Journal of Advances in Medicine and Medical Research

Volume 36, Issue 12, Page 1-11, 2024; Article no.JAMMR.126126
ISSN: 2456-8899, NLM ID: 101711724
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

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

Zara Suharwardy [a*], Rajnish K.Jain [a], Ambica Khetarpal [a] and Anju Bala [a]

[a] *Department of Conservative Dentistry & Endodontics, PDM Dental College & Research Institute, Bahadurgarh (Haryana), India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jammr/2024/v36i125649

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/126126

Original Research Article

Received: 12/09/2024
Accepted: 14/11/2024
Published: 21/11/2024

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.

**Corresponding author: E-mail: suharwardy55@gmail.com;*

Cite as: *Suharwardy, Zara, Rajnish K.Jain, Ambica Khetarpal, and Anju Bala. 2024. "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". Journal of Advances in Medicine and Medical Research 36 (12):1-11. https://doi.org/10.9734/jammr/2024/v36i125649.*

Materials and methods: 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.

Results: The intergroup comparison of mean shear bond strength between SDR and Dyad flow was statistically significant (_<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.

1. 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 (Doozaneh et al. 2016, Raina et al. 2020, Ajami et al. 2013). 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 (Lozano-Guillen et al. 2022). 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 (Rahmanian et al. 2018). 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 (Ajami et al. 2013). 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" (Raina et al. 2020). 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 (Peskersoy et al. 2021 , Silva et al. 2006). 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 (Tyagi et al. 2016). MTA is composed of calcium oxide in the form of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and bismuth oxide, which provides radiopacity (Camilleri 2008). 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 (Sindhi 2021). The primary drawbacks of MTA are its extended setting time and challenging handling properties (Omar and El-deen 2019).

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) (Kaur et al. 2017, Camilleri et al. 2013). 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 (Zarean et al. 2019). Biodentine may be the viable choice for conducting “preventive” endodontics (Arandi and Thabet 2021). Biodentine has demonstrated beneficial effects on vital pulp cells, promoting the stimulation of tertiary dentin formation and the early development of reparative dentin (Mahmoud et al. 2018).

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 (Birant et al. 2021). 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 (Siboni et al. 2017, Abboud et al. 2021).

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 (Zeid et al. 2017).

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 (Altunsoy et al. 2015).

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 (Shaalan et al. 2021, Poitevin et al. 2013).

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 (Raina et al. 2020).

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 (Abbasi et al. 2018).

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 (Hardan et al. 2021). 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 (Karale et al. 2022, Yu et al. 2021).

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.

2. MATERIALS AND METHODS

2.1 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:

