SCIENTIFIC REPORT

Grandio – Shrinkage stress

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The term shrinkage stress has been frequently used in recent discussions about the quality of restoratives. The information presented here provides a definition of shrinkage stress and discusses the effect of shrinkage tension on long-term marginal integrity of composite restorations.

All dimethacrylate-based restoratives shrink in the course of the polymerisation reaction. Modern nano-hybrid composites are distinguished by extremely low shrinkage (Grandio: 1.57 %): Nevertheless, a possible negative effect on the long-term success should be discussed with respect to these materials. Shrinkage is stated in volume percent. Pure volume shrinkage on bonded surfaces, however, is impossible in the clinical reality, so that here tensile force develops on the bond through the shrinkage. This tensile force is also labelled as shrinkage stress.

Measurement of the shrinkage stress

Two approaches for determining shrinkage force are found in the literature. The first approach consists of a simple experimental set-up, which is shown in Figure 1. A composite test specimen is bonded onto a glass plate and the top side of the test specimen is connected to a tension gauge.

The test specimen shrinks when it is exposed to light through the glass plate, then the shrinkage force can be metered directly from the attached tension gauge. This experimental set-up, however, has a critical disadvantage: The opposing "cavity walls" are only connected with one layer of composite - a situation the dentist tries to avoid with the help of the layer technique. Bulk fillings are only applied in very small cavities. In these situations, the actual layer thickness is considerably thinner than in the experimental shrinkage stress measurements, so that the stress in the clinical reality does not reach the values of these measurements.

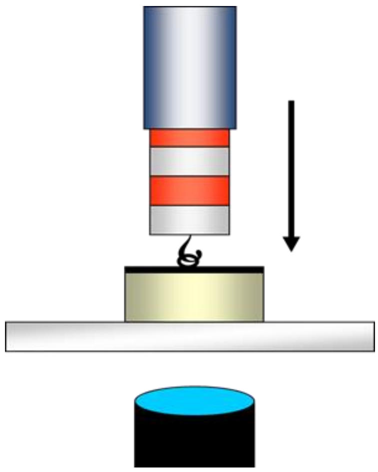

Figure 1: Schematic experiment set-up for determining shrinkage stress

In addition to direct strength measurements, optical techniques are also employed to determine the shrinkage.[1] Test specimens are fabricated from Araldite B for this purpose. This material has the interesting property that internal stress can be visualized through polarized light. With this method, the shrinkage strength can be calculated from the distance of the stress lines made visible. The dimension of the test cavity is, however, interesting here: The measurements were 5x5x5 mm. Furthermore, the cavity was filled with only one increment. The unfavourable C-factor and forgoing the layer technique naturally maximized the shrinkage strengths. The clinical reality in turn is therefore not exactly represented. Other optical test methods also frequently measure the stress of very thick increments and thus permit only limited conclusions about the clinical reality. Despite the challenges in the instrumental set-up of the experiments, it is worthwhile to look at the results of the shrinkage measurements.

Results of the shrinkage stress measurements

To date, few independent studies have been conducted on the measurement of shrinkage stress that included Grandio in the evaluation. A current measurement is found in the March 2010 edition of Clinicians Report.[2] The results of the measurements presented there are shown in Figure 3. The values lie between 1.5 and 3 MPa; the values for the different materials therefore hardly differ. Grandio earned a place in midfield in this study with a shrinkage stress of 2.7 MPa.

