ORIGINAL RESEARCH

Assessment of the Efficacy and Bond Strength of Different Dentin-bonding Agents with Adhesives on Primary Teeth: An *In Vitro* Study

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Abstract

Aim: The purpose of this study was to evaluate the effectiveness and strength of three various dentin-bonding agents used with adhesives on primary teeth.

Materials and methods: The study used 80 recently extracted, healthy human maxillary anterior primary teeth that had undergone physiologic resorption, or over-retention. Teeth were cut to expose a flat dentin surface at a depth of 1.5 mm. All samples were divided into four groups (20 samples in each group) as follows: Group I—Control group, Group II—Primary teeth bonding with 6th-generation bonding agent, Group III—Primary teeth bonding with 7th-generation bonding agent, Group IV—Primary teeth bonding with 8th-generation bonding agent. All of the samples' dentinal surfaces were covered with composite resin using a Teflon mold after adhesive had been applied. A universal testing machine (INSTRON) was used to assess the shear bond strength. Data were collected and statistically analyzed.

Results: The maximum mean shear bond strength was found in 8th-generation bonding agent (30.76 ± 0.16), followed by 7th-generation bonding agent (26.08 ± 0.21), 6th-generation bonding agent (25.32 ± 0.06), and control group (6.18 ± 0.09). Statistically significant difference was found between the three different bonding agents ($p < 0.001$).

Conclusion: On conclusion, the 8th-generation bonding agent demonstrated a greater shear bond strength to dentin than the 7th and 6th-generation bonding agent.

Clinical significance: The emergence of different bonding techniques to the market improves the durability and quality of restorations. An effective bonding to the tooth would also reduce bacterial penetration, marginal microleakage, possibility of pulpal inflammation preserve tooth structure, and postoperative sensitivity by allowing less cavity preparation.

Keywords: Adhesive, Dentin-bonding agents, Primary teeth, Shear bond strength.

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Introduction

Esthetic restoration of deciduous teeth is very challenging work for the clinicians due to pulpal anatomy, small size, and thin enamel of the tooth. Parents and patients alike are very concerned about the restoration of primary teeth that are traumatized, discolored, distorted, or have numerous surface cavities. Currently, composite is one of the most widely used and promising tooth-colored restoration materials; it adheres to the tooth with the use of bonding agents, or adhesive. An efficient bond would limit pulpal inflammation, postoperative discomfort, bacterial penetration resulting in secondary caries, marginal microleakage, and preserve the tooth structure by requiring less cavity preparation.[1]

The coronal tooth structure is strengthened and its resistance to fracture is increased by the composite core buildup. The bonding agent industry has evolved from a multistep process (etching, washing, drying, priming, and adhesive) to a simpler approach (self-etch and one bottle system). The perfect bonding agent should adhere to both enamel and dentin, have sufficient bond strength, and be biocompatible. Different dentin-bonding agents were created in order to raise the standard of composite restorations and adhesives.[2]

The effectiveness and quality of the bonding system, which creates a strong, long-lasting contact between the composite and the tooth structure while also minimizing microleakage, play a major role in the clinical success of composite restorations. Two crucial characteristics of dentin-bonding systems that contribute to the long-term viability of composite restorations are shear bond strength and microleakage. Research indicates that the bonding rate in single-stage systems (6th, 7th, and 8th-generation) is 26–27 MPa, and in multistage systems (4th and 5th-generation), it is 5–32 MPa.[3]

The 7th-generation bonding agents are self-etch adhesives that combine etchant, primer, and bonding agent into a single

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(all-in-one system) component and are applied in a single step. The 6th-generation bonding agents are composed of acidic primer and bonding resin separately.[4] Nanocomposites and nanoadhesives containing nanosized fillers have been developed as a result of advancements in nanotechnological dentistry. Solutions containing nanofillers are known as nano-bonding agents, and they improve the strength of the enamel and dentin connection, absorb stress, and extend the shelf life. It has been noted that *in vitro* bond strength was increased by filling bonding agents. The producer of dentin adhesives with nanofills recently referred to their product as an 8th-generation bonding agent.[5,6]

