Effect of Different Cavity Configurations on The Micro-Tensile Bond Strength to Dentin Using Low Shrinking Resin Composites

Thesis Submitted to
Faculty of Oral and Dental Medicine, Cairo University
In Partial Fulfillment of the Requirements for
Master Degree in Operative Dentistry

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2002

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2009

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Dedication

I Dedicate This Work

To My Devoted & Encouraging Parents,

To My Supportive & Loving Husband

& To My Beloved Children.

Acknowledgement

I would like to express my deepest appreciation and gratitude to ***Prof. Dr. Hussein Abd Al-Fattah Gomaa*** *Professor of Operative Dentistry, Faculty of Oral and Dental Medicine, Cairo University, for his help, support, great effort and meticulous supervision throughout this work and through years of my dental career.*

A great gratitude is owed to ***Prof. Dr. Ola Ibrahim Fahmy****, Professor of Operative Dentistry, Faculty of Oral and Dental Medicine, Cairo University. From whom I have learned a lot and will always be grateful to her respected personnel, sincere support and tremendous encouragement. It was a great honor to work under her guidance and supervision.*

I'm greatly honored to express my deepest appreciation to ***Dr. Dina Wafik El-Kassas****, Lecturer of Operative Dentistry, Faculty of Oral and Dental Medicine, Cairo University, for her close supervision, precious suggestions, constructive criticism, encouragement, tremendous support, understanding and generous care.*

I would like to cordially thank all the staff members and colleagues at The Department of Operative Dentistry, Faculty of Oral and Dental Medicine, Cairo University, in particular ***Prof. Dr. Mohamed Riad Farid,*** *Professor and Head of The Department with a direct special thanks to* ***Prof. Dr. Inas Mohy El-Din****, Professor and Former Head of The Department for her precious unforgettable help and support through years of my dental career.*

Special thanks and great appreciation are extended to ***Prof. Dr. Jeffery A. Platt,*** *Professor and Head of Division of Dental Materials, School of Dentistry, Indiana University, USA, and to whom I owe great respect and gratitude, for his unforgettable help and support throughout the practical course of this work.*

I would like to extend my gratitude to staff members of Restorative Dentistry Department, School of Dentistry, Indiana University and to ***Dr. Hatem El-Damanhoury****, Lecturer of Operative Dentistry, Suez Canal University, for their friendly support, valuable assistance, concern and cooperation.*

Special thanks are extended to ***Dr. Wolfganag Weinmann and Dr. Rainer Guggenberger,*** *3M ESPE, Seefeld, Germany, for their constant scientific help and technical support.*

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Polymerization shrinkage is one of the dental clinician's primary concerns when placing direct resin-based posterior composite restorations. Polymerization of dimethacrylate-based composites is always accompanied by substantial volumetric shrinkage in the range of 2 to 6% **(Bowen, 1967; Walls et al, 1988; Labella et al, 1999)**. During polymerization, the molecules previously existing at Van der Waal's force distances become linked through shorter covalent bonds. The reduction in free volume within the monomer structure as it transforms to a more densely packed polymer contributes to the overall contraction **(Patel et al, 1987; Venhoven et al, 1993**).

This shrinkage manifests itself as stress when the resulting strain in composite restoration is hindered by the confinement of the material bonded to the tooth walls. Thus the material is restrained from changing shape, except at the free surface, and further internal stresses will result **(Versluis et al, 1996).**

The contraction stress has a detrimental effect on the bond strength between resin composites and tooth substrate **(Yoshikawa et al, 1999; Chen et al, 2001).** The maturing bond strength is in competition with the developing shrinkage stress of the setting material. If the forces of polymerization contraction exceed dentin bond strength, interfacial sealing is lost resulting in failure of the composite tooth interface (adhesive failure) **(Davidson et al, 1984).** The created gaps will lead to clinical problems, such as microleakage, post-operative sensitivity, marginal staining and secondary caries **(Pashly, 1990)**. Even when the integrity of the bond at the tooth/restoration interface is maintained, contraction stress will be transferred to the tooth and will be a potential source for cuspal deformation and enamel cracks **(suliman et al, 1994; Meredith and Setchell, 1997; Braga and Ferracane, 2002).**

Previous studies have shown that the induced polymerization stress is influenced by characteristics of the composite such as filler content **(Condon and Ferracane, 2000)**, polymerization rate **(Bouschlicher and Rueggeberg, 2000)**, degree of conversion **(Braga and Ferracane, 2002)** and modulus of resin elasticity as well as by characteristics of the cavity to be restored. In particular, the influence of the confinement conditions imposed on the composite (C- factor), restoration’s volume and restorative techniques in addition to the compliance of the bonding substrate **(Alster et al, 1997 b)**.

