

Original Research Article

An In Vitro Study Comparing the Shear Bond Strength of a Self-Adhering Flowable Composite and a Bulk-Fill Flowable Composite to Various Pulp Capping Materials, Including NEO MTA PLUS, Dycal, Biodentine, and MTA

ABSTRACT

Aim: This study aimed to compare the shear bond strength of a self-adhering flowable composite (SAFC) and a bulk-fill composite when bonded to pulp capping materials, including NEO MTA Plus, Dycal, Biodentine, and MTA.

Material and method: A total of eighty acrylic blocks, each with a central hole 2 mm deep and 4 mm in diameter, were fabricated and assigned to two main groups (n=40 per group) based on the type of composite used (Dyad Flow or SDR). These groups were then subdivided into four subgroups according to the pulp capping material applied. The shear bond strength (SBS) was measured using a universal testing machine with a crosshead speed of 1 mm/min. Data were analysed using One way ANOVA test, Post Hoc Tuckey test and independent t- Test was used.

Result: The intergroup comparison of mean shear bond strength between SDR and Dyad flow was statistically significant ($p < 0.05$) with higher strength in SDR as compared to Dyad flow when analysed using independent t test.

Conclusion: Among the eight subgroups, the combination of NEO MTA Plus and SDR demonstrated the highest shear bond strength.

Keywords: Biodentine, Bulk-fill composite, Dyad flow, Mineral trioxide aggregate, NEO MTA Plus, SDR

INTRODUCTION

Subsequent to experiencing traumatic injuries or undergoing dental procedures, it is feasible for the dental pulp to be inadvertently exposed. In this context, essential pulp therapy is executed through the application of direct pulp capping biocompatible substances to preserve the integrity and vitality of the dental pulp.^(1,2,3) Vital pulp therapy is warranted in instances where there exist manifestations or indications of reversible or potentially irreversible pulpitis, provided that no periapical lesions of endodontic etiology are detected.⁽⁴⁾ The purpose of the treatment is to maintain healthy pulp by sealing the pulp tissue against bacterial infiltration and forming dentine bridge at the exposed site.⁽⁵⁾ Pulp-capped teeth necessitates the application of restorative substances such as amalgam or resin composite for effective sealing. The adhesion between restorative materials and pulp capping agents is of paramount significance; in the absence of an adequate seal, bacterial infiltration into the pulp and subsequent failure of the pulp capping procedure may ensue.⁽³⁾ Historically, calcium hydroxide has been the preferred material for achieving optimal bonding between pulp capping agents and restorative materials due to its antimicrobial properties, alkaline pH, and ability to stimulate mineralization. Sulfonamide, butylene glycol disalicylate, calcium phosphate, calcium tungstate, and oxides of zinc, iron, and titanium are all found in the calcium hydroxide-based substance known as "Dycal".⁽²⁾ But recent research has shown that calcium hydroxide can be extremely harmful to tissue culture cells. Tissue change and breakdown have been demonstrated to result from it, which could

lead to erratic and unpredictable results like reparative dentin bridges with numerous tunnel defects and aseptic necrosis patches.^(6,7) As a result, the use of calcium hydroxide as a pulp-capping agent has declined.

Introduced in 1993, mineral trioxide aggregate (MTA) has since become the gold standard for a variety of endodontic procedures.⁽⁸⁾ MTA is composed of calcium oxide in the form of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and bismuth oxide, which provides radiopacity.⁽⁹⁾ MTA is a highly biocompatible material with superior sealing capabilities. It is believed to provide a dual seal: a physical seal through its cement-like properties and a biological seal by promoting cementogenesis. Additionally, MTA can effectively seal even in the presence of moisture.⁽¹⁰⁾ The primary drawbacks of MTA are its extended setting time and challenging handling properties.⁽¹¹⁾

To address the long setting time of MTA, tricalcium silicate-based materials with reduced setting times have been developed. Biodentine, a calcium silicate cement, is one such material that exhibits dentin-like mechanical properties. It consists of water, calcium chloride (which shortens the setting time), and a hydrosoluble polymer (a water-reducing agent). The powder component of Biodentine includes tricalcium silicate (the primary component), dicalcium silicate (the secondary component), zirconium oxide (for radiopacity), and calcium carbonate (as a filler).^(12,13) Biodentine has shown superior performance compared to MTA, exhibiting better sealing ability, higher compressive strength, shorter setting time, reduced microleakage, enhanced antimicrobial properties, and lower toxicity. Additionally, it offers improved biocompatibility, bioactivity, and biomineralization.⁽¹⁴⁾ Biodentine may be the viable choice for conducting “preventive” endodontics.⁽¹⁵⁾ Biodentine has demonstrated beneficial effects on vital pulp cells, promoting the stimulation of tertiary dentin formation and the early development of reparative dentin.⁽¹⁶⁾

NeoMTA Plus was formulated with properties similar to those of MTA. It includes tricalcium silicate, dicalcium silicate, tantalum oxide, calcium sulfate, and silica. Tantalum oxide is used as a radiopacifier in place of bismuth oxide.⁽¹⁷⁾ NeoMTA Plus is mixed with a water-based gel, which enhances its handling properties. The powder-to-gel ratio can be adjusted, allowing for a thinner consistency suitable as an orthograde sealer, or a thicker mixture for use as a root-end filling material.^(18,19)