- 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

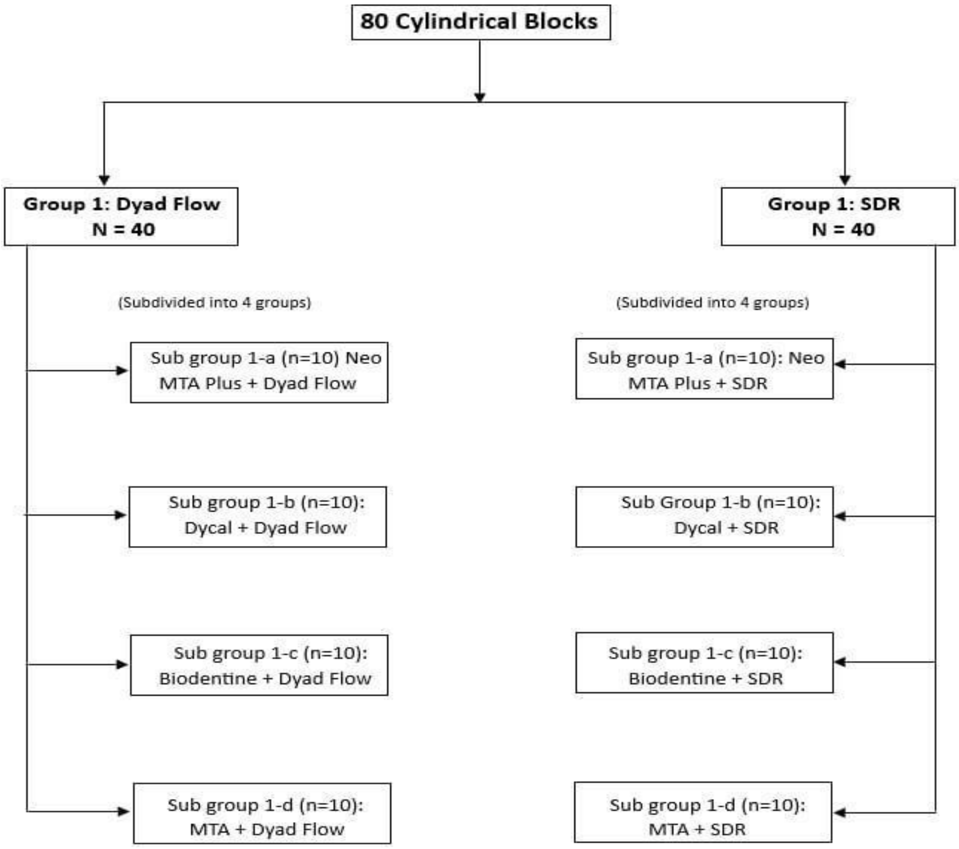
We will mix MTA, Dycal, NEO MTA Plus, and Biodentine as directed by the manufacturer and apply them to their appropriate blocks. Each of the 80 blocks will be coded and incubated for 72 hours at 37°C and 100% humidity.

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.

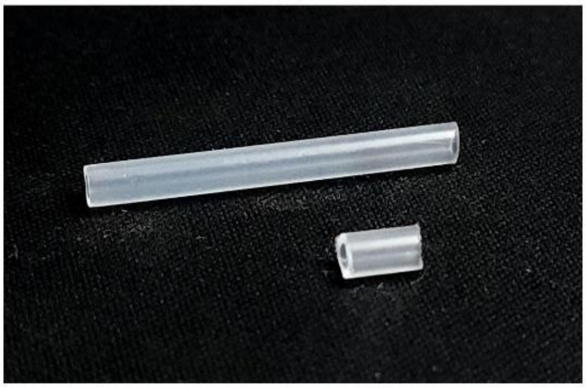
Optibond all-in-one self-etch adhesive was applied in two increments on group II blocks (n=40), and each increment was light cured for 20 seconds using the LED unit. Using a plastic spatula, SDR was then positioned over the capping agents, and the LED device was used to light cure it for 20 seconds. Every specimen was incubated for 24 hours at 370 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.



Flow chart 1. Study design



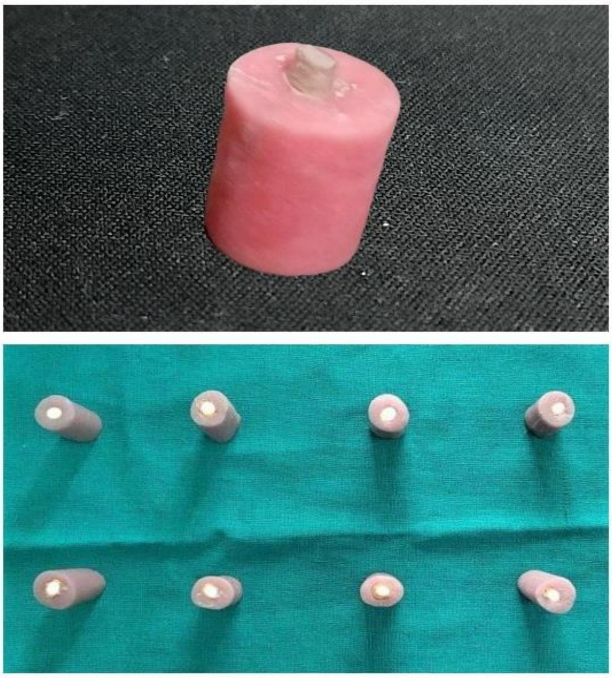


Image 1. Acrylic blocks with pulp capping agents

3. 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.

