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Evaluation of the micro-tensile bond strength of three self-adhesive bulk-fill resin composites compared to a reinforced glass ionomer restoration and their failure modes

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Abstract:

Aim: The current research aimed to evaluation the μ-TBS of three self-adhesive bulk-fill resin composites compared to a reinforced glass ionomer restoration, and its failure modes by stereomicroscopy. **Method:** 40 human permanent mandibular molars were selected to be utilized in the present research. Each molar has sectioned to 4 mm occlusal to cementoenamel junction. The roof of pulp chamber of each tooth was removed by taper stone bure with high-speed hand piece for making place for putting the tested filling materials. The samples were randomized divided into three identical test groups with 10 teeth in each group depending on the kind of resin composite restoration and pretreatment agent that were examined; every group had ten teeth, and each tooth had three cylinders of restorative material (n = 30): Group 1: Tetric Power fill , Group 2: Surefil one , Group 3: 3M ESPE , and Group 4: Fuji II LC. The filling steps and procedures were done in each group according to the manufacture recommendations. For a month, the artificial saliva was replaced every week while it was stored. The preparing the teeth for the μ-TBS test and determining the types of failure modes. **Results:** Group 1 (Tetric Powerfill) had the greatest reported μ-TBS (38.5 ± 7.9), then Group 3 (3M ESPE) recorded 35.9 ± 6.3, followed by Group 2 (Surefil one) which recorded 33.9 ± 8.4, while Group 4 (Fuji II LC) recorded the lowest μ-TBS 28.8 ± 7.4. Statistically, there was statistically significant different between Group 4 (Fuji II LC) and other 3 groups ($p = 0.007$), while there was not a statistically significant different amongst the composite groups ($P > 0.05$). The failure mode displayed that the mixed-type failure mode (54%) was the most common one seen in Group 1 (Tetric Powerfill), (50%) recorded in Group 3 (3M ESPE), (48%) recorded in Group 2 (Surefil one), and the lowest was (39%) recorded in Group 4 (Fuji II LC). While the distribution of adhesive failure mode was (51%) recorded in Group 4, (38%) recorded in Group 2, (37%) recorded in Group 3, and 30% in Group 1. The distribution of Cohesive failure mode was 16%, 14%, 13%, and 10% in groups

1,2,3, and 4 respectively. **Conclusion:** Self-adhesive bulk-fill restorative materials reduced the time needed during its application with good μ-TBS results.

Introduction:

When it comes to restoring decaying and discoloured teeth, composite resin has shown great effectiveness. These days, composites are the preferred restorative material for direct restorations on both anterior and posterior teeth because of minimal cytotoxicity, suitable mechanical qualities, and acceptable cosmetic qualities [(1,2)]. Its primary disadvantage, however, is polymerization shrinkage stress, which compromises the reliability of the tooth/restoration contact [(3,4)].

The main drawback of employing composites is polymerization shrinkage, which causes tensions between the tooth and the restoration and can result in cuspid displacement, micro gaps, and adhesive interface failures. The strains brought on by this shrinkage may show up clinically as pulpitis, recurrent caries, hypersensitivity, and enamel microcracks, which will shorten the restorations' lifespan [(5)].

A resin-based substance that was just launched is bulk-fill composite. With capabilities to cure to a thickness of 4 mm, it is regarded as a breakthrough in resin-based restorations. The working period may be cut in half compared to the traditional resin composite [(6)].

The notion of minimally invasive restorative dentistry has advanced significantly with the introduction of novel hybrid materials, sometimes known as "self-adhesive," "bulk-fill," or "ion-releasing" restorative materials. By doing away with the requirement for separate adhesives, these innovative restorative materials lower the possibility of blood or saliva contamination. They also treat any adhesive-related problems such postoperative sensitivity. A further move toward simplicity is the bulk-fill idea, and the majority of these substances also have the capacity to release ions. Numerous research documented the advantages of ion-release characteristics for tooth caries prevention as well as remineralization [(7,8)].

Self-adhesive resin composites with purported fluoride-releasing and "bulk-fill" qualities are a newest advancement in dental restorations. These so-called "bioactive" or "smart" materials have a different chemical makeup than the well-known glass ionomer cement (GIC) category. Initial research reveal that they possess the ability to outperform the effectiveness of GICs [9].

Bond strength examinations, including the micro-tensile bond strength, are the most often utilized methods to assess the bonding efficacy of adhesive systems. Sano et al. proposed the micro-tensile test technique in 1994 [10]. The use of micro-tensile tests, which are highly suitable for detecting bonding strength because of neck wedge imperfections, has been the subject of numerous investigations [11-13].

