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Original Article

Comparison of the Shear Bond Strengths of Two Different Restorative Materials to Biodentine and BIOfactor MTA

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CLINICAL SIGNIFICANCE

Biodentine exhibited significantly higher shear bond strength to both flowable composite and glass ionomer cement. Notably, the Biodentine–flowable composite combination yielded the most favorable results.

ABSTRACT

Objectives: The aim of this study was to compare the shear bond strengths of glass ionomer cement and flowable composite to the calcium silicate-based materials- Biodentine and BIOfactor MTA.

Materials and Methods: Biodentine and BIOfactor MTA were prepared and placed in teflon molds with a diameter of 8 mm and a height of 2 mm. Material discs were incubated at 37°C and 100% humidity for 24h. Material samples were embedded in acrylic blocks. Flowable composite (Ruby Flow, Ruby Dent, InciDental, England, Turkiye) or glass ionomer cement Nova Glass F, Imicryl, Konya, Turkiye) with 3-mm diameter and 2-mm height was applied on the calcium silicate based cements. Samples were incubated under the same conditions for 24 hours. Samples were subjected to the shear test method using a universal test machine with the loading speed of 1 mm/min. The peak force was recorded when bond failure occurred. Statistical analysis was carried out using Kruskal Wallis and Mann-Whitney U tests.

Results: A significant difference was found between the shear bond strength of BIOfactor MTA-flowable composite and Biodentine-flowable composite groups ($p<0.05$). There was a significant difference between BIOfactor MTA-glass ionomer cement and Biodentine glass ionomer cement groups ($p<0.05$). Biodentine showed higher bond strength to both materials. Both Biodentine and BIOfactor MTA showed higher shear bond strength with the flowable composite than glass ionomer cement.

Conclusion: Biodentine has higher shear bond strength to restorative materials than BIOfactor MTA. Both calcium silicate-based cements have higher shear bond strength to flowable composite.

1. Introduction

Vital pulp therapies include procedures such as indirect pulp capping, direct pulp capping, partial pulpotomy, and total pulpotomy. Calcium hydroxide-based materials have long been considered the gold standard in endodontics and have been used in many treatments, including vital pulp therapies. However, calcium hydroxide has disadvantages such as not setting as quickly as mineral trioxide aggregate (MTA), dissolving over time, causing microleakage, and requiring prolonged presence in the environment to be effective.[1]

Bioceramics or bioactive endodontic cements are biocompatible cements containing compounds such as tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate dihydrate, bismuth oxide, calcium oxide, aluminum oxide, and many similar components.[2] MTA and other bioceramics have a wide range of clinical applications and have been used with successful clinical outcomes in vital pulp therapy, root resorptions, perforation repair, root-end filling in apical surgery, apexification and regenerative endodontic procedures.[1,3] The main advantages of bioceramics are their high biocompatibility, excellent sealing ability, and ability to set in the presence of moisture.[4] Their disadvantages include long setting time, potential wash-out when exposed to oral fluids, tooth discoloration, difficulty in application, and high cost.[5,6] In addition, once set, they are difficult to remove, and there is no known solvent for them.[7]

Biodentine, an important prototype of bioceramics, is a fast-setting, easy-to-use bioceramic material. It is prepared by adding liquid to the powder contained in a capsule and then agitating it in a mixer to achieve a cement-like consistency.[8] Biodentine offers advantages such as superior physical and biologic properties.[9]

A recently introduced material, BIOfactor MTA (Imicryl Dental, Konya, Turkiye), has similar indications to other bioceramic materials. It can be prepared in either high or low viscosity depending on the type of treatment. Recent studies have investigated the bond strength of BIOfactor MTA to root dentin. Akbulut et al.[10] reported that the push-out bond strength of BIOfactor MTA was comparable to that of MTA-Angelus and Biodentine in permanent teeth, with all materials showing similar resistance to dislodgement forces. In another study focusing on primary teeth, Özer et al.[11] found that BIOfactor MTA demonstrated significantly higher bond strength to root canal dentin compared to calcium hydroxide-based sealers, suggesting its potential as a durable alternative in pediatric endodontics.

