IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 19, Issue 2 Ser.1 (February. 2020), PP 53-63
www.iosrjournals.org

Effect of C- Factor and Placement Technique on the Microtensile Bond Strength of a Self-etch Adhesive to Dentin

Heba Hassan, BDS a, Ali Abdalla, PhD b, MirvatSalama, PhD c
a Department of Restorative Dentistry, University of Tanta, Faculty Of Dentistry, Tanta University, Egypt
b Professor, Department of Restorative Dentistry, University of Tanta, Faculty Of Dentistry, Tanta University, Egypt
c Professor, Department of Restorative Dentistry, University of Tanta, Faculty Of Dentistry, Tanta University, Egypt
Corresponding author: *Heba Hassan*
Department of Restorative Dentistry, University of Tanta, Faculty of Dentistry, Tanta University

Date of Submission: 17-01-2020 Date of Acceptance: 05-02-2020

I. Introduction:

The main drawback of composites is their polymerization shrinkage and the stresses they cause.Polymerization shrinkage have the potential to originate failure of the composite-tooth interface, producing interfacial gaps, micro-leakage, marginal discoloration and secondary caries.[1]Also, polymerization contraction stresses when transferred to the tooth can cause its deflection resulting in post-operative sensitivity and may open pre-existing enamel micro-cracks.[2]

The shrinkage stresses following the polymerization procedureare influenced by restorativetechnique, resin elastic modulus, and configuration of the cavity or ‘‘C-factor,’’which is defined as the ratio between bonded andun-bonded composite resin surface area.[3-6] In order to reduce these stresses, the use of anincremental technique is recommended, which promotesa smaller ratio of bonded to un-bonded areas ineach composite resin layer, achieving a lower C-factorduring polymerization of each layer.[7]

An incremental composite placement technique has been usedfor years as a standard to prevent gaps caused by polymerization stress and to achieve the sufficient bond between composites and teeth.[7, 8]

However, bulk-fill composites have recently been introduced to reduce the time and cost of the restoration.[9]

Bulk-fill composites are intended to be used in 4 to 6 millimeters of thickness.[9, 10] According to what the manufacturing factory claimed, they can adjust to the walls of a cavity very well and they can reduce the cuspal deflection.[11]On the other hand, one of the potential problems of these composites is a high C-factor due to the increased thickness of each layer which may amplify the stress caused by the polymerization shrinkage resulting in de-bonding, leakage, and post-operative pain.[12, 13]

Some studies have been conducted to investigate how to use the cavity restoration technique with bulk-fill composites in deep and narrow cavities.[7, 9, 14, 15]The results have been conflicting due to the variety of composites, bonding techniques, and curing intensity. It has not been clarified what effect the C-factor has on the bond strength especially with this type of composite. Thus, our studyis conducted to ascertain the effect of C-factor together with the placement technique.

Severalvariables affect the mechanical behavior of therestorations to be studied; therefore, a systematicunderstanding of the distribution of stress patternsinvolved in adhesion failure is important for correctinterpretation of results. Laboratory bond strength test using the microtensile bondstrength (μTBS) is the most common method toobtain information about the adhesion betweenrestorative material and tooth structure.[16] The (μTBS) test is considered to be reliable because of itsversatility and reliability in vitro.[17]

So, the aim of this study was toinvestigate the effect of C-factor and placement technique on the microtensile bond strength (μTBS) of composite resins to dentin.

II. Materials and Methods:

1-Teeth selection:

Thirty-two freshly extracted human sound molars were used. Teeth were extracted for periodontal reasons from patients with age range (40-55) years old. They were examined using light microscope at 5x magnification to exclude those with cracks or other structural defects.[18] All teeth were collected from the Department of Oral and Maxillofacial surgery of Faculty of Dentistry, Tanta University.

Approval for this study was obtained from Faculty of dentistry, Tanta University Research Ethics Committee (REC). The purpose of the present study was explained to the patients and informed consents were obtained to use their teeth in the research according to the guidelines on human research adopted by the Research Ethics Committee (REC) at Faculty of Dentistry, Tanta University.

The teeth were cleaned of debris and calculus using periodontal scaler, washed, then stored in distilled water to be used in the experiment which was scheduled within one month of extraction.The distilled water was changed on daily basis throughout the procedures.[19]

Each tooth was mounted in self-cure acrylic resin[i]till the cemento-enamel junction. This step was done using a pre-fabricated mold. Each metallic mold is composed of an external cylindrical part surrounding other split metallic halves. These two metallic compartments were adjusted together by means of two external screws to facilitate the insertion and the removal of the acrylic block from the mold.

The fitting surface was covered with a separating medium (Vaseline) to prevent sticking of the resin to the mold. The purpose of using this mold was to standardize the acrylic resin with a height of 19 mm and a diameter of 14 mm and to facilitate handling the teeth.

1- Specimens grouping and preparation:

The specimens were randomly divided into two groups according to the preparations (n=16), then each group was further subdivided into two sub groups A and B (n=8) according to the composite used. All groups and subgroups are represented in Table I.

- **Group I**: **Flat surface (n=16)**

The crown of each tooth was marked by a pencil 4 mm below the level of the cusp tip, then it was cut to form a flat surface exposing mid-coronal dentin, with the use of a double-faced diamond disc adapted to a low speed hand piece[ii] under copious water cooling. Then the exposed dentin surface was abraded with 600 grit Silicon Carbide abrasive papers in a circular motion under water cooling then rinsed to produce a standardized smear layer.[20, 21]

- **Group II: Class I cavity (n=16)**

The crown of each tooth was built up till the level of the cusps' tips to elevate the occlusal plane forming a flat surface using Nexcomp flowable composite. 37% Meta Etchant gel was applied to the occlusal surface's enamel for 15 seconds, then it was rinsed for 20 seconds and plot dried. A double coat of Meta P&Bondwas applied using micro-brush, gently air dried for 5 seconds and light cured for 10 seconds. FinallyNexcomp Flow Nano-hybrid flowable composite was delivered directly from the disposable tip and was light cured for 20 seconds according to manufacturer's instructions.

