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THE EFFECT OF THERMO-CYCLING ON MACRO SHEAR BOND STRENGTH OF BULK FILL AND INCREMENTAL RESIN COMPOSITE USING TWO DIFFERENT BONDING SYSTEMS

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ABSTRACT

Objective: This study was carried out to assess the effect of self-etch vs etch & rinse dental adhesives and thermocycling on the shear bond strength (SBS) of bulk and incremental resin composite.

Materials and Methods: A total of forty sound extracted human molars were used in current study and were equally divided into two main groups (20 each) according to filling technique; bulk and incremental technique. Each group was subdivided into 2 subgroups (10 each) according to bonding systems. Each subgroup was divided into two divisions (5 each) according to thermo-cycling.

Results: There was no statistically significant difference between shear bond strength of the two resin composite technique with etch and rinse bonding system as regards non-thermo-cycled specimens. Similarly, with thermo-cycled specimens; there was no statistically significant difference between shear bond strength of the two resin composite technique. The bulk fill resin composite showed statistically significantly higher shear bond strength than incremental resin composite with self-etch bonding system and non-thermocycled specimens. While with thermocycled specimens; there was no statistically significant difference between shear bond strength of the two resin composite technique.

Conclusion Thermocycling has no significant effect on shear bond strength values for the two adhesive systems tested. In bulk filled composite, thermocyling decreased the bond strength of the etch & rinse adhesive. Higher bond strength values were observed in two step self etch adhesives in comparison to non-thermocycled etch & rinse adhesives.

KEYWORDS: shear bond strength, thermocylcling, etch and rinse, self-etch

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INTRODUCTION

The composite restoration longevity is related directly to the strength of the adhesive system applied, as poor bonding and insufficient marginal sealing may lead to failure of the restoration. Resin composite material undergoes polymerization shrinkage. The incremental packing technique is a technique sensitive procedure which requires increments of maximum two millimeter for filling the cavity. [1-3] The use of dental products, particularly bulk fill resin product, is targeting reduction of the restorative technique sensitivity by decreasing the procedures steps and thus shortening the clinical time. The bulk fill resin composite allows filling the cavity in a single increment (within 4 millimeter depth) and shortening the clinical time compared to the incremental placement technique. [4,5]

The different composition of tooth structure leads to the development of many resin adhesive systems. Adhesive systems consist of hydrophilic monomers enhance the wetting to the tooth structure, and hydrophobic monomers to co-polymerize with the hydrophobic restorative material. All these with inorganic fillers, curing initiators and inhibitors or stabilizers. [6-8] Etch and rinse system causes demineralization of the inter-tubular and peri-tubular dentin.

Hydroxyapatite crystals from the collagen network, and individual fibers are exposed and coated by the hydrophilic monomers of the adhesive along with anchoring themselves in the exposed network during the polymerization, this leads to lower adhesive strength by nano-leakage (etching procedure cause high formation of micro tags that cannot be fully penetrated by the adhesive). [9]

The etch and rinse system technique sensitivity led to the production of the self etch adhesive system. Although the self-etch system produce comparable results with etch and rinse system when used under strict manufacturer instructions, etch and rinse techniques were considered as technique sensitive due to the accuracy required for the adhering steps. [10] Thermo-cycling is a laboratory procedure using a special machine that causes temperature changes to the dental material and tooth structure resembling the oral cavity. These temperature changes cause change in the thermal expansion and contraction coefficient affecting the bond strength between restoration and tooth structure. [11,12] Temperature changes are one of the major factors affecting shear bond strength at tooth restoration interface. [13] During mastication, there is a lot of forces (compressive, tensile and shear) transferred from enamel to under lying dentin, these forces are lowered in case of the presence of sound tooth structure. While in restored teeth these forces are transferred to the dental restoration in a more complex way. Shear bond strength is one of major factors that determines the strength of material adhesion to the tooth structure. In case of high bond strength, the failure will be an adhesive cohesive failure. [12] The process of adhesion of dental materials to tooth structure is the main purpose to reach a successful dental restoration. It is challenging to reach an optimum bond due to the heterogeneous composition of dentine and the presence of smear layer during cavity preparation. The shear bond strength measurement of many adhesive systems is the determining factor to evaluate the quality and success of the bond at the tooth restoration interface. [2]

MATERIALS AND METHODS

The materials brand name, description and their manufacturers are listed in Table 1.

