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MICROTENSILE BOND STRENGTH AND FAILURE TYPE OF TWO BULK-FILL RESIN COMPOSITES BONDED TO DENTIN OF DECIDUOUS POSTERIOR TEETH

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Abstract

The ultimate goal of pediatric dentistry is to establish a strong adhesion to dental tissues, particularly with primary teeth, which tend to have weaker bond. This study aimed on assessing and comparing the microtensile bond strength in dentin restored with conventional composite (Filtek™ Z250), non-self-adhering bulk-fill composite (SureFil™), or self-adhering bulk-fill composite (Surefil one™) in mandibular second primary molars. This study, was performed on 45 beams, obtained from (15) unidentified, freshly extracted mandibular second primary molars, that had been removed for reasons unrelated to this study (such as shedding). After the molars' dentin was exposed 1 mm under the dentin-enamel junction, they were randomly divided into three groups (n=5): Filtek™ Z250 group, SureFil™ group, and Surefil one™ group. Then, molars were restored according to the restoration that was assigned to them. Every restored molar underwent 5000 cycles of thermocycling at a range of temperatures from 5 to 55°C, with 20s of dwell time and 10s of transfer time. The reconstructed molars were sectioned longitudinally in the buccolingual and mesio-distal directions to obtain 1mmx1mm beam thickness. The beams were subjected to tensile stress using a universal testing machine, and an analysis of the failure type was performed on each beam. Primarily, collected data was examined for outliers, following normality test (with a significance level of 0.05) by using Shapiro-Wilk and/or Kolmogorov-Smirnov tests. The current investigation found that the three groups' microtensile bond strength test showed a highly significant difference. The highest value was noted for SureFil™ group, followed by Filtek™ Z250 group, and then Surefil one™ group. The three tested groups did not differ significantly in their failure type analysis. The self-adhesive bulk-fill composite showed bond strength less than the acceptable minimal value that is needed to resist polymerization shrinkage stress for durable restoration.

Keywords: Primary, Molars, μTBS, Self-Adhesive, Composite, Bulk-Fill.

INTRODUCTION

Young children's primary teeth are essential to their development. A thorough understanding of the caries mechanism, the composition of the tooth structure, and the characteristics of restorative materials is essential to make every effort to keep these teeth for as long as possible.

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This highlights the role of pediatric dentists in evaluating and treating patients with dental caries and choosing the most suitable restorative material with minimal clinical steps [1].

Intra-coronal restorative materials available for primary dentition, includes metallic restorations like amalgam, and tooth-colored materials like GICs, resin composite material, and modifications of both materials. Many factors regarding the material properties must be taken into consideration when choosing the suitable restorative material, including ease of handling, physical and chemical properties, longevity and durability, and biological properties [2].

Resin-Based Composites materials (RBCs) are aesthetic restorative materials, that can bond to enamel and dentin, by means of conditioning and bonding. They have reasonable mechanical properties and can be controlled by photopolymerization [3]. This material has demonstrated some limits, including postoperative sensitivity, microleakage, polymerization shrinkage stress, and technique sensitivity. Researchers proposed a 2 mm incremental filling technique for better curing penetration and lower shrinkage stress. However, this increases working time, nevertheless, the bonding steps making the whole procedure more time-consuming for treating children, especially uncooperative ones [4].

The ultimate goal of adhesive dentistry is to establish a strong adhesion to dental tissues, particularly with primary teeth, which tend to have weaker bond, due to their differing physiological, morphological, and chemical characteristics from permanent teeth. Primary teeth have lower mineral content, thinner enamel, and the prisms in the enamel are less organized compared to permanent teeth, besides, a prismatic layer is more evident in primary teeth, making it more challenging to achieve strong adhesion. Moreover, primary teeth dentin is more permeable with larger tubules and a higher organic content than permanent dentin [5].

For the convenience of children, dentistry seeks to provide durable and strong restorative material, with few clinical steps to decrease chairside time. Improvements have been made to the resin-based composite materials to overcome their drawbacks and simplify the workflow, such as bulk-fill composite and the most recent self-adhesive bulk-fill composite [6].

Recently, a new generation of self-adhesive bulk-fill composite has been launched (Surefil one™ Dentsply Sirona), bulk-fill composite, which is dual-cured, self-etched, and self-adhered. According to the manufacturer, this material has mechanical properties similar to those of the conventional composite, moreover, it is characterized by chemical adhesion and fluoride release properties that are similar to the glass ionomer. This incorporation is thought to reduce chairside time and decrease postoperative sensitivity making it more friendly to young patients. [7] [8].

In this study, the microtensile bond strength in dentin was evaluated and contrasted with conventional (Filtek™ Z250) composite, non-self-adhering bulk-fill composite (SureFil™), or self-adhering (Surefil one™) bulk-fill composite in mandibular second primary molar.

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This study adopted a null hypothesis since there is no significant difference in the microtensile bond strength in dentin restored with the conventional (Filtek™ Z250) composite, non-self-adhering bulk-fill composite (SureFil™), or self-adhering (Surefil one™) bulk-fill composite in mandibular second primary molar.

