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Internal adaptation of resin composites at two configurations: Influence of polymerization shrinkage and stress

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ABSTRACT

Objective. This study compared internal adaptation of composites under different C-factors and examined the relationship between internal adaptation and polymerization shrinkage parameters.
Methods. Cylindrical cavities 3 mm in diameter were prepared in 100 human third molars in two depths: 4 mm high C-factor (H-CF) or 1 mm low C-factor (L-CF). After adhesive application (Clearfil SE One, Kuraray Noritake), the composite was placed in two increments in three subgroups: Filtek Supreme (FS, 3 M ESPE); Charisma Diamond (CD, Heraeus Kulzer); Amelogen Plus (AP, Ultradent); and as a single increment in two subgroups: Tetric EvoCeram Bulk Fill (TB, Ivoclar Vivadent) and Venus Bulk Fill (VB, Heraeus Kulzer). After thermo-mechanical load-cycles, imperfect margin percentage (%IM) was calculated using swept-source optical coherence tomography (SS-OCT) imaging. The relationships between %IM and linear shrinkage (LS) and shrinkage stress, measured under either zero-compliance (PS0) or compliance-allowed (PS) conditions were evaluated.
Results. The %IM was significantly different between H-CF and L-CF groups. The %IM in H-CF turned out to be as groups CD, FS $\leq$ TB $<$ AP, VB. The %IM in L-CF showed as groups CD, TB $\leq$ FS, AP $<$ VB. There were significant correlations between shrinkage parameters and %IM, except between PS0 and %IM in L-CF.
Significance. Internal adaptation in a high C-factor cavity was inferior to that in a low C-factor cavity for both conventional and bulk-filled composites. Internal adaptation, polymerization

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shrinkage, and stress were different among composite materials. Polymerization stress under the compliance-allowed condition showed significant correlations with internal adaptations in high and low C-factor cavities.

1. Introduction

Developments in resin composite technology and dentin bonding systems have improved the physical properties of these materials. However, in spite of the significant increase in physical properties and bonding strength values, the occurrence of microleakage and gap formation remains a frequent issue [1]. This can be due to resin composite shrinkage, which still ranges between 1% and 6% by volume even for the newly developed low-shrinkage products. [2,3]. Polymerization stress in composite restorations develops as a result of this polymerization shrinkage under confinement created by bonding to cavity walls.

The magnitude of the polymerization shrinkage stress is influenced by numerous factors. These factors can be divided into the cavity configuration and the material properties. The cavity configuration includes elements such as cavity size, ratio of bonded to unbonded surfaces known as C-factor and compliance of the cavity wall. The C-factor defines configuration of cavity walls and is known as an important variable that should be considered when placing composites. In addition, the compliance of the substrate to be bonded affects stress development. As for the material properties, filler content of composite, matrix formulation, polymerization shrinkage, elastic modulus, flow of the resin and adherence of the resin to the wall should be considered [4–7]. Filler content in composite resin can be one of the key factors; if the composite has high inorganic filler content, it will show low volumetric shrinkage and high stiffness [6,7]. The amount of polymerization shrinkage and viscoelastic properties can also be variables in shrinkage stress. Braga et al. indicated that volumetric shrinkage prevails over viscoelastic properties in determining contraction stress [5]. The viscoelastic properties include its flow capacity and elastic modulus, both of which can be variable during polymerization [8,9]. Lower elastic modulus and better viscous flow at the early stage of polymerization can reduce shrinkage stress. In fact, the interplay among these factors determines the polymerization shrinkage stress.

The most frequent method of measuring contraction stress is to use the tensilometer; however, there is some controversy about this method. One of these concerns is the compliance of the testing system. There are two types of measurement systems: zero-compliance (rigid) setup and compliance-allowed (non-rigid) setup. Zero (or near-zero) compliance means that a feedback system exists during the polymerization shrinkage measurement to keep a constant distance between the measurement components, simulating a situation in which the shrinking composite is completely confined by rigid walls. When the test system does not have a feedback system, it indicates that the compliance is allowed, when composite resin can shrink relatively freely. When contraction stress is measured with a non-rigid setup, the shrinkage stress can be dissipated through the components of the system. There are conflicting reports on the relationship of the shrinkage stress to the C-factor with these two settings. When the rigid (zero or near-zero) compliance system was used, there was a direct relationship between the polymerization stress and C-factor value [10,11]. If the non-rigid system was used, an inverse relationship could be found [12,13]. These findings raised the questions of why there were opposite results of the relationship between the stress and C-factor and which one of the two measurement systems would be applicable to evaluating microleakage or internal adaptation.

The C-factor concept should be carefully applied to clinical practice. Cavity configurations have a much more complex geometry than the specimens used in an experimental test. When it comes to C-factor and microleakage, Uno et al. reported that there was no relationship between the C-factor and gap dimension in compomer restorations with different C-factors [14]. Another research suggested that microleakage seemed to be related to a restoration's volume but not to its C-factor [15]. However, in these studies, samples of different C-factors, set by different volumes of composite, were compared. The C-factor seemed to be a valid parameter in comparisons of restorations of identical shapes and volumes.

Microleakage is an inevitable consequence of polymerization shrinkage in composite restoration. Some studies have correlated the results from contraction stress tests and those from microleakage tests [16,17]. Ferracane et al. investigated the relationship between composite contraction stress and microleakage in Class V restorations [18]. Calheiros et al. studied the polymerization contraction stress of low-shrinkage composite and its correlation with microleakage [17]. They found a direct relationship between contraction stress values and microleakage for the composites. Marginal gap formation is the result of a localized bond failure [5] and it is a concern where the microgap is found in the interfaces of the restorative material and tooth substrate, resulting in a leak. Nevertheless, marginal seal could be different from internal adaptation because localized debonding may produce microgaps that are not always associated with the outside margin and are not readily apparent [16]. For the Class I cavity, it was found that microgaps were dominantly formed on the pulpal cavity floor rather than on the outer enamel margin [14].

Internal adaptation, which defined how well a restoration adapted internally to the dental substrate, can involve the evaluation of microgaps at the pulpal floor of a restoration. Clinically, it may affect hypersensitivity to cold or pain on mastication and, possibly, mechanical strength and durability of a restoration [19]. For internal adaptation evaluation, the specimen should be cut and examined unless a non-destructive method is used. Physical sectioning of specimens might lead to increased artefacts and interfacial gap values