Feilzer et al in 1987 & 1989 and **Davidson and Feilzer in 1997** reported that the extent of polymerization shrinkage stress can be influenced by the cavity configuration (C-factor, bonded surface/ unbonded free surface). As the C-factor increases, the compensation for polymerization shrinkage by the flow of composite decreases, and thus, the polymerization stress at the bonded surface increases **(Lee et al, 2007).**

Numerous compensatory phenomena were introduced by manufacturer to limit the build up of polymerization shrinkage stresses. Recently a new category of resin composites are introduced known as low shrinkage composites. Innovations in this category ranged between modifications performed to the fillers with the introduction of "nanofilled composite" **(Roeters et al, 2005)** or innovations performed to the resin matrix. Alternatives to dimethacrylates for dental composite matrices were introduced by **Guggengerger and Weinmann in 2000**, who described a family of molecules called siloranes, the name being derived from the combination of siloxanes and oxiranes (epoxies). These molecules polymerize by cationic photo-initiation and produce dental composites with comparable properties and reduced shrinkage compared with Bis – GMA- based materials.

The rationale behind testing the adhesive’s bond strength is that the stronger the adhesion between tooth and biomaterial, the better it will resist stress imposed by resin polymerization and oral function **(De Munck1et al, 2005).** When using conventional bond strength test methods, the tendency exists for specimens made with a large bonding surface area to exhibit cohesive fracture in the dentin **(Erickson et al, 1989; Perinka et al, 1992)**. The introduction of the micro-tensile test by **(Sano et al, 1994)** has facilitated the study of regional bond strengths, providing more information regarding adhesion within clinically relevant cavity preparation. Moreover, the small size of the specimens has led to a more favorable stress distribution, and thus the failure of bonds which are closer to their true ultimate strengths **(Pashley et al, 1995)**.

Theoretically speaking, the use of non shrinking resin composite could balance the effect of cavity configuration. Thus, this study was carried out to investigate the effect of different cavity configuration factors on the micro-tensile bond strength to dentin using low shrinking resin composites.

This study was carried out to investigate the effect of different cavity configurations on the micro-tensile bond strength to dentin using low shrinkage resin composites.

Objectives:

1. To measure the micro-tensile bond strength of low shrinkage resin composites in different cavity configurations and compare it to that of conventional methacrylate-based resin composite.

2. To measure the polymerization shrinkage stress and monitor the shrinkage kinetics of the low shrinkage resin composites in comparison to the conventional methacrylate-based resin composites.

3. To determine the flexural modulus of the three materials under investigation.

Successful adhesion of resin based composites to tooth structure is an indispensable prerequisite for clinical success. The induced shrinkage stress of these materials during polymerization may endanger the durability of the bond strength to the tooth structure and consequently, jeopardize the clinical performance of the restoration. Therefore, studying the factors affecting bond strength is a necessity for better understanding of the material's behavior.

The maximum setting shrinkage develops in the earliest stage, but fortunately in this stage only chain formation takes place and cross-linking is not yet at full reaction, allowing molecules to slip into new positions. In general, a majority of the shrinkage can be resolved in the early plastic state (before the polymerization gel point) by flow, or minimizing contraction stresses by allowing the composite volume to change shape **(Ferracane et al, 1981; Davidson and de Gee, 1984)**.

Simultaneously, the polymer gains rigidity as the lengthening chains become entangled with one another and bridges of covalently bonded molecules link chains together to form a cross-linked network. The result is a loss of freedom of motion for individual chains as they become trapped within a rapidly stiffening structure, as indicated by the nearly instant increase in stiffness or elastic modulus **(Dauvillier et al, 2000).**

At this point any additional change in dimension due to polymerization contraction generates stress, since subsequent shrinkage is obstructed and the material is rigid enough to resist sufficient plastic flow to compensate for the original volume **(Davidson and Feilzer, 1997)**. According to Hooke's law, where stress is equal to the elastic modulus multiplied by the strain, thus, increases in shrinkage, combined with an increasing elastic modulus, produce increased stress within the composite structure. The maximum stress rate occurs early in the polymerization reaction in association with this rapid gain in rigidity **(Davidson and de Gee, 1984)**.