METHODS

Under authorization number 619/2023, The study's protocols were waived by the Suez Canal Univ., Faculty of Dentistry's Research Ethics Committee (REC), in agreement with the Helsinki Declaration of the World Medical Association (WMA, 2008). Thirty unidentified primary second molars were removed for non-research-related causes, such as natural exfoliation or orthodontic procedures, from the pediatric dentistry and oral and maxillofacial surgery departments of Suez Canal University.

Parents or legal guardians of every patient under 16 who visited the above-mentioned departments sign informed permission forms allowing the study to use their extracted teeth. By using the software G*Power (ver.3.1.9.2) [9], sample size was performed with effect size of 0.48, with a power of 80% under level of 0.05 and 0.20 for alpha (α) and beta (β), respectively. Thus, a minimum of 45 specimens were determined to be needed, drawn from an acceptable number (15) of recently extracted, identifiable mandibular second primary molars.

Sample Selection

Extracted sound or carious enamel in mandibular second primary molars, according to Caries Assessment Spectrum and Treatment (CAST), scored from 0 to 3, with at least one-third of the length of the roots is still present, were selected.

The bucco-lingual and mesio-distal diameters of the teeth were selected to be similar, with an acceptable deviation of ±1mm using digital caliper [10]. Teeth with abnormal morphology and structure as hypomineralized or hypoplastic were excluded [11].

Sample Storage and Disinfection

The selected molars were cleaned from remnant tissues then disinfected with 0.1 thymol by weight for seven days and stored in distilled water [12].

Sample Mounting

A rubber mold of 12 mm in diameter and 23 mm in height was used to fix each of the chosen molars individually using self-curing acrylic resin (Fig. 1). Chemical-cured acrylic resin was combined corresponding to the manufacturer's instruction, as 0.5 ml of liquid was dispensed into a mixing cup, then 1 g of powder was added and mixed with together a spatula for 10-15s and poured inside the mold, when the material reached dough-like consistency [13], the tooth was placed vertically in the mold, leaving 2mm below CEJ in the cervical direction and their occlusal plane was parallel to the acrylic resin base (Fig. 2).

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Figure 1: Rubber mold diameter

Figure 2: Tooth in the acrylic mold

Sample Randomization and Grouping

Fifteen mandibular second primary molars were randomly divided by the website www.randomizer.Org into three groups. (n=5 for each group) and received three different restorative materials, as follows:

- **Filtek™ Z250 group (control)**: five mandibular second primary molars were restored with Filtek™ Z250 composite.
- **SureFil™ group**: five mandibular second primary molars were restored with SureFil™ bulk-fill composite.
- **Surefil one™ group**: five mandibular second primary molars were restored with Surefil one™ self-adhesive bulk-fill composite.

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Molars Preparation

Following these procedures, all molars were prepared in accordance with the recommendations given [14].

1. To create a smooth dentin surface, the occlusal enamel surface was cut 1 mm below the dentin-enamel junction using a diamond saw (isomet 4000 microsaw, Bosch, USA) while being cooled with water (Fig. 3a, b & c).
2. Fine-grit sandpaper was used to further hand polish the exposed dentin surfaces, to create a homogenous standardized smear layer by removing any irregularities made from the previous cut.

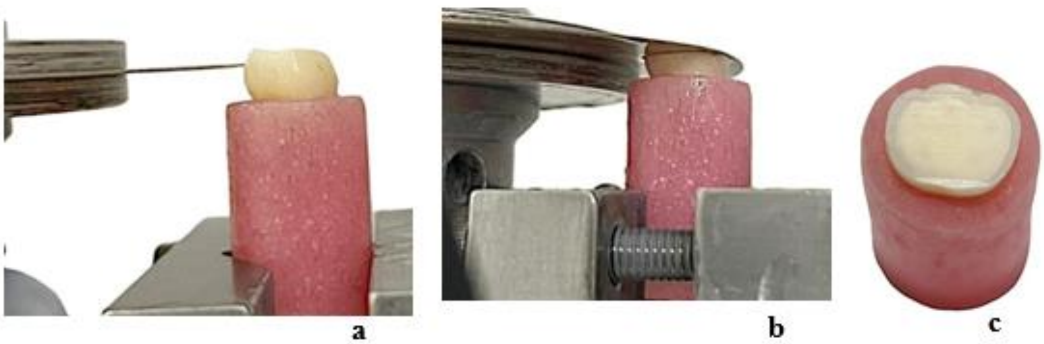

Figure 3: a, b & c Cut perpendicular to each tooth's longitudinal axis before and after

Teflon Mold Construction

The cut molars' bucco-lingual width was measured using a digital caliper, to detect a suitable dimension of the special cylindrical split Teflon mold, as the mean value of 9mm was calculated, according to this, a special cylindrical split Teflon mold (7 mm diameter and 4 mm height) was constructed to cover the dentin only (Fig. 4a & b), for application of restorative materials.

