YEDITEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF RESTORATIVE DENTISTRY

SHEAR BOND STRENGHT OF THREE BULK-FILL COMPOSITES AND CONVENTIONAL COMPOSITES RESTORATIVE MATERIAL TO DENTINE : IN-VITRO

MSc Master thesis

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ABSTRACT

The aim of this in vitro study is to assess the shear bond strength of different Bulk fill composites with two steps self etch adhesive system to dentin.

Twenty extracted sound human molar teeth were selected and sectioned mesiodistally, then the substrate surfaces were roughened with 600- grit silicon carbide grinding paper to achieve flat homogeneous dentin surfaces and the samples were then equally and randomly divided into 4 groups, 10 samples for every group . The bonding system (AdheSE, Ivoclar-Vivadent)was used in accordance with the manufacturer's instructions. A mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) was adapted on the specimen and filled with resin composite in two consecutive increments of 2 mm for the regular RC (Filtek™ Z250 3M/ESPE, St. Paul, MN, USA) and in one 4-mm increment for the bulk-fill RCs(Venus® bulk fill ,Heraeus Kulzer GmbH, Hanau, Germany), (SureFil SDR flow; Dentsply, Konstanz, Germany) and (everX Posterior GC, Tokyo, Japan), followed by polymerizing each increment for 20 s (Bluephase 20I; Ivoclar-Vivadent). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine.

The statistical analysis of the results were performed by "Oneway Anova" and"Tukey HSD" tests ($p<0.05$).

The highest mean value was for the control group (Filtek Z250 3M/ESPE, St. Paul, MN, USA),after that (SureFil SDR flow; Dentsply, Konstanz, Germany),than (Venus® bulk fill ,Heraeus Kulzer GmbH, Hanau, Germany),and the last one was (everX Posterior GC, Tokyo, Japan).

No significant differences were found between the different groups P=**0,129** ($p > 0.05$).

Keywords: Bulk fill composite, shear bond strength, two steps self etch adhesive.

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List of Abbreviations

mm.	Millimetre
min.	Minute
µm.	Micrometre
nm.	Nanometre
˚C	Centigrade
RBCs	Resin based composites
RCs	Resin composites
SBS	Shear bond strenght
DC	Degree of conversion
TEGDMA.	triethylene glycol dimethacrylate
EBADMA.	ethoxylated bisphenol-A-dimethacrylate;
Bis-GMA.	bisphenol-A-glycidyl dimethacrylate;
Bis-EMA.	ethoxylated bisphenol-Adimethacrylate
UDMA.	urethane dimethacrylate
MPTMS	3-methacryloxypropyl trimethoxysilane
SD.	standard deviation
ANOVA.	analysis of variance
n.	number of specimen
Vo l% .	volume percentage
W t% .	weight percentage
DMAEMA	dimethylamino ethylmethacrylate
CQ	Camphoroquinone
PPD	1-phenyl-1,2-propanedione
(BHT	2, 6-di-tert-butyl-methylphenol
MEHQ	hydroquinone monomethylether

1. GENERAL INTRODUCTION

1.1 Historical Background of Dental Resin Composites

Early attempts at aesthetic restoration materials were focused on silicate cements. Solubility problems with these materials gave rise to the development of unfilled acrylic systems[1].

The 1950s saw the introduction of unfilled acrylic resin based on Methyl Methacrylate. The method of creating fine grains of polymer, which could be softened by a monomer of the same composition, was devised in Germany by Kulzer GmbH. This methodology allows the production of dental materials in a desired shape. Acrylic-based materials have since retained a prominent position in restorative and prosthetic dentistry. Restoration with methyl methacrylate was associated with many problems, such as a polymerization shrinkage up to 20-25%, poor color stability, low stiffness and lack of adhesion to the tooth structure [2]. In 1951, Knock and Glenn [3] developed a new type of restorative material, which was supposed to solve the polymerization shrinkage problem, by including inorganic filler particles in the resin. The first versions showed high wear and discoloration, due to absence of coupling agent between the filler particles and the resin matrix. In the early 1950s, Bjorksten and Yeager [4] published an article concerning a silane coupling compound, which enhanced bonding between ceramic surfaces and resin. In 1955, Michael Buonocore discovered the concept of acid-etching to improve the adhesion of acrylic resin to the enamel surface [2].

A notable development of composite materials is the invention of bisphenol glycidyl dimethacrylate (Bis-GMA) by Bowen in 1962 [5]. The advantages of Bis-GMA over traditional polymethyl methacrylate are lower volatility and diffusion into tissues, higher cross linking ability, less polymerization shrinkage and rapid hardening under oral conditions [6].

Robert Chang in 1969 and Henry Lee in 1970 were the first to implement the use of composite in the paste/liquid form [7]. The late 1970s saw the development of a photo-polymerized resin composite system [8]. Such a polymerization method provided dentists with the ability to polymerize a composite at a fast rate, upon placing and contouring. At first, an ultraviolet light source (365 nm) was used to provide the required light energy, but its shallow polymerization and iatrogenic side-effects led to its replacement by visible light (427-491 nm), which is currently in use and undergoing further development [9].

The introduction of new bonding systems and composites has had a major impact on restorative dentistry. It not only brought a change in materials and techniques, but also a change in treatment philosophy called minimal invasive dentistry[10,11].

1.2 Composition of Dental Resin Composites

Resin-based composite materials are very complex mixtures composed of an organic phase, an inorganic filler, a coupling agent that improves filler/resin interactions and other minor additives including polymerization initiators, stabilizers and coloring pigments [12,13].

1.2.1 Organic Polymer Resin Matrix

The organic phase (matrix resin) consists of a mixture of various polymerizable monomers such as:

1.2.1.1 Dimethacrylate

The resin phase in most commercially available composite resins comprises the aromatic base monomer bisphenol-A glycidyl dimethacrylate (Bis-GMA). Bis-GMA is a long-chain monomer with two methacrylate groups available for cross-linking polymerization. However, due to its large size, it is very viscous and it quickly reaches the gel point of photopolymerization, resulting in a relatively low degree of conversion (DC) due to the retardation of the diffusion of the monomer to the radical sites on the relatively immobilized network structure [14]. Also, the high viscosity limits the filler loading capacity of dental composites [15].

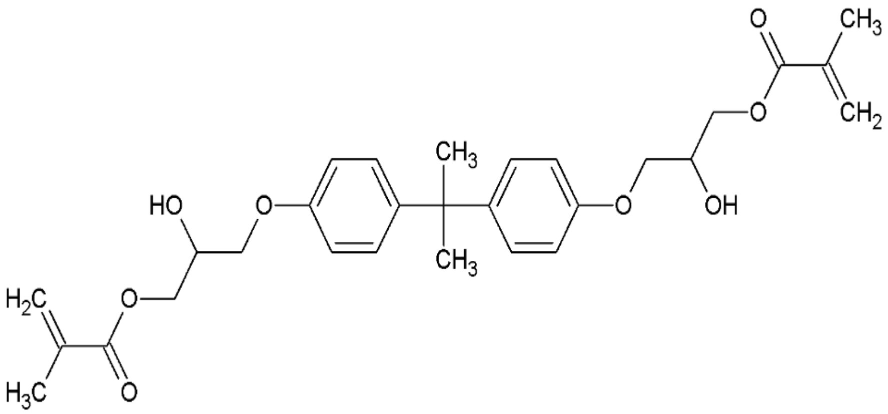


Figure 1.1 Chemical structure of Bis-GMA

This difunctional monomer has relatively low polymerization shrinkage (≈6. 0%); free-radical polymerization, stimulating rapid hardening; low volatility; good mechanical properties when the monomer is cured and production of stronger and stiffer resins [16]. The di-functional monomer is better than methyl methacrylate, due to its large molecular size and chemical structure [17]. As a result of its high strength and hardness, Bis-GMA is more widely used as an organic monomer for dental composite materials [18]. The hydrogen bonding interactions that occur between hydroxyl groups result in the high viscosity of Bis-GMA [19, 20] (1.0-1.2 kPa.s at 23˚C) [16]. To solve this viscosity issue, manufacturers typically dilute the monomer with a more fluid comonomer: triethylene glycol dimethacrylate (TEGDMA) [21]. In addition to this, the aromatic monomer Bis-GMA is much more rigid than dimethacrylate EGDMA and TEGDMA [17].

Urethane dimethacrylate UDMA 1,6-bis[2-(methacryloyloxy) ethoxycarbonylamino]-2,4,4-trimethylhexane has lower viscosity (approximately 11,000 mPa.s at 23˚C) and excellent flexibility which leads to better durability [22]. Furthermore, it offers an improvement in mechanical properties compared with Bis-GMA [23.24]. and similar or slightly less water sorption in comparison with Bis-GMA [25].

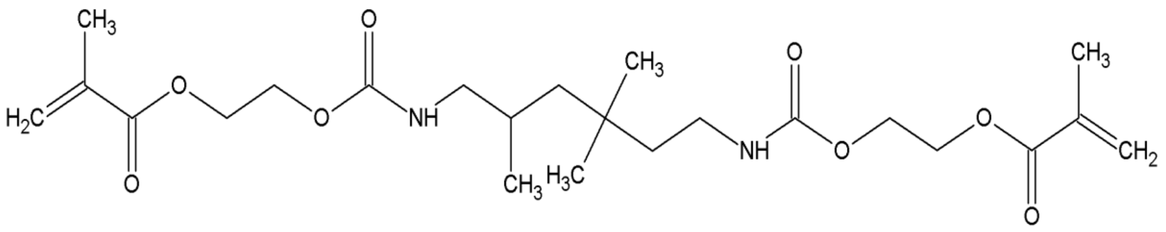


Figure 1.2 Chemical structure of UDMA

UDMA has been used alone or in combination with other monomers, such as BisGMA and TEGDMA. triethylene glycol dimethacrylate TEGDMA has less viscosity than Bis-GMA [19] (10 mPa.s 23˚C[17]). This lower viscosity monomer may comprise 10-50% of a composite resin's content [26]. Typically, a 1:1 ratio of TEGDMA and Bis-GMA is used. A small flexible molecule is found in this monomer, which not only forms cross links, but is also found to cyclise [27]. TEGDMA enhances the molecular mobility in the polymerization process and delays the gel point of photo-polymerization because of its low viscosity. Composite formulations with higher amounts of TEGDMA usually exhibit higher DC and allow increased filler concentrations, but also exhibit higher polymerization shrinkage [28] and higher hydrophilicityof the composite[29].

TEGDMA results in a clinically objectionable increase in polymerization shrinkage [30, 31]. Thus, monomers such as ethoxylated bisphenol-A dimethacrylate (BisEMA), with low viscosity and high MW, are found in many commercial formulations, either partially or as a replacement of TEGDMA (32). Dental polymers based on BisEMA usually exhibit higher DC and lower polymerization shrinkage than the typical Bis-GMA/ TEGDMA resins (14).

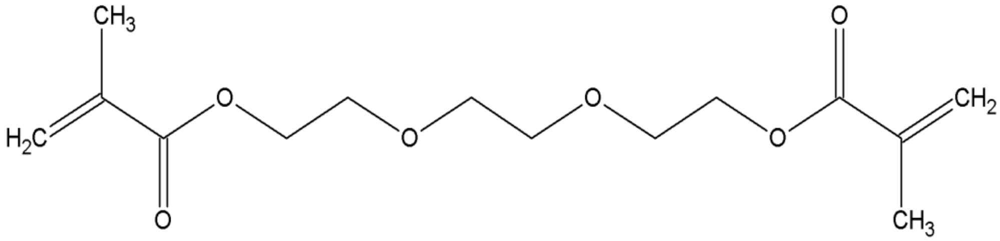


Figure 1.3 Chemical structure of TEGDMA

1.2.1.2 Non-Dimethacrylate

1.2.1.2.1 Ormocers

In dental biomaterials, pure Organically Modified Ceramics (Ormocers) matrix or a combination of Ormocers organic matrix with dimethacrylate has been used in restorative dentistry to overcome the disadvantages of conventional dimethacrylate matrix. the large size of the monomer molecule minimises polymerisation shrinkage (33,34) and wear (35,36). Ormocers are hybrid materials that are prepared by varied processing based on nano-scale technology, which combines organic/inorganic components on a nanoscopic scale through the sol-gel method instead of conventional physical mixing of the different components of a matrix. The organic part is responsible for the cross-linking network, flexibility and optical properties. The inorganic part (glasses, ceramics) provides chemical and thermal stability [37].

