DOI: 10.21608/adjc.2024.296748.1572 **Advanced Dental Journal**
Volume 7 (2025) | Issue 3| Pages 344-353 **©Faculty of Dentistry-Cairo University**

Original Article

Shear Bond Strength of Three Flowable Restorative Materials in Dentin Cavities of Extracted Primary Molars: An In Vitro Study

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Submitted: 10-6-2024
Accepted: 26-7-2024

Abstract

Aim: The purpose of this study was to determine the shear bond strength of Smart Dentin Replacement, Compomer, and Flowable Composite Resin, in dentin cavities of extracted primary molars.

Materials and Methods: In this study, thirty-three primary molars with at least one intact proximal surface were selected. After exposing a flat dentine surface, the teeth were randomly assigned into three equal groups: Smart Dentin Replacement, Compomer and Flowable Composite Resin. The restorative materials were applied to the assigned groups using a ready-made cylindrical mould and shear bond strength was tested using Universal Testing Machine.

Results: There was no statistically significant differences between the three groups (p=0.396). The highest mean value was found in Intervention group I (Smart Dentin Replacement) (29.11±4.98) (MPa), followed by Control Group (Flowable Composite resin) (27.40±6.03) (MPa), while the lowest value was found in Intervention Group II (Flowable Compomer) (25.63±6.61) (MPa).

Conclusion: The Results were not statistically significant; Smart Dentin Replacement showed the highest values.

Keywords: Primary molars, shear bond strength, Smart Dentin Replacement, Flowable Compomer, Flowable Composite Resin.

I. INTRODUCTION

Dental caries is one of the most prevalent oral infections. Implications of untreated dental caries in primary teeth vary greatly, including psychological problems, lack of masticatory function, less facial support as well as risk of harm to adjacent soft tissues and successors **(Farooki et al. 2015 and Quock, 2015)**.

According to The American Academy of Pediatric Dentistry (AAPD), “the objectives of restorative treatment are to repair or limit damage from caries, protect and preserve tooth structure, re-establish adequate function, restore aesthetics (where applicable), and facilitate good oral hygiene". Recently, tooth-colored restorations have become a more popular choice among clinicians replacing Amalgam **(Casagrande et al., 2013 and Hussainy et al., 2018)**.

Compomers were introduced as materials that combine properties from both Glass Ionomer and Composite Resin, their mechanical properties lie halfway between the two materials. However, their manipulation is similar to Composite Resin as they require the application of an adhesive. The application of conventional Composite Resin present multiple drawbacks including, stresses created due to polymerization shrinkage, limited depth of cure (two mm), and increased risk of contamination in addition to weak bonding between increments (**Joseph et al., 2013 and Todor et al., 2022)**.

The application of low viscosity bulk-filled Composite Resin restoration such as Smart Dentin Replacement, is usually accompanied by a capping layer of conventional Composite Resin. This is done to overcome its drawbacks of having undesirable surface hardness and modulus of elasticity, due to its reduced filler load and filler composition **(Ilie et al., 2013)**.

However, due to its easy and time saving application procedure as well as its convenient use in small narrow cavities, Smart Dentine Replacement may be considered as a final filling material in primary molars with no need for capping **(Ehlers et al., 2013)**.

One of the most valuable tools to measure the success of any restorations, is the shear bonding strength of the restorative material to dentin surface. A restored surface transfers tension, compression and shear along the tooth/restoration interface. Thus, the bond should be strong enough to counteract these forces, or else it may lead to failure. **(Naz et al., 2021)**.

The aim of this study was to compare the shear bond strength and microleakage of Smart Dentin Replacement, Compomer and Flowable Composite Resin in dentin cavities of primary molars.

II. MATERIALS AND METHODS

A. Study Setting:

This is an in-vitro study was conducted in the Pediatric Dentistry and Dental Public Health Department, Faculty of Dentistry. The Faculty Research Ethics Committee reviewed the study proposal was gave its approval on 31/5/2022 with approval number (15.5.22).

B. Study Design and Sample Preparation:

Extracted primary molars were collected from the Outpatient's Clinic of Pediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Cairo University. The reasons for the extraction of primary molars are bad prognosis, orthodontic reasons, recurrent pathological infections, and systemic problems. Only molars that met eligibility criteria were included. Thirty -three molars were randomly assigned into three groups: Group (I): Smart Dentine Replacement (Dentsply Sirona, Milford, DE, USA), Group (II): Compomer (Twinky Star Flow, VOCO, Cuxhaven, Germany) and Group (III): Flowable Composite Resin (Filtek Supreme, 3M ESPE, Neuss, Germany). A sequence of randomization was generated using Random.org.

