ORIGINAL RESEARCH

Effect of Bonding Agents on the Shear Bond Strength of Tooth-colored Restorative Materials to Dentin: An *In Vitro* Study

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Abstract

Aim: The aim of the study is to determine the difference in the shear bond strengths to dentin among dental composite (Filtek Z350®, 3M), compomer (Dyract Flow®, Dentsply) and Giomer (Beautifil®, Shofu) with 3M™ Single Bond™ Universal Adhesive (SBU) (7th generation, self-etch, single solution adhesive) and Adper™ Single Bond 2 Adhesive (ASB) (5th generation, total-etch, two solution adhesive).

Materials and methods: Sixty extracted human permanent teeth were collected, cleansed of debris, and placed in distilled water. The samples were segregated into two groups depicting the two bonding agents—Adper™ (ASB) and 3M™ Single Bond Universal (SBU) and sub-grouped into three groups depicting the three restorative materials (Composite, Giomer, and Compomer) used. Groups were respresented as follows: Group I—ASB + Composite; Group II—ASB + Giomer; Group III—ASB + Compomer; Group IV—SBU + Giomer; Group V—SBU + Compomer; Group VI—SBU + Composite. After applying the bonding agent as per the manufacturer's instructions, following which the restorative material was placed. A Universal Testing Machine (Instron 3366, UK) was employed to estimate the shear bond strength of the individual restorative material and shear bond strengths were calculated.

Results: Composite bonded with SBU (group VI) displayed the greatest shear strength (11.16 ± 4.22 MPa). Moreover, Giomers and flowable compomers displayed better bond strengths with ASB compared with their SBU–bonded counterparts.

Conclusion: These results mark the importance of careful material selection in clinical practice and the bonding agent used to achieve optimal bond strength and enhance the clinical longevity and durability of dental restorations.

Clinical significance: From a clinical perspective, to avoid a compressive or a shear failure, it would be preferrable to use a direct composite restorative material with SBU (Single bond universal adhesive, 7th generation) to achieve maximum bond strength.

Keywords: Bonding agent, Composite, Dentin bonding, Shear bond strength.

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Introduction

Dental caries is by far, the most commonly occurring ineradicable condition across the globe.[1] Accurate diagnosis, appropriate treatment planning, and timely intervention using a suitable restorative material remain the ideal approach in any clinical practice to manage such carious lesions. The inception of acid etching of the dental enamel by Buonocore in 1955 marked a significant milestone in the application of adhesives in the field of restorative dentistry.[2] Since then, there has been a tremendous shift toward the use of materials with better esthetics, and improved bonding to the tooth surface, all while trying to achieve properties like that of natural teeth. Glass ionomer cements (GICs) rely on their ability to chemically bond to the tooth in addition to their fluoride releasing property.[3] However, the mechanical strength and esthetics of this material prove to be inadequate to match the patient's needs.[4] In 1962, Bowen developed a methyl methacrylate monomer called Bis-GMA, which found widespread use in most modern composite resin-based restorations.[5] It gained popularity for possessing superior mechanical properties while serving the esthetic standards for restorative materials in comparison to GICs. However, their hydrophobic nature entailed the use of a bonding agent during placement.[6]

An efficacious bonding agent can provide uniformly powerful bonds to both the homogeneous enamel and the highly variable

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dentin.[7] Thus, several handling and material characteristics determine the success of a restorative therapy. Bonding agents have been classified (Flowchart 1) into four generations (IV, V, VI, VII) and two major classes (etch-and-rinse and self-etch). Though bonding agents among the 5th generation are commonly used in a dental practice, 6th generation systems have shown the highest retention rates.[7]

