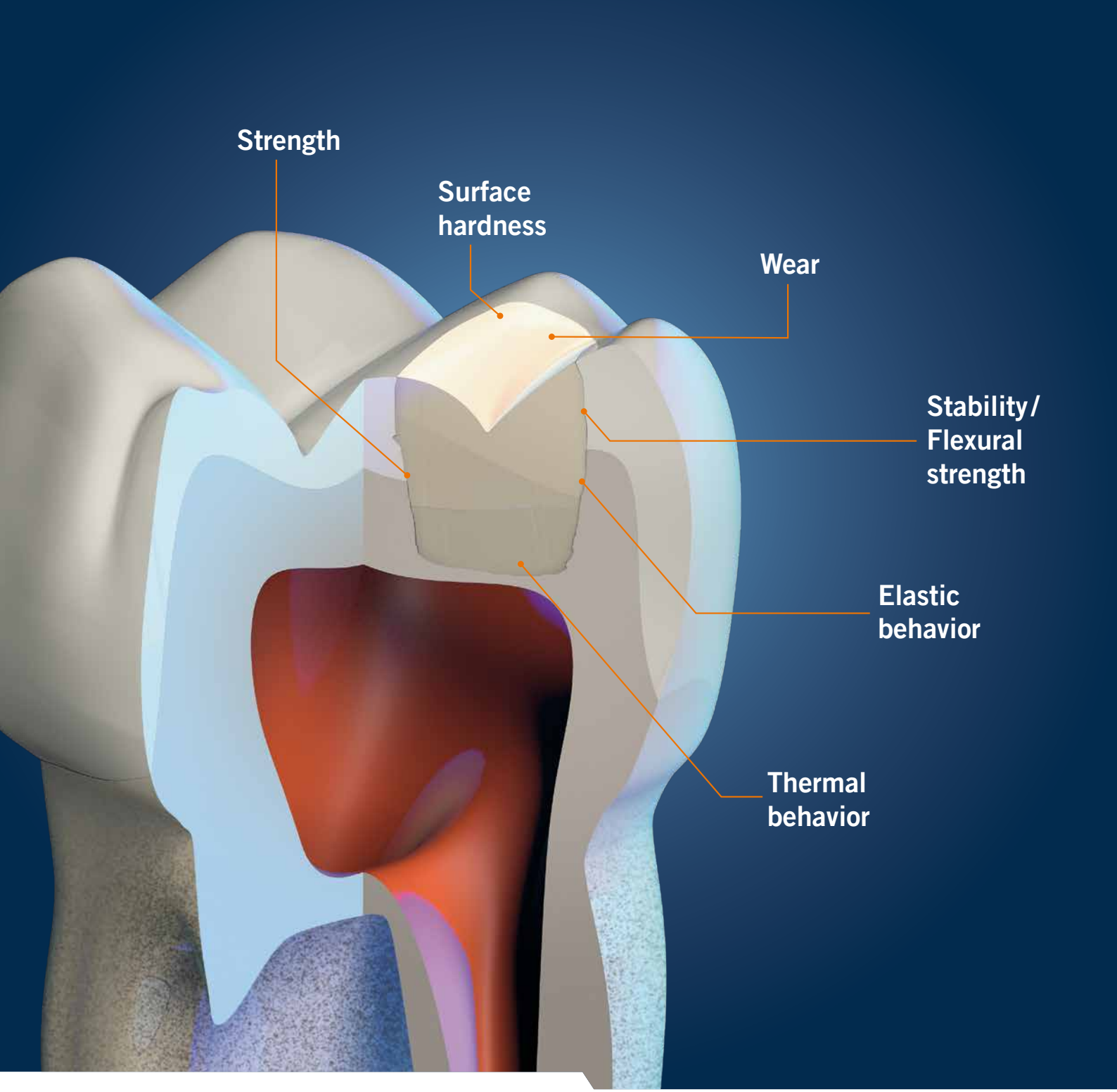

MARGIN CALL:

Toothlike physical properties extending the long-term value of your material investments

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VOCO
DIE DENTALISTEN

In the composite restorative material marketplace, the only thing that remains constant, is change. Every year, manufacturers continue to evolve current material technologies, or introduce brand new technological concepts to the marketplace.

Every composite restorative material developed is created with one goal in mind: to be the synthetic restorative material that will mimic natural tooth structure as closely as possible so as to optimize the long-term clinical outcome of the restoration. While many materials can claim to be the "best" in one or more performance categories or properties, the best material, theoretically, will be the one that captures the most of those categories or properties. The ultimate end-game is to become the most "toothlike" synthetic restorative material that can be produced.