A standard 4-mm-deep box-type (4 x 3 x 4 mm) Class I cavity was prepared on the flat composite surface. The length and width were traced as a (4 x 3) rectangle using a pencil, then prepared using a cylindrical diamond stone with a rounded end adapted to a high speed hand piece[iii]. The diamond stone was traced at 4 mm to mark the depth of the cavity.

For the purpose of standardizing, all cavities were performed by the same operator, and the length, width and depth of each cavity was verified using William's periodontal probe, and an electronic digital caliper[iv]. The mean dimensions that were established are: mesio-distal length of 4 mm, bucco-lingual width of 3 mm, and depth of 4 mm. Mid-coronal dentin is present both on the flat surfaces and in the cavities, ensuring that effects of regional variability on μTBS is negligible.[5]

Each group was subdivided into two subgroups according to the type of composite used into:

- **Subgroup A**: (n=8) in which Tetric N-Bond Universal adhesive with Tetric N-Ceram nano-hybrid incremental composite were used.
- **Subgroup B**: (n=8) in this subgroup, Tetric N-Bond Universal adhesive with TetricEvoCeram bulk fill composite were used.

3-Restorative procedures:

I. Group (I) flat surface:

a) Sub-group IA:

The flat surface was treated with the adhesive (Tetric N-Bond Universal) in a self-etch mode by applying a thick layer and brushing it in for at least 30 seconds, then the excess amount of the bond was dispersed with a stream of air until there is no longer any movement of the material. Tetric N-Bond Universal adhesive was

[i] Imircryl, Konya, Turkey

[ii] KaVoSMARTmatic S10 S low speed hand piece

[iii] W&H Synea Vision Contra-angle Handpiece WK-99 LT REF 30023000

[iv] NEIKO electronic digital caliper (Accuracy: 0.001" / 0.02mm)

polymerized for 10 seconds at a light intensity of ≥500 mW/cm² using Woodpecker I-LED[i], according to manufacturer's instructions.

Then the composite (Tetric N-Ceram) was added to the surface using a pre-fabricated split teflon mold of same dimensions of the Class I cavity prepared in Group II (4 x 3 x 4 mm). It was stabilized in its place on the flat occlusal surface by the mean of another split metallic ring fitted inside the external cylindrical metallic mold. The composite was inserted in two increments of 2 mm thickness per increment. The material was adapted to the mold using Comproller of kerr[ii] which has interchangeable silicone tips for proper packing.

The first increment was polymerized for 20 sec at a light intensity ≥ 500 mW/cm² with holding the light emission window as closely as possible to the surface of the restorative material, according to manufacturer's instructions. Then after adding the second layer, a transparent matrix strip was placed over the restorations and a glass slab of 250 g weight was placed on the set for 30 seconds to provide a flat smooth surface and to extrude the excess material. When this time elapsed, the weight was removed and light activation was performed as previously mentioned. The excess material was removed with a sharp scalpel.[22] Then the specimen was removed from the mold.

b) Sub-group IB:

The bond application is similar to that of the previous group, then a bulk-fill composite (TetricEvoCeram) was applied in one increment of 4 mm, then adapted with a suitable instrument (e.g. Comproller of kerr).

After filling the mold, the rest of the restorative procedures was completed in the same way as in sub-group IA.

II. Group (II) Class I cavity:

a) Sub-group IIA: The restorative procedures of this group are similar to that of group (I) sub-group IA.

b) Sub-group IIB: The restorative procedures of this group are similar to that of group (I) sub-group IB.

The samples were stored in distilled water at 37±1ºC, for 24 hours before µTBS testing.[23]

4- µTBS testing:

Using IsoMet saw[iii]; each tooth was sectioned perpendicular to the adhesive/tooth bucco-lingually into slabs of 1-mm thickness afterwards they were sectioned mesio-distally under water cooling. Then the mounted tooth was rotated 90º and sectioned at its cervical portion to separate the micro-specimens.[24] This serial sectioning produced numerous rectangular bars of 1.0 mm × 1.0 mm non-trimmed micro-specimens of an average length of 6 mm (2mm of dentin and 4mm of composite) for µTBS testing.

The specimens were examined using a light microscope[iv] at a magnification of 50X to check for the presence of of voids at the specimens' interface. All such samples were excluded from further testing.

Then the samples were mounted in an Instron universal testing machine[v]using a specially prepared attachment which they were glued to by using cyanoacrylate glue[vi]. The samples were stressed until failure at a cross-head speed of 1 mm/ min, using a load cell of 500 N. The µTBS was expressed in MPa, calculated by dividing the imposed force (N) at the time of fracture by the bond area (mm²) according to the following equation:

$$R = \frac{\mathrm{K} \times \mathrm{F}}{\mathrm{A}}$$

Where R= µTBS in (MPa), K=Test load in (kg), F= Constant of acceleration due to gravity (9.8m/s²), and A=Bonded area of specimen in (mm²).

The µTBS data was collected and tabulated to compare the tested groups using Simple T-test. Statistical analysis was performed using SPSS version 20 (SPSS Inc., Chicago, IL, USA).

4- Mode of failure:

All fractured surfaces of the debonded samples were examined under a stereomicroscope[vii] at a magnification 50X to record the mode of failure[25], which was classified into:

- **Adhesive failure**; where the dentin surface is sound without any traces of composite restorative material on it.
- **Cohesive failure**; where the failure occurred within the bulk of the dentin or the restorative material.
- **Mixed failure**; which is a combination between the previous two types where traces of composite material can be found on the dentin surface.