NeoMTA Plus is easy to manipulate and stays in place without being washed away, thanks to its unique gel properties. Additionally, it does not cause staining of the tooth.⁽²⁰⁾

The bond strength between the pulp capping material and the superimposed restoration is crucial for the efficacy of the treatment. A properly bonded adhesive interface between the restoration and the pulp capping material has the potential to uniformly distribute stresses across the entire bonding area.⁽²¹⁾

A significant advancement was made with the introduction of self-adhering flowable composite (SAFC), which combines the benefits of both adhesive and restorative materials into a single application process, representing the eighth generation of dental composites.^(22,23)

A recently developed self-adhesive flowable composite is called Dyad Flow. Chair time is decreased when an all-in-one bonding mechanism is incorporated into the composite, which removes the need for adhesive application.⁽²⁾

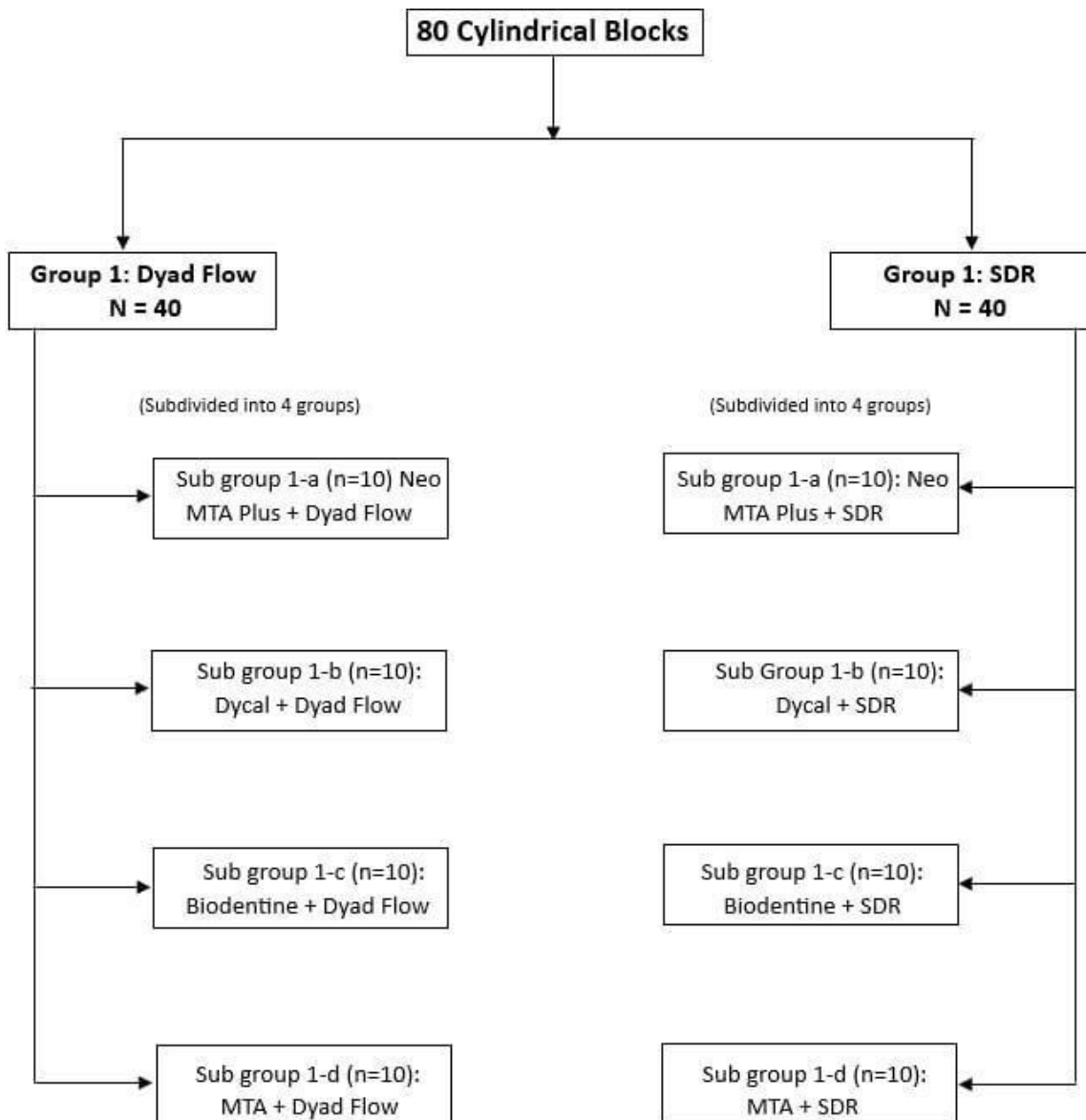
Bulk-fill composites have been shown to generate less polymerization shrinkage stress compared to conventional microhybrid composites, both during and after the light-curing process.⁽²⁴⁾

Surefil SDR (Dentsply, Konstanz, Germany) is a light-cured bulk-fill material that contains fluoride and is radiopaque, designed to establish close contact with cavity surfaces.⁽²⁵⁾ Bulk-fill composites (BFCs) were developed to shorten placement time and enhance the fracture resistance of endodontically treated teeth (ETT). These materials' improved translucency and low polymerization shrinkage stress allow them to be layered in bulk up to 4-5 mm.^(26,27)

Thus, the study's objective was to evaluate the shear bond strength (SBS) of bulk-fill flowable composites (SDR) and self-adhering flowable composites (Dyad Flow) in relation to pulp capping materials such as MTA, NEO MTA Plus, Dycal, and Biodentine.

