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OPTIMIZING MARGINAL ADAPTATION OF DIRECT COMPOSITE RESTORATION

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Department of Restorative and Aesthetic Dentistry in partial fulfilment for the

bachelor degree of dental surgery

BY

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SUPERVISOR CERTIFICATION

This is to certify that this thesis was prepared by **Monther Arkan Hassan** under my supervision in the Department of Conservative Dentistry, College of Dentistry/ University of Baghdad, as partial fulfilment of the graduation requirements for the Bachelor degree in dentistry.

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(Conservative Dentistry)

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DEDICATION

To my father, who helped and supported me through my journey in the college , to my father who didn't waste any effort for my comfort and gave me his car (soso) since the beginning of this wonderful journey

To my mother, who didn't waste an effort in staying beside me and helping me to become the man I am today.

To my friends (M13) who were always making my days better through the hardest times in this journey

To Zainab Baher, I will be always thankful for investing your abilities in supporting, helping and even your moodiness in making the past times wonderful to live.

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1-INTRODUCTION:

Tooth-colored posterior restoration has emerged as an essential and vital component of the restorative procedure instead of dental amalgam due to aesthetic and conservative demand. This was accompanied by the fact that composite material received large attention and development in its properties such as wear resistance, adhesion, mechanical properties, shade selection, color stability, polishability and handling properties (Eklund 2010)

In spite the great advancement in dental composite formulations, till now many researches documented high failure rate posterior composite restorations. One of the detrimental factors that could affect the restoration performance is the development of marginal gap with the resultant staining, microleakage, recurrent caries and postoperative sensitivity (Subbiya, Venkatesh et al. 2020).

Possible causes of marginal gap development are polymerization shrinkage, viscoelastic behavior, effect of configuration factor (C-factor), differences in coefficients of thermal expansion between the tooth and restorative materials, and water sorption, (Subbiya, Venkatesh et al. 2020)

Many techniques were suggested to reduce the adverse efects of shrinkage stress, among these suggestions are: altered light curing cycles (intensity and time curing), polymerization-induced phase separation, ring-opening polymerization, hybrid polymerization reactions, thiol-ene photopolymerization, preheating, vibration, stress absorbing layers with low elastic modulus liners and diverse composite layering techniques (Deliperi and Bardwell 2002)

Different placement techniques of posterior composite were

adopted to reduce polymerization shrinkage. Among these techniques, a widely used method named Incremental Technique which rely on applying composite in 2mm increment in different suggested ways such as: horizontal technique, oblique successive cusp build-up technique, centripetal incremental technique, split horizontal technique and three-site technique. (Chandrasekhar, Rudrapati et al. 2017)

Till now very few studies were published concerning the impact of these recent placement techniques on marginal leakage. In addition, the placement techniques used in these studies although given similar names but they vary in their detailed steps which makes comparison and results interpretation difficult.

2-MARGINAL ADAPTATION:

Adaptation has been defined as the degree of proximity and interlocking of a filling material to the cavity wall (Jablonski, 1987). The term ‘marginal adaptation’ however is less easily defined as it has been somewhat abused as a term in the literature. The term has come to be used synonymously with adaptation at the cavosurface margin. As in the case of microleakage studies, there are very many publications in the field of marginal adaptation. Although there are similarities amongst techniques used, there is not as yet a standard method for examining or measuring the adaptation of restorative .materials. Important variations exist between cavity preparation and design and the restorative technique employed. In addition, varying the restorative material may allow individual properties, such as ability to bond to dentine or postplacement water absorption, to influence marginal adaptation. Similarly, differences in finishing techniques have been shown to be an important factor, whilst perhaps the greatest variety is seen in methods of assessing marginal adaptation. . One of the detrimental factors that could affect the restoration performance is the development of marginal gap with the resultant staining, microleakage, recurrent caries and postoperative sensitivity (Subbiya, Venkatesh et al. 2020). Possible causes of marginal gap development are polymerization shrinkage, viscoelastic behavior, effect of configuration factor (C-factor), differences in coefficients of thermal expansion between the tooth and restorative materials, and water sorption, (Subbiya, Venkatesh et al. 2020)

3-Objective for Optimize marginal adaptation in direct composite restoration:

To reduce the factors that could affect the restoration performance like, development of marginal gap with the resultant staining, microleakage, recurrent caries and postoperative sensitivity

4-Factors Related to the marginal adapation for direct composite restoration:

4.1.Anatomic variation of enamel and dentin:

4.1.1.Enamel

Enamel is the hardest material produced by biological processes. It is derived from the epithelium and forms the anatomical crown of a tooth. Composed of approximately 96% inorganic apatite crystals and 4% organic material and water, this highly mineralized, acellular, and avascular tissue has been shaped by natural selection for its abrasion-resistant properties. To these ends, enamel apatite crystals are packed together as parallel alternating crystallite enamel rods and inter-rod enamel (Nanci, 2017). Enamel thickness varies on the dental crown, being thickest on the buccal surfaces (about 2.5 mm) and thinner toward the cervix. Enamel is translucent and varies in color from yellowish to grayish white. Ameloblasts, or enamel-forming cells, eventually disappear as the development completes. Accordingly, enamel cannot be repaired or remodeled. An enamel defect or chipping/spalling damage is permanent. Therefore, diseases that have an impact on enamel formation may leave permanent “scars” in the enamel structure.(33)