Over the past decade, enormous advancements in material science research have warranted a closer look at the mechanical properties of newer restorative materials, that seek to combine highly desirable properties of both GICs (adhesion, fluoride release) and composite resins (strength, esthetics). Compomers, which are essentially polyacid-modified composites, were launched in the 1990s. Pre-reacted glass ionomer was added to composite resin to manufacture this material, which does not set via an acid–base reaction.[8] However, this hampered their ability to chemically bond to the tooth.[9,10] and also resulted in lower release of fluoride, in comparison to conventional GICs.[11,12] A newer restorative material named Giomers involved the use of pre-reacted glass ionomers dispersed within the resin matrix, leading to true hybridization of GICs and composites.[13] This material possessed promising qualities, such as superior esthetics, better handling properties, improved radiopacity in addition to exhibiting enhanced fluoride release.[14] Furthermore, it is imperative to take into consideration the mechanism of bonding of the material to the tooth structure, as the durability and longevity of the restoration largely relies on the bond strength.[15] These bonding agents act as intermediaries to facilitate the bonding of the restorative material to the tooth.[16] Factors such as the type of bonding agent used and its method of bonding positively influence the establishment of the strong bond. Currently, there is no systematic evaluation on the effect of bonding agents as a parameter directly impacting the bond strength between the tooth and tooth-colored restorative materials. Among a plethora of options available in the market for restorative dentistry, the selection of the suitable material depends on the clinician's prowess in selecting the appropriate case. Additionally, it is also vital to consider the patient's requests and expectations, which poses a challenge to the clinician. There has been constant improvement in the adhesive systems over a period of time.

The Adper™ Single Bond 2 (5th generation bonding agent) is a single-component adhesive agent, with stable nanofiller that remains homogeneously distributed during dispersion. The unique dispensing system is fast, easy, and practical for the most common adhesive procedure in the dental office—direct restorations with composite resin. A fast, easy, and convenient total-etch, single-component bonding agent offering exceptional bond strength.

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The most recent being 7th generation bonding agents (3M™ Single bond Universal adhesive). These are available in One-bottle, one-coat convenience. They are also proven to have long-term bond strength and virtually NO postoperative sensitivity. They are also moisture tolerant and uniquely suited for the "selective" etch technique.

Our aim with the present research was executed to determine the difference in the shear bond strengths to dentin among dental composites, Compomer and Giomer, with 3M™ Single Bond™ Universal Adhesive (SBU) (7th generation, self-etch, and single solution adhesive) and Adper™ Single Bond 2 Adhesive (ASB) (5th generation, total-etch, two solution adhesive).

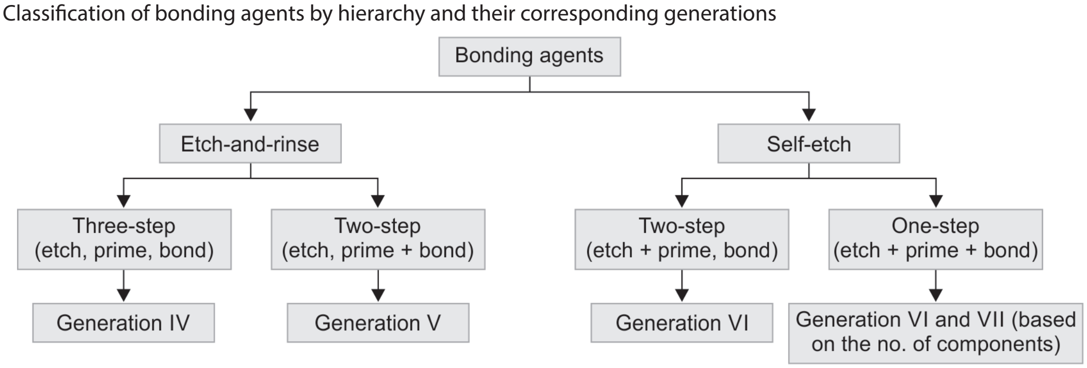
Materials and Methods

After obtaining IEC Clearance (Project No. 197/2020), this *in vitro* experimental study performed at the Department of Dental Materials, Manipal College of Dental Sciences, Manipal. This study was conducted over a period of 6 months. G-power software 3.1.9.2 was used to calculate a sample size of 60 with a power of study of 80.