MATERIALS AND METHODS

Study design



Flowchart 1: **Study design**

A total of 80 acrylic blocks, each measuring 2 cm in height and 2 cm in interior diameter, were made. Each block had a 4 mm diameter and 2 mm deep hole punched in the centre. These 80 blocks were split up into the groups listed below:

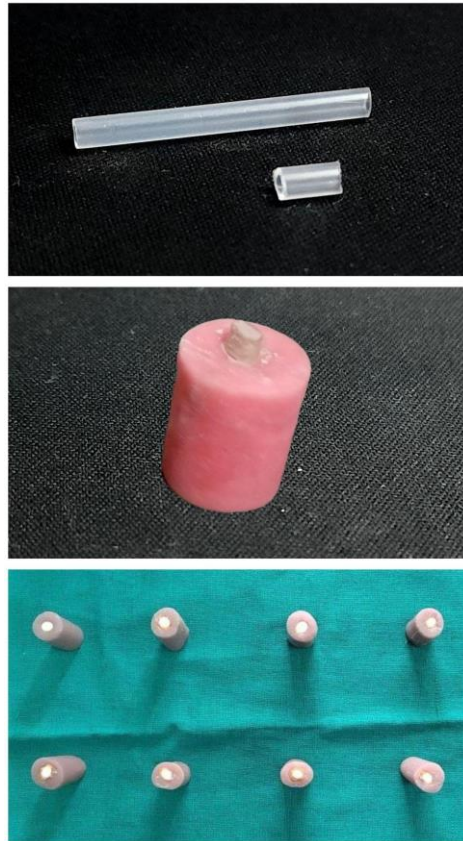


Image 1 - Acrylic blocks with pulp capping agents

- Group I: Dyad Flow(n=40)
 - Subgroup I-a (n=10): NEO MTA Plus +Dyad Flow
 - Subgroup I-b (n=10): Dycal + Dyad Flow
 - Subgroup I-c (n=10): Biodentine + Dyad Flow
 - Subgroup I-d (n=10): MTA + Dyad Flow

- Group II: SDR (n=40)
 - Subgroup II-a (n=10): NEO MTA Plus + SDR
 - Subgroup II-b (n=10): Dycal + SDR
 - Subgroup II-c (n=10):Biodentine + SDR
 - Subgroup II-d (n=10): MTA + SDR

We will mix MTA, Dycal, NEO MTA Plus, and Biodentine as directed by the manufacturer and apply them to their appropriate blocks. Each of the 80 blocks will be coded and incubated for 72 hours at 37°C and 100% humidity.

Following incubation, a plastic cylinder measuring 2 mm in height and 2 mm in diameter was used to distribute Dyad Flow directly over the capping agents in group I blocks in two increments of 1 mm each, via a dispensing tip. The LED device was used to light cure each increment for 15 to 20 seconds.

Optibond all-in-one self-etch adhesive was applied in two increments on group II blocks (n=40), and each increment was light cured for 20 seconds using the LED unit. Using a plastic spatula, SDR was then positioned over the capping agents, and the LED device was used to light cure it for 20 seconds. Every specimen was incubated for 24 hours at 37°C and 100% humidity.

Using a knife-edge blade and a crosshead speed of 1 mm/min, the specimens were placed in a universal testing machine (Instron CORP, Canton, MA) and sheared. Newtons (N) were used to record the load at failure, and the adhesive surface area (mm²) was divided by the load at failure to get the bond strength in megapascals (Mpa).

A plasma sputtering coater was used to sputter gold onto each specimen, and the bond failure manner was then assessed under a scanning electron microscope. Adhesive, cohesive, and mixed bond failure modes were identified.

RESULTS

Data were analysed using SPSS version 23.0 version. The level of significance for the present study was fixed at 5%. Descriptive and analytical statistics were done. The intergroup comparison was done using the One Way ANOVA and independent t-test followed by post hoc Analysis. The Shapiro-Wilk test was used to investigate the distribution of the data and Levene's test to explore the homogeneity of the variables.

Table 1 shows mean and standard deviations of shear bond strength comparison between the Dyad flow and SDR composite resins used with 4 pulp capping materials.

Intergroup comparison between dyad flow and SDR

In the SDR Group the mean shear bond strength of Dycal was 3.63 ± 1.29 , in the MTA was 5.36 ± 1.58 , in the Biodentin was 7.51 ± 1.72 and in the MTA plus was 9.18 ± 1.27 . In the Dyad Flow the mean shear bond strength of Dycal was 1.44 ± 01 , in the MTA was 2.47 ± 1.17 , in the Biodentin was 3.68 ± 1.27 and in the MTA plus was 4.98 ± 1.36 . The intergroup comparison of mean shear bond strength between SDR and Dyad Flow was statistically significant with higher strength in SDR as compared to Dyad Flow when analysed using Independent t-test