So, the purpose of the current research was to evaluate the μ-TBS of three newly developed bulk-fill self-adhesive restorations in comparison to a reinforced glass ionomer restoration, and its failure modes by stereomicroscopy.

Materials and methods:

Teeth selection

From the outpatient clinic of the Faculty of Dental Medicine at Al Azhar University, forty recently extracted undamaged, caries-free, and free from restoration permanent molars were gathered. Periodontal problems were the cause of the extraction. A hand scalar (Nordent, Ivory #2&3, USA) was used to remove calculus and soft-tissue debris. A rubber cup (Prophy rubber polishing cup, China) and fine pumice water slurry (PSP, Dylan Rd, Belvedere, England) were used to polish the teeth, and they were then kept at room temperature in distilled water to prevent dehydration [14]. All teeth were examined under a magnification lens to check for cracks.

Sample preparation

All sample roots were set into self-curing acrylic resin (Acro stone, Heliopolis, Cairo, Egypt) up to 2 mm below the cement-enamel junction (CEJ). For every molar, a consistent mid-coronal dentin exposure was generated by removing a predefined thickness of coronal enamel and superficial dentin. The mid-coronal dentin position was identified using preoperative radiography assessments and labelled on the tooth's exterior surface.

Utilizing a slow speed programmed diamond saw (PICO 155 precision saw, Pace Technologies, Tucson, AZ, USA) under copious amount of water-coolant throughout the cutting process, the cutting process was made perpendicular to every molar longitudinal axis. The exposed dentin surfaces were then finished by rotating 600-grit silicon carbide paper (Micro cut, Buehler, Lake Bluff, IL, USA) for 30 seconds while running water to produce a uniform smear layer.

The roof of pulp chamber of each tooth was removed by taper stone bure with high-speed hand piece for making place for putting the tested filling materials.

Specimens' grouping:

The Specimens were randomized divided into three identical test groups with 10 teeth in each group depending on the kind of resin composite restoration and pretreatment agent that were examined; every group had ten teeth, and each tooth had three cylinders of restorative material (n = 30):

- **Group 1: Tetric Power fill**

  It is a self-adhesive bulk-fill composite, Ivoclar Vivadent, Schaan, Liechtenstein.
- **Group 2: Surefil one**

  It is a self-adhesive bulk-fill composite, Dentsply Sirona, USA.
- **Group 3: 3M ESPE**

  It is a self-adhesive bulk-fill composite 3M ESPE, St. Paul, MN, USA.
- **Group 4: Fuji II LC**

  It is a light-cured resin-reinforced glass ionomer restorative (Tokyo, Japan).

The filling steps and procedures were done in each group according to the manufacture recommendations, then evaluated for Micro Tensile Bond Strength Testing after a month of storage in artificial saliva, that was prepared at faculty of pharmacy at Al Azhar University, at 37 ℃ in an incubator. For a month, the artificial saliva was replaced every week while it was stored.

Preparing the samples for Micro Tensile Bond Strength Testing:

The specimens were cut with the long access of each tooth to make 5 to 6 slices with 1-mm breadth, and these slices were cut utilizing a slow-speed diamonds blade such that they were perpendicular to the tooth buccal wall (adhesive contact). The molars were turned 90° and sliced to yield portions that were 1 ± 0.3 mm thickness. The portions were left connected to the remaining portion of the molar for additional division. From every molar, 3 to 5 slices were extracted. Three rods were used for each tooth.

The samples were inspected optically and then assessed using Leica stereomicroscopy (model S8APO, LAS 3.4 software) at a magnification of 20×.

30 sticks from each group were selected with total of 120 sticks were selected from all groups for the μTBS test [11] (figure 1).

Using cyanoacrylate adhesive, every sample was attached to a Geraldelli jig and tensioned (using a Micro-tensile tester from Isomet, USA) at a 1 mm/min crosshead speed until failure [15]. Bond strengths were computed by dividing the force applied until failure by the cross-sectional bonding region. Mega Pascals were used to compute bond strength and were measured in Newtons.