Collected teeth were disinfected and cleaned following the regulations and policies of the Occupational Safety and Health Administration. Molars were mechanically cleaned to remove residual tissues, washed under running water and stored in distilled water in opaque, sealed containers with sequential numbers **(Abdelmegid et al., 2017)**.

Included teeth were freshly extracted primary molars, having at least one intact proximal surface. Any teeth having caries extending more than half of mesio-distal dimension of the occlusal surface, developmental defects or previous restorations were excluded.

Using a low speed cutting machine with water coolant (Isomet 4000, saw buehler USA), with the cutting direction of saw parallel to the long axis of the tooth in a mesio-distal direction. The buccal surface of each tooth was cut two mm from the surface to obtain a flat dentine surface. The roots were then removed two mm below the cemento-enamel junction, using the same low speed cutting machine, as shown in Figure (1).

All the specimens were then mounted in acrylic resin moulds with their buccal surfaces exposed and perpendicular to the long axis of the mould as shown in Figure (2).

C. Steps for restorations application:

In Groups I, II and III Dentsply Sirona Prime&Bond Universal™ (Milford, DE, USA), Futurabond M+® (Cuxhaven, Germany) and 3M™ Single Bond Universal Adhesive (Neuss, Germany) were applied respectively. According to the manufacturer's instructions the adhesives were applied without pooling to the exposed dentin surface of each tooth using a disposable brush (Nuoshen, Shanghai, China). It was agitated for 20 seconds, then excess solvent was flowed with gentle oil free compressed air for five seconds until a uniform, glossy appearance was evident. The exposed dentin surface was then light cured for 20 seconds using LED curing unit (Woodpecker light cure I LED, Guilin Woodpecker, Guangxi, China. light intensity: 1000 mW/cm2).

A ready-made plastic cylindrical shaped mould (3 mm in diameter and 3 mm in height) was placed on the dentin surface of each tooth. Restorative material was injected into the mould and polymerized according to manufacturers' instructions using an LED curing unit (Woodpecker light cure I LED, Guilin Woodpecker, Guangxi, China. light intensity: 1000 mW/cm2). Each restorative material was applied to its assigned group as shown in Figure (3).

The plastic moulds were removed after setting of the restorative materials, and the specimens were then stored in distilled water for a maximum duration of one month until testing for shear bond strength **(Güngör et al., 2016)**.

D. Assessment of Shear Bond Strength:

Using the Universal Testing Machine, (INSTRON universal testing machine, model 3345 England), a shear force was applied perpendicularly to the restoration cylinder, using a knife edge chisel, at a distance of one mm from the dentine surface to the loading head until bond failure as shown in Figure (4). The load necessary to de-bond the restoration was recorded in Newtons. The bond strength was expressed in mega-Pascals (MPa) by dividing the load at failure by the bonded surface area in square mm **MPa: $\tau = P/A$** Where; τ =bond strength (in MPa), P =load at failure (in N), A= the bonded surface area in square millimeters (mm^2) **(Güngör et al., 2016)**.

E. Statistical Analysis:

Numerical data were presented as mean and standard deviation values. They were checked for normality by viewing the distribution and by using Shapiro-Wilk's test. Data were analyzed using one-way ANOVA followed by Tukey's post hoc test. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows.