	SDR		Dyad Flow		P value
	Mean	Std. Deviation	Mean	Std. Deviation	
Dycal	3.63	1.29	1.44	1.01	0.001 (Sig)
Mineral trioxide aggregate	5.36	1.58	2.47	1.17	0.001 (Sig)
Bio dentin	7.51	1.72	3.68	1.27	0.001 (Sig)
Neo MTA Plus	9.18	1.27	4.98	1.36	0.001 (Sig)

Table 1: Intergroup comparison between dyad flow and SDR

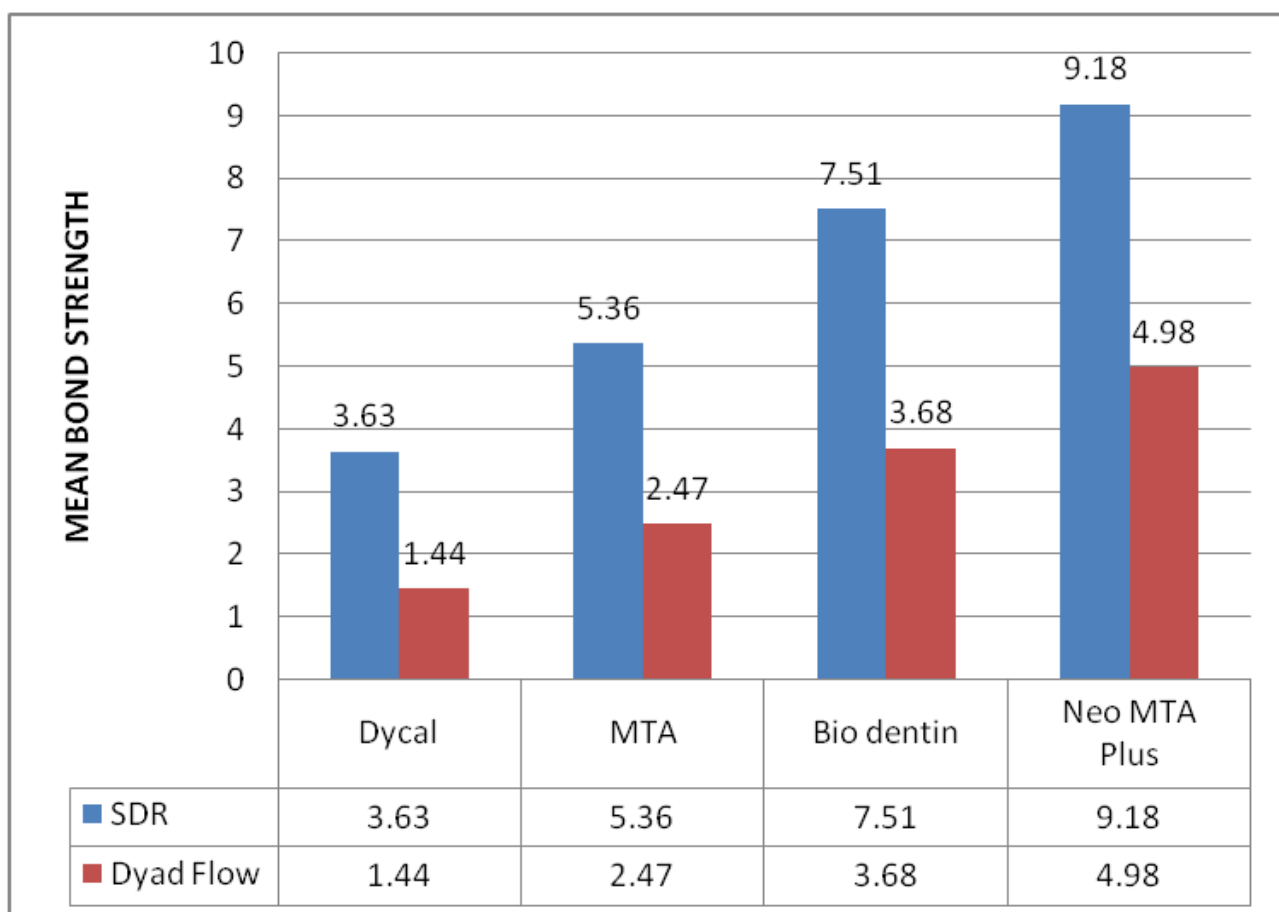


Fig. 1. Graphical presentation showing mean bond strength

DISCUSSION

Shear, tensile, micro-shear, and micro-tensile tests are among the several tests used to gauge the clinical performance and bond strength of composite resin. Shear bond strength was employed in this investigation as a dependable and useful technique.⁽²⁸⁾

Since histology events and clinical results rarely align, it is very impossible to predict the type and extent of pulpal damage in restorative procedures requiring pulp exposure. However, by removing dental cavities and employing biocompatible materials to create a robust barrier against bacterial microleakage, the physician should do everything in their power to preserve vitality.⁽²⁹⁾

Self-adhesive resin composites, such as dyad flow, are a class of novel resin-based materials. The stages that are typically necessary to adhere a resin composite to dentin and enamel—etching, priming, and bonding—are removed.⁽³⁰⁾⁽³¹⁾⁽³²⁾ Because of its low pH and the chemical interactions between the tooth's calcium ions and the monomer's phosphate groups, it forms a connection with the tooth through micromechanical etching.⁽²⁾

Bulk-fill composite promotes less polymerisation shrinkage stress. These resins' improved translucency results from the addition of additional photoinitiator chemicals, which promote deeper photopolymerization and enable the material to be inserted into thick 4–5 mm increments with uniform polymerization and conversion degree.⁽³³⁾⁽³⁴⁾