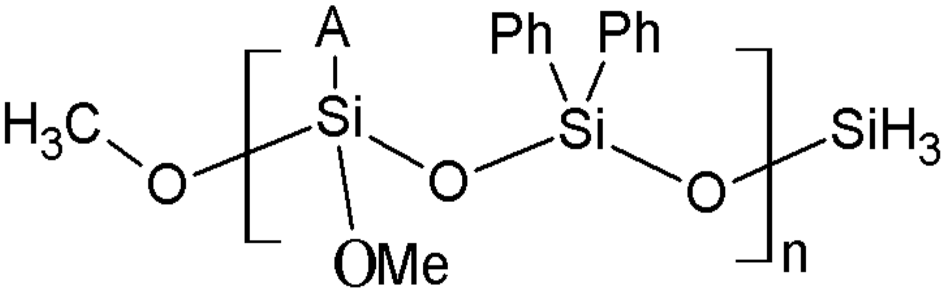


Figure 1.4 Molecular structures of Ormocer

1.2.1.2.2 Silorane Restorative Materials

The name silorane is derived from the combination of its chemical building blocks siloxanes and oxiranes. The siloxane block acts like a backbone for the silorane structure and also it improves the physical properties of composite by providing hydrophobicity to the silorane thus reducing the water sorption. Moreover this hydrophobic nature tends to absorb less stain from a normal daily diet [38].

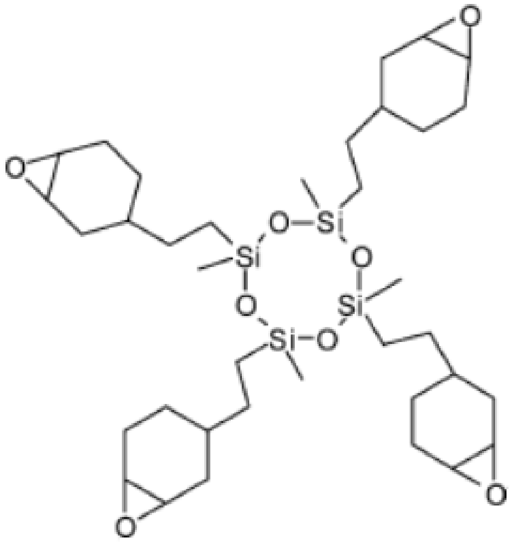


Figure 1.5 Chemical structure of Silorane

The network of siloranes is generated by the cationic ring opening polymerization of the cycloaliphatic oxirane groups, which results in low shrinkage and consequently low polymerization stress [38]. The major contrast between silorane and methacrylate based composite curing is that methacrylates are cured by free radical intermediates whereas siloranes are cured by polymerization of oxiranes via cationic intermediates. Silorane based materials have lower polymerisation shrinkage, but an overall mixed mechanical and higher flexural strength and fracture toughness than methacrylate based restorative materials [39]. However a recent study has shown that silorane based materials exhibited higher colour change and surface degradation [40].

1.2.2 Inorganic Filler

Many properties of material for composite restoration are improved by increasing the amount of fillers [17]. Fillers are used in dental composites to provide strengthening[41, 42], increased stiffness [43, 44], reduced dimensional change when heated and cooled [45, 46], reduced setting contraction [47], increased radiopacity [48], enhanced aesthetics, and improved handling .There is a direct relation between the physical/mechanical properties of the resin composite and the amount of filler added[19].

There is a wide range of fillers available. Glass particles are the most common, due to their improved optical properties. Previously, quartz was favoured and very commonly used. This was because of its better mechanical properties, availability and stability in contrast to other fillers [49]. However, due to the hardness of quartz particles, enamel attrition was increased [50]. This feature has led to the decline of quartz and increase in popularity of glass. Other commonly used fillers include borosilicate glass, lithium, barium aluminium silicate, and strontium or zinc glass. Silica particles are commonly used because of their enhanced polishability. A range of silica-based glass fillers is available, including amorphous or colloidal silica, fused silica and sol-gel zirconia silica. Currently, nano-fillers sized particles are used because of their mechanical and aesthetic properties [19].

1.2.3 Coupling Agent

Since polymeric matrix is hydrophobic, whereas the silica-based filler is hydrophilic, a durable connection must form between these two phase to obtain an acceptable properties of resin composite during polymerization. Bonding is achieved by the manufacturer treating the surface of the fillers with a coupling agent. the coupling agent used for dental resin composites typically consists of a molecule that has silanol (Si-OH) groups on one side and methacrylate groups (containing C=C) on the other. These molecules have the ability to bond covalently, with both the silicon-oxygen groups in the silica-based fillers and the methacrylate groups of the resin matrix. This bond assists in stress distribution over the bulk material and its transition from the weak organic matrix to the inorganic filler particles that possess higher mechanical properties. It also enhances the dispersability of silanated fillers in the resin matrix [50]. Furthermore, it increases the resistance of resin-composite to hydrolytic degradation [51].

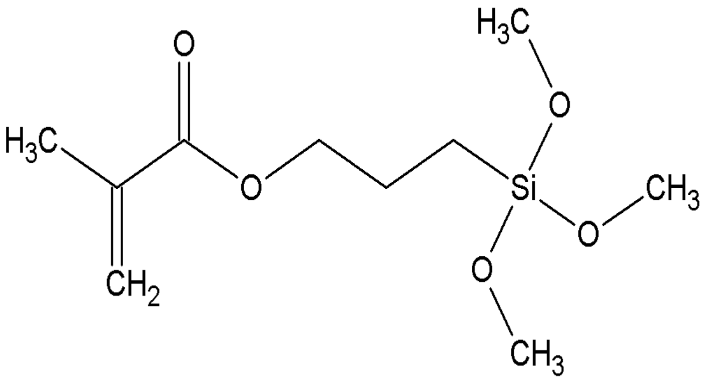


Figure 1.6 Chemical structure of MPTMS

In methacrylic resin based dental composites, the bond between the polymer matrix and the filler particles is usually accomplished by the use of the silane coupling agent, 3-methacryloxypropyl trimethoxysilane (MPTMS). It is a bifunctional molecule capable of reacting through its alkoxysilane groups with the filler, with itself, and with the resin, by virtue of its methacrylate functional group [50]. However, MPTMS is not considered being a good choice of surfactant for zirconia surfaces since the Zr-O-Si bond is not as stable towards hydrolysis as the silicon counterpart, siloxanes and it has been reported that silanes are not always able to bind to zirconia[52]. Several studies have showed that methacrylate-decyl dihydrogenphosphate (MDP) is a better coupling agent than MPTMS for zirconia systems[53,54,55]. In order to improve the quality and durability of the matrix/filler interface, more hydrophobic and flexible silane coupling agents other than MPTMS have been used [56]. A significant advantage of silane coupling agents is that the hydrolysis (and reformation) of the chemical bond between silane coupling agents and filler materials is a reversible process. This is beneficial as it may reduce internal stresses in the material[57].

1.2.4 Initiators and Accelerators

1.2.4.1 Chemically Activated Resins

Reacting benzoyl-peroxide and a tertiary amine initiate the polymerization of chemically activated composite resins. The combination of these two materials (one paste containing a chemical activator and the other containing a chemical initiator) results in the production of a free radical. The initiator, benzoyl peroxide, which is activated by the tertiary aromatic amine N, N-bis (2- hydroxyethyl)-p-toluidine, is the component that most chemically activated composite materials contain. A multistep process leads to the formation of the polymerization-initiating benzoyl radicals [58]. the use of chemical polymerization was limited by decreased colour stability of the initiator chemistry, reduced mechanical properties due to increased porosity produced on mixing of the two components [59], inconsistent extent of polymerization and also clinically unacceptable times to realise cure [60].

1.2.4.2 Light-Activated Resins

Light activation is the most common method of curing dental composites. Camphoroquinone (CQ) is the photo-initiator in light-activated dental composites. It is sensitive to blue light in the 470-nm region of the electromagnetic spectrum. CQ reactivity is further improved by the addition of an amine-reducing agent such as dimethylamino ethylmethacrylate (DMAEMA), ethyl-4-dimethylaminobenzoate (EDMAB), or N, N-cyanoethyl-methylaniline (CEMA). CQ and amine concentrations vary in commercial composites from 0.2 to 1.2 wt% [36]. Another photoinitiator, 1-phenyl-1,2-propanedione (PPD), which has an absorption peak near 410 nm has also been suggested as an alternative [61].

A)

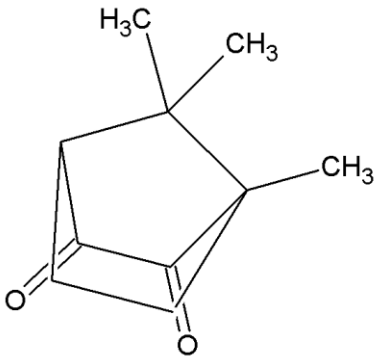
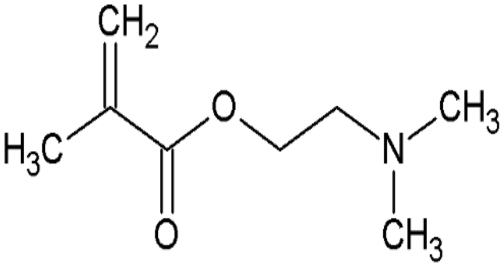


Figure 1.7 Chemical structures of photo-initiator system, A) CQ



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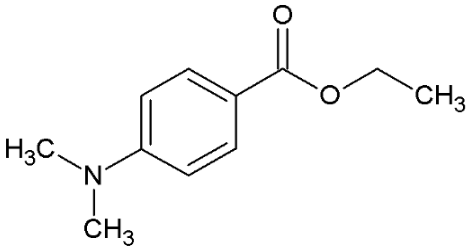

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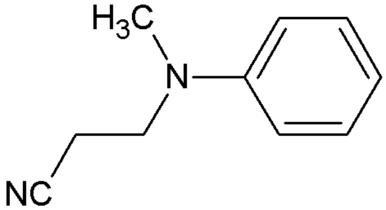

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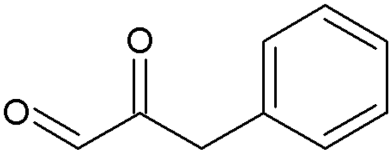

E)

Figure 1.8 Chemical structures of photo-initiator systems, B) DMAEMA; C) EDMAB; D) CEMA; E) PPD

1.2.5 inhibitors and Stabilizers

Inhibitor systems such as phenols, e.g. 2, 6-di-tert-butyl-methylphenol (BHT) and hydroquinone monomethylether (MEHQ) are used for their chemical stability in order to prevent unwanted polymerization when the material is exposed to the room light or during storage. UV photostabilizers provide colour stability and minimize the effects of UV light on the amine compounds in the initiator system, which can otherwise cause discolouration over a medium to long time period. Examples of such photostabilizers include 2-hydroxybenzophenones and 3-(2-hydroxyphenyl)-benzotriazols, in amounts of 0.10 to 0.50% wt [62].

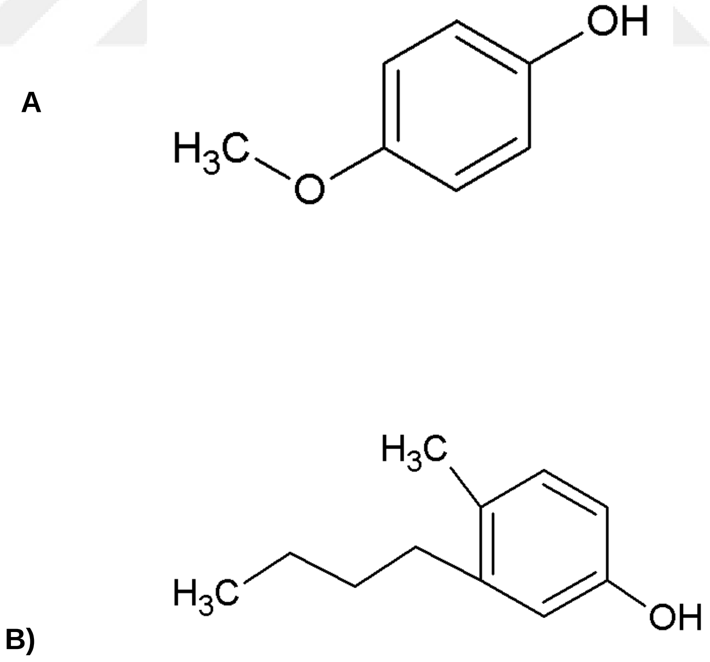

Figure 1.9 Chemical structures of inhibitor systems, A) BHT; B) MEHQ

1.2.6 Pigments

The main advantage of dental resin composites is their ability to approximate the natural colour of teeth. A variety of shades and translucencies of dental restorative materials were introduced in the 1950s. This allowed an improvement in the aesthetic performance of restorations [63]. Visual colouration of dental composites (shading) is achieved by adding different pigments, which often consist of different metal oxides that are added in minute amounts. Metal oxides pigments, such as ferric oxide (Fe2O3, red) or ferric hydroxide (Fe(OH)3, yellow), are the most commonly used pigments ,These optical modifiers can affect transmission of curing light through layers of resin composite and thus the darker the shade the more curing time is needed. [62].