Sample Preparation

Sixty human permanent teeth (premolars and molars) which were extracted for orthodontic reasons were collected, cleansed, and placed in distilled water to prevent dehydration. The teeth were ground on one side to establish an even and flat dentinal surface. The flattened specimens were mounted on custom-fabricated autopolymerizing orthodontic resin molds (25 × 10 × 10 mm), exposing the coronal section. A plastic tube (internal height: 4 mm; diameter: 3 mm) was mounted on each specimen and the adhesive was light cured for 30 seconds. The specimen was segregated randomly into two groups depicting the two bonding agents with 30 specimens in each (Adper™ single bond 2 adhesive, $n = 30$ and 3M™ Single bond universal adhesive, $n = 30$) then each group was additionally sub-divided into three, depicting the type of restorative material used (Table 1). Thus, the conclusive number of specimens in each sub-group being $n = 10$. Following the instructions of the manufacturer, the respective bonding agent was applied, the tubes were filled with the assigned restorative material and allowed to set, after which the tubes were removed.

Flowchart 1: Classification of bonding agents by hierarchy and their corresponding generations



Shear Bond Strength Assessment

A Universal Testing Machine (Instron 3366, UK) was employed to estimate the shear bond strength of the individual restorative material. For every mounted specimen, shear loading was employed to the adhesive interface at 0.5 mm/minutes till debonding was achieved. The shear bond strength was then quantified as the quotient of the maximum load recorded prior to failure and the area of the sample. The values for the shear bond strength (in MPa) and the strain at the highest load were tabulated. Highest load before failure for each specimen was then measured using the values of shear bond strength, and the surface area of the plastic tube ($p = F/A$). For each sub-group, the outliers were removed and the sample size per group was restricted to $n = 8$. Further, the mean and the median load values, and their respective standard deviations were calculated. The normality of the distribution was evaluated using the Shapiro–Wilk Test and the Kolmogorov–Smirnov Test. The homogeneity of the variances was assessed using Levene's test. To test the statistical significance between the medians of the different groups, Friedman test was used.

Statistical Analysis

Statistical analyses were conducted in GraphPad Prism (v9). One-way ANOVA test was carried out to compare the variations in the shear bond strengths between the groups. Tukey's test was used for pairwise comparisons.

Results

The distribution passed the normality tests with p-values more than 0.05. Levene's test portrayed statistical significance in variance of each group ($p = 0.005$). Among all the groups, composite bonded with SBU (group VI) showed the greatest shear bond strength (11.16 ± 4.22 MPa). The lowest strength was observed in group IV where giomer was bonded with SBU (6.09 ± 0.90 MPa). Unlike composites, flowable compomers and giomers bonded better with the ASB (Table 2).

