# SCIENTIFIC REPORT

## Grandio blocs – Fatigue through simulated masticatory loading

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**Glass ceramics and oxide ceramics, especially zirconium dioxide, have established as materials for the fabrication of indirect restorations. Now there are also hybrid materials based on ceramics, which come into focus as an excellent alternative. They show similar stabilities like dental ceramics, whereby especially the flexural strength or compressive strength are considered as parameters. However, hybrid materials imitate more the properties of the natural tooth than ceramics do. The values of important properties such as modulus of elasticity or thermal conductivity of hybrid materials are comparable with the ones of a natural tooth, meaning that the restoration and the tooth form a homogeneous unit. With ceramics, the values sometimes deviate strongly from each other, so that restoration and tooth are rather inhomogeneous to each other. The clinical durability of CAD/CAM materials can be estimated in *in vitro* studies. In the study at the University of Regensburg a new loading method for hybrid materials has been developed and implemented, which conditions comply more with the oral situations and long-term loadings than the pure measurement of physical properties. This Scientific Report describes the results obtained in the study of seven different hybrid materials regarding their survival rate depending on flexural strength and simulated masticatory loading.[1]**

Direct filling composites nowadays show excellent physical properties, therefore they can even be used for indirect restorations such as inlays and onlays.[2] The CAD/CAM hybrid materials for indirect restorations are polymerised under conditions such as high temperature and high pressure and therefore show slightly improved properties compared to light-cured composites. State-of-the-art-Composites and especially CAD/CAM hybrid materials can compete with conventional ceramics today.

In order to make a prediction on the clinical durability of restorations, important parameters such as flexural strength, modulus of elasticity or surface hardness are used. However, the cyclic loads in the chewing simulator combined with temperature loading are more significant. 1.2 million chewing cycles with a force of 50 N and a frequency of 1.3 Hz as well as 10,000 thermal load changes between 5 °C and 50 °C have proven as standard. A wearing time of five years was simulated with these parameters.[3]

Nevertheless, attempts are still being made to optimise such stress tests in order to achieve predictions that are even more reliable or to simplify them. In a previous study of Nishioka it was shown that the fracture strength decreases up to 40 % if the load increases during the chewing simulation compared to a load with a constant force.[4] Based on these facts a new method was developed within this study. Since a restoration in a clinical case rarely fails due to a sudden overload, but will more often fail due to repetitive loading of cracks and defects of low intensity, the flexural strength was here tested using a fatigue analysis with increasing loading force. To make the experimental setup as clinically relevant as possible, the biaxial flexural strength measurements were carried out in water, the specimen were permanently loaded with 20 N and then cyclic with a higher load of 30 N, which after one million cycles was increased by 10 N. The frequency of the load was set to 1 Hz according to the real chewing tempo.

## Study design

Table 1 shows the materials and their values of the physical properties according to manufacturer information. All CAD/CAM blocks were drilled into cylinders with a 10 mm diameter and each cut into 5 discs. (Leica SP1600, diamond disc, water cooling, 600 U/min). The thickness of the specimen of 1 mm was selected as clinically relevant for crowns. The specimen were neither polished nor processed after milling in order to simulate the worst case. For the loading test the specimen were placed on a ring (diameter 8 mm) and loaded with a Steatite sphere (Ceram Tec; diameter 6 mm). This corresponds to a scenario to determine the biaxial flexural strength.

**Table 1:** overview of the examined CAD/CAM materials and their physical properties (manufacturer specifications)

| Product / manufacturer | Material | Filler content [% by weight] | Flexural strength [MPa] | Modulus of elasticity [GPa] |
|---|---|---|---|---|
| Grandio blocs / VOCO | ceramic based hybrid material | 86 | 330 | 18,0 |
| BRILLIANT Crios / Coltène | ceramic based hybrid material | 70 | 198 | 10,3 |
| Estelite P Block / Tokuyama | ceramic based hybrid material | 70 | 225 | 13,8 |
| Katana Avencia Block / Kuraray | ceramic based hybrid material | 62 | 190 | 12,4 |
| KZR-CAD HR 2 / Yamakin | ceramic based hybrid material | 65 | 235 | 10,4 |
| Lava Ultimate / 3M ESPE | ceramic based hybrid material | 80 | 204 | 12,8 |
| SHOFU Block HC / SHOFU | ceramic based hybrid material | 61 | 191 | 9,5 |
| VITA ENAMIC / VITA | resin infiltrated hybrid ceramic | 86 | 155 | 30,0 |

The specimen were permanently loaded with a force of 20 N. This force was increased one million times up to 30 N with a frequency of 1 Hz. After a million cycles the loading force was then increased by another 10 N, so that the individual loading steps looked as follows: 20 N-30 N, 20 N-40 N. 20 N-50 N, 20 N-60 N, 20 N-70 N, 20 N-80 N. The measurements were made in water at 25 °C. The survival rate (number of load cycles survived) and the achieved loading force are shown in figure 1.