[i] I-led light curing unit (output light intensity is about 1000 mW/cm2 – 1200 mW/cm2, Guilin woodpecker medical instrument company).

[ii] CompoRoller™ Kerr U.S.A. 1717 West Collins Avenue Orange, CA 92867(800) KERR-123 KerrDental.com

[iii] IsoMet™ 4000 Linear Precision Saws, BUEHLER, a division of Illinois Tool Works Inc.Lake Bluff, Illinois 60044-1699 USA

[iv] MSA 166305 stereomicroscope, Wild; Heerbrugg, Switzerland

[v] Instron5848 Micro Tester; High Wycombe, UK

[vi] Super Bonder Flex Gel, Henkel Loctite AdesivosLtda, Itapevi, SP, Brazil

[vii] SZ-CTY Olympus, Japan

Thisdata was collected, tabulated and the percentage of each type of failure was calculated to compare the mode of failure of the different groups and subgroups.

Then, representative debonded specimens were washed with copious amount of water in order to remove any surface contaminants and left to dry. Then the samples were mounted on an aluminum cylinder and sputter-coated with gold using ion sputtering device[i]and examined under scanning electron microscope[ii] (SEM). (SEM).

III. Results:

Microtensile bond strength:

All the data were collected, recorded, tabulated and statistically analyzed at 95% level of significance and the descriptive statistics were expressed as mean and standard deviation.

The mean and standard deviation of the microtensile bond strength (MPa) of the groups and sub-groups are summarized in table (II).

Concerning all tested groups; as illustrated in table (II), the highest mean value was recorded for group I subgroup A (flat surface group filled with the nano-hybrid incremental composite Tetric-N ceram), recording 21.860 MPa ± 9.363 , while the lowest mean bond strength value 15.568 MPa ± 6.213 was found at group II sub-group A (Class I cavity group filled with the nano-hybrid incremental composite Tetric-N ceram).

To determine the effect of C-factor:

Simple T-test was used to compare the tested groups, at a level of significance $P \leq 0.05$ and reported a statistical significant difference when group I was compared to group II regardless subgrouping with P value. There was another significant difference when group IA was compared to group IIA with P value =0.023=0.008as shown in tables III & IV. There was no significant difference between groups IB vs. IIB with P value=0.136.

To determine the effect of Placement technique:

There were no statistical differences between groups A vs B regardless sub-grouping with P value=0.772, between groups IA vs. IB with P value=0.988, or between group IIA vs. IIB with P value=0.414.

Mode of failure:

After sectioning all the samples into micro-specimens, all the ones that had a part of the axial cavity wall included, or the ones fractured during the procedure were considered pre-test failures (ptf's) and were excluded from bond strength testing. The ptf's were 0% in both subgroups IA and IB, 37.5% in group IIA, and 31.2% in group IIB.

After μTBS testing of the remaining specimens, all the fractured samples were examined under digital stereomicroscopic and evaluated to determine the mode of failure. Frequency of each mode of failure in the different groups is presented intable V.

SEM examination of the fractured dentin surfaces:

The scanning electron microscope (SEM) of the representative specimens confirmed the failure mode recorded by a 50x magnification with the stereomicroscope. The scanning electron micrographs of some selected specimens are displayed in (Fig 1-3).

IV. Discussion:

The purpose of this in-vitro study was to evaluate the effect of C-factor and Placement technique on the microtensile bond strength (μTBS) of two types of composites, (Tetric N-Ceram Nano-hybrid incremental composite) and (TetricEvoCeram Bulk Fill composite) to dentin using the same one-step universal adhesive (Tetric N-Bond Universal Adhesive) in a self-etch mode.

Even though clinical trials are the ultimate test for dental restorations, they can't differentiate the true reason for failure due to the simultaneous impact of diverse stresses on restorations within the aggressive oral cavity environment.[26, 27]

Since the purpose of this study was to evaluate the effect of C-factor and placement technique on the microtensile bond strength, the type of adhesive had to be eliminated as a variable. So we used a single type of adhesive (Tetric N-Bond Universal Adhesive) for all the tested groups.

[i] JEOL JFC-1100E ION Sputtering device
[ii] JEOL JSM-5300 scanning microscope

This adhesive is an alcohol-based system. The alcohol helps the adhesive to penetrate into the collapsed collagen network,apparently, it can create a higher microtensile bond strength.[28].

The adhesive was used in a self-etch mode since the main aim of bulk-filling is to simplify and speed-up the placement of large posterior cavities' restorations, so it made sense to rely on a bonding technique that is time-saving and user-friendly.[5]

The two types of composite were chosen from the same manufacturer of the adhesive (IvoclarVivadent) to avoid the effect of cross compatibility between products from different manufacturers.[29]

When dentin is used as a bonding substrate toevaluate adhesive systems reaching critical bond strengths over 15MPa, shear and tensile procedurestend to produce non-uniform stresses during the de-bonding process resulting in cohesive fracturesin dentin.However, cohesive fractures indentin do not represent the clinically relevantfailure mechanism in real cavities.[30, 31]

This particularproblem can be prevented with microtensile testingbecause the predominant failure is adhesive as shown during the present investigation. This confirms thefindings of other studies dealing with microtensile testing.[17, 32]**Shono et al.**[33] reported in recent investigationsusing the μTBS methodology, that bondingto flattened dentin surfaces exhibits different results atvariable distances from the pulp, potentially resulting in regional dentin bond strength differences.Therefore, only the very central areas of thespecimens were used to obtain a reliable randomizationof test specimens like in previous studies.[34, 35]

Selecting microtensile bond strength test is justified because it has multiple advantages over conventional tensile bond strength test. It permits fabricating several bonded dentin-resin rods from each single tooth (better economic use of teeth). There is a better control of regional differences in bond strengths within the same tooth (e.g. peripheral versus central dentin). It allows for testing substrates of clinical significance, such as carious dentin, cervical dentin, and enamel.[36]

There is a much better stress distribution at the true interface, which allows testing irregular surfaces and very small areas and facilitates microscopic examinations of the failed bonds due to smaller areas. Finally, it results in fewer defects occurring in the small-area specimens; this is reflected in higher bond strengths. According to **Sano et al .,**[32] there is an inverse relationship between bond strength and bond area: the smaller the area, the greater is the bond strength. A small surface area improves the specimen in terms of stress distribution and in having a reduced number of internal defects, and it generally results in only adhesive failures.