A history of composite restorative materials has shown that several manufacturers have taken their composite and "updated" it over time, trying with each iteration to become more tooth-like. In analogous terms, many materials have climbed one step-at-a-time, trying to reach the top. However, to date, nobody has reached the summit in a single step.

VOCO took Grandio, an innovative and the world's first nano-hybrid material, and improved and elevated that pioneering material. The result of this engineering was the creation of GrandioSO, arguably the most "tooth-like" composite restorative material ever created.

The union of natural tooth and a synthetic composite restorative material is facilitated by the use of an adhesive system/bonding agent. The bond secures the "margin" or border, between these two somewhat dissimilar materials and is required to hold the union and continue to provide a tight and sealed margin during the life of the restoration. The placement of a composite that does not closely mimic the physical qualities or properties of a tooth, will often generate stresses at the bonded interface, between the material and the tooth structure. These repeated stresses can contribute to a premature, restorative failure which often begins with some form of a breach of the margin. A composite is subjected to many different assaults while in the oral cavity, heating and
cooling create the cycle of expansion and contraction, while functional load can cause chipping or fracturing. Volumetric shrinkage and shrinkage stress, while only occurring during the polymerization process, can nevertheless also impact the integrity of the marginal interface. Further examination, might lead one to the conclusion, that almost all of the various stresses between the composite material and the tooth structure can ultimately have a negative influence at the margin. Thus, the importance of using the most "tooth-like" composite material one can find, is of paramount concern.

This paper will analyze the various testing protocols found in the GrandioSO Scientific Compendium1. Most people review bar graphs without really being able to equate how the testing protocol impacts the clinical performance. This paper will explain how each of the performance values found in literature speak to real clinical needs of wet-fingered everyday dentistry.

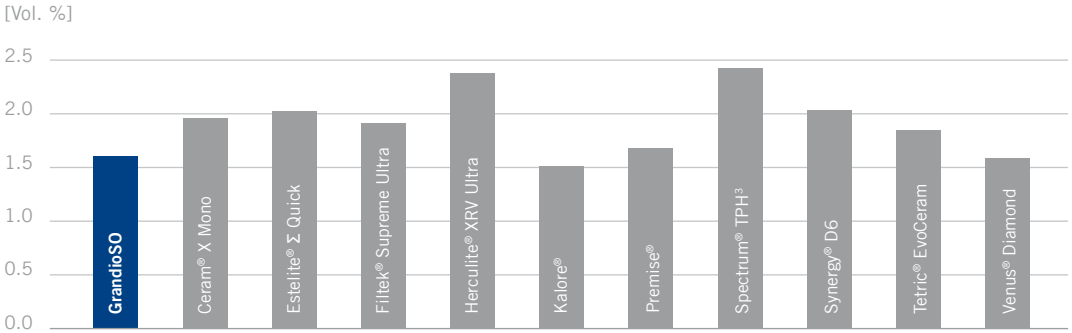
All composites are presented with values for a variety of “tests”. These tests follow protocols and methodologies as defined by the International Standards Organization (ISO). VOCO GmbH adheres to these specific standards and protocols when testing any of their materials. While all of the tests performed and documented contribute to the overall performance of a material, some have a greater significance than others within the oral environment. The following will outline several “key” performance indicators for successful long-term restoratives.

A. VOLUMETRIC SHRINKAGE

For many years, manufacturers have been driving volumetric shrinkage lower and lower, and for a long time this was perceived as a composite’s greatest beneficial quality. It is generally agreed that the material with a lower volumetric shrinkage when curing will create lower stress at the bonded interface. However, when we assign this value to its level of importance on the scale of “all properties”, it does not rank as the most important.

The reason is quite simple: a low volumetric shrinkage only comes into effect in the restoration once, during the curing process. Once the composite material cures and then shrinks, it does not continue to shrink with each subsequent exposure to light energy. For this reason, I tend to label volumetric shrinkage as a one-trick pony! It is very common to see materials’ shrinkage hovering around the 2% by volume mark, but several materials are down to 1.6% or lower. Below, the results of a study:

The volumetric shrinkage during polymerization was determined according to the “bonded disc” method described by Prof. D.C. Watts (University of Manchester). (Watts et al., 1991, Watts et al. 2000)2. For this, a discoidal test specimen made from composite material with a diameter of approx. 8 mm and a height of approx. 1 mm was exposed to a polymerization light (Celalux 2, Softstart, VOCO) from underneath for a total of 40 seconds. The polymerization shrinkage was recorded with a sensor from the opposite side (top) over a period of 30 minutes.



