SCIENTIFIC REPORT

Grandio blocs –
In vitro performance and fracture resistance of CAD/CAM crowns

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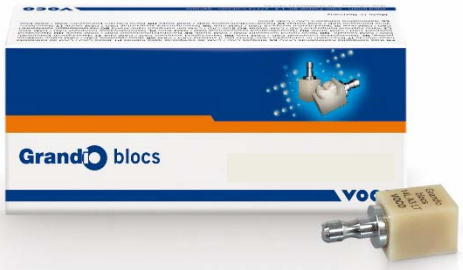

The imitation of dental hard tissue is the ultimate goal in the development of restoratives. Decades of composite optimisation have resulted in what are known as ceramic-based hybrid materials.[1] Some of these are characterised by a high stability which even exceeds that of most glass ceramics. In addition, some of the ceramic-based hybrids display an elasticity similar to that of natural teeth and are even capable of absorbing or redistributing the loads when force is applied without breaking themselves.[2] That is a property that ceramics cannot offer. Nevertheless, some critics are still not convinced by the longevity of ceramic-based hybrid restorations. This study investigated what parameters are important for producing long-lasting restorations and how they can be determined *in vitro*. Two ceramic-based hybrid materials were investigated: Grandio blocs VOCO) and Lava Ultimate (3M ESPE); they were compared against the lithium disilicate ceramic IPS e.max CAD (Ivoclar Vivadent).[3]

Study design

This study was performed using extracted human molars. For each test group, eight molars were prepared in accordance with the guidelines for indirect ceramic restorations with isogingival chamfer preparations at an anatomical reduction of 1.5 mm. Two different preparation designs were applied: retentive preparation, height approx. 8 mm, preparation angle approx. 8° and non-retentive preparation, height approx. 4 mm, preparation angle approx. 15°. The teeth were fixed in resin blocks (Palapress Vario, Kulzer) and the elastic compliance of the teeth simulated with a 1 mm thick layer of polyether (Impregum, 3M ESPE).

Table 1: Overview of the materials used and manufacturer's specifications

Product/manufacturer	Material	Flexural strength [MPa]	E-Modulus [GPa]	Water absorption [µg/mm^3]	Pre-treatment
Grandio blocs / VOCO	Ceramic-based hybrid	333	18	13.6	50 µm Al_2O_3, 2 bar, Ceramic Bond, Bifix QM (VOCO)
Lava Ultimate / 3M ESPE	Ceramic-based hybrid	170-200	12-15	36.0	50 µm Al_2O_3, 2 bar
IPS e.max CAD / Ivoclar Vivadent	Lithium disilicate	360±60	95±5	0.0	20 s, HF (5%), Monobond plus (Ivoclar Vivadent)

Digital impressions were taken of the preparations (CEREC Omnicam, Dentsply Sirona). A total of 112 molar crowns were produced (CEREC, MC XL, Dentsply Sirona) and organised into groups containing eight specimens each. The crowns were milled from two different ceramic-based hybrid blocks: Grandio blocs (VOCO) and Lava Ultimate (3M ESPE). IPS e.max CAD lithium disilicate ceramic blocks (Ivoclar Vivadent) were used as a control, see Table 1.
The restorations all displayed a circular layer thickness of 1.5 mm, but the occlusal dimensions varied between 1.5 mm and 5.5 mm depending on the preparation design. The accuracy of fit of the crowns was either optimised with a gap width of 100 µm or reduced with a gap width of 250 µm. The internal surfaces of the restorations were pre-treated in accordance with the manufacturer's specifications (see Table 1) and luted with either the self-adhesive composite cement RelyX Unicem 2 Automix (3M ESPE) or the universal adhesive Futurabond U (VOCO) in combination with the resin cement Bifix QM (VOCO).
In addition, eight test specimens each were luted on implants with RelyX Unicem 2 Automix (3M ESPE).

An intraoral wearing period of five years was simulated for all specimens by means of: water immersion (90 days, 37 °C), thermocycling (2 x 3,000 cycles between 5/55 °C) and mechanical loading in a chewing simulator ($1.2x10^6$ cycles at 50 N, frequency 1.6 Hz). Following this loading, the fracture resistance was determined for all specimens that had not failed. The fracture patterns of the restorations which failed during the loading were assessed under a scanning electron microscope.

Results

The results are summarised in Table 2. They show clearly that the preparation design, accuracy of fit, type of cementation and, above all, the material itself affect the longevity and fracture resistance. Restorations made of Lava Ultimate and luted with the self-adhesive technique did not even survive the water immersion. In this aspect, all cases of decementation occurred on the tooth side and the layer of cement remained on the restoration. 75 % of the Lava Ultimate restorations cemented with the adhesive technique also displayed decementation in the case of non-retentive preparation in combination with reduced accuracy of fit. In comparison, only 25 % of the Grandio blocs failed during the water immersion and when subjected to masticatory loads.

