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Comparison of Shear Bond Strength Between HEMA-Based and Non-HEMA Bonding Agents on Dentin Surface

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ABSTRACT

Background: Resin composite restorative materials have become increasingly popular in dental practice in recent decades due to their esthetic properties that meet patient demands. Adhesive ability predicts the durability of a restoration to a certain extent. It is hoped that the filling material will not come off easily and will function optimally in the oral cavity during attachment to the tooth structure. Bonding material is needed to attach the composite to dentin. The choice of HEMA and non-HEMA-based bonding materials on the dentin surface influences the bond strength test results, including the shear strength test. **Objective:** to analyze the shear attachment strength of HEMA and non-HEMA-based bonding after application to the dentin surface. **Materials and Methods:** This research is an experimental laboratory with a post-test without a control group design. The samples were bovine incisor teeth (N=32), namely HEMA-based Palfique Bond bonding (n=16) and non-HEMA-based G-Bond bonding (n=16) with Palfique LX5 composite restorations for HEMA and G- ænial composite for non-HEMA with a diameter of 5 mm and a thickness of 3 mm. The shear bond strength was tested using a Universal Testing Machine (Shimadzu, Japan). **Results:** Based on the results of research using the T-test, it show a significant difference in shear bond strength between HEMA and non-HEMA-based bonding, with a significance of (< 0.05). **Conclusion:** Non-HEMA-based bonding materials have higher shear strength than HEMA-based bonding after application to the dentin surface.

Keywords: HEMA, Non-HEMA, Shear Bond Strength, Universal Testing Machine

ABSTRAK

Latar Belakang: Bahan restoratif komposit resin semakin populer digunakan dalam praktik kedokteran gigi dalam beberapa dekade terakhir karena sifat estetiknya yang memenuhi tuntutan pasien. Kemampuan adhesive memprediksi daya tahan suatu restorasi hingga batas tertentu. Bahan tumpatan diharapkan tidak mudah lepas dan berfungsi optimal pada rongga mulut saat proses perlekatan dengan struktur gigi. Bahan bonding sangat diperlukan untuk merekatkan komposit dengan dentin. Pemilihan bahan bonding berbasis HEMA dan non-HEMA pada permukaan dentin mempengaruhi hasil uji kekuatan ikatan diantaranya uji kekuatan geser. **Tujuan:** untuk menganalisis kekuatan perlekatan geser bonding berbasis HEMA dan non-HEMA setelah diaplikasikan pada permukaan dentin. **Bahan dan Metode:** Penelitian ini merupakan Eksperimental Laboratorium dengan desain Post Test Without Control Group Design. Sampel adalah gigi incisivus sapi (bovine) (N=32), yaitu bonding Palfique Bond berbasis HEMA (n=16) dan bonding G-Bond berbasis non-HEMA (n=16) dengan restorasi komposit Palfique LX5 untuk HEMA dan komposit G-ænial untuk non-HEMA dengan diameter 5 mm dan ketebalan 3 mm. Kekuatan ikatan geser diuji dengan alat Universal Testing Machine (Shimadzu, Jepang). **Hasil:** Berdasarkan hasil penelitian dengan uji Independent Samples T-test, menunjukan perbedaan kekuatan perlekatan geser yang signifikan antara bonding berbasis HEMA dan non-HEMA, dengan signifikansi yaitu 0.004 (< 0.05). **Kesimpulan:** Penggunaan bahan bonding berbasis non-HEMA memiliki kekuatan geser lebih tinggi dibandingkan dengan bonding berbasis HEMA setelah diaplikasikan pada permukaan dentin.

Kata Kunci: HEMA, Non-HEMA, Kekuatan Ikatan Geser, Universal Testing Machine.