Volumetric Shrinkage [%] of the analyzed composites, VOCO 2010

Source: GrandioSO Scientific Compendium, Pg. 11

With a volumetric shrinkage value of 1.61% vol, **GrandioSO** is surpassed only by Kalore. However, this is only ONE of several test values a clinician needs to consider when selecting his/her optimal material.

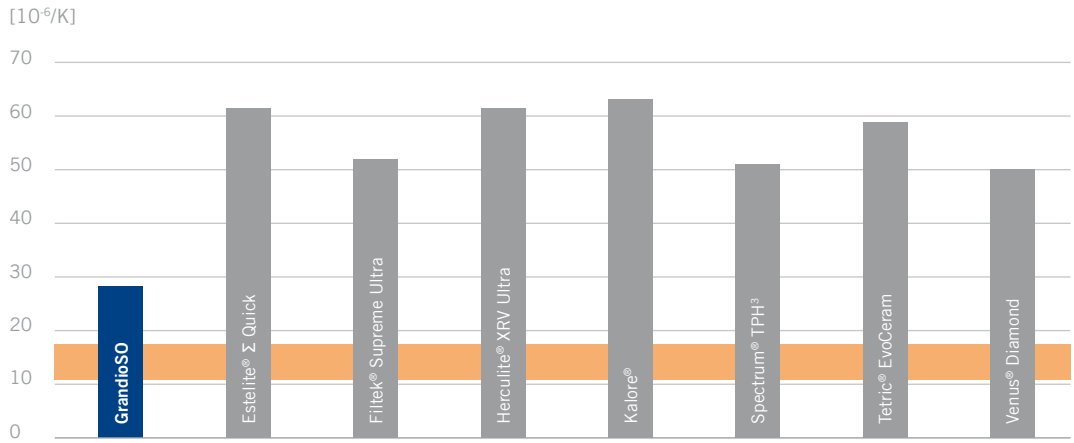
B. THERMODYNAMIC EXPANSION & CONTRACTION (TEC)

Every day, teeth expand and contract as a result of increasing or decreasing temperatures which occur during the consumption of cold and/or hot liquids or foods (such as the transition from the cold milk in cereal to a hot coffee). Given that this will be a daily occurrence for the life of a restorative material's placement, does it not make sense that the composite should move as synergistically as possible with the tooth?

Expansion and contraction rates that differ from tooth structure can cause stress at the composite/adhesive/tooth interface. This cyclical stress can potentially result in a fracture of the material or even create the formation of a marginal gap and subsequent, secondary caries!

The study below clearly shows how GrandioSO, once again, is the closest material to natural tooth structure of the materials tested.

A baseline for comparison:
Dentin 10.59 [10^{-6}/K] & Enamel 16.96 [10-6/K][3,4]



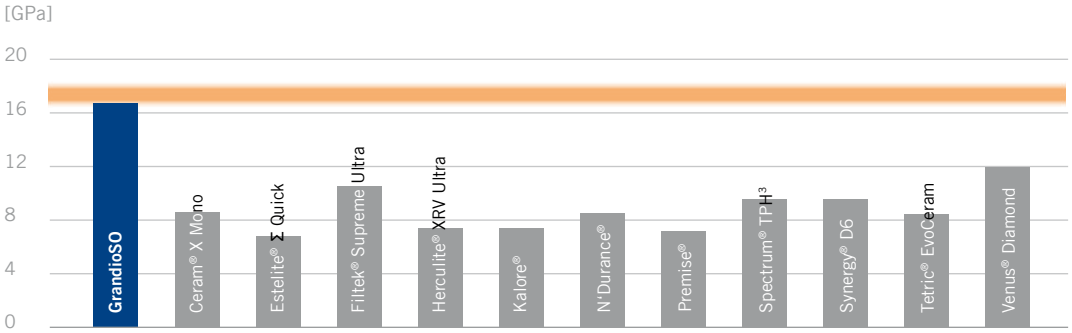
Thermal Expansion Coefficient [10-6/K] of the analyzed composites, VOCO 2010

Source: GrandioSO Scientific Compendium, Pg. 14

C. MODULUS OF ELASTICITY (MOE)

MOE ~ To withstand load/stress, deform and then return to its original profile without any permanent deformation. The listed value represents the “elastic behavior” of the composite as it relates to natural dentition. One might suggest that modulus, combined with TEC, may be the most important combination of all the values tested. Simply put, MOE is how the synthetic composite “moves” in comparison to the tooth structure into which it has been placed.