1.2.7 Viscosity Controllers

Viscosity is a measure of the resistance of a fluid. The flow of uncured resin composites is dependent on the intrinsic rheology of the matrix monomers [64]. The Bis-GMA monomer has a high viscosity at room temperature as a result of its rigid molecular structure and hydrogen bonds. This in turn results in the need to dilute Bis-GMA with a low viscosity monomer to form an organic matrix. Studies have shown that the viscosity of a resin composite decreases with an increase in the amount of low molecular weight diluting monomer (TEGDMA) [65-66]. TEGDMA is the lowest viscous resin, as compared with the other two most commonly used monomers: 2-hydroxyethyl methacrylate (HEMA) and 3-hydroxypropyl methacrylate (HPMA). This may be due to the fact that TEGDMA is a larger molecule [64].

The rheological properties of resin composites can be controlled with the use of inorganic fillers. Larger filler particles have a lower viscosity than smaller filler size particles since a smaller filler size requires a higher number of filler particles to preserve the filler volume. Consequently, the total active area increases, resulting in an increase in interactions between filler particles and the resin matrix, and between the filler particles themselves [65].

1.3 Classification of Resin-composites

1.3.1 Types of Resin-composites According to the Filler Particle Size

1.3.1.1 Macrofilled (Conventional) Resin Composites

Macrofilled composites were first introduced in the late 1950s [67]. They were the result of grinding larger particles, consisting of radiopaque glass, quartz or ceramics, into smaller particles by mechanical means [62]. Fillers of this nature contained glass or quartz filler particles, with sizes ranging from 0.1µm to 100 µm, added to the resin matrix up to 70-80% wt. This resulted in better properties as compared to unfilled resin polymers. Macrofilled composites do remain stronger than microfilled composites [68]. However, there were also many disadvantages, including poor wear resistance due to crack propagation at the matrix/filler interface and loss of the filler particles because of the large size and extreme hardness of the filler particles[69], which in turn leads to poor polishability as well as early discolouration and staining due to surface roughness[70]

1.3.1.2 Microfilled Resin Composites

Microfilled resin composites were a development of the late 1970s. The filler size averages about 0.02 µm within a range of 0.01- 0.05µm of amorphous silica particles in an organic matrix, to obtain filler content of 35% wt. The filler loading may be increased by pre-polymerizing the resin containing the colloidal silica, grinding it into particles and incorporating it as filler. This would allow an increase of 50-60% wt [19,71]. Microfilled resin composites give the final finish a high degree of smoothness, while the surface becomes even smoother with time, which is highly advantageous. They are most favoured where a moderate strength is required in conjunction with an aesthetic and smooth finish restoration [72].

1.3.1.3 Hybrid Resin Composites

The development of hybrid materials has increased filler loading of RBCs and has aimed to combine the improved mechano-physical properties of microfills with higher filler loading achieved in traditional RBCs [43]. Bimodal ‘hybrid’ materials contain two distinct filler size distributions in the same matrix consisting of micro- or submicron-sized colloidal silica (0.01-0.05μm) particles and larger macro-sized (15-20μm) particles [72,73]. A carefully graded distribution of filler size minimises gaps between particles, theoretically allowing them to fit together more efficiently and therefore maximising packing density [74].The hybrid RBCs contain a wide diversity of filler particle sizes and distributions, suggesting that dental manufacturers load the resin matrix with one of three filler ratios, namely either an equal quantity of large and small particles or either a greater quantity of large or small particles compared with a smaller quantity of the remaining particle size[75]. The classification of ‘hybrid’ is largely redundant as the majority of modern RBCs contain two distinct particle size ranges, one of which is typically colloidal silica to improve rheological properties, instead the term ‘microhybrid’ is routinely used to describe the majority of modern RBCs [76].

1.3.1.4 Nano Resin Composites

More recently, developments in nanotechnology have produced potentially clinically superior resin composites for use in both aesthetic and load-bearing situations. Nanotechnology permits the uses of nanoscale (1-100nm) level of filler size [77]. Nanometre-sized filler particles and larger groups of fused nano-particles (nano-clusters) are dispersed in a resin matrix to produce a nanocomposite . Combining individual particles and clusters allows for increased filler loading without increased viscosity imparting improved physical properties and good handling characteristics. The material is highly polishable and since nano-clusters will breakdown under force as opposed to becoming dislodged, this lustre is long lasting. Nano-filled composite are thought to be alternative favourably with current universal and micro-filled composites [78], however recent studies have shown that either no difference or better properties of micro-filled composite compared with nano-filled composites with the exception of surface roughness (79, 80).

1.3.2 Types of Resin-composites According to the Consistency

The majority of resin-composites present with medium viscosity. However, some other types of resin-composites can be classified as high-viscosity “packable” resin-composites or low-viscosity “flowable” resin-composites.

1.3.2.1 Packable Resin composites

Packable resin-composites possess high amount of filler loading (around 80% by weight), which makes them easier to be placed, condensed into the cavity and carved to the desired shape. The use of these materials is particularly useful for re-establishing the tooth contour and proximal contacts [81]. However, increasing the amount of filler particles beyond what had been conventionally used simply resulted in porosity and insufficient wetting of the particles by the resin matrix. The early packable resin-composites had a higher viscosity than conventional materials, making them relatively difficult, if not impossible, to extrude through small-bore syringes or a unit-dose delivery system [82]. For the resin-composite, it is preferable to be able to stick to the cavity wall but not to the dental instruments. Manufacturers were able to eliminate stickiness by slightly altering filler content and reducing the matrix viscosity by using varied matrix monomers. This provided the material with sufficient flow to adapt to the cavity preparation during packing [83, 84].

1.3.2.2 Flowable Resin Composites

These are low-viscosity composite resins, making them more fluid than conventional composite resins. The percentage of inorganic filler is lower and some substances or rheological modifiers which are mainly intended to improve handling properties have been removed from their composition (84).Their main advantages are: high wettability of the tooth surface, ensuring penetration into every irregularity; ability to form layers of minimum thickness, so improving or eliminating air inclusion or entrapment ,high flexibility, so less likely to be displaced in stress concentration areas, radio-opaqueness and availability in different colours. The drawbacks are: high curing shrinkage, due to lower filler load, and weaker mechanical properties(85).

2.3.3 Types of Resin composites According to the Placement Method

2.3.3.1 Incrementally Placed Resin Composites

To reduce polymerization shrinkage stresses, the incremental technique has been introduced for the placement of resin-composite materials (86). The resin-composite material is placed in the cavity in layers of 2 mm thickness and. irradiated before adding the next layer until the cavity preparation is completed (87-88).

The incremental placement techniques were intended to reduce the C-factor and consequently, to relieve the polymerization shrinkage stresses developed at the bond interface between the tooth and the resin-composite (89-90).The placement in increments of visible light-cured resin-composite is considered an acceptable method to provide optimum contour, particularly for difficult inaccessible restorations (88).

Performing a trouble-free direct composite restoration with care and in a reasonable time is a valuable technique that a dentist must have if he or she desires a satisfying and successful practice [91]. Incremental layering has long been accepted as a standard technique for placement of resin-composite in cavity preparations. Typically, this technique consists of placing increments of resin-composite material in thickness of 2 mm or less followed by exposure to light curing from an occlusal direction and then repeating increments until the preparation is filled [92].

One obvious advantage for this technique is the limitation of the thickness of resin to be penetrated by light, as it has been shown that light energy transmitted through resin-composite decreases exponentially with resin-composite thickness [93]. Therefore, limiting increment thickness to 2 mm or less provides adequate light penetration and subsequent polymerization. Adequate polymerization results in enhanced physical properties [94,95], improved marginal adaptation [96] and decreased cytotoxicity of the resin-composite. Inadequate polymerization may result in reduced conversion of the various components of the resin-composite and therefore a higher residual monomer content remains in the material [97]. This residual monomer, in addition to other drawbacks in the materials like poor mechanical properties [98], increases the cytotoxicity of the resin-composite [97,99–101].

A second reason to use the incremental technique is to decrease the amount of shrinkage occurring during polymerization. The reduction of polymerization shrinkage is beneficial because the developing stress can cause cuspal deformation with resulting sensitivity or microcracks in resin or tooth structure. The stress can also cause adhesive failure at the tooth/resin interface resulting in marginal gaps, microleakage, and secondary caries [96,102–104].

Despite these benefits, the incremental technique has disadvantages. These may include , the possibility of incorporating voids or contamination between composite layers, bond failures between increments, difficulty in placement because of limited access in conservative preparations and the increased time required to place and polymerize each layer [105,106].

In addition, as the bonding and filling steps are the most crucial, perfect isolation during these steps must be maintained to guarantee a successful restoration. However, when the patient salivates and moves the tongue constantly during the placement of composite layers, this could potentially compromise the accuracy of the filling. Every additional increment increases the likelihood of failure [76].

1.3.3.2 Bulk Fill Resin Composites

Recently, In an attempt to overcome these disadvantages a new category of RBCs—so-called bulk fill RBCs—was introduced as bulk fill material and as liner in class I and II restorations. The particularity of the new material category is stated to be the option to place it in 4 mm thick bulks instead of the current incremental placement technique.

Several authors [107,108] recommended that the “bulk-fill” composite materials must possess some important characteristics. These include low polymerization shrinkage, more flowability to allow for better cavity adaptation, easy to dispense with minimal handling, enhanced physical characteristics and improved depth of cure, at least 4 mm.

Regarding regular RBCs, the changes made in bulk-fill RBCs to enlarge the DOC addressed primarily the fillers, decreased filler load and increased filler size (filler size >20 mm as observed in several materials such as x-tra fil and x-tra base, VOCO, Cuxhaven, Germany; SureFil SDR flow, Dentsply Caulk, Milford, DE, USA; SonicFill, Kerr, Orange, CA, xffddsews USA)[109] to reduce light scattering and increase the transmittance for blue light in the depth, [110] with the consequence of worsening aesthetic properties, lowering mechanical properties, and potentially increasing abrasion or surface roughness[109].

Matching the refractive indices of filler and matrix is also essential for improving the translucency and the optical properties of the resin-composite material [111–113]. If the filler and matrix have mismatched refractive indices, the filler will increase light scattering in the resin–filler interface and produce opaque materials [114,115].

However, based on their chemical composition on regular RCs, bulk-fill RCs also benefit from innovative changes, such as the implementation of new higher-molecular weight monomers (SureFil SDR flow) or new initiator systems (Ivocerin in Tetric Evo Ceram Bulk Fill; Ivoclar Vivadent Inc., Schaan, Liechtenstein) are further attempts headed for the same purpose[116].

Also polymerization modulator, chemically embedded in the center of the polymerizable resin backbone of the monomer to lower polymerization shrinkage, the modulator is supposed to optimize flexibility and network structure of the resin [117,118].

The mechanical stability in stress bearing areas of fillings restored with bulk-fill RBCs is still an open question, since long-term clinical studies are not available so far. In vitro studies revealed for bulk-fill RBCs, as a material class, similar flexural strength values as the class of nano- and micro-hybrid RBCs, and significantly higher values when compared to flowable RBCs. The modulus of elasticity, the indentation modulus and the hardness classify this materials as between the hybrid RBCs and the flowable RBCs, while in terms of creep, bulk-fill and flowable RBCs perform similar, both showing a significantly lower creep resistance when compared to the nano- and micro-hybrid RBCs.(119) Other studies found, however, that bulk-fill RBCs exhibited a creep deformation within the range of regular RBCs.(120)

Bulk-fill RCs have been proven in several studies to enable restoration in thick layers, up to 4 mm, maintaining the mechanical properties and the degree of conversion within the whole increment.(121–124) Besides, decreased polymerization shrinkage stress,(125–127) , Thus, problems related to polymerization shrinkage (128) like gap formation causing secondary caries due to bacteria colonization (129, 130), pulp irritation, post-operative sensibility when chewing (131), or cusp deflection when the “C” factor is high (132,133) could be minimized. good bond strengths regardless of the filling technique and the cavity configuration,(134) and improved self-levelling ability for low-viscosity materials(135) are reported. The mechanical properties of the bulk-fill RCs vary in a large range(136) as the function of the filler content. They have shown reduced cuspal deflection when compared with a conventional resin composite filled in an oblique incremental layering technique (137).Also, when marginal integrity was evaluated, bulk fill composites performed well (138).