Deep dentin has high water content than superficial dentin due to larger diameter and number of tubules per unit area. This water may dilute the organic solvents of some bonding systems, causing monomers to leave the soluble phase and form resin globules in water. As deeper cavities are prepared, both cavity configuration and effect of dentin depth may combine to result in lower bond strengths to the cavity floor.[37]

In order to perform the test, we needed to create a cavity with 4 mm depth without the risk of pulpal exposure, and to have the final specimens with uniform dimensions that are appropriate to handle and test without the very high risk of pre-test failure. The specimens' total length should have been around 6mm (4mm composite + 2mm dentin). In order to achieve that, the crowns were cut in Group I 4 mm starting from the cusp tips instead of the central grooves. To create a similar condition for the other group (Group II) the crowns were built till the level of the cusps' tips forming a flat surface using Nexcomp flowable composite. Then a standard 4-mm deep Class I cavity was prepared.[5]

Regarding the effect of C-factor on the μTBS, the results showed that it was an effective variable, as the group with the lower c-factor had a higher bond strength. There was a significant difference when when Group I was compared to Group II. That was also the case when comparing Group IA vs. Group IIA. Whilewhen comparing Group IB vs.Group IIB there were no significant difference.

These findings were in conformity with the studies conducted by **Armstrong et al.,Yoshikawa et al., Choi et al., and Shiraiet al.,**[12, 37-39] where the effect of cavity configuration on bond strength of resin composite in different cavity configurations was evaluated and revealed that bond strength decreases with an increase in C-factor.

C-factor is considered to represent a significant element that can affect the developing stress when cavities are restored with resin composite. This effect was markedly demonstrated in the results of this study, which showed a significantly decreased bond strength when the material became more restricted by increasing the bonded surfaces (Class I cavity Group).[5, 40]The reduction of the free surface area limits the flow of the shrinking material, depriving the material of the ability to change its shape and restricting relaxation of the developed stress. In addition, the shrinking material will pull the opposing walls of the cavity closer together, thereby increasing the stresses generated at the bonded walls, and decreasing the μTBS values in return.[41, 42]

In flat preparations, surrounding walls are absent, contributing to a lower C-factor; thus, composite resin increments deform without restriction of the proximal walls, reducing the residual shrinkage stress, which may be why bond strength values were higher for the flat preparation samples in this study.[43]

The expected magnitude of stress might be estimated through the ratio of the bonded to the un-bonded areas, also known as the configuration factor.[41] The higher the C-factor, the higher the stress level generated;

this aspect was observed in the Class I cavity tested in the present study. On the contrary, a higher ratio of un-bonded to bonded walls, represented by the flat cavity tested in this study, would be responsible for lower values of stress as shrinkage would freely occur at the un-bonded surface areas. In addition, without proximal walls, the increments may receive light energy more effectively, since insufficient curing is associated with lower bond strength and mechanical properties.[44]

Even though the difference in the μTBS between Group I vs. Group II is mainly attributed to shrinkage stress acting on the bond to cavity-bottom dentin and weakening it, other factors might have influenced the bond strength as well. The one-step adhesive (Tetric N-Bond Universal Adhesive) should be strongly air thinned to prevent phase separation.[45] In a cavity, spreading of the adhesive is limited, so that the occurrence of porosities and pooling of the adhesive in the cavity corners cannot be avoided.[46] Such an excess of adhesive has been reported to negatively influence bond strength.[47] Moreover, better adaptation can be obtained on flat surfaces as the mold is not physically connected to the tooth surface, the gap may serve as a sprue through which air can escape. In cavities, however, some air inclusions in the sharp angles of the cavity bottom were inevitable[48] and may have influenced stress distribution in the specimens.[49]

The possible explanation that TetricEvo-Ceram Bulk-Fill resin composite's μTBS values were not affected in both C-factors (insignificant difference P=0.136) may be attributed to the lower modulus of elasticity of the material which represents the stiffness of the material within the elastic range. The values of the elastic modulus affects the polymerization shrinkage which in return affects the bonding strength. According to Hooke's law, stress is equal to the elastic modulus multiplied by the strain.[7]

Regarding the effect of the placement technique on the μTBS, the results showed that it was not an effective variable, as there was no significant difference whensubgroups A was compared to subgroups B. That was also the case when comparing subgroup IA vs. subgroup IB, and when comparing subgroup IIAvs.subgroup IIB.

Overall the Bulk-fill composite showed similar or even higher μTBS values than the nano-hybrid incremental composite. This result agrees with **Karatas et al.,**[50]who concluded that bulk-fill flowable composites exhibit a higher degree of μTBS values than methacrylate-based flowable composites at a 4-mm thickness. They attributed that to the bulk-fill composite's monomer chemistry, and its surface energy and wettability characteristics, which are higher than those of the other composites used.