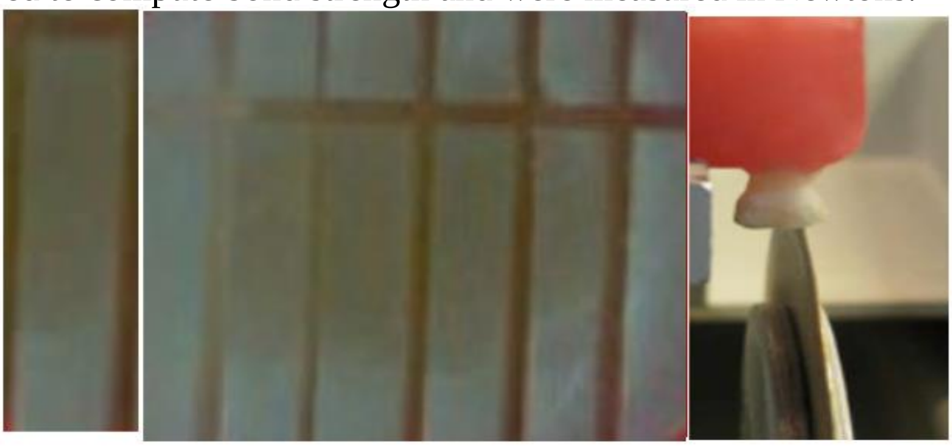

Figure (1): A photograph showing preparing a specimen to be measured by the Micro-tensile bond strength.

The failure modes assessment:

Utilizing the stereomicroscopy at 40^x magnification, the failure modes was assessed and categorized into three categories as follows: (1) Cohesive (breakage along with the adhesive layer), (2) adhesive failure (failure mode happens when one or both surfaces of the bonding surface have very little adhesion), and (3) mixed failure.

Statistical analysis:

Using IBM, Chicago, IL, USA, SPSS software, an analysis of statistics was carried out. Tamhane's T2 post hoc tests and one-way analysis of variance (ANOVA) were utilized to compare the micro tensile bond strength results. The chi-square test was utilized for analyzing the failure mode distributions.

Results:

The means and standard deviations of micro tensile bond strength were represented in Table (1) and illustrated in Figure (2) while the failure modes by (%) of different groups were represented in Table (2) and Figure (3).

Group 1 (Tetric Powerfill) had the greatest reported μ-TBS **(38.5 ± 7.9),** then **Group 3 (3M ESPE)** recorded **35.9 ± 6.3**, followed by **Group 2 (Surefil one)** which recorded **33.9 ± 8.4**, while **Group** 4 **(Fuji II LC)** recorded the lowest μ-TBS **28.8 ± 7.4.** Statistically, there was statistically significant different between **Group** 4 **(Fuji II LC)** and other 3 groups (p = 0.007), while there was not a statistically significant different amongst the composite groups (P > 0.05).

Table (1) Showing the micro tensile bond strengths (MPa) of different groups.

Groups	means ± standard deviations
Group 1: Tetric Powerfill	**38.5 ± 7.9^{A}**
Group 2: Surefil one	**33.9 ± 8.4^{AB}**

Group 3: 3M ESPE	**35.9 ± 6.3^{A}**
Group 4: Fuji II LC	**28.8 ± 7.4^{C}**
P value	**P = 0.007**

Significant differences are indicated via various letters.

