OVC_3 Material Properties

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Table of Contents

Summary

Crowns are the largest part of a typical general dentist's practice revenue, accounting for about one-third to more than one-half of all income for an average general practice (Christensen G. , 2016)

Many adult dental patients require some form of full occlusal restoration. Although the industry provides abundant and effective material options, clinical procedures are generally restricted to either CAD/CAM or lab-made restorations. However, these two effective options are both time-consuming, relatively costly and this translates into a high expense for the patient and sub-optimal productivity for the dentist.

Furthermore, patients want better time-efficiencies and immediacy from their dentists. According to Dentsply-Sirona, 85% of patients prefer a one-visit crown and 66% would travel further or would change their dentist for a one-visit crown (GmbH, 2015).

Rhondium has been producing posterior One Visit Crowns (OVC) since 2013, and has adapted their product and procedure during this time to provide a one-visit chair side option that is clinically simple and applicable for both insured and uninsured patients. Rhondium's new OVC_3 now provides an additional clinical option for the general dentist. Products are offered in both a lithium disilicate option, or a hybrid ceramic for all posterior teeth shapes and sizes. It is generally accepted that dental crowns need high compressive strength, high flexural strength, low wear resistance and a strong bond to the tooth. The OVC_3 meets these requirements.

The OVC_3 has clinical application as a full crown, ¾ crown, onlay or full occlusal restoration, and is thus a versatile option for a clinic. It is one of the only *one visit* options that does not require capital investment into a CAD/CAM system, and can be profitable after the first case.

Rhondium OVC_3 hybrid ceramic material flexural strength is 146 MPa and its compressive strength is 312MPa, which compare well with human dentin (193MPa) (Kinney JH, 2003) and other hybrid materials.

The OVC_3 Lithium compressive strength is 454MPa compared to e.max (400MPa). The flexural strength of the OVC_3 Lithium is 621MPa, and is 24% higher than IPS e.max (500MPa) (Ivoclar Vivodent). OVC_3 helps reconstruct the function of the natural compression dome (Milicich, 2017). This means that the tooth can again mimic nature's ability to absorb compression forces whilst safely distributing tensile forces.

Wear testing for both the OVC_3 Lithium and OVC_3 Hybrid show similar results at approximately 0.6mm in the first decade and are less than half that of IPS e.max, which wears 276% faster than enamel (Lawson NC, Bansel R, Burgess JO, 2016:32).

The high bonding strengths achieved by direct bonding allows OVC_3 crown preps to be more conservative by retaining more tooth substance and are thereby less harmful to the delicate pulpal tissues. In addition, micro-leakage testing of OVC_3 crowns found no microleakage in any of the test teeth after 500 thermocycles.

1. Material Properties

The following sections discuss in detail the mechanical properties of the OVC_3 materials.

1.1. Compressive strength

Rhondium's in-house laboratory testing shows the compressive strength of Rhondium's Lithium (lithium disilicate material) is 454MPa and the compressive strength of the OVC_3 Hybrid (hybrid ceramic material) is 312MPa.

In comparison, here are some newer composites and lithium disilicate materials compared to human enamel and dentin. (M Hegde, 2011), (KJ Chun, 2014)