The higher μTBS values for TetricEvoCeram Bulk-fill composite can be attributed to its composition, the manufacturer states that, besides having a regular camphorquinone/amine initiator system (CQ), it has introduced an ''initiator booster'' (Ivocerin) able to polymerize the material in greater depth.This germanium-based initiator system has an absorption spectrum very close to that of CQ and was reported to have a higher photo-curing activity than CQ, due to its higher absorption of visible light.[51]

Even though there is a strong correlation between filler amount and modulus of elasticity measured for RBCs.[52, 53]TetricEvoCeram Bulk-fill is an exception, as it shows lowto moderate values for the modulus of elasticity, despite having a high filler content. It must, however, be considered that TetricEvoCeram Bulk Fill also contains pre-polymerized fillers (PPF) up to 50 μm, consisting of inorganic fillers (barium glass, silica) embedded in an already polymerized organic matrix. These are included in the total filler amount (fillers are 80% wtincluding 17% pre-polymers) Thus, the inorganic filler content, which in effect increases the modulus of elasticity is lower.[54]

This special patented filler which is partially functionalized by silanes, acts as a unique shrinkage stress reliever. When the composite is cured, the monomer chains located on the fillers together with the silanes begin a cross-linking process and forces between the individual fillers come into play and place stress on the cavity walls. This stress is influenced by both volumetric shrinkage and the modulus of elasticity of the composite.Due to its low elastic modulus (10 GPa) the shrinkage stress reliever within TetricEvoCeram Bulk Fill acts like a spring (expanding slightly as the forces between the fillers grow during polymerization) amongst the standard glass fillers which have a higher elastic modulus of (71 GPa).[55]

Additionally, the shape of TetricEvoCeram Bulk-fill fillers is approaching round-shaped fillers, which were shown to positively influence the translucency which in return allows light penetration to the deep layers of the composite and sufficient polymerization of the material and in return better physic-mechanical properties including its bond strength to the tooth structure.[56]

Tetric N-Ceram comprises features of nanotechnology. "Nano additives" have been incorporated in a targeted fashion. The rheological modifier contained in Tetric N-Ceram is an example of such a nano additive. As in Tetric Ceram, this modifier is responsible for the material's viscosity and good pliability.[54]

TetricEvoCeram Bulk-Fill presents close properties to those of its conventional counterpart from the same manufacturer (Elastic modulus~ 6–7 GPa, Vickers Hardness Test~ 50)this can explain why the differences between the μTBS values of the two types of composite were not significant.[57]

Some micro-specimens were excluded from bond strength measurement because part of the axial cavity wall was included, which revealed information that may very likely explain the high amount of pre-test failures (ptf's) observed in Group I. **Van Ende et al.,**[5]discovered that the ptf's exceeded 50% in his test group

when bonded to cavities, and that percentage reached 100% when using incremental composite in Class I cavity configuration.

V. Conclusions

Under the limitations of this study, the results suggest that:

1. Bulk-fill composite might be used in cavities with high C-factor in 4-mm depth increments without significantly affecting the μTBS.
2. Bulk-fill composite was a great alternative to Incremental composite.
3. The cavity configuration (C-factor) was an effective variable on the μTBS to dentin, while the placement technique was not.

References:

[1]. Soares CJ, Faria ESAL, Rodrigues MP, Vilela ABF, Pfeifer CS, Tantbirojn D, et al. Polymerization shrinkage stress of composite resins and resin cements - What do we need to know? Braz Oral Res. 2017;31:e62.

[2]. Singhal S, Gurtu A, Singhal A, Bansal R, Mohan S. Effect of Different Composite Restorations on the Cuspal Deflection of Premolars Restored with Different Insertion Techniques- An In vitro Study. J Clin Diagn Res. 2017;11:ZC67-ZC70.

[3]. Kumagai RY, Zeidan LC, Rodrigues JA, Reis AF, Roulet JF. Bond Strength of a Flowable Bulk-fill Resin Composite in Class II MOD Cavities. J Adhes Dent. 2015;17:427-32.

[4]. Labella R, Lambrechts P, Van Meerbeek B, Vanherle G. Polymerization shrinkage and elasticity of flowable composites and filled adhesives. J Dent Mater. 1999;15:128-37.

[5]. Van Ende A, De Munck J, Van Landuyt K, Van Meerbeek B. Effect of Bulk-filling on the Bonding Efficacy in Occlusal Class I Cavities. J Adhes Dent. 2016;18:119-24.

[6]. Versluis A, Douglas WH, Cross M, Sakaguchi RL. Does an incremental filling technique reduce polymerization shrinkage stresses? Journal of dental research. 1996;75:871-8.

[7]. Park J, Chang J, Ferracane J, Lee IB. How should composite be layered to reduce shrinkage stress: incremental or bulk filling? J Dent Mater. 2008;24:1501-5.

[8]. Furness A, Tadros MY, Looney SW, Rueggeberg FA. Effect of bulk/incremental fill on internal gap formation of bulk-fill composites. J Dent. 2014;42:439-49.

[9]. Van Ende A, De Munck J, Van Landuyt KL, Poitevin A, Peumans M, Van Meerbeek B. Bulk-filling of high C-factor posterior cavities: effect on adhesion to cavity-bottom dentin. J Dent Mater. 2013;29:269-77.

[10]. F F, Ar D, Z H. The Effect of Bulk Depth and Irradiation Time on the Surface Hardness and Degree of Cure of Bulk-Fill Composites. Journal of dental biomaterials. 2016;3:284-91.

[11]. Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR, Fleming GJ. Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. J Dent. 2012;40:500-5.

[12]. Armstrong SR, Keller JC, Boyer DB. The influence of water storage and C-factor on the dentin-resin composite microtensile bond strength and debond pathway utilizing a filled and unfilled adhesive resin. J Dent Mater. 2001;17:268-76.

[13]. Ilie N, Kessler A, Durner J. Influence of various irradiation processes on the mechanical properties and polymerisation kinetics of bulk-fill resin based composites. J Dent. 2013;41:695-702.

[14]. Nikolaenko SA, Lohbauer U, Roggendorf M, Petschelt A, Dasch W, Frankenberger R. Influence of c-factor and layering technique on microtensile bond strength to dentin. Dental materials : official publication of the Academy of Dental Materials. 2004;20:579-85.