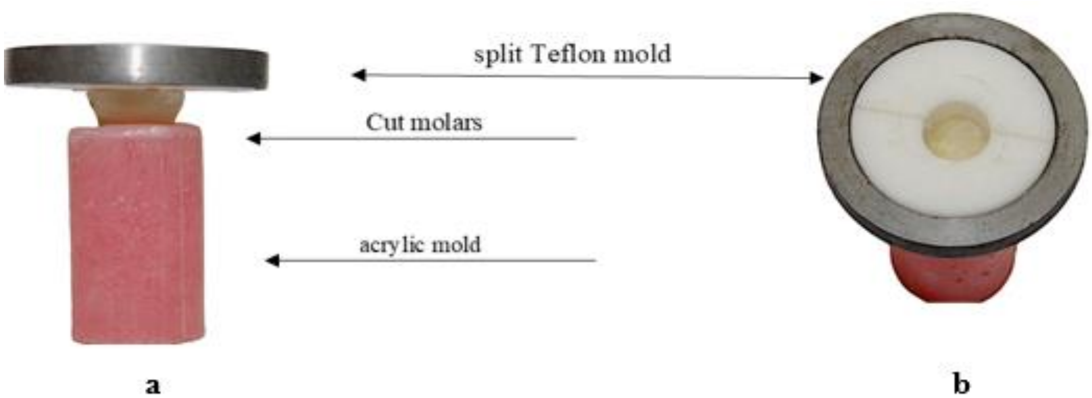

Figure 4: a & b Split Teflon mold

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Molar's Restorations

1- Acid etching step: the etching agent, Caulk® 34% Tooth Conditioner Gel, was applied 15s on dentin for Filtek™ Z250 group and SureFil™ group only according to the manufacturer's instruction (Fig. 5). Then, thoroughly rinsed with water spray for 15s as the same time of etching, and excess water was blot-dried with an absorbent pellet, leaving the dentin surface visibly moist (wet-bonding) (Fig. 6).

Figure 5: Dentin etching for 15s

Figure 6: Blot-drying with an absorbent pellet

2- Bonding step: bond (Adper™ Single Bond 2) was applied on the dentin surface of the Filtek™ Z250 group, while the same amount of bond (Prime & Bond® NT™) was applied on the dentin surface of the SureFil™ group, in compliance with the manufacturer's guidelines, using the bristle brush applicator. Agitation of the bond for 10s was done, next the teeth were air-dried for 5s and light cured for 10s.

3- Restorative materials application: The cylindrical Teflon mold was placed in the center of the cut molars and restored with the restorative materials according to the manufacturer's instructions. In Filtek™ Z250 group, the composite was incrementally inserted with two increments of 2mm thickness each and was measured with a calibrated probe, each layer was photoactivated separately for 20 sec. In SureFil™ group composite was inserted as one increment of 4mm and then photoactivated for 20 sec. While in the Surefil one™ group, no etching and no bonding were needed, only activation of the capsule by pressing it and then immediately placing it in the capsule mixer (4200-4600osc/min) and mixed for 10s. The capsule was then put into the extruder, and the material was dispensed into the

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cylindrical Teflon mold at the deepest point. The nozzle remained in the material as it moved up in the mold (Fig. 7a & b), (working time not exceeding 90 seconds after capsule activation as manufacturers indicate) and then photoactivated for 20 sec. The mold was not removed before 6 minutes from capsule activation as the manufacturer recommended.

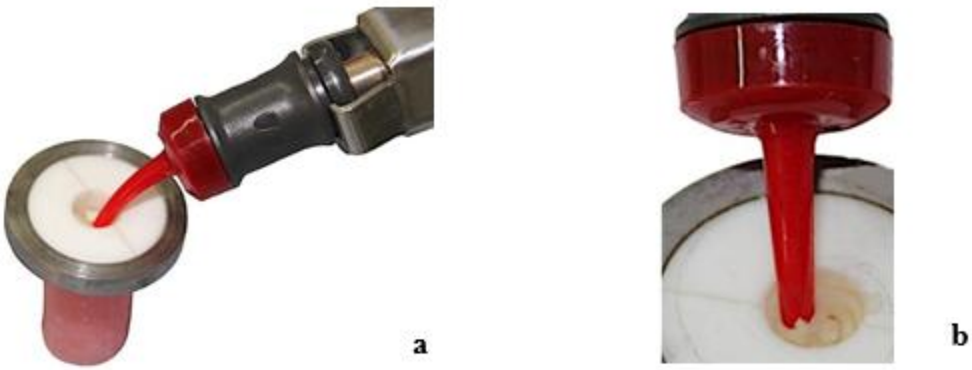

Figure 7: a & b Surefil one™ dispensed at the deepest part in the mold.

All restorations were photoactivated using soft start mode in light cure of wavelength 420-480nm and power ≥1200 mW/cm2, for 20s with no distance from the curing tip and the mold. Then all restorations from the three groups were finished with yellow soflex disc with coolant to obtain a smooth surface with no sharp angles.

4- Storage step: All restored molars from the three groups were stored in distilled water for 24 hrs (Fig. 8).

Figure 8: Restorations from the three groups

Thermocycling

By using a (100 SD thermocycler, Germany), all samples were thermocycled 5000 cycles between 5-55°C with 20s of dwell time and 10s of transfer time using [15].

