POLYMERIZATION SHRINKAGE OF COMPOSITE RESINS: A NEW PERSPECTIVE TO AN OLD PROBLEM- A REVIEW

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Polymerization shrinkage is one of the primary problems leading to failure of resin-based composite restorations. The clinician should therefore have a thorough understanding of the mechanisms that cause polymerization shrinkage and also the various methods and techniques to control it. The basic objective and aim of this review is to focus on the role of polymerization shrinkage, factors affecting it, and the various methods to control it.

Key words: Polymerization shrinkage, dental composites, placement techniques, material advancements, curing techniques

INTRODUCTION

The composition of resin based dental composites has evolved significantly since the materials were introduced to dentistry more than 50 years ago. Until recently the most important changes have involved the reinforcing filler, which has been purposely reduced in size to produce materials that are more easily and effectively polished and demonstrated greater wear resistance. Current changes are more focussed on the polymeric matrix of the material, principally to develop systems with reduced polymerization shrinkage and stress and to make them self-adhesive to tooth structure. The advantages of using composite resins are: esthetics, minimum tooth preparation, micromechanical bonding to tooth structure resulting in good adhesion, very low thermal conductivity, extended working time, reparability and ability to be polished in the same appointment. But composite resins have their own disadvantages out of which the primary disadvantage of using composite resins is polymerization shrinkage. The procedure is technique sensitive and time consuming. Composite resins also have a high coefficient of thermal expansion so if bonding is inadequate it may lead to micro leakage. Amongst all the disadvantages the primary concern is polymerisation shrinkage. Polymerization shrinkage is the pulling away of the material from the cavity walls during polymerization due to shrinkage of the composite resin. This process is responsible for the formation of a gap between the composite resin restoration and the cavity wall. The gap may vary from 1.67 to 5.68 % of the total volume of restoration. The gap formed leads to ingress of oral fluids and bacteria that are responsible for hypersensitivity, staining at the margins and recurrent caries. As the monomer cross links with another monomer, the mobile monomer molecules move closer and convert into covalent bonds like a polymer network incurring the volumetric shrinkage or bulk contraction. The majority of the shrinkage takes place before solidification called “gel point” or “pre-gelation phase” while the mass of materials is still plastic enough to flow, because in the early phase only the chain formation occurs and cross linking is not yet at full reaction allowing molecules to move into new positions. In-vitro measurement of polymerization shrinkage varies from 0.2% to 2% linearly and 1.5% to 6% volumetrically. Factors influencing polymerization shrinkage are use of higher molecular weight monomers (Bis-GMA, Bis-EMA, UDMA) in place of lower molecular weight monomers like TEGDMA which would increase the viscosity and reduce the contraction of resin composite. Increasing the filler/composite ratio results in decreasing polymerization shrinkage. C-factor is the ratio of bonded (restrained) surfaces to unbonded surfaces (free) of composite restoration and affects polymerization shrinkage significantly. The effect of polymerization shrinkage is somewhat tempered by the phenomenon of water sorption and its resulting hygroscopic expansion which causes the resins to swell. Shrinkage solely depends on the organic matrix and on the number of reactions that takes place. It rises with the degree of conversion and falls with increasing monomer molecular weight. This literature review will provide a perspective on dental composite resin shrinkage during polymerization and methods to minimise polymerization shrinkage.

Methods to Minimise polymerization shrinkage

There are different techniques to minimise the polymerization shrinkage

1. By placement techniques
2. By the materials used
3. By curing techniques
BY PLACEMENT TECHNIQUES

Incremental technique: It is widely accepted that the resin composite should be placed layer by layer instead of using a bulk technique to reduce polymerization shrinkage. The advantages associated with this are: Application of a small volume of materials and minimal contact with opposing cavity walls during polymerization leading to decreased polymerization shrinkage. Various incremental techniques used are:  

Horizontal technique: This technique is an occlusogingival layering generally used for small restorations. This technique increases the C-factor of the restoration. (Fig. 1)  

Vertical technique: This is a gingiva occlusal layering technique. (Fig. 2)  

Oblique technique: In this technique, wedge shaped composite increments are placed to further prevent distortion of cavity walls and reduce the C-factor. This technique may be associated with polymerization first through the cavity walls and then from the occlusal surface to direct the vectors of polymerization toward the adhesive surface (indirect polymerization technique).  

