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# Factors involved in the development of polymerization shrinkage stress in resin-composites: A systematic review

**Roberto R. Braga**[a,*], **Rafael Y. Ballester**[a], **Jack L. Ferracane**[b]

[a]*Department of Dental Materials, School of Dentistry, University of São Paulo, Av. Prof. Lineu Prestes, 2227, São Paulo, SP 05508-900, Brazil*
[b]*Division of Biomaterials and Biomechanics, Department of Restorative Dentistry, Oregon Health and Science University, Portland, OR, USA*

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**Summary** *Objectives*. Polymerization shrinkage stress of resin-composite materials may have a negative impact on the clinical performance of bonded restorations. The purpose of this systematic review is to discuss the primary factors involved with polymerization shrinkage stress development.

*Data*. According to the current literature, polymerization stress of resin composites is determined by their volumetric shrinkage, viscoelastic behavior and by restrictions imposed to polymerization shrinkage. Therefore, the material's composition, its degree of conversion and reaction kinetics become aspects of interest, together with the confinement and compliance of the cavity preparation.

*Sources*. Information provided in this review was based on original scientific research published in Dental, Chemistry and Biomaterials journals. Textbooks on Chemistry and Dental Materials were also referenced for basic concepts.

*Conclusions*. Shrinkage stress development must be considered a multi-factorial phenomenon. Therefore, accessing the specific contribution of volumetric shrinkage, viscoelastic behavior, reaction kinetics and local conditions on stress magnitude seems impractical. Some of the restorative techniques aiming at stress reduction have limited applicability, because their efficiency varies depending upon the materials employed. Due to an intense research activity over the years, the understanding of this matter has increased remarkably, leading to the development of new restorative techniques and materials that may help minimize this problem.

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* Corresponding author. Tel.: +55 11 3091 7840x224; fax: +55 11 3091 7840x201.
*E-mail address:* rrbraga@usp.br (R.R. Braga).

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## Introduction

In the last three decades, adhesive dentistry has evolved remarkably, greatly due to the development, in the late 1950s, of BisGMA-based composites [1]. The incorporation of new monomers (e.g. UEDMA, BisEMA), new initiation systems and filler technologies have significantly improved the physical properties of these materials, expanding their use as direct and indirect restoratives. However, even considering the intense research on bonding mechanisms between composites and the dental substrate, clinical failure due to the disruption of the bonded interface remains a frequent occurrence [2]. Such interfacial defects may develop as a consequence of long-term thermal and mechanical stresses, or during the restorative procedure itself, due to stresses generated by composite polymerization shrinkage [3]. In fact, a direct relationship between polymerization shrinkage stress and marginal integrity has been demonstrated, in vitro, in class V restorations [4–6] and in teeth restored with bonded porcelain inlays [7].

Contraction stress in composite restorations is the result of polymerization shrinkage taking place under confinement, due to bonding to cavity walls. The material's viscoelastic behavior, characterized by its flow capacity at early stages of the curing reaction and by the elastic modulus acquired during polymerization, has also been identified as another important factor in contraction stress development [8].

As both volumetric shrinkage and viscoelastic properties are influenced by the same variables, accessing their specific role on stress development is a difficult task. For example, composites with relatively high inorganic filler content present lower shrinkage values but higher stiffness (i.e. lower strain capacity), compared to materials with lower inorganic content [9,10]. On the other hand, increasing degree of conversion of the polymer matrix increases volumetric shrinkage and elastic modulus simultaneously [11,12]. The complexity of this issue is heightened by the fact that stress development is affected by reaction kinetics. As the composite's plastic deformation (or viscous flow) is a time-dependent event, slower curing rates may provide extended periods where the material is able to yield to contraction forces before acquiring higher elastic modulus [13]. In fact, reducing polymerization rates in composites has been shown to lower stress levels significantly [14–16].

The influence of confinement conditions imposed on the composite sample and the compliance of the bonding substrate have also been a subject of intense debate in the literature. A direct relationship between contraction stress and confinement of the composite sample was found when a rigid, noncompliant testing system was employed [17]. However, other authors have found that these two variables were inversely related when using a less rigid, more compliant set-up [18,19].

From a clinical standpoint, it is important to determine how these laboratory results can be applied to the restorative procedure. The purpose of this systematic review is to discuss the various factors that influence the development of contraction stresses in dental composites, i.e. volumetric shrinkage, viscoelastic properties, and extent of cavity constraint, as well as their influence on different aspects of the restorative procedure.

## Volumetric shrinkage

When monomers in proximity react to establish a covalent bond, the distance between the two groups of atoms is reduced and there is a reduction in free volume, both of which translate into volumetric shrinkage. The magnitude of volumetric shrinkage experienced by a composite is determined by its filler volume fraction and the composition and degree of conversion of the resin matrix.

Shrinkage values reported for BisGMA (5.2%) and TEGDMA (12.5%) are substantially higher than those displayed by typical composites, which range between 2 and 3% [9,20,21]. This difference is due to the fact that in hybrid composites, approximately 60% of the volume is occupied by filler particles. Microfilled composites, though their inorganic content is typically about 40 vol%, have shrinkage values similar to hybrids, due to the presence of pre-polymerized composite particles, sometimes referred to as 'organic fillers', which render them similar to hybrid composites in terms of the actual volume fraction of polymerizing resin. Low-viscosity (flowable) composites present volumetric shrinkages up to 5%, in large part due to their reduced inorganic content, which is typically below 50 vol% [9]. The shrinkage values reported should be considered approximate, because they are completely dependent upon the extent of the polymerization reaction. This makes the comparison of shrinkage data from different studies a tenuous proposition, as it is not typical for authors to measure degree of conversion along with shrinkage, except in rare cases [15,16].

The volumetric shrinkage of composites has been shown to be proportional to its degree of conversion