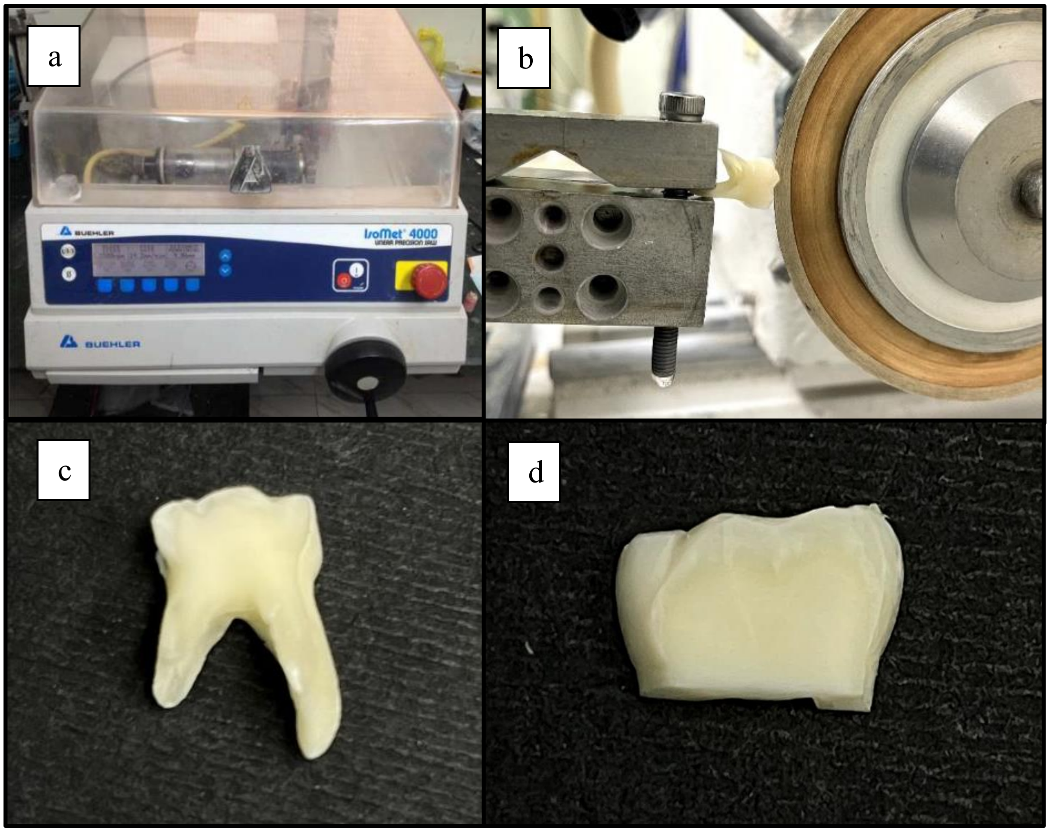

Figure (1): Specimen preparation for shear bond strength testing.
a: Isomet 4000, saw buehler USA.
b: Buccal surface cutting in a mesio-distal direction using low-speed cutting machine, with water coolant.
c: Buccal surface is cut to obtain a flat dentine surface.
d: The roots are removed two mm below cemento-enamel junction.

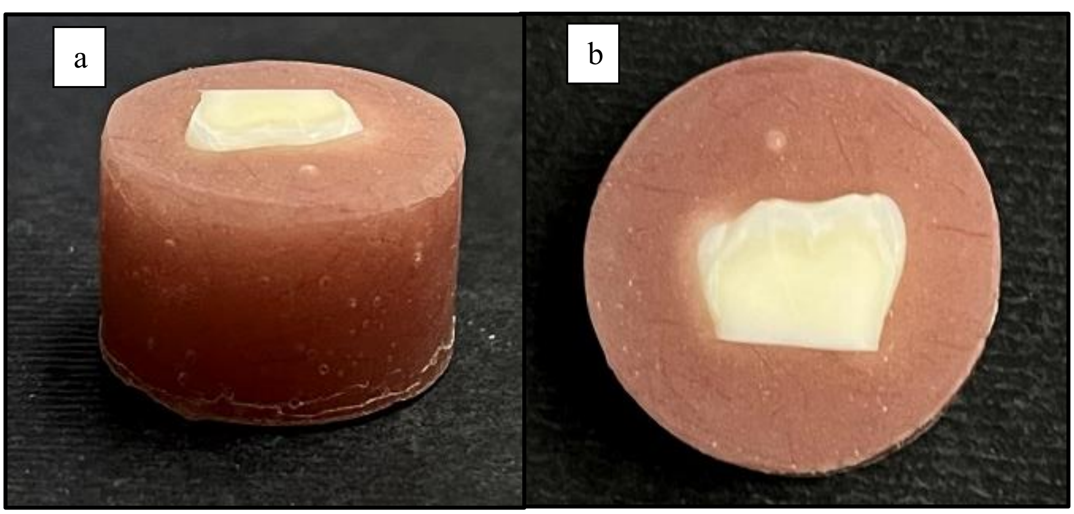

Figure (2): Final Specimen presentation.
a: Occlusal view of the mounted tooth.
b: Buccal view of the mounted tooth.