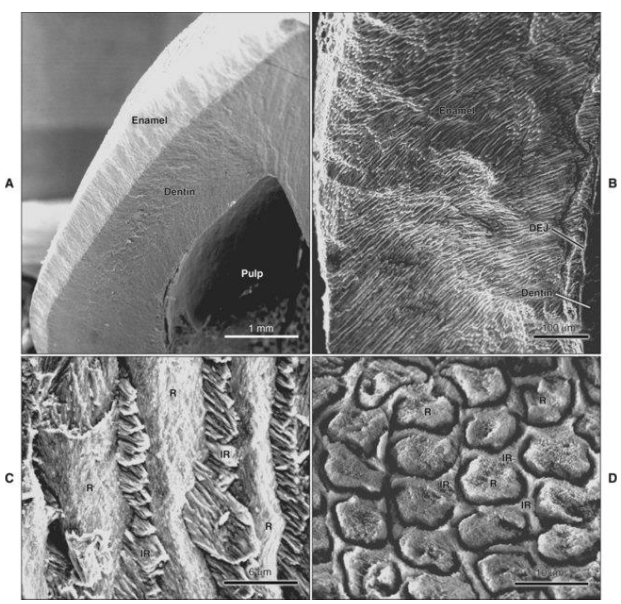

Fig. -1- Scanning electron microscope views of (A) the enamel layer covering coronal dentin, (B) the complex distribution of enamel rods across the layer, (C and D) and perspectives of the rod-interrod relationship when rods are exposed (C) longitudinally or (D) in cross section. Interrod enamel surrounds each rod. DEJ, Dentinoenamel junction; IR, interrod; R,rod.{34]

the anatomical variation of the enamel can effecting the bonding process of the restoration furthermore the marginal adaptation ,like the enamel thickness, the composition of enamel ,the orientation of enamel rods we will give an example about the composition of the enamel: there is a study comparing between the layer of enamel that reach this conclusion: It has been suggested that, in general, the surface eprismless' layers are strongly resistant to enamel caries (Sheykholeslam Z and Buonocore MG,1972) and acid etching (Conniff JN and Hamby GR,1976), so resin-tags based on a prism structure may not be formed on the eprismless' surface by the acid-etch bonding technique. It is, therefore, necessary that the eprismless' layer be removed by grinding or by deep acid etching. (Bozalis WG et al..1979)

4.1.2.DENTIN:

Dentin is a yellowish, somewhat elastic but mineralized avascular tissue that supports the enamel and encloses the pulp chamber. Approximately 60% of the dentin is inorganic apatite, while the remaining 40% is a fibrillar protein collagen all arranged in tubular structures radially, oriented from the pulp chamber and toward enamel and cementum boundaries. Odontoblasts are dentin-producing cells that remain active at the ends of these tubules, located at the innermost edges of the dentin. Dentin can be remodeled to a degree as odontoblasts can produce new tissue (secondary dentin) if required (e.g., excessive tooth wear that exposes the dentin).[35]

The anatomical variations of the dentin are more than the enamel and these variations make the dentin very sensitive during the bonding process for example of that we will compare between the bond strength between the dentin layers, There was a significant fall in bond strength values as one reaches deeper levels of dentin from superficial to intermediate to deep.(Van Meerbeek B et al..2011)

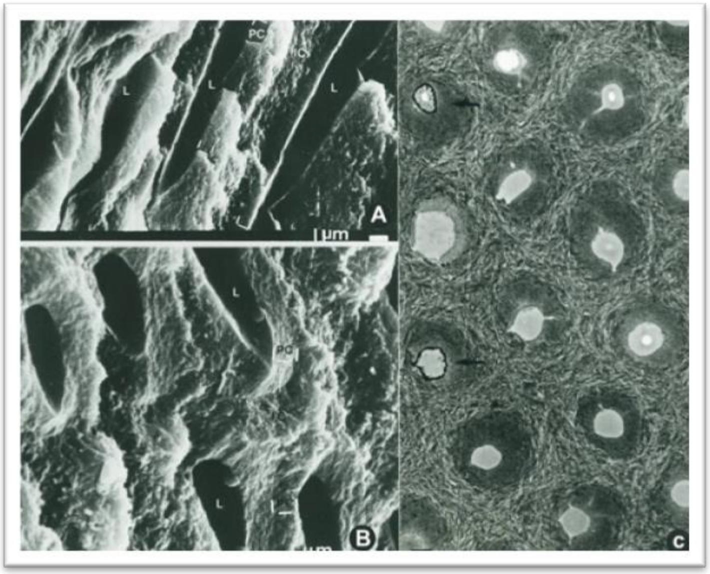

Fig.-2-. The peritubular dentin surrounds the lumen of the tubules. Intertubular dentin forms a continuous collagen-rich network. Left: horse's dentin observed with the SEM. Right: human dentin observed with the transmission electron microscope (TEM)

5.2-Factors Related to the Cavity restoration:

Whether standardized or not, cavity shape will influence adaptation. This is principally due to variations in contraction stresses within the confines of the cavity. These stresses are related both to the configuration of the cavity and the flow of unset material during the setting of the restoration.

6.7.4. **Configuration Factor (C-factor)**

A factor that affects the degree of polymerization stress is: - the restoration's configuration factor, often known as the "C-Factor," which is the ratio between bonded and unbounded surfaces (Summitt et al., 2001).

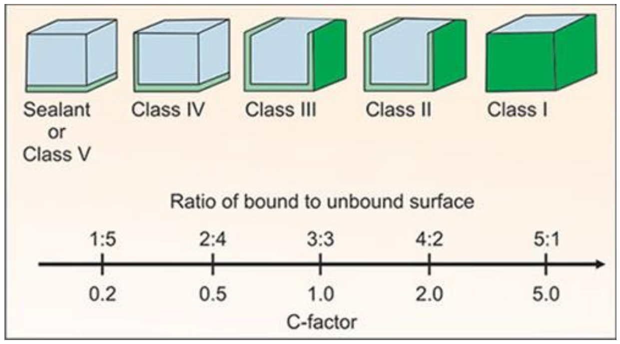

Fig.3 Configuration factors (C-factors) associated with polymerization shrinkage for different situations using dental restorative materials.