Beams preparation:

Beams were prepared through sectioning in mesio-distal (Fig. 9) and bucco-lingual direction (Fig.10), across the bonded interface to the restored molars in each group. A horizontal cut at the level of cemento-enamel junction was done to separate the beams from the tooth. Only the middle beams were chosen for the test which were marked with red color, while the outer beams were excluded, to obtain from each group 15 resin-dentin beams of approximately 1mmx1mm dimension (Fig. 11a, b & c), confirmed with a digital caliper.

Figure 9: Sectioning in mesio-distal direction

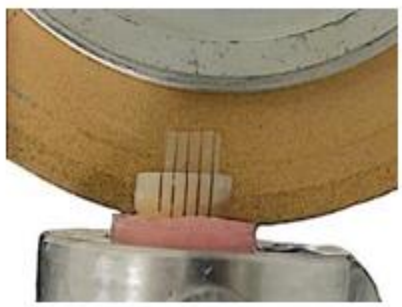

Figure 10: Sectioning in bucco- lingual direction

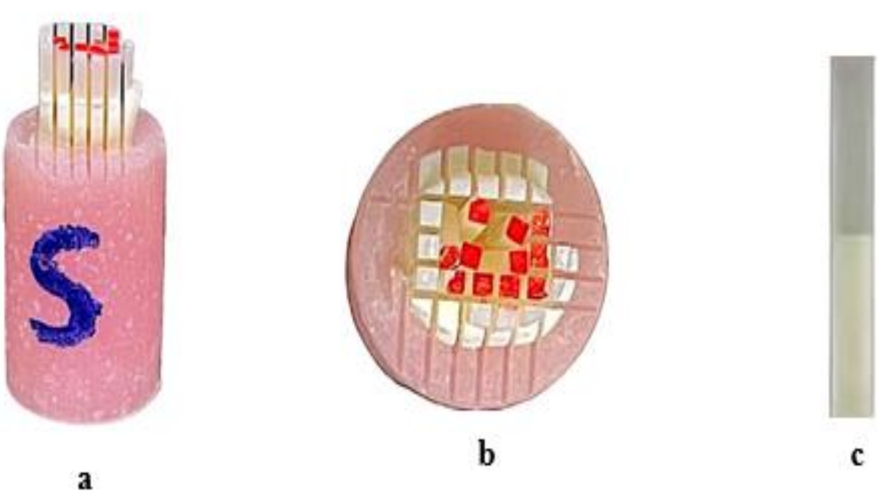

Figure 11: a, b & c the chosen middle beams

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Micro Tensile Bond Strength Assessment

In total, 45 beams were used in the test, 15 from each group. Cyanoacrylate adhesive was used to join the ends of each resin-dentin bonded beam to the microtensile device attachment utilizing beam holder equipment. The bonded contact was precisely positioned between the beam holding apparatus's two proximal ends. The beams were tested using a universal testing machine (Model 5565, Instron Co., Canton, MA, USA). They were subjected to static loading with tension, at a 50N load cell and a crosshead speed of 0.5mm/min, until they fractured (Fig. 12a, b & c). Computer software (Bluehill 3, Instron) was used to record the data. The µTBS values in MPa (µTS=F/A) were calculated by dividing the load at failure, in Newtons, by the cross-sectional bonding area. For statistical purposes, the average µTBS values (MPa) of all beams, for each group were calculated [16].

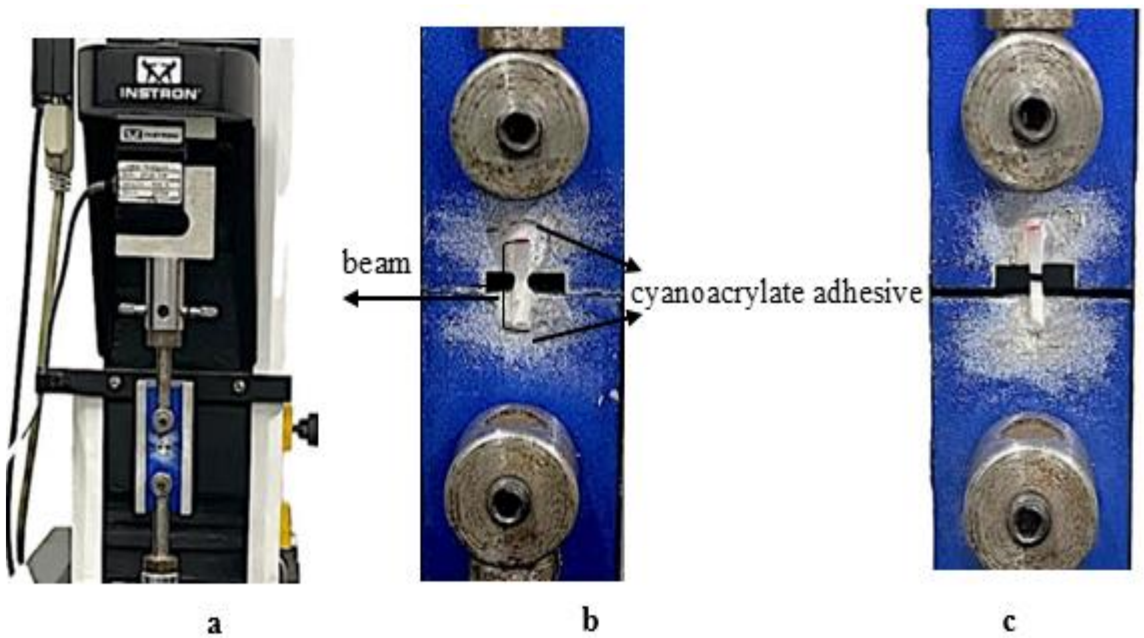

Figure 12: a, b & c Beam on the beam holding apparatus in the universal testing machine before the test and the fractured beam after the test