The current dentin-bonding technology has made the clinical application process easier and can have a shear bond strength that is on equal with or higher than the previous system, it simply makes ideal for the dentist to employ it. There are numerous studies being conducted right now to strengthen bonds. Adverse effects of weak bonding strengths and challenging dentin-bonding systems include increased technical sensitivity, more steps required during work, increased error during the process, discoloration from reoccurring caries surrounding the restorations, and ultimately restoration loss.[7] Therefore, the aim of the current study was to evaluate the effectiveness and strength of various dentin-bonding agents used with adhesives on primary teeth.

Materials and Methods

The present *in vitro* study was conducted in the Department of Preventive Dental Sciences, College of Dentistry, Prince Sattam Bin Abdulaziz University, Saudi Arabia during the year of 2024. Ethical approval was obtained from the institution. The present study included 80 recently extracted, healthy human primary anterior teeth that had undergone physiologic resorption, or over-retention. Carious teeth, teeth with dental anomalies, and teeth with restorations were eliminated from the study, while noncarious teeth, unrestored teeth, and teeth without any dental anomalies were included.

Samples Preparation

After being cleansed and polished with a pumice slurry to get rid of stains, pellicle, and plaque, the removed teeth were kept at room temperature in artificial saliva. Root portion of all the teeth were removed from cementoenamel junction using slow speed straight handpiece along with diamond disk bur. Using a straight fissure diamond point, teeth were sliced to reveal a smooth dentin surface at a depth of 1.5 mm; a 1.5 mm standardization groove was used. All teeth were divided into four groups (20 samples in each group) and according to the manufacturer's recommendations, the following bonding agents were used:

Group I: Control Group

There was no bonding agent used.

Group II: Primary Teeth Bonding with 6th-generation Bonding Agent

In accordance with the manufacturer's recommendations, bonding agent (Adper SE plus 3M ESPE) was applied to the tooth surface in two layers using a microbrush for 15–20 seconds, air thinned for 5 seconds, then light-cured for 20 seconds.

Group III: Primary Teeth Bonding with 7th-generation Bonding Agent

About 20 samples were treated in accordance with the recommendations made by the bonding manufacturer (USA, Adper Easy one, 3M ESPE). The bonding was applied to the dentin surface using a microbrush for 20 seconds, then it was gently allowed to air dry for 5 seconds before being cured for 20 seconds.

Group IV: Primary Teeth Bonding with 8th-generation Bonding Agent

The manufacturer's recommendations were followed for treating 20 specimens with the 8th-generation (Futurabond DC, VOCO, Germany) bonding agent. This group's dentin surface was bonded for 20 seconds with a microbrush, followed by a gentle air spray and 20 seconds of curing.

After the adhesive was applied, a Teflon mold was used to build the composite resin (Beautifil, Shofu) using a two-layer increment approach on the dentinal surface of each sample. The samples measured 2 mm in diameter and 3 mm in height. For every increment, a vertical light-emitting diode light curing unit (Ellipar 3M) was used to light cure each layer for 40 seconds. In order to make sure the material had completely polymerized, the cylinder was subjected to an additional 60-second circumferential curing process. The curing point was positioned as close to the composite as feasible for each specimen. Following the composite assembly, the Teflon matrix was eliminated. Before the shear bond strength was tested, every specimen was kept in a humidor for 24 hours at 37°C in deionized distilled water.

Evaluation of Shear Bond Strength of Different Bonding Agents

A universal testing machine (INSTRON) was used to assess the shear bond strength. The specimen was fastened to the apparatus and exposed to a shear force in the compression mode of the UTM at a cross-head speed of 1.5 mm/minute. The shearing blade at the composite–dentin interface was perpendicular due to the horizontal positioning of the bonded composite cylinder. Every sample was loaded up until it broke. The applied force (N) was divided by the cross-sectional area (mm^2). Megapascals (MPa) were used to express the measurements of the shear bond strength.