With an increase in the number of bonded surfaces, there is a rise in the C-factor and a corresponding increase in the contraction stress on the adhesive bond. It is only the free surface of a resin restoration that may serve as a reservoir for plastic deformation during the early stage of polymerization since it is not limited by adhering to the cavity walls (Braga et al., 2006).

Stresses within the restoration have been shown (Davidson and Gee, 1984; Kemp-Scholte, 1989) to be related to the proportion of restoration which is in contact with tooth substance (bonded surface) compared with the surface area which is exposed (free surface). As the relative proportion of bonded surface to free surface increases so does the internal stress within the material. Thus the internal stresses within an incisal restoration areless than in a Class II restoration, whilst the highest values would be expected within Class I and Class V cavities. Modifications of cavity design have been incorporated and tested in a number of investigations. The bevelling of enamel margins prior to etching has been shown to reduce leakage (Blunck and Roulet, 1989; Holtan et al., 1990) although standardization of enamel bevel has not been reported. Holtan ef al. have reported marginal failure in etched, bevelled enamel margins following artificial ageing of the restorative resin using a thermocycling technique. Other workers using saucer-shaped preparations with shallow depth and long bevels into both enamel and dentine (Krejci and Lutz, 1990) have shown improved adaptation to enamel, but few restorations were considered to maintain an adequate seal in dentine. There is always a difference of opinion regarding principles of cavity preparation. Certain authors follow conventional GV. Black formulas, while others are of the view that specific width, depth, etc. is not required in composites.

5.3- factors related to the Adhesive System

Adhesion means The condition in which two surfaces are held together by interfacial forces, which may consist of balance forces, interlocking forces, or both," according to the American Society for Testing and Materials (standard D907), (Packham, 1992). After solidification, any adhesive substance, typically a viscous fluid, transmits weight between the adherent surfaces it has adhered to (Van Meerbeek et al., 1998). A primary aim of employing an adhesive is to establish a close bond between the restoration and the surrounding tooth structure. The adhesive must be able to moisten a solid substance to allow for structural interaction to occur for lasting adhesion to occur (Söderholm, 1991).

5.3.1. Classification of Adhesive Strategies;

Etch and rinse (E&R), self-etch (SE), and multimode or universal adhesive are the three kinds of adhesives available.

5.3.1.1. Etch and Rinse Strategy (total-etch)

This approach consists of two kinds of adhesives, which are differentiated by the number of steps they require (3-steps, or 2-steps E&R adhesives). The steps of 3-steps E&R adhesive are: the first step is to etch the surface with phosphoric acid and then rinse it off with water. Second step: application of a solvent-rich primer (hydrophilic functional monomer) that is then allowed to dry naturally, and lastly the third stage is the polymerization of bonding resin (hydrophobic cross-linker resin), which is required Adhesives that need two steps to involve acid etching with phosphoric acid as the first step, followed by the second phase where a single solution combining both the hydrophilic primer and adhesive is applied, which is then allowed to dry naturally before polymerization. It is always necessary to utilize phosphoric acid in a gel form at a concentration ranging between 30 and 40 percent (pH = 0.1 to 0.4) (Van Meerbeek et al., 2003).

5.3.1.2. Self-etch Strategy

Because SE adhesive solutions eliminate the issues associated with acid demineralized dentin depth and resin penetration of E&R adhesives, they provide a less-sensitive approach to tooth sensitivity. The objectives of this approach are to minimize the amount of time spent on the application and to make it simpler. In accordance with the number of stages required, the SE adhesive approach may be classified into two categories of adhesives:

SE adhesives that need two steps: Dentin and enamel are prepared and primed with an acidic self-etching primer in the first stage, and an adhesive resin is applied in the second step, which must be polymerized before it can be used. However, there is a unique solution for one-step SE adhesives that contains both the acidic primer and the adhesive resin. This solution precondition, primes, and infiltrates the substrate before the polymerization process. Aqueous solutions include functional monomers (phosphoric acid and/or carboxylic acid esters), monofunctional comonomers, cross-linkers monomers, and additives (e.g. fillers and photoinitiators) are used in both kinds of self-adhesive solutions (Van Landuyt et al., 2009).

5.3.1.3. Multi-mode or Universal Adhesives

An innovative transformation of adhesive systems, with the potential for chemical adhesion, has been introduced. Known as multi-mode or universal adhesives due to their many-sided instructions for use, universal adhesives could be used in both adhesive strategies (total etching and self-etching strategies). (Perdigão et al., 2014).

Single Bond Universal Adhesive Scotchbond™M Universal Adhesive is a multi-mode, single-bottle, a no-mix solution that can be used reliably in the R, SE or selective etch mode for both direct and indirect restorations, and used on all surfaces without any extra primer step according to the manufacturer (3M ESPE 2013).

Single Bond Universal(SBU) has 10- methacryloxy decyl phosphate (10-MDP) and the polyalkenoic co-polymer within contents. 10-MDP is described as an amphiphilic functional monomer with a hydrophilic polar phosphate group on one end that is capable to bond chemically to tooth tissues, metals, and zirconia, and a hydrophobic methacrylate group on the other end, that is capable of bond chemically to methacrylate-based restoratives, and cement. In addition, it is in combination with polyalkenoic co-polymer, molecules can form ionic bonding with calcium hydroxyapatite (Alex, 2015). When SBU was applied on dentin, microtensile bond micro tensile, not vary with the variations in dentin moisture or the adhesive strategy used. However, nanoleakage was significantly lower when SBU was applied in SE mode(Jlekh and Abdul-Ameer, 2018). This means that SBU is not sensitive to the degree of dentin moisture. The insensitivity of SBU to air-dried dentin may be explained by the water content of this adhesive (10-15% by wt.) that permits the expansion of the collagen network (Sezinando, 2014).