2- Failure Type Analysis

The fractured samples were taken from the device and were examined by stereomicroscope (Nikon Eclipse MA 100, Japan), at 50x magnification, to assess the failure type [17], which was classified in (Table 1) as:

Table 1: Failure type classification

A. D	Adhesive failure (lack of adhesion)
C.D	Cohesive failure in dentin (failure of dental substrate)
C.C	Cohesive failure in resin composite (failure of resin composite)
M	Mixed adhesive and cohesive failure

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Statistical Analysis

Data was checked for normality using Shapiro-Wilk and Kolmogorov-Smirnov to check whether the data is parametric or nonparametric. The microtensile bond strength data was parametric; however, failure type analysis was nonparametric. Inferential statistics for microtensile bond strength to compare between the three different composite groups were performed using one-way ANOVA for parametric data, followed by Tukey's HSD at a significant level of 0.05.

The inferential statistic for failure type analysis were performed in terms of Kruskal Wallis test, followed by Dun's Bonferroni posthoc test. Statistical analysis was performed using the software application SPSS (The Statistical Package for Social Sciences; Inc., Chicago, IL, USA) [18], version 29 for Mac OS.

RESULTS

Microtensile Bond Strength Results

The microtensile bond strength of the control Filtek™ Z250 group, SureFil™ group,and Surefil one™ group were presented in (Table 2) and (Fig. 13). It was found that the difference in the microtensile bond strength between the three groups was highly significant ($p<0.001$***), where the highest value was for the SureFil™ group ranged between 14.9 to 27.6 MPa with an average of 19.6±4.2 MPa, followed by control Filtek™ Z250 group ranged between 10.2 to 20.3 MPa with an average of 15.0±2.9 MPa and finally the lowest value was recorded for Surefil one™ group ranged between 0.9 to 10.6 MPa with an average of 5.5±2.9 MPa.

For further comparisons between groups, Tukey's HSD Test was performed, where means followed by different letters are significantly different according to Tukey's HSD at 0.05 level.

Table 2: The Microtensile bond strength of the three different groups

Descriptive statistics	Microtensile bond strength (MPa)		
	Filtek™ Z250 group	SureFil™ group	Surefil one™ group
Min	10.2	14.9	0.9
Max	20.3	27.6	10.6
Mean	**15.0**	**19.6**	**5.5**
SD±	2.9	4.2	2.9
SE	0.7	1.1	0.8
Mean±SD	**15.0±2.9**	**19.6±4.2**	**5.5±2.9**
Tukey's HSD	**b**	**a**	**c**
ANOVA	**<0.001*** **		

*, **, ***= significant at different leves $p<0.05$, <0.01, <0.001, respectively.

Ns= non-significant at level $p>0.05$

a,b,c According to Tukey's HSD, means that are followed by distinct letters differ considerably.

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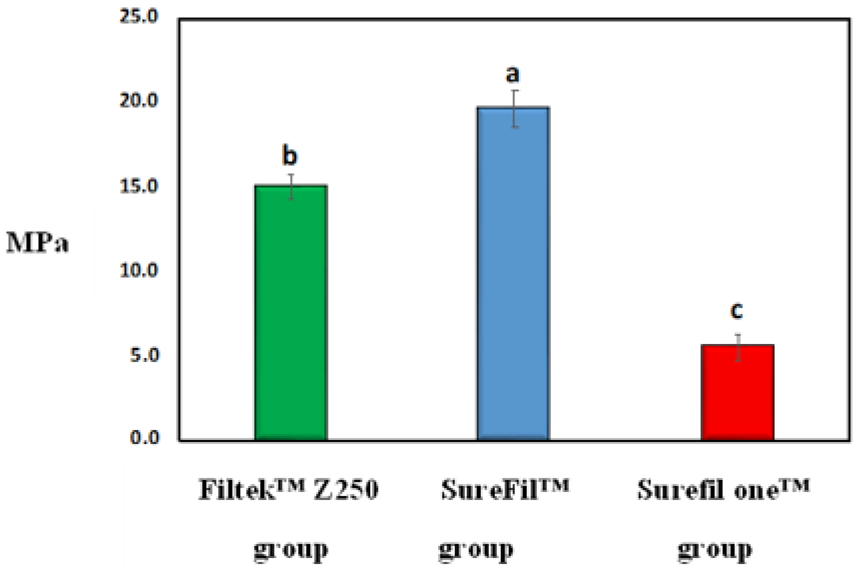

Figure 13: A bar chart showing the three groups' respective microtensile bond strengths

Failure Type Analysis Results

The failure type analysis was recorded for Filtek™ Z250 group, SureFil™ group and Surefil one™ group by stereomicroscope (Nikon eclipse MA 100, Japan), at 50x magnification.