1. Introduction

Over the past few decades, composite resin restorative materials have been increasingly used in dental practice. The design of these conservative cavities relies significantly on an adequate bond between dentin and the bonding agent.[1] However, the durability of this bond has become a challenging topic in adhesive dentistry. The durability of a restoration can be measured by bond strength testing. Bond strength tests are frequently used to analyze and evaluate dental materials.[2]

Dental fillings applied to the dentin surface have been known to stop the process of tissue destruction. Still, the attachment of filling materials to the tooth structure is very complex, especially in the attachment to dentin [3]. The fluid in the dentin's dentinal tubules causes the tissue to be wet, so the hydrophobic composite resin cannot easily adhere to the dentin. As a result, bonding materials are required for dentin and composite [4].

Bonding agents are materials used to restore the tooth surface by attaching the restoration material to the enamel and dentin surfaces [5]. Bonding agents, generally esters, are specific functional monomers derived from the reaction of bivalent alcohols with methacrylic acid and phosphorus or carboxylic acid derivatives. 2-hydroxyethyl methacrylate (HEMA) is the base material of the adhesive material, one of the many functional monomers available as an adhesive material [6].

Dentin bonding is composed of HEMA-based materials and non-HEMA materials. However, HEMA-based dentin bonding is most commonly used because it has several advantages: it is relatively easy to manufacture, lasts quite long due to the addition of preservatives, and functions as both hydrophobic and hydrophilic groups [3]. 2-hydroxyethyl methacrylate (HEMA) is hydrophilic, highly compatible with dentin, and is also able to penetrate demineralized substrates easily. On the other hand, its hydrophilicity makes it susceptible to hydrolysis and absorption. It is also known to cause allergic reactions [7]. 2-hydroxyethyl methacrylate (HEMA) decreases the mechanical properties of polymerized bonding because its mono methacrylate chemical structure affects the hydrolytic degradation of the adhesive layer.

Thus, some dentin bondings exclude HEMA in their composition [8]. Dentin bonding materials also have different solvent compositions in each material, which may affect the attachment strength of dentin bonding to collagen fibrils. This study aimed to investigate whether there is a difference in shear attachment strength between HEMA-based and non-HEMA-based bonding after application to the dentin surface.

2. Material and Methods

Sample Preparation

The study used a laboratory experimental method with a Post-Test Without a Control Group Design, categorized as a true experimental design. The samples used in this study were bovine incisor teeth. The teeth were carefully cleaned by removing debris using a brush for soft or hard tissue and a sharp scalpel. Throughout the cleaning process, the teeth were kept moist to prevent dehydration. After cleaning, the teeth were immersed in a 0.9% NaCl solution to simulate an oral environment and stored in a refrigerator at 4°C to maintain moisture.

The enamel layer on the labial surface was removed to expose the dentin using a fissure bur and contra-angle handpiece in a uniform direction. The dentin surface was then smoothed using sandpaper to achieve a flat and even surface. The crown of each tooth was sectioned at the cervical level using a diamond disc bur.

Sample Embedding

Each prepared bovine tooth was embedded in a cylindrical mold. A PVC pipe mold with a diameter of 18 mm and a height of 26 mm was placed on a glass plate as a base, and the bovine tooth was positioned at the center of the mold's base. A plaster mixture was prepared by mixing plaster powder with water and stirring with a spatula. The mixture was then poured into the cylindrical mold until filled and left to harden. To define the treatment area, A plasticine barrier was created to create a circular limitation of 5 mm diameter and 3 mm height at the center of the exposed dentin surface. A Teflon mold was used to shape this area, and once the desired size was obtained, the Teflon mold was removed.

Grouping of Samples

The embedded samples were divided into two groups. Group one consisted of sixteen samples treated with HEMA-based bonding (Palfique Bond, Tokuyama). Group two consisted of sixteen samples treated with non-HEMA-based bonding (G-Bond, GC).

Bonding and Composite Application

The bonding agents were applied to the dentin surface using a micro brush for 10 seconds. Then, the bonded surfaces were gently air-dried for 5 seconds to remove the solvent. The samples were irradiated with a light cure (Noblesse) for 10 seconds. A composite material was applied in layers on top of the bonding agent. Each layer was irradiated with a light cure (Noblesse) for 20 seconds to ensure proper polymerization (Figure 1).