Statistical Analysis

The collected data were then tabulated and subjected to statistical analysis with version 20 of the Statistical Package for Social Sciences (SPSS). Using one-way analysis of variance and the *post hoc* Tukey's test, the variable was compared between groups. A statistically significant *p*-value was defined as one that was less than 0.05.

Results

Table 1 presents the mean shear bond strength of three different bonding agents. The mean shear bond strength of control group was 6.18 ± 0.09, 6th-generation bonding agent was 25.32 ± 0.06, 7th-generation bonding agent was 26.08 ± 0.21 and 8th-generation bonding agent was 30.76 ± 0.16.

Table 2 depicted the comparison of mean shear bond strength of three different bonding agents. The maximum mean shear bond

Table 1: Evaluation of the mean shear bond strength of three different bonding agents

Bonding agents	*N*	*Mean ± SD (MPa)*
Group I: Control group	20	6.18 ± 0.09
Group II: 6th-generation bonding agent	20	25.32 ± 0.06
Group III: 7th-generation bonding agent	20	26.08 ± 0.21
Group IV: 8th-generation bonding agent	20	30.76 ± 0.16

Table 2: Comparison of the mean shear bond strength of three different bonding agents

Bonding agents	*n*	*Mean ± SD (MPa)*	*F-value*	*p-value*
Group I: Control group	20	6.18 ± 0.09		
Group II: 6th-generation bonding agent	20	25.32 ± 0.06		
Group III: 7th-generation bonding agent	20	26.08 ± 0.21	22.486	0.001
Group IV: 8th-generation bonding agent	20	30.76 ± 0.16		

Table 3: Overall comparison of the mean shear bond strength of three different bonding agents using *post hoc* Tukey's test

Bonding agents	*Comparison with*	*Mean difference*	*p-value*
Group I	Group II	−19.14	0.001
	Group III	−19.90	0.001
	Group IV	−24.58	0.001
Group II	Group I	19.14	0.001
	Group III	−0.76	0.644
	Group IV	−5.44	0.001
Group III	Group I	19.90	0.001
	Group II	0.76	0.644
	Group IV	−4.68	0.001
Group IV	Group I	24.58	0.001
	Group II	5.44	0.001
	Group III	4.68	0.001

strength was found in 8th-generation bonding agent (30.76 ± 0.16) followed by 7th-generation bonding agent (26.08 ± 0.21), 6th-generation bonding agent (25.32 ± 0.06) and control group (6.18 ± 0.09). And there was a statistically significant difference found between the three different bonding agents ($p < 0.001$).

Table 3 shows the overall comparison of the mean shear bond strength of three different bonding agents using *post hoc* Tukey's test. There was a highly significant difference found between group I vs group II, group I vs group III and group I vs group IV ($p < 0.001$). And there was no significant difference found between group II vs group III ($p > 0.001$).

Discussion

Maintaining the primary teeth in the arch is essential for controlling the dentition as it develops and for establishing in children a healthy attitude towards oral hygiene. When it comes to dental esthetics, material selection is crucial. The clinical success of composite resin restoration mainly depends upon the adhesive system that provides durable bonding of composite and dentin, effectively sealing restoration's margins, improves retention, and avoids postoperative discomfort.[8]

Bonding procedures in dentistry nowadays are becoming easier to use. These days, an excellent bonding needs to have attributes including biocompatibility, extended durability, and easy processes. As a result, the 6th and 7th-generation bonds were created; the 7th-generation has the primer and etch in a single container and the bonding in a different bottle. The hydrophobic bonding of the 6th-generation has the advantage of making it less soluble in water due to dentin water or microleaks. However, the 7th-generation simplified the 6th-generation's design so that all the components could be found in a single bottle. Although the enamel bond is ideal, the hydrophilic bonding process causes it to dissolve more quickly and results in improper dentin bonding.[9]

Because of this, the 8th-generation which combines etch, bond, and primer in a bottle was recently released. It offers the advantages of the 7th-generation, including shortened working time and no need for separate etching, as well as strong bond strength. Manufacturers assert that their shear bond strength is comparable to that of generation IV and V two- and three-stage systems.[10]