Failure Types Were Recorded as Follows:

- Failure in adhesive layer (AD) (Fig. 14).
- Failure in dentin (C.D) (Fig. 15).
- Failure in composite (C.C) (Fig. 16).
- Mixed failure, adhesive, and cohesive (M) (Fig. 17).

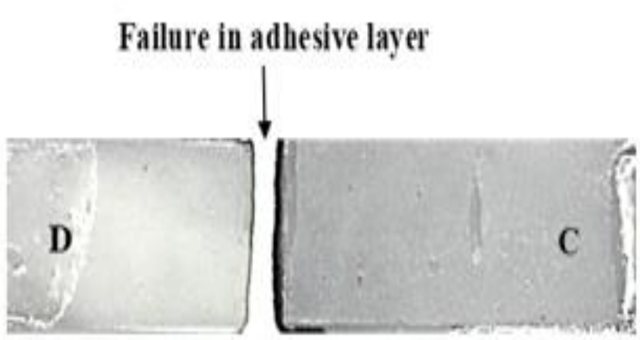

Figure 14: Showing AD failure. D: dentin, C: Composite. At 50x Magnification

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Figure 15: Showing CD failure. D: dentin, C: Composite. At 50x Magnification

Figure 16: Showing M failure. D: dentin, C: Composite. At 50x Magnification

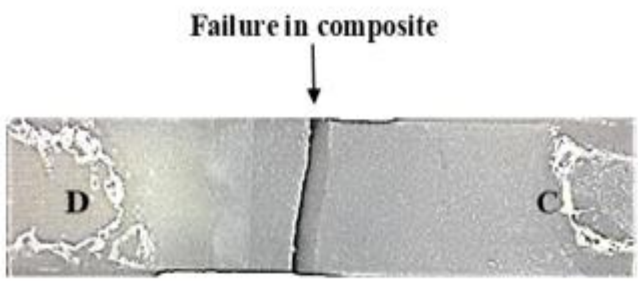

Figure 17: Showing C.C. failure. D: dentin, C: Composite. At 50x Magnification

It was found that the difference between the three composites groups in failure type analysis was non-significant (p=0.533) as revealed by Kruskal-Wallis test (Table 3) and by Dun's Bonferroni posthoc test. (Fig. 18).

The failure type analysis results for Filtek™ Z250 group ranged between 1 to 4.0 with an average (±SD) of 2.5±1.5, while for SureFil™ group ranged between 1 to 4.0 with an average (±SD) of 2.6±0.3, lastly for Surefil one™ group ranged between score 0 to 4.0 with an average (±SD) of 2.0±1.1. For further comparisons between groups, Tukey's HSD Test was used, and the results showed that means that were followed by the same letter were not significantly different at the 0.05 level.

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Table 3: The failure type analysis of the three different groups

Failure type	Filtek™ Z250 group		SureFil™ group		Surefil one™ group		Kruskal-Wallis sign.
	Frequency		Frequency		Frequency		
	N	%	n	%	n	%	
A.D.	**4**	**26.7**	**4**	**26.7**	**6**	**40.0**	**0.533 ns**
C.D.	**2**	**13.3**	**0**	**0.0**	**0**	**0.0**	
C.C.	**2**	**13.3**	**9**	**60.0**	**6**	**40.0**	
M.	**7**	**46.7**	**2**	**13.3**	**3**	**20.0**	
Total	**15**	**100**	**15**	**100.0**	**15**	**100**	
Chi-square	0.215ns		0.074ns		0.549ns		
Mean	**2.50**		**2.60**		**2.00**		
SD±	1.50		0.30		1.10		
Median	3.00		3.00		3.00		
Mode	4.00		3.00		1.00		
Q1	1.00		1.00		1.00		
Q3	4.00		3.00		3.00		

*, **, ***= significant at different leves p<0.05, <0.01, <0.001, respectively.

ns= non-significant at level p>0.05

a, Means followed by similar letters are not significantly different according to Dun's Bonferroni.