Shear Bond Strength Testing

After the composite application, the samples were subjected to shear bond strength testing using a universal testing machine. A force of 50 kgF was applied at a 0.5 mm/min crosshead speed until bond failure was detected. The results of the bond strength testing were recorded for further analysis.

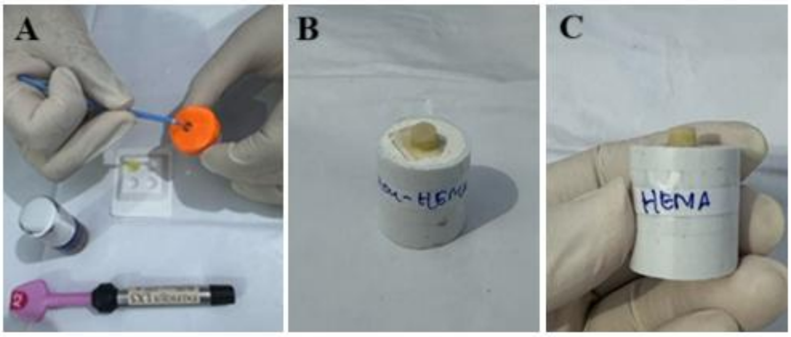

Figure 1. Bonding agents on the dentin surface. (A)cBonding and Composite Applications, (B) Composite restoration HEMA and non-HEMA-based bonding.

3. Result and Discussion

Based on the shear bond strength testing results between HEMA-based and non-HEMA-based bonding agents, the average shear bond strength of HEMA-based bonding was 1.83 MPa, while the average shear bond strength of non-HEMA-based bonding was 3.53 MPa. These findings highlight that non-HEMA-based bonding demonstrated higher shear bond strength than HEMA-based bonding. This difference suggests that non-HEMA-based bonding may have superior adhesive properties, contributing to a stronger and more durable bond with the dentin surface.

The enhanced performance of non-HEMA-based bonding can be attributed to its ability to better penetrate and bond with dentin, likely due to the differences in solvent composition. This makes it more suitable for clinical applications involving high masticatory loads. A detailed summary of the descriptive analysis is provided in Table 1. At the same time, the visual representation of the data can be observed in Figure 2, which illustrates the distribution of the shear bond strength values through a histogram.

Table 1. Analysis of HEMA & non-HEMA bonding shear strength results

Groups	n	Mean (MPa)	SD
HEMA based bonding	16	1.83 MPa	0.951
Non-HEMA based bonding	16	3.53 MPa	1.932

Information: n = Number of samples, Mean = Average value, SD = Standard Deviation

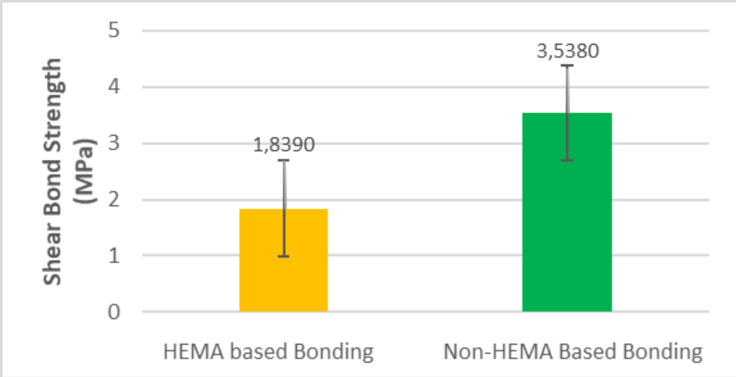

Figure 2. Histogram of shear bond strength test (MPa)

Table 2. *Shapiro-Wilk Test*

	Treatment	*Shapiro-Wilk*		
		Statistics	df	p-value
Shear Bond Strength	Bonding Non-HEMA	.910	16	.116
	Bonding HEMA	.921	16	.174

Shapiro-Wilk Significant ($p > 0.05$)