Smart Dentin Replacement (SDR) is a bulk-fill composite treatment. Lower cuspal deflection may also be a result of the SDR's improved translucency and stress-relieving flowability, which enhance light transmittance and improve polymerization kinetics up to 4 mm.⁽²⁶⁾⁽³⁵⁾

Significant variations in the link strength between the SDR and Dyad flow groups were discovered in the current investigation. The findings showed that the SDR group's shear bond strength was greater than that of the Dyad flow group. Since Dyad Flow is a self-adhesive composite, no adhesive was needed. Nevertheless, we employed the OptiBond all-in-one self-etch adhesive in the SDR group.⁽²⁾ According to Vichi et al., as compared to all-in-one adhesive systems, dyad flow demonstrated improved marginal sealing ability but a lesser binding strength to dentin and enamel.⁽³⁶⁾ A potential reason for the low bond strength of self-adhesive flowable composites could be the absence of compression force or pressure during placement. This lack of pressure is essential to eliminate open spaces at the interface, which can negatively impact the long-term durability of the resin.⁽²⁾

The 15% barium glass filler (0.04 μ) in OptiBond, according to the product's maker, not only strengthens the hybrid layer but also effectively enters dentinal tubules and creates a structural link that is absent from unfilled or nanofilled composite resins. This filler prevents microleakage and strengthens the binding to the tooth surfaces.⁽³⁷⁾

NEO MTA Plus and Dycal had the highest (9.18 + 1.27) and lowest (3.63 + 1.29) SBS among the four capping agents employed in our investigation respectively.

NEO MTA Plus is a calcium silicate based cement. Its small particle size may accelerate the hydration process and improve bond strength by increasing cement penetration into dentinal tubules..⁽³⁸⁾⁽³⁹⁾ Dycal is made of calcium hydroxide. Dycal tends to release less calcium ions than calcium silicate-based materials, which explains its lower shear bond strength. The mineralization and development of pulp cells depend on calcium ions.⁽⁴⁰⁾

Biodentine displayed a higher SBS than MTA in the current investigation. Better interlocking of Biodentine may be facilitated by smaller, more consistent components. A smaller biodentine particle size influences cement's ability to enter dentinal tubules in a tag-like structure, creating a micromechanical anchor.⁽⁴¹⁾⁽⁴²⁾ Additionally, the presence of calcium chloride enhances the material's resistance to displacement, thereby improving its bond strength.⁽²⁾ Also Biodentine induces tertiary dentin formation and has a shorter setting time when compared to MTA.⁽¹¹⁾ According to Tulumbaci et al., MTA had a stronger bond with composite and composite than Biodentine.⁽⁴³⁾ But according to Cantekin and Avci, Biodentine has a greater SBS than composites made of methacrylate.⁽⁴⁴⁾

Tricalcium silicate, dicalcium silicate, tricalcium aluminate, and bismuth oxide, which acts as a radio opacifying agent, are the forms of calcium oxide that make up MTA.⁽⁴⁵⁾⁽⁴⁶⁾⁽⁴⁷⁾ MTA's drawbacks include its high solubility, discoloration, and extended setting time.⁽⁴⁸⁾⁽⁴⁹⁾

NEO MTA Plus is a new cement made of calcium silicate. Instead of using bismuth oxide as a radiopacifying agent, it uses tantalum oxide. It imparts good handling properties and does not stain the tooth. In several studies it has been mentioned that bismuth oxide causes tooth discoloration.⁽⁵⁰⁾⁽⁵¹⁾⁽⁵²⁾⁽⁵³⁾⁽⁵⁴⁾ The release of calcium and hydroxyl ions was longer and more significant, which is essential for induction and formation of mineralised tissue. Additionally it shows the potential to form calcium phosphate layer.⁽⁵⁵⁾⁽⁵⁶⁾ NEO MTA Plus stimulates tissue repair and may be bioactive.⁽⁵⁷⁾⁽⁵⁸⁾ In some studies this material has shown biocompatibility with human dental pulp stem cells.⁽⁵⁹⁾ It can also be used for root canal treatment of primary successors molars without successors based on radiographic evidence.⁽⁶⁰⁾

NEO MTA Plus has several advantages in terms of handling, setting time, resistance to washout, and improved formulation.⁽⁵⁹⁾⁽⁶¹⁾

Following SBS analysis of the specimens, the failure mechanisms were assessed under SEM and documented as cohesive (failure within the capping agent or composite), adhesive (failure at the capping agent-composite interface, two flat surfaces), or mixed (a combination of cohesive and adhesive)⁽²⁾

Cohesion was the predominant mode of failure. The tendency towards cohesive fracture might be attributed towards to the uneven distribution of stresses within the bonded materials, resulting in early failure before the bonded surface affected.⁽¹⁴⁾ Therefore, it may be concluded that when cohesive failure is absent, pulp capping materials may have a higher SBS to composites.

CONCLUSIONS

According to the study's constraints, NEO MTA Plus demonstrated the highest SBS in both self-adhering and bulk fill flowable composites, followed by biodentine, MTA, and Dycal. In comparisons utilizing the same pulp capping agent, the bulk-fill flowable composite adhered more well than the self-adhesive flowable composite.