Methods

TABLE (1) The used materials in the study.

Material	Manufacturer name	batch number
Bulk fill resin composite (Sonic-Fill 2)	Kerr USA	5116395
Incremental nano-filled resin composite (3M™ ESPE™ Filtek™ Supreme Ultra Universal Restorative Material)	3M™ ESPE USA	N969839
Etch: Echo-Etch	Ivoclar Germany	X32799
Adhesive: Adper Single Bond 2	3M ESPE USA	N961805
Single bond universal	3M ESPE, Germany	80425A

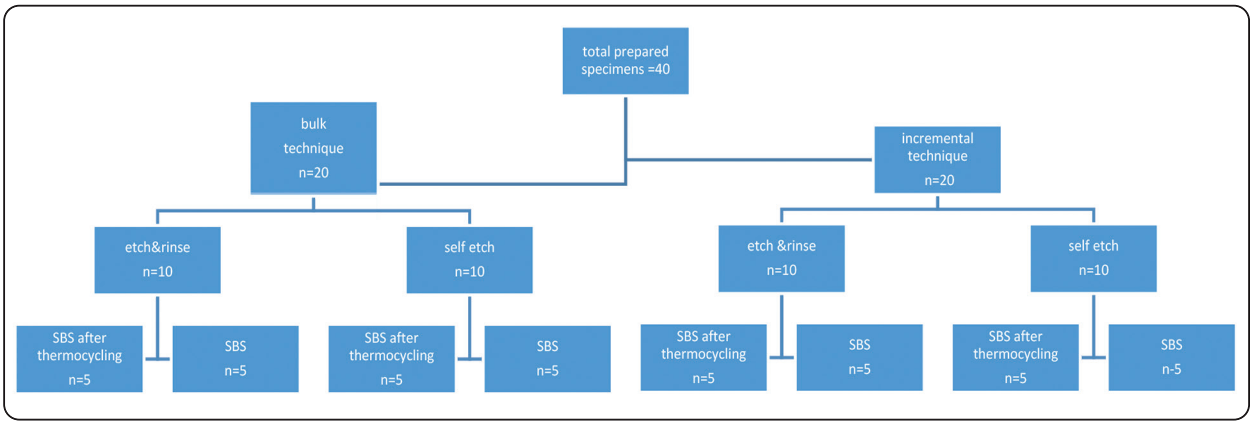

Fig. (1) Flowchart showing the study design and grouping of the present study

Study design:

Forty sound human extracted molars were collected and randomly allocated into two main groups (n=20), representing the application technique of resin composite [BRC= bulk technique & IRC=incremental technique]. Each main group was further equally distributed into two subgroups (n=10) according to the used adhesive system [ER = etch and rinse & SE= self-etch]. Each subgroup was then distributed into two groups (n=5) according to the thermocycling TC [TC & no TC] . fig.1

The teeth were cleaned from blood and the tissues were removed using a hand and ultrasonic scaler. The teeth were stored at room temperature in distilled water, which is periodically replenished every 24 hours during the storage period.

Teeth preparation:

Each molar was sectioned horizontally in a mesio-distal direction, using low speed diamond discs under copious water irrigation below the dentino-enamel junction by 1.5mm. Cutting of the dentine surface was done using #600 grit silicone carbide for 30 seconds for standardization of smear layers. Each molar was placed in self-cured acrylic block from the root side, till the cemento-enamel junction (CEJ).

Bonding procedures and teeth restoration:

For subgroup ER, Echo-Etch etching gel (Ivoclar Germany) was used in etching of the prepared specimens enamel for time:15-s according to the directions by the manufacturer. Then, the etching gel was been washed. The bonding agent, Adper -Single-Bond-2 (3M ESPE USA) was then applied in 2-3 coats for time:30-s followed by mild air thinning for time:5-s, for adhesive layer film thickness adjustment. Light curing of the bonding agent was done by light curing unit (Elipar-S-10, 3M- ESPE, USA) for 20-s with intensity (≥1000/ cm^2).