[15]. Flury S, Peutzfeldt A, Lussi A. Influence of increment thickness on microhardness and dentin bond strength of bulk fill resin composites. Dental materials : official publication of the Academy of Dental Materials. 2014;30:1104-12.

[16]. Betamar N, Cardew G, Van Noort R. Influence of specimen designs on the microtensile bond strength to dentin. J Adhes Dent. 2007;9:159-68.

[17]. Pashley DH, Carvalho RM, Sano H, Nakajima M, Yoshiyama M, Shono Y, et al. The microtensile bond test: a review. J Adhes Dent. 1999;1:299-309.

[18]. Sisodia N, Manjunath MK. Impact of low level magnification on incipient occlusal caries diagnosis and treatment decision making. JCDR. 2014;8:ZC32-ZC5.

[19]. Davari A, Daneshkazemi A, Behniafar B, Sheshmani M. Effect of Pre-heating on Microtensile Bond Strength of Composite Resin to Dentin. J Dent (Tehran). 2014;11:569-75.

[20]. Awang RAR, Masudi S, Mohd Nor W. Effect of desensitizing agent on shear bond strength of an adhesive system. Arch of Orofac Sci. 2007;2:32-5.

[21]. Can Say E, Nakajima M, Senawongse P, Soyman M, Ozer F, Ogata M, et al. Microtensile bond strength of a filled vs unfilled adhesive to dentin using self-etch and total-etch technique. J Dent. 2006;34:283-91.

[22]. Abuelenain D, Abou Neel E, Aldharrab A. Surface and Mechanical Properties of Different Dental Composites2015. 1019-21 p.

[23]. Isaac SZ, Bergamin ACP, Turssi CP, Amaral FLBd, Basting RT, Franca FMG. Evaluation of bond strength of silorane and methacrylate based restorative systems to dentin using different cavity models. J Appl Oral Sci. 2013;21:452-9.

[24]. Abdalla AI, El Zohairy AA, Aboushelib MM, Feilzer AJ. Influence of thermal and mechanical load cycling on the microtensile bond strength of self-etching adhesives. Am J Dent. 2007;20:250-4.

[25]. Nassar A, El-Sayed H, Etman W. Effect of different desensitizing adhesive systems on the shear bond strength of composite resin to dentin surface. Tanta Dental Journal. 2016;13:109-17.

[26]. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, et al. Buonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. J Oper Dent. 2003;28:215-35.

[27]. Nakornchai S, Harnirattisai C, Surarit R, Thiradilok S. Microtensile bond strength of a total-etching versus self-etching adhesive to caries-affected and intact dentin in primary teeth. J Am Dent Assoc. 2005;136:477-83.

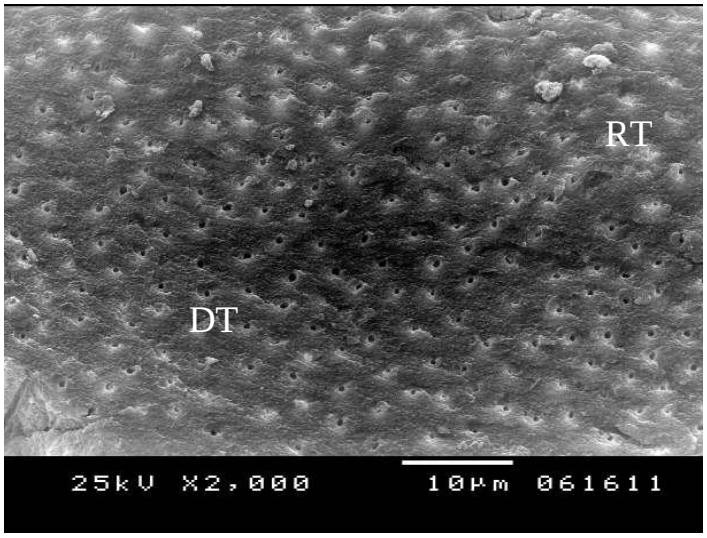
[28]. Rueggeberg FA. State-of-the-art: dental photocuring--a review. J Dent Mater. 2011;27:39-52.

[29]. Roh OD, Chung JH. Micro-shear bond strength of five resin-based composites to dentin with five different dentin adhesives. Am J Dent. 2005;18:333-7.

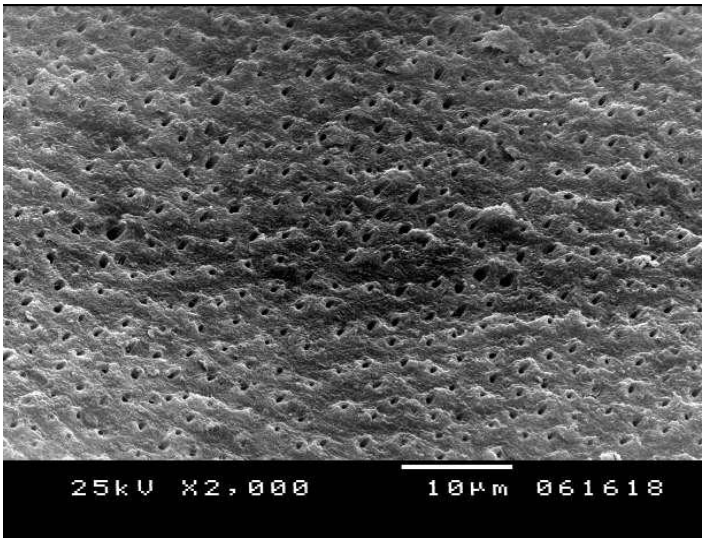
[30]. El Mourad AM. Assessment of Bonding Effectiveness of Adhesive Materials to Tooth Structure using Bond Strength Test Methods: A Review of Literature. Open Dent J. 2018;12:664-78.

