

An In-vitro Evaluation of Fracture Resistance of Pulpotomised Permanent Teeth Restored with Different Aesthetic Restorative Materials

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ABSTRACT

Introduction: One of the fundamental goals of modern dentistry, centered around the ideology of minimally invasive dentistry, is to maintain tooth pulp viability. The dental pulp has the capacity for repair, depending on the intensity of damage and the level of pulp inflammation. All attempts are made to preserve the vitality of the radicular pulp. Pulpotomy has been reinvestigated as a definitive therapeutic option for mature permanent teeth with extensive carious lesions. Furthermore, Class II Mesio-Occluso-Distal (MOD) cavity preparation undergoing pulpotomy reduces the teeth's fracture resistance.

Aim: To evaluate and compare the fracture resistance of pulpotomised premolars treated with calcium silicate materials, such as Mineral Trioxide Aggregate (MTA) or Biodentine (BD), in Class II MOD cavities restored using Cention-N and nanohybrid composite.

Materials and Methods: An in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India, from November 2023 to December 2023. A total of 55 extracted maxillary premolars were collected, embedded in acrylic resin molds, and divided into five groups of 11 teeth each. Group 1: Intact teeth, Group 2: Standardised Class II MOD cavities were prepared, coronal pulpotomy was performed, and teeth were restored with MTA. After the complete setting of MTA, a Glass Ionomer Cement (GIC) base was placed, followed by restoration with a nanohybrid composite, Group 3: Similar

procedure as Group 2, but with MTA as the capping material and restored with Cention-N, Group 4: Similar procedure as Group 2, but with BD as the capping material and restored with a nanohybrid composite, Group 5: Similar procedure as Group 2, but with BD as the capping material and restored with Cention-N. Specimens were subjected to a fracture resistance test using a Universal Testing Machine (UTM). The load at which restorations fractured was recorded in Newtons (N), and the obtained data were statistically analysed using One-way Analysis of Variance (ANOVA) and post-hoc tests. Data were considered significant if $p \leq 0.05$.

Results: Intact teeth (1273.64 N) had the highest mean fracture resistance compared to other groups. Group 5 (973.64 N) showed the highest mean fracture resistance, followed by Group 3 (895.45 N), Group 4 (700 N), and Group 2 (633.64 N). The differences in fracture resistance were statistically significant ($p < 0.05$).

Conclusion: The present in-vitro study found that intact teeth had the highest fracture resistance. Among the experimental groups, pulpotomised premolars restored with BD and Cention-N showed significantly greater fracture resistance. In contrast, restorations using MTA and nanohybrid composites exhibited lower resistance. BD and Cention-N outperformed the MTA-Cention-N, BD-Nanohybrid, and MTA-Nanohybrid combinations. Therefore, BD and Cention-N can be considered preferred materials for restoring pulpotomised maxillary premolars with Class II MOD cavities.

Keywords: Biodentine, Calcium silicate, Composite resin, Mineral trioxide aggregate

INTRODUCTION

In minimally invasive dentistry, pulpotomy is gaining recognition for managing deep caries in mature permanent teeth. This shift is driven by a better understanding of pulp biology and advancements in biologically active materials [1]. When a deep cavity leads to exposure of the pulp without symptoms, or reversible pulpitis without periapical pathology, pulpotomy can preserve the radicular pulp and address any inflammation or pain [2]. Pulpotomy is also effective for recent traumatic or mechanical pulp exposure [3,4].

Calcium silicate materials like MTA offer quick application, can set in moisture or blood, exhibit minimal cytotoxicity, biocompatibility, low microleakage, and possess antimicrobial properties [4-6]. Biodentine (BD) supports tissue repair, biomimetic mineralisation, antibacterial effects, high compressive strength, fast setting, and bioactivity [7]. However, pulpotomised teeth are more fracture-prone than healthy ones, and their fracture resistance is influenced by the restorative material used.

Glass Ionomer Cement (GIC) serves as a reliable base due to its compressive strength and adhesion to tooth structure [8]. The fracture resistance of a material is a measure of its ability to resist crack initiation and propagation [9]. Many direct filling materials are available in modern dentistry, with composite resins becoming more preferred than amalgam for aesthetically pleasing posterior restorations—even in stress-bearing locations [10,11]. Composite resins strengthen teeth by distributing functional stresses [4]. Nanohybrid resin composites, created by incorporating 5-100 nm nanofillers into microhybrid resins, feature increased filler volume and smaller particle size, enhancing resistance to mastication forces [12-14].