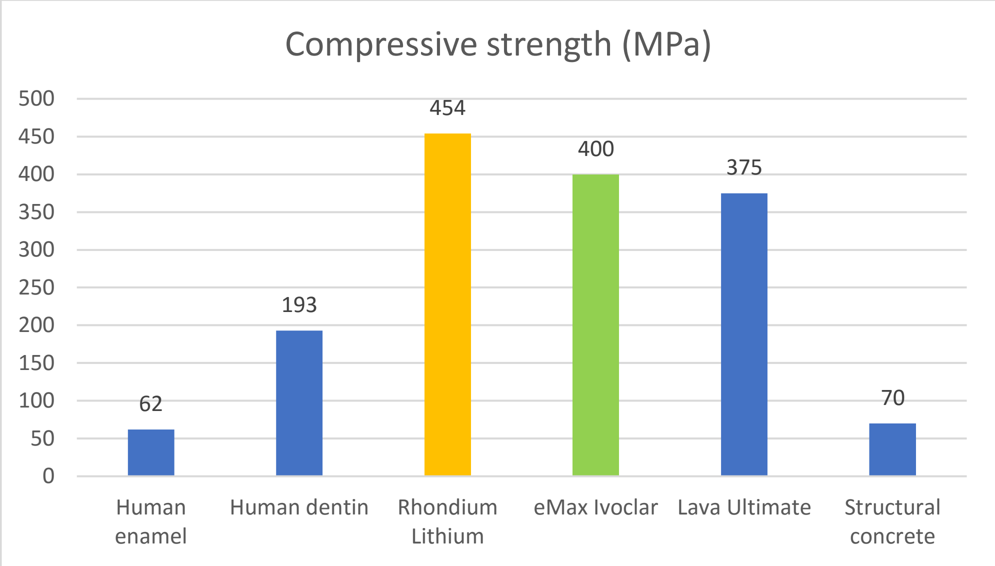


Figure 1. Compressive strength comparison with other CAD/CAM materials

The compressive strength of human enamel (62MPa)(±23.8), dentin (193MPa)(±30.6), (KJ Chun, 2014) and structural concrete (70MPa) has been added for comparison.

The compressive strength of the Rhondium hybrid ceramic material is compared with a range of materials below.

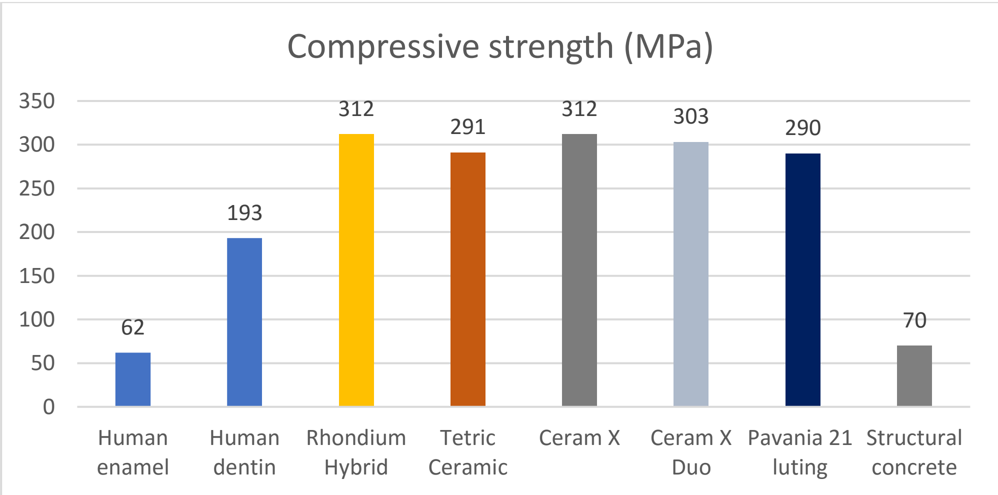


Figure 2. Compressive strength comparison with other composite materials

1.2. Flexural strength

The flexural strength of Rhondium's OVC_3 lithium disilicate material is 621MPa (inhouse testing in accordance with ISO 6872) and compares well with other well-known ceramic dental materials. See comparison graph below.