Therefore, given its higher SBS, Neo MTA Plus may be preferred as a pulp capping agent. It may be better to use bulk fill flowable composite instead of self-adhesive flowable composite when it comes to pulp capping agents.

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REFERENCE

1. **Doozaneh M, Koohpeima F, Firouzmandi M, Abbassiyan F. (2016).** Shear bond strength of self adhering flowable Composite and Resin- modified Glass Ionomer to Two pulp capping materials. Iranian Endodontic Journal 2017;12(1):103-107
2. **Raina A, Sawhny A, Paul S, and Nandamuri S.(2019).** Comparative evaluation of bond strength of self adhering and bulk fill flowable composites to MTA Plus, Dycal, Biodentine, Theracal as in vitro study. Restor Dent Endod.2020 Feb;45(1):e10
3. **Ajami AA, Navimipour EJ, Oskoe SS, et al.(2013).** Comparison of shear bond strength of resin-modified glass ionomer and composite resin to three pulp capping agents. J Dent Res Dent Prospect 2013;7(3):164-168
4. **Lozano-Guillen A, Lopez-Garcia S, et al.** Comparative cytocompatibility of the new calcium silicate - based cement Neo Putty versus NeoMTA Plus and MTAon human dental pulp cells: an in vitro study. Clin Oral Investig. 2022 Dec; 26(12): 7219-7228
5. **Rahmanian E, Azimzadeh S, Eskandarizadeh A.** Dental pulp response to MTA, CEM and Biodentine as pulp cap materials(review of evidence). Annals of Dental speciality.2018;6(3):369-371
6. **Peskersoy C, Lukarcanin J, Turkun M.** Efficacy of different calcium silicate materials as pulp-capping agents: Randomized clinical trial. J Dent Sci. 2021 Mar;16(2):723-731.
7. **Silva GA, Lanza LD, Lopes-Júnior N, Moreira A, Alves JB.** Direct pulp capping with a dentin bonding system in human teeth: a clinical and histological evaluation. Oper Dent. 2006 May-Jun;31(3):297-307.

8. **Tyagi N, Chaman C, Tyagi SP, Singh UP, Sharma A.** The shear bond strength of MTA with three different types of adhesive systems: An in vitro study. J Conserv Dent. 2016 Mar-Apr;19 (2):130-3
9. **Camilleri J .** The chemical composition of mineral trioxide aggregate. J Conservative Dent 2008 Oct;11(4):141-3.
10. **Sindhi AS.** An in vitro study to assess the effectiveness of the shear bond strength of mineral trioxide with different adhesive systems. J Pharm Bioalloed SCI.2021 Jim;13 (Suppl 1): S672-S675.
11. **Omar, Asmaa and El-deen, Mohsen.(2019).** Evaluation of shear bond strength of self adhering flowable composite to Mineral trioxide aggregate and biodentine. Al- Azhar Dental Journal for Girls.
12. **Kaur M, Singh H, Dhillon JS, Batra M, Saini M.** MTA versus Biodentine: Review of Literature with a Comparative Analysis. J Clin Diagn Res. 2017 Aug;11(8):ZG01-ZG05..
13. **Camilleri J, Sorrentino F, Damidot D.** Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. Dent Mater. 2013 May;29(5):580-93.
14. **Zarean P, Roozbeh R et al.** In vitro comparison of shear bond strength of a flowable composite resin and a single-component glass- ionomer to three different pulp-capping agents. Dent Med Probl.2019;566(3):239-244
15. **Arandi NZ, Thabet M.** Minimal Intervention in dentistry: A literature review on biodentine as a bioactive pulp capping Material. Biomed Res Int. 2021 Apr 3, 2021: 5569313

16. **Mahmoud SH, EL- Negoly SA, Zaen El-Din AM, El- Zekrid MH et al.** Biodentine versus mineral trioxide aggregate as a direct pulp capping material for human mature permanent teeth- A systemic review. J Conserv Dent.2018 Sept- Oct;21(5):466-473
17. **Birant S, Gokalp M, Duran Y, Koruyucu M, Akkoc T, Seymen F.** Cytotoxicity of Neo MTA Plus, ProRoot MTA and Biodentine on human dental pulp stem cells. J Den SCI.2021 Jul;16(3):971-979.
18. **Siboni F, Taddei P, Prati C, Gandolfi MG.** Properties of NEO MTA Plus and MTA Plus cements for endodontics. Int Endod J.2017 Dec; 50 Suppl 2; e83-e94.
19. **Abboud KM, Abu- Seida AM, Hassanien EE, Tawfik HM.** Biocompatibility of NeoMTA Plus versus MTA Angelus as delayed furcation perforation repair materials in a dog model. BMC Oral Health.2021 Apr 13;21(1):192.
20. **Zeid, S.T.A, Najlaa, A.A, Khafagi, M.G., and Abou Neel, E.A.(2017).**Chemistry and bioactivity of NeoMTA Plus versus MTA Angelus Root Repair Materials. Journal of Spectroscopy, 2017 , Article 8736428.
21. **Altunsoy M, Tanriver M, Ok E, Kucukyilmaz E.** Shear Bond Strength of a Self-adhering Flowable Composite and a Flowable Base Composite to Mineral Trioxide Aggregate, Calcium-enriched Mixture Cement, and Biodentine. J Endod. 2015 Oct;41(10):1691-5.
22. **Shalan OO, Abou-Auf E.** A 24-Month Evaluation of Self-Adhering Flowable Composite Compared to Conventional Flowable Composite in Conservative Simple Occlusal Restorations: A Randomized Clinical Trial. Contemp Clin Dent. 2021 Oct-Dec;12(4):368-375.