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The magnitude of these predominantly contraction generated stresses and the strength of the adhesive bond to tooth structure, which is expected to counteract these stresses become the next concern. If the resulting stresses within the material and at the tooth-restoration interface exceed the adhesive strength of the restorative, it can have a deleterious effect on marginal integrity in terms of bond strength and gap formation **(Davidson et al, 1984; Pashly, 1990; Yoshikawa et al, 1999).**

Several factors affect these stresses, including the polymerization rate of the composite, its formulation, including filler and monomer composition **(Condon and Ferracane, 2000; Bouschlicher and Rueggeberg, 2000),** and the constraints imposed by the geometry of the cavity preparation; when resin composite bonds to walls and floor of prepared cavity, a competition occurs between the opposing walls, as the restorative resin shrinks during polymerization and pulls them closer together **(Braga et al, 2005).** Only the flow of the material from the unbonded surfaces can compensate for the materials shrinkage and decrease the stresses generated at the bonded walls **(Davidson et al, 1984**; **Feilzer et al, 1987**). The magnitude of this phenomenon depends on the configuration of the cavity and hence is called the cavity configuration factor or C-factor. It was reported by several investigators that the increase in C-factor is associated by progressive deterioration of the bond strength (**Yoshikawa et al, 1999; Armstrong et al, 2001; Nikaido et al, 2002; Price et al, 2003; Choi et al, 2004; Shirai et al, 2005).**

The majority of studies dealing with dentin bond strengths were carried out in flat bonding surfaces. Most of the available data regarding bond strength in cavities with different C-factors either compared the bond strength in box like cavities (C5) to flat bonding surface (C1) **(Yoshikawa et al, 1999; Armstrong et al, 2001; Nikaido et al, 2002; Nikolaenko et al, 2004**) or were carried on artificial substrate for bonding **(Kishikawa et al, in 2005)**. Therefore they do not reflect all the clinical situations in addition to the misleading data revealed when an artificial model was used. Mainly the results obtained from these studies indicated the negative potential of cavity geometries on dentin bond strength. No sufficient data is available regarding the effect of cavity configuration when low shrinkage composites are used. Consequently the objective of this in vitro study was to investigate how the bond strength of materials with low shrinkage stress will be affected in cavities with different configurations.

Human molar teeth were selected in this investigation, as the size of their occlusal surfaces is sufficient to prepare cavities with relatively large dimensions (4.5X4.5 mm). These dimensions were chosen in order to obtain adequate number of beams from the center of the restoration of each tooth.

A direct relation between the volume of the restoration in a confined system as a prepared cavity and the exerted polymerization shrinkage stress on this cavity walls was reported by many investigators **(Atai and Watts 2006; Braga et al, 2006; Witzel et al, 2007)**, thus, any change in the volume of composite specimen will severely affect the magnitude of the resultant shrinkage stress and add a new variable to the study. Accordingly, altering cavity configuration in this study were carried out following the methodology reported by **Mallmann et al in 2003,** which allowed the change in cavity configuration without parallel change in the volume of composite.

Silorane-based composite [Filtek Silorane (SIL)] was selected in this study as a new generation of low shrinkage composite, which was claimed by the manufacturer to have lower polymerization shrinkage than all currently available composites and that was attributed to the difference in the polymerization mechanism **(Weinmann et al, 2005).** The second resin composite under investigation [Aelite LS (AL)] was selected to represent low-shrinkage methacrylate-based composites, where the higher molecular weight Bis-EMA replaced most of the lower molecular weight TEGDMA decreasing the double bonds per unit of weight as reported by **Sideridou et al, 2003; Yap and Soh, 2004 and Cadenaro et al in 2007**. Therefore this material was selected in an attempt to compare bond strengths of materials with different chemistry, polymerization kinetics and polymerization shrinkage properties in different cavity configurations. A conventional methacrylate-based composite [Filtek Z250 (Z)] was used as a control. Each material was bonded to the tooth surface with its corresponding adhesive system following the recommendation of Filtek Silorane manufacturer, due to its different