The MOE range of natural dentin falls between 16.55 - 18.62 GPa (Craig et al., 1958)[5]



Modulus of Elasticity [GPa] of the analyzed composites, VOCO 2010

Source: GrandioSO Scientific Compendium, Pg. 13

With an MOE of 16.65 GPa, only GrandioSO behaves in exactly the same manner as natural tooth structure!

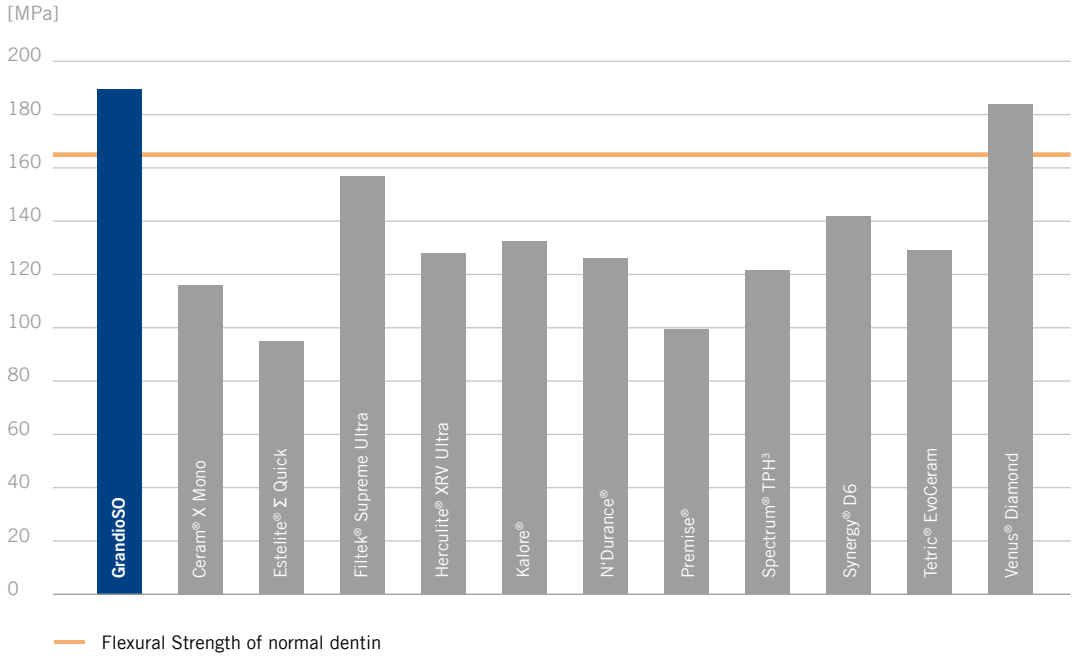
Restoratives are subjected to powerful intra-oral loads every day. Normal mastication force, on average, represents 30.6 ± 5.6 MPa (Miyaura et al., 1999)[6] whereas pressure on smaller contact areas (e.g. splitting of a nut) is much greater. To evaluate the stability of a composite, many diverse physical properties are taken into consideration, such as flexural strength(s), compressive strength, edge strength and tensile strength.

D. 3-POINT FLEXURAL STRENGTH

A composite slab is created as per the ISO 4049 testing standard. The composite sample measuring 2 x 2 x 25 mm is cured and supported on two bars, spaced equidistantly. A third loading bar applies a downward force until the sample fractures. The minimum mandatory value for light-cured composite materials is 80 MPa. Literature has established the value for normal, healthy Dentin as 165.6 MPa (Jameson et al., 1993)[7]. As illustrated in the study below, GrandioSO delivered a value of 187 MPa and is actually stronger than dentin.