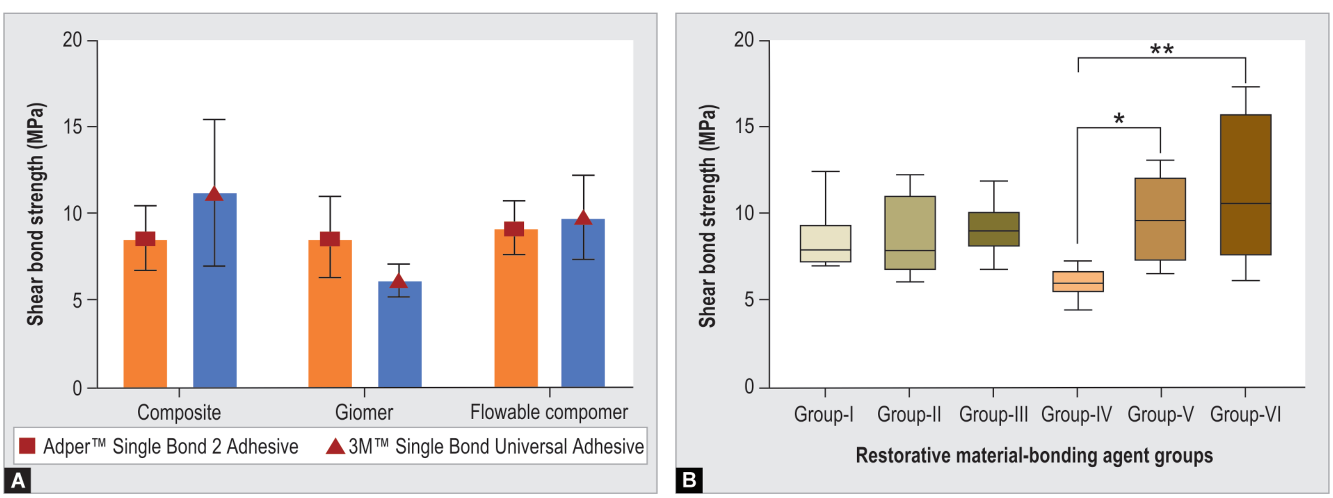
The difference in the shear bond strengths across the groups were statistically significant ($p = 0.0067$) and the pairwise comparisons revealed statistical significance between group IV and group V ($p = 0.0469$), and group IV and group VI ($p = 0.0021$) (Fig. 1). Use of Adper single bond 2 adhesives resulted in similar bond strength values among the various restorative materials used. However, with 3M single bond adhesive, superior bond strength was observed only with composite materials whereas least bond strength was observed with giomer. To summarize, composite bonded with SBU (group VI) displayed the greatest shear bond strength (11.16 ± 4.22 MPa).

Table 1: Study groups illustrating the restorative materials and bonding agents used in this study

Bonding agent used	*Restorative material used*	*Group number*
Adper™ Single Bond 2 Adhesive (5th Gen)	Composite (Filtek Z350®, 3M)	Group I
	Giomer (Beautifil®, Shofu)	Group II
	Compomer (Dyract Flow®, Dentsply)	Group III
3M™ Single Bond Universal Adhesive (7th Gen)	Giomer (Beautifil®, Shofu)	Group IV
	Compomer (Dyract Flow®, Dentsply	Group V
	Composite (Filtek Z350®, 3M)	Group VI

Table 2: The mean and standard deviation of the compressive stresses (MPa) corresponding to each sub-group

Group	*Compressive stress at maximum force (MPa) Mean ± Standard deviation*
I – (Adper™ + Composite)	8.57 ± 1.84
II – (Adper™ + Giomer)	8.63 ± 2.32
III (Adper™ + Flowable Compomer)	9.15 ± 1.55
IV (3M™ Single Bond + Giomer)	6.09 ± 0.90
V (3M™ Single Bond + Flowable Compomer)	9.77 ± 2.45
VI (3M™ Single Bond + Composite)	11.16 ± 4.22



Figs 1A and B: (A) The descriptive statistics (means and standard deviations) of the mean shear bond strengths between the different study groups; error bars indicate the standard deviation. (B) The statistical analysis of the mean shear bond strengths across the different groups; error bars indicate the minimum and maximum values. Asterisk indicates a statistically significant finding (*$p \leq 0.05$, **$p \leq 0.01$)

Discussion

This study was designed to determine the difference in the shear bond strengths to dentin among dental composites, Compomer and Giomer, with 3M Single Bond™ Universal Adhesive (SBU) (7th generation, self-etch, and single solution adhesive) and ASB (5th generation, total-etch, two solution adhesive).

This *in vitro* study showed that the usage of 7th generation bonding agents resulted in a general trend of higher shear bond strengths between the composite and the dentin. There was an overall higher shear bond strength for restorative materials with the use of SBU, except for Giomers. There was a statistical significance noted between the shear bond strengths across the different groups ($p = 0.0067$). Both self-etching and etch-and-rinse techniques appear reliable, and the restorative material used does have a role to play in determining a more predictable bond to the tooth.