3.1 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.

4. 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 (Serin et al. 2018).

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 (Ford et al. 1996).

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 (Tulogu et al. 2014, Vichi et al. 2011, Colak et al. 2016). 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 (Raina et al. 2020).

Table 1. Intergroup comparison between dyad flow and SDR

	SDR		Dyad Flow		
	Mean	**Std. deviation**	**Mean**	**Std. deviation**	**P value**
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)

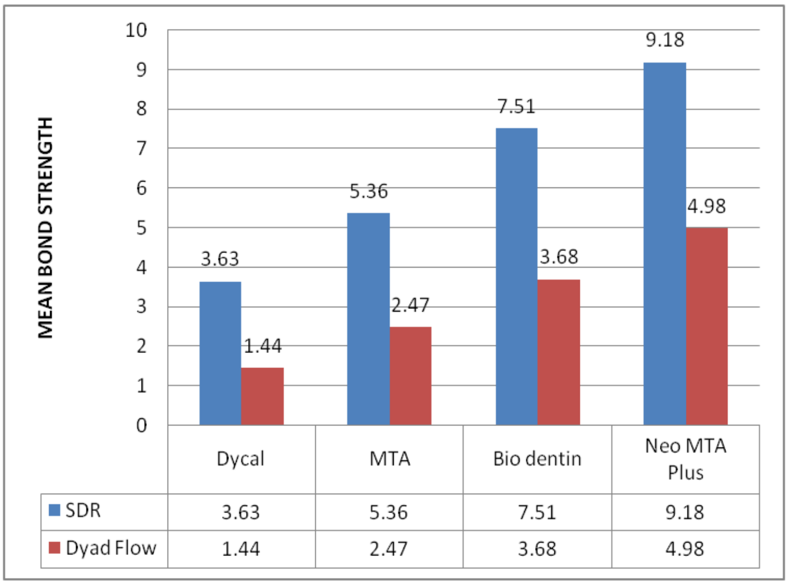


Fig. 1. Graphical presentation showing mean bond strength

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 (Fronza et al. 2015, El-Safety et al. 2012).

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 (Karale et al. 2022, Van et al. 2017).

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 (Raina et al. 2020). According to Vichi et al. (2011) as compared to all-in-one adhesive systems, dyad flow demonstrated improved marginal sealing ability but a lesser binding strength to dentin and enamel (Yesilyurt et al. 2014). 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 (Raina et al. 2020).

The 15% barium glass filler (0.04µ) 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 (Poorzandpoush et al. 2019).

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 (Anju et al. 2022, Aktemur et al. 2016). 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 (Gandolfi et al. 2015).

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 (Kaup et al. 2015, Guneser et al. 2013). Additionally, the presence of calcium chloride enhances the material's resistance to displacement, thereby improving its bond strength (Raina et al. 2020). Also Biodentine induces tertiary dentin formation and has a shorter setting time when compared to MTA (Omar et al. 2019). According to Tulumbaci et al. (2017), MTA had a stronger bond with composite and composite than Biodentine (Tulumbaci et al. 2017). But according to Cantekin and Avci, Biodentine has a greater SBS than composites made of methacrylate (Cantekin et al. 2014).

Tricalcium silicate, dicalcium silicate, tricalcium illuminate, and bismuth oxide, which acts as a radio opacifying agent, are the forms of calcium oxide that make up MTA (Camilleri 2008, Funteas et al. 2003, Camilleri et al. 2005). MTA's drawbacks include its high solubility, discoloration, and extended setting time (Islam et al. 2006, Parirokh et al. 2010).

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 (Camilleri 2015, Marciano et al. 2014, Marciano et al. 2015, Mohebbi et al. 2016, Możyńska et al. 2017). 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 (Jacob et al. 2020, Tanomaru-Filho et al. 2017). NEO MTA Plus stimulates tissue repair and may be bioactive (Hoshino et al. 2021, Quintana et al. 2019). In some studies this material has shown biocompatibility with human dental pulp stem cells (Tomás-Catalá et al. 2018). It can also be used for root canal treatment of primary successors molars without successors based on radiographic evidence (Doğan et al. 2022).