Because *in vitro* research plays a significant role in the creation of novel materials and aids clinicians in comprehending the mechanical, biological, and physical characteristics of dental materials, the current study was designed to be conducted in this manner. The most popular laboratory metric for measuring and assessing the effectiveness of dentin adhesive systems is shear bond strength. The universal testing machine (Instron), which is widely used to assess the adhesive capacity of adhesive/restorative materials, was utilized in the current investigation.[11]

In the current investigation, the 8th-generation bonding agent had the highest mean shear bond strength, followed by the 7th, 6th, and control groups. In a similar way, Joseph et al.[5] examined the bond strengths of dentin-bonding agents from the 6th, 7th, and 8th-generations on human molars teeth and concluded that the 8th-generation had the highest bond strength (34.9332 MPa), followed by those from the 6th and 7th-generations (32.4377 and 31.8826 MPa, respectively). According to the results of another investigation by Kamble et al.[4] on molar teeth, the 8th-generation dentin-bonding agent had the maximum tensile bond strength (34.74431), followed by the 6th-generation (32.2465) and 7th-generation (31.6734). El Sayed et al.[12] examined the impact of thermocycling on the microshear bond strength of solvent-free and solvent-containing self-etch adhesive systems on third molars, which is in contrast to the findings of our investigation. The findings demonstrated that Futurabond DC's bond strength was lower than Adper Easy's in lacking of thermocycling.

An 8th-generation dentin-bonding agent (Futurabond DC) is made of polyfunctional adhesive monomers, which are modified methacrylate esters with phosphoric acid. Additionally, highly functionalized SiO_2 nanoparticles (Ô 20 nm) are included in the 8th-generation dentin-bonding agent, which helps the resin components cross-link. Similarly, according to Can Say E et al.[13] Nanofilled adhesive forms a thicker adhesive layer and a more flexible interface, which may help to counteract stress resulting from polymerization shrinkage of the resin composite. As per Solhi L et al.,[14] the higher shear bond strength of Futurabond DC may be attributed to the existence of SiO_2 nanoparticles. The mechanical qualities of dentin-bonding agents are enhanced by the incorporation of nanoparticles. According to Wahab FK et al.,[15] the dentin and the composite can be accommodated by the elastic resin–dentin interface provided by the resin-impregnated dentin and the intermediate layer on molars teeth. According to Kim JS et al.,[16] the dentin-bonding agent-containing silica nanofiller showed the maximum microtensile bond strength at 1 weight percent. According to their findings, adding nanofillers larger than the interfibrillar gap (20 nm) results in an aggregation of filler contents on the dentin surface in addition to an increase in viscosity.

In this investigation, bonding agents from the 7th-generation showed higher shear bond strength than the 6th-generation. Fewer components save time and minimize confusion and no reapplication or waiting period is required. The smear layer is dissolved without ever leaving the open tubules thanks to the unique formulation of the 7th-generation bonding agent, which demineralizes the dentin and enamel surfaces. Better bonding and reduced gap formation are the ultimate outcomes. This is in contrast to a study by Chauhan U et al.[17] which found that when compared with a 6th-generation bonding agent, a 7th-generation bonding agent demonstrated extremely low binding strength.

The present study's limitations, however, include the need for additional *in vivo* implementation as the laboratory test was conducted using extracted teeth without consideration for the pulpal pressure and the presence of dentinal fluid under physiologically realistic conditions, which could have a negative impact on dentin bonding. The dentin's collagen fibrillar network may collapse in excised teeth, preventing the dentin from properly absorbing resin. Long-term clinical trials are therefore necessary to assess the effectiveness and longevity of these bonding agents.

Conclusion

Within the limitations, the present study concluded that the 8th-generation bonding agent demonstrated a greater shear bond strength to dentin than the 7th and 6th-generation bonding agent. Currently, the challenge in adhesive dentistry is to make the adhesive-tooth interface more resistant to aging. This could increase the restorative treatment's long-term predictability in terms of durability and clinical performance.

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