Successive cusp build up technique: In this technique, the first composite increment is applied to a single dentin surface without contacting the opposing cavity walls, and the restoration is built up by placing a series of wedge shaped composite increments to minimize the C-factor in 3-D cavity preparations. Each cusp then is built up separately.  

Centripetal build up technique: The first step here involves the placement of a light cure GIC liner upon the pulpal floor. After that an unfilled bonding liquid resin is applied to all internal and external aspects of the preparation and light cured for 20 seconds. Then a small increment of semi-transparent posterior composite is condensed towards the matrix band using composite condenser and light cured for 20 seconds. It leads to the formation of an occlusal ring made up of a semi-transparent layer of composite. Then the cavity is filled with small increments of dentin shade composites.  

The advantages with centripetal techniques are that it utilises a thin metal matrix band and wooden wedges, eliminating the need for transparent matrix bands which may not provide firm contact areas and anatomical proximal contours. By first creating a very thin proximal layer the internal curing of this layer is effective which can strengthen the composite and reduce cervical gaps. And even if cervical gaps form, the next consecutive layer which is condensed towards the gingival floor is likely to fill this gap. It is conservative in design and so preserves tooth structure. The Advantages of using GIC liners are that it provides excellent thermal insulation, releases fluoride and has a co-efficient of thermal expansion closer to dentin.

BY MATERIALS USED

To overcome polymerization shrinkage, researchers have attempted to develop newer monomers like:  

Spiroothocarbonates (SOCS) which expand. Use of high molecular weight molecules such as multiethylene-glycol dimethacrylate and co-polymers which manage to achieve 90 to 100% conversion by reducing C=C bonds. Ormocers (modified composites with organic and inorganic fillers) have also demonstrated their ability to reduce curing shrinkage. Hybrid composites made up of polymer groups (organic phase) reinforced by an inorganic phase, comprising 60% or more of the total content. They are composed of glasses of different composition and sizes, with particle size ranging from 0.6 to 1 micrometer and containing 0.04 micrometer size colloidal silica. Their advantages are: Less curing shrinkage, Low water absorption, excellent polishing and texturing properties, Co-efficient of thermal expansion similar to tooth structure.

Nano-technology has led to the development of a new composite resin characterised by the presence of nano particles measuring approximately 75 nm, which are made up of zirconium/silica or nano-silica particles. The aggregates are treated with silanes so that they bind to the resin. The distribution of the filler (aggregates and Nano particles) gives a high load up to 79.5%. Siloranes, a ring opening novel monomer which is a combination of siloxane and oxirane moieties called “silorane” are currently being explored. Based
on the ring opening polymerization of silorane presents a low shrinkage. The difference here in the polymerization process is that methacrylate based materials are cured by ‘radical intermediates’ and oxiranes are cured by ‘cationic intermediates’. The advantages of siloranes are: Here the considerable amount of polymeric matrix is relatively decreased by incorporating large amount of inorganic fillers decreasing polymerization shrinkage. Mechanical properties like hardness and compressive strength are increased. By adding glass filler, the thermal expansion becomes similar to tooth, various features like colour, translucency and fluorescence can be moderated by fillers.

**BY CURING TECHNIQUES**

Types of curing light and modes of curing have also shown to affect the degree of polymerization and related shrinkage of resin based composites to great extent. The composite resin requires a light source at a specific wavelength for its polymerization. To deliver this light source various light curing units were introduced. These units are:

- **Ultra violet light polymerizing devices** which produces a UV radiation of wave length 10nm to 380 nm. Disadvantages with this are limited depth of curing within the composite resin and through the tooth structure.