Cention-N, a novel alkaite posterior restorative material, releases ions to neutralise acid and offers excellent mechanical properties. As a dual-cure, Urethane Dimethacrylate (UDMA)-based material, it consists of a powder with glass fillers, initiators, and pigments, as well as a liquid with dimethacrylates and initiators, making it suitable for bulk filling [15,16].

The preservation of pulpal vitality is of paramount importance, as the vital functioning pulp has a unique reparative capacity [2]. However, pulpotomised teeth with extensive Class II MOD cavities are structurally compromised and prone to fracture. While MTA and Biodentine are widely used for their biological benefits, the ideal coronal restorative material to enhance fracture resistance remains unclear. Newer aesthetic materials like nanohybrid composites and Cention-N show promising mechanical properties, but comparative data is limited for Cention-N, a contemporaneous material that is becoming popular among clinicians.

Thus, the present study aimed to analyse and contrast how pulpotomised premolars resist fracture when treated with MTA or BD in Class II MOD cavities restored with Cention-N and nanohybrid composite. The null hypothesis states that there is no significant difference in the fracture resistance of pulpotomised premolars treated with MTA or Biodentine in Class II MOD cavities restored with either Cention-N or nanohybrid composite. In contrast, the alternate hypothesis states that there is a significant difference in the fracture resistance among pulpotomised premolars treated with MTA or Biodentine and restored with either Cention-N or nanohybrid composite.

MATERIALS AND METHODS

An in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India, from November 2023 to December 2023. Approval (Pr.199/IEC/SIBAR/2023) was obtained from the Institutional Ethics Committee of Sibar Institute of Dental Sciences, Guntur, before the initiation of the study.

Inclusion and Exclusion criteria: Maxillary premolars with intact crowns extracted for periodontal or orthodontic purposes were included, while teeth with caries, restorations, developmental anomalies, severe attrition, abrasion, or erosion were excluded.

Sample size calculation: Sample size was determined using G*Power (3.1.9.2) with an effect size of 0.6, α error of 0.05, and power of the study set at 80%, with an allocation ratio of 1:1. The determined sample size was 55, with 11 samples in each group.

Study Procedure

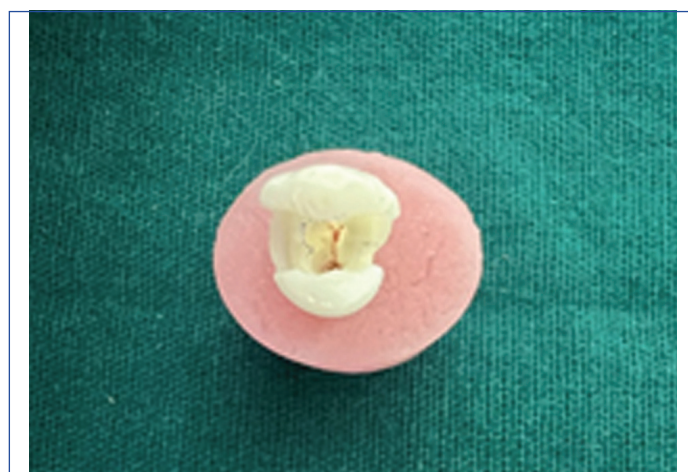
Specimen preparation and allocation: A total of 55 extracted maxillary premolars were cleaned with a scaler (EMS, Piezon system, Switzerland) and stored in a 0.1% thymol solution (Sigma Aldrich Chemicals Pvt. Ltd., USA) until use. The teeth were then mounted in self-cure acrylic resin (DPI, India) 2 mm below the cemento-enamel junction, ensuring parallel alignment to the mold. They were randomly divided into a control group and four experimental groups (n=11 each).

- Group 1 (n=11): Intact teeth (control)
- Group 2 (n=11): Class II MOD cavities with coronal pulpotomy restored with MTA (Dentsply Proroot MTA, USA), a GIC (Ketac Molar, 3M, USA) base, and a nanohybrid composite (Filtek Z250 XT, 3M ESPE, USA).
- Group 3 (n=11): Same as Group 2 but restored with Cention-N (Ivoclar Vivadent, Liechtenstein).
- Group 4 (n=11): Class II MOD cavities with coronal pulpotomy restored with BD (Septodont, France), a GIC base, and a nanohybrid composite.
- Group 5 (n=11): Same as Group 4 but restored with Cention-N.