## Results

The different products show individually different survival rates. The weakest material could only survive an average of 59,339 cycles at a maximum loading force of 30 N. The strongest material though survived an average of 2,691,240 cycles with a force up to 50 N. These results can mainly be attributed to the different compositions (type of fillers and the resin matrix) and the manufacturing process (polymerisation parameters such as temperature and pressure).

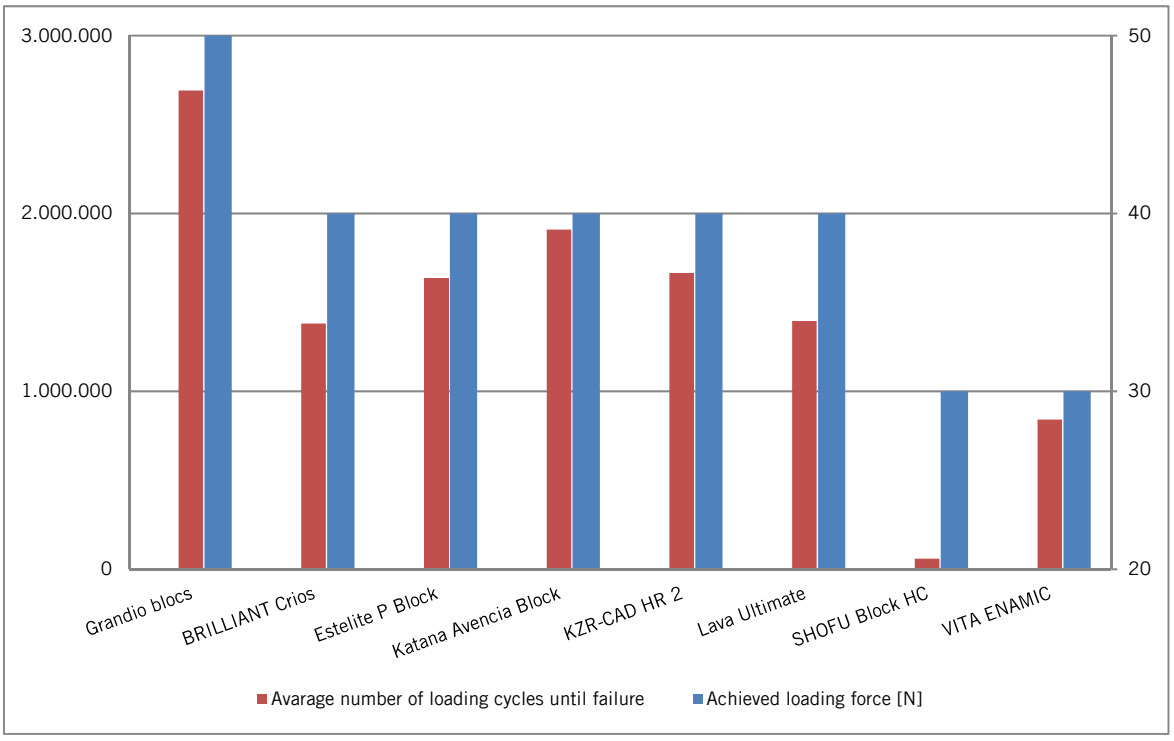


**Figure 1**: Average number of loading cycles until failure and the achieved loading force.

It becomes clear that Grandio blocs, the material with the highest filler content, survive the most loading cycles by far and as the only material withstands loadings with 50 N. Shofu Block HC on the other hand is the material with the lowest filler content and shows the poorest stability. VITA Enamic does have the same filler content as Grandio blocs with 86 %, however it is a resin-filled ceramic, which behaves rather brittle such as feldspar ceramic and despite high ceramic content shows the second-lowest stability. But Katana Avencia shows the second highest stability of the ceramic based hybrid materials despite the low filler content of 62 %. Therefore, a correlation of stability and filler content can be excluded. In fact, the entire system of a composite with a balanced filler system and a matching resin matrix are responsible for high stability and durability.

