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A REVIEW ON POLYMERIZATION SHRINKAGE OF RESIN COMPOSITES.

Running title : Polymerization shrinkage- a review

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Abstract

Currently, dental patients are expectingthat restorative material should fulfill both aesthetic and functional excellence. Composite resin can meet these requirements but with the major limitation of shrinkage during polymerization. This shrinkage will be manifested as marginal leakage,marginal staining, subsequent secondary caries,cuspal deflection, tooth or restoration fracture, postoperative sensitivity which ultimately ends by a failed restoration.Polymerization shrinkage of composite resin generates high degree of stress at the tooth/restoration interface owing to the failure of resin-based composites. The magnitude of these stressesdepends on the composition of resin composites, its ability to flow before solidification,cavity configuration and curing characteristics of the composites.Since, polymerization shrinkage cannot be completely eliminated, various techniques has been suggested in the manipulation for resin based composites to minimize the shrinkage and associated stresses. The purpose of this article is to review on theorigin of polymerization shrinkage, various factors involved in the process of polymerization shrinkage,the clinical factors affecting polymerization stress and the various material science advances and techniques that are currently available to deal with polymerization shrinkage in a clinical practice.

Key words: Polymerization shrinkage, resin composites, restoration failure.

INTRODUCTION

Over these years, many changes have been made in the development of aesthetic restorative materials. Among these materials composite resin shows superior aesthetic properties with the main limitation of undergoing polymerization shrinkage. Generally, polymer engages less volume than the monomers, the difference of which is termed as polymerization shrinkage. During polymerization, the weak vanderwaals forces between the monomer chains are converted to covalent bonds thereby decreasing the distance betweenthem[1]. There is asteady increase inthe viscosity of the resin material during this conversion which minimizes its flowing property. In the initial stages of polymerization, resin flows from unbound surfaces to compensate for the shrinkage[2].The point at which the resin changes from viscous solid to an elastic solid is termed as gel point. When this point is attained, the flow stops and the bonded composite resin transmits stress to the surrounding tooth structure[3]. As a result of polymerization the composite resin shrinks and the opposing walls and floor of the cavity is pulled closer together and the magnitude of this pull is dependent on the configuration factor of the cavity[4].Thusshrinkage occurs which can damage the marginal seal of the restorations, interfacial gap formation, postoperative sensitivity, secondary cariesand crack formation[5]. Inspite of various developments over the last years, polymerization shrinkage of composites still possess a major clinical problem. Therefore, this review article will focus on the origin of polymerization shrinkage,various factors involved in the process of polymerization shrinkage,the clinical factors affecting polymerization stress and various protocols that are currently available to deal with polymerization shrinkage in a clinical practice.

POLYMERIZATION SHRINKAGE

Following activation by the blue light, the photo initiatorcamphoroquinonein the composite resin is converted to an excited state. This excited camphor quinone reacts with the co- initiator amine to produce free radicals[6]. These free radicals start the polymerization process by reacting with the monomer molecules in the resin forming active centers[7].The polymerization continues by constant addition of monomers to the active centers forming long cross linking polymer chains. The Monomer molecules which are held together by VanderWaals forces with the intermolecular distance of 0.3 nm - 0.4 nm are replaced by covalent bonds after their polymerization where the intermolecular distance is reduced to 0.15 nm. This reduction in the distance between the molecules leads to volumetric polymerization shrinkage[8]. Resin composites applied in dentistry shows volumetric shrinkage values from 1% to 6%[9].

FACTORS AFFECTING POLYMERIZATION SHRINKAGE

CONFIGURATION FACTOR

Class 1 and class V cavity exhibit greatest stress because the restoration is bonded to five walls of the cavity. High C – factor results in debonding of the restoration. Lowest stress is seen in class IV cavity because it has enough unbonded surfaces providing stress relief. Hence it is important to have lower configuration cavity[10].

COMPOSITION OF RESIN COMPOSITES

A resin matrix with monomers of high molecular weight will result in lower shrinkage values than those formulated with monomers of low molecular weight. Molecular functionalities, molecular structure, molecular mass and size have major influences upon the amount of shrinkage and also on monomer viscosity[11].

MATERIAL PROPERTIES

There are three inherent properties of the resin composites that are crucial over the magnitude of stress:i) volumetric shrinkage ii) material stiffness(elastic modulus) and degree of conversion from double bonds to single bonds

FILLER VOLUME FRACTION

Filler volume fraction is inversely proportional to volumetric shrinkage. As the volume of filler content increases, the volume of resin matrix decreases and hence volumetric shrinkage reduces proportionately[12].

INTENSITY OF CURING LIGHT

Higher the light intensity, greater the polymerization shrinkage. This is due to the greater degree of conversion. The slower polymerization retards the gel point, which provides time for stress relaxation[13].

THICKNESS OF COMPOSITE RESIN

Incremental curing produces lesser polymerization shrinkage stress than bulk curing[14].