Three – Point Flexural Strength [MPa] of the analyzed composites, VOCO 2010

Source: GrandioSO Scientific Compendium, Pg. 18

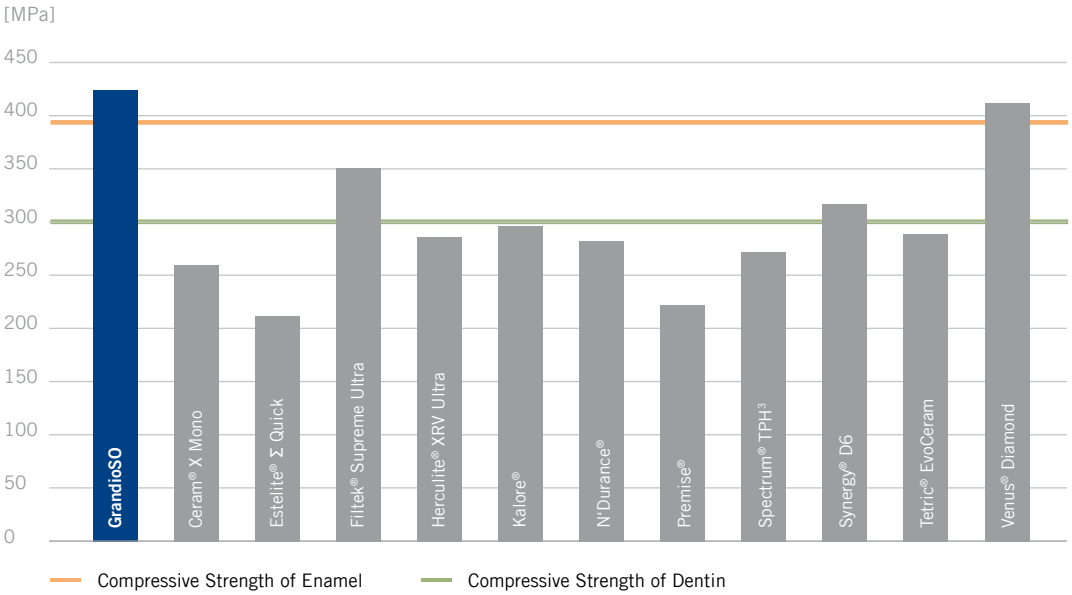


E. COMPRESSIVE STRENGTH

Having a high compressive strength value is an indication of how well the composite restorative material will handle the daily stress of functional load and mastication forces.

Literature has long established a baseline for the fracture resistance of natural tooth structure. Healthy **Dentin** has shown to offer a compressive strength of **297 MPa** (Craig et al., 1961)[5], while **Enamel** is typically capable of withstanding a higher **384 MPa** of load before fracturing (Craig et al., 1961)[8].

As illustrated in the study below, GrandioSO delivered a value of 439 MPa and is actually stronger than natural tooth structure. This assures that the composite can withstand peak loads over time, providing a very strong and durable restorative option for the clinician. Compressive strength has no direct correlation to end-hardness or wear. Nor does it have any negative impact on opposing dentition.



Compressive Strength [MPa] of the analyzed composites, acc. ISO 9917, VOCO 2010

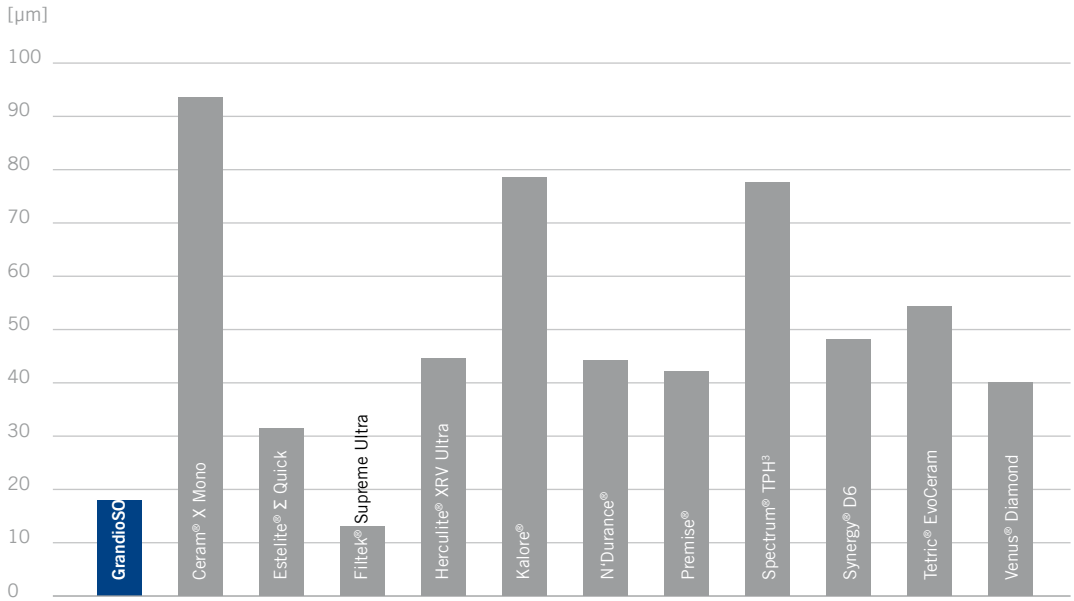
Source: GrandioSO Scientific Compendium, Pg. 22

E. THREE (3) BODY WEAR

While there are many ways to test the resistance to the wearing down of a composite, 3-body wear offers the most accurate representation of an oral environment. The testing protocol simulates erosive wear (1) and contact sliding wear (2) in the presence of a third-body medium/food (3). A sample of the composite is held in a jig device, while an antagonist (sanding disc) applies pressure on the composite and a slurry of Al2O3 Paste (De Gee et al., 1994)[9] – simulating food -- is injected in between the antagonist and the sample. The result is a 3-body wear test that simulates natural chewing with enamel grinding down on a composite restoration, with food in between the two substrates.