Class II MOD cavity preparation with complete pulpotomy: Standardised Class II MOD cavities (4.0 mm depth, flat floors, and 1 mm above the CEJ) were prepared in all experimental groups (Groups 2-5) using diamond burs (SF-31, Mani Inc, Japan) and an airrotor (W&H, Austria). Cavities were prepared to a width of one-third of the intercuspal distance, with 90° cavosurface margins

and parallel facial and lingual walls. A digital caliper (Panama Orthodontics Inc, USA) ensured precise measurements.

Pulp chambers were accessed with a round bur (BR-46, Mani Inc, Japan), deroofed with a safe-end bur (EX-24, Mani Inc, Japan), and cleaned with a spoon excavator. A cotton pellet soaked in 3% sodium hypochlorite (Vishal Dento Care Pvt., Ltd., India) was placed for one minute, followed by thorough saline (Prime Dental Products, India) irrigation and air drying [Table/Fig-1].



[Table/Fig-1]: Class II Mesio-Occluso-Distal (MOD) cavity prepared followed by complete coronal pulpotomy.

Restoration of Pulpotomy site with MTA or BD: In Groups 2 and 3, MTA was mixed with distilled water according to manufacturer guidelines, placed over the canal orifices with an amalgam carrier (GDC, India), and adapted using a moist cotton pellet, which remained until set [4]. In Groups 4 and 5, BD was triturated according to the manufacturer's guidelines, placed over the canal orifices, and adapted with a round condenser.

Permanent restoration with Nanohybrid composite or Cention-N: After MTA (Groups 2, 3) and BD (Groups 4, 5) were set, a GIC base was placed. Cavities were surface treated with 37% phosphoric acid (d-tech, India) for 15 seconds, rinsed, dried, and an etch-and-rinse adhesive (Te-Econom adhesive, Ivoclar Vivadent, Liechtenstein) was applied, air-thinned for five seconds, and light-cured for 20 seconds. A Tofflemire retainer (GDC, India) and matrix band were applied.

Nanohybrid composite (Groups 2, 4) was placed incrementally, with each layer cured for 20 seconds using a light-curing unit (Woodpecker iLED Plus, China), while Cention-N (Groups 3, 5) was bulk-filled and cured for 20 seconds. After removing the retainer, additional curing for 20 seconds was performed on the mesial and distal walls. Restorations were finished using a composite polishing kit (Shofu Dental Pvt., Ltd., India), stored at 100% humidity (Humidifier, Remi Instruments Ltd., India) and 37°C for 24 hours, and tested for fracture resistance with a UTM (Fuel Instruments & Engineers, India).

Preparation of specimens for UTM: All specimens underwent fracture resistance testing in a UTM using a 3 mm stainless steel plunger at a 1 mm/min crosshead speed, and fracture loads (N) were recorded [Table/Fig-2].

STATISTICAL ANALYSIS

Data were analysed using the Statistical Package for the Social Sciences (version 26.0, SPSS Inc., Chicago). The Kolmogorov-Smirnov test confirmed normal distribution. Intergroup comparisons were made using one-way ANOVA, with Tukey's post-hoc test employed for multiple pair-wise comparisons. Significance was set at ($p \leq 0.05$).

RESULTS

One-way ANOVA revealed significant differences in mean fracture resistance among the groups. Intact teeth (Group 1) exhibited the highest fracture resistance at 1273.64 N, followed by Group 5



[Table/Fig-2]: Specimens were subjected to a Universal Testing Machine (UTM) to test fracture resistance.

(973.64 N), Group 3 (895.45 N), Group 4 (700 N), and Group 2 (633.64 N) [Table/Fig-3]. Tukey's post-hoc test demonstrated the following results: Group 1 significantly differed from all other groups. Group 2 differed significantly from Groups 1, 3, and 5, but not from Group 4. Group 3 differed significantly from Groups 1, 2, and 4, but not from Group 5. Group 4 significantly differed from Groups 1, 3, and 5, but not from Group 2. Group 5 differed significantly from Groups 1, 2, and 4, but not from Group 3 [Table/Fig-4].