NEO MTA Plus has several advantages in terms of handling, setting time, resistance to washout, and improved formulation (Tomás-Catalá et al. 2018, Alazrag et al. 2020).

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) (Raina et al. 2020).

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 (Zarean et al. 2019). Therefore, it may be concluded that when cohesive failure is absent, pulp capping materials may have a higher SBS to composites.

5. 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that generative AI technologies, such as large language models, have been used during the writing or editing of the manuscript. Specifically, the generative AI technology utilized is “ChatGPT” by OpenAI, dated 2024. The prompts provided to the technology included instructions as following: “Extend the explanation ofthe paper to make the understanding of the reader simple.”

FUNDING

This research is self financed by the main author.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abbasi, M., Moradi, Z., Mirzaei, M., Kharazifard, M. J., & Rezaei, S. (2018). Polymerization shrinkage of five bulk-fill composite resins in comparison with a conventional composite resin. *Journal of Dentistry (Tehran)*, 15(6), 365–374.

Abboud, K. M., Abu-Seida, A. M., Hassanien, E. E., & Tawfik, H. M. (2021). Biocompatibility of NeoMTA Plus versus MTA Angelus as delayed furcation perforation repair materials in a dog model. *BMC Oral Health*, 21(1), 192.

Ajami, A. A., Navimipour, E. J., Oskoee, S. S., et al. (2013). Comparison of shear bond strength of resin-modified glass ionomer and composite resin to three pulp capping agents. *Journal of Dentistry Research, Dental Prospects*, 7(3), 164–168.

Aktemur Turker, S., Uzunoglu, E., & 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.

Alazrag, M. A., Abu-Seida, A. M., El-Batouty, K. M., & El Ashry, S. H. (2020). Marginal adaptation, solubility, and biocompatibility of TheraCal LC compared with MTA-Angelus and Biodentine as a furcation perforation repair material. *BMC Oral Health, 20*(1), 298.

Altunsoy, M., Tanrıver, M., Ok, E., & Kucukyilmaz, E. (2015). Shear bond strength of a self-adhering flowable composite and a flowable base composite to mineral trioxide aggregate, calcium-enriched mixture cement, and Biodentine. *Journal of Endodontics*, 41(10), 1691–1695.

Anju, P. K., Purayil, T. P., Ginjupalli, K., & Ballal, N. V. (2022). Effect of chelating agents on push out bond strength of Neo MTA Plus to root canal dentin. *Pesquisa Brasileira em Odontopediatria e Clinica Integrada, 22*, e210058.

Arandi, N. Z., & Thabet, M. (2021). Minimal intervention in dentistry: A literature review on biodentine as a bioactive pulp capping material. *Biomedical Research International*, 2021, 5569313.

Birant, S., Gokalp, M., Duran, Y., Koruyucu, M., Akkoc, T., & Seymen, F. (2021). Cytotoxicity of NeoMTA Plus, ProRoot MTA and Biodentine on human dental pulp stem cells. *Journal of Dental Sciences*, 16(3), 971–979.

Camilleri, J. (2008). The chemical composition of mineral trioxide aggregate. *Journal of Conservative Dentistry*, 11(4), 141–143.

Camilleri, J. (2008, May). Characterization of hydration products of mineral trioxide aggregate. *International Endodontic Journal, 41*(5), 408-417.

Camilleri, J. (2015). Staining potential of Neo MTA Plus, MTA Plus, and Biodentine used for pulpotomy procedures. *Journal of Endodontics, 41*, 10.

Camilleri, J., Montesin, F. E., Brady, K., Sweeney, R., Curtis, R. V., & Ford, T. R. (2005, April). The constitution of mineral trioxide aggregate. *Dental Materials, 21*(4), 297-303.

Camilleri, J., Sorrentino, F., & Damidot, D. (2013). Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. *Dental Materials*, 29(5), 580–593.