Three – Body ACTA Abrasion [µm] of the analyzed composites, VOCO 2010

Source:
GrandioSO Scientific Compendium, Pg. 31



Literature[10] has shown that the average "steady wear rate" on occlusal contact areas (enamel on enamel) is 29 µm per year for molars and 15 µm per year for pre-molars. With a recorded wear value of 17 µm, GrandioSO once again exhibits excellent performance in the oral cavity.

Source:
Dr. Walter Denner, Fulda / Germany

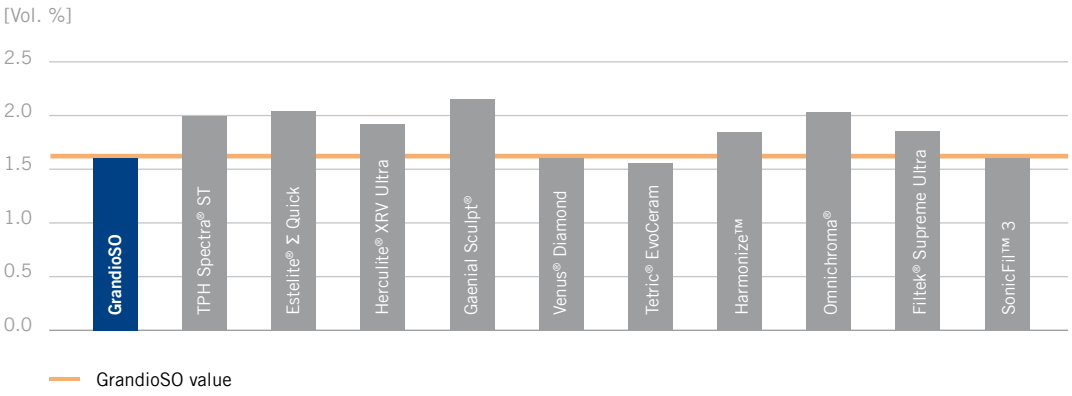
This paper has presented the key performance indicators for success and the associated values for GrandioSO and many of the mainstream materials available during the initial launch of the product.

However, as always, new technologies and chemistries have continued to be developed and the question one must ask, is after all these developments over the course of a decade, how does GrandioSO stack up against the modern materials now present in the marketplace?

The following section of this paper will share the testing results for the key performance indicators for GrandioSo and some common competitors.

1. Volumetric Shrinkage - 2022

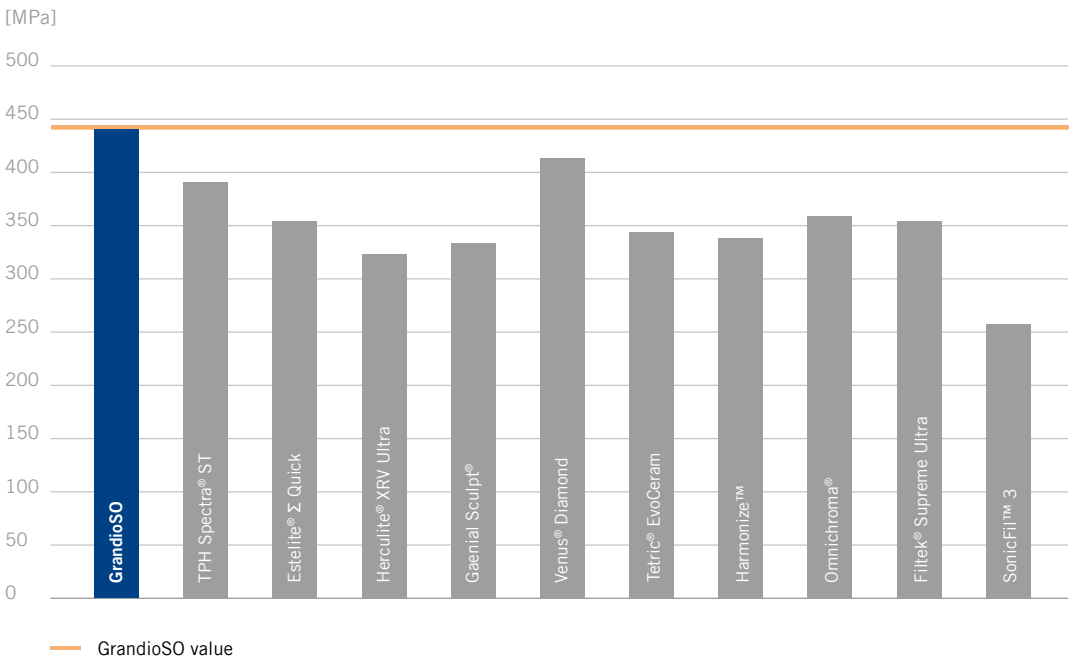
GrandioSO presents with a volumetric shrinkage value of 1.61%, SonicFil 3 with a value of 1.65% and Venus Diamond, a value of 1.60%. Even after a decade, GrandioSO is still a leader in this testing category.