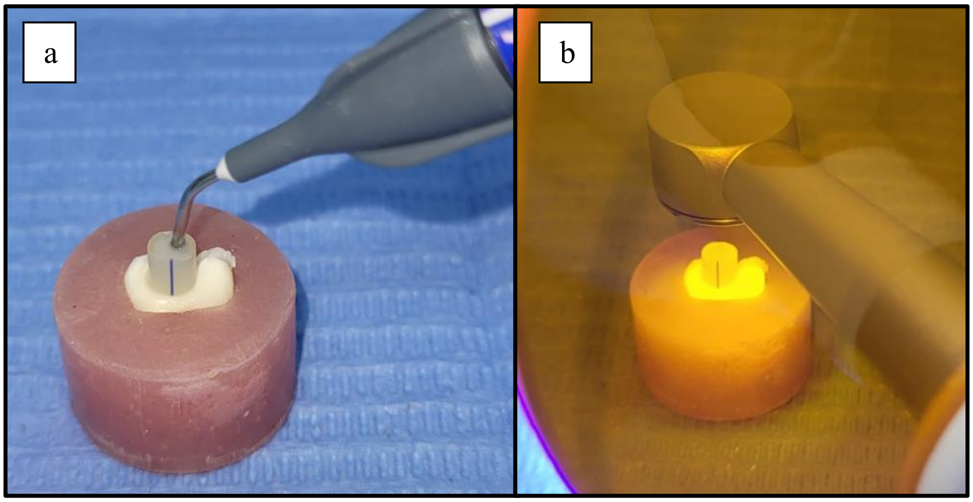

Figure (3): Application of Filtek Supreme restoration.
a: Application of Filtek Supreme into the plastic cylindrical mould.
b: Light curing of Filtek Supreme.

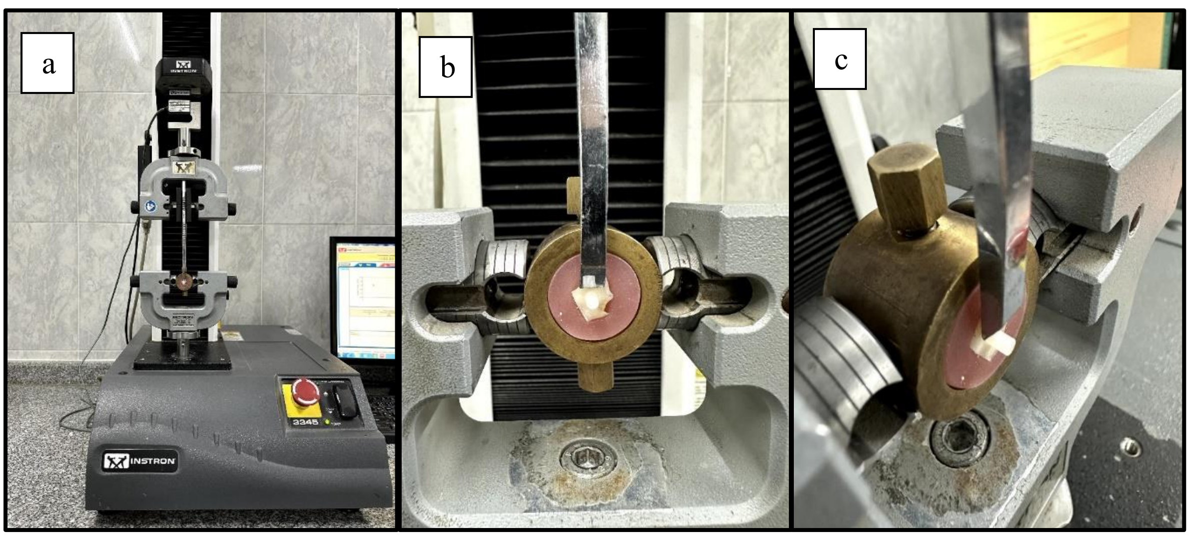

Figure (4): Shear bond strength test.
a: INSTRON universal testing machine, model 3345 England.
b: Front view of shear force applied perpendicularly to the restoration cylinder.
c: Side view of shear force applied perpendicularly to the restoration cylinder.

III. RESULTS

Intergroup comparison, mean and standard deviation values of shear bond strength (MPa) are presented in Table (1) and in Figure (5).