Based on Table 2, the normality test results indicate that both sample groups' shear bond strength values follow a normal distribution. The normality test for the non-HEMA-based bonding group yielded a p-value of 0.116, greater than the significance level of 0.05, confirming that the data in this group is normally distributed. Similarly, the normality test for the HEMA-based bonding group resulted in a p-value of 0.174, which is also greater than 0.05, indicating that this group's data is normally distributed. Since both datasets meet the normality assumption, further statistical analysis was conducted to compare the shear bond strength between the two groups. The difference test was performed using the Independent Samples T-test, which is appropriate for comparing the means of two independent groups when the data is normally distributed. This test determines whether there is a statistically significant difference in shear bond strength between the HEMA-based and non-HEMA-based bonding agents. The detailed results of this comparative analysis can be seen in Table 3.

Table 3. Independent Samples T-test

	Groups	n	Mean (MPa)	SD
Shear Bond Strength	Non-HEMA	16	1.83 MPa	0.951
	HEMA	16	3.53 MPa	1.932
	Total	32		

Independent Samples T-test Significant ($p < 0.05$)

The Independent Samples T-test analysis results showed that the shear bond strength of non-HEMA-based bonding had a p-value of 0.004, which is less than 0.05, with an average value of 3.53 MPa. Similarly, the shear bond strength of HEMA-based bonding also had a p-value of 0.004, with an average value of 1.83 MPa. These findings indicate a statistically significant difference between the two groups, with non-HEMA-based bonding exhibiting higher shear bond strength than HEMA-based bonding.

These results suggest that non-HEMA-based bonding provides superior shear bond strength when applied to the dentin surface, making it more suitable for composite resin restorations subjected to high masticatory pressure. In contrast, HEMA-based bonding may be more appropriate for restorations in areas experiencing lower occlusal stress. The ability of bonding agents to withstand shear forces is critical for the longevity of restorations, particularly in posterior teeth, where higher masticatory forces are exerted.[9] Furthermore, shear bond strength directly influences the stability of the bonded interface, which plays a vital role in preventing microleakage and restoration failure.[10]

The enhanced shear bond strength observed in non-HEMA-based bonding (G-Bond), which contains acetone as a solvent, can be attributed to its ability to promote stronger adhesion compared to HEMA-based bonding (Palfique Bond), which contains an alcohol solvent. Acetone evaporates more rapidly, allowing optimal water removal from the dentin surface.[11] This property increases dentin moisture sensitivity and improves dentin wetting, resulting in better resin penetration into the collagen fibrils. Consequently, non-HEMA-based bonding forms a thicker and more uniform hybrid layer, leading to stronger adhesion properties.[12] In contrast, the slower evaporation rate of alcohol in HEMA-based bonding may result in suboptimal water removal, reducing its sensitivity to dentin moisture and limiting dentin wetting. As a result, resin infiltration into the collagen fibrils is lower, leading to a thinner hybrid layer and weaker adhesion strength.[13] This is consistent with previous research that demonstrated that non-HEMA-based bonding, a mixture of hydrophilic and hydrophobic materials, solvents, and water, enhances bond effectiveness by increasing resin penetration into dentin.[14]

However, the findings of this study contrast with those reported by Mohammed et al. (2017)[7], who concluded that HEMA-based bonding provides higher bond strength than non-HEMA-based bonding. This discrepancy may be due to 2-hydroxyethyl methacrylate (HEMA), which helps maintain resin monomers in a single solution, prevents phase separation in the hydrophilic phase, and enhances adhesion. Additionally, HEMA improves dentin wetting, significantly contributing to bond strength enhancement.[15] Moreover, it has good biocompatibility and, despite evaporating only in small amounts, still contributes to increasing bond performance.[16]

The overall shear bond strength values observed in this study were relatively low for HEMA- and non-HEMA-based bonding. Compared to previous research, these values were considerably lower, where the shear bond strength of HEMA-based bonding reached 18.39 MPa, while non-HEMA-based bonding was 14.99 MPa.[17] Preview research reported significantly higher values, with HEMA-based bonding reaching 30.7 MPa and non-HEMA-based bonding at 27.7 MPa.[18]