5.3.1.4. The concolusion of Study about Bond Strength of Different Adhesive Systems to Dental Hard Tissues

Within the limitations of this in vitro study, bond strengths were found to be dependent upon the type of adhesive system used, and they varied with respect to tooth regions.While enamel bond strengths were greater than dentin for all the adhesive systems tested, The enamel bonding of the Single Bond one-bottle total-etch adhesive system was significantly greater than the self-etching adhesive systems. One-bottle total-etch and self-etching adhesive systems displayed significantly different bond strengths at both dentinal depths. (G. Schmalz et.al.. 2002)

5.4.Factors related to the composite resin

5.4.1. Composition

The dental composite is comprised primarily of the resin matrix (organic phase), filling particles (inorganic phase), the interface, and minor additives like polymerization initiator, stabilizers, coloring pigments, inhibitors of polymerization (Ruyter and Sjoevik, 1981).

5.4.1.1. Organic resin matrix

The resin is the component of the composite that is chemically active in nature. it is a fluid monomer that is transformed into a hard polymer via the procedure of polymerization (Schneider et al., 2010). Different matrix systems had been developed. so composite material can be classified according to the methacrylate-based matrix, inorganic, acid-modified methacrylate, and ring-opening epoxide(silorane based) (Zimmerli et al., 2010)

5.4.1.2. Inorganic Filler

The dispersed filler particles in the polymer matrix comprise several inorganic materials such as quartz (fine particles), silica glasses containing barium or strontium, other silica-based glass fillers including colloid silica (micro-fine particles), lithium-aluminum silicate glass, or zirconia-silica nanoclusters, and silica nanoparticles which are produced by nanotechnology (Yu-Chih, 2009).

There are essentially two types of filler particles: microfill particles and macrofill particles while a combination of microfill and macrofill particles are termed "hybrids". While macrofilll particles reserve more strength, microfill particles are more often easier to polish, allowing for a much more aesthetic finish

(Roeters et al., 2005).

With increasing filler content, the polymerization shrinkage, the linear expansion coefficient, and water absorption are reduced. On the other hand, with increasing filler content, the compressive and tensile strength, the modulus of elasticity, and wear resistance are generally increased.

When the filler loading is increased, the viscosity of the final composite-based resin restoration is likewise higher; as a general rule, the higher the filler loading, the higher the viscosity and strength of the final composite-based resin restoration.

According to viscosity, composite materials can be classified in to:

(Jackson & Morgan, 2000).

5.4.1.2.1.Flowable Composites

It was in 1996 that flowable composites were first introduced into clinical practice. The low viscosity of the composite is due to the use of smaller filler particles, which are similar in size to the hybrid composite's particles (0.04-1 um in diameter); however, by reducing the filler content (44-54) percent of the total volume filled and allowing the increased resin to reduce the viscosity of the matrix (Fortin & Vargas, 2000).

Among their many benefits are the following: great wettability of the tooth surface, which ensures penetration into every irregularity, and the ability to create layers of minimal thickness, which improves or eliminates air inclusion or entrapment in the tooth structure (Olmez et al., 2004).

The disadvantages of flowable composites include significant curing shrinkage as a result of the reduced filler load, as well as poor mechanical characteristics after curing. As a result, the most apparent and predominant use for these materials is in tiny class III or Class V cavities, as well as as a liner material in class I or II cavities. When viscous materials are employed as liners, they may result in a decrease in microleakage at all cavosurface edges, as well as a reduction in postoperative sensitivity and discomfort (Leevailoj et al., 2001).

5.4.1.2.2.packable composites:

Packable composite provides a greater viscosity by increasing the filler load excess of 86% wt. and wide filler size distribution (0.04-10m) (Combe & Burke, 2000).

According to reports, the packable composites can resist higher occlusal pressures and are thus suggested for usage in restoration where amalgam had previously been the preferred restorative material. (Fortin and Vargas, 2000).

6- Techniques to reduce shrinkage stress

6.1. Modification in composition of resin composite:

The two major components of dental composites are the polymer matrix and the filler particles. Changes in composition and chemistry of the constituent monomers and filler can alter the physical properties of the materials (Finer and Santerre, 1999).

6.1.1. Modification of Resin Matrix:

The amount and types of monomer are greatly affect the polymerization shrinkage of dental composites (Kamalak et al., 2018). Evolving improvements in resinous phase of the dental composites were progressed to decrease the polymerization shrinkage to the least value.

6.1.1.1. Use of thiol-ene-based monomers:

Thiol–ene monomers were developed as an alternative to methacrylate-based systems. The mechanism of polymerization relies on radical- mediated step-growth between thiol and vinyl monomer. During the initiation stage, a thiyl radical is produced, which adds to a vinyl group, leading to a carbon-centered radical. Thus, formation of a thioether and a thiylradical.

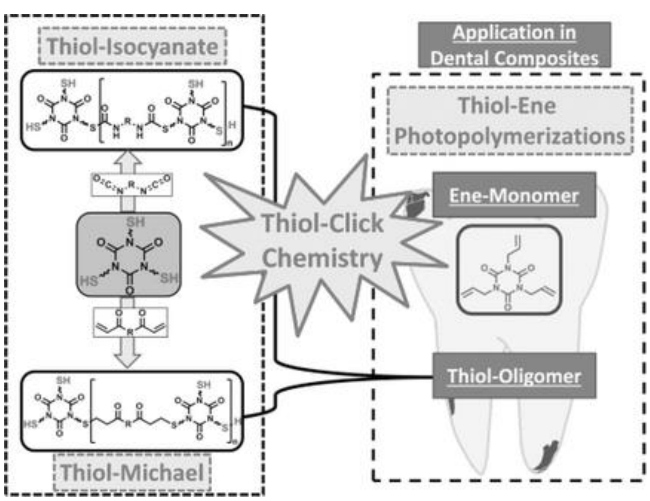

Fig.4 The thiol-ene moieties function as a solvent and chain transfer agent during the early stages of the polymerization, resulting in an overall lower stress buildup(N.B. Cramer)

The step-growth polymerization mechanism resulting in delayed gelation compared to the chain-growth mechanism of methacrylates with a significant polymerization shrinkage reduction (Machado et al.,2017).