23. **Poitevin A, De Munck J, Van Ende A, Suyama Y, Mine A, Peumans M, Van Meerbeek B.** Bonding effectiveness of self-adhesive composites to dentin and enamel. *Dent Mater.* 2013 Feb;29(2):221-30.
24. **Abbasi M, Moradi Z, Mirzaei M, Kharazifard MJ, Rezaei S.** Polymerization Shrinkage of Five Bulk-Fill Composite Resins in Comparison with a Conventional Composite Resin. *J Dent (Tehran).* 2018 Nov;15(6):365-374.
25. **Hardan, L.; Lukomska-Szymanska, M.; Zarow, M.; Cuevas-Suárez, C.E.; Bourgi, R.; Jakubowicz, N.; Sokolowski, K.; D’Arcangelo, C.** One-Year Clinical Ageing of Low Stress Bulk-Fill Flowable Composite in Class II Restorations: A Case Report and Literature Review. *Coatings* **2021**, *11*, 504.
26. **Karale R, Prathima BJ, Prashanth BR, Shivarajan NS, Jain N.** The effect of bulk-fill composites: Activa and Smart Dentin Replacement on cuspal deflection in endodontically treated teeth with different access cavity designs. *J Conserv Dent.* 2022 Jul-Aug;25(4):375-379.
27. **Yu, Peng & Xu, Yong-Xiang & Liu, Yu-Shu.** (2021). Polymerization shrinkage and shrinkage stress of bulk-fill and non-bulk-fill resin-based composites. *Journal of Dental Sciences.* 17. 10.1016/j.jds.2021.12.004.
28. **Serin BA, Dogan MC, Yoldas Ho.** Comparison of the shear bond strength of Silorane- Based Composite resin and methacrylate based composite resin to MTA. *J Dent Res Dent Clin Dent Prospects.* 2018 Winter;12(1):1-5
29. **Ford TR, Torabinejad M, Abedi Hr, Bakland LK, Kariyawasam SP.** Using mineral trioxide aggregate as a pulp capping material. *J Am Dent Assoc.* 1996 Oct;127 (10):1491-4

30. **Tulogu N, Sen Tunc E, Ozer S, Bayrak S.** Shear bond strength of self adhering flowable composite on dentin with and without application of an adhesive system. *J Appl Biomater Funct Mater.* 2014 Sept 5;12(2):97-101.
31. **Vichi, Alessandro and Goracci, Cecilia and Ferrari, Marco.(2011).** Clinical study of the self adhering flowable composite resin Vertise Flow in Class I restoration: Six month follow up. 5. 14-24
32. **Colak, Ercan E, Hamidi MM.** Shear bond strength of bulk-fill and nano-restorative materials to dentin. *Eur J Dent.*2016 jan-Mar;10(1):40-45.
33. **Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, Ambrosano G, Giannini M.** Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk- fill resin composites. *Dent Mater.*2015 Dec;31(12):1542-51
34. **El- Safety S, Akhtar R, Silikas N, Watts DC.** Nanomechanical properties of dental resin- composites. *Dent Mater.* 2012 Dec;28(12):1292-300.
35. **Van Ende A, De Munck J, Lise DP, Van Meerbeek B.** Bulk-Fill composites: A review of the current literature. *J. Adhes Dent.* 2017;19(2): 95-109.
36. **Yesilyurt C, Ceyhanli KT, Kedici Alp C, Yildirim T, Tasdemir T.** In vitro bonding effectiveness of new self adhering flowable composite to calcium silicate based material. *Dent Mater J.* 2014; 33(3): 319-24.

37. **Poorzandpoush K,Shahrabi M, Heidari A, Hosseinipour ZS.** Shear bond strength of self adhesive flowable composite, Conventional Flowable composite and resin modified glass ionomer cement to primary dentin. *Front Dent.*2019 Jan-Feb;16(1)62-68.
38. **Anju Pk, Purayil TP, Ginjupalli K, Ballal NV.** Effect of chelating agents on push out bond strength of Neo MTA Plus to root canal dentin.*Pesqui Bras Odontopediatria Clin Integr.* 2022; 22:e210058.
39. **Aktemur Turker, S.,Uzunoglu, E., and Bilgin, B.(2016).** Comparative evaluation of push out bond strength of NEO MTA Plus with Biodentine and white ProRoot MTA. *Journal of Adhesion Science and technology*,31(5),502-508
40. **Gandolfi MG, Siboni et al.** Calcium silicate and calcium hydroxide materials for pulp capping: biointeractivity, porosity, solubility and bioactivity of current formulations. *J Appl Biomater Funct Mater.*2015 jan- Mar;(1):43-60.
41. **Kaup M, Dammann CH, Schäfer E, Dammaschke T.** Shear bond strength of Biodentine, ProRoot MTA, glass ionomer cement and composite resin on human dentine ex vivo. *Head Face Med.* 2015 Apr 19;11:14.
42. **Guneser MB, Akbulut MB, Eldeniz AU.** Effect of various endodontic irrigants on the push-out bond strength of biodentine and conventional root perforation repair materials. *J Endod.* 2013 Mar;39(3):380-4.
43. **Tulumbaci F, Almaz ME, Arikan V, Mutluay MS.** Shear bond strength of different restorative materials to mineral trioxide aggregate and Biodentine. *J Conserv Dent.* 2017 Sep-Oct;20(5):292-296.