Table 2: Overview of fracture resistances, fracture patterns and failures. Fracture patterns by type of fracture: crown (C), tooth (T), crown/tooth (CT) and chipping (CH).

Material	Luting	Preparation	Accuracy of fit	Failures after water immersion	Failures after loading	Fracture resistance [N]	Quantity	Fracture patterns
Grandio blocs	Adhesive	Retentive	Optimal			2021	8	2xC, 6xCH
Grandio blocs	Adhesive	Retentive	Reduced			1872	8	4xC, 3xCT, 1xCH
Grandio blocs	Adhesive	Non-retentive	Optimal			2242	8	5xC, 2xCT, 1xT
Grandio blocs	Adhesive	Non-retentive	Reduced	1	1	2070	6	5xC, 1xCT
Grandio blocs	Self-adhesive	Retentive	Optimal			2171	8	3xC, 3xCT, 1xT, 1xCH
Grandio blocs	Self-adhesive	Retentive	Reduced	8			0	
Grandio blocs	Self-adhesive	Non-retentive	Optimal	6	2		0	
Grandio blocs	Self-adhesive	Non-retentive	Reduced	8			0	
Grandio blocs on implant	Self-adhesive	Non-retentive	Reduced			2765	8	
Lava Ultimate	Adhesive	Retentive	Optimal			1534	8	8xC
Lava Ultimate	Adhesive	Non-retentive	Reduced	5	1	1227	2	2xC
Lava Ultimate	Self-adhesive	Retentive	Optimal	8			0	
Lava Ultimate	Self-adhesive	Non-retentive	Reduced	8			0	
Lava Ultimate on implant	Self-adhesive	Non-retentive	Reduced			1722	8	
IPS e.max CAD	Adhesive	Retentive	Optimal			2618	8	7xC, 1xCT
IPS e.max CAD	Self-adhesive	Non-retentive	Reduced	1		2119	7	5xC, 2xCT

In contrast, all of the restorations made of Grandio blocs luted with the adhesive technique survived the water immersion and the masticatory loads. Only the group with non-retentive preparation and reduced accuracy of fit produced two failures. All the crowns in the self-adhesive group also survived as long as the preparation was retentive and the accuracy of fit optimal. However, if the preparations were non-retentive, the accuracy of fit not optimal or both, almost all specimens failed as early as during the water immersion or application of masticatory loads.
The fracture resistances measured for Grandio blocs reveal excellent values more comparable with those of ceramic restorations. In optimal conditions (retentive preparation/optimal accuracy of fit), the fracture resistances are just approx. 20 % below those of IPS e.max CAD. In comparison, Lava Ultimate only achieves approx. 60 % of IPS e.max CAD's strength.
The results indicate that the failures following the water immersion correlate with the materials' water absorption. IPS e.max CAD displays no, Grandio blocs only minimal and Lava Ultimate, in contrast, high water absorption (see Table 1). The more water a material absorbs, the higher the increase in volume, which puts the cement layer under stress and can result in loss of adhesion. For example, only one restoration made of Grandio blocs with non-retentive preparation, reduced accuracy of fit and adhesive luting failed compared with five restorations made of Lava Ultimate. In the case of retentive preparation, optimal accuracy of fit and self-adhesive luting, all eight Lava Ultimate specimens but none of the Grandio blocs restorations failed.
Failures during the chewing simulation were very rare for all materials. This indicates that a tooth-like modulus of elasticity is very advantageous for the restorations. The more elastic a material, the more it deforms under masticatory loads and the greater the possibility of mechanical decementation. Too rigid materials with high moduli of elasticity (> 100 GPa) pass on stresses without damping and can also result in decementation or, in the worst case scenario, destruction of the tooth. For this reason, restoratives with a tooth-like modulus of elasticity (15-30 GPa) which can buffer stresses and redistribute them in all directions at the same time without deforming too much are suitable.

The results for the luting of crowns on implants are very positive. The specimens did not fail during the water immersion or chewing simulation. Compared with Lava Ultimate, restorations made from Grandio blocs display approx. 60 % higher fracture resistances, which are even approx. 27 % higher than the fracture resistances of restorations on prepared teeth.

Conclusion: The study confirms that both the preparation and the accuracy of fit as well as the type of luting have a great impact on the longevity of ceramic-based hybrid materials. Retentive preparations and small gap widths (< 100 µm) should be maintained. The recommendation is to lute restorations made of ceramic-based hybrid materials with composite-based cements in combination with an adhesive. Self-etching and self-adhesive composite cements do not offer the required stability and longevity. The physical properties of the materials employed also play an important role. Preference should be given to a high filler content, low water absorption and a tooth-like modulus of elasticity.

[1] Arnetzl G, Arnetzl GV, *Int. J. Comp. Dent* (2015) *18 (2)*, 177.
[2] Kern M, *Teamwork* (2018) *1*, 26.
[3] Rosentritt M, Preis V, Behr M, Hahnel S, *J. Dent.* (2017) *65*: 70.