6.1.1.2. Use of silorane-based monomers:

Silorane-based resin revealed a lower polymerization shrinkage compared to thedimethacrylates such as (Bis-GMA, UDMA, and TEGDMA). Silorane molecules polymerize through cationic ring-opening intermediates, instead of free radical cross-linked polymerization of dimethacrylate monomers

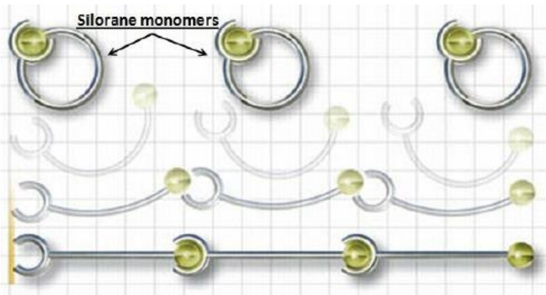

Fig. 5: Silorane- based composite has ring-shaped monomer particles instead of the linear onesthat found in the methacrylate-based composite. The reaction between the ring-shaped monomers is initiated by their opining and extending toward each other, which theoretically results in low polymerization shrinkage <1% (Ilie N, Hickel R)

Which in turn may produce polymerization shrinkage values less than 1% ,The epoxy ring of the oxirane monomer rings are responsible for the reduced polymerization shrinkage. During polymerization it is opened to produce a linear chain with volumetric expansion that may compensate for volumetric shrinkage to some extent (karaman et al., 2017).

6.1.2. Modification of filler:

Generally, the increase in the inorganic filler load on the expense of the resin matrix will consequently reduce the polymerization shrinkage. However, the addition of inorganic fillers to polymer resin has a certain limitation in order to achieve an adequate wettability of the resinous matrix to the fillers without creation of weak interface between these two phases (Fronza et al.,2019).Inorganic fillers modification is considered as the ultimate goals in evolution of dental resin composites, because filler type, load, size, and distribution will greatly affect the dental composites clinical success. Vast approaches have been done to improve the filler component load and quality (Cramer et al., 2011):

6.1.2.1. Incorporation of nanogels:

Nanogels are a prepolymerized polymer in nanosized that cross-linked with the resin matrix and chemically attached to the inorganic filler surface, forming interphase structure between resin matrix and fillers. Nanogel prepolymer utilization in resin composite manufacturing considered as a versatile approach promote the incorporation of inorganic filler into resin matrix. Although, their polymeric origin, nanogels have been exposed to enhance mechanical properties of nanogel-modified composites. Moreover, they reduce the polymerization shrinkage associated with high nanogel content (Fronza et al., 2019).

6.1.2.2. Incorporation of bioactive nano-sized fillers:

Polymerization shrinkage of dental resin composite could be reduced by decreasing the resin/filler ratio, which may be achieved by incorporation of more reinforcing inorganic filler, while at the same time get the unique benefit of the added fillers (Par and Tarle., 2018). A novel type fillers were advocated as a possible solution to induce bioactivity, remineralization capability and to enhance mechanical feature of the restoration such as: Nano-hydroxyapatite ,bioactive glass, calcium silicates , calcium phosphates, and other calcium-based derivative (Abdelnabi et al, 2020).

6.1.2.3. Organic filler:

The incorporation of pre-polymerized resin fillers (organic fillers) decreases the volume fraction of the polymerizable resin and increases the filler volume fraction resulting in reduction of the polymerization shrinkage.

6.2. Altered Light Curing Cycles (Intensity and Time Curing)

To decrease shrinkage stress without sacrificing other characteristics such as mechanical properties, one of the techniques that have been proposed is to reduce the initiation rate by using lower irradiation intensities, such as soft-start, ramping, and delayed curing (Cramer et al., 2011).

6.3. Incremental Curing of Composites-Layering Techniques

The reason for using multilayer methods is to decrease overall Polymerization stress by increasing the number of increments and providing them an optimum shape to increase the total free surface area of the polymerization product (Park et al., 2008)

6.4. Stress Absorbing Layers with Low Elastic Modulus Liners

In the case of resin-based composites, liners such as flowable composite and resin-modified glass ionomer cement are used (Kwon et al., 2010). The lower filler content and lower elastic modulus of these materials suggest that they may be used as a "stress breaker," absorbing the forces of shrinkage during polymerization and loading under cyclic conditions. Using a flowable resin composite as an intermediary thin layer to overcome polymerization shrinkage stress has been proposed as a means of overcoming polymerization shrinkage stress. This is based on the idea of an "elastic cavity wall" previously proposed for filled adhesives (Braga et al., 2005). Under the "elastic cavity wall concept," the shrinkage stress produced by the following layer of greater modulus resin composite may be absorbed by an elastic intermediate layer, decreasing the tension at the tooth-restoration interface (Unterbrink & Liebenberg, 1999). Restorative materials, on the other hand, come in a broad range of shrinkage and elastic modulus values.

As a result, certain combinations may have worse overall effectiveness when compared to the typical restorative substance used alone. Some author stateded that the shrinkage stress of flowable resin composites was found to be comparable to that of conventional resin composites, confirming the hypothesis that the use of flowable materials does not result in a significant stress reduction and that the risk of debonding at the adhesive interface as a result of polymerization contraction is the same for both types of material. (Cadenaro et al., 2009).