The alleged changes in the rheology of bulk-fill RBCs compared to regular RBCs that are supposed to allow a better adaption to the cavity walls remained unconfirmed by in vitro microleakage(139) and marginal integrity studies.(140) The material’s reliability however, a characteristic associated with lower surface defects that are able to initiate crack propagation, proved to be very high in low viscosity bulk-fill RBCs (high values for the Weibull modulus), but moderate, and hence comparable to regular nano- and micro-hybrid RBCs in high viscosity RBCs(141).

On the basis of differences in viscosity and application technique, the materials are classified in low- and high-viscosity bulk-fill RBCs. The low mechanical properties of the former[137] require to finish a restoration by adding a capping layer made of regular RBCs. Restorations made with low viscosity bulk-fill RBCs (SureFil1SDR, Dentsply; Venus Bulk Fill, Heraeus Kulzer; xtra base, VOCO; FiltekTM Bulk Fill, 3M ESPE) must be finished by adding a capping layer made of regular RBCs, while high viscosity bulk-fill RBCs (SonicFillTM, Kerr; Tetric EvoCeram1 Bulk Fill, Ivoclar Vivadent; X-tra Fil, VOCO) may be placed without capping.

Brand	Manufacturer	Matrix	Inorganic filler	type	Need for capping
SDR	Dentsply, USA	TEGDMA, EBADMA,	68 wt%, 44 vol%, barium borosilicate glass	flowable	Yes
X-tra base	Voco,Cuxhaven, Germany	Bis-EMA, MMA	75 wt%, 58 vol% silica	flowable	Yes
x-tra fil	Voco,Cuxhaven, Germany	Bis-EMA, UDMA, TEGDMA MMA	Bis-EMA, UDMA, TEGDMA MMA	paste	No
Venus bulk fill	HerausKultzer, USA	UDMA, EBADMA,	65 wt%, 38 vol%, barium silicate glass and silica	flowable	Yes
Filtek Bulk Fill	3M/ESPE, St. Paul, MN, USA	bis-GMA, bis-EMA, UDMA	Zirconia, 64 wt%, 42 vol%	flowable	Yes
SonicFil	Kerr Corporation, CA, USA	Bis-GMA, bis-EMA,	21SiO2, glass, oxide 83.5/	paste	No
TetricEvoCeram	Ivoclar Vivadent, Schaan,Liechtenstein	Bis-GMA, UDMA	Ba glass, YbF3, oxides and prepolymers (80% by wt and 60% by vol)	paste	No
XENIUS previous version of Ever-posterior)	GCEurope (Leuven, Belgium	Bis-GMA, PMMA, TEGDMA	Short E-glass fiber filler, barium glass 74.2 wt%, 53.6 vol%	Paste with glass microfibres	Yes
everX Posterior	GC, Tokyo, Japan)	Bis-GMA, PMMA, TEGDMA	load 74.2 wt%; 53.6 vol%	Paste with glass microfibres	Yes

Table1.1 Different types of bulk fill composite.

2. MATERİALS AND METHOD

Two Low viscosity bulk fill composites (Venus® bulk fill ,Heraeus Kulzer GmbH, Hanau, Germany), (SureFil SDR flow; Dentsply, Konstanz, Germany) and one high viscosity bulk fill composite (everX Posterior GC, Tokyo, Japan) were compared in terms of SBS to dentin substrates with a regular hybrid RC (Filtek Z250 3M/ESPE, St. Paul, MN, USA) with the use of(adheSE, Ivoclar Vivadent AG) as a bonding agent (Table 2.1).

Brand	Manufacturer (Lot)	Type	SHADE	Matrix composition	Inorganic filler content
Venus Bulk fill	HerausKultzer, Germany -10029	Bulk-fill composite	universal	UDMA, EBADMA	65 wt%, 38 vol%, barium silicate glass , silica
SureFil SDR	Dentsply, USA -101006	Bulk-fill composite	universal	TEGDMA, EBADMA,	68 wt%,44 vol %, barium borosilicate glass
Ever-X posterior	GC,Tokyo, Japan	Fiber reinforced Bulk-fill composite	universal	Bis-GMA, PMMA, TEGDMA	Short E-glass fiber filler,Barium glass 74.2 wt%, 53.6 vol%
Filtek Z250	3M/ESPE, St. Paul, MN, USA (8RX)	Regular resin composite	A1	Bis-GMA, bis-EMA, UDMA,	Zirconia,78 wt %, 60 vol%

Table-2.1 the bulk fill composites investigated and their composition

2.1 Materials

SureFil SDR (Smart Dentine Replacement)

Single component, fluoride containing, visible light-cured, radiopaque resin composite restorative material can be placed in 4mm bulk-fill increments. SDR technology has a unique chemical structure that incorporates a polymerization modulator, which helps the monomers to form a more relaxed network. this reduces shrinkage stress by up to 60% compared to other posterior and bulk-fill composites. Compatible with all methacrylate based bondings and composites for capping. SDR flow-like consistency results in an excellent internal cavity adaptation and no void/air bubbles(142).

Figure 2.1.SDR bulk fill composite

VENUS BULK FİLL RESİN COMPOSİTE

Venus® Bulk Fill is a low stress flowable composite that enables bulk filling of 4mm. Compatible with all methacrylate based bonding adhesives and composites. Venus Bulk Fill exhibits a reduction in polymerization shrinkage 3.4%. Venus Bulk Fill delivers a high depth of cure and Its high radiopacity guarantees a reliable diagnosis(143).

Figure 2.2. venus bulk fill composite

GC EVERX POSTERIOR

GC everX Posterior is a fibre-reinforced composite designed to be used as dentine replacement, in conjunction with conventional composite as enamel replacement. The short fibres of GC everX Posterior will make it a perfect sub-structure to reinforce any composite restoration in large size cavities. Fibres will also prevent and stop crack propagation through the filling, which is considered to be the main cause of composite failures. it enables bulk filling of 4mm , minimal horizontal shrinkage as fibres contribute to shrinkage reduction in the direction of their orientation and Reliable bond to overlaying composite as well as to the tooth substance(144).

Figure 2.3. everX Posterior bulk fill composite

FILTEK Z250 RESİN COMPOSİTE

Filtek™ Z250 Nano Hybrid Universal Restorative is an esthetic a visible light-activated composite designed for use in both anterior and posterior restorations. All shades are radiopaque and fluorescent. Filtek Z250 is Nano Hybrid restorative composite, The particle size distribution is 0.01µm to 3.5µm with an average particle size of 0.6µm. The material is incrementally placed and cured in the cavity. The maximum cure depth for an increment is 2.5mm for most shades(145).

Figure 2.4. Filtek™ Z250 composite

AdheSE

AdheSE is a light-curing, self-etching two-component adhesive system for enamel and dentin bonding. it is time-saving application: no need for etching. Very high bond strengths. it remains unchanged on dry or moist dentin and even if it is distributed with a strong stream of air. AdheSE contains primer: phosphonic acid acrylate 25-50%, bis-acrylamide 20-25%, water, initiators and stabilizers .Bonding: Bis-GMA 25-50%,glycerin-1.3-dimethacrylates 25-50%, 2-hydroxy ethyl methacrylate 20-25%, highly dispersed silicon dioxide,initiators and stabilizers(146).

Figure 2. 5. AdheSE adhesive system(Ivoclar-Vivadent)

2.2 Method

20 newly extracted sound caries-free human molars teeth were selected. The teeth were cleaned and placed in distilled water before use. The roots were separated from the crowns at CEJ then the teeth were bisected mesiodistally at the middle to buccal and palatal parts using (isomet low speed saw,buehler, USA) (figure 2.6), and embedded in methacrylate resin (Technovit 4004, Kulzer, Germany) in a stainless steel cylinder (diameter: 25 mm, height: 30 mm) with their buccal and palatal surfaces facing up and only about half of the tooth was embedded in the resin and the buccal and palatal surfaces protruded well above the resin. This positioning avoided any possible contamination of the dentin surface by resin when the buccal and palatal surfaces were ground flat picture.

The enamel surfaces were removed with 250 grit silicon carbide grinding paper and then was roughened with 600 grit silicon carbide grinding paper using (Phoenix beta,Buehler, USA)(figure 2.7), respectively, to achieve flat homogeneous dentin surfaces without exposing of the pulp in all the samples (figure 2.8). Since dentin depth and tubule orientation have been shown to affect bond strengths and resin penetration (147,148) the teeth were ground to approximately the same depth half way between the dentoenamel junction and the pulp. This depth was considered to most accurately represent the depth of a typical cavity preparation and thus was a representative site to test resin-dentin bond strengths. The teeth were inspected to ensure that there was no enamel or pulpal exposure at the bonding site.

Figure 2.6. Isomet (Buehler, USA)

Figure2. 7. Polishing Machine, (Buehler, USA)

Figure 8. Exposed dentin surface

The teeth were then randomly coded and stored in distilled water and covered with a thin adhesive strip, leaving the area to be bonded exposed (circle of 3-mm diameter). Then, the samples were equally and randomly divided into 4 groups, 10 samples for every group.

The bonding system was used in accordance with the manufacturer's instructions.

a mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) (figure2. 9) was adapted on the specimen and filled with resin composite in two consecutive increments of 2 mm for the regular RC (Filtek Z250) followed by polymerizing each increment for 20 s (Bluephase 20I; Ivoclar-Vivadent)(figure2.10). and in one 4-mm increment for the bulk-fill RCs (SDR ,venus and everX Posterior) followed by light curing for 20 s (Bluephase 20I; Ivoclar-Vivadent)(figure2.10). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine (Instron Universal Test Machine, USA) (figure2.11) at a constant crosshead speed of 0.5 mm/min until fracture. The load at fracture was recorded and reported to calculate the SBS.

Figure 2.9. Metal mould

Figure2.10. Bluephase 20I ; (Ivoclar-Vivadent)

Figure 2.11. Instron Universal Test Machine (USA)

Group 1 : The dentin surface was conditioned with the self-etching adheSE primer for at least 30 sec, then dispersing the excess amounts with a strong stream of air, then apply AdheSE Bond and dispersing the excess amounts with a very weak stream of air and light curing it for 10 s with a blue-violet LED curing unit (Bluephase 20I; Ivoclar-Vivadent, Schaan, Liechtenstein)(figure2.10). After that a mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) (figure2.9) was adapted on the specimen and filled with resin composite (SureFil SDR flow; Dentsply, Konstanz, Germany)(figure 2.1) in one 4-mm increment , followed by light curing for 20 s (Bluephase 20I ; Ivoclar-Vivadent)(figure2.10). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine (Instron Universal Test Machine) (figure2.11) at a constant crosshead speed of 0.5 mm/min until fracture. The load at fracture was recorded and reported to calculate the SBS.

Group 2 : The dentin surface was conditioned with the self-etching adheSE primer for at least 30 sec, then dispersing the excess amounts with a strong stream of air, then apply AdheSE Bond and dispersing the excess amounts with a very weak stream of air and light curing it for 10 s with a blue-violet LED curing unit (Bluephase 20I ; Ivoclar-Vivadent, Schaan, Liechtenstein)(figure2.10). After that a mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) (figure 2.9) was adapted on the specimen and filled with resin composite (Venus® bulk fill ,Heraeus Kulzer GmbH, Hanau, Germany) (figure2.2) in one 4-mm increment , followed by light curing for 20 s (Bluephase 20I; Ivoclar-Vivadent)(figure2.10). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine (Instron Universal Test Machine) (figure2.11) at a constant crosshead speed of 0.5 mm/min until fracture. The load at fracture was recorded and reported to calculate the SBS.