For subgroup (SE), the two step self-etch adhesive Single -bond -universal (3M- ESPE, Germany) was used and air-dried for 5-s and light-cured for 20-s by the same curing unit.

Plastic transparent rings (6-mm diameter x 4-mm height) were applied at the highest convexity of the prepared specimens, and Incremental nano-filled resin composite material (3M™ ESPE USA) was inserted inside the plastic rings in incremental technique for IRC group. The Bulk fill resin composite Sonic-Fill 2 (Kerr USA) was inserted in bulk technique for BRC group. Celluloid matrices were then used on the top of the restorations surface. Following instructions by the manufacturer, the resin composite was light-cured for 20-s. The plastic rings were then removed and any remnants that extended beyond composite discs base were cut using a sharp blade.

Thermo-cycling procedure :

In each subgroup, five specimens were subjected to Thermo-cyling TC with temperatures ranges from 5°C - 55°C, 500 cycles with a dwell time 30-s/cycle. The prepared specimens were preserved inside well-sealed containers with distilled water at 37˚C till the Shear Bond Strength measurements was accomplished

Shear bond strength test (SBS)

Using the universal testing machine, each prepared specimen was tested with shear force until fracture occurs (Model :3345; Instron -Industrial-Products, Norwood, MA, USA) with a loadcell =5 K-newton. Results were registered using a computer with software (Instron® Bluehill -Lite -Software). The shear bond strength value in megapascals unit (MPa) was calculated by dividing the maximum force in Newtons by the bonded surface area in mm^2.

Failure analysis

The fractured specimens were analysed by means of a digital microscope -USB (U500x Digital -Microscope, China) at magnification x35. The images were caught and transmitted to a computer that has an image software (Image J 1.43U, National Institute of Health, USA) to assess the subsequent mode of failure. Then, Fracture modes were classified in the following way;

Adhesive: Fracture at tooth–resin interface

Cohesive: Fracture in the composite resin material itself Mixed: Fracture of the composite resin material itself and partial or complete de-bonding from the tooth–resin interface

RESULTS

Shear bond strength (SBS):

Etch and rinse bonding system

As regards non-thermo-cycled specimens; the two resin composite techniques showed no statistically significant difference in shear bond strength values (P-value = 0.251, Effect size = 0.780).

Similarly, with thermo-cycled specimens; the two resin composite techniques showed no statistically significant difference between shear bond strength values (P-value = 0.116, Effect size = 1.141).

Self-etch bonding system

As regards non-thermocycled specimens; bulk fill technique showed higher statistically significant values than incremental technique (P-value = 0.028, Effect size = 1.926).

While with thermocycled specimens; there was no statistically significant difference between two incremental and bulk resin composite techniques (P-value = 0.463, Effect size = 0.475).

Bulk fill resin composite

As regards non-thermo-cycled specimens; etch and rinse showed lower statistically significant values than self-etch (*P*-value = 0.009, Effect size = 2.928).

While with thermo-cycled specimens; there was no statistically significant difference between shear bond strength of the self-etch and etch and rinse systems (*P*-value = 0.140, Effect size = 1.043).

Incremental resin composite

As regards non-thermo-cycled specimens; there was no statistically significant difference between shear bond strength of the self-etch and etch and rinse systems (*P*-value = 0.465, Effect size = 0.475).

Similarly, with thermo-cycled specimens; there was no statistically significant difference between shear bond strength of the self-etch and etch and rinse systems (*P*-value = 0.117, Effect size = 1.141).

Bulk fill resin composite:

With etch and rinse bonding system; both non-thermo-cycled and thermo-cycled specimens showed no statistically significant difference (*P*-value = 0.600, Effect size = 0.335).

While with self-etch bonding system; non-thermo-cycled specimens showed statistically significantly higher median shear bond strength than thermo-cycled specimens (*P*-value = 0.009, Effect size = 2.928).