Shrinkage [vol. %]

Source:
VOCO internal data.

2. Compressive Strength - 2022



Compressive Strength

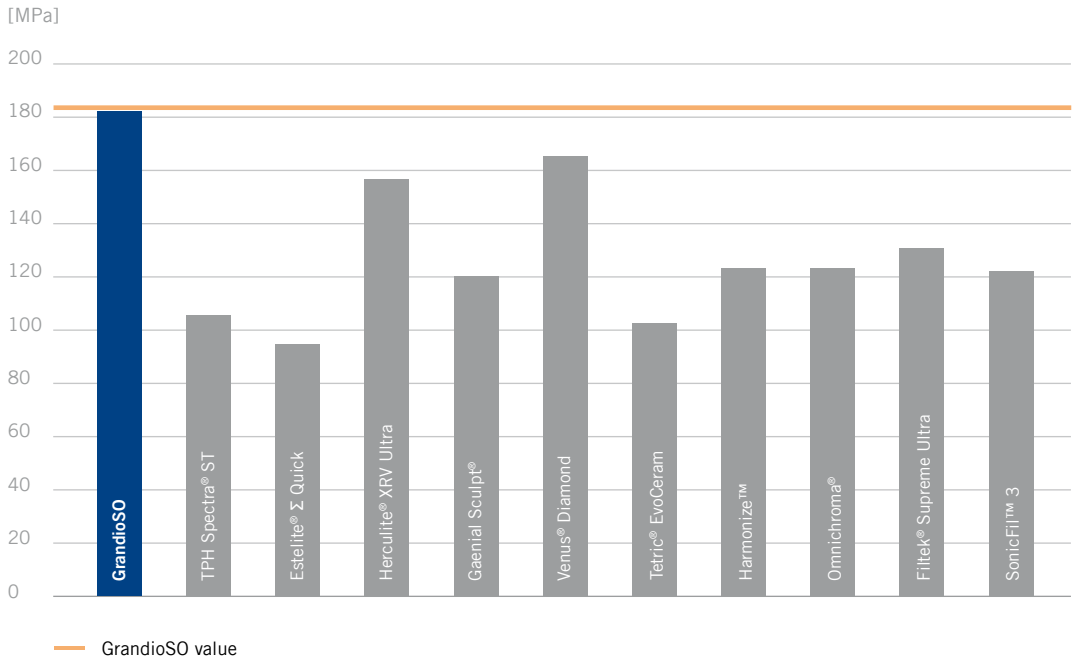
Source:
VOCO internal data.

GrandioSO presents with a compressive strength that eclipses all other brands in this study group with a value of 439 MPa – the clear leader in this testing category.

3. Flexural Strength – 2022

Flexural Strength

Source:
VOCO internal data.