Groups	Mean $\pm$ SD	F-value	Significance
Group 1 (Intact teeth-control)	1273.64 $\pm$ 79.909	113.704	>0.01*
Group 2 (MTA, composite)	633.64 $\pm$ 64.849		
Group 3 (MTA, cention)	895.45 $\pm$ 53.547		
Group 4 (Biodentin, composite)	700.00 $\pm$ 99.197		
Group 5 (Biodentin, cention)	973.64 $\pm$ 87.438		

[Table/Fig-3]: Descriptive and comparative analysis of mean differences in fracture resistance (N) within each group using One-way ANOVA.
*p $\leq$ 0.05 considered statistically significant; Test: One-way ANOVA

Groups	Groups	Mean difference	Significance
Group 1 (Intact teeth-control)	Group 2 (MTA, composite)	640.000*	*p $\leq$ 0.05
	Group 3 (MTA, cention)	378.182*	*p $\leq$ 0.05
	Group 4 (Biodentin, composite)	573.636*	*p $\leq$ 0.05
	Group 5 (Biodentin, cention)	300.000*	*p $\leq$ 0.05
Group 2 (MTA, Composite)	Group 1 (Intact teeth-control)	-640.000*	*p $\leq$ 0.05
	Group 3 (MTA, cention)	-261.818*	*p $\leq$ 0.05
	Group 4 (Biodentin, composite)	-66.364	0.29
	Group 5 (Biodentin, cention)	-340.000*	*p $\leq$ 0.05
Group 3 (MTA, cention)	Group 1 (Intact teeth-control)	-378.182*	*p $\leq$ 0.05
	Group 2 (MTA, composite)	261.818*	*p $\leq$ 0.05
	Group 4 (Biodentin, composite)	195.455*	*p $\leq$ 0.05
	Group 5 (Biodentin, cention)	-78.182	0.15
Group 4 (Biodentin, composite)	Group 1 (Intact teeth-control)	-573.636*	*p $\leq$ 0.05
	Group 2 (MTA, composite)	66.364	0.29
	Group 3 (MTA, cention)	-195.455*	*p $\leq$ 0.05
	Group 5 (Biodentin, cention)	-273.636*	*p $\leq$ 0.05
Group 5 (Biodentin, cention)	Group 1 (Intact teeth-control)	-300.000*	*p $\leq$ 0.05
	Group 2 (MTA, composite)	340.000*	*p $\leq$ 0.05
	Group 3 (MTA, cention)	78.182	0.15
	Group 4 (Biodentin, composite)	273.636*	*p $\leq$ 0.05

[Table/Fig-4]: Multiple pair-wise comparisons within each group using Tukey's post-hoc test.

*p $\leq$ 0.05 considered statistically significant; Test: Tukey's Post-hoc test

DISCUSSION

Fracture resistance is crucial for the longevity of restored teeth, particularly in posterior regions subjected to high occlusal forces

[17]. The authors emphasise the importance of a robust study design to enhance the internal validity and reliability of the results. Several key confounding factors that may influence results, apart from the interventions used, were addressed. These included:

- Tooth type and anatomy (only premolars were selected)
- Extent of tooth structure loss (Class II MOD cavities were standardised)
- Type of restorative and pulpotomy materials (the same materials were used within each group)
- Tooth storage conditions
- Fatigue loading protocols
- Operator variability (a single operator conducted all procedures)

These factors were controlled during the study design to minimise bias.

The anatomical shape of premolars makes them susceptible to failure due to heavy occlusal forces, which may lead to wear, erosion, or cusp fractures ranging from small marginal ditching to fracture lines extending to the pulp [17]. Maxillary premolars were chosen for this study due to their strategic placement in the arch and low crown-to-root ratio, which results in a higher incidence of cusp fractures compared to other posterior teeth [18].

Teeth are more prone to fracture after pulpotomy due to extensive caries and the removal of tooth structure, which increases cusp deflection and fracture risk [19]. De-roofing during pulpotomy reduces the tooth's support against chewing forces. Therefore, selecting materials for both the pulp chamber and Class II MOD cavities that provide protection against fractures is crucial [4,20]. According to Nagas E et al., intraorifice barriers beneath final restorations can help resist stresses that lead to vertical fractures [21].

Restorative materials should possess compressive strength similar to that of natural tooth structure and demonstrate better adhesion, signifying the importance of restorative materials in resisting fractures for Class II carious teeth under heavy occlusal loads. Chaipattanawan N et al., found that teeth treated with vital pulp therapy, particularly those undergoing partial and coronal pulpotomy, had 2.4 and 4.6 times elevated fracture risk, respectively. They emphasised the importance of careful restoration planning and selecting restorative materials with superior mechanical properties to mitigate these risks [22].

