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# Effect of Different Cavity Liners on Shear Bond Strength of Nanofilled Composite to Dentin: An In-Vitro Study

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## Abstract

Aim: To evaluate and compare the shear bond strength of Nano-filled composite resin to dentin in presence of different cavity liners.

Methods and Material: Fifty caries-free mandibular molars were prepared with standardized flat dentin surfaces and randomly assigned to five groups: Dycal (Group I), TheraCal LC (Group II), MTA (Group III), Biodentine (Group IV), and Control with no liner (Group V). Each liner was applied in a 1.5-mm layer followed by standardized bonding and composite build-up (4 × 4 mm). Specimens were subjected to shear bond strength testing using a universal testing machine, and SBS (MPa) was calculated from the failure load and bonded area.

Statistical analysis used: Descriptive statistics were computed, data showed normal distribution (Shapiro–Wilk, $p > 0.05$). Group comparisons were performed using unpaired t-tests and Tukey's post hoc test for pairwise analysis.

Results: The control group showed the highest bond strength ($p < 0.001$), with Theracal LC performing closest to it ($p = 0.022$) and significantly higher than MTA, Dycal, and Biodentine (all $p < 0.001$). MTA showed moderate strength, superior to Dycal ($p = 0.027$) and Biodentine ($p < 0.001$), while Dycal and Biodentine demonstrated the lowest values, with no significant difference between them ($p = 0.294$).

Conclusions: The control group exhibited the highest shear bond strength, with Theracal LC showing the best performance among the liners, approaching control values. MTA demonstrated moderate strength, while Biodentine and Dycal showed significantly lower bond strength, with Dycal performing the weakest.

**Keywords**: SBS, Biodentine, Theracal LC

## Introduction

Cavity liners are materials applied to the floor of cavity preparations to protect the pulp. Phillips defined a liner as a coating material placed at the cavity base for pulpal protection[1], while Marzouk et al. described liners as film-forming, therapeutic agents applied mainly to dentin, with thicknesses up to 25 µm. [2] Advancements in restorative dentistry emphasize pulpal protection, especially when remaining dentin thickness (RDT) is minimal. Pashley reported that an RDT of 0.5 mm reduces material toxicity by 75% and 1.0 mm by 90%, underscoring dentin's protective role. When RDT is <0.5 mm, cavity liners are essential to guard the pulp from thermal, chemical, and bacterial irritation. [3]

Pulpal injury may arise from caries, thermal or chemical insult, or mechanical trauma during preparation. [4] Protecting the odontoblastic layer is crucial, often achieved using bases, sealers, and liners. In deep cavities, direct or indirect pulp capping with materials such as calcium hydroxide, MTA, or Biodentine is indicated. [5]

Common liners include calcium hydroxide, introduced by Herman in 1920 which stimulates healing but has low strength and high solubility [6]; glass ionomer cements, which bond chemically and release fluoride but are moisture-sensitive [7]; resin-modified GICs, which provide superior strength but may shrink during polymerization[5]; these eventually led the development of bio ceramic liners such as MTA introduced by Torabinejad in 1993 and Biodentine introduced in 2009 which showed excellent biocompatibility. [8,9] TheraCal LC, launched in 2011, a fourth-generation light-cured calcium silicate material offered improved strength and lower solubility compared to calcium hydroxide.[10]

Strong bond strength is essential for restoration longevity, enabling adhesives to withstand polymerization shrinkage and functional stresses. Although some studies show adequate adaptation without liners [11], liners remain necessary in specific clinical situations.

This in vitro study compares the shear bond strength of nanofilled composite resin to dentin using various dental liners.

**Subjects and Methods:**

**Materials and Methods**

This in-vitro study assessed the shear bond strength (SBS) of nanofilled composite resin to dentin when used with different cavity liners.

**Sample Selection**

Fifty freshly extracted, caries-free human mandibular permanent molars were collected. Teeth with restorations or fractures were excluded. Specimens were cleaned using an ultrasonic scaler and stored in normal saline until use.