The rationale behind the usage of 5th and 7th generation bonding agents was the sound scientific basis regarding their clinical longevity and performance. Kallenos TN et al., conducted a study involving testing of microleakage of methylene blue microscopically when different bonding agents were used to restore the teeth samples with composites. 88.5% of the samples using 5th generation agents showed no microleakage. This was followed by 7th generation agents and then 6th generation agents with 78.5 and 46.35% of the specimen showing no evidence of microleakage.[17] However, in a study by Ganesh et al. G Premio Bond (eighth generation) showed effective shear bond strength than generation 5 (ASB), 6 Clearfil SE, 7: Single Bond Universal. G Premio Bond was compatible with self-etch without the use of primer which gives highly long-lasting esthetics and wear resistance.[18]

McLean DE et al., assessed the enamel bond strengths of composites to enamel using several bonding agents in self-etch and etch-and-rinse modes. They concluded that etching the enamel produced better enamel bond strengths as opposed to self-etching. Self-etched adhesives mainly produced adhesive failures and etch-and-rinse adhesives had a higher incidence of mixed failures. Similar to this study, Deniz Sen et al. compared the shear bond strengths of two composite core materials after using all-in-one and single-bottle dentin bonding materials and concluded that shear bond strengths for single-bottle adhesive systems were significantly higher than those for all-in-one adhesive systems.[19]

As a reinforcement to our study, Thanaratikul B et al. estimated the micro-shear bond strengths of composite to dentin employing various bonding agents, namely, ASB, Clearfil SE Bond, and SBU (self-etch and etch-and-rinse modes) agents. They found that SBU had better dentin bond strengths than ASB. However, both self-etch, and etch-and-rinse modes produced similar bond strengths, revealing that the material plays a greater role than the mode of application.[20]

Furthermore, Pradeep S et al. primarily evaluated the shear bond strength of different adhesives under intra-pulpal pressure and inferred interesting results. SBU had a higher bond strength (6.74 ± 1.59 MPa) than ASB (5.36 ± 0.03 MPa). Both the agents primarily produced cohesive failures.[21]

Prabhakar AR et al. demonstrated a remarkably higher shear bond strength for composites in comparison to compomers in permanent teeth.[22] Chitnis D et al. concluded that composites displayed a higher bond strength than giomers when used to bond orthodontic brackets onto teeth.[23] Also, in an *in vitro* study by Sharma et al., it was observed that composite resin had the highest shear bond strength value, followed by compomer whereas GIC showed the least shear bond strength.[24] These two studies independently reinforce the findings of our study where composites have performed better than giomers and flowable compomers, when used with SBU.

Conversely, Vicente et al. have shown that a giomer, Beautifil Flow (Shofu) has a higher adhesive capacity than X-Flow, a flowable compomer.[25] Our study portrays that flowable compomers performed significantly better than giomers when used with SBU ($p = 0.0469$). On an average, compomers performed well, and had high bond strengths when used with either of the bonding agents. Xie et al. concluded similar findings in which scanning electron microscopy demonstrated an "intimate adaptation in the restoration/dentin interfaces" when compomer was used.[26]

According to a study by Elif Ataol et al. which compared the sealing effectiveness of fissure sealants bonded to enamel with universal adhesive systems applied in self-etch (SE) or etch-and-rinse (ER) modes, The ER Mode significantly reduced the microleakage of universal adhesives.[27]

Based on the current findings of our study, composites when used with SBU displayed maximum bond strength with dentin. On the other hand, giomers and flowable compomers displayed better bond strengths with ASB, in comparison to their SBU-bonded counterparts. Hence, it can be inferred that the effect of bonding agent on bond strength of the material with dentin is largely based on restorative material used.

Limitations

Due to the limited scope of this study, there are some limitations. Some of them include a small sample size, after the exclusion of outliers, and the lack of justification with the use of a power analysis for initial sample size estimation.