Cantekin, K., & Avci, S. (2014, July-August). Evaluation of shear bond strength of two resin-based composites and glass ionomer cement to pure tricalcium silicate-based cement (Biodentine®). *Journal of Applied Oral Science, 22*(4), 302-306.

Colak, E., Hamidi, M. M., & Ercan, E. (2016, January-March). Shear bond strength of bulk-fill and nano-restorative materials to dentin. *European Journal of Dentistry, 10*(1), 40-45.

Doğan, Ö., Gökçe, E., Altıntepe Doğan, S. S., Karakan, N. C., & Çelik, İ. (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.

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*, 12(1), 103–107.

El-Safety, S., Akhtar, R., Silikas, N., & Watts, D. C. (2012, December). Nanomechanical properties of dental resin-composites. *Dental Materials, 28*(12), 1292-1300.

Ford, T. R., Torabinejad, M., Abedi, H. R., Bakland, L. K., & Kariyawasam, S. P. (1996, October). Using mineral trioxide aggregate as a pulp capping material. *Journal of the American Dental Association, 127*(10), 1491-1494.

Fronza, B. M., Rueggeberg, F. A., Braga, R. R., Mogilevych, B., Soares, L. E., Martin, A. A., Ambrosano, G., & Giannini, M. (2015, December). Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. *Dental Materials, 31*(12), 1542-1551.

Funteas, U. R., Wallace, J. A., & Fochtman, E. W. (2003, April). A comparative analysis of mineral trioxide aggregate and Portland cement. *Australian Endodontic Journal, 29*(1), 43-44.

Gandolfi, M. G., Siboni, W. S., et al. (2015, January-March). Calcium silicate and calcium hydroxide materials for pulp capping: biointeractivity, porosity, solubility and bioactivity of current formulations. *Journal of Applied Biomaterials & Functional Materials, 1*, 43-60.

Guneser, M. B., Akbulut, M. B., & Eldeniz, A. U. (2013, March). Effect of various endodontic irrigants on the push-out bond strength of biodentine and conventional root perforation repair materials. *Journal of Endodontics, 39*(3), 380-384.

Hardan, L., Lukomska-Szymanska, M., Zarow, M., Cuevas-Suárez, C. E., Bourgi, R., Jakubowicz, N., et al. (2021). One-year clinical ageing of low stress bulk-fill flowable composite in Class II restorations: A case report and literature review. *Coatings*, 11, 504.

Hoshino, R., Delfino, M., Silva, G., Guerreiro-Tanomaru, J., Tanomaru-Filho, M., & Sasso-Cerri, E. C. (2021). Biocompatibility and bioactive potential of the Neo MTA Plus endodontic bioceramic-based sealer. *Restorative Dentistry & Endodontics*.

Islam, I., Chng, H. K., & Yap, A. U. (2006, March). Comparison of the physical and mechanical properties of MTA and Portland cement. *Journal of Endodontics, 32*(3), 193-197.

Jacob, V. P., Paião, L. I., da Silva, A. C. G., Magario, M. K. W., Kaneko, T. Y., Martins, C. M., Monteiro, D. R., & Mori, G. G. (2020, December). Antimicrobial action of NeoMTA Plus on mono- and dual-species biofilms of *Enterococcus faecalis* and *Candida albicans*: An in vitro study. *Archives of Oral Biology, 120*, 104925.

Karale, R., Prathima, B. J., Prashanth, B. R., Shivaranjan, N. S., & Jain, N. (2022). The effect of bulk-fill composites: Activa and Smart Dentin Replacement on cuspal deflection in endodontically treated teeth with different access cavity designs. *Journal of Conservative Dentistry*, 25(4), 375–379.

Kaup, M., Dammann, C. H., Schäfer, E., & Dammaschke, T. (2015, April 19). Shear bond strength of Biodentine, ProRoot MTA, glass ionomer cement and composite resin on human dentine ex vivo. *Head & Face Medicine, 11*, 14.