Incremental resin composite

With etch and rinse bonding system; both non-thermo-cycled and thermo-cycled specimens showed no statistically significant difference (*P*-value = 0.251, Effect size = 0.780).

Similarly, with self-etch bonding system; there was no statistically significant difference between non-thermo-cycled and thermo-cycled specimens (*P*-value = 0.917, Effect size = 0.066).

TABLE (2) Results and descriptive statistics of Mann-Whitney (U test) of shear bond strength values of different tested groups.

Bonding system	Thermo-cycling	Bulk fill	Incremental	*P*-value	Effect size *(d)*
Etch and rinse	Non-thermocycled				
	Median (Range)	2.6 (1.5 – 3.9)	8.1 (1.3 – 9.5)	0.251	0.780
	Mean (SD)	2.6 (0.9)	6 (3.7)		
	Thermo-cycled				
	Median (Range)	2.8 (1.3 – 4.7)	9.5 (0.9 – 13.5)	0.116	1.141
	Mean (SD)	2.8 (1.2)	8.7 (4.7)		
Self-etch	Non-thermocycled				
	Median (Range)	7.6 (4.7 – 8.1)	3.1 (2.7 – 7.2)	0.028*	1.926
	Mean (SD)	6.8 (1.5)	3.8 (1.9)		
	Thermo-cycled				
	Median (Range)	2.1 (1.3 – 2.8)	4.5 (1 – 8.5)	0.463	0.475
	Mean (SD)	2.1 (0.6)	4.5 (3.3)		

: Significant at P ≤ 0.05

Failure analysis:

The thermocycling and the non-thermocycling bulk fill specimens using the etch and rinse bonding system (n=10): all the specimens showed adhesive/ cohesive fracture.

The thermocycling bulk fill specimens using the self-etch bonding system (n=5): 3 showed adhesive/ cohesive and 2 showed adhesive failure.

The non-thermocycling bulk fill specimens using the self-etch bonding system (n=5): 3 showed adhesive/cohesive and 2 showed adhesive failure.

The thermocycling incremental fill specimens using the etch and rinse bonding system (n=5): 2 showed adhesive/cohesive failure, 2 showed adhesive and one showed cohesive failure.

The non-thermocycling incremental fill specimens using the etch and rinse bonding system (n=5): 2 showed adhesive/cohesive failure, 3 showed adhesive failure.

The thermocycling incremental fill specimens using the self-etch bonding system (n=5): 3showed adhesive/cohesive failure, 2 showed adhesive failure.

The non-thermocycling incremental fill specimens using the self-etch bonding system (n=5): all showed adhesive failure.

DISCUSSION

In laboratory and clinical studies have showed that the strength of adhesion depends on many factors, for example; adhesive penetration into the demineralized surface, the adhesive degree of conversion, resin composite mechanical properties and compatibility between the restoration/tooth surface.

To imitate the oral environments, thermocycling is applied as an artificial aging process. It has been concluded that the Single-Bond shear bond strength was not significantly decreased by thermocycling practice [13,14]. However, others stated a significant reduction in shear bond strength after thermocycling process. This contradiction could be explained by the difference in the adhesive system tested. During thermocycling, the specimens were exposed to frequent thermal changes and also more water contact. The resultant thermal stresses due to differences in the coefficients of thermal expansion led to mechanical stresses which at the end result in adhesive failure at the restoration/tooth interface [15].

DE McLean et al 2015 [3], affirmed that the universal adhesives/enamel shear bond strengths were enhanced if the bonding agents were applied as etch-and-rinse adhesives rather than only one-step self-etch. As previously concluded, etching prior to universal adhesive thoroughly remove smear layer and selectively demineralized the enamel rods. This step creates enamel micro-porosities that are penetrated by bonding agents. Micromechanical interlocking of micro resin tags, following its polymerization, within the rough enamel surface provides a strong micromechanical bond to enamel surface. On the other hand, self-etch technique only partially removes the smear layer and leaving the dissolved products, as no rinsing step, to become incorporated within the adhesion layer.