Bioceramics are applied directly over the exposed pulp tissue during vital pulp therapies. Their use in regenerative procedures involves controlling infection, disinfecting the root canal, inducing bleeding, and then applying a barrier material.[12,13] In both cases, it is recommended to place a restorative material such as glass ionomer cement (GIC), resin modified glass ionomer cement (RMGIC), or flowable composite over the bioceramic material, followed by a final restoration using either composite or amalgam.[14,15]

Although the main focus in teeth undergoing vital pulp therapy or regenerative endodontic treatment is pulp health and tooth vitality, all restorative materials used in the oral cavity are exposed to chewing forces of varying direction and magnitude. Dentin and bioceramic/restorative materials bond together through adhesive forces. Furthermore, calcium silicate-based materials and the restorative materials applied over them are exposed to intraoral

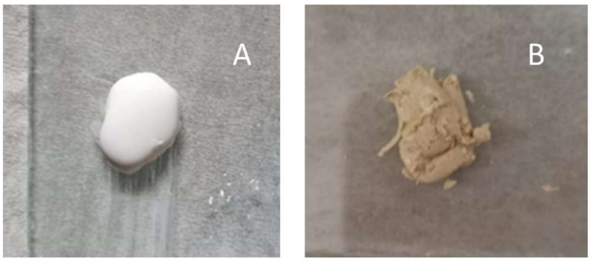

Fig. 1. BIOfactor MTA (A) and Biodentine (B) specimens prepared according to the manufacturer's instructions for placement into molds for the study

masticatory forces; therefore, their shear bond strength is a critical clinical success parameter. The strength of the adhesive bond between materials used in endodontic procedures also affects marginal adaptation and microleakage. This in vitro study aimed to evaluate and compare the shear bond strength of Biodentine and a newly developed calcium silicate-based material, BIOfactor MTA, to flowable composite resin or conventional GIC applied over them as restorative materials.

2. Materials and Methods

The calcium silicate-based materials Biodentine (Septodont, Saint-Maur-des-Fossés, France) and BIOfactor MTA (Imicryl Dental, Konya, Turkiye) were tested in this study. All materials were prepared according to the manufacturers' instructions to ensure standardization and optimal handling properties. BIOfactor MTA was prepared by mixing 1 scope of powder with 1 drop of liquid on a glass slab. Biodentine was prepared by adding 5 drops of liquid into one capsule of powder and mixing it for 30 seconds in a mixer (Fig. 1).

The mixed materials were transferred into Teflon molds measuring 8 mm in diameter and 2 mm in height, forming cylindrical material discs (n = 30). The prepared material samples were incubated for 24 hours at 37°C in 100% humidity. After removal from the incubator (Nüve, Ankara, Turkiye), the samples were embedded in the center of autopolymerizing acrylic resin blocks (BG Dental, Integra, Ankara, Turkiye). To obtain identical surfaces, the specimens were polished under distilled water for 30 seconds.

The specimens were randomly assigned to two restorative material subgroups (n = 15 each): one receiving a flowable composite (Nova Compo HF, Imicryl Dental, Konya, Turkiye) and the other GIC (Nova Glass F, Imicryl Dental, Konya, Turkiye). This resulted in four experimental groups of 15 samples each (Fig. 2):

Group 1A: BIOfactor MTA with Flowable Composite
Group 1B: BIOfactor MTA with GIC
Group 2A: Biodentine with Flowable Composite
Group 2B: Biodentine with GIC

A Teflon mold with an inner cavity of 3 mm in diameter and 2 mm in height was placed on top and at the center of the BIOfactor MTA and Biodentine material discs. The mold was filled with either a flowable composite or GIC. For the flowable composite specimens, the surfaces of the BIOfactor MTA or Biodentine were first etched with acid (RubyEtch, Incidental, Istanbul, Turkiye) for 30 seconds, rinsed for 15 seconds to remove acid residues, and then air-dried. A universal adhesive (Nova Compo B Plus, Imicryl Dental, Konya, Turkiye) was then applied to the surface using an applicator for 20 seconds and gently air-thinned. The adhesive was polymerized using a light-curing unit (Woodpecker Medical Instruments, Guilin, China) for 20 seconds. The flowable composite

