactive glass may therefore represent a promising alternative to MTA as a pulp-capping material.

How to cite this article: Bobbin Gill¹ Dr. Shruti Atul Kamanwar² Dr. Deepika Sharma³ Dr. Kalyani Karwa⁴ Dr. Harshita Tilayacha² Dr. Chandrashekhar Sharma².. IN VITRO COMPARISON OF SHEAR BOND STRENGTH

IN VITRO COMPARISON OF SHEAR BOND STRENGTH OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.

OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.. *Int J Drug Deliv Technol.* 2026;16(83s):618-624. DOI: 10.25258/ijddt.16.83s.77.

INTRODUCTION

VPTs or vital pulp treatments are defined by the European Society of Endodontology (ESE) as 'treatment strategies aimed at maintaining the health of all or part of the pulp'.²

Various materials are used for pulp capping, including calcium hydroxide, mineral trioxide aggregate (MTA) and newer silicate-based cements, such as BioAggregate®, EndoSequence®, Biodentine™, etc

Mineral trioxide aggregate is a hydrophilic cement composed of calcium oxide, silica and bismuth oxide. Several successful clinical applications have been reported for MTA as use for vital pulp therapy¹.

Long-term studies (over 3 years) have reported that the success rate of vital pulp therapy with MTA is higher than in the case of calcium hydroxide (78% vs 60%). These favorable outcomes for vital pulp therapy with MTA have been confirmed in recent systematic reviews⁶.

Despite the various reported advantages, MTA has some disadvantages, including potential for discoloration, difficult handling, long setting time, high cost, unavailability of a solvent⁶.

Bioactive glass is a promising pulp-capping material due to its ability to release bioactive ions and promote apatite formation, supporting mineralization and dentin bridge formation. Its favorable bioactivity, biocompatibility, and potential to enhance the pulp-dentin healing response make it a promising alternative to conventional pulp-capping materials.¹¹

One of the most important issues in vital pulp therapy is the ability to seal the pulp-capping agents, because keeping them intact affects the prognosis of the therapeutic procedure. An effective seal at the interface between the pulp-capping material and the overlying composite restoration is essential to prevent microleakage and bacterial penetration. A well-sealed interface also helps maintain the integrity of the restoration, promotes favorable pulpal healing, and ultimately improves the long-term clinical outcome of vital pulp therapy.⁴

Therefore the current research aimed to evaluate and compare the bond strength in vitro of commercially available BAG and MTA with a nanohybrid composite.

MATERIALS AND METHODOLOGY

A total of 20 cylindrical acrylic resin blocks of same dimension were prepared for the purpose of this in vitro study. A cavity, measuring 4 mm in diameter and 1mm in depth, was prepared at the center of each cylinder. The

blocks were divided into 2 groups (n=10) according to the pulp capping agent used: Group 1: MTA (Safe Endo Biostructure) and Group 2: Bioactive glass (Nishika, Japan).

Placement of Pulp Capping Agents:

Group 1: Mineral trioxide aggregate was mixed at a powder-to-liquid ratio of 3:1 according to the manufacturer's instructions to achieve a proper consistency.

In group 2: Bioactive glass sealer as pulp capping agent was prepared as per manufacturing instructions by adding BG multipowder to the paste to acquire desired consistency.

The prepared MTA and bioactive glass were subsequently carried into the cavity using amalgam carrier and gently condensed and adapted to the cavity surface to obtain a uniform layer in a thickness of 1mm and intimate contact with the cavity walls. Care was taken during placement of both materials to avoid air entrapment and ensure consistent material adaptation before the application of the restorative material.

After setting of the pulp capping materials, the specimen surfaces were etched with (Ivoclar N Etch) for 15 seconds, followed by rinsing with water for 5 seconds and gentle drying using an oil-free air stream for 5 seconds. Subsequently, the adhesive bonding agent (Ivoclar Tetric N Bond) was applied uniformly to the etched surfaces and gently air-dried for 5 seconds to facilitate solvent evaporation. The adhesive was then light-cured according to the manufacturer's instructions before composite resin application. The specimens were stored in distilled water and were thermocycled at 100% humidity at 37° for 24hrs.