[31]. Tang L, Zhang Y, Liu Y, Zhou Y. Influence of EDC on Dentin-Resin Shear Bond Strength and Demineralized Dentin Thermal Properties. Materials (Basel). 2016;9.
[32]. Sano H, Shono T, Sonoda H, Takatsu T, Ciucchi B, Carvalho R, et al. Relationship between surface area for adhesion and tensile bond strength--evaluation of a micro-tensile bond test. J Dent Mater. 1994;10:236-40.
[33]. Shono Y, Ogawa T, Terashita M, Carvalho RM, Pashley EL, Pashley DH. Regional measurement of resin-dentin bonding as an array. Journal of dental research. 1999;78:699-705.
[34]. Frankenberger R, Lopes M, Perdigao J, Ambrose WW, Rosa BT. The use of flowable composites as filled adhesives. J Dent Mater. 2002;18:227-38.
[35]. Perdigao J, Frankenberger R. Effect of solvent and rewetting time on dentin adhesion. Quint Int. 2001;32:385-90.
[36]. Sirisha K, Rambabu T, Ravishankar Y, Ravikumar P. Validity of bond strength tests: A critical review-Part II. J Cons Dent. 2014;17:420-6.
[37]. Yoshikawa T, Sano H, Burrow MF, Tagami J, Pashley DH. Effects of dentin depth and cavity configuration on bond strength. Journal of dental research. 1999;78:898-905.
[38]. Choi KK, Ryu GJ, Choi SM, Lee MJ, Park SJ, Ferracane JL. Effects of cavity configuration on composite restoration. J Oper Dent. 2004;29:462-9.
[39]. Shirai K, De Munck J, Yoshida Y, Inoue S, Lambrechts P, Suzuki K, et al. Effect of cavity configuration and aging on the bonding effectiveness of six adhesives to dentin. J Dent Mater. 2005;21:110-24.
[40]. Bakhsh TA, Sadr A, Shimada Y, Mandurah MM, Hariri I, Alsayed EZ, et al. Concurrent evaluation of composite internal adaptation and bond strength in a class-I cavity. J Dent. 2013;41:60-70.
[41]. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. Journal of dental research. 1987;66:1636-9.
[42]. Braga RR, Ballester RY, Ferracane JL. Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review. J Dent Mater. 2005;21:962-70.
[43]. El-Sahn NA, El-Kassas DW, El-Damanhoury HM, Fahmy OM, Gomaa H, Platt JA. Effect of C-factor on microtensile bond strengths of low-shrinkage composites. J Oper Dent. 2011;36:281-92.
[44]. Price RB, Doyle G, Murphy D. Effects of composite thickness on the shear bond strength to dentin. J Can Dent Assoc. 2000;66:35-9.
[45]. Van Landuyt KL, Snauwaert J, De Munck J, Coutinho E, Poitevin A, Yoshida Y, et al. Origin of interfacial droplets with one-step adhesives. Journal of dental research. 2007;86:739-44.
[46]. De Munck J, Arita A, Shirai K, Van Landuyt KL, Coutinho E, Poitevin A, et al. Microrotary fatigue resistance of a HEMA-free all-in-one adhesive bonded to dentin. J Adhes Dent. 2007;9:373-9.
[47]. D'Arcangelo C, Vanini L, Prosperi GD, Di Bussolo G, De Angelis F, D'Amario M, et al. The influence of adhesive thickness on the microtensile bond strength of three adhesive systems. J Adhes Dent. 2009;11:109-15.
[48]. Nazari A, Sadr A, Saghiri MA, Campillo-Funollet M, Hamba H, Shimada Y, et al. Non-destructive characterization of voids in six flowable composites using swept-source optical coherence tomography. J Dent Mater. 2013;29:278-86.
[49]. Bolhuis PB, de Gee AJ, Kleverlaan CJ, El Zohairy AA, Feilzer AJ. Contraction stress and bond strength to dentinfor compatible and incompatible combinations of bonding systems and chemical and light-cured core build-up resin composites. J Dent Mater. 2006;22:223-33.
[50]. Karatas O, Bayindir YZ. A comparison of dentin bond strength and degree of polymerization of bulk-fill and methacrylate-based flowable composites. J Cons Dent. 2018;21:285-9.
[51]. Moszner N, Fischer UK, Ganster B, Liska R, Rheinberger V. Benzoyl germanium derivatives as novel visible light photoinitiators for dental materials. J Dent Mater. 2008;24:901-7.
[52]. Ilie N, Hickel R. Investigations on mechanical behaviour of dental composites. Clin Oral Investig. 2009;13:427-38.
[53]. Masouras K, Silikas N, Watts DC. Correlation of filler content and elastic properties of resin-composites. J Dent Mater. 2008;24:932-9.
[54]. Schenck L, Burtscher P, Vogel K, Weinhold H. Major breakthrough in the field of direct posterior composite resins-thanks to the combined use of Tetric EvoCeram Bulk Fill and Bluephase Style. Special Feature DZW. 2011;38:3-15.
[55]. Jang JH, Park SH, Hwang I-N. Polymerization Shrinkage and Depth of Cure of Bulk-Fill Resin Composites and Highly Filled Flowable Resin2014.
[56]. Arikawa H, Kanie T, Fujii K, Takahashi H, Ban S. Effect of filler properties in composite resins on light transmittance characteristics and color. Dent Mater J. 2007;26:38-44.
[57]. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent. 2014;42:993-1000.

