POLYMERIZATION SHRINKAGE OF COMPOSITE RESINS – A REVIEW

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ABSTRACT

The greatest limitation in the use of composite resins as a posterior restorative material seems to be shrinkage during polymerization, which often leads to marginal fracture , subsequent secondary caries , marginal staining , restoration displacement , tooth fracture and, or post operative sensitivity. The objectives of this article are to throw light on the origin of polymerization shrinkage, the clinical factors affecting polymerization stress, and methods advocated to reduce shrinkage stress and the effectiveness of these methods.

INTRODUCTION

Many developments have been made in the field of resin composites for dental applications. However, the manifestation of shrinkage due to the polymerization process continues to be a major problem. As a consequence, marginal failure and subsequent secondary caries, marginal staining, restoration displacement, tooth fracture, and/or post-operative sensitivity are clinical drawbacks of resin composite application.[1] The aim of the current paper is to present an overview about the shrinkage stresses created during resin-composite applications, consequences, and advances.

POLYMERIZATION REACTION

The most common type of setting reaction for direct tooth-colored restoratives involves the formation of resin polymers. “Poly” means many, and “mono” means one. Polymers form from one or more types of monomer. The process of converting monomers into a polymer is called polymerization. [2]

An initiation system starts the transformation of monomers into polymers and copolymers. The initiation reaction creates a molecule with a free radical (an unpaired electron). Ideally, this process continues until all of the monomers become polymerized. The degree to which monomers convert into a polymer is referred to as the degree of conversion.[3]

SHRINKAGE-STRESS DEVELOPMENT

Polymerization shrinkage stress depends on multiple factors such as the configuration factor, composition of resin composites and material properties.

CONFIGURATION FACTOR

The c-factor (configuration factor) is a term used for the ratio of the number of walls bonded to unbounded

During polymerization the restorative resin shrinks and pulls the opposing walls and floor of the cavity closer together. The magnitude of this phenomenon depends upon the configuration of the cavity.[2]

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The greatest stress occurs when composite is bonded to five walls of a prepared cavity (C = 5) as in Class 1 or Class 5 restorations. The lowest C-factor values are obtained with class IV cavities because the material has enough unbonded surfaces to flow, providing stress relief. A high C-factor creates a risk for debonding of the restoration. Therefore, it is important to have a lower configuration cavity.

COMPOSITION OF RESIN COMPOSITES

A resin matrix formulated with monomers of high molecular weight (M_w) will result in lower shrinkage values than those formulated with monomers of low M_w. Thus, monomer functionalities, molecular structure, molecular mass and size have major influences upon the amount of shrinkage and also monomer viscosity.[2]

MATERIAL PROPERTIES

There are three inherent properties of the resin composites that are crucial over the magnitude of stress: the volumetric shrinkage, the material's stiffness (elastic modulus), and the degree of conversion from double carbon bonds into single carbon bonds. The complexity of polymerization shrinkage stress relies on the fact that these three components are interrelated and it is hard to identify the relative contribution of each individual factor; although some recent studies tried to isolate those.[1]

METHODS TO REDUCE POLYMERIZATION SHRINKAGE

1. MATERIAL ASPECT

There has been a general consensus about the addition of reinforcing filler to a resin matrix in a composite resins . This is because these inorganic fillers do not undergo any contraction during the setting reaction.

A study performed by Razak AAA et al has shown the mean linear shrinkage for the 79%, 65 % and50 % filler experimental Prisma APH composite cone was 0.33 %, 0.35 % and 0.42 % respectively. The correlation between filler content and shrinkage was $r = -0.958$ which was significant ($P < 0.01$). From this result, it is shown that the increase in filler content decreases the polymerization shrinkage.[2]

Recently, novel monomer combinations and alterations of the resin-composite formulation have been developed and evaluated with the goal of decreasing polymerization shrinkage stress.[1]

Nanocomposites contain a combination of non-agglomerated 20-nm-size nano silica filler and aggregated zirconia/silica nanocluster (primarily 5- to 20-nm size) filler.[4] The combination of nanomer-sized particles and the nanocluster formulations reduces the interstitial spacing of the filler particles. This reportedly provides increased filler loading ,thus, reduced polymerization stress.