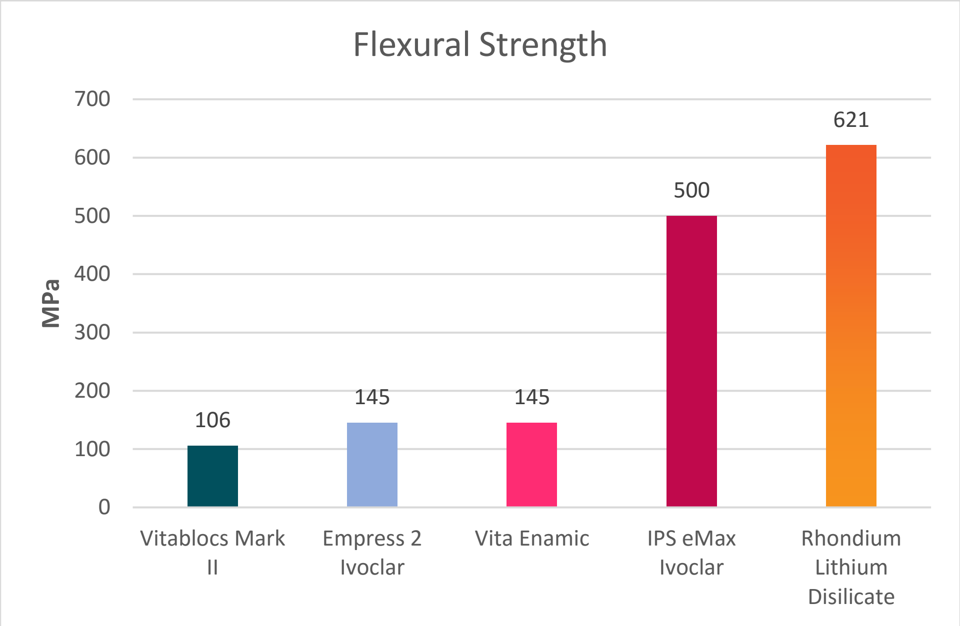


Figure 3. Flexure strength of ceramics comparison graph

Source links:

http://www.odontomega.com.br/images/online/mp5800_downloads_49979_Flexural_strength_of_Lithium_disilicate.pdf

https://www.ncbi.nlm.nih.gov/pubmed/26013069

The flexural strength of Rhondium's OVC_3 hybrid ceramic material is 146MPa (inhouse testing in accordance with ISO4049) and compares well with other well-known composites. See comparison graph below.

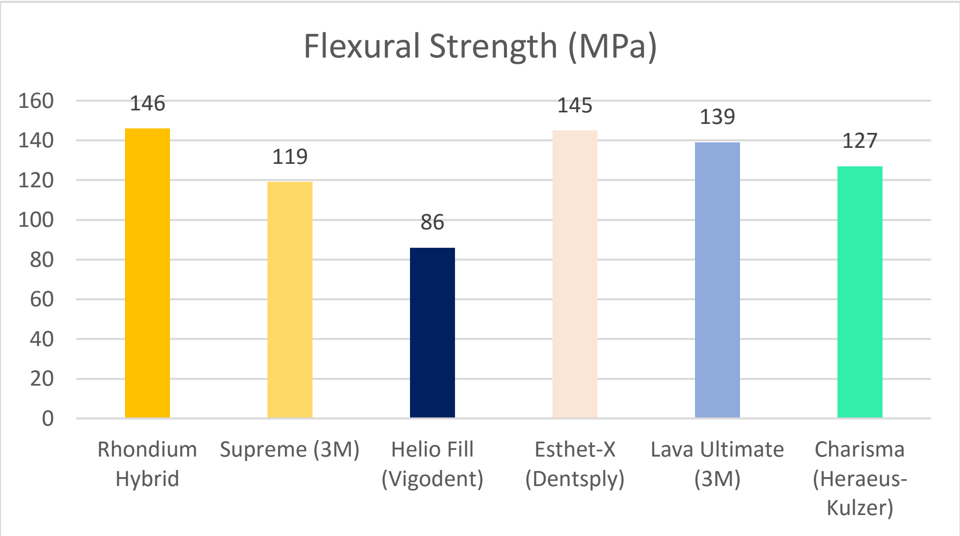


Figure 4. Flexure strength of composite comparison graph

Data Source Link 1

1.3. Fracture resistance

OVC Hybrid crowns have been subjected to destructive load testing (inhouse testing). Extracted human lower right molar teeth were used in this study. The following restorations were compared, and five teeth were in each group:

Restoration System
Filtek Supreme Large MOD
Premise Large MOD
OVC Hybrid
IPS e.max crown (CAD/CAM)
Lava Ultimate crown (CAD/CAM)

The crowns were bonded to the tooth with Multilink (Ivoclar) and the MOD restorations were bonded with Optibond FL (Kerr).