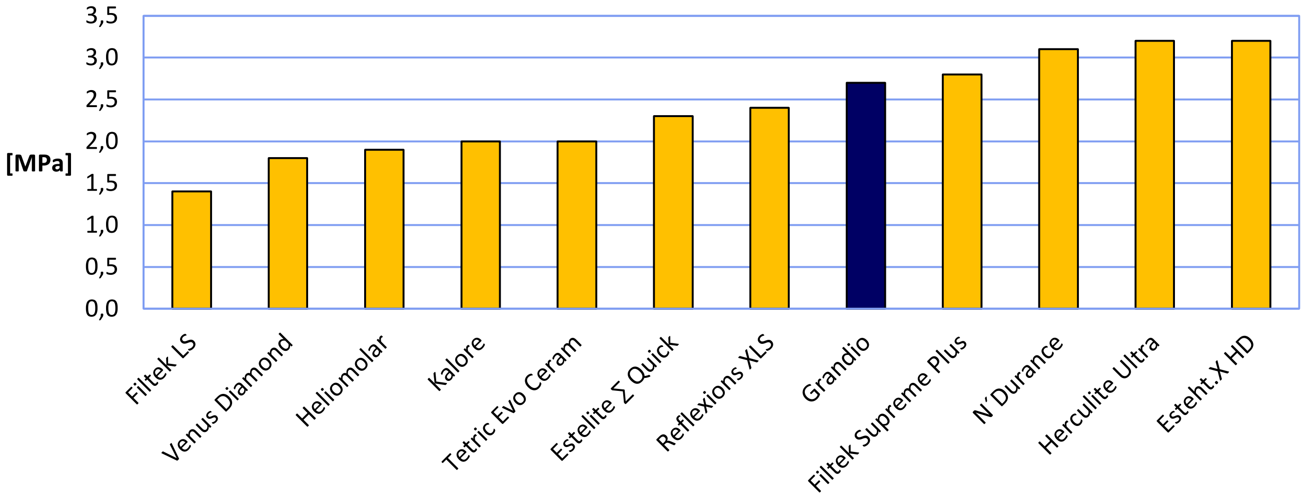

Figure 2: Results of a shrinkage stress measurement [MPa][2]

An additional study was conducted at the University of Sao Paulo (Brazil) in 2007 (Figure 3). [3] Grandio also achieved slightly higher values in this study. The difference between the likewise tested materials is, however, minimal.

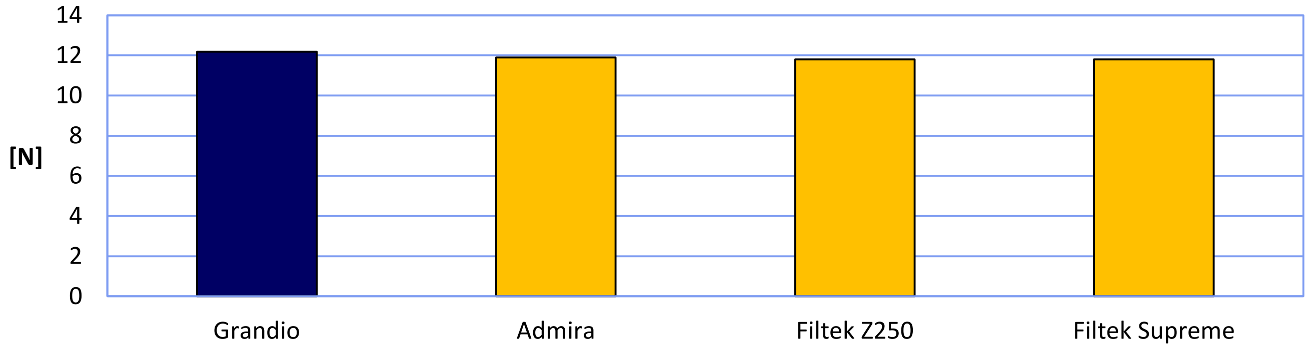

Figure 3: Shrinkage stress according to Pereira et al.[3]

Clinical studies

Clinical studies offer a substantially better view of the reality in the dental surgery. According to the theory of very influential shrinkage stress, particularly the materials that demonstrate the higher values in the shrinkage stress measurements would have to score poorly in the area of margin adaptation in these tests. Figure 4 shows the result of a clinical 4 year study. [4] In this study, Class V cavities were restored with the combination of Futurabond NR and Grandio. According to the theory of shrinkage stress, poor values should result for Grandio, especially with respect to marginal discoloration and marginal integrity.

In contrast, 90 % the restorations were rated as clinically faultless in both disciplines after 4 years. Less than 5 % of the restorations required a revision.