Future Scope

More extensive research should be conducted to investigate how to improve the shear bond strength of newer restorative materials along with bonding agents to improve the bond strength. The clinical performance of these materials maybe performed on a larger *in vivo* sample size.

Conclusion

The findings of our study provide valuable insights into the shear bond strengths of different restorative materials when paired with two different generations of bonding agents. The findings suggest that the choice of bonding agent significantly influences the bond strength between the restorative material and dentin. These results underscore the importance of careful material selection in clinical practice, as well as the choice of bonding agent, to achieve optimal bond strength and enhance the longevity of dental restorations. Clinicians should consider the specific needs of each case and patient preferences when making these decisions.

Further research with larger sample sizes and clinical trials are warranted to validate these findings and provide more robust clinical recommendations. Ultimately, successful restorative dentistry requires a combination of clinical expertise, material knowledge, and patient-centerd decision-making to achieve the best outcomes for each individual case.

Clinical Significance

From a clinical perspective, to avoid a compressive or a shear failure it would be preferrable to use a direct composite restorative material with SBU to achieve maximum bond strength. Ideally, 3M^{TM} ESPE SBU may provide a better shear bond strength and lower failure rate when compared with 3M^{TM} ESPE ASB, thus enhancing the clinical longevity and durability of restorations. Nevertheless, the success of any restoration primarily depends on the clinician's ability for appropriate case selection and the choice of restorative material.