44. **Cantekin K, Avci S.** Evaluation of shear bond strength of two resin-based composites and glass ionomer cement to pure tricalcium silicate-based cement (Biodentine®). *J Appl Oral Sci.* 2014 Jul-Aug;22(4):302-6.
45. **Camilleri J.** Characterization of hydration products of mineral trioxide aggregate. *International Endodontic Journal.* 2008 May;41(5):408-417.
46. **Funteas UR, Wallace JA, Fochtman EW.** A Comparative Analysis Of Mineral Trioxide Aggregate And Portland Cement. *Aust Endod J.*2003 Apr;29(1):43-4.
47. **Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Ford TR.** The constitution of mineral trioxide aggregate. *Dent Mater.* 2005 Apr;21(4):297-303.
48. **Islam I, Chng HK, Yap AU.** Comparison of the physical and mechanical properties of MTA and portland cement. *J Endod.* 2006 Mar;32(3):193-7.
49. **Parirokh M, Torabinejad M.** Mineral trioxide aggregate: a comprehensive literature review--Part III: Clinical applications, drawbacks, and mechanism of action. *J Endod.* 2010 Mar;36(3):400-13.
50. **Camilleri, Josette.** (2015). Staining Potential of Neo MTA Plus, MTA Plus, and Biodentine Used for Pulpotomy Procedures. *Journal of endodontics.* 41. 10.
51. **Marciano MA, Costa RM, Camilleri J, Mondelli RF, Guimarães BM, Duarte MA.** Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. *J Endod.* 2014 Aug;40(8):1235-40.

52. **Marciano MA, Duarte MA, Camilleri J.** Dental discoloration caused by bismuth oxide in MTA in the presence of sodium hypochlorite. *Clin Oral Investig.* 2015 Dec;19(9):2201-9.

53. **Mohebbi P, Tour Savadkouhi S.** Tooth discoloration induced by calcium-silicate based materials: a literature review. *Minerva Stomatol.* 2016 Dec;65(6):378-384. Epub 2016 Apr 22.

54. **Możyńska J, Metlerski M, Lipski M, Nowicka A.** Tooth Discoloration Induced by Different Calcium Silicate-based Cements: A Systematic Review of In Vitro Studies. *J Endod.* 2017 Oct;43(10):1593-1601

55. **Jacob VP, Paião LI, da Silva ACG, Magario MKW, Kaneko TY, Martins CM, Monteiro DR, Mori GG.** Antimicrobial action of NeoMTA Plus on mono- and dual-species biofilms of *Enterococcus faecalis* and *Candida albicans*: An in vitro study. *Arch Oral Biol.* 2020 Dec;120:104925.

56. **Tanomaru-Filho M, Andrade AS, Rodrigues EM, Viola KS, Faria G, Camilleri J, Guerreiro-Tanomaru JM.** Biocompatibility and mineralized nodule formation of Neo MTA Plus and an experimental tricalcium silicate cement containing tantalum oxide. *Int Endod J.* 2017 Dec;50 Suppl 2:e31-e39.

57. **Hoshino, Roberto & Delfino, Mateus & Silva, Guilherme & la &Guerreiro-Tanomaru, Juliane & Tanomaru-Filho, Mário & Sasso-Cerri, Este Cerri, Paulo.** (2021). Biocompatibility and bioactive potential of the NeoMTA Plus endodontic bioceramic-based sealer. *Restorative Dentistry & Endodontics.*

58. **Quintana RM, Jardine AP, Grechi TR, Grazziotin-Soares R, Ardenghi DM, Scarparo RK, Grecca FS, Kopper PMP.** Bone tissue reaction, setting time, solubility, and pH of root repair materials. *Clin Oral Investig.* 2019 Mar;23(3):1359-1366.

59. **Tomás-Catalá, Christopher & Collado-González, M Mar & García-Bernal, David & RE, Oñate-Sánchez & Forner, Leopoldo & Llena, Carmen & Lozano, Adrian & Moraleda, Jose & Rodríguez Lozano, Francisco Javier.** (2018). Biocompatibility of New Pulp-capping Materials NeoMTA Plus, MTA Repair HP, and Biodentine on Human Dental Pulp Stem Cells. *Journal of Endodontics*. 44. 126-132.

60. **Doğan Ö, Gökçe E, Altintepe Doğan SS, Karakan NC, Çelik İ** (January 1, 2022) ROOT CANAL FILLING WITH NEOMTA PLUS IN SECOND PRIMARY MOLAR TEETH WITH MISSING SUCCESSOR: TWENTY-FOUR MONTHS OF FOLLOW-UP. *Cumhuriyet Dental Journal* 24 4 442–447.

61. **Alazrag MA, Abu-Seida AM, El-Batouty KM, El Ashry SH.** Marginal adaptation, solubility and biocompatibility of TheraCal LC compared with MTA-angelus and biodentine as a furcation perforation repair material. *BMC Oral Health*. 2020 Oct 29;20(1):298.