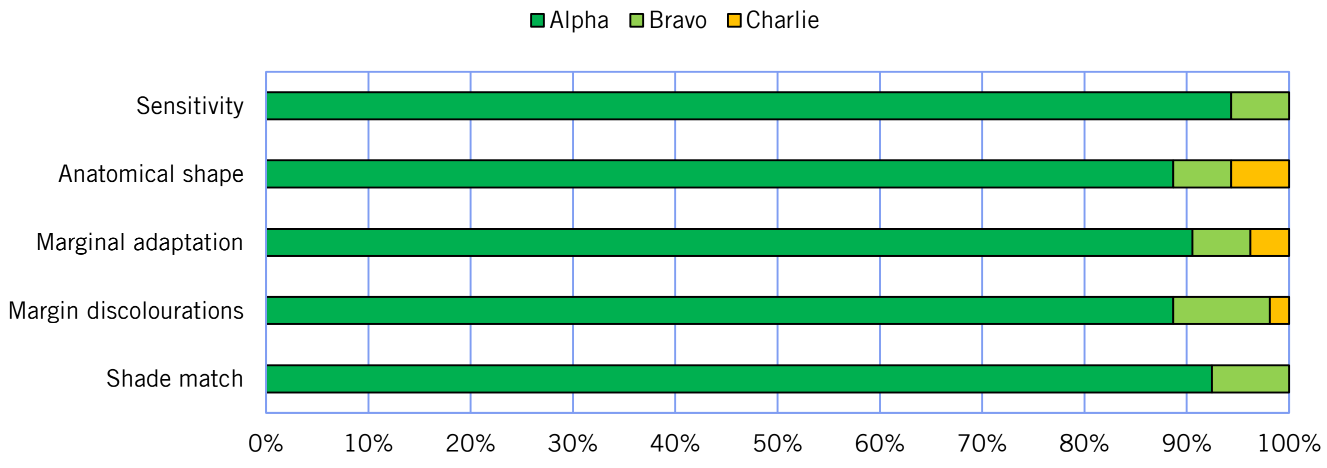

Figure 4: Results of a 4 year clinical study (Futurabond NR/Grandio in Class V cavities)[4]

A comparison with Filtek Silorane (3M ESPE), a material that exhibits little shrinkage that is equally characterized by very low shrinkage stress is also interesting. The result of a 1 year clinical study is represented in Figure 5; only the evaluation of the marginal adaption is shown here.[5]

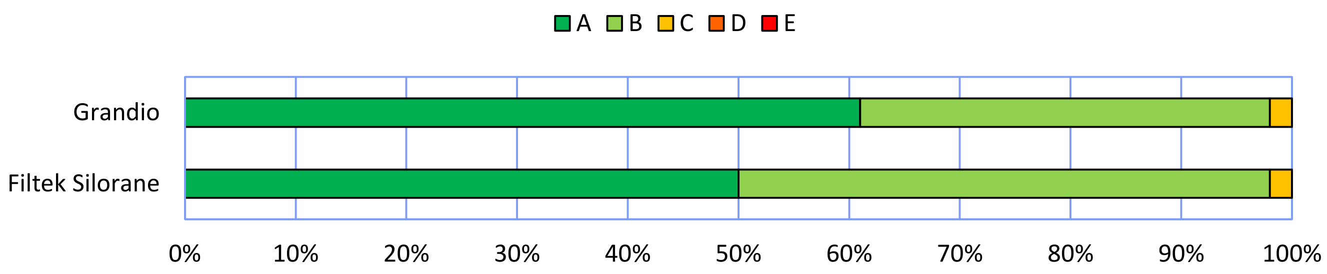

Figure 5: Marginal adaption after one year (Class II cavities) [5]

Despite the slightly increased shrinkage stress, Grandio scored better than Filtek Silorane in this study. The shrinkage stress is obviously only a subordinate factor if long-term, intact adhesion of a restoration is concerned.

Other factors affect the durability of the marginal integrity of a restoration

The shrinkage stress described in detail above represents a static load for the adhesive layer. A bond, however, is not only subject to this static load, but also to dynamic loads that occur every day. The most important dynamic load represented in this context is the chewing stress. Forces during the chewing process affect a restoration every day. To what extent these forces are evenly transferred over the restoration is significantly determined from the modulus of elasticity, which describes the elastic behaviour of the material during loading. The closer the elasticity behaviour of the restorative is to the behaviour of the natural tooth substance lies, the better the distribution of the occurring forces is. Asmussen et al. examined the dependence of the amount of chewing stress from the modulus of elasticity of the materials.[6] The result of this study is shown in Figure 6.

As it can be gathered from the graphic, the load on the adhesive bond sinks with the increase in the modulus of elasticity of the material. A low modulus of elasticity, which brings slight advantages with regard to the static stress, thus negatively affects the daily chewing load. While most composites exhibit a modulus of elasticity of 8-12 GPa (Again, flowable composites fall below this range.), Grandio has a modulus of elasticity comparable to dentine. The results of a measurement of modulus of elasticity at the University of Athens (Greece) are represented in Figure 7.[7] The huge difference between Grandio and other restoratives is shown here.