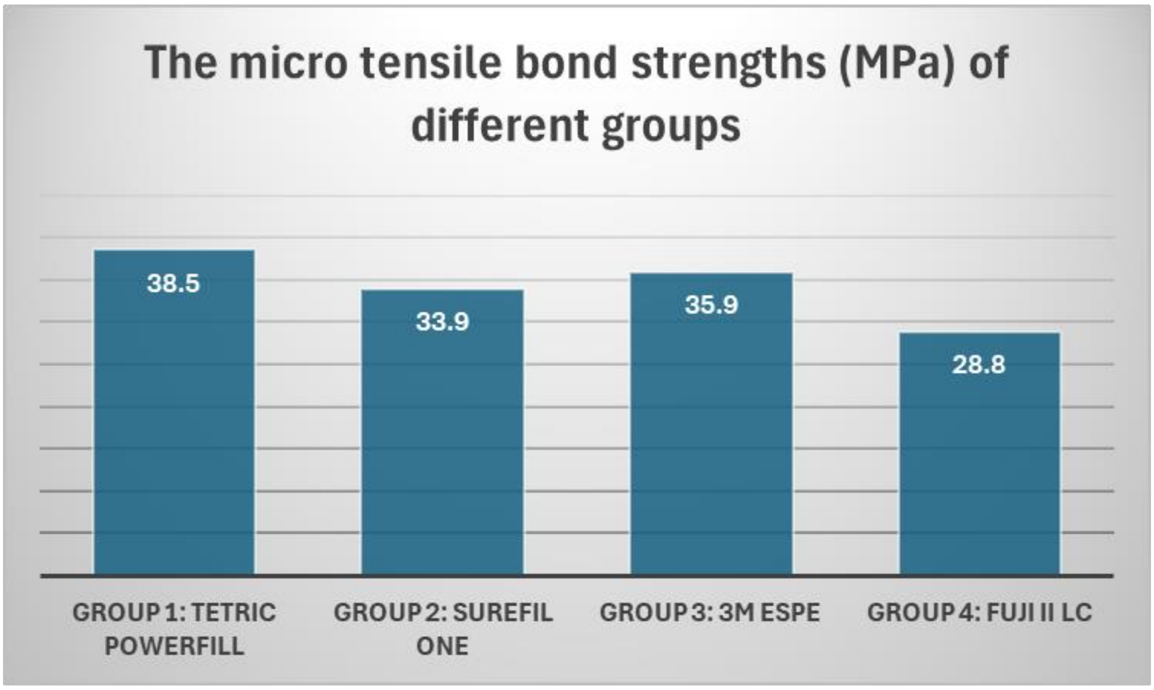

Figure (2): A photograph showing the µ-TBS means values.

The failure modes displayed that the mixed-type failure mode (54%) was the most common one seen in **Group 1 (Tetric Powerfill)**, (50%) recorded in **Group 3 (3M ESPE), (**48%) recorded in **Group 2 (Surefil one),** and the lowest was (39%) recorded in **Group 4 (Fuji II LC).** While the distribution of adhesive failure mode was (51%) recorded in **Group 4,** (38%) recorded in **Group 2,** (37%) recorded in **Group 3, and** 30% in **Group 1.** The distribution of Cohesive failure mode was 16%, 14%, 13%, and 10% in groups 1,2,3, and 4 correspondingly.

Table (2) Showing the failure modes by (%) of different groups.

Groups	**Failure Modes (%)**		
	Cohesive	**Adhesive**	**Mixed**

Group 1: Tetric Powerfill	**16**	**30**	**54**
Group 2: Surefil one	**14**	**38**	**48**
Group 3: 3M ESPE	**13**	**37**	**50**
Group 4: Fuji II LC	**10**	**51**	**39**

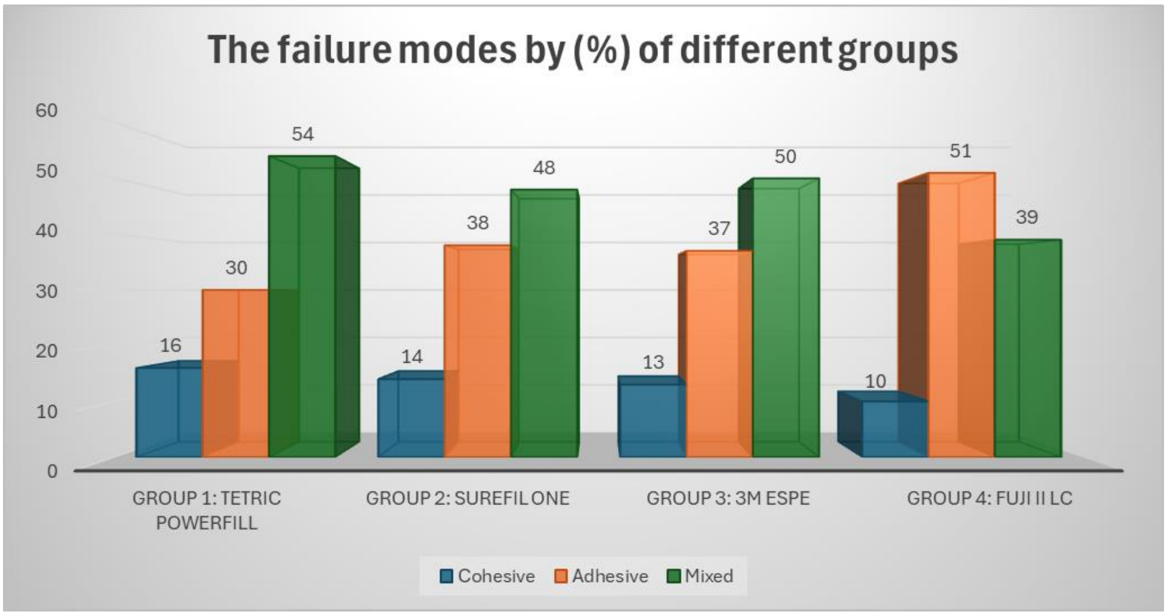

Figure (3): A photograph showing the failure modes by (%) of different groups.