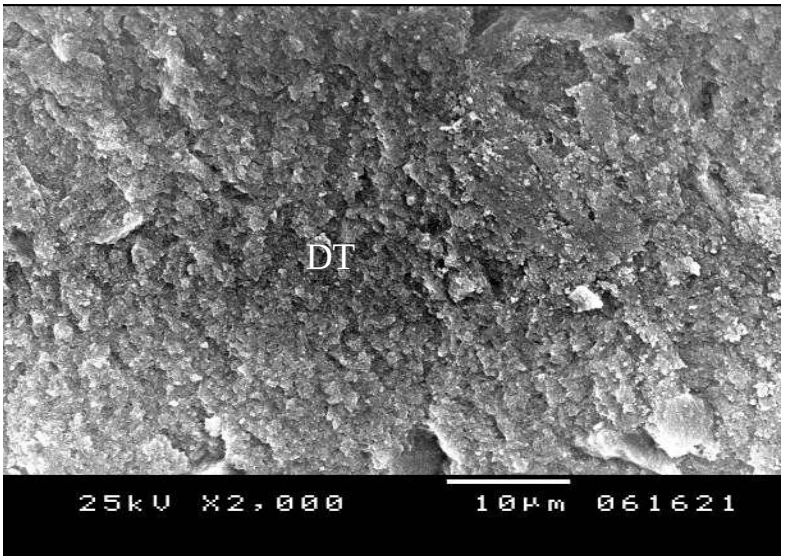
Figures:



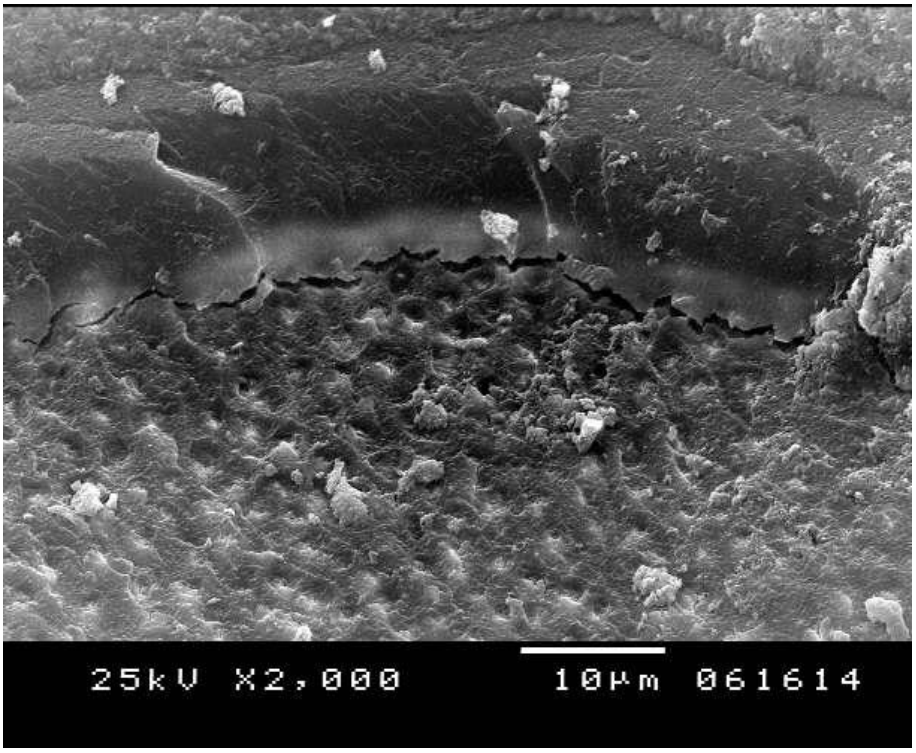
(Fig.1) Fractured surface from subgroup IIA showing adhesive failure. The dentinal tubules (DT) can be observedas well as a few resin tags (RT) (SEM).



(**Fig.2) Fractured surfacefrom subgroup IA showing cohesive failure in dentin (SEM)**



(Fig.3) Fractured surface from subgroup IA showing cohesive failure in composite (SEM).



(Fig.4) Fractured surface from subgroup IIB showing mixed failure. There is both a failure between the composite (C) and the dentin (D) together with a failure within the dentin itself (SEM).

Tables:

Table I: showing the groups and subgroups of the study.

	Group I	Group II
Subgroup A	**Flat** surface group with Tetric N-Ceram nano-hybrid incremental composite	**Class I** cavity group with Tetric N-Ceram nano-hybrid incremental composite
Subgroup B	**Flat** surface group with TetricEvoCeram bulk fill composite	**Class I** cavity group with TetricEvoCeram bulk fill composite

Table II: showing the mean and standard deviation of the microtensile bond strength of the groups and sub groups.

	Group I		Group II	
	Sub-group **A**	Sub-group **B**	Sub-group **A**	Sub-group **B**
Range	5.133- 42.373	4.003 - 38.417	3.253- 29.202	9.76- 26.73
Mean ±SD	21.860 ± 9.363	21.821 ± 10.709	15.568 ± 6.213	17.337 ± 5.441

Table III: showing a comparison between the microtensile bond strength (MPa) of Group I vs. Group II regardless subgrouping using simple T-test:

MPa	Groups						T-Test	
	Group I			Group II			t	P-value
Range	4.003	-	42.373	3.253	-	29.202	2.732	0.008*
Mean ±SD	21.840	±	9.973	16.453	±	5.808		

Table IV: showing a comparison between the microtensile bond strength (MPa) of Group IA vs. Group IIA using simple T-test:

Mpa	Subgroups						T-Test	
	Group IA			Group IIA			t	P-value
Range	5.133	-	42.373	3.253	-	29.202	2.350	0.023*
Mean ±SD	21.860	±	9.363	15.568	±	6.213		

Table V: showing the frequency of each failure mode in the different test groups.

	Adhesive failure	Cohesive failure	Mixed failure
IA	66.67%	26.67%	6.67%
IB	70%	26.67%	3.33%
IIA	80%	20%	0%
IIB	66.67%	26.67%	6.67%

Heba Hassan, etal. "Effect of C- Factor and Placement Technique on the Microtensile Bond Strength of a Self-etch Adhesive to Dentin." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 19(2), 2020, pp. 53-63.