The composite resin (Ivoclar Vivadent Tetric N Ceram) was placed in a single increment using a composite filling instrument and subsequently light-cured for 30 seconds.

IN VITRO COMPARISON OF SHEAR BOND STRENGTH OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.



Fig no: 1 - samples tested under UTM

Subsequently, the samples were transferred to a universal testing machine, equipped with a chisel-shaped head measuring 5 mm in width. A perpendicular force was applied at the restorative material-pulp-capping agent interface at a cross head speed of 1 mm/min until failure occurred at the restorative material-pulp-capping agent interface. The load required to produce interfacial failure was recorded for each specimen and used for evaluation of the shear bond strength. Finally, all samples were evaluated under a stereomicroscope (20X magnification) for the fracture modes.



Fig no 2: cohesive and adhesive bond failure

RESULTS:

Parameter	MTA	Bioactiveglass
Mean $\pm$ SD	4.24 $\pm$ 0.89	4.59 $\pm$ 0.57
Median	4.25	4.85
Coefficient of Variation	21.0%	12.4%
Range	3.0 - 6.0	3.8 - 5.5
95% CI	3.62 - 4.86	4.19 - 4.99
Interpretation	Slightly lower mean, more variable	Higher mean, more consistent

Table 1: Descriptive statistics of shear bond strength using T test.

The table compares the descriptive statistics of MTA and bioactive glass. Bioactive glass shows a higher mean value (4.59 $\pm$ 0.57) than MTA (4.24 $\pm$ 0.89), indicating overall better performance for the measured parameter. This is supported by the higher median for bioactive glass (4.85) compared with MTA (4.25). In addition, bioactive glass demonstrates greater consistency, as reflected by a lower coefficient of variation (12.4%) compared with MTA (21.0%). The wider range observed with MTA (3.0–6.0) suggests more variability in outcomes, whereas bioactive glass shows a narrower range (3.8–5.5). The 95% confidence interval for bioactive glass (4.19–4.99) is narrower and lies at higher values than that of MTA (3.62–4.86), further indicating more reliable and consistently higher results.

The Shapiro-Wilk test indicated that the shear bond strength data for both group 1 ($W = 0.927$, $p = 0.421$) and group 2 ($W = 0.912$, $p = 0.301$) were normally distributed. Levene's test for equality of variances ($F = 1.735$, $p = 0.205$) confirmed that the assumption of homogeneity

IN VITRO COMPARISON OF SHEAR BOND STRENGTH OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.

of variance was met. These results justified the use of independent T test tests for comparing the two materials.

There is a significant difference ($p < 0.05$) in failure mode distribution between group 1 and group 2.

- Group1 (MTA) predominantly shows adhesive failures, indicating weaker interfacial bonding.
- Group2 (BAG) demonstrates cohesive , reflecting stronger bond integrity.

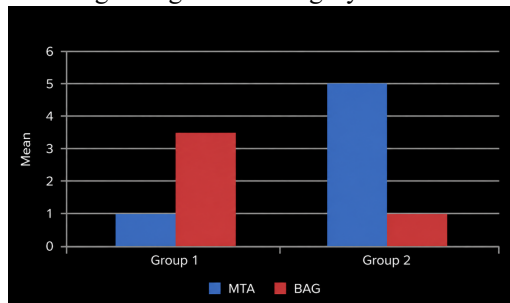


Table no 2: Mean adhesive and cohesive bond failure.

The graph illustrates a clear difference in the distribution of outcomes between MTA and bioactive glass. Overall, the pattern highlights that bioactive glass tends to perform more favorably and consistently in the primary outcome measure, whereas MTA shows comparatively lower or more variable results. These statistics reinforcing that bioactive glass provides more reliable and improved outcomes compared with MTA for the parameter evaluated.