- **Plasma- Arc light devices** which gives light of range 400 nm to 500 nm. It uses a fluorescent bulb containing plasma. Disadvantages with this system are that it is large, heavy and requires adequate ventilation.

- **Quartz- Tungsten- Halogen** deliver energy density outputs of 400mW/cm². The light here is filtered to limit heat & narrow the spectrum of the wavelength.

- **LED** that provides a light in the blue visible spectrum with a range of 450nm to 490 nm. The first generation LED curing devices had low energy outputs. The latest generation of LED curing devices provide consistent energy outputs of greater than 1000mW/cm². The advantages: Gives a consistent, constant and higher light energy output, More practitioner friendly since these are lighter in weight, Either a heat sink or smaller and quieter fan to cool the LED is present. Incorporation of broader light spectrum to ensure more complete photo polymerization.

**Ramped curing technique:** In this technique, during exposure, intensity is gradually increased or “ramped up.” This can be in stepwise, linear, or exponential modes. For ramped curing, the intensity is increased with time (30 secs) either by bringing the light toward the tooth from a distance, curing through a cusp, or using a curing light designed to increase in intensity. This sequential curing of composite from low to high intensity significantly reduced polymerization shrinkage without compromising the depth of cure. Ramp curing allows the light-cured material to have a longer gel phase in which polymerization contraction stresses are dissipated more readily.

**Stepped curing technique (Staged curing/ delayed curing technique):** In this format, the restoration is initially cured at low intensity to contour and shape the restoration in occlusion, followed by a second exposure to completely cure the restoration. This allows substantial relaxation of polymerization stresses. The longer the period available for relaxation, the lower the generation of residual stresses is. This method also aids in the finishing of composite restorations—a partially cured composite material can be easily finished as compared with fully cured material. By filtering the light during an initial cure, obtaining a soft, easily finished material is possible. Thereafter, the filter is removed and the composite is cured completely.

**Pulse delay technique:** In the pulse-delay method, a series of exposure pulses is used, each separated by a dark interval. An initial exposure of up to 1 J/cm² is considered to be most efficient in reducing shrinkage stresses. Another important parameter is delay time between irradiances. During the dark period, polymerization reaction occurs at a reduced rate. Thus, longer delays lead to a greater amount of chain relaxation. Significant reductions in shrinkage stress and micro-leakage and increased micro-hardness have been reported for pulse-delay methods, with dark periods from 1 min to 5 mins. For pulse-delay curing, the greatest reduction of polymerization shrinkage is achieved with a delay of 3 mins to 5 mins. No statistically significant difference is reported in micro-leakage of nano-filled and micro-hybrid resin based composites cured with different soft-start polymerization modes (pulse, ramp, and staged).

**Soft start technique:** the technique involves curing initially with low intensity and finishes with high intensity. The approach allows for slow initial rate of polymerization.

Polymerization shrinkage is the main disadvantage of resin based composites. Both curing lights and curing methods contribute greatly to this shrinkage. The clinical performance of the new generation of light-curing units is reported to be similar to the conventional units. These new generation systems have high power density, high light intensity, and shortened exposure time, leading to reduced chair-side time and enhanced depth of cure. However, these high-intensity units have disadvantages and are not readily used in dental practice. Further modification and improvement of the light units may help achieve the best outcome and successful RBC restorations. Similarly, curing techniques, such as soft-start polymerization, have been shown to improve the polymerization kinetics of resin based composites. Thus, both the quantity and quality of polymerization can be improved with a proper selection of light-curing units and clinical curing techniques.

**Conclusion**

Dental composites are versatile materials whose usage has continued to grow since their introduction to the profession over 50 years ago. But the major disadvantage which remains highlighted with the usage of composite resin is polymerization shrinkage. In this article we have outlined the various methods to minimize and control polymerization shrinkage in three aspects: 1) Placement techniques 2) Material advancements 3) Curing techniques. Research is still underway to develop resin based composites with novel monomers, new photo-initiators and improved particle systems to reduce polymerization shrinkage.
REFERENCES


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