**Sample Preparation**

Occlusal surfaces were reduced to expose a flat dentin surface using a diamond disc under continuous water cooling. Final surface refinement was performed with 600-grit sandpaper. Teeth were embedded up to the cervical region in self-cure acrylic resin using silicone molds (2 × 1.5 × 2 cm), leaving the coronal portion exposed.

Standardized polyethylene tubes ensured uniform material dimensions:

1. Cavity liner application: 1.5 mm height × 1.5 mm internal diameter
2. Composite build-up: 4 mm height × 4 mm internal diameter (ISO-recommended)

**Grouping and Material Manipulation**

Samples were randomly divided into five groups (n = 10):

1. Group I – Dycal Liner - Dycal (calcium hydroxide liner) was mixed by combining equal amounts of base and catalyst pastes on a mixing pad until homogeneous. A 1.5-mm layer was applied onto exposed dentin using a small instrument, ensuring intimate adaptation and eliminating voids. The material was allowed to set undisturbed for 2–3 minutes.
2. Group II – TheraCal LC - TheraCal LC was dispensed directly onto the dentin in small increments from its syringe. The liner was shaped to a uniform 1.5-mm thickness and light-cured for 20 seconds using an LED curing unit, with the curing tip positioned close to the surface for optimal polymerization.
3. Group III – MTA - MTA powder was mixed with the supplied liquid at a 3:1 ratio to obtain a putty-like consistency. The material was carried to the dentin surface and adapted into a uniform 1.5-mm layer. It was allowed to set for 10–15 minutes without disturbance to ensure initial hardening.
4. Group IV – Biodentine - Five drops of the supplied liquid were added to the pre-dosed Biodentine capsule, which was mixed in an amalgamator for 30 seconds at 4000–4200 rpm. The freshly mixed material was applied to dentin in a 1.5-mm layer and gently condensed. The material was allowed to set for approximately 12 minutes.
5. Group V – Control - No liner was applied. These samples served as the baseline for comparison.

After setting of liners, polyethylene tubes were removed. All specimens were etched with 37% phosphoric acid gel for 15 seconds, rinsed with distilled water, and gently dried to maintain moist dentin. A dentin bonding agent was applied actively for 15 seconds, air-thinned for 5 seconds, and light-



Volume 8, Issue 6; November-December 2025; Page No 494-500

cured for 10 seconds. A new polyethylene tube (4 × 4 mm) was positioned, and nanofilled composite was placed in 2-mm increments. Each increment was light-cured for 40 seconds. Tubes were removed after complete polymerization to expose standardized composite cylinders.

**Shear Bond Strength Testing**

Specimens were mounted on a universal testing machine. A chisel-shaped loading head applied shear force at the composite–dentin interface at a crosshead speed of 1 mm/min. Failure load (N) was recorded. SBS (MPa) was calculated by dividing the failure load by the bonded area. Data were statistically analysed to compare performance across groups.

**Results:**

Table 1 demonstrated distinct variations in shear bond strength across the five groups. The control group (Group V, no liner) exhibited the highest bond strength, significantly outperforming all experimental groups. Among the tested materials, Group II (Theracal LC) showed the most favorable bonding performance, with values significantly higher than those of Group I (Dycal), Group III (MTA), and Group IV (Biodentine), and closely approaching the control group. Group III (MTA) presented moderate bond strength, significantly exceeding that of Dycal and Biodentine, yet remaining notably lower than Theracal LC and the control. Group IV (Biodentine) showed considerably reduced bond strength, performing significantly worse than Theracal LC, MTA, and the control group, and demonstrating no statistically significant difference from Group I. Dycal (Group I) recorded the lowest bond strength among all groups, reflecting the weakest overall performance.