A tungsten carbide spherical ball was used in a load testing machine until the restoration fractured.

Figure 5. Fracture resistance equipment

The results are graphed below.

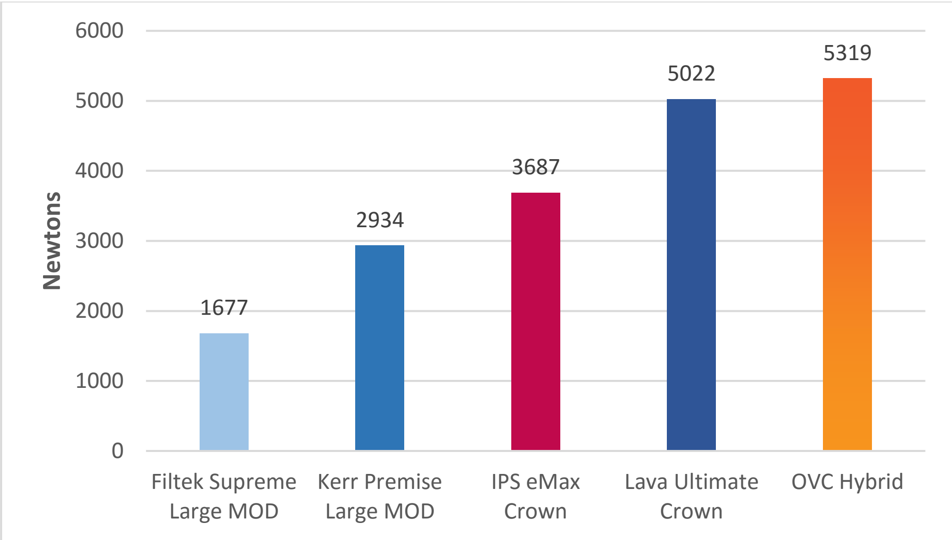


Figure 6. Fracture resistance graph - average maximum load at failure

Note that both the Lava Ultimate and the OVC Hybrid withstood more than half a metric ton before they disintegrated. This is an astonishing high load, especially since the load was applied to the crown via a small steel ball.

The OVC Hybrid withstood a 44% higher load than the e.max crowns and more than double that of the MOD restorations.

Typically, at the maximum load (average 5319N), the entire OVC Hybrid crown/tooth complex gave way.

Sample Number	OVC Restoration Before Loading	OVC Restoration After Loading
Tooth 1		

Figure 7. Typical example of OVC Hybrid crown at maximum load

In contrast, the e.max crowns tended to fracture at maximum load (average 3687N) as shown below:

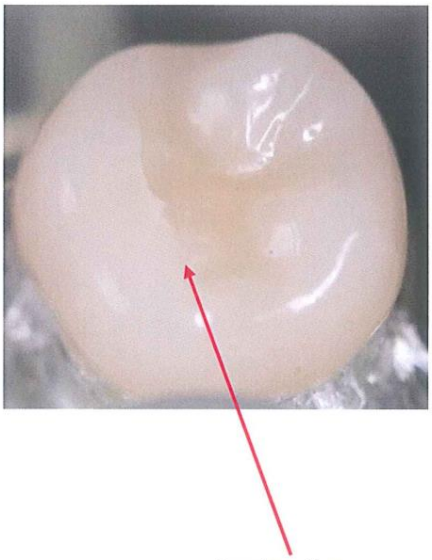
Sample Number	e.max Restoration Before Loading	e.max Restoration After Loading
Tooth 1	 	

Figure 8. Typical example of eMax crown at maximum load

[Reference inhouse study RHTR0032 Comparison of Load Bearing Properties]

Note that the maximum loads that humans can apply to teeth is around 600N for females and up to 850N for males but can be higher when individuals unintentionally bite hard on say, a stone in food (Waltimo A, 1193).