Kaur, M., Singh, H., Dhillon, J. S., Batra, M., & Saini, M. (2017). MTA versus Biodentine: Review of literature with a comparative analysis. *Journal of Clinical and Diagnostic Research*, 11(8), ZG01–ZG05.

Lozano-Guillen, A., Lopez-Garcia, S., et al. (2022). Comparative cytocompatibility of the new calcium silicate-based cement Neo Putty versus NeoMTA Plus and MTA on human dental pulp cells: An in vitro study. *Clinical Oral Investigations*, 26(12), 7219–7228.

Mahmoud, S. H., El-Negoly, S. A., Zaen, E. I.-Din, A. M., El-Zekrid, M. H., et al. (2018). Biodentine versus mineral trioxide aggregate as a direct pulp capping material for human mature permanent teeth: A systematic review. *Journal of Conservative Dentistry*, 21(5), 466–473.

Marciano, M. A., Costa, R. M., Camilleri, J., Mondelli, R. F., Guimarães, B. M., & Duarte, M. A. (2014, August). Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. *Journal of Endodontics, 40*(8), 1235-1240.

Marciano, M. A., Duarte, M. A., & Camilleri, J. (2015, December). Dental discoloration caused by bismuth oxide in MTA in the presence of sodium hypochlorite. *Clinical Oral Investigations, 19*(9), 2201-2209.

Mohebbi, P., & Tour Savadkouhi, S. (2016, December). Tooth discoloration induced by calcium-silicate based materials: a literature review. *Minerva Stomatologica, 65*(6), 378-384. Epub 2016 April 22.

Możyńska, J., Metlerski, M., Lipski, M., & Nowicka, A. (2017, October). Tooth discoloration induced by different calcium silicate-based cements: A systematic review of in vitro studies. *Journal of Endodontics, 43*(10), 1593-1601.

Omar, A., & El-deen, M. (2019). Evaluation of shear bond strength of self adhering flowable composite to mineral trioxide aggregate and biodentine. *Al-Azhar Dental Journal for Girls*.

Parirokh, M., & Torabinejad, M. (2010, March). Mineral trioxide aggregate: a comprehensive literature review--Part III: Clinical applications, drawbacks, and mechanism of action. *Journal of Endodontics, 36*(3), 400-413.

Peskersoy, C., Lukarcanin, J., & Turkun, M. (2021). Efficacy of different calcium silicate materials as pulp-capping agents: Randomized clinical trial. *Journal of Dental Sciences*, 16(2), 723–731.

Poitevin, A., De Munck, J., Van Ende, A., Suyama, Y., Mine, A., Peumans, M., & Van Meerbeek, B. (2013). Bonding effectiveness of self-adhesive composites to dentin and enamel. *Dental Materials*, 29(2), 221–230.

Poorzandpoush, K., Shahrabi, M., Heidari, A., & Hosseinipour, Z. S. (2019, January-February). Shear bond strength of self adhesive flowable composite, conventional flowable composite and resin modified glass ionomer cement to primary dentin. *Frontiers in Dentistry, 16*(1), 62-68.

Quintana, R. M., Jardine, A. P., Grechi, T. R., Grazziotin-Soares, R., Ardenghi, D. M., Scarparo, R. K., Grecca, F. S., & Kopper, P. M. P. (2019). Bone tissue reaction, setting time, solubility, and pH of root repair materials. *Clinical Oral Investigations, 23*(3), 1359-1366.

Rahmanian, E., Azimzadeh, S., & Eskandarizadeh, A. (2018). Dental pulp response to MTA, CEM and Biodentine as pulp cap materials (review of evidence). *Annals of Dental Specialty*, 6(3), 369–371.

Raina, A., Sawhny, A., Paul, S., & Nandamuri, S. (2020). Comparative evaluation of bond strength of self adhering and bulk fill flowable composites to MTA Plus, Dycal, Biodentine, Theracal: An in vitro study. *Restorative Dentistry & Endodontics*, 45(1), e10.

Serin, B. A., Dogan, M. C., & Yoldas, H. O. (2018). Comparison of the shear bond strength of Silorane-based composite resin and methacrylate-based composite resin to MTA. *Journal of Dental Research, Dental Clinics, Dental Prospects*, 12(1), 1–5.