Discussion:

One crucial component that is prone to weakness in dental restorations is the adhesive contact. A series of unfavorable outcomes, such as discolouration, bacterial penetration, and ultimately restorative failure, can result from inadequate adherence to tooth tissue or microleakage at this contact (16).

To that end, the present research sought to evaluate the μ-TBS of three newly developed bulk-fill self-adhesive restorations (**Group 1: Tetric Powerfill, Group 2: Surefil one, and Group 3: 3M ESPE)** compared to a reinforced glass ionomer restoration **(Group 4: Fuji II LC)**, and its failure modes by stereomicroscopy.

Utilizing a diamond disc bur, each molar was sectioned to a 4 mm occlusal to cementoenamel junction in order to standardize and ensure that the pulp chamber wall was 3 mm above the pulp chamber floor.

In this research we used 3 types of Bulk Fill Restorative to put 3 mm single layer of composite and a reinforced glass ionomer restoration because these materials are widely used.

The bulk application technique is simpler, it reduces the number of clinical steps, making the work easier and faster. Numerous bulk-fill resin composites were created and made available to the dentistry community, to decrease the polymerization shrinkage strain accumulation and associated harmful consequences. These materials can be placed in a 4 mm bulk placement, Because of their strong reactivity to light curing and decreased polymerization stress [(17,18)].

Because of its exceptional capacity to form a chemical contact with the surfaces of hard teeth structure, the resin-modified glass ionomer has been chosen as the control restoration for the present research . This material's remarkable bioactivity and ability to release and replenish fluoride ions have made it attractive in spite of a few minor drawbacks, including difficulty reaching the dentin surface and decreased bond strength [(19)].

Also, we used μ-TBS evaluation due to the most utilized tests for assessing adhesive solutions' bonding efficacy, is attributed to the bond strength assessment of very tiny samples (sectional widths < 1 mm^2), and its homogenous strain and stress pattern is crucial in achieving most of the bond interfacial breakdown [(20)].

The outcomes of this research regarding the μ-TBS showed that the greatest μ-TBS was reported within **Group 1 (Tetric Powerfill)** had the greatest reported μ-TBS **38.5,** then **Group 3 (3M ESPE)** recorded **35.9**, followed by **Group 2 (Surefil one)** which recorded **33.9**, while **Group** 4 **(Fuji II LC)** recorded the lowest μ-TBS **28.8.**

Statistically, a statistically significant different was showed amongst **Group** 4 **(Fuji II LC)** and other 3 groups (p = 0.007), while there was not a statistically significant different amongst the composite groups (P > 0.05).

The significant different between reinforced glass ionomer restoration and other 3 composite types in this study, may be due to throughout storage, water sorption and dissolution are frequent occurrences that cause chemical alterations and negatively impact the mechanical characteristics of polymeric materials. Depending on the materials' structure and composition, the dissolution of polymeric chains due to solvent diffusion into the polymer chain structure results in a volumetric expansion. The degradation of non-reacted elements, eroding of the filler-matrix interface, and the plasticization with a reduction in rigidity, toughness, resilience to wear, and flexural strength are all consequences of swelling brought on by aqueous solvent absorption. On the other hand, GICs have a history of performing badly in locations that are subjected to stress, and the adhesive contact may have been directly impacted by their weak mechanical qualities [(21)].

In concerning the outcomes of this research about the distribution of failure modes, displayed that the mixed-type failure mode (54%) was the most common one seen in Group 1 (Tetric Powerfill), (50%) recorded in Group 3 (3M ESPE), (48%) recorded in Group 2 (Surefil one), and the lowest was (39%) recorded in Group 4 (Fuji II LC).

While the distribution of adhesive failure mode was (51%) recorded in Group-4, (38%) recorded in Group-2, (37%) recorded in Group-3, and 30% in Group-1.

The distribution of Cohesive failure mode was 16%, 14%, 13%, and 10% in groups 1,2,3, and 4 respectively.

This was explanted by the results of the μ-TBS , when increasing the conditions for good bond strength so, the adhesive failure modes will be decrease and the mixed failure modes will be increase [(22)].

Conclusion:

Self-adhesive bulk-fill restorative materials reduced the time needed during its application with good μ-TBS results.

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