The present study evaluated the fracture resistance of pulpotomised maxillary premolars treated with either MTA or Biodentine (BD) and restored with nanohybrid composite or Cention-N in Class II MOD cavities. It was found that intact teeth exhibited the greatest fracture resistance, leading to the rejection of the null hypothesis, as different restorative materials resulted in significant differences in fracture resistance compared to intact teeth.

Intact teeth demonstrated greater fracture resistance due to the presence of intact cusps and marginal ridges, which reinforce the tooth structure [23]. In the experimental groups, Biodentine, used as a barrier material over the pulpotomy site, provided better fracture resistance than MTA. This is likely due to its finer particle size, enhanced adhesion with dentin, and superior physical properties [24]. Additionally, the biocompatibility and physical characteristics of Biodentine were observed to be better than those of MTA, attributed to the enhanced hydroxyapatite apposition on the surface following exposure to tissue fluids [25,26]. This finding aligns with Topcuoglu G and Topcuoglu HS, who highlighted Biodentine as a suitable base material to enhance fracture resistance in pulpotomised primary molars [25].

In contrast, Elnaghy AM and Elsaka SE found no significant difference in fracture resistance between white MTA and Biodentine in regenerative endodontics [27]. Nevertheless, the present study demonstrates that Biodentine outperforms MTA as an intracoronal barrier material over the pulpotomy site.

The final restorative material placed over the intracoronal barrier significantly influenced fracture resistance, with Cention-N outperforming the nanohybrid composite. Cention-N's higher resistance may be attributed to its stress-relieving Isofiller, alongside barium aluminum fluorosilicate and calcium fluorosilicate glasses, and Ytterbium trifluoride with Ivocerin photo-initiator. Through surface modification, these fillers seamlessly integrate into the polymer matrix, exhibiting excellent interfacial interaction and resisting extrusion from the surface. This unique composition of Cention-N significantly contributes to its exceptional strength [28].

The greater fracture resistance exhibited by Cention-N may derive from its advanced matrix material, characterised by a highly crosslinked structure that exhibits a high degree of polymerisation [29,30]. Cention-N comprises four different dimethacrylates (UDMA, PEG-400 DMA, aromatic aliphatic-UDMA, and DCP), which constitute 21.6% of the final manipulated material. These dimethacrylates combine and form cross-links during polymerisation, resulting in robust mechanical properties [31].

The incremental filling technique in composite resin restorations decreases shrinkage stress but can be time-consuming, increasing contamination risk between the layers and potentially leading to voids [32]. This may explain the decrease in fracture resistance in the nanohybrid composite resin compared to Cention-N, which is a bulk fill material that reduces polymerisation shrinkage and improves mechanical strength [33].

Studies have reported conflicting results regarding Cention-N compared to composite resins in terms of fracture resistance. While the present study supports the effectiveness of Cention-N in reinforcing pulpotomised teeth, findings from Mishra A et al., contrast this, as they reported that the nanohybrid composite exhibited the highest compressive and flexural strength compared to Cention-N [34]. Conversely, Sharma A et al., investigated the fracture resistance of root canal-treated premolars restored with Cention-N, Z350 composite, and GIC, finding comparable fracture resistance between Cention-N and Z350 composite, with no significant difference [28]. Supporting the current study's findings, Chowdhury D et al., concluded that Cention-N significantly reinforced teeth following Class II cavity preparation when compared to nanofill composite resin [30].

Limitation(s)

While the study provides valuable insights into the fracture resistance of pulpotomised premolars restored with different materials, several limitations must be acknowledged. The in-vitro study design cannot precisely simulate the oral environment, which includes factors like saliva, pH, temperature variations in the oral cavity, and occlusal loads. The use of standardised cavity preparations may not reflect the exact clinical variability where cavity extent is dictated by caries. Although most confounding factors were controlled during study design, some uncontrolled confounding factors beyond the scope of the design might have affected the results, such as variability in the forces applied during tooth extraction and individual tooth characteristics before extraction.

CONCLUSION(S)

Despite its limitations, this in-vitro study confirmed that intact teeth had the highest fracture resistance. Among the experimental groups, restoring pulpotomised premolars with Class II MOD cavities using BD and Cention-N exhibited the greatest fracture resistance, while MTA and nanohybrid composite showed the lowest. These findings suggest that BD and Cention-N are preferable for restoring pulpotomised maxillary premolars with Class II MOD cavities.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Apr 11, 2025
- Manual Googling: Sep 27, 2025
- iThenticate Software: Sep 30, 2025 (10%)

ETYMOLOGY: Author Origin

EMENDATIONS: 5

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

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