In this study non thermo-cycled Bulk fill resin composite specimens with self-etch bonding system, showed higher statistically significant difference in shear bond strength than etch and rinse bonding system. This result is in agreement with Y Korkmaz et al 2010 [15], who stated that the self-etch adhesive system resulted in significantly higher values than the non-thermocycled etch & rinse adhesives. However, this finding can be contrasted with many previous studies that indicated, when it comes to in vitro studies, etch and rinse techniques stay the benchmark for other systems. [16]. The reason for this could be attributed to the difference in bonding surfaces.

In this study thermo-cycled Bulk fill resin composite specimens with self-etch bonding system, showed no statistically significant difference in shear bond strength compared to etch and rinse bonding system. In the thermo-cycled and non thermo-cycled incremental resin composite, there was no significant difference between etch and rinse vs self-etch adhesive. This is in contrast to the study conducted by Nicoleta Ilie et al 2014 [10]. They stated that self etch adhesives have better performance in dentine relative to enamel with bulk fill resin composite in both permanent and deciduous teeth. This could be explained by the difference in the number of cycles used in both studies which led to different outcome of the study performed.

In this study thermo-cycled Bulk fill resin composite specimens with self-etch bonding system, showed no statistically significant difference in shear bond strength compared to etch and rinse bonding system.

In the thermo-cycled and non thermo-cycled incremental resin composite, there was no significant difference between etch and rinse and self-etch adhesives. This study disagrees with the results of Rene Steiner et al 2019 [11] who stated that the application of etch and rinse adhesive systems showed significantly better bond strength than self-etch adhesive systems. This contrast in the results is due to difference in test conditions.

The study conducted by Yuhyun Kim et al 2017 [16], assessed the bond strengths of self-etch adhesives to primary tooth. The results showed that the self-etch adhesives showed higher values with additional acid etching. This disagreement in results could be attributed to the use of primary teeth which have dentinal tubules with higher density and smaller diameter than permanent teeth.

In this study, there is no significant different of etch and rinse bonding system with bulk fill and incremental resin composite. This is in agreement with Neslihan Tekçe et al 2016 [9], who stated that between the bulk-fill and incremental technique groups, there was no difference in shear bond strength when using the etch and rinse adhesive system.

Also, comparable findings were found in a research performed by Hakan Colak et al 2019 [6]. They showed that the hybrid composite and Bulk-Fill viscosity systems exhibited statistically similar shear bond strength values. The resin composite in Bulk-fill technique could be photo-cured in larger increments, as the curing depth and the physical properties can be retained until 4-mm layers with irradiation time 20-s. Consequently, adding two 2-mm increment by increment with hybrid composite or one 4-mm layer with Bulk-Fill technique might produce similar physical properties as conventional incremental techniques. This was explained by the better curing depth in bulk fill technique was improved by incorporating a novel initiator in addition to the traditional camphor quinone/amine initiator systems, Ivocerin. This novel initiator addition allows faster and deeper depth of cure of the Bulk Fill technique with no need for increasing translucency.

Rene Steiner et al 2019 [11], showed the difference in shear bond strength between incremental and bulk-fill resin composites techniques was not significant. This is in an agreement with our study as using Sonic Fill, a single-step bulk-fill composite reduces the consistency of the resin composite film thickness due to the effect of sonic energy. This helps in increasing adaptation to the internal walls and restoration margins.

The fracture modes analysis was added to confirm the shear bond strength findings in this study. The mixed fracture modes were the most represented for all tested groups. Researchers concluded that the shear bond strength is stated to be accepted if the bond failure observed inside material rather than at resin/tooth interface that’s to say cohesive rather than adhesive [15,16].

CONCLUSION

It may be concluded that:

1. Self-etch and etch and rinse shear bond strength values were not significantly affected by thermocycling.
2. Thermocyling negatively affected the shear bond strength of the etch & rinse adhesive, in bulk filled composite.
3. The shear bond strength was improved significantly in self- etch adhesive system rather than in etch and rinse with non-thermocycling .

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