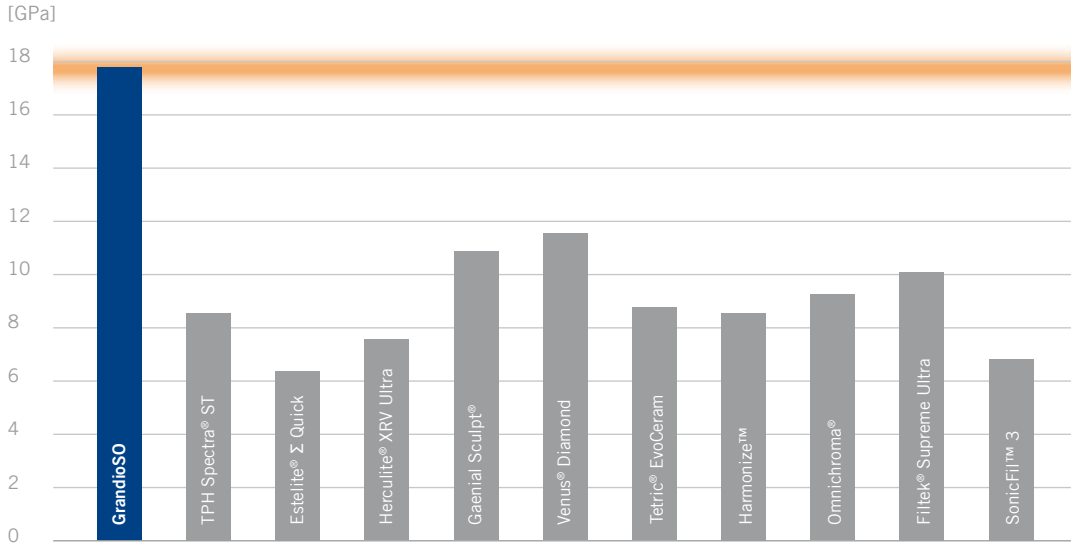


As clearly evidenced in the graph above, GrandioSO still outperforms even some of the newest and technologically advanced composites of today. A high value for flexural strength affords a material the capability to absorb functional load repeatedly, without any deleterious outcome befalling the restoration.

4. Modulus of Elasticity (MOE) – 2022

Modulus of Elasticity

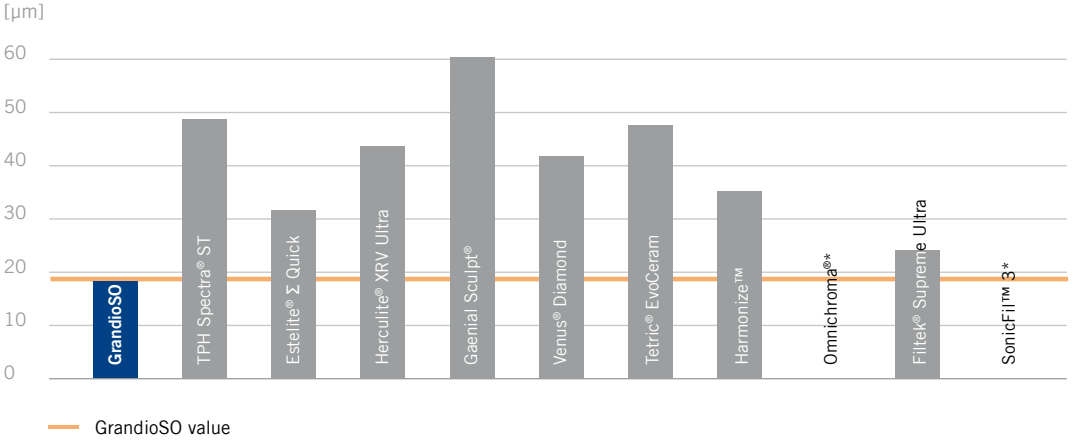
Source:
VOCO internal data.



The MOE range of natural dentin falls between 16.55 – 18.62 GPa4

Research has identified that the natural range of Modulus of Elasticity for dentin is between 16.55 – 18.62 GPa. As the MOE of a composite increases in value and becomes closer to that of natural tooth structure, one can see a direct correlation to the reduction of stress at the bonded interface. Therefore, the closer a composite's MOE is to natural teeth, the greater the probability of that restoration maintaining long term marginal integrity and security. GrandioSO matches natural tooth structure almost perfectly, with a MOE value of 16.65 GPa.

5. Three (3) Body Wear - 2022



Body Wear

Source:
VOCO internal data.

*Data not available at time of publication

Even after a decade of continuous material development and new composite technology being introduced, GrandioSO continues to offer one of the best wear values of any material tested.

References

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FINAL THOUGHTS

As noted in the outset of this paper, the ultimate goal of a composite is to be the synthetic equivalent of natural tooth structure. No single property or value can allow a material to claim the title of most “tooth-like”. It is the “sum of all the parts” that will ultimately determine the material that can lay claim to that title.

GrandioSO has over ten years of clinical placement in over one hundred countries around the world. With over a decade of millions of restorations and intra-oral placement, GrandioSO is not only the first “supercomposite” ever launched in the industry, but based on its key clinical performance indicators, one might say that it is in fact, the most “tooth-like” composite made thus far. As with all dental materials, one needs to really identify the key performance indicators for the clinical application of the material under consideration before adopting the material into one’s practice.

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