1.4. Wear resistance

Rhondium conducted in-house testing in accordance with the method described by (Heintze, 2006) using a chewing simulator. The results showed that the OVC_3 Hybrid wear is very similar to OVC_3 Lithium and is around 0.6mm per decade. Natural human enamel wears at around 45µ per year or 0.45mm per decade (Lawson NC J. S., 2014) so this indicates that the OVC_3 might wear at a slightly faster rate than natural teeth. However, the difference is small and may not be clinically significant.

The graph below shows a decreasing wear rate over time and this is because initially the antagonist is a point loading but as the surface wears, the wear indentation enlarges and the force per area decreases. This is also true for natural teeth until the enamel has worn through.

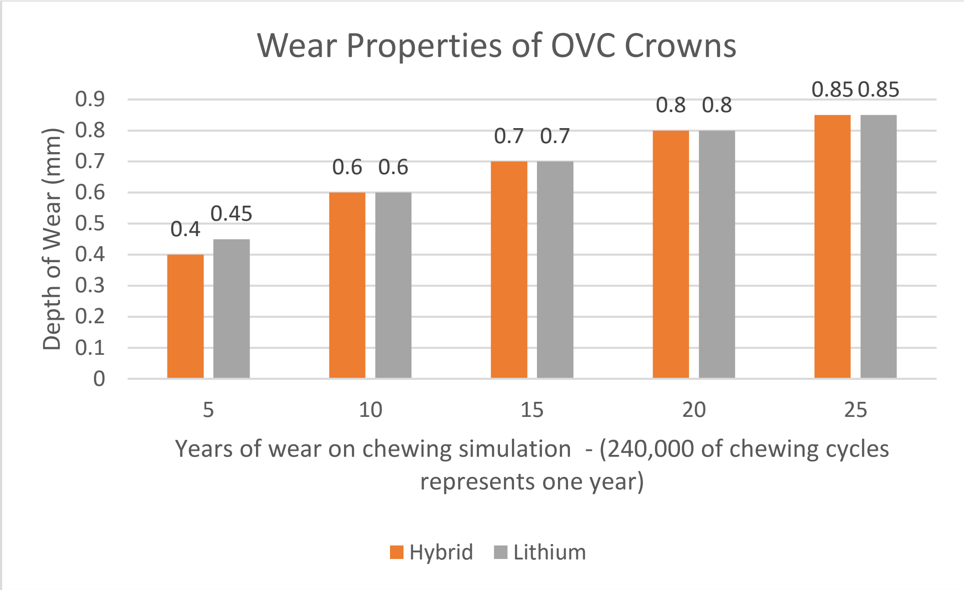


Figure 9. Wear resistance of OVC crowns

A recent study (NC Lawson, 2016) compared the wear resistance of several CAM/CAM hybrid materials (Paradigm MZ100, Cerasmart and Lava Ultimate) with lithium disilicate (eMax) and results are in the table below:

Table 3 – Material and enamel wear of CAD/CAM restorative materials and reference enamel.

Material	Material wear (mm^3) (mean ± SD)	Enamel wear (mm^3) (mean ± SD)
Paradigm MZ100	0.182(0.06)^{a,b}	0.108(0.02)^{a}
Cerasmart	0.180(0.07)^{a,b}	0.056(0.03)^{a}
LAVA Ultimate	0.152(0.04)^{a,b}	0.0610(0.02)^{a}
Enamic	0.21(0.06)^{a,b,c}	0.280(0.07)^{b,c}
Celtra Duo unfired	0.241(0.09)^{b,c}	0.375(0.14)^{c,d}
Celtra Duo fired	0.220(0.05)^{a,b,c}	0.276(0.07)^{b,c}
e.max CAD	0.329(0.18)^{c}	0.420(0.09)^{d}
Enamel	0.119(0.07)^{a}	0.247(0.09)^{b}

Materials labeled with similar letters in each column are not statistically different.

The material wear for the three hybrid materials was significantly less than e.max and the hybrids causes less than 25% of the wear on the enamel antagonist.