6.5. Preheating

Preheating resin composites have been found to reduce the shrinkage of polymerization because the increased temperature reduces the material's viscosity and increases radical mobility. This would lead to increased polymerization and increased degree of conversion (Kusai Baroudi, 2015).

6.6. Vibration

Based on the premise that vibration reduces the viscosity of the composite, enabling the material to flow and readily adapt to the cavity walls without voids, this method is comparable to flowable composites in its performance characteristics. So instead of having to deal with the drawbacks of large polymerization shrinkage and poor mechanical characteristics of a flowable composite, a condensable material with a higher viscosity may be utilized in a similar manner two examples are Sonicfill composite and Compothixo instrument (lovan et al., 2011).

6.7. Factors Related to development of polymerization shrinkage stress in dental composite

6.7.1. Polymerization Shrinkage and Stress

During the polymerization process, shrinkage of composite resin seems to be the most significant issue in the use of composite resin as a posterior restorative material. Polymerization shrinkage is related to the conversion of monomers to polymers as a polymer occupies less volume than the monomers.

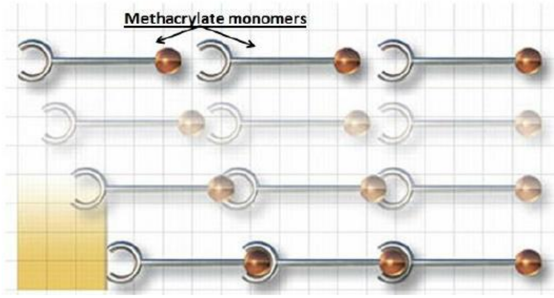

Fig. 6: When methacrylate monomers in the resin composites react to establish acovalent bond, the distance between the two groups of atoms is reduced by their shiftingcloser together in linear response, resulting in substantial reduction in the free volume which is translated into volumetric shrinkage(Anusavice KJ 2003)

During polymerization, the distance between monomer chains is reduced when the weak van der Waals forces are converted into covalent bonds so volumetrical shrinkage will result. Unfortunately, almost all composite resins currently available in the dental market exhibit shrinkage during transforming monomers into polymers, ranging from 2 to 7% volumetrically (Hassan and Khier 2019).

Composite polymerization could well be split into two phases: the pre gel phase and the post gel phase. Prior to gelation, the reactive species exhibit sufficient mobility to reorganize and adjust for volumetric shrinkage without producing substantial quantities of internal and interfacial Stresses (Perdigão et al., 2012; Sezinando, 2014). Polymerization shrinkage occurs after the gel point, causing strain on the network and the attachment region to the bonding system after the gel point. This stress condition is known as polymerization shrinkage stress (Hilton, 2002a, 2002b).

The high polymerization shrinkage stresses can generate one of the following three detrimental effects: (1) Adhesive failure resulting in interfacial gap formation, microleakage, and recurrence of caries. In this type of failure, the contraction forces within the resin are greater than the strength of the bond to the tooth. (2) Cohesive failure resulting in micro-cracks of composite. In this type of failure, the contraction forces are high, the bond to the tooth is strong and the tooth itself is strong. (3) Cuspal deformation results in postoperative sensitivity, where, the contraction forces are high, the bond to the tooth are strong and the tooth itself is weak.

6.7.2. Volumetric Shrinkage

When the monomers react to form a covalent link, the distance and the free volume between the two groups of atoms are reduced, both of which result in volumetric shrinkage of the polymer structure. The amount of volumetric shrinkage experienced by a composite is governed by the volume fraction of filler used, the composition of the resin matrix, and the degree of conversion experienced by the resin matrix (Braga et al., 2005)

6.7.3.Viscoelastic Behavior

Resin composites are solids that exhibit complicated viscoelastic behavior due to the presence of resin. Composites have primarily viscous behavior early in the polymerization process, and they show progressive transition to predominately elastic behavior later in the reaction (Vaidyanathan & Vaidyanathan, 2001). It is known as the elastic modulus or Young's modulus that the interfacial tension created by resin composite shrinkage is positively linked with the stiffness rate of the setting material.

The most rigid material (the material with the highest elastic modulus) will thus produce the greatest amount of stress for a given shrinkage value. The elastic modulus rises as the polymerization process progresses as well (Feilzer et al., 1990).

Conforming to Hooke's Law, the stress is determined by the volumetric shrinkage multiplied by the elastic modulus of the material under consideration. A composite's contraction stress increases in direct proportion to its elastic modulus and polymerization shrinkage, which are both large (Giachetti et al., 2006).

6.7.4. Configuration Factor (C-factor)

6.7.5. Intensity of curing light

A linear association exists between polymerization shrinkage and light intensity, which means that higher light intensity produces greater polymerization shrinkage when the exposure time is constant (Sakaguchi and Ferracane, 2001).

6.7.6. Water sorption

The quantity of water absorbed by a material via the exposed surface and into the substance's body is referred to as water absorption by the material. Two opposing processes occur as a result of the diffusion of water into the matrix. In certain composites, water will leak away free unreacted monomers and ions that have not yet been reacted. This outward migration of ions leads to additional shrinkage and weight loss of the material as a result of the process. Hygroscopic absorption of water, on the other hand, results in a swelling of the material as well as an increase in weight .This process may allow for a degree of relaxation of the tensions that are created inside the matrix during polymerization shrinkage if the matrix is sufficiently flexible (Shalan and Yasin, 2011).

6.8. Composite Placement Techniques

6.8.1 Incremental Technique

The incremental technique has been widely accepted as a standard method for resin composites placement because it depends on layering thickness of 2mm or less than allows enough light penetration for adequate polymerization. This will enhance the physical properties, marginal adaptation, reduce cytotoxicity, and minimized polymerization shrinkage of composite restoration by reducing the volume of material and C-factor (Costa et al., 2017).