Several factors may have contributed to this study's lower shear bond strength values. One potential issue was inadequate control of dentin moisture levels. If the dentin becomes too dry during the drying process, collagen fibrils may collapse, and the residual water in the solvent may not be sufficient to re-expand the collagen.[19] This could reduce the interaction between the bonding agent and dentin collagen fibrils, weakening adhesion strength. Conversely, if the dentin surface was too wet, excess water molecules around the collagen could form hydrogen bonds with amino collagen, interfering with the bonding agent's ability to bind effectively to collagen.[20] Therefore, achieving an optimal dentin surface condition is crucial for maximizing bond strength.

Another possible factor affecting the results was the depth of dentin tissue removal. This study removed enamel without a precise measuring tool, which may have led to excessive dentin exposure. Further dentin removal during the smoothing process with sandpaper may have altered the bonding mechanism. This aligns with findings from other research that reported that dentin depth negatively impacts bond strength, with deeper dentin layers exhibiting weaker bonding performance due to a decrease in the density of collagen fibrils and a higher concentration of tubular dentin.[21]

Additionally, using bovine teeth in this study may have influenced the results. Differences in tooth age among the bovine samples could have led to variations in enamel and dentin thickness, affecting adhesion properties.[22] Previous studies have shown that dentin permeability and composition vary with age, potentially influencing bond strength outcomes.[23] Future research should consider standardizing sample selection based on tooth age and structure to ensure consistent bonding conditions. Thus, while this study provides insights into the comparative shear bond strength of HEMA-based and non-HEMA-based bonding agents, further investigations are needed to optimize bonding procedures and identify factors that influence adhesion performance. Future studies should focus on controlling dentin moisture levels, standardizing dentin depth removal, and considering the impact of tooth age and composition to achieve more reliable and clinically relevant outcomes.

4. Conclusion

Based on the results, it can be concluded that there is a significant difference in shear bond strength between HEMA-based and non-HEMA-based bonding when applied to the dentin surface. Non-HEMA-based bonding material demonstrates superior shear strength during mastication and articulation due to an acetone solvent, which enhances adhesion properties compared to HEMA-based bonding, which contains an alcohol solvent.