The most recent modification on the polymer matrix is based on using ring opening polymerization of the silorane molecules,

These monomers “open” their molecular structures with local volumetric expansion and this may partly or totally compensate for volumetric shrinkage from C=C or similar polymerization.[5] As silorane-based composite polymerizes, “ring opening” monomers connect by opening, flattening and extending towards each other. The molecules of these “linear monomers” connect by actually shifting closer together in a linear response.

SILORANE system has been developed to minimize polymerization shrinkage and polymerization stress, while providing a high performance bond to the tooth.

2.INCREMENTAL LAYERING TECHNIQUE

Many researchers have suggested the use of "incremental layering techniques" for resin-composite restoration to reduce the polymerization shrinkage stress and cusp deflection . By using an incremental technique, the bonded/unbonded ratio would be reduced and, consequently, the stress level within the cavity might be lower, preserving the bonded area. Cuspal tension from polymerization shrinkage is common. Research shows this tension can be minimized if the composite is placed in at least three increments and each increment is sloped up one cavity wall at a time.[6]

Various techniques include the horizontal occluso-gingival layering, the wedge-shaped oblique layering, the successive cusp buildup technique, and the split-increment, horizontal placement technique.[5]

3. EFFECTS OF CURING TECHNIQUE

When composite resins are cured, light passes through the composite attenuates, which means that deeper layers of composite resin are less cured. Any factor that decreases the light intensity passing through the composite will lower the conversion rates of the composite resin. If inadequate levels of conversion are achieved during polymerization, polymerization shrinkage would result and wear resistance is reduced. Curing composite in 2-mm increments is recommended. Even though different curing units have different curing modes, the composite selected affects shrinkage more than the method of curing. The clinical effectiveness of the soft-, ramp-, or pulse-delay cure is questionable. Continued development of composite resins with reduced shrinkage is critically needed.[7]

4. STRESS ABSORBING LAYERS WITH LOW ELASTIC MODULUS LINERS

The use of a flowable resin composite as an intermediate thin layer has been suggested as a mean of overcoming polymerization shrinkage stress based on the concept of an "elastic cavity wall" suggested for filled adhesives . According to the "elastic cavity wall concept" the shrinkage stress generated by a subsequent layer of higher modulus resin composite can be absorbed by an elastic intermediary layer, thereby reducing the stress at the tooth-restoration interface manifested clinically as a reduction in cuspal deflection.[8] However, actual implementation of such a "stress absorbing" material is problematic.

5. PREHEATING

Recently, preheating resin composites have been advocated as a method to increase composite flow, improve marginal adaptation and monomer conversion. The benefits of preheating composites may have an impact on daily restorative procedures as well, with the application of shorter light exposure to provide conversion values similar to those seen in unheated conditions [9].

The reasons for increased conversion are based on many factors. Increased temperature decreases system viscosity and enhances radical mobility, resulting in additional polymerization and higher conversion. The collision frequency of unreacted active groups and radicals could increases with elevated curing temperature when below the glass transition temperature. Therefore, at raised temperatures, in theory, it would be possible to obtain higher degree of conversion before the vitrification point, decreasing the magnitude of stress. However, real benefits were not fully demonstrated and, until now, there are no published studies showing stress reduction by warming resin composites.[10]

CONCLUSIONS

Reduction of polymerization shrinkage has been an important issue. Despite considerable efforts, none of the newer developed resins are successful enough to tackle this problem. Thus, continued development of composite resins with reduced shrinkage is critically needed. However, judicious selection of composite resins and effective methods to reduce polymerization shrinkage can be used to create more predictable esthetics in resin based composites.

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