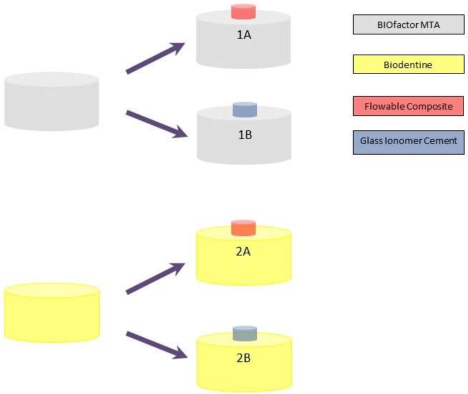

Fig. 2. Schematic representation of the materials used and the experimental groups in the study.

was applied into the mold and polymerized using the same light-curing device for another 20 seconds.

For the GIC, the material was mixed using a cement spatula at a 3:1 powder-to-liquid ratio for approximately 35 seconds and applied into the Teflon mold. The mold was removed either immediately after flowable composite polymerization or 15 minutes after the application of the GIC.

The specimens prepared in this way were incubated again at 37°C and 100% humidity for 24 hours. Then, the samples were placed in a universal testing machine (Besmak, Ankara, Turkiye). A sloped loading head was used to apply force perpendicularly to the calcium silicate cement–restorative material interface and the surface at a constant speed of 1 mm/min until failure occurred (Fig. 3). The maximum force at the point of failure was recorded in Newtons and then converted into megapascals (1 MPa = 1 N/mm²).[16]

To evaluate the failure types (adhesive, cohesive, or mixed) in each group, the surfaces of the BIOfactor MTA and Biodentine specimens were examined under a stereomicroscope (Olympus SZ61, Tokyo, Japan) at 12× magnification and the failures were categorized as follows:
Adhesive Failure: Bond failure occurring at the interface between BIOfactor MTA/Biodentine and the restorative material.
Cohesive Failure: Bond failure occurring within the structure of the BIOfactor MTA, Biodentine, or restorative material.
Mixed Failure: A combination of adhesive and cohesive failure.

Statistical Analysis

Statistical analyses in this study were performed using the SPSS 23.0 software package. The normality of the data distribution was first assessed using the Kolmogorov-Smirnov test. The p-values obtained from the Kolmogorov-Smirnov test were found to be less than 0.05, indicating that the data did not follow a normal

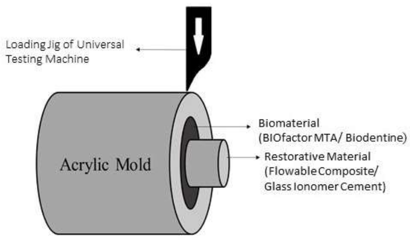

Fig. 3. Schematic illustration showing the experimental setup including all components of the study and the direction of the applied force.

Table 1. Comparison of Shear Bond Strength Values (MPa) Between Materials

	Flowable Composite	GIC	P-value
BIOfactor MTA	5.89±0.50	2.86±0.20	0.001*
Biodentine	7.98±1.13	3.05±0.24	0.001*
P-value	0.001*	0.028*	

distribution. Therefore, non-parametric statistical tests were deemed appropriate for data analysis. To compare the Newton and MPa values between the different material groups, the Mann-Whitney U test was used for pairwise comparisons. A p-value of <0.05 was considered statistically significant.

3. Results

The mean shear bond strength values for each material are presented in Table 1. The highest shear bond strength was observed in the Biodentine – flowable composite group (7.98 ± 1.13), while the lowest value was recorded in the BIOfactor MTA – GIC group (2.86 ± 0.20).

A statistically significant difference was found between the shear bond strengths of BIOfactor MTA to flowable composite and to GIC ($p<0.05$). Similarly, Biodentine also exhibited a statistically significant difference in shear bond strength when bonded to flowable composite versus GIC ($p<0.05$). In both materials, higher bond strengths were observed with flowable composite.