When the incremental technique was used for insertion of the composite, there was a reduction in microleakage, which could be due to the reduced volume of the resin and the stress generated on the cavity walls, as well as to more uniform and efficient polymerization of the resin composite throughout its entire thickness (Pfeifer et al., 2006). The followings are some examples of variations associated with different stratifications (Nadig et al, 2011)

6.8.2. Horizontal Technique

This is an occlusogingival layering technique that is usually utilized less than 2 mm thickness of composite restorative material against the prepared cavity surface is done and cured. But the primary disadvantage is that there is an increase of the C-factor, which in turn increase the shrinkage (Reis et al., 2003) (Figure 12- A)

6.8.3. Oblique technique

The concept of the oblique technique was first introduced by Lutz et al., (1986) to improve resin flow and therefore reduce polymerization shrinkage stress by increasing adhesive-free surface area. In this method, wedge-shaped composite increments are inserted and polymerized just from the occlusal surface, rather than the whole surface. Because the form of the increment in the oblique method covers less cavity wall surface than the horizontal technique does, it may have resulted in less stress being applied to the wall (Mereufä et al., 2012). (Figure 12- B)

6.8.4. Centripetal Incremental Technique:

Was developed by Bicho in 1994. It included the creation of a thin composite proximal wall before filling the whole preparation with horizontal increments, resulting in greater adaptability of the composite to cavity walls (Nadig et al., 2011). (Figure12-C)

6.8.5. Split Horizontal Technique:

A variation of the centripetal and horizontal incremental methods, the split horizontal incremental approach has been suggested, in which, after constructing the proximal wall, the horizontal increments put to fill the class I cavity thus created are divided to further decrease the C factor (lovan et al., 2011). (Figure 12-D)

6.8.6. Three-Site Technique:

For many years, it was thought that contraction in light-curing resin composites always occurred toward the light source. However, this was shown incorrect (Lutz et al., 1986). This method is linked with the employment of a reflecting wedge and a modified transparent matrix, among other components. To begin, the curing light is directed through the matrix and wedges in an attempt to guide the polymerization vectors toward the gingival margin. This has resulted in a reduction in the intensity of the light, a reduction in contraction stresses, and an improvement in the adaptation ((Lindberg et al., 2007); Karthick etal.,2011) (Figure 12- E) .

6.8.7. Successive cusp build-up Technique:

In this method, the initial composite increment is placed to a single dentin surface without coming into touch with the opposing cavity walls, and then the restoration is built up by putting a succession of wedge-shaped composite increments to reduce the C-factor. Giachetti et al. (2006) describe the process of building up each cusp one at a time (Figure 12-F).

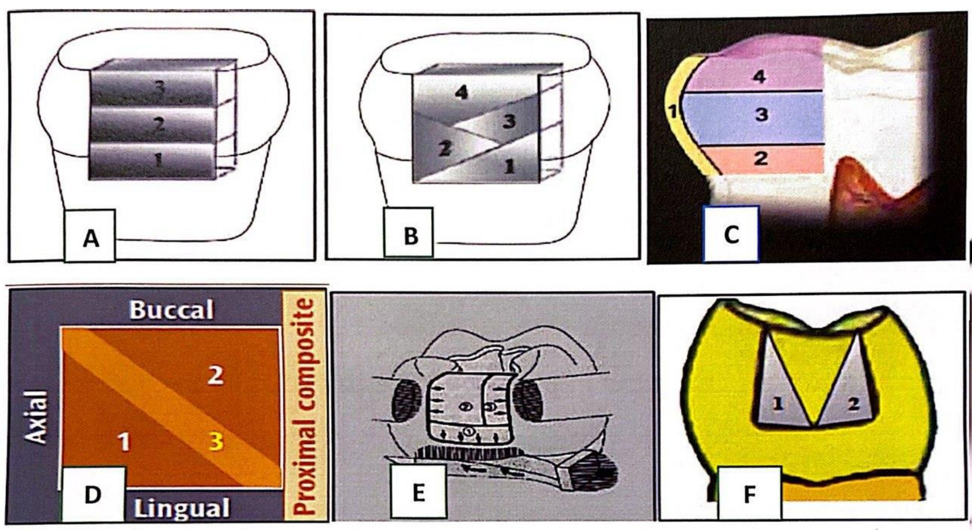

Fig.7: Incremental technique, A: Horizontal Technique (Reis et al., 2003), B: Oblique Method(Reis et al., 2003).. C: Centripetal Incremental Technique (Szep et al., 2001), D: Split Horizontal Technique((Nadig et al., 2011), E: Three-Site Technique (Karthick et al., 2011), F: Successive cusp build-up Technique(Giachetti et al., 2006).

6.8.8. Bulk Technique

This technique refers to the use of a regular consistency bulk-fill composite in one increment up to 4-5mm without an additional capping layer as shown in Figure

(13) (Hirata et al., 2015). This helps to decrease curing time and controlled polymerization shrinkage that leads to time-saving for the dentist and patient and produces more comfortable restoration (Ilie et al.,2013)

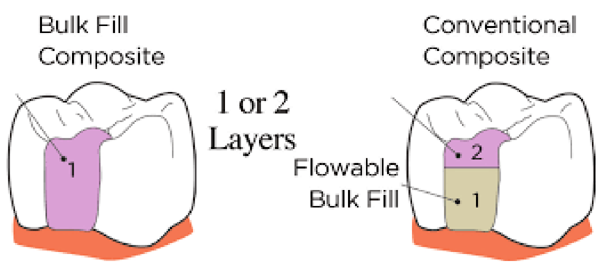

Fig.8: Bulkfill Technique

Bulk fill receives Innovative modifications in monomer chemistry, initiation system, and filler content, as well as developing novel polymerization strategies (Elshazly et al., 2020).