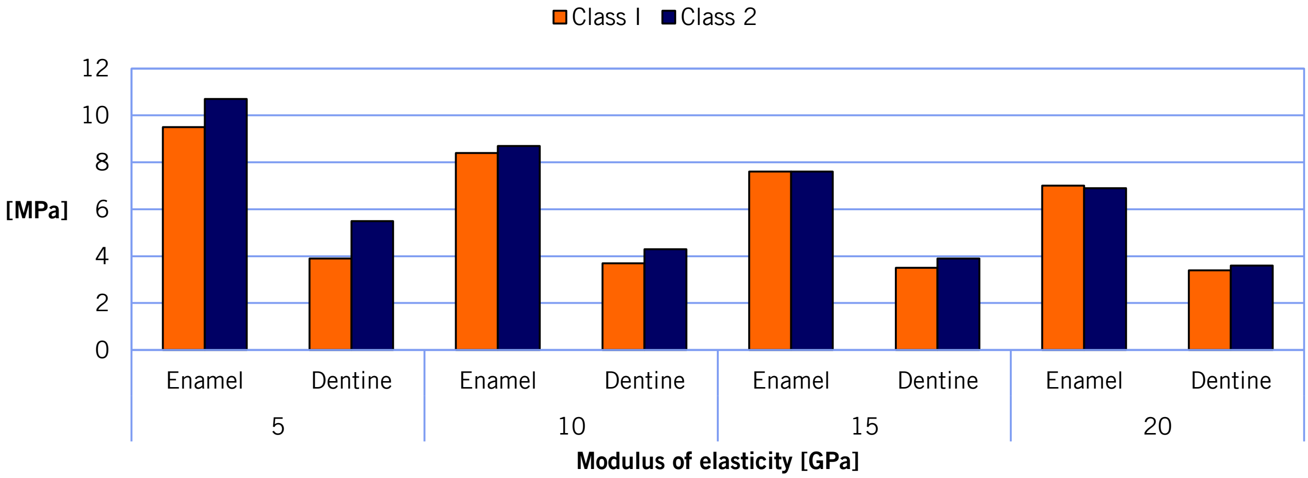

Figure 6: Stress on the cavity wall depending on the modulus of elasticity of the restorative [6]

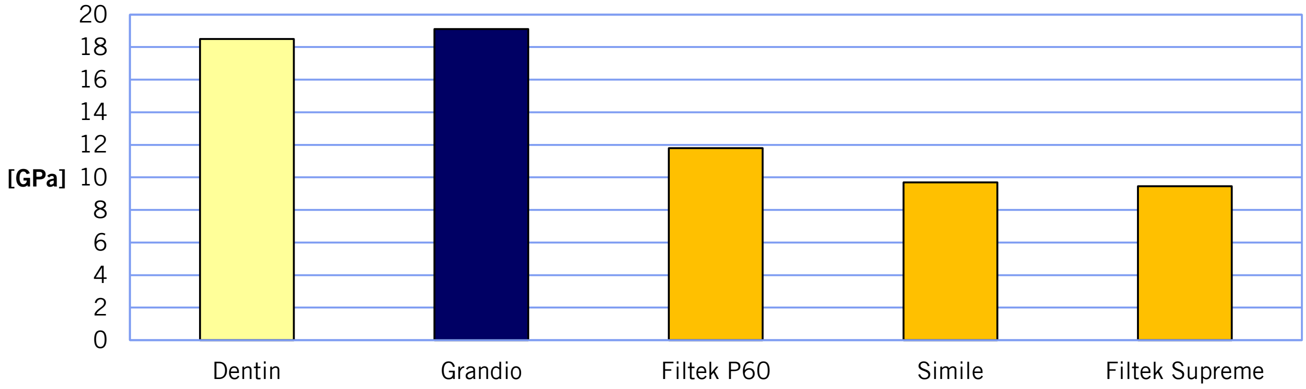

Figure 7 Modulus of elasticity of diverse restoratives [7]

Stress from thermal expansion and/or contraction represent an additional load for the bond. Like many other materials, composites expand when heated and shrink when cooled. Teeth also exhibit this thermal behaviour. If the extent of the thermal shrinkage of the restorative differs from that of the tooth, then stress occurs with every portion of ice cream or other food and drink. The thermal behaviour of diverse composites was examined at the Fraunhofer Institute for Silicate Research. [8] The results of this study are shown in Figure 8.