Shaalan, O. O., & Abou-Auf, E. (2021). A 24-month evaluation of self-adhering flowable composite compared to conventional flowable composite in conservative simple occlusal restorations: A randomized clinical trial. *Contemporary Clinical Dentistry*, 12(4), 368–375.

Siboni, F., Taddei, P., Prati, C., & Gandolfi, M. G. (2017). Properties of Neo MTA Plus and MTA Plus cements for endodontics. *International Endodontic Journal*, 50(Suppl 2), e83–e94.

Silva, G. A., Lanza, L. D., Lopes-Júnior, N., Moreira, A., & Alves, J. B. (2006). Direct pulp capping with a dentin bonding system in human teeth: A clinical and histological evaluation. *Operative Dentistry*, 31(3), 297–307.

Sindhi, A. S. (2021). An in vitro study to assess the effectiveness of the shear bond strength of mineral trioxide with different adhesive systems. *Journal of Pharmaceutical Bioallied Sciences*, 13(Suppl 1), S672–S675.

Tanomaru-Filho, M., Andrade, A. S., Rodrigues, E. M., Viola, K. S., Faria, G., Camilleri, J., & Guerreiro-Tanomaru, J. M. (2017, December). Biocompatibility and mineralized nodule formation of Neo MTA Plus and an experimental tricalcium silicate cement containing tantalum oxide. *International Endodontic Journal, 50*(Suppl 2), e31-e39.

Tomás-Catalá, C., Collado-González, M. M., García-Bernal, D., Oñate-Sánchez, R. E., Forner, L., Llena, C., et al. (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.

Tulogu, N., Sen Tunc, E., Ozer, S., & Bayrak, S. (2014, September 5). Shear bond strength of self adhering flowable composite on dentin with and without application of an adhesive system. *Journal of Applied*

Biomaterials & Functional Materials, 12(2), 97-101.

Tulumbaci, F., Almaz, M. E., Arikan, V., & Mutluay, M. S. (2017, September-October). Shear bond strength of different restorative materials to mineral trioxide aggregate and Biodentine. *Journal of Conservative Dentistry, 20*(5), 292-296.

Tyagi, N., Chaman, C., Tyagi, S. P., Singh, U. P., & Sharma, A. (2016). The shear bond strength of MTA with three different types of adhesive systems: An in vitro study. *Journal of Conservative Dentistry*, 19(2), 130–133.

Van Ende, A., De Munck, J., Lise, D. P., & Van Meerbeek, B. (2017). Bulk-fill composites: A review of the current literature. *Journal of Adhesive Dentistry, 19*(2), 95-109.

Vichi, A., Goracci, C., & Ferrari, M. (2011). Clinical study of the self adhering flowable composite resin Vertise Flow in Class I restoration: Six-month follow-up. *Journal of Adhesive Dentistry, 5*, 14-24.

Yesilyurt, C., Ceyhanli, K. T., Kedici Alp, C., Yildirim, T., & Tasdemir, T. (2014). In vitro bonding effectiveness of new self adhering flowable composite to calcium silicate based material. *Dental Materials Journal, 33*(3), 319-324.

Yu, P., Xu, Y.-X., & Liu, Y.-S. (2021). Polymerization shrinkage and shrinkage stress of bulk-fill and non-bulk-fill resin-based composites. *Journal of Dental Sciences*. https://doi.org/10.1016/j.jds.2021.12.004

Zarean, P., Roozbeh, R., et al. (2019). In vitro comparison of shear bond strength of a flowable composite resin and a single-component glass-ionomer to three different pulp-capping agents. *Dental Medicine Problems*, 56(3), 239–244.

Zeid, S. T. A., Najlaa, A. A., Khafagi, M. G., & Abou Neel, E. A. (2017). Chemistry and bioactivity of Neo MTA Plus versus MTA Angelus root repair materials. *Journal of Spectroscopy*, 2017, Article 8736428.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/126126