**Discussion:**

Dental composites have been widely used for over six decades due to their strength, abrasion resistance, translucency, ease of application, and polishability. Their main limitation, however, is an inherently weak bond to tooth structure, which has driven extensive research into improved adhesive systems. [12]

Remaining dentin thickness (RDT) is crucial for protecting the pulp during restorative and endodontic procedures. It acts as a natural barrier against thermal, mechanical, and chemical insults, with reduced RDT increasing permeability and risk of pulpal inflammation. Permanent teeth have 40,000–41,000 tubules/mm² at 0.4–0.5 mm from the pulp, versus 26,390 tubules/mm² in deciduous teeth, highlighting dentin's buffering role. [13] An RDT ≥1 mm protects against cytotoxic materials, while <0.25 mm allows bacterial penetration, emphasizing the need to preserve dentin for pulp health. [14]

Pulp-protecting agents—liners, bases, and pulp-capping materials—are used to preserve pulp vitality and stimulate reparative dentin. Direct pulp capping aims to maintain pulpal health following exposure by placing a therapeutic material before restoration. [15]

Calcium hydroxide, introduced in 1920, remains the gold standard due to its antibacterial action, predictable dentin bridge formation, and long-term clinical success across procedures such as pulp capping, apexogenesis, apexification, perforation repair, and intracanal dressing. [16]

Mineral trioxide aggregate (MTA) forms calcium hydroxide upon hydration, contributing to its biocompatibility. It promotes thicker dentinal bridges with minimal inflammation and offers advantages such as antibacterial properties, high pH, radiopacity, and bioactivity, though its long setting time, discoloration, and cost remain limitations. [17] It is widely used in perforation repair, root-end filling, resorption management, apexification, apexogenesis, and pulp capping. [18]

Biodentine, designed to overcome the drawbacks of calcium hydroxide and MTA, consists of tricalcium silicate–based powder and a calcium chloride liquid. [19] It demonstrates excellent biocompatibility, antibacterial effects, rapid setting (~12 minutes), good sealing ability, and stimulation of tertiary dentin formation, although long-term clinical data are still limited. [20,21]

TheraCal LC is a light-cured, resin-modified calcium silicate liner composed of ~45% mineral content (type III Portland cement), 10% radiopaque agents, 5% hydrophilic thickeners, and ~45% resin matrix containing UDMA, BisGMA, TEGDMA, HEMA, and PEGDMA. It provides excellent sealing ability, strong adhesion to moist dentin, high radiopacity, and significant calcium ion release, with lower solubility than ProRoot MTA and Dycal. Its main limitation is its opaque white colour, which may affect aesthetics under translucent composites. [22]

Composite resins, introduced to overcome limitations of acrylic resins and silicate cements, serve as tooth-coloured materials capable of restoring both function and aesthetics. Composite properties also affect bond strength—high filler content reduces polymerization shrinkage, while high viscosity may create voids. Polymerization stress is critical in high C-factor cavities. [23]

Enamel offers predictable micromechanical bonding after etching, whereas dentin presents challenges due to its higher organic content, tubular structure, and fluid dynamics. [24] Shear bond strength (SBS) reflects a restoration's resistance to forces acting parallel to the tooth–restoration interface and is essential for retention, marginal integrity, and long-term success. SBS evaluates the adhesion of composites to dentin, which is critical for retention, reduced microleakage, and long-term restoration success. While various tests exist—shear, tensile, micro-shear, and micro-tensile—the SBS test remains widely used for its simplicity and ability to screen adhesive performance. [25]

Adhesives have evolved from etch-and-rinse to self-etch and universal systems. Etch-and-rinse works well on enamel but is technique-sensitive on dentin, while self-etch preserves the smear layer and reduces sensitivity, though bond depth may be limited. Universal adhesives offer flexibility but variable performance. [26]