1.5. Shrinkage

In most cases, deep cavity defects are cured in layers using standard procedures before the OVC_3 is placed. Contraction issues related to the OVC_3 technique are small since the C-factor is 1. Any minor contraction issues are even further reduced by spot-curing the centre of the OVC_3 first. By spot-curing the centre, any shrinkage can draw additional uncured composite from the surrounding uncured material, while very slightly pulling the crown towards the tooth. This spot curing reduces internal stresses. The final cure only cures the periphery of the OVC_3 which can shrink inwards towards the centre.

Shrinkage concerns can be further ameliorated by light curing from the centre outwards using the spot-curing selector key in a circular motion, in gradually increasing circles, until the crown has cured.

The above indicates that shrinkage vectors are not a significant issue with the OVC_3.

In contrast, large direct composite restorations, such as MODBL, have major issues with shrinkage because the C-factor is high, and the layering of composite causes internal stresses to build up.

1.6. Micro-leakage

Rhondium inhouse testing compared the micro-leakage of spot-curing the OVC_3 followed by full occlusal curing, versus only full occlusal curing. All restored teeth were subjected to 500 thermocycles (5°C to 55°C) and then immersed in dye for 48 hours. The teeth were then sectioned multiple times using a diamond saw mounted in a CNC machine.

These results are in the table below.

Description	Sample size	Occurrence of microleakage
Spot curing for 5 seconds plus full occlusal curing	5	No evidence of any leakage
Full only occlusal curing	5	No evidence of any leakage

Interestingly, none of the OVC_3 crowns in either group had any evidence of microleakage. This is unusual as there are numerous microleakage studies of both indirect restorations and direct composite restorations in the literature that show some signs of micro-leakage.

The lack of microleakage is reassuring regarding both the bond strength and the resistance to secondary caries.

A typical example is shown below.

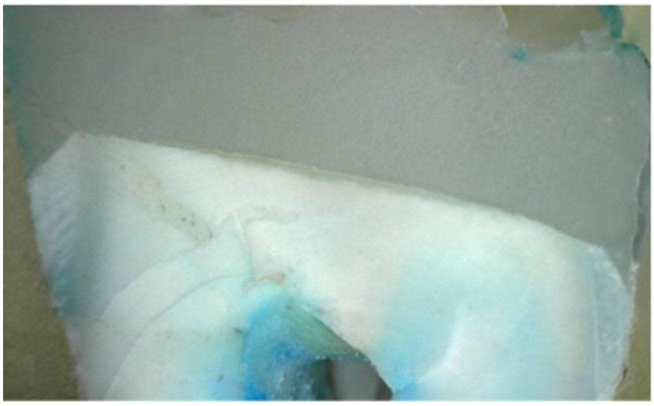


Figure 10. Sectioned OVC showing lack of dye penetration.

1.7. Quality of margins

Computer-aided design of restorations has several potentially accuracy compromising aspects: during data collection, locating the margin in the digital representation, and the restoration design (ED Rekow, 2011). This issue is not present with the OVC_3 as the uncured hybrid composite layer is directly bonded to the margins of the tooth preparation.

1.8. Bond-strength between OVC_3 Lithium and composite

The under surface of the lithium layer is conditioned to achieve high bond strength with the hybrid ceramic sub-layer. Our internal testing shows that we are consistently achieving a shear bond-strength of 33MPa between these layers. At such a high bond strength, our laboratory testing shows that the composite fails cohesively before the bond between the two layers fails. In short, we have not seen a single delamination in any of our tests.