Group 3 : The dentin surface was conditioned with the self-etching adheSE primer for at least 30 sec, then dispersing the excess amounts with a strong stream of air, then apply AdheSE Bond and dispersing the excess amounts with a very weak stream of air and light curing it for 10 s with a blue-violet LED curing unit (Bluephase 20I ; Ivoclar-Vivadent, Schaan, Liechtenstein)(figure2.10). After that a mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) (figure 9) was adapted on the specimen and filled with resin composite (everX Posterior ,GC, Tokyo, Japan) (figure2. 3) in one 4-mm increment , followed by light curing for 20 s (Bluephase 20I ; Ivoclar-Vivadent)(figure2.10). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine (Instron Universal Test Machine) (figure2.11) at a constant crosshead speed of 0.5 mm/min until fracture. The load at fracture was recorded and reported to calculate the SBS.

Group 4 : The dentin surface was conditioned with the self-etching adheSE primer for at least 30 sec, then dispersing the excess amounts with a strong stream of air, then apply

AdheSE Bond and dispersing the excess amounts with a very weak stream of air and light curing it for 10 s with a blue-violet LED curing unit (Bluephase 20I; Ivoclar-Vivadent, Schaan, Liechtenstein)(figure2.10). After that a mould with a central cylindrical cavity (3 mm in diameter and 4 mm in height) (figure2. 9) was adapted on the specimen and filled with resin composite (Filtek Z250 , 3M/ESPE, St. Paul, MN, USA)(figure2. 4) in two consecutive increments of 2 mm , followed by light curing each increment for 20 s (Bluephase 20I ; Ivoclar-Vivadent)(figure2.10). Specimens were then stored for 24 h at room temperature in distilled water, and were then loaded in a universal testing machine (Instron Universal Test Machine) (figure2.11) at a constant crosshead speed of 0.5 mm/min until fracture. The load at fracture was recorded and reported to calculate the SBS.

3.Results

The shear bond strength values (MPa) of bulk fill composite resin and hybrid composite resin to dentin, mean values (MPa) and standard deviation for the various groups are shown in Table (3.1).

Group 1

The shear bond strengths of group 1 (SDR) ranged from 5.038 to 15.98 MPa with mean shear bond strength of 10.903 MPa ,which was higher than Group 2 and Group 3 and less than Group 4 , but their difference in the mean shear bond strength was not statistically significant ($p > 0.05$).

Group 2

The shear bond strengths of group 2 (venus) ranged from 3.959 to 18.163 MPa with mean shear bond strength of 7.944 MPa ,which was higher than Group 3 and less than Group 1 and Group 4 , but their difference in the mean shear bond strength was not statistically significant ($p > 0.05$).

Group 3

The shear bond strengths of group 3 (everx) ranged from 3.455 to 15.498 MPa with mean shear bond strength of 7.556 MPa ,which was the lowest of all groups , but showed no statistically significant difference in the mean shear bond strength from the other groups ($p > 0.05$).

Group 4

The shear bond strengths of group 4 (Z250) ranged from 3.429 to 21.43 MPa with mean shear bond strength of 11.160 MPa ,which was the highest of all groups , but showed no statistically significant difference in the mean shear bond strength from the other groups ($p > 0.05$).

Groups	Group1 SureFil SDR	Group 2 Venus Bulk fill	Group 3 Ever-X posterior	Group 4 Filtek Z250
Sample 1	12.699	10.153	9.838	8.97
Sample 2	12.729	8.374	9.479	4.561
Sample 3	13.767	8.498	5.949	3.429
Sample 4	15.98	18.163	8.034	11.216
Sample 5	6.213	7.604	15.498	21.43
Sample 6	11.946	4.408	4.823	17.346
Sample 7	9.974	5.204	5.224	12.181
Sample 8	12.258	6.935	4.88	13.632
Sample 9	8.426	6.144	3.455	6.956
Sample 10	5.038	3.959	8.384	11.88
Mean	10.903	7.944	7.556	11.16
S.D	3.446	4.083	3.533	5.55

Table (3.1). SBS values (MPa), mean values (MPa) , and standard deviation for tested composite.

The highest mean value was for the control group (Filtek Z250 3M/ESPE, St. Paul, MN, USA), after that (SureFil SDR flow; Dentsply, Konstanz, Germany), than (Venus® bulk fill ,Heraeus Kulzer GmbH, Hanau, Germany), and the last one was (everX Posterior GC, Tokyo, Japan)(Table 3.2).

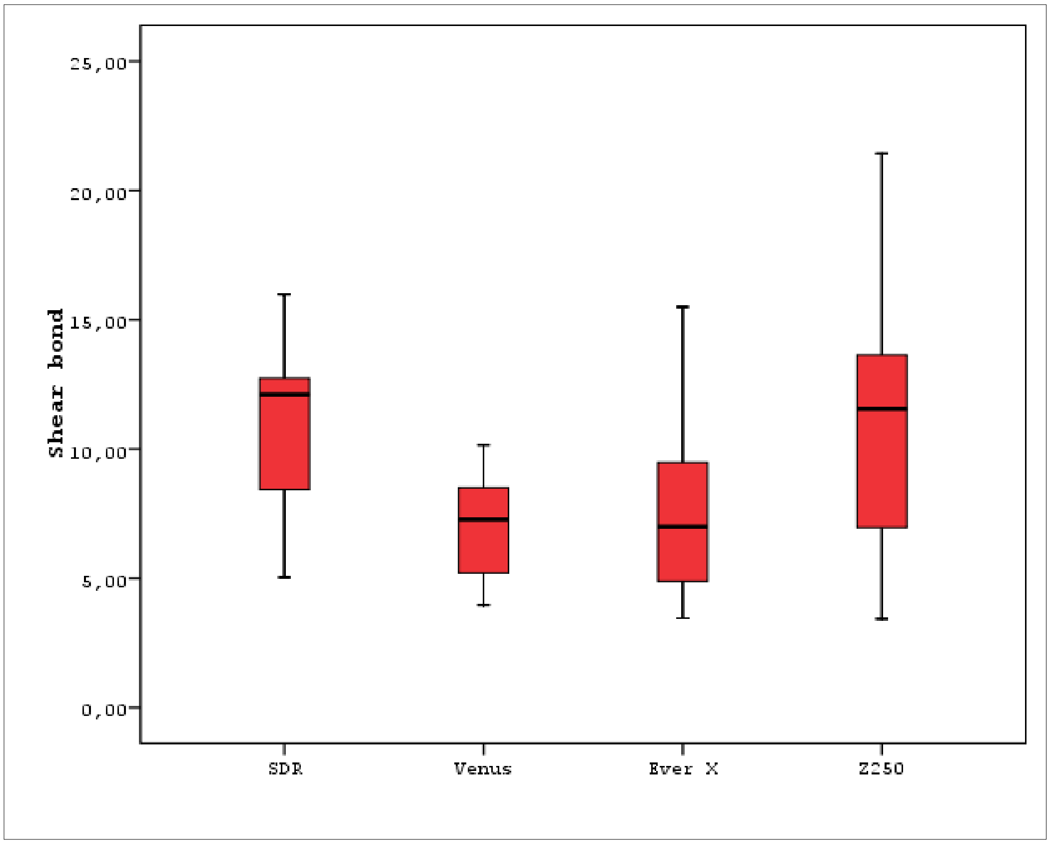

Figure 3.1 Mean values and standard deviation

This box represents the spreading of the data between the first and third quartile. The central horizontal line represents the median .The whiskers extend to the minimum and maximum value measured.

Statistical analysis

Power and Sample Size program was performed using power analysis in the shear bond parameters for the Δ: 5.5, SD: 4, Once we receive Power: 0.80 and α: 0:05. determined for the sample size for each group the minimum n = 9, in this study for each group we used 10 samples.

Statistically analyzes were performed with IBM SPSS Statistics 22 (IBM SPSS, Turkey) program was used for statistical analysis. when assessing the Study data , the suitability of the parameters to the normal distribution was evaluated by Kolmogorov-Smirnov test and was found to be in accordance with the normal distribution of the parameters. Between-group comparisons of parameters Anova test (Table 3.2) and post hoc Tukey's HDS (Table 4) test was used in the evaluation. Differences were considered significant for a value of *P* < 0.01(Table 3.3).

Oneway ANOVA Test	**Shear Bond**
	Mean±SD
Group 1 (SDR)	10,90±3,44
Group 2 (Venus)	7,94±4,08
Group 3 (Ever X)	7,55±3,53
Group 4 (Z250)	11,16±5,55
p	**0,129**

Table 3.2 Comparison of groups shear bond strength

Tukey HSD Test	**P**	**significance**
Group 1 / Group 2	0,413	Not significant
Group 1 / Group 3	0,306	Not significant
Group 1 / Group 4	0,999	Not significant
Group 2 / Group 3	0,997	Not significant
Group 2 / Group 4	0,340	Not significant
Group 3 / Group 4	0,245	Not significant

Table 3.3: Post hoc pairwise comparisons between the groups.

No significant differences were found between the different groups P=**0,129** ($p > 0.05$).

4. DISCUSSION

Simplified and fast restorative procedures, such as placing bulk fill resin composite instead of layering resin composite became more and more popular. this study aims to evaluate and to compare the shear bond strength (SBS) of bulk-fill composite resin to permanent teeth, by separately considering the dentine as substrates and using a clinically established resin composite as a reference restorative material.

Polymerization shrinkage and Degree of conversation (DC) are the most important factor of the setting light cure composite resins. A main concern when curing large increments remains however potentially increased polymerization shrinkage stress at the tooth-material interface. composite resin’s shrinkage ranges between 2 and 6% by volume during polymerization, there is a moment, referred to as the *gel point,* when the composite's elastic limit reaches a certain level where its increasing stiffness does not allow enough plastic deformation (or flow) in order to compensate for the reduction in volume. If the composite is bonded to cavity walls, shrinkage forces will start to build-up, resulting in stresses on the bond between the composite and the tooth structure. These forces are not uniformly distributed along the cavity walls, potentially causing failure of the bond and eventually, the restoration itself. Otherwise, if the bonding interface remains intact, residual forces create stresses to surrounding tooth structure, and may result in apparent tooth strain or fracture .[149-151] When bonding performance is inferior, it is possible that both initial and residual polymerization stresses lead to gap formation, leakage, recurrent caries, post-operative sensitivity, marginal discoloration, secondary caries, pulp inflammation or necrosis and maybe retention loss.[150,152–156]

Incremental layering has long been accepted as a standard technique for placement of resin-composite in cavity preparations. Typically, this technique consists of placing increments of resin-composite material in thickness of 2 mm or less followed by exposure to light curing from an occlusal direction and then repeating increments until the preparation is filled [92].

One obvious advantage for this technique is the limitation of the thickness of resin to be penetrated by light, as it has been shown that light energy transmitted through resin-composite decreases exponentially with resin-composite thickness [93]. Therefore, limiting increment thickness to 2 mm or less provides adequate light penetration and subsequent polymerization. Adequate polymerization results in enhanced physical properties [94,95], improved marginal adaptation [96] and decreased cytotoxicity of the resin-composite. Inadequate polymerization may result in reduced conversion of the various components of the resin-composite and therefore a higher residual monomer content remains in the material [97].

A second reason to use the incremental technique is to decrease the amount of shrinkage occurring during polymerization. The reduction of polymerization shrinkage is beneficial because the developing stress can cause cuspal deformation with resulting sensitivity or microcracks in resin or tooth structure. The stress can also cause adhesive failure at the tooth/resin interface resulting in marginal gaps, microleakage, and secondary caries .Contraction stress is determined by characteristics of the composite. Filler content and resin matrix composition dictate the amount of volumetric shrinkage and elastic modulus values of the material. Activation mode, type and concentration of initiators regulate reaction kinetics and degree of conversion [96,102–104].

Another concern when curing large increments is the decrease in curing-light intensity with depth in the material. The intensity of light at a given depth and for a given irradiance period is a critical factor in determining the extent of reaction of monomer into polymer, typically referred to as the degree of monomer conversion, and significantly associated with values of mechanical properties, biocompatibility, color stability , volumetric shrinkage and would therefore be expected to be associated with clinical success of the restoration [157].

unfortunately there is a linear relationship between polymerization shrinkage strain and DC, The higher the rate of monomer conversion, the faster the gel point is reached, and the lower is the flow capacity of the material .The higher the degree of conversion, the higher is the composite's final shrinkage and its elastic modulus, both of which contribute to producing higher stresses . Therefore, the maintenance of the bond integrity and sufficient shear bond strength (SBS) of the restoration without the loss of the ultimate physical and mechanical properties can be obtained through the relaxation of the stress through the composite flow (158). In our study Z250 resin composite was used with incrementel technique as control group to compare bulk fill resin composite.