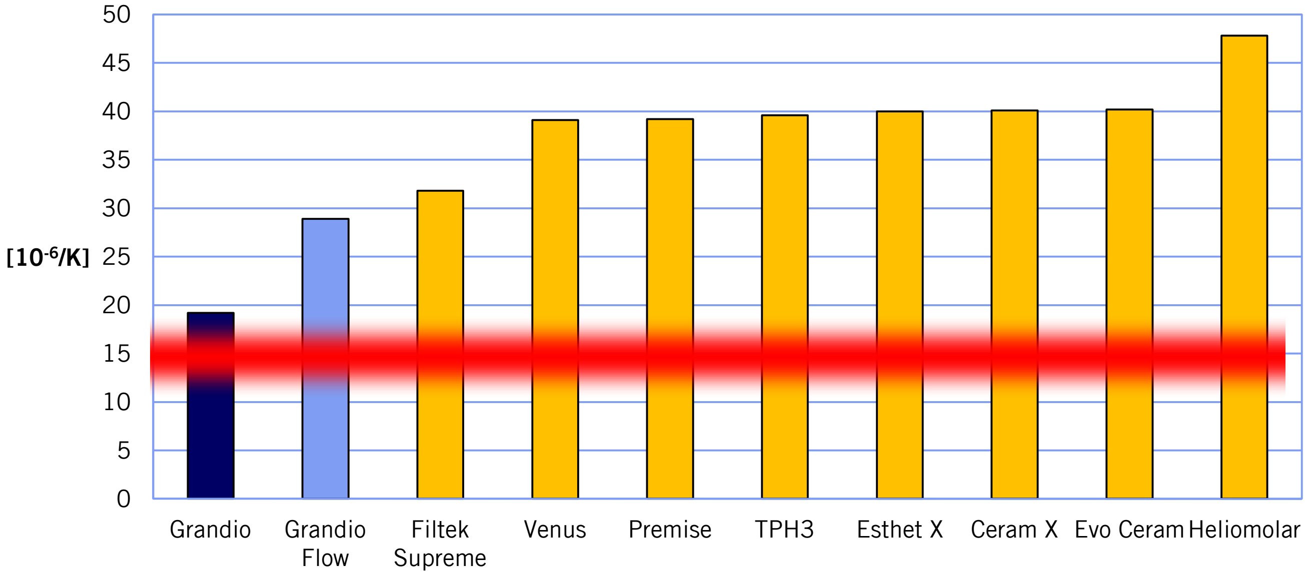

Figure 8: Thermal expansion coefficient (Red line: dentine 11, enamel 17)[8]

The absolute measurement of the value represented here is not decisive, but rather where it lies in comparison to the behaviour of the natural tooth. Since the marginal integrity on the surface should be the focus, the comparison to the contraction behaviourof the enamel must therefore be brought into the discussion. In this comparison, it turned out that Grandio simulated the behaviour of the natural tooth significantly better than other restoratives.

While the shrinkage stress can be influenced and thus minimized by the use of the layer technique and choice of a suitable C-factor, these dynamic loads cannot be influenced by the dentist. Both chewing stress and thermal loading occur every day and appear to have a greater influence on a long-term, intact margin than pure shrinkage stress.

Conclusion: Grandio has slightly higher shrinkage stress with its tooth-like modulus of elasticity of elasticity in comparison to other restoratives. The high modulus of elasticity however leads to a significant reduction in the dynamic loads. In total, this high modulus of elasticity is better suited for long-term marginal integrity, especially since the static load can be influenced by the shrinkage stress with the assistance of the layer technique.

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[2] G. J. Christensen, *Clinicians Report*, Märzausgabe 2010.

[3] R. A. Pereira, P. A. de Araujo, J. C. Castaneda-Espinosa, R. F. L. Mondelli, *J. Appl. Oral Sci.* **2008**, *16*, 30-34.

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[8] Dr. B. Wolter, Fraunhofer-Institut für Silikatforschung ISC, 2005, data on file, VOCO GmbH.