In this study, the control group showed the highest bond strength due to direct adhesive-dentin contact, optimal hybrid layer formation, and absence of interfacial barriers, consistent with previous reports. [11] TheraCal LC demonstrated significantly higher SBS than Dycal, MTA, and Biodentine, closely approximating the control, likely due to its resin-modified calcium silicate composition, which allows both micromechanical and chemical bonding. [27] Its intact, less porous surface and high flowability enhance adhesive infiltration compared to MTA, which forms a more cracked surface after acid etching. MTA showed moderate bond strength, benefiting from bioactivity and micromechanical adaptation, though its performance was lower than Theracal LC and control. Dycal and Biodentine exhibited the lowest SBS, reflecting weaker adhesive interaction and surface characteristics. Dycal, a chemically cured calcium hydroxide material, relies solely on micromechanical retention without any resin-based chemical bonding. Its high solubility, porous chalky surface, and limited hybrid layer formation contribute to its inferior bonding performance. [28] Biodentine also showed significantly lower SBS than TheraCal LC, MTA, Control, and even Dycal. This is attributed to its primarily cementitious composition and lack of resin content, which restricts interaction with adhesives. Although bioactive, Biodentine requires extended maturation for optimal mechanical properties, with full crystallization of calcium silicate gel taking up to 2 weeks. [25,28,29] Early placement of composite after initial setting (~12 min) likely reduced bond strength, as reported in previous studies, while SBS improves with delayed restoration. [28]

These findings align with previous reports, confirming that resin-modified calcium silicate liners like TheraCal LC provide superior immediate bond strength, whereas cement-based materials such as Biodentine and MTA require longer maturation for optimal adhesive performance. [25,28,30,31]

## Conclusion

TheraCal LC demonstrated superior shear bond strength compared to MTA, Dycal, and Biodentine, highlighting its effectiveness as a pulp-protective liner. Its resin-modified formulation with hydrophilic methacrylate monomers enhances chemical adhesion, reduces microleakage, and supports immediate placement of composite restorations. These properties make TheraCal LC a clinically advantageous material for procedures such as direct pulp capping and sandwich restorations, ensuring durable restorations with efficient treatment outcomes.

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Volume 8, Issue 6; November-December 2025; Page No 494-500

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**Table 1: Pairwise Comparison of Shear Bond Strength between Group I (Dycal), Group II (Theracal LC), Group III (MTA) , Group IV (Biodentine) and Group V (Control)**

| (I) Groups | (J) Groups | Mean Difference (I-J) | Std. Error | P value |
|---|---|---|---|---|
| Group I (DYCAL) | Group II (THERACAL LC) | -5.95400* | .41464 | <0.001** |
| | Group III (MTA) | -1.28200* | .41464 | .027* |
| | Group IV (BIODENTINE) | .81900 | .41464 | .294 |
| | Group V (CONTROL) | -7.26800* | .41464 | <0.001** |
| Group II (THERACAL LC) | Group I (DYCAL) | 5.95400* | .41464 | <0.001** |
| | Group III (MTA) | 4.67200* | .41464 | <0.001** |
| | Group IV (BIODENTINE) | 6.77300* | .41464 | <0.001** |
| | Group V (CONTROL) | -1.31400* | .41464 | .022* |
| Group III (MTA) | Group I (DYCAL) | 1.28200* | .41464 | .027* |
| | Group II (THERACAL LC) | -4.67200* | .41464 | <0.001** |
| | Group IV (BIODENTINE) | 2.10100* | .41464 | <0.001** |
| | Group V (CONTROL) | -5.98600* | .41464 | <0.001** |

| | | | | |
|---|---|---|---|---|
| Group IV (BIODENTINE) | Group I (DYCAL) | -.81900 | .41464 | .294 |
| | Group II (THERACAL LC) | -6.77300* | .41464 | <0.001** |
| | Group III (MTA) | -2.10100* | .41464 | <0.001** |
| | Group V (CONTROL) | -8.08700* | .41464 | <0.001** |
| Group V (CONTROL) | Group I (DYCAL) | 7.26800* | .41464 | <0.001** |
| | Group II (THERACAL LC) | 1.31400* | .41464 | .022* |
| | Group III (MTA) | 5.98600* | .41464 | <0.001** |
| | Group IV (BIODENTINE) | 8.08700* | .41464 | <0.001** |

*Statistical significance at p<0.05 and **p<0.001 high statistically significant difference



Volume 8, Issue 6; November-December 2025; Page No 494-500