References

1. Selwitz RH, Ismail AI, Pitts NB. Dental Caries. Mol MedMicrobiol 2007;369(4):51–59. DOI: 10.1016/S0140-6736(07)60031-2.
2. Buonocore MG. A Simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J D Res 1955;34(6): 849–853. DOI: 10.1177/00220345550340060801.
3. Kucukyilmaz E, Savas S, Kavrik F, et al. Fluoride release/recharging ability and bond strength of glass ionomer cements to sound and caries-affected dentin. Niger J Clin Pract 2017;20(2):226–234. DOI: 10.4103/1119-3077.178917.
4. Almuammar MF, Schulman A, Salama FS. Shear bond strength of six restorative materials. J Clin Pediatr Dent 2001;25(3):221–225. DOI: 10.17796/jcpd.25.3.r8g48vn51l46421m.
5. Asmussen E, Peutzfeldt A. Influence of UEDMA, BisGMA and TEGDMA on selected mechanical properties of experimental resin composites. Dent Mater 1998;14(1):51–56. DOI: 10.1016/s0109-5641(98) 00009-8.
6. Tay FR, Pashley DH, Kapur RR, et al. Bonding BisGMA to dentin—A proof of concept for hydrophobic dentin bonding. J Dent Res 2007;86(11):1034–1039. DOI: 10.1177/154405910708601103.
7. McLean DE, Meyers EJ, Guillory VL, et al. Enamel bond strength of new universal adhesive bonding agents. Oper Dent 2015;40(4):410–417. DOI: 10.2341/13-287-L.
8. Andersson-Wenckert IE, Folkesson UH, Van Dijken JWV. Durability of a polyacid-modified composite resin (compomer) in primary molars. A multicenter study. Acta Odontol Scand 1997;55(4):255–260. DOI: 10.3109/00016359709115424.
9. Martin R, Paul SJ, Heinz L, et al. Dentin bond strength of Dyract Cern. Am J Dent 1997;10(1):27–31. PMID: 9545917.
10. Moodley D, Grobler SR. Compomers: adhesion and setting reactions. J South African Dent Assoc 2003;58(1):21, 24–28. PMID: 12705101.
11. Shaw AJ, Carrick T, McCabe JF. Fluoride release from glass-ionomer and compomer restorative materials: 6-month data. J Dent 1998;26(4):355–359. DOI: 10.1016/s0300-5712(97)00016-x.
12. Grobler SR, Rossouw RJ, Van Wyk Kotze TJ. A comparison of fluoride release from various dental materials. J Dent 1998;26(3):259–265. DOI: 10.1016/s0300-5712(97)00011-0.
13. Gordan VV, Mondragon E, Watson RE, et al. A clinical evaluation of a self-etching primer and a giomer restorative material: Results at eight years. J Am Dent Assoc 2007;138(5):621–627. DOI: 10.14219/jada.archive.2007.0233.
14. Wiegand A, Buchalla W, Attin T. Review on fluoride-releasing restorative materials-Fluoride release and uptake characteristics, antibacterial activity and influence on caries formation. Dent Mater 2007;23(3):343–362. DOI: 10.1016/j.dental.2006.01.022.
15. Tay FR, Smales RJ, Ngo H, et al. Effect of different conditioning protocols on adhesion of a GIC to dentin. J Adhes Dent 2001;3(2):153–167. PMID: 11570684.
16. Cavalcanti AN, De Lima AF, Peris AR, et al. Effect of surface treatments and bonding agents on the bond strength of repaired composites. J Esthet Restor Dent 2007;19(2):90–98. DOI: 10.1111/j.1708-8240.2007.00073.x.
17. Kallenos TN, Al-Badawi E, White GE. An in vitro evaluation of microleakage in class I preparations using 5th, 6th and 7th generation composite bonding agents. J Clin Pediatr Dent 2005;29(4):323–328. DOI: 10.17796/jcpd.29.4.b51q018j100403p5.
18. Ganesh AS. Comparative evaluation of shear bond strength between fifth, sixth, seventh, and eighth generation bonding agents: an in vitro study. Indian J Dent Res 2020;5:752–757. DOI: 10.4103/ijdr.IJDR_635_19.
19. Sen D, Akgüngör G. Shear bond strengths of two composite core materials after using all-in-one and single-bottle dentin adhesives. J Prosthodont 2005;14(2):97–103. DOI: 10.1111/j.1532-849X.2005.00018.x.
20. Thanaratikul B, Santiwong B, Harnirattisai C. Self-etch or etch-and-rinse mode did not affect the microshear bond strength of a universal adhesive to primary dentin. Dent Mater J 2016;35(2):174–179. DOI: 10.4012/dmj.2015-109.
21. Arikatla SK, Chalasani U, Mandava J, et al. Interfacial adaptation and penetration depth of bioceramic endodontic sealers. J Conserv Dent 2018;21(4):373–377. DOI: 10.4103/JCD.JCD_64_18.
22. Prabhakar A, Raj S, Raju O. Comparison of shear bond strength of composite, compomer and resin modified glass ionomer in primary and permanent teeth: An in vitro study. J Indian Soc Pedod Prev Dent 2003;21(3):86–94. PMID: 14703213.
23. Chitnis D, Dunn WJ, Gonzales DA. Comparison of in-vitro bond strengths between resin-modified glass ionomer, polyacid-modified composite resin, and giomer adhesive systems. Am J Orthod Dentofac Orthop 2006;129(3):330.e11–330.e3.3E16. DOI: 10.1016/j.ajodo.2005.11.011.
24. Sharma C, Kaur H, Aggarwal M, et al. Comparative evaluation of shear bond strength of glass ionomer cement, composite and compomer in primary teeth: an in vitro study. SVOA Dentistry 2023;4(2):52–56. DOI: https://doi.org/10.58624/SVOADE.2023.04.0127.
25. Vicente A, Bravo LA. Evaluation of different flowable materials for bonding brackets. Am J Dent 2009;22(2):111–114. PMID: 19626975.
26. Xie H, Zhang F, Wu Y, et al. Dentine bond strength and microleakage of flowable composite, compomer and glass ionomer cement. Aust Dent J 2008;53(4):325–331. DOI: 10.1111/j.1834-7819.2008.00074.x.
27. Ataol E, Ertan AA, Cehreli ZC. Sealing effectiveness of fissure sealants bonded with universal adhesive systems: Influence of different etching modes. J Adhes Sci Technol 2017;31(14):1626–1634. DOI: 10.4317/jced.54471.