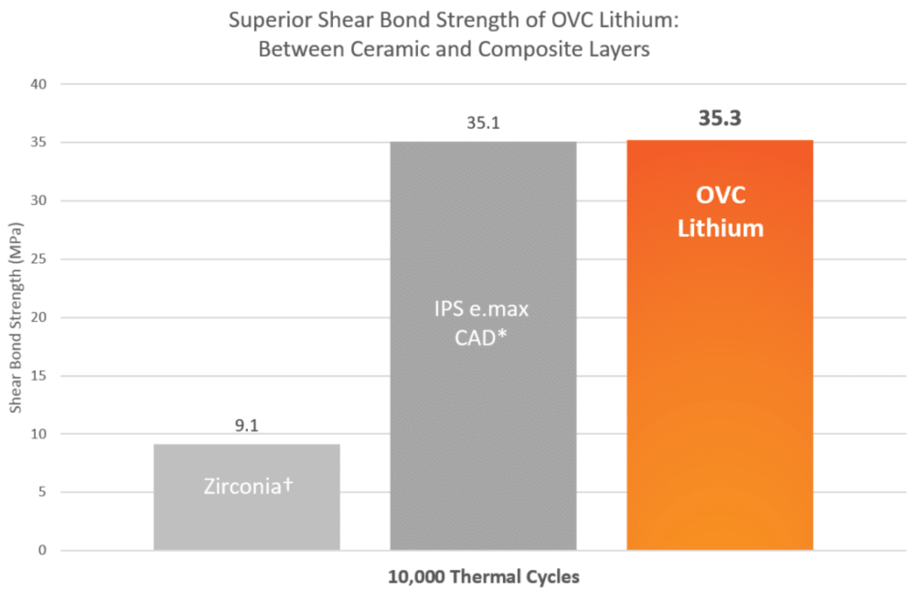


Figure 11. Bond strength of lithium layer to composite sub-layer

The outer margin of the lithium disilicate material is etched and bonded to prevent staining. If the interfaces are not polished properly when the OVC_3 is placed, there is a possibility of staining in the future. If it does happen, the crown can be easily polished at the recall visit.

1.9. Bond-strength of OVC_3 and tooth

The OVC_3 uses a *direct* bonding protocol. Before we talk about direct bonding, let's take a moment to consider the drawbacks of *indirect* crown cementation.

1. Tooth contamination. Temporary cement can be hard to see and completely remove. Temporary crowns frequently leak and allow bacterial contamination of the dentin tubules, which in turn is potentially damaging to the dental pulp.
2. If Immediate Dentin Sealing (IDS) is used at the first appointment, a separating agent such as petroleum jelly is recommended to prevent an excessively strong bond to the temporary crown. The petroleum jelly must be totally removed at the second appointment for obvious reasons. In addition, the IDS that was applied at the first appointment must be sand-

blasted carefully and there is a risk that too much might be removed (Magne, 2005).

3. Crown contamination. The intaglio surface of the crown can be contaminated. The in-office milling of CAD/CAM crowns leaves a smear layer of dust and this must be removed prior to cementation by sand-blasting (air-abrasion) or hydrofluoric acid. The use of hydrofluoric acid is not indicated for hybrid CAD/CAM blocks and must be sand-blasted. Not all dentists have air-abrasion readily available.
4. Issues with fit. There are many well know causes of poor fit and these potentially can interfere with the bonding procedure.
5. Too tight proximal contacts in indirect crowns can be hard to diagnose and remove and can prevent proper seating of the crown during cementation.
6. Temporization of minimally invasive crown preps is fraught with difficulty as the temporary crowns often come off.
7. Crown luting cements do not bond with such high bond strengths, particularly to zirconia crowns. Shear bond strengths in the range of 7.3 to 16.4 MPa are commonly found with zirconia crowns (Attia, 2011) and this is the main reason that destructive ferrule-type crown preparations are recommended for zirconia crowns.

Direct dental bonding agents have been performing exceptionally well for many years. For example, mean shear bond strengths to enamel ranged from 18.1 MPa for Xeno IV to 41.0 MPa for OptiBond FL. On dentin, the means ranged from 33.3 MPa for OptiBond FL to 47.1 MPa for Clearfil SE Bond (R Walter, 2011). These high bond strengths generally mean that the test sample fractures cohesively through the substrate rather than along the bonding interface.

In general, direct bonding agents give higher shear-bond strengths compared to indirect luting agents.