METHODS TO MINIMIZE POLYMERIZATION SHRINKAGE

SILORANE BASED COMPOSITE FORMULATION

Silorane was synthesized by combining oxirane and siloxane molecules.Due to the ring-opening oxirane monomer the silorane-based resin possess the advantages of low polymerization shrinkage. These monomers produce circumscribed volumetric expansion because of the opening of ring , which make up for the volumetric shrinkage[15].

MODIFICATION IN THE PHOTO INITIATOR SYSTEMS

Increasing the inhibitor concentration reduces polymerization shrinkage without altering the final degree of conversion. Camphoroquinone substituted by phenylpropane Dione reduced the stress produced by polymerization[16].

LIGHT CURING TECHNIQUES

These techniques reduce polymerization shrinkage by providing low rate of polymerization at initial stages which in turngives enough time for stress relaxation before reaching the gel state.

SOFT START POLYMERIZATION

In this technique, curing begins with low intensity and ends with high intensity. This offers advantage of stress relaxation before maximum possible conversion.Soft start polymerization is subdivided into three techniques: i) staged cure ii) ramped cure and iii) pulse delay[17].

STAGED CURE/ DELAYED CURING

The restoration is initially cured at lower intensity until the contour and shape of the restoration is achieved. The second exposure with high intensity is applied to cure the final restoration. This provides substantial stress relaxation period. The longer the relaxation period, lower the stress generated.

RAMPED CURING

The intensity is gradually increased during the polymerization process. It is achieved by increasing the intensity with every 30 seconds either by bringing the light closer to the tooth or using a curing light designed to change its intensity. This allows the light curing material to have a prolonged gel phase during which the polymerization stresses are distributed readily[18].

PULSE DELAY

In this method, each exposure is separated by a dark interval. During this phase the polymerization reaction takes place at a slow rate. The greatest reduction in the shrinkage is accomplished with the delay of 3 to 5 minutes.

Curing done for 10 seconds at 1-cm distance with a time gap of 10 seconds followed by 20 seconds curing in contact with the tooth surfaceproves to be a suitable technique to reduce the polymerization shrinkage without compromising the degree of conversion[19].

USE OF STRESS ABSORBING LINERS

The application of a low modulus flowable composite acts as a elastic buffer to compensates polymerization shrinkage stress by flowing readily into the cavity’s line angles and irregularities. When elastic modulus is low, the composite will expand to adapt to the inherent modulus of the tooth. Flowable composite can be used as an intermediate stress absorbing layer as it reduces the stress at the tooth-restoration interface.

Resin-modified glass ionomer cements (RMGICs) may be a better alternative material to be used as a liner under resin composites as it reduces the amount of polymerization shrinkage, microleakage and secondary caries[20].

PLACEMENT TECHNIQUES

INCREMENTAL LAYERING TECHNIQUE:

Incremental filling of composites decreases polymerization shrinkage stress as a result of reduced material volume. This method of incrementally curing resin-based composite ensure complete polymerization and helps to achieve better marginal seal thereby preventing distortion of the cavity wall[21].The various placement techniques for composites based on incremental layering are:

HORIZONTAL TECHNIQUE

It involves placement of composite material in an occlusogingival direction particularly used to restore small cavities. This layering technique increases the C-factor[22].

THREE-SITE TECHNIQUE

This layering technique is performed with the use of a matrices and reflective wedges. It guides the vectors of polymerization towards the gingival margin preventing any gap formation.

OBLIQUE TECHNIQUE

This technique involves placement of wedge shaped composite increments to prevent distortion of cavity walls. This method might be associated first with polymerization through the cavity walls followed by the occlusal surface to direct polymerization vectors towards the adhesive surface[23].

SUCCESSIVE CUSP BUILDUP TECHNIQUE

This technique involves the placement of first composite increment to a single dentin surface with no contact to the opposite cavity walls followed by restoration build-up by placing a series of wedge shaped composite increments[24].

BULK TECHNIQUE

The bulk technique is used to reduce stress at the Cavo surface margins which is not supported by a recent study[25].

PREHEATING

Preheating increases composite flow, improves marginal adaptation and monomer conversion. Preheating causes temperature rise which reduces the viscosity and increases radical mobility resulting in the higher degree of conversion and additional polymerization.

INSERTION OF GLASS MEGA FILLERS

Inserting spherical glass mega fillers into the composite restoration before polymerization, will decrease the amount of resin matrix thereby reducing polymerization shrinkage. Its spherical shape does not hinder the flow ability of the composite during polymerization[26].

CONCLUSION

It has been a constant challenge for both clinicians and researchers to minimize the polymerization shrinkage to improve the success rate of resin based restorations. However there are numerous techniques and protocols to overcome the polymerization shrinkage stress. With the combination of proper case selection and effective placement techniques can help to reduce these stresses for successful, long-lasting resin based composite restorations.

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