DISCUSSION

The long-term success of vital pulp therapy depends not only on the biological properties of the pulp-capping material but also on the establishment of an adequate and durable interface between the pulp-capping agent and the overlying restorative material.¹ A satisfactory bond at this interface is essential because inadequate adhesion may result in interfacial gaps, microleakage, bacterial penetration, and ultimately compromise the prognosis of vital pulp therapy.² Therefore, evaluation of the bond strength between pulp-capping materials and restorative composites is clinically relevant when selecting materials for definitive restoration following vital pulp treatment.³

Mineral trioxide aggregate (MTA) has been extensively used in vital pulp therapy because of its favorable biocompatibility, bioactivity, sealing ability, and capacity to promote hard-tissue formation.⁴ Clinical studies have demonstrated favorable outcomes with MTA when compared with calcium hydroxide. Mente et al. reported a success rate of 78% for MTA compared with 60% for calcium

hydroxide after direct pulp capping, while a subsequent long-term study reported success rates of 80.5% and 59%, respectively.^{5,6} Similarly, a practice-based randomized clinical trial demonstrated a lower probability of failure with MTA than with calcium hydroxide after 24 months.⁷ Recent systematic-review evidence has also supported the superior clinical performance of MTA over calcium hydroxide for direct pulp capping.⁸

Despite these biological advantages, MTA presents several clinical limitations, including prolonged setting time, difficult handling, high cost, and potential tooth discoloration.^{4,9} These limitations have encouraged the development of newer bioactive materials that aim to provide comparable biological performance while improving handling and restorative integration.⁹ Bioactive glass (BAG) has attracted considerable attention because of its biocompatibility, ion-releasing ability, apatite-forming potential, antimicrobial properties, and capacity to promote hard-tissue regeneration.^{10,11}

The present study evaluated the shear bond strength of MTA and commercially available bioactive glass used beneath a nanohybrid composite resin. The mean shear bond strength obtained for BAG was 4.59 ± 0.57 MPa, whereas MTA demonstrated a mean value of 4.24 ± 0.89 MPa. Although results did not show significant differences.

The higher median value observed for BAG (4.85 MPa) compared with MTA (4.25 MPa) further supports the favorable numerical trend observed in the BAG group. In addition, BAG demonstrated a lower coefficient of variation (12.4%) compared with MTA (21.0%), suggesting that the BAG specimens exhibited less variability in their bond-strength measurements. The narrower range observed with BAG (3.8–5.5 MPa) compared with MTA (3.0–6.0 MPa) similarly indicates greater consistency within the BAG group. Such consistency may be clinically advantageous because predictable interfacial behavior is important for maintaining the integrity of the restoration.¹²

Although BAG demonstrated higher mean and median bond-strength values and lower variability than MTA, the difference in the primary bond-strength outcome was not statistically significant ($p = 0.286$). Therefore, the results suggest that BAG performed at least comparably to MTA under the experimental conditions, with a favorable numerical trend, rather than establishing BAG as statistically superior.

The present findings are in agreement with previous investigations demonstrating that

IN VITRO COMPARISON OF SHEAR BOND STRENGTH OF TWO PULP CAPPING AGENTS WITH NANOHYBRID COMPOSITE RESIN.

bioactive glass can interact favorably with dental hard tissues and promote mineral deposition at the material–tissue interface.^{11,13} Bioactive glass undergoes surface reactions in an aqueous environment, resulting in the formation of a calcium-phosphate-rich layer with apatite-like characteristics.^{10,13} This bioactive surface may potentially contribute to improved interaction with mineralized dental substrates and may partly explain the relatively consistent bond-strength values observed in the present BAG group.

Previous biological investigations have also demonstrated the potential of BAG as a pulp-capping material. Long et al. reported that experimental BAG pulp-capping materials produced favorable pulpal responses, with formation of a substantial dentin bridge and minimal inflammatory response, findings comparable with those observed for MTA.¹⁴ Similarly, Hanada et al. demonstrated that a novel bioactive-glass-based cement was biocompatible, promoted reparative dentin formation, and showed potential for use as a direct pulp-capping material.¹⁵ These biological findings, together with the favorable interfacial performance observed in the present study, support further investigation of BAG as an alternative bioactive pulp-capping material. The present study also evaluated the failure patterns following shear testing. A statistically significant difference was reported in the distribution of failure modes between MTA and BAG. MTA predominantly demonstrated adhesive failures, whereas BAG showed a greater tendency toward cohesive failure. Therefore, the greater occurrence of cohesive failure in the BAG group may suggest a more favorable interfacial interaction between BAG and the restorative system used in this study.