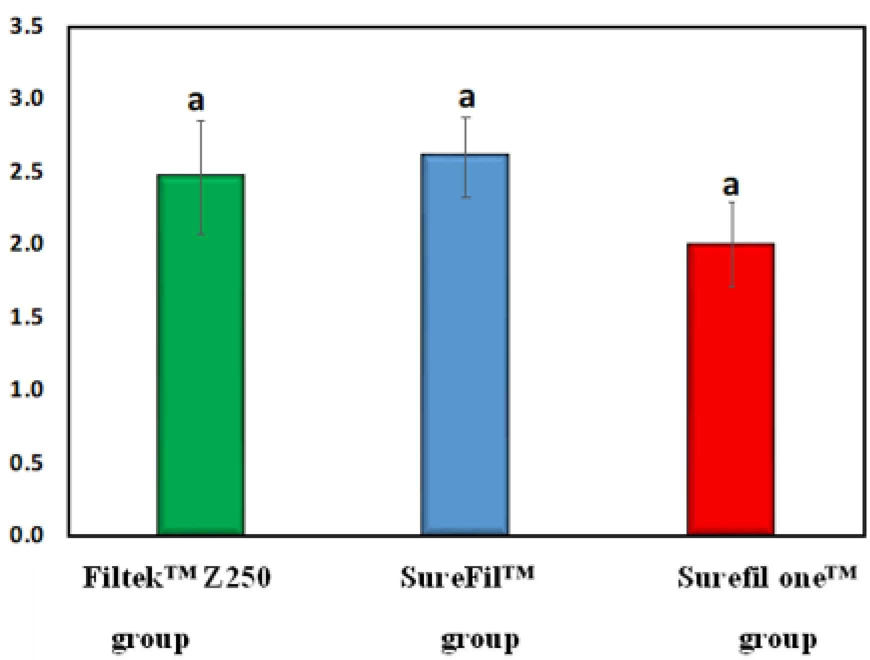

Figure 18: Bar chart presenting the failure type analysis of the three different groups

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DISCUSSION

Finding a balance between simple clinical procedures for restorations and the durability of the material, which is associated with a good bond strength, and adequate adaptation to the tooth structure, is one of the challenges in restorative dentistry [8].

This *in-vitro* study was conducted to create a standardized controlled environment by eliminating many of the drawbacks of clinical testing, such as individual human variations. In addition, it optimizes statistical analysis as it is faster to conduct and permits study reproducibility [19]

Mandibular second primary molars were used in this study to standardize restorative procedures, minimize tooth anatomy influence, and have enough occlusal table for conducting laboratory tests. In addition, these teeth play a crucial role in mastication, occlusion maintenance, and space preservation. Moreover, they preserve the overall health of the child as these teeth' lifespans range from 8 to 10 years [20].

This study focuses on sound or carious enamel scored from 0 to 3 (CAST), as carious dentin has a variable degree of demineralization which is difficult to standardize, whereas sound dentin ensures the differences observed in the results are due to the treatment or the material being tested, not due to the variations of the substrate [21].

The selected teeth were disinfected with 0.1 thymol by weight, due to its strong antibacterial qualities and ability to preserve the integrity of the dental structure[22]. In addition, thymol disinfection does not affect bond strength and microleakage [23].

A flat dentin surface 1 mm below the dentin enamel junction was obtained to expose superficial dentin because the bond strength in superficial dentin is higher and more stable than in deep dentin as it has more mineral and less water content [24]. Moreover, the flat dentin surface reflects a low C factor (ratio between the bonded surfaces to the unbonded surfaces in a cavity), this minimizes the shrinkage stress and the effect on µTBS and marginal gap formation [25].

Dentin in group Filtek™ Z250 and group SureFil™ were etched with phosphoric acid 37% for 15 seconds only as this is the optimal etching time for dentin in primary teeth [26]. Over-etching for primary and permanent teeth may create a deeper depth of demineralized collagen for adhesives to penetrate, thus weakening the bond or denaturing the remaining collagen [27].

Blot-drying was applied leaving a moist surface (wet bonding technique) to avoid excessive dryness from causing collagen fibers to collapse that decreases the bonding agent penetration ability [28] [29].

In Surefil one™ group no etching nor bonding was needed, as this material used a unique monomer technology modified polyacid system (MOPOS), combining self-adhesive qualities of glass ionomers with crosslinking capabilities for enhanced mechanical strength [30].

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This study used a soft start curing mode, allowing a gradual composite cure[31]. This leads to longer polymer chains and reduced cross-linking, in turn, slows down the development of the elastic modulus and decreases shrinkage stress [32].

All restored molars were thermocycled in this study for 5000 cycles of dwell time 20s (dwell time simulates the patients' tolerance on exposure to extremes of the temperature range) and transfer time of 10s at 5 º and 55º, 5000 cycles are equivalent to 6 months intraorally, this provides a more precise test of material durability and long-term bond integrity [33].

The microtensile bond strength test (µTBS) has several advantages over conventional shear bond strength testing methods, as it gives a chance to investigate interfacial bond strengths on small areas of 1mm and below, this makes the test more versatile, as a higher number of beams can be obtained from a single tooth allowing for multiple measurements per tooth, moreover, it decreases the possibility of the existence of critical-sized defects less than larger specimens [34].

The study used 1mmx1mm beams, revealing a non-trimming technique that is the easiest and the least technique-sensitive in specimen preparation compared to the other specimens preparation, such as the hourglass trimming technique, that showed more cohesive failure due to more stress concentration, or the dumbbell geometric technique with cylindrical cross-sectional that is more difficult in fabrication and time-consuming [35].

A static load was applied in this study, although it is clinically less relevant than micro-tensile fatigue resistance, however, according to a study by Poitevin et al., (2010) [36] who concluded there were no relative differences between micro-tensile fatigue resistance and µTBS in the results and taking into account that fatigue testing is more time-consuming.

In this study, the highest mean value of µTBS of restored mandibular primary second molars were found in the SureFil™ group with 19.6 MPa, followed by Filtek™ Z250 group with 15 MPa, while the lowest mean value was found in Surefil one™ group with 5.5 MPa, the difference in µTBS between the three groups was highly significant.