Table (1): Comparison of Mean and Standard Deviation values of shear bond strength in (MPa) among the three study groups.

Material	Shear bond strength (MPa) (mean±SD)	p-value
Intervention I (SDR)	29.11±4.98^{A}	**0.396ns**
Intervention II (Compomer)	25.63±6.61^{A}	
Control (Flowable Composite Resin)	27.40±6.03^{A}	

Values with different superscript letters within the same horizontal row are significantly different.

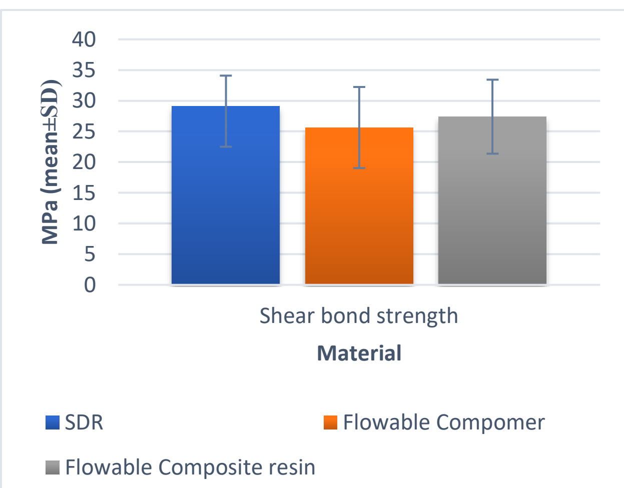

Figure (5): Bar chart showing mean and standard deviation (error bars) values of shear bond strength (MPa) in the three study groups.

The comparison between the three groups in shear bond strength revealed that there was no significant difference between different groups (p=0.396). The highest mean value was found in Intervention group I (SDR) (29.11±4.98) (MPa), followed by Control Group (Flowable Composite resin) (27.40±6.03) (MPa), while the lowest value was found in Intervention Group II (Flowable Compomer) (25.63±6.61) (MPa).

IV. DISCUSSION

Recently, oral health awareness campaigns aim to spread the knowledge that the health of primary dentition is as important as the health of permanent dentition. Many problems can arise from neglected oral health in children, such as, pain, infection, swellings, and future orthodontic problems in permanent dentition. Proper awareness would also reduce the future burdens on the health care facilities by changing the behavior and attitude of both patients, and parents/guardians towards regular oral health care. Primary teeth exhibit faster spread of dental caries than permanent teeth, thus, carious lesion should be treated as early as possible to avoid any pulpal damage **(Mishra et al., 2018 and Santamaría et al., 2020)**.

The gold standard of aesthetic restorations remains Composite Resins, low-viscosity Composite Resins have been developed by reducing the filler content in relation to the matrix, arguably, this reduces the mechanical properties. Bulk-fill flowable Composite Resins, such as SDR, were developed to reduce the treatment time and polymerization shrinkage. Another material used to restore primary teeth is Compomer, it exhibits favorable aesthetics and acceptable mechanical properties **(Jager et al., 2016; Rodrigues et al., 2019 and Andaş et al., 2023)**. Thus, the aim of this study was to compare the mechanical properties, specifically shear bond strength, of SDR, Twinky Star Flow and Filtek Supreme in dentin cavities of primary molars.

In the current study, freshly extracted primary molars were collected, teeth were stored for maximum time of one month, to avoid degenerative changes that occur to dentin substrate indicated by ISO/TS 11405 ***(ISO, 2003)***. Teeth were stored in distilled water at room temperature to ensure their hydration ***(Sirisha et al., 2014)***.

To test for shear bond strength the buccal surface was ground to expose a flat dentine surface, this was performed to be able to place the restorative material in the form of a cylinder projecting from, and perpendicular to the buccal surface. It also enabled measuring the maximum stress the material could withstand before failure once the load was applied perpendicular to the restorative material and parallel to the tooth surface, at the adhesive junction. This test was selected because it provides fast results with relative ease of execution, and no further need of specimen processing after bonding **(El Mourad, 2018)**. The use of this method was in accordance with **Güngör et al., (2016)**; **Abdelmegid et al., (2016)**; **Abdelrahman et al., (2016)**; **Panchal et al., (2018)**.