The use of nanohybrid composite resin as the restorative material is also clinically relevant. Composite restorations provide an effective definitive coronal seal when appropriately bonded; however, the success of the restoration depends on adequate adhesion to the underlying pulp-capping material.^{2,3} A strong and stable interface may reduce the risk of restoration displacement and minimize pathways for bacterial penetration. Consequently, the mechanical compatibility between the pulp-capping agent and the restorative material represents an important consideration in the overall success of vital pulp therapy.¹²

However, the relatively small sample size of 10 specimens per group should be considered when interpreting the statistical findings, as small in-vitro samples may have limited power to detect modest differences between materials.

Nevertheless, several limitations should be acknowledged. First, the study was conducted in vitro using acrylic resin blocks rather than natural teeth; therefore, the results cannot fully reproduce the complex biological, structural, and moisture-related conditions present clinically. Second, the sample size was relatively small, with only 10 specimens in each group. Third, the study evaluated immediate shear bond strength and did not investigate the durability of the interface after thermocycling, prolonged water storage, mechanical fatigue, or aging. Previous studies have shown that aging and storage conditions can influence the bond strength and reliability of bioactive-glass-containing restorative systems.^{19,20}

Furthermore, shear bond-strength testing provides information about interfacial resistance under a particular loading configuration but does not completely reproduce the multidirectional stresses experienced by restorations clinically.¹² The fracture pattern observed under stereomicroscopic examination should therefore be regarded as complementary evidence rather than a direct predictor of clinical longevity. Future studies should incorporate larger sample sizes, natural human teeth, thermocycling, long-term aging, microscopic interfacial analysis, and clinical evaluation to establish the long-term performance of BAG beneath composite restorations.

Conclusion:

Within the limitations of the present investigation, bioactive glass demonstrated a higher shear bond strength than MTA, although the difference in bond strength was not statistically significant. The significantly different failure-mode distribution, with a greater tendency toward cohesive failure in the BAG group, suggests a potentially favorable interfacial relationship with the nanohybrid composite resin. Therefore, BAG may be considered a promising alternative to MTA from the standpoint of restorative interfacial performance, although further laboratory and clinical studies are necessary before definitive conclusions regarding its superiority can be established.

References

1. Duncan HF, Galler KM, Tomson PL, Simon S, El Karim I, Kundzina R, et al. European Society of Endodontology position statement: Management of deep caries and the exposed pulp. *International Endodontic Journal*. 2019;52:923-934.