A statistically significant difference in bond strength was found between the BIOfactor MTA–flowable composite group and the Biodentine–flowable composite group ($p<0.05$). Similarly, a statistically significant difference was observed between the BIOfactor MTA– GIC and Biodentine– GIC groups ($p<0.05$). In both comparisons, Biodentine demonstrated higher bond strength to the restorative materials than BIOfactor MTA. The classification of bond failures observed on the surfaces of the BIOfactor MTA and Biodentine specimens under a stereomicroscope is presented in Table 2. Representative images of the cohesive, adhesive, and mixed failure types observed are shown in Fig. 4.

4. Discussion

In endodontic practice, the use of calcium silicate-based materials such as MTA and Biodentine has become increasingly popular due to their successful clinical outcomes. This growing popularity has highlighted the need for further scientific research on the subject.

Although there is a general consensus that calcium silicate-based materials exhibit superior clinical performance compared to other materials in vital pulp therapies [3], there is still no clear agreement in the literature regarding the most appropriate base

Table 2. Comparison of Shear Bond Strength Values (MPa) Between Materials

Materials	Adhesive	Cohesive	Mix	Total
BIOfactor MTA- Flowable Composite	6 (40%)	7 (47%)	2 (13%)	15
BIOfactor MTA-GIC	9 (60%)	3 (20%)	3 (20%)	15
Biodentine- Flowable Composite	4 (27%)	8 (53%)	3 (20%)	15
Biodentine-GIC	8 (53%)	2 (13%)	5 (34%)	15
Total	27	20	13	60

material to be placed over them.[12] Composite resins, GICs, and RMGICs are commonly recommended as base materials over calcium silicate-based materials.[17] Composite resins demonstrate superior bonding strength to dentin and various materials due to their micromechanical bonding mechanisms and advanced adhesive technologies. However, concerns remain about their potential effects on the vital pulp, as they release high heat during polymerization and contain chemical monomers.[18] In contrast, GIC is a biocompatible material composed of a glass matrix that includes elements such as Ca, F, and Al.[19] In our study, we preferred to use flowable composite and GIC as base materials.

Biodentine completes its final setting reaction in approximately 85 minutes.[20] It is also known that MTA has certain disadvantages, such as a delayed setting time and challenging handling characteristics.[21] To avoid applying physical force to the material during the setting phase, the use of flowable composite—capable of spreading over the bioceramic surface without exerting pressure—may be a more appropriate approach. Therefore, in our study, the resin-based material selected was a flowable composite. Our other base material was GIC, a biocompatible material composed of a glass matrix.

In a study comparing the shear bond strengths between MTA and composite resin using different adhesive systems, the total-etch technique—also employed in our study—demonstrated comparable shear bond strength.[22] Similarly, in our research, the total-etch adhesive approach was used prior to the application of the flowable composite. Phosphoric acid, which is currently the most widely accepted and frequently used etchant, was also preferred in our study.

Our findings suggest that Biodentine exhibited higher shear bond strength than BIOfactor MTA to both flowable composite and GIC. When similar studies in the literature are examined, the findings of Gürcan et al.[23] also indicate that Biodentine exhibited higher bond strength values compared to BIOfactor MTA. However, in their study, this difference was not found to be statistically significant. In this respect, while both studies show a similar trend in terms of general outcomes, the statistical significance of the results differs. Moreover, Gürcan et al.[23] investigated various adhesive strategies and employed more complex protocols, whereas the present study focused on