Regarding the acidic monomers, the adhesives used in all three study groups contained 10-methacryloyloxydecyl dihydrogen phosphate (MDP), it operates by etching the dental surface and releasing calcium ions that interact with tooth surface forming calcium phosphate complex that remain in the hybrid layer. It also reduces the surface tension of the adhesive, which reduces viscosity and ensures efficient penetration of the dentin collagen network, thus; resulting in a better seal. It is one of the most commonly used acidic monomers and considered the most promising **(Abdelrahman et al., 2016)**.

The method of measuring the shear bond strength used in the current study, using a knife edge chisel, was chosen due to its ease of application and reproducibility. It is the most commonly used method and was selected for its availability, this was in accordance to **Panchal et al., (2018)**. However, according to **El Mourad, (2018)**; the concentration of stress on the loaded area may result in lower shear bond strength values.

The results revealed that the differences found between the three study groups were not statistically significant, however, SDR (Intervention Group I) showed the highest values (29.11±4.98 mean±SD) when used with Dentsply Sirona Prime&Bond Universal™. These results were in accordance with **Abdelmegid et al., (2016)**; who reported that SDR showed the highest mean value of (14.044±0.676 mean±SD) when compared with Biodentine, Fuji LC and Multicore Flow. Results of another study conducted by **Choudhury and Nekkanti, (2022)**; was in accordance with the results of the current study, where SDR showed the highest mean value of shear bond strength (22.19 ±5.43 mean±SD) when compared with Biodentine and Resin Modified Glass Ionomer.

This may be due to several factors; firstly, besides MDP, another acidic monomer was included in the composition of the adhesive, dipentaerythritol pentacrylate phosphate (PENTA). Aside from the advantage shared with MDP, PENTA also exhibits a hydrophilic core that improves wettability, as well as, five double bonds per molecule, that renders it a great cross linker **(Han et al., 2022)**.

Another possible reason for SDR achieving higher shear bond strength than the other two study group materials, is the difference in composition. Bulk-fill Composite Resins such as SDR contain monomers such as UDMA, that interact with other monomers and result in polymerization with hydrophobic nature upon light activation. These monomers ensure reinforcement and strengthening of the restoration. SDR contains a polymerization modulator, that regulate the process of polymerization, incorporated with the urethane-based dimethacrylate monomers. These regulators ensure a stable and efficient chemical bonding between the substrates. Also, SDR can be applied in a single increment with four mm in thickness, which can reduce the polymerization stresses significantly **(Abdelmegid et al., 2016)**.

Also, in this study, flowable Composite Resin (Control Group) showed higher values for shear bond strength (27.40±6.03 mean±SD) than Compomer (Intervention Group II) (25.63±6.61 mean±SD). These results were in accordance to the results concluded by **Dugar et al., (2022)**; where Filtek Z350 XT showed higher mean value for shear bond strength (13.57±0.89 mean±SD) when compared with Compomer.

The rationale for this may be that different materials have different quantities of methacrylate monomers that are photoactivated during polymerization. Also, the presence of HEMA in the adhesive system of Control Group, enables the formation a hybrid layer that locks to the dentin surface micromechanically and stabilized the bonded surface. HEMA was not listed by the manufacturer as a component of the adhesive system used with Intervention Group II (**Dugar et al., 2022)**.

Other factors may attribute to the different in vitro values of shear bond strength and result in high standard deviation between the three study groups. These factors include the age of dentin, the type of storage media and testing conditions. To minimize these variations, conditions of collection and storage were standardized as much as possible **(Panchal et al., 2018)**.

Limitations of the study:

The current in vitro study did not provide any information about clinical success rate, also, there was no consideration to the pressure applied to the pulp and movement of dentinal fluid under normal physiological conditions. Moreover, extracted teeth may show collapsed dentin structure; which may reduce resin penetration.

Also, an alternative method to measure shear bond strength may be used, using a wire loop, that can evenly distribute the load on a larger surface area, and provide a more reliable measurement compared with knife-edge chisel.

V. CONCLUSION

Based on the results and limitations of the current study, it could be concluded that SDR, Compomer and Flowable Composite Resin showed comparable shear bond strength values, also, all test materials are acceptable treatments for primary teeth.

Conflict of interest: No conflict of interest.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics: This study protocol was approved by the ethical committee of the faculty of dentistry-Cairo university on: 31/5/2022, approval number: 15.5.22

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