2. Cox CF, Sübay RK, Ostro E, Suzuki S, Suzuki SH. Tunnel defects in dentin bridges: Their formation following direct pulp capping. *Operative Dentistry*. 1996;21:4-11.
3. Aguilar P, Linsuwanont P. Vital pulp therapy in vital permanent teeth with cariously exposed pulp: A systematic review. *Journal of Endodontics*. 2011;37:581-587.
4. Parirokh M, Torabinejad M. Mineral trioxide aggregate: A comprehensive literature review—Part III: Clinical applications, drawbacks, and mechanism of action. *Journal of Endodontics*. 2010;36:400-413.
5. Mente J, Geletneky B, Ohle M, Koch MJ, Friedrich Ding PG, Wolff D, et al. Mineral trioxide aggregate or calcium hydroxide direct pulp capping: An analysis of the clinical treatment outcome. *Journal of Endodontics*. 2010;36:806-813.
6. Mente J, Hufnagel S, Leo M, Michel A, Gehrig H, Panagidis D, et al. Treatment outcome of mineral trioxide aggregate or calcium hydroxide direct pulp capping: Long-term results. *Journal of Endodontics*. 2014;40:1746-1751.
7. Hilton TJ, Ferracane JL, Mancl L; Northwest Practice-based Research Collaborative in Evidence-based Dentistry Research Group. Comparison of CaOH with MTA for direct pulp capping: A PBRN randomized clinical trial. *Journal of Dental Research*. 2013;92(7 Suppl):16S-22S.
8. *Clinical success of vital pulp therapy for pulp-exposed permanent teeth: A systematic review and meta-analysis*. 2025. This recent meta-analysis found significantly higher direct pulp-capping success with
9. *Clinical success of vital pulp therapy for pulp-exposed permanent teeth: A systematic review and meta-analysis*. 2025. This recent meta-analysis found significantly higher direct pulp-capping success with MTA than calcium hydroxide.
10. Pushpalatha C, Dhareshwar SS, Sowmya SV, Augustine D, Vinothkumar TS, Renugalakshmi A, et al. Modified mineral trioxide aggregate—A versatile dental material: An insight on applications and newer advancements. *Journal of Pharmacy and Bioallied Sciences*. 2022;14(Suppl 1):S9-S14.
11. Jones JR. Review of bioactive glass: From Hench to hybrids. *Acta Biomaterialia*. 2013;9:4457-4486.
12. El-Ghannam A. Advanced bioceramics for bone tissue engineering: Design principles and applications. *Journal of Materials Chemistry*. 2005;15:1316-1323.
13. *Bio-Inductive Materials in Direct and Indirect Pulp Capping—A Review Article*. This review emphasizes that sealing ability and bond strength between pulp-capping materials and restorative materials are important determinants of successful pulp-capping procedures.
14. Sauro S, Osorio R, Watson TF, Toledano M. Assessment of the effect of bioglass incorporation into dental restorative materials. Studies on mineral deposition and interaction with dental hard tissues support the bioactive potential of BAG.
15. Long Y, Liu S, Zhu L, Liang Q, Chen X, Dong Y. Evaluation of pulp response to novel bioactive glass pulp capping materials. *Journal of Endodontics*. 2017;43:1642-1647.
16. Hanada K, Morotomi T, Washio A, Yada N, Matsuo K, Teshima H, et al. In vitro and in vivo effects of a novel bioactive glass-based cement used as a direct pulp capping agent. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*. 2019;107:161-168.
17. *Comparison of shear bond strength of resin-modified glass ionomer and composite resin to three pulp capping agents*. *Journal of Dental Research, Dental Clinics, Dental Prospects*. 2013. The study demonstrated that composite resin can achieve stronger bonding to tested pulp-capping materials than resin-modified glass ionomer, while also highlighting the importance of the pulp-capping/restorative interface.
18. *Shear bond strength of calcium silicate-based cements to composite resin using a universal adhesive in different application modes: An in vitro study*. *Australian Dental Journal*. 2023. The study found that adhesive strategy and calcium-silicate cement type influenced the shear bond strength to composite resin.

19. *Shear bond strength of self-adhering flowable composite and resin-modified glass ionomer to two pulp capping materials. Journal of Clinical and Experimental Dentistry.* 2017. Additional bonding-agent application significantly improved the bond strength of resin-based restorative material to MTA.
20. Par M, Tarle Z, Hickel R, Ilie N. Dentin bond strength of experimental composites containing bioactive glass: Changes during aging for up to 1 year. *Journal of Adhesive Dentistry.* 2018;20:325-334.
21. Sakai H, Sasaki JI, Kitagawa H, Funayama N, Inubushi T, Moriyama K, et al. Synthesis and characterization of lithium- and strontium-releasing smart bioactive glasses for direct pulp capping application. 2026;42(5):815-824. doi:10.1016/j.dental.2026.01.005.
22. Kim M, Kim R. Physical and biological properties of bioactive glass-containing Bis-GMA-free pulp capping materials: An in vitro study.. 2025;44(5):479-486. doi:10.4012/dmj.2024-392. □
23. Xu X, He Y, Chen X, Fan Z, Wang D. Preparation and characterization of mesoporous core-shell bioactive glass-based cements for direct pulp capping. . 2025;20(2). doi:10.1088/1748-605X/adb119.