5. References

1. Dionysopoulos D, Gerasimidou O, Papadopoulos C. Current modifications of dental adhesive systems for composite resin restorations: a review in literature. Journal of adhesion Science and technology 2022;36(5):453-68.
2. El Mourad AM. Assessment of bonding effectiveness of adhesive materials to tooth structure using bond strength test methods: a review of literature. The open dentistry journal 2018;12:664.
3. Wurdani E, Soetojo A, Juniarti D. Differences in tensile adhesion strength between HEMA and nonHEMA-based dentin bonding applied on superficial and deep dentin surfaces. Dental Journal (Majalah Kedokteran Gigi) 2017;50:14-18.
4. Winda S, Desi Listya N, Sartika P. Perbedaan Kekuatan Geser dan Kekuatan Tarik pada Restorasi Resin Komposit Microhybrid dengan Bonding Generasi V dan Bonding Generasi VII. Insisiva Dental Journal: Majalah Kedokteran Gigi Insisiva (IDJ) 2013;2(2):69-76.
5. Nabilla K, Djafri D, Sumantri D. Perbandingan Kebocoran Mikro Pada Restorasi Komposit Dengan Pemakaian Bonding Generasi Kelima dan Bonding Generasi Ketujuh. Andalas Dental Journal 2017.
6. Soetojo A, Sumarto IS, Mudjiono M, Lunardhi CGJ. Perbedaan Kekuatan Ikatan Kimia Antara Bahan Bonding Hema dengan Pelarut Aseton dengan Bahan Bonding Hema dengan Pelarut Etanol Pada Kolagen. Conservative Dentistry Journal 2019;8(2):69-76.
7. Hardan L, Orsini G, Bourgi R, et al. Effect of Active Bonding Application after Selective Dentin Etching on the Immediate and Long-Term Bond Strength of Two Universal Adhesives to Dentin. Polymers 2022;14(6):1129.
8. Jang JH, Jeon BK, Mo SY, et al. Effect of various agitation methods on adhesive layer formation of HEMA-free universal dentin adhesive. Dental materials journal 2019;38(1):101-06.
9. Vilde T, Stewart CA, Finer Y. Simulating the intraoral aging of dental bonding agents: a narrative review. Dentistry Journal 2022;10(1):13.
10. Fan-Chiang Y-S, Chou P-C, Hsiao Y-W, et al. Optimizing dental bond strength: insights from comprehensive literature review and future implications for clinical practice. Biomedicines 2023;11(11):2995.
11. Bourgi R, Hardan L, Cuevas-Suárez CE, et al. The Use of Warm Air for Solvent Evaporation in Adhesive Dentistry: A Meta-Analysis of In Vitro Studies. Journal of Functional Biomaterials 2023;14(5):285.
12. Wendlinger M, Nuñez A, Moreira PH, et al. Effect of the Absence of HEMA on the Bonding Properties of Universal Adhesive Systems Containing 10-MDP: An In Vitro Study. Operative dentistry 2023;48.
13. Hitmi L, Bouter D, Degrange M. Influence of drying and HEMA treatment on dentin wettability. Dental materials : official publication of the Academy of Dental Materials 2002;18:503-11.
14. Nishitani Y, Yoshiyama M, Donnelly AM, et al. Effects of resin hydrophilicity on dentin bond strength. J Dent Res 2006;85(11):1016-21.
15. Costa MP, Giacomini MC, Zabeu GS, et al. Impact of functional monomers, bioactive particles, and HEMA, on the adhesive performance of self-etch adhesive systems applied to simulated altered dentin. Journal of Dentistry 2024;151:105379.
16. Wu D, Yao Y, Cifuentes-Jimenez CC, et al. Long-Term Dentin Bonding Performance of Universal Adhesives: The Effect of HEMA Content and Bioactive Resin Composite. Journal of Functional Biomaterials 2024;15(12):379.
17. Mohammed N, Wakwak M, Al-Kady H. In Vitro Study Compared The Shear Bond Strength of HEMA-free and HEMA-containing Bonding Agents To Different Dentin Surface Treatments. Al-Azhar Dental Journal for Girls 2017;4:359-69.
18. Felizardo KR, Lemos LV, de Carvalho RV, et al. Bond strength of HEMA-containing versus HEMA-free self-etch adhesive systems to dentin. Braz Dent J 2011;22(6):468-72.
19. Almusa AH. Chemical Analysis of Dental Adhesives and Their Application with Self-Sealing Composites [UCL (University College London); 2024.
20. Breschi L, Maravic T, Cunha SR, et al. Dentin bonding systems: From dentin collagen structure to bond preservation and clinical applications. Dental Materials 2018;34(1):78-96.
21. Yoshikawa T, Sano H, Burrow MF, Tagami J, Pashley DH. Effects of dentin depth and cavity configuration on bond strength. J Dent Res 1999;78(4):898-905.
22. Möhring S, Cieplik F, Hiller K-A, et al. Elemental compositions of enamel or dentin in human and bovine teeth differ from murine teeth. Materials 2023;16(4):1514.
23. Hardan L, Bourgi R, Kharouf N, et al. Bond strength of universal adhesives to dentin: A systematic review and meta-analysis. Polymers 2021;13(5):814.

Authors Contribution

Contribution	Asmah, N	Mattulada, I.K	Aslan, S	Anas, R	Arsyad, MA
Concepts or ideas	√				
Design	√	√	√		
Definition of intellectual content	√	√	√	√	√
Literature search	√	√	√	√	√
Experimental studies	√	√	√	√	√
Data acquisition	√	√	√	√	√
Data analysis	√	√	√	√	√
Statistical analysis	√	√	√	√	√
Manuscript preparation	√	√	√	√	√
Manuscript editing	√	√	√	√	√
Manuscript review	√	√	√	√	√

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