Chapter 4.21
Relationship Between Shrinkage and Stress

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ABSTRACT

Residual stress due to polymerization shrinkage of restorative dental materials has been associated with a number of clinical symptoms, ranging from post-operative sensitivity to secondary caries to fracture. Although the concept of shrinkage stress is intuitive, its assessment is complex. Shrinkage stress is the outcome of multiple factors. To study how they interact rEquationuires an integrating model. Finite element models have been invaluable for shrinkage stress research because they provide an integration environment to study shrinkage concepts. By retracing the advancements in shrinkage stress concepts, this chapter illustrates the vital role that finite element modeling plays in evaluating the essence of shrinkage stress and its controlling factors. The shrinkage concepts discussed in this chapter will improve clinical understanding for management of shrinkage stress, and help design and assess polymerization shrinkage research.

WHAT IS SHRINKAGE STRESS?

The concept of shrinkage stress is intuitive. The notion that stresses arise if a composite filling shrinks inside a tooth is not difficult to convey. The actual assessment of shrinkage and its effects, however, has turned out to be complex and

is often a source of confusion. Shrinkage became an issue in dentistry when resin-based composites were introduced as restorative materials (Bowen, 1963), and has remained a persistent concern since. The main difference between resin-based composite and the classic amalgam restorations was adhesion to the tooth structure. Bonding of composite restorations enabled more conservative cavity designs that no longer relied on undercuts for retention and thus preserved more tooth tissue. Unlike unbonded amalgam fillings, an adhesive composite restoration becomes an integral part of the tooth structure. This allows recovery of the original distribution of masticatory loads in a treated tooth. Hence, a composite "filling" actually restores structural integrity lost by decayed tooth tissue and during the process of cavity preparation (Versluis & Tantbirojn, 2006). However, by becoming a more integral part of the load-bearing tooth structure, changes in the composite, such as shrinkage, will also be transferred into the tooth structure causing so-called *residual* stresses.

The origin of shrinkage is the formation of a polymer network during the polymerization reaction. This process results in a denser material, where the density change is manifested in volumetric contraction or shrinkage. Where the composite is bonded to the tooth, the tooth structure will confine the dimensional changes. This leads to the generation of shrinkage stresses in both the restoration and tooth. Under normal clinical conditions, shrinkage movement is so small that it is practically imperceptible. However, the effects of shrinkage may show up indirectly in clinical symptoms. Shrinkage stress has been associated with enamel crack propagation, microleakage and secondary caries, voids in the restoration, marginal loss, marginal discrepancy, and post-operative sensitivity (Jensen & Chan, 1985; Eick & Welch, 1986; Unterbrink & Muessner, 1995). It should be pointed out that none of these clinical symptoms are actually stresses, and their correlation with shrinkage stresses, if any, is not obvious. Further-

more, clinical symptoms are seldom caused by only one factor. Therefore, the precise correlation of these symptoms with polymerization shrinkage is debatable and remains an area of investigation.

To understand the contributions of polymerization shrinkage under clinical conditions, the nature of shrinkage stress has to be studied. The scientific method for studying any subject is creating a theoretical "model" of reality that expresses the current understanding. SubsEquationuently, such models are tested with precise observations and measurements, and if needed, amended or replaced based on new insights. In this chapter, a progression of shrinkage models will be used to discuss advances in dental shrinkage stress research.

SHRINKAGE STRESS MODEL: CORRELATION WITH SHRINKAGE

The most simple model for shrinkage stress is that the residual stress is related to shrinkage. This intuitive model is based on the observation that without shrinkage there will be no shrinkage stress. The observation is subsEquationuently extrapolated into a positive correlation between shrinkage and stress, because it appears credible that when shrinkage increases, shrinkage stress increases too. This intuitive model is probably the most common and practical expression of our understanding of the nature of polymerization shrinkage stress. Manufacturers, clinicians, and researchers alike have the same initial response when confronted with shrinkage data: "a composite with higher shrinkage values must cause higher stresses". To validate this model, the relationship between shrinkage and stress will be considered more closely.

It is important to clearly distinguish between shrinkage and stress. A shrinkage value α is a dimensional change which is defined as the amount of change divided by the original dimension:

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