Despite these benefits, the incremental technique has disadvantages. These may include the possibility of incorporating voids or contamination between composite layers, bond failures between increment, difficulty in placement because of limited access in conservative preparations and the increased time required to place and polymerize each layer [105,106].

Recently, In an attempt to overcome these disadvantages a new category of RBCs—so-called bulk fill RBCs—was introduced as bulk fill material and as liner in class I and II restorations. The particularity of the new material category is stated to be the option to place it in 4 mm thick bulks instead of the current incremental placement technique.

Several authors [107,108] recommended that the “bulk-fill” composite materials must possess some important characteristics. These include low polymerization shrinkage, more flowability to allow for better cavity adaptation, easy to dispense with minimal handling, enhanced physical characteristics and improved depth of cure, at least 4 mm.

Regarding regular RBCs, the changes made in bulk-fill RBCs to enlarge the DOC addressed primarily the fillers, decreased filler load and increased filler size (filler size >20 mm as observed in several materials such as x-tra fil and x-tra base, VOCO, Cuxhaven, Germany; SureFil SDR flow, Dentsply Caulk, Milford, DE, USA; SonicFill, Kerr, Orange, CA, xffddsews USA)[109] to reduce light scattering and increase the transmittance for blue light in the depth, [110] with the consequence of worsening aesthetic properties, lowering mechanical properties, and potentially increasing abrasion or surface roughness[109].

Matching the refractive indices of filler and matrix is also essential for improving the translucency and the optical properties of the resin-composite material [111–113]. If the filler and matrix have mismatched refractive indices, the filler will increase light scattering in the resin–filler interface and produce opaque materials [114,115].

Also polymerization modulator, chemically embedded in the center of the polymerizable resin backbone of the monomer to lower polymerization shrinkage, the modulator is supposed to optimize flexibility and network structure of the resin [117,118].

In this study, shear bond strength test method was chosen for determine to bulk fill composite resin’s bond strength to dentin. In a shear bond test, two materials are connected via an adhesive agent and loaded in shear until fracture occurs. Definitely most commonly used is the shear bond-strength technique, it was found to have been used in 26% of scientific papers reporting on bond strength. As no further specimen processing is required after the bonding procedure, as it is the most easy and fastest method [159].

Conflicting findings were published on the influence of crosshead speed on dentin bond strengths. Different cross-head speeds may influence the shear bond strength and the fracture pattern in dentin substrate[160,161]. Shear bond strength using crosshead speeds of

0.50 mm/min and 0.75 mm/min should be preferred due to their better cohesive versus adhesive results[162].

International Standards Organization (ISO) Technical Specification No. 11405 provides guidance on substrate selection, storage, and handling as well as essential characteristics of different test methods for quality testing of the adhesive bond between restorative materials and tooth structure. It also presents some specific test methods for bond strength measurements [163].

Dentin permeability increases almost logarithmically with cavity depth. In majority of studies, lower shear bond strengths were reported with increased dentin depth and permeability [164]. In this study shear bond strength test was performed in midcoronal dentin. Where bonding surface was standardized to optimum bond strength. Very few macro-test studies were reported regarding effect of regional variables (occlusal/buccal dentin) on dentin bonding. High shear bond strengths to occlusal dentin were observed than buccal dentine, whereas tensile bond strengths were 20-30% higher for buccal dentin[165]. Thus, substrate location has to be specified while studying bond strength. In this study, buccal and palatal surfaces of dentin were used.

The ISO/TR 11405 does not identify a specific value for bond area but it mentions a clear delimitation of the bonding area as an important requirement and shows a diagram of a split mould with a 3-mm diameter hole [163]. the diameter of the bonded surface must be taken into consideration while comparing bond strengths. In our study for standardizing 3-mm diameter dentin surface , we used strip band with 3 mm diameter hole and 4 mm height split mold.

The mean shear bond strength values and standard deviations have been shown in the (Table 10) (Figure 26) One way ANOVA revealed no significant differences among the specimens (p>0.05).

Control group (Filtek Z250) exhibited the highest mean shear bond strength value (11.160 Mpa) among the other three groups, which was comparable to the result in other study[164]. But there isn't any statistical differences between all groups. We think that in spite of mean values are not statistically differences, highest value of Z250 depends on using the incremental technique in this group.

However, based on their chemical composition on regular RCs, bulk-fill RCs also benefit from innovative changes, such as the implementation of new higher-molecular weight monomers (SureFil SDR flow) or new initiator systems (Ivocerin in Tetric Evo Ceram Bulk Fill; Ivoclar Vivadent Inc., Schaan, Liechtenstein) are further attempts headed for the same purpose[116].

Our findings showed that SureFil SDR bulk fill composite exhibited the highest mean value among the bulk fill composite groups (10.903 Mpa) which was comparable to the result in other study [165]. Compared with SureFil SDR, however, both materials, Venus Bulk fill and Ever-X posterior Bulk Fill, performed slightly inferior by trend. The mechanical properties, especially the modulus of elasticity, measured for SureFil SDR are consistently lower compared with Venus Bulk fill and Ever-X posterior Bulk Fill [163]. Thus, the significantly higher SBS observed must be a result of a better wettability/adaptability of the former material on the tooth substrate because of the higher flowability of the material. This was indirectly confirmed in other studies, given that

SureFil SDR showed better internal adaptation than conventional composites in high C-factor cavities[166].

Also to Increase the depth of cure changes were done in both the filler system and the monomer matrix in SureFil SDR. In one study to evaluate the translucency characteristics of Venus Bulk fill, Surefill SDR and short fiber-reinforced composite EverX was tested. And SDR and EverX were translucent up to 4 to 5mm, while control group Supreme XT (3MEspe) and Filtek Universal Supreme XTE (3MEspe) filling composite were translucent to between 2 and 3 mm[167]. In our opinion this light translucency ability of Bulk Fill resin composites supports the degree of conversion and it gives the ability to be cured up to 4 mm increment.

There was a weak but statistically significant correlation between dentin bond strength and composite flexural properties [168,169]. Hence, while testing bond strength of an adhesive, it is recommended to select a composite resin with a comparable elastic modulus. There was a weak but statistically significant correlation between dentin bond strength and composite flexural properties. Hence, while testing bond strength of an adhesive, it is recommended to select a composite resin with a comparable elastic modulus. Garoushi and et al, showed that the new short fiber reinforced composite (EverX) exhibited the significantly higher fracture toughness (4.6 MPa $m^{1/2}$) and flexural strength (124.3 MPa) than all other materials. They pointed their findings showed that fracture toughness of polymer-based materials was improved when they were reinforced with glass fiber-reinforced composite [170]. In present study even tough fiber reinforced bulk fill composite EverX has highest fracture toughness and flaxurel strength, Sure Fill SDR has highest shear bond strength ($p > 0.05$) values.

Present study one adhesive system were used whereby only material depended shear bond strength was analyzed. In a former study highest influence on the SBS was exerted by the adhesive used, whereas the effect of material and substrate was minor. Authors said that clinically, flowable bulk fill resin composite might be an advantage in restoring deep, narrow cavities, with difficult access angels, whereas larger cavities might be restored easly and faster using high-viscosity compounds.

5.CONCLUSION

1) Shear bond strength to dentin of Resin Composite and Bulk Fill Resin Composite tested were not statistical difference ($p > 0.05$).

2) The shear bond strength mean value of group 4 (Z250) is 11.60 ± 5.5 MPa, which was the highest value of all groups, but there is not any statistical difference from the other groups ($P > 0.05$).

3) The shear bond strength mean value of group 1 (SDR) is 10.903 ± 3.4 MPa ,which was the highest of all groups, but there is not any statistical difference from the other groups ($P > 0.05$).

6.References

1. Leinfelder KF. New Developments in Resin Restorative Systems. Journal of the American Dental Association, 1997; 128: 573-581.

2. Ferracane JL .Hygroscopic and hydrolytic effects in dental polymer networks. Dent Mater (2006) 22:211-222.

3. Knock FE, Glenn JF. Dental materials and methods. US Patent 1951No 2558139.

4. Bjorksten J, Yaeger LL. Vinyl silane size for glass fabric. Modern platics 1952;29:124, 188.

5. Ferracane JL, Mitchem JC, Condon JR, Todd R Wear and marginal breakdown of composites with various degrees of cure. J Dent Res 1997; 76:15081516.

6. Ozcan M, Alander P, Vallittu PK, Huysmans MC, Kalk W Effect of three surface conditioning methods to improve bond strength of particulate filler resin composites. J Mat Sci Mater Med 2005; 16:21-27.

7. Glenn JF. Composition and Properties of Unfilled and Composite Resin Restorative Materials. In: Biocompatibility of Dental Materials. Edited by Smith DC, Williams DF. 10th ed. Boca Raton (FL): CRC Press; 1982. pp. 98-125.

8. Craig RG. Chemistry, Composition, and Properties of Composite Resins. Dental Clinics of North America, 1981; 25: 219-239.

9. Rueggeberg FA. From Vulcanite to Vinyl, a History of Resins in Restorative Dentistry. Journal of Prosthetic Dentistry, 2002; 87: 364-379.

10. da Silva E, Poskus L, Guimaraes J, Barcellos A, Fellows C Influence of light polymerization modes on degree of conversion and crosslink density of dental composites. J Mat Sci Mater Med 2008; 19:1027-1032.

11. Gauthier MA, Stangel I, Ellis TH, Zhu XX A new method for quantifying the intensity of the C=C band of dimethacrylate dental monomers in their FTIR and Raman spectra. Biomaterials 2005; 26:6440-6448.

12. Summit JB, Robbins JW, Hilton TJ, Schwartz RS. Fundamentals of operative dentistry. Acontemporary approach. Third ed. Chicago: Quintessence Publishing Co, Inc. 2006;105: 97-116

13. Tarle Z, Meniga A, Ristic M, Sutalo J, Pichler G, Davidson CL. The effect of the photopolymerization method on the quality of composite resin samples. J Oral Rehabil. 1998;25(6):436-42.

14. Skrtic D, Antonucci JM. Effect of chemical structure and composition of the resin phase on vinyl conversion of amorphous calcium phosphate-fill composites. Polym Int. 2007;56(4):497-505.

15. Puckett AD, Fitchie JG, Kirk PC, Gamblin J. Direct composite restorative materials.Dent Clin North Am. 2007;51(3):659-75.

16. Moszner N, Salz U. New Developments of Polymeric Dental Composites. Progress in Polymer Science (Oxford), 2001; 26: 535-576.

17. Peutzfeldt A. Resin Composites in Dentistry: The Monomer Systems. European Journal of Oral Sciences, 1997; 105: 97-116.

18. Lovell LG, Stansbury JW, Syrpes DC, Bowman CN. Effects of Composition and Reactivity on the Reaction Kinetics of Dimethacrylate/Dimethacrylate Copolymerizations. Macromolecules, 1999; 32: 3913-3921.

19. Ferracane JL. Current Trends in Dental Composites. Critical Reviews in Oral Biology and Medicine, 1995; 6: 302-318.

20. Atai M, Watts DC. A New Kinetic Model for the Photopolymerization Shrinkage-Strain of Dental Composites and Resins. Dent Mater, 2006; 22: 1-7.

21. Rueggeberg FA. From Vulcanite to Vinyl, a History of Resins in Restorative Dentistry. Journal of Prosthetic Dentistry, 2002; 87: 364-379.

22. Glenn JF. Composition and Properties of Unfilled and Composite Resin Restorative Materials. Biocompatibility of Dental Materials, 1982; 3: 97-130

23. Asmussen E, Peutzfeldt A. Mechanical Properties of Heat Treated Restorative Resins for Use in the Inlay/Onlay Technique. Scandinavian Journal of Dental Research, 1990; 98: 564-567.

24. Indrani DJ, Cook WD, Televantos F, Tyas MJ, Harcourt JK. Fracture Toughness of Water-Aged Resin Composite Restorative Materials. Dental Materials, 1995; 11: 201-207.

25. Venz S, Dickens B. Nir-Spectroscopic Investigation of Water Sorption Characteristics of Dental Resins and Composites. Journal of Biomedical Materials Research, 1991; 25:1231-1248.

26. Puckett AD, Fitchie JG, Kirk PC, Gamblin J. Direct composite restorative materials.Dent Clin North Am. 2007;51(3):659-75.