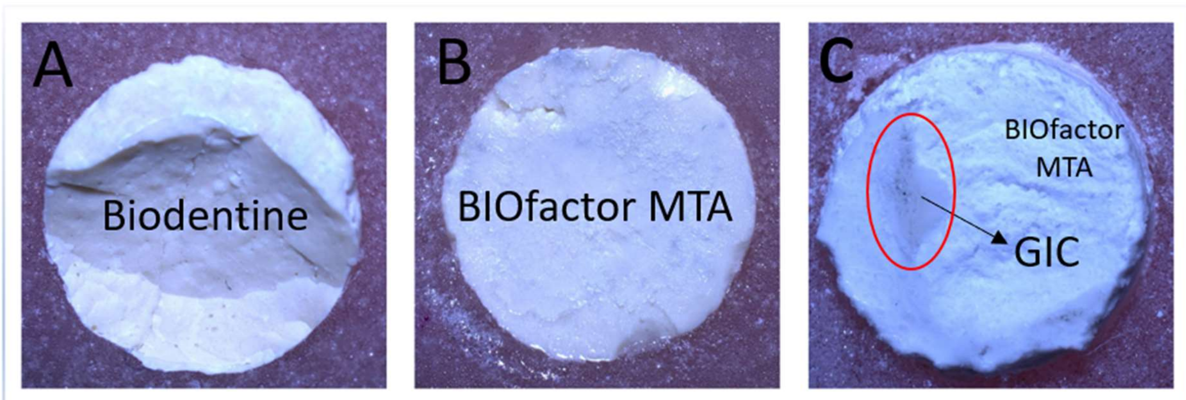

Fig. 4. Cohesive (A), adhesive (B), and mixed (C) bond failures observed on the surfaces of BIOfactor MTA and Biodentine (from left to right).

simplified conditions using only flowable composite and conventional GIC. The fact that both studies were conducted independently and within a similar time frame highlights the growing scientific interest in this subject. It also emphasizes the value of assessing the same materials through different application techniques, thereby enriching the existing body of knowledge in the literature.

In another study investigating the shear bond strengths of MTA, Biodentine, GIC and composite resin to dentine, findings indicated that Biodentine exhibited higher bond strength than MTA, and composite resin adhered better than other materials.[6] The higher bond strength of Biodentine could be attributed to the particle size that penetrates the dentinal tubules.[24] The more uniform and finer particle structure of Biodentine could provide better adhesion compared to BIOfactor MTA.

The limitations of the present study include the lack of evaluation of shear bond strength at different time intervals, as only the values at 24 hours were measured. Additionally, shear bond strength under different adhesive protocols was not assessed. In another study investigating time-dependent changes, Biodentine's shear bond strength was shown to increase significantly between 2 days and 1 week.[25] Furthermore, this was an in vitro study, and in vivo conditions such as the presence of blood, irrigants, and acidic environments may significantly alter the outcomes. Another point that differs from clinical procedures is that in this study, the materials were subjected to mechanical force only after completing their initial setting reaction.

However, in clinical scenarios, a 24-hour incubation period may not always be feasible, and both the tooth and the calcium silicate-based material may be exposed to occlusal forces shortly after placement. Despite the use of standardized Teflon molds and strict adherence to material preparation protocols, the bond strength data did not follow a normal distribution. This may be attributed to inherent variability in manual procedures such as mixing, specimen handling, and surface treatment, which are difficult to eliminate entirely even under controlled conditions. These minor deviations may have introduced variability in the physical properties of the test specimens and should be considered a methodological limitation of the study. Moreover, the flowable composite material was applied in 2 mm increments, consistent with the manufacturer’s instructions, which permit application in layers of ≤ 2 mm using a dispensing tip. However, it is acknowledged that most manufacturers recommend a maximum increment thickness of 1 mm for optimal light polymerization. Although the protocol was in accordance with the manufacturer’s guidelines and thorough light curing was performed to enhance polymerization depth, it is possible that the use of a 2 mm increment may have influenced the degree of polymerization and, consequently, the bond strength outcomes. This potential limitation should be taken into consideration when interpreting the results. Further studies are warranted to investigate the impact of increment thickness on bond strength, particularly in relation to the material-specific polymerization characteristics and curing protocols.

5. Conclusion

Biodentine exhibited significantly higher shear bond strength to both flowable composite and GIC compared to BIOfactor MTA. Additionally, both calcium silicate-based cements demonstrated higher bond strength values when paired with flowable composite rather than GIC.

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CRediT Author Statement
Y.E.Y. :Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Visualization, Funding acquisition, M.A.Ç : Methodology, Software, Validation, Resources, Data Curation, Funding acquisition, M.B.A.: Conceptualization, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration

Data Availability Statement
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Ethics Approval
Since sources obtained from humans or animals were not used in this study, ethics committee approval was not obtained.

Conflict of Interest
The authors declare that there are no conflict of interest and not have any financial interest in the companies whose materials are included in this article.

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