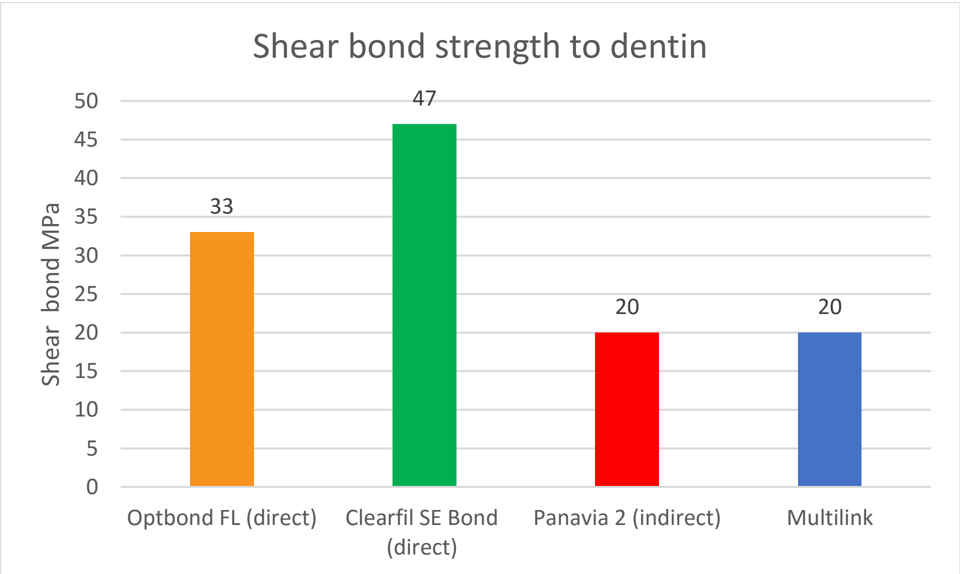


Figure 12. Shear bond strength to dentin

Since the OVC_3 crown is bonded directly to the tooth with such agents, very high bond strengths are obtained. Freshly cut dentin is considered the ideal substrate for dentin bonding (Magne, 2005). Furthermore, with the OVC_3 system, the bonding agent has the opportunity to form an intimate chemical bond directly to fresh composite.

Since the bonding interface has a C-factor of 1, the bond could be considered in a similar way to immediate dental sealing (IDS) since there are no shrinkage vectors pulling on the bonded surface, and this allows stress-free dentin bond development (Magne, 2005).

1.10. Light-curing

The OVC_3 technique requires deep parts of the crown-prep (greater than 3mm from the occlusal surface) to be built up and cured before the OVC_3 is placed. Spot-curing the centre of the OVC_3 is recommended to control shrinkage and simplify the clinical technique. See Shrinkage issues above 1.5.

Rhondium inhouse testing has demonstrated that curing for 30 seconds with a curing light >1000 lumens/cm^3 cures through the centre of the OVC_3 to a depth of 3.4mm to 3.8mm (depending on the tooth-type). [Ref RHTR0111 L-OVC Spot Cure Depth]

The use of curing lights with less than 1000 lumens/cm^3 is ineffective and strongly discouraged.

1.11. Rationale of lithium disilicate with a composite base layer

Clearly, lithium disilicate cannot have its intaglio surface altered at the chairside without a CAD/CAM machine. However, an uncured and bonded layer of composite can be manipulated at the chairside.

A traditional ceramic crown/onlay sits directly on dentin which has a stiffness (modulus of 7-10 GPa). Dentin's modulus (Kinney JH, 2003) is very similar to the OVC's underlying composite (modulus of 10Gpa). Since the modulus of the composite and dentin are so similar, the OVC_3 restoration mimics a traditional adhesive ceramic crown/onlay as if it were sitting on dentin.

1.12. Comparison of Rhondium OVC_3 Lithium and OVC_3 Hybrid Ceramic

During the last 10 years lithium disilicate has become popular. However, over the same period, a number of studies have shown that some hybrid ceramic materials show similar or better characteristics. Pascal Magne has conducted extensive comparisons of ceramic versus hybrid ceramic materials and found that composite overlay type restorations consistently out perform all ceramic restorations (P Magne, 2009).

Rhondium's inhouse testing has shown that the OVC_3 Hybrid has greater wear resistance and fracture resistance compared to the OVC_3 Lithium. However, Rhondium makes and sells both versions and it is up to the clinician to decide which version is most suitable for them, keeping in mind clinical and reimbursement factors that differ from country to country.

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