27. Elliott JE, Lovell LG, Bowman CN. Primary Cyclization in the Polymerization of Bis-Gma and Tegdma: A Modeling Approach to Understanding the Cure of Dental Resins. Dental Materials, 2001; 17: 221-229.

28. Cramer NB, Stansbury JW, Bowman CN. Recent advances and developments in composite dental restorative materials. J Dent Res. 2011;90(4):402-16.

29. J.M. Antonucci, S.H. Dickens, B.O. Fowler, H.H.K. Xu, W.G. McDonough, Chemistry of silanes: Interfaces in dental polymers and composites, Journal of Research of the National Institute of Standards and Technology. 110 2005; 541-558.

30. Floyd CJE, Dickens SH. Network Structure of Bis-Gma- and Udma-Based Resin Systems. Dental Materials, 2006; 22: 1143-1149.

31. Dewaele M, Truffier-Boutry D, Devaux J, Leloup G. Volume Contraction in Photocured Dental Resins: The Shrinkage-Conversion Relationship Revisited. Dental Materials, 2006; 22: 359-365.

32. Goncalves F, Kawano Y, Pfeifer C, Stansbury JW, Braga RR. Influence of Bisgma, Tegdma, and Bisema Contents on Viscosity, Conversion, and Flexural Strength of Experimental Resins and Composites. European Journal of Oral Sciences, 2009; 117: 442-446.

33. Rosin, M., Urban, A.D., Gärtner, C., Bernhardt, O., Splieth, C. and Meyer, . Polymerization shrinkage-strain and microleakage in dentin-bordered cavities of chemically and light-cured restorative materials. Dent Mater 2002;18 (7): 521-528.

34. Kournetas, N., Chakmakchi, M., Kakaboura, A., Rahiotis, C. and Geis-Gerstorfer, J. Marginal and internal adaptation of Class II ormocer and hybrid resin composite restorations before and after load cycling. Clin Oral Investig.2004; 8 (3):123-129.

35. Lutz, F. and Krejci, I.V.O. Amalgam Substitutes: A Critical Analysis. J Esthet Restor Dent 2000;12 (3): 146-159.

36. Manhart, J., Kunzelmann, K.H., Chen, H.Y. and Hickel, R.. Mechanical properties and wear behavior of light-cured packable composite resins. Dent Mater 2000;16 (1): 33-40.

37. Cavalcante LM, Schneider LFJ, Silikas N, Watts DC. Surface Integrity of Solvent-Challenged Ormocer-Matrix Composite. Dental Materials, 2011; 27: 173-179.

38. Weinmann, W., Thalacker, C. and Guggenberger, R.. Siloranes in dental composites. Dent Mater 2005; 21 (1): 68-74.

39. Lien, W. and Vandewalle, K.S.. Physical properties of a new silorane-based restorative system. Dent Mater 2010; 26 (4): 337-344.

40. Pires-de-Souza, F.C.P., Garcia, L.F.R., Roselino, L.M.R. and Naves, L.Z. Color stability of silorane-based composites submitted to accelerated artificial aging-an in situ study. J Dent: 2011; e18-e24.

41. 41Brauer GM. Initiator-Accelerator Systems for Acrylic Resins and Composites. Polymer Science and Technology, 1981; 14: 395-409.

42. Leinfelder, K.F. and Roberson, T.M.Clinical evaluation of posterior composite resins. Gen Dent (1983). 31 (4): 276-80.

43. Lutz, F. and Phillips, R.W. (1983). A classification and evaluation of composite resin systems. J Prosthet Dent 50 (4): 480-8.

44. Chae KH, Sun GJ. Phenylpropanedione; a New Visible Light Photosensitizer for Dental Composite Resin with Higher Efficiency Than Camphorquinone. Bulletin of the Korean Chemical Society, 1998; 19: 152-154.

45. Klapdohr S, Moszner N. New Inorganic Components for Dental Filling Composites. Monatshefte fur Chemie, 2005; 136: 21-45.

46. Yu B, Lee YK. Influence of Color Parameters of Resin Composites on Their Translucency. Dental Materials, 2008; 24: 1236-1242.

47. Silikas N, Watts DC. Rheology of Urethane Dimethacrylate and Diluent Formulations. Dental Materials, 1999; 15: 257-261.

48. Lee J-H, Um C-M, Lee I-b. Rheological Properties of Resin Composites According to Variations in Monomer and Filler Composition. Dental materials : official publication of the Academy of Dental Materials, 2006; 22: 515-526.

49. 49Beun S, Bailly C, Devaux J, Leloup G. Rheological Properties of Flowable Resin Composites and Pit and Fissure Sealants. Dental Materials, 2008; 24: 548-555.

50. Ferracane JL, Antonio RC, Matsumoto H. Variables Affecting the Fracture Toughness of Dental Composites. Journal of Dental Research, 1987; 66: 1140-1145.

51. Chung KH, Greener EH. Correlation between Degree of Conversion, Filler Concentration and Mechanical Properties of Posterior Composite Resins. Journal of Oral Rehabilitation, 1990; 17: 487-494.

52. 52Derand T, Molin M, Kvam K. Bond strength of composite luting cement to zirconia ceramic surfaces. DentalMaterials 2005;21:1158-62.

53. Kern M, Wegner SM. Bonding to zirconia ceramic: Adhesion methods and their durability. Dental Materials 1998;14:64-71.

54. Yoshida K, Tsuo Y, Atsuta M. Bonding of dual-cured resin cement to zirconia ceramic using phosphate acid ester monomer and zirconate coupler. Journal of Biomedical Materials Research Part B-Applied Biomaterials 2006;77B:28-33.

55. Della Bona A, Anusavice K, Hood JAA. Effect of ceramic surface treatment on tensile bond strength to a resin cement. Int.J.Prosthodont. 2002;15:248-53.

56. McDonough WG, Antonucci JM, Dunkers JP. Interfacial Shear Strengths of Dental Resin-Glass Fibers by the Microbond Test. Dental Materials, 2001; 17: 492-498.

57. 57Venhoven BAM, De Gee AJ, Werner A, Davidson CL. Silane Treatment of Filler and Composite Blending in a One-Step Procedure for Dental Restoratives. Biomaterials, 1994; 15: 1152-1156.

58. Braem M, Finger W, Van Doren VE, Lambrechts P, Vanherle G. Mechanical Properties and Filler Fraction of Dental Composites. Dental Materials, 1989; 5: 346-349.

59. Kim KH, Park JH, Imai Y, Kishi T. Microfracture Mechanisms of Dental Resin Composites Containing Spherically-Shaped Filler Particles. Journal of Dental Research, 1994; 73: 499-504.

60. Soderholm KJM. Influence of Silane Treatment and Filler Fraction on Thermal Expansion of Composite Resins. Journal of Dental Research, 1984; 63: 1321-1326.

61. Yamaguchi R, Powers JM, Dennison JB. Thermal Expansion of Visible-Light-Cured Composite Resins. Operative Dentistry, 1989; 14: 64-67.

62. Munksgaard EC, Hansen EK, Kato H. Wall-to-Wall Polymerization Contraction of Composite Resins Versus Filler Content. Scandinavian Journal of Dental Research, 1987; 95: 526-531.

63. Van Dijken JWV, Wing KR, Ruyter IE. An Evaluation of the Radiopacity of Composite Restorative Materials Used in Class I and Class Ii Cavities. Acta Odontologica Scandinavica, 1989; 47: 401-407.

64. Soderholm KJM. Leaking of Fillers in Dental Composites. Journal of Dental Research, 1983; 62: 126-130.

65. O'Brien WJ. Dental Materials and Their Selection. Chicago: London: Quintessence Pub. Co.; 2002; 73: 499-504.

66. Lang BR, Jaarda M and Wang RF. Filler particle size and composite resin classification systems. Journal of Oral Rehabilitation, 1992; 19: 569-584.

67. Anusavice KJ, Phillips RW. Phillips' Science of Dental Materials. Philadelphia: W. B. Saunders; 2003.

68. Sideridou ID, Karabela MM, Micheliou CN, Karagiannidis PG, Logothetidis S. Physical Properties of a Hybrid and a Nanohybrid Dental Light-Cured Resin Composite. Journal of Biomaterials Science, Polymer Edition, 2009; 20: 1831-1844.

69. Phillips RW, Avery DR, Mehra R, Swartz ML, McCune RJ. Observations on a Composite Resin for Class Ii Restorations: Two-Year Report. The Journal of Prosthetic Dentistry, 1972; 28: 164-169.

70. Heuer GA, Garman TA, Sherrer JD, Williams HA. A Clinical Comparison of a Quartz- and Glass-Filled Composite with a Glass-Filled Composite. The Journal of the American Dental Association, 1982; 105: 246-247.

71. Van Noort R. Introduction to Dental Materials. 3rd ed. London: UK: Elsevier; 2007.

72. Ferracane JL. Resin Composite - State of the Art. Dental Materials, 2011; 27: 29-38. 68.

73. Van Noort R. Introduction to Dental Materials. Mosby Publications, 2007; (3rd Edition): Chapeter 2.2.

74. Darvell BW. Materials science for denistry. BW Darvell HK 2006; (8th Edition): Chapter 6.

75. Gladys S, Van Meerbeek B, Braem M, Lambrechts P and Vanherle G. Comparative physico-mechanical characterization of new hybrid restorative materials with

conventional glass ionomer and resin composite restorative materials. Journal of Dental Research, 1997; 76: 883-894.

76. Ferracane JL. Current trends in dental composites. Critical Review Oral Biological Medicine, 1995; 6: 302-318.

77. Sharma, S., Cross, S.E., Hsueh, C., Wali, R.P., Stieg, A.Z. and Gimzewski, J.K. (2010). Nanocharacterization in dentistry. Int J Mol Sci 11 (6): 2523-45.

78. Beun S, Glorieux T, Devaux J, Vreven J and Leloup G. Characterization of nanofilled compared with universal and microfilled composites. Dental Materials, 2007; 23: 51-59.

79. Garoushi S, Vallittu PK and Lassila LVJ. Short glass fibre reinforced restorative composites resin with semi-inter penetrating polymer network matrix. Dental Materials, 2007; 23: 1356-1362.

80. Palaniappan, S., Bharadwaj, D., Mattar, D.L., Peumans, M., Van Meerbeek, B. and Lambrechts, P. Nanofilled and microhybrid composite restorations: Five-year clinical wear performances. *Dent Mater* (2011). 27 (7): 692-700.

81. Loguercio AD, Reis A, Hernandez PAG, Macedo RP, Busato ALS. 3-Year Clinical Evaluation of Posterior Packable Composite Resin Restorations. *Journal of Oral Rehabilitation,* 2006; 33:144-151.

82. Leinfelder KF, Bayne SC, Swift Jr EJ. Packable Composites: Overview and Technical Considerations. *Journal of Esthetic Dentistry (Canada),* 1999; 11:234-249.

83. Sturdevant JR, Bayne SC, Wilder AD, Heymann HO, Lisk M, Foster E. 3-Year Clinical Study of a Failed Condensable Posterior Composite. *Journal of Dental Research,* 1993; 72:380-386.

84. Olmez A, Oztas N, Bodur H. The effect of flowable resin composite on microleakage and internal voids in class II composite restorations. Oper Dent 2004;29:713-9.

85. Yacizi AR, Ozgunaltay G, Dayangac B. The effect of different types of flowable restorative resins on microleakage of Class V cavities. Oper Dent 2003;28:773-8

86. Miguez PA, Pereira PNR, Foxton RM, Walter R, Nunes MF, Swift Jr EJ. Effects of Flowable Resin on Bond Strength and Gap Formation in Class I Restorations. *Dental Materials*, 2004; 20:839-845.

87. Yearn JA. Factors Affecting Cure of Visible Light Activated Composites. *International Dental Journal*, 1985; 35:218-225.

88. Podshadley AG, Gullett CE, Crim G. Interface Seal of Incremental Placement of Visible Light-Cured Composite Resins. *The Journal of Prosthetic Dentistry*, 1985; 53:625-626.

89. Davidson CL, de Gee AJ, Feilzer A. The Competition between the Composite-Dentin Bond Strength and the Polymerization Contraction Stress. *Journal of Dental Research*, 1984; 63:1396-1399.

90. Feilzer AJ, De Gee AJ, Davidson CL. Increased Wall-to-Wall Curing Contraction in Thin Bonded Resin Layers. *Journal of Dental Research*, 1989; 68:48-50.