The result of this study comes in agreement with Ilie *et al*., (2014) [37] and Mandava et al., (2017) [38] who found that the bulk-fill composite in deciduous and permanent teeth showed higher bond strength than the conventional composite, which makes bulk-fill material to be clinically an option for a faster restoration in both permanent and deciduous teeth. Additionally, this study coincides with a study by EL Sayed et al., (2020) [39], who found a significant difference between micro-hybrid resin composite and bulk-fill resin composite material, with higher µTBS value for restored primary molars with bulk-fill resin composite material.

These results can be explained by the high filler volume for SureFil™ material 66% vol, which is higher than Filtek™ Z250 with a filler volume of 60% vol and higher than Surefil one™ with filler volume of 58% vol. Higher filler volume results in lower polymerization shrinkage and higher resistance to shearing stress [40].

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The lower bond strength of Filtek™ Z250 material may also explained by the presence of HEMA (adhesion-promoting monomer) in the bonding material (Adper™ Single Bond 2**)**, although it enhances wetting of the dentin through absorbing water, however, this water absorption can adversely compromise the integrity and durability of the polymerized adhesive [41].

This study agrees with Latta et al., (2020) [42] who found self-adhesive material's shear bond strength values were lower than those generated with composite resin bonded with an adhesive, as the non-self-adhesive composite material has deeper penetration and micromechanical interlocking when treating the dentinal surface with phosphoric acid [43].

The low value of μTBS in Surefil one™ group is considered less than the acceptable minimal value of bond strength to dentin in primary and permanent teeth which is 17.6 MPa [44], that is needed to resist polymerization shrinkage stress to avoid marginal gap formation for durable restoration [45].

This low value of μTBS in Surefil one™ group could be explained by having restricted chemical bonding and inferior demineralization ability, which may be due to the competition between the acid-base reaction and the resinous polymerization reaction that occurs during the curing [46]. Besides, dual polymerization by itself, can induce a higher polymerization shrinkage stress leading to a greater challenge for adhesion to the dentin [19].

The result does not agree with a study by Fronza et al., (2018) [47] who tested the μTBS of bulk-fill restorative systems bonded to dentin of third molars and found that conventional composite material (Herculite Classic) showed higher μTBS than bulk-fill composite materials (Tetric EvoCeram). The contradictory results can be attributed to substrate composition, composite resin restorative material properties, bonding material properties, and techniques, in addition, to the different storage medium and different periods of aging [48].

The mode of failure in μTBS tests can provide valuable insights into the nature of bond weaknesses and potential areas for improvement [49]. In this study, the predominant mode of failure in Filtek™ Z250 group was a mixed failure, while in SureFil™ group was a cohesive composite failure, and in Surefil one™ group showed predominantly adhesive and cohesive composite failure.

These findings confirm the obtained μTBS values, where, the highest μTBS value (in SureFil™) leads to the highest value of cohesive composite failure of the material, which is a favorable mode of failure and it is explained by when the bond strength is high due to a strong adhesive bond, failure will occur in the next weakest area (inside the material) [50].

When the bond strength is low as a result in Surefil one™ group, the failure will occur in the weakest area (inside the bond and the material in the case of Surefil one™) [51]. The result of this study lines up with the result of a study by Alghamdi et al., (2024) [52] who

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stated adhesive and cohesive composite mode of failure to be the most frequently reported failure mode for Surefil one material in μTBS. Based on the results of this study, the null hypothesis was rejected. The statistical analysis showed that there is a highly significant difference in the microtensile bond strength in dentin restored with the conventional (Filtek™- Z250) composite, non-self-adhering bulk-fill composite (SureFil™) or self-adhering (Surefil one™) bulk-fill composite in mandibular second primary molar.

Limitations

- Collecting sound lower second primary molars teeth with at least two-thirds of the root present was difficult.

CONCLUSION

- The current study found that there was no significant difference in failure type analysis among the three tested groups, however there was a highly significant difference in the μTBS test, with the highest value recorded for the SureFil™ group.
- Cohesive composite failure is a more desirable failure mode than adhesive failure.
- The self-adhesive bulk-fill composite showed bond strength less than the acceptable minimal value that is needed to resist polymerization shrinkage stress for durable restoration.

Recommendations

- Further studies on the use of self-adhesive composite bulk-fill Surefil one™ with adhesive application.
- To use Surefil one™ as an interim restoration.

Contributions of the Authors

Project was conceptualized by A.A.S.; Y.S.H. and A.A.S. planned the methodology; A.H.C. and A.A.S. worked on the software, validation was done by Y.S.H. formal analysis was executed by A.H.C. and A.A.S.; investigation was performed by A.H.C., A.A.S. and Y.S.H.; resources were collected by A.H.C.; data curation was done A.A.S.; A.H.C., Y.S.H., and A.A.S. prepared the original draft; A.H.C., Y.S.H., and A.A.S. wrote the review and editing; A.H.C. performed the visualization; A.H.C. acquired the funding. Each author approved the final manuscript after reviewing it.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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