6.8.9. Snow plow technique

The snowplow technique involves the placement of a layer of flowable composite on the pulpal floor and the gingival margin of the proximal box of a posterior composite resin restoration. However, the layer of flowable composite is not cured before the placement of a denser-filled composite resin restorative material. In this way, the flowable is pushed into a very thin layer, and the excess is pushed out of the preparation. Reportedly, this will leave a very thin film of the high-shrinking flowable composite (Opdam et al., 2003). The flowable and the initial heavier-filled composite layer are light-cured as one increment. In contrast, a flowable composite cured in the traditional manner prior to subsequent incremental placement has been shown to increase the polymerization stress at the adhesive interface leading to a possible adhesive failure (Oliveira et al., 2010). Figure (14).

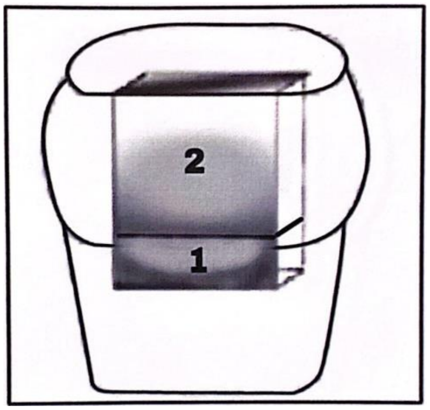

Fig.9: Snowplow technique 1:uncured flowable composite 2: packable composite ,the two layers cured simultaneously.

6.8.10. Injection molding technique

The injection-molded composite technique was firstly suggested by David J. Clark in 2010, who proposed using one layer of adhesive followed by flowable composite then finally injecting the paste composite. The resin-flowable paste mass is polymerized together in a single light cure. The concept of injection-molded composite dentistry can be compared to impressioning, in which the low-viscosity, light-body material is syringed into subgingival areas, and then followed and partially displaced by a heavier, high-viscosity impression material that has appropriate physical characteristics. In this technique, successively higher-viscosity materials are applied in sequence, and the bonding resin and flowable composite act as wetting agents, which are subsequently displaced by the heavier paste-composite material. (Clark, 2010) (Figure 15).

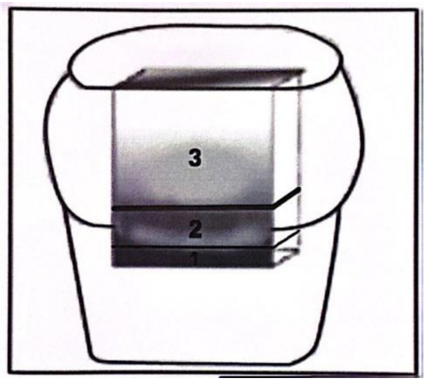

Fig.10: Injection molding technique 1 :uncured adhesive ,2. uncured flowable, 3packable composite, the three layers cured simultaneously

6.9.Finishing and Polishing

A surface finish attained with the use of a plastic matrix band is the most desirable finish for resin restorations; however, the need for contouring and removal of excess material, make it difficult to obtain such finish. Hence, it is advisable to contour the unpolymerized composite with hand instruments, so that the need for removal of large amounts of set resin leading to surface damage are minimized. Excess composite at the cavosurface margins is scraped away using a scalpel or a sharp gold knife. The use of stainless steel instruments should be avoided, as these tend to leave grey marks on the restoration. For the proximal surfaces, the matrix is removed and the restoration inspected for any voids or faulty contour. Excess composite is removed with scalpel or thin knife. Finishing is required in the gingival embrasure area to reduce gingival irritation. A very fine abrasive should be used so that the surface inside the restoration is not flattened. Strips are used with short strokes. . (Vimal k sikri .2016)

Fig. 11: Finishing kit

Resin-modified glass ionomer cements rather than conventional glass ionomers should be used in Class V cavity sites to allow immediate finishing and to reduce the incidence of microleakage. Dry finishing of RMGIs with abrasive disks is recommended because it produces a smoother surface and does not contribute to microleakage. However, wet finishing of conventional glass ionomers is still recommended to avoid desiccation. (AD Wilder Jr et al...2000)

The final luster is obtained with polishing pastes that may contain pumice, silica, silicon carbide and zirconium silicate, etc. The paste is made by mixing the abrasive with water or glycerine and carried to the restoration with brushes.

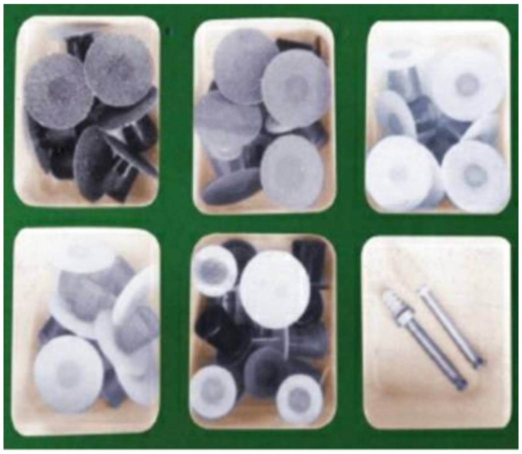

Fig.12: Polishing kit

6.10.The longevity of Interface:

Early composite resin materials showed failure rates as high as 50% after 10 years.2 This has drastically improved with the introduction of newer products. These materials can currently be classified as nanofilled, microfilled, or micro/nanohybrid materials with filler quantities varying from 42-55%. Of these, the hybrid composites performed the best with annual failure rates of 1.5-2%, most often as a result of restoration fracture. The major drawbacks of these materials are polymerization shrinkage and polymerization stress. These have the potential to initiate failure at the composite-tooth interface which will result in post-operative sensitivity and the opening of pre-existing enamel microcracks.

Rodolpho PA,2011)

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