91. Jose-Luis R. Dental technique—restorations with resin-based, bulk fill composites. AEGIS Communications 2010:31.

92. Pilo R, Oelgiesser D, Cardash HS. A survey of output intensity and potential for depth of cure among light-curing units in clinical use. Journal of Dentistry 1999;27:235–41.

93. Lazarchik DA, Hammond BD, Sikes CL, Looney SW, Rueggeberg FA. Hardness comparison of bulk-filled/transtooth and incremental-filled/occlusally irradiated composite resins. Journal of Prosthetic Dentistry 2007;98:129–40.

94. Poskus LT, Placido E, Cardoso PEC. Influence of placement techniques on Vickers and Knoop hardness of class ii composite resin restorations. Dental Materials 2004;20:726–32.

95. Kovarik RE, Ergle JW. Fracture toughness of posterior composite resins fabricated by incremental layering. The Journal of Prosthetic Dentistry 1993;69:557–60.

96. Lutz F, Krejci I, Barbakow F. Quality and durability of marginal adaptation in bonded composite restorations. Dental Materials 1991;7:107–13.

97. Sigusch BW, Pflaum T, Völpel A, Gretsch K, Hoy S, Watts DC, et al. Resin-composite cytotoxicity varies with shade and irradiance. Dental Materials 2012;28:312–9.

98. Geurtsen W. Substances released from dental resin composites and glass ionomer cements. European Journal of Oral Sciences 1998;106:687–95.

99. Sigusch BW, Völpel A, Braun I, Uhl A, Jandt KD. Influence of different light curing units on the cytotoxicity of various dental composites. Dental Materials 2007;23:1342–8.

100. Al-Hiyasat AS, Darmani H, Milhem MM. Cytotoxicity evaluation of dental resin composites and their flowable derivatives. Clinical Oral Investigations 2005;9:21–5.

101. Quinlan CA, Zisterer DM, Tipton KF, O'Sullivan MI. In vitro cytotoxicity of a composite resin and compomer. International Endodontic Journal 2002;35:47–55.

102. Tjan AHL, Bergh BH, Lidner C. Effect of various incremental techniques on the marginal adaptation of class II composite resin restorations. The Journal of Prosthetic Dentistry 1992;67:62–6.

103. Giachetti L, Russo DS, Bambi C, Grandini R. A review of polymerization shrinkage stress: current techniques for posterior direct resin restorations. Journal of Contemporary Dental Practice 2006;7:079–88.

104. Schneider LFJ, Cavalcante LM, Silikas N. Shrinkage stresses generated during resin-composite applications: a review. Journal of Dental Biomechanics 2010;1:10–24.

105. Abbas G, Fleming GJP, Harrington E, Shortall ACC, Burke FJT. Cuspal movement and microleakage in premolar teeth restored with a packable composite cured in bulk or in increments. Journal of Dentistry 2003;31:437–44.

106. Sarrett DC. Clinical challenges and the relevance of materials testing for posterior composite restorations. Dental Materials 2005;21:9–20

107. Jose-Luis R. Dental technique—restorations with resin-based, bulk fill composites. AEGIS Communications 2010:31.

108. Lowe RA. The search for a low-shrinkage direct composite. Oral Health Journal 2010;6(March):78–82.

109. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Operative Dentistry 2013;38(6):618–25.

110. Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clinical Oral Investigations 2014, January. 9:203–14 .

111. Silikas N, Masouras K, Satterthwaite J, Watts DC. Effect of nanofillers in adhesive and aesthetic properties of dental resin-composites. International Journal of Nano and Biomaterials 2007;1:116–27.

112. Taira M, Suzuki H, Toyooka H, Yamaki M. Refractive index of inorganic fillers in seven visible-light-cured dental composite resins. Journal of Materials Science Letters 1994;13:68–70.

113. Hirabayashi S, Hirasawa T. Improvements to light transmittance in light-cured composite resins by the utilisation of low refractive index dimethacrylates. Dental Materials Journal 1990;9:203–14.

114. Kim JJ, Moon HJ, Lim BS, Lee YK, Rhee SH, Yang HC. The effect of nanofiller on the opacity of experimental composites. Journal of Biomedical Materials Research Part B: Applied Biomaterials 2007;80:332–8.

115. Shortall AC, Palin WM, Burtscher P. Refractive index mismatch and monomer reactivity influence composite curing depth. Journal of Dental Research 2008;87:84–8.

116. Moszner N, Fischer UK, Ganster B, Liska R, Rheinberger V. Benzoyl germanium derivatives as novel visible light photoinitiators for dental materials. Dental Materials 2008;24:901–7.

117. Condon JR, & Ferracane JL .Evaluation of composite wear with a new multi-mode oral wear simulator Dental Materials1996; 12(4) 218-226.

118. Gladys S, Van Meerbeek B, Braem M, Lambrechts P and Vanherle G. Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass ionomer and resin composite restorative materials. Journal of Dental Research, 1997; 76: 883-894.

119. Ilie N, Bucuta S, Dreaenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Operative Dentistry 2013. [9:203–14].

120. El-Safty S, Silikas N, Watts DC. Creep deformation of restorative resin-composites intended for bulk-fill placement. Dental Materials 2012;28:928–35.

121. Czasch P, Ilie N. In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clinical Oral Investigations 2013;17:227–35.

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

123. Finan L, Palin WM, Moskwa N, McGinley EL, Fleming GJ. The influence of irradiation potential on the degree of conversion and mechanical properties of two bulk-fill flowable RBC base materials. Dental Materials 2013;29:906–12.

124. Garoushi S, Sailynoja E, Vallittu PK, Lassila L. Physical properties and depth of cure of a new short fiber reinforced composite. Dental Materials 2013;29:835–41.

125. El-Damanhoury H, Platt J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Operative Dentistry 2013. [Epub ahead of print].

126. Jin X, Bertrand S, Hammesfahr P. New radically polymerizable resins with remarkably low curing stress. Journal of Dental Research 2009;88:1651.

127. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR technology. Dental Materials 2011;27:348–55.

128. Chen HY, Manhart J, Hickel R, Kunzelmann KH .Polymerization contraction stress in light-cured packable composite resins. Dent Mater 2001;17:253–259.

129. Davidson CL, de Gee AJ, Feilzer A .The competition between the composite–dentin bond strength and the polymerization contraction stress. J Dent Res 1984;63:1396–1399.

130. Leinfelder KF .Posterior composite resins: the materials and their clinical performance. J Am Dent Assoc 1995; 126(5):663–672.

131. Carvalho RM, Pereira JC, Yoshiyama M, Pashley DH A review of polymerization contraction: the influence of stress development versus stress relief. Oper Dent 1996; 21:17–24.

132. McCullock AJ, Smith BG In vitro studies of cusp reinforcement with adhesive restorative material. Br Dent J 1986;161:450–452.

133. Alomari QD, Reinhardt JW, Boyer DB Effect of liners on cusp deflection and gap formation in composite restorations. Oper Dent 2001; 26:406–411.

134. 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. Dental Materials 2013;29:269–77. .

135. Petrovic LM, Zorica DM, Stojanac I, Krstonosic VS, Hadnadjev MS, Atanackovic TM. A model of the viscoelastic behavior of flowable resin composites prior to setting. Dental Materials 2013;29:929–34.

136. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Operative Dentistry 2013;38(6):618–25.

137. Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR,Fleming GJP, Cuspal Deflection. Microleakage in premolarteeth restored with bulk-fill flowable resin-based compositebase materials. J Dent 2012;40:500–5.

138. Roggendorf MJ, Krämer N, Appelt A, Naumann M,Frankenberger R. Marginal quality of flowable 4-Mm base vs.conventionally layered resin composite. J Dent 2011;39:643–7.

139. 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. Journal of Dentistry 2012;40:500–5.

140. Roggendorf MJ, Kramer N, Appelt A, Naumann M, Frankenberger R. Marginal quality of flowable 4-mm base vs. conventionally layered resin composite. Journal of Dentistry 2011;39:643–7.

141. Ilie N, Bucuta S, Dreaenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Operative Dentistry 2013. [Epub ahead of print].

142. Surefil® SDR™ flow Product Brochure (2010) Dentsply.

143. Venus bulk fill. Technical information. HerausKultzer, Germany2013.

144. Ever-x posterior .brochure. GC,Tokyo, Japan 2011.

145. Technical report 3M ESPE,St. Paul,MN,2009.

146. AdheSE. Technical bulletin. Ivoclar-Vivadent 2013.

147. Wakefield CW, Draughn RA, Sneed WD, Davis TN. Shear bond strengths of six bonding systems using the pushout method of in vitro testing. *Oper Dent*1998; 23:69-76.

148. Yoshiyama M, Carvalho RM, Sano H, Horner JA, Brewer PD, Pashley DH. Regional bond strengths of resins to human root dentine. *J Dent*1996; 24:435-42.

149. Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. Operative Dentistry 2004;29:481–508.

150. Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. 12- year survival of composite vs. amalgam restorations. Journal of Dental Research 2010;89:1063–7.

151. Van Meerbeek B, De Munck J, Yoshida Y, et al. Buonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. Operative Dentistry2003;28:215–35.

152. Ernst CP, Canbek K, Aksogan K, Willershausen B. Two-year clinical performance of a packable posterior composite with and without a flowable composite liner. Clinical Oral Investigations 2003;7:129–34.

153. Frankenberger R, Reinelt C, Petschelt A, Kra¨mer N. Operator vs. material influence on clinical outcome of bonded ceramic inlays. Dental Materials 2009;25:960–8.

154. Garcia-Godoy F, Kramer N, Feilzer AJ, Frankenberger R. Long-term degradation of enamel and dentin bonds: 6-year results in vitro vs. in vivo. Dental Materials 2010;26:1113–8.

155. Kramer N, Garcia-Godoy F, Reinelt C, Feilzer AJ, Frankenberger R. Nanohybrid vs. fine hybrid composite in extended Class II cavities after six years. Dental Materials2011;27:455–64.

156. Peumans M, De Munck J, Van Landuyt KL, Poitevin A, Lambrechts P, Van Meerbeek B. A 13-year clinical evaluation of two three-step etch-and-rinse adhesives in non-carious class-V lesions. Clinical Oral Investigations, EPub ahead of print.

157. Musanje L, Darvell BW. Curing-light attenuation in filled-resin restorative materials. Dental Materials 2006;22:804–17.

158. Ferracane JL, Greener EH. The effect of resin formulation on the dedental restorative resin. Journal of Biomedical Materials Research 1986;20:121–31.

159. Burke FJT, Hussain A, Nolan L, Fleming GJP. Methods used in dentine bonding tests: an analysis of 102 investigations on bond strength. Eur J Prosthodont Rest Dent 2008;16:150.

160. Watanabe LG, Marshall GW, Marshall SJ. Variables Influence on shear bond strength testing to dentin. In: Tagami J, Toledano M, Prati C, editors. Advanced

Adhesive Dentistry, 3rd International Kuraray Symposium, Vol. Granada International Symposium. Kuraray Co. Ltd; 1999. p. 75-90

161. Lindemuth JS, Hagge MS. Effect of universal testing machine crosshead speed on the shear bond strength and bonding failure mode of composite resin to enamel and dentin. Mil Med 2000;165:742-6.

162. Tagami J, Tao L, Pashley DH. Correlation among dentin depth, permeability and bond strength of adhesive resins. Dent Mater 1990;6:45-50.

163. Øilo G, Olsson S. Tensile bond strength of dentin adhesives: A comparison of materials and methods. Dent Mater 1990;6:138-44

164. Technical specification ISO/TS 11405. Dental materials - testing of adhesion to tooth structure. Second ed. Switzerland; 2003

165. Velasquez LM. Effect of placement agitation and placement time on the shear bond strength of 3 self-etching adhesives. Oper Dent. 2006 Jul-Aug;31(4):426-30

166. Nicoleta Ilie .An in-vitro assessment of the shear bond strength of bulk-fill resin composites to permanent and deciduous teeth . journalofdentistry 42 (2014) 850–855

167. *Annelies Van Ende.* Bulk-filling of high C-factor posterior cavities: Effect on adhesion to cavity-bottom dentin. denalmaterials29 (2013) 269–277

168. Lippo V. translucency of flowable bulk fill composite with various thickness.the chinase journal of dental research 2011;30:206-11

169. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR technology. Dental Materials 2011;27:348–55.

170. Burgess J, Cakir D. Comparative properties of low-shrinkage composite resins. Compendium of Continuing Education in Dentistry 2010;31:10–5.