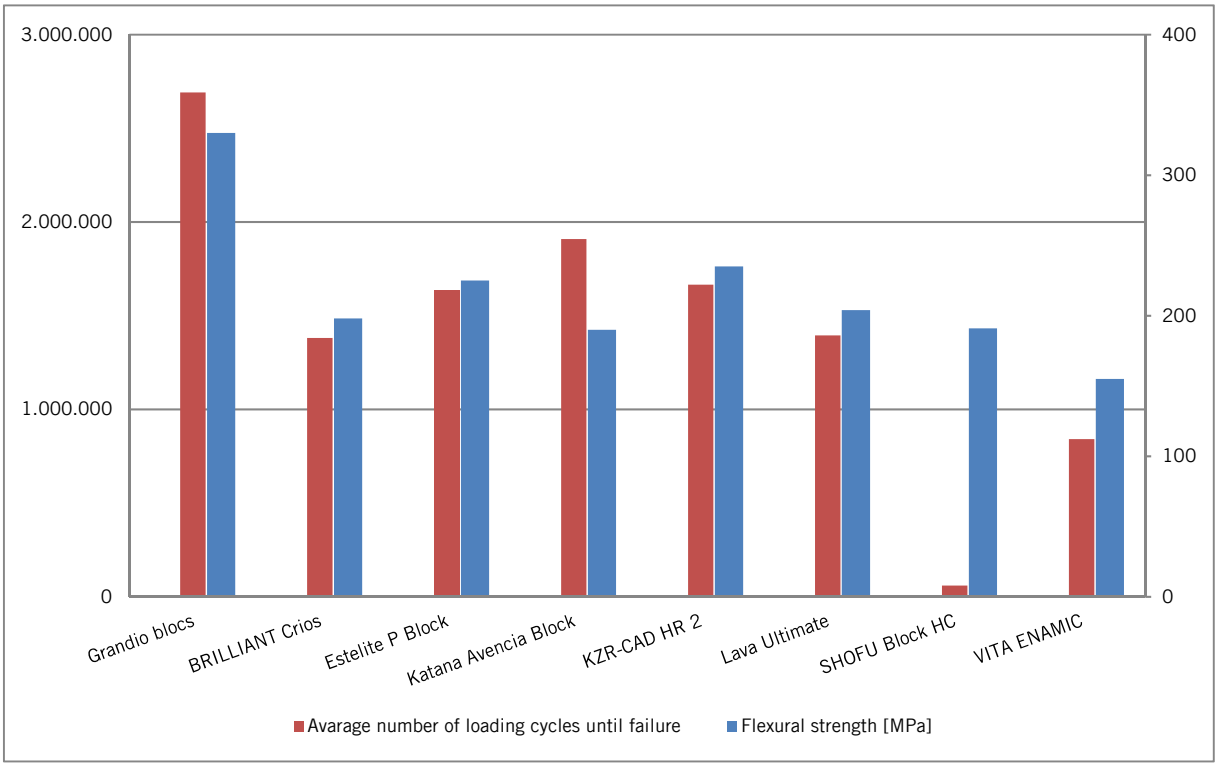


**Figure 2**: Correlation of the number of loading cycles until failure with the flexural strength.

However, a correlation could be established between the flexural strength and the number of loading cycles, which is clearly shown in figure 2. Grandio blocs show the highest flexural strength and at the same time the highest survival rate. In contrast, Shofu Blocks HC show the lowest flexural strength as well as the lowest survival rate. Correlations to other parameters such as modulus of elasticity or surface roughness with the number of loading cycles could not be identified.

**Conclusion: In this study, a novel and clinically relevant *in vitro* testing was presented with which the durability of CAD/CAM materials can be predicted. A cyclic load with increasing loading force can realistically simulate the clinical conditions that restorations must withstand every day. Using this method, it could be proven that there is a significant correlation between the flexural strength and the survival rate of the individual materials. Explicit correlations to other physical properties could not be confirmed. In fact, other factors are essential and the overall system of a composite with a balanced filler system and matching resin matrix is mainly responsible for high stability and durability. Therefore, the materials tested here show widely differing behaviour. Grandio blocs show the highest flexural strength and, consequently, the highest survival rate.**

[1] Rosentritt M *et al.*, *J. Mech. Beh. Biomed. Mat.* **2019** *98*, 311.

[2] Pott P *et al.*, *Eur. J. Pediatr. Dent.* **2016**, *17 (3)*, 223.

[3] Krejci I *et al.*, *Monatsschr Zahnmed* **1990**, *100 (8)*, 953.

[4] Nishioka G *et al.*, *Braz. Oral Res.* **2018**, *32*, e53.