Translating the Science
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Veneer Cement Bond Strength Durability and Resistance to Toothbrush Abrasion

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INTRODUCTION:

Veneer Cements are specialized cements for demanding esthetic cases in which any color change over time is the most apparent and mechanical retention and bonding surface area is at a minimum. Ideally, esthetic veneer cements should have a long working time, curing on demand, excellent color stability, and high strength.

Veneer restorations, inlays and onlays differ from other indirect restorations in that there is a relatively larger margin exposed compared to the size of the restoration, while more margin is often directly exposed to toothbrush abrasion rather than being protected by gingiva. Over time, toothbrush abrasion and chemical attack may wear enough of the cement margin to allow increased staining to occur, bacteria to accumulate or present a change in gloss which can show an unsightly cement margin. Self-cured and dual-cured cements tend to suffer from increased shade shift overtime compared to light-cured only cements. This is a reason why many veneer cements are light-cured only; to achieve the highest possible color stability as chemical curing initiators and adhesive monomers can increase color change. This also allows l ight-cured only cements to have higher filler loading and increased strength as they don't need to have a viscosity low enough to allow mixing with a dual-barrel syringe.

In this study, we compared the bond strength of three veneer cements after six months of artificial aging to Dentin, Enamel, ***IPS e.max CAD*** (Ivoclar Vivadent, Inc.) and ***KATANA™ STML*** (Kuraray Noritake Dental, Inc.) Zirconia. Bond strength test was conducted by curing through 1.5 mm of Zirconia to test the worst-case scenario of limited light penetration through an indirect restoration. We also tested the resistance to toothbrush abrasion, simulating about 5.5 years of regular toothbrush use while measuring the depth of wear, change in surface roughness and gloss.

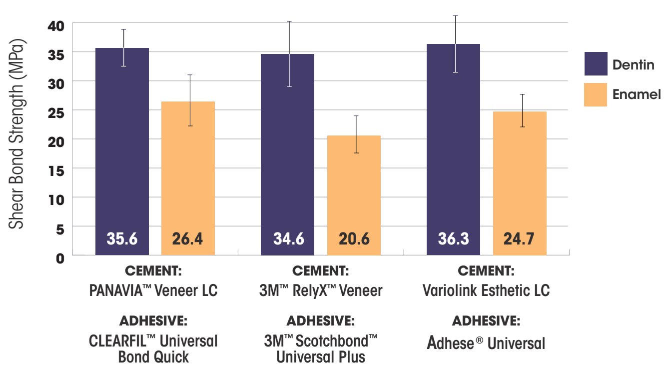
Bond Strength to multiple substrates:

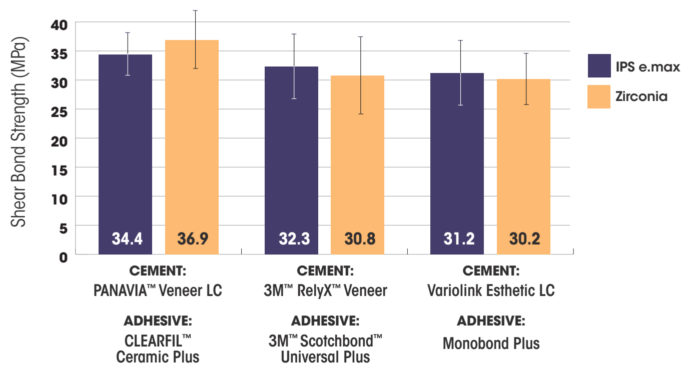
Our test method for bond strength of cements for indirect restorations is based on an ISO/TS 11405 method in which a 100-micron thickness by 3 mm diameter space is created using single-sided PTFE tape for the cement between two substrates. In this study, one side of the test was always an approximately 1.5 mm thickness x 6 mm diameter disc of zirconia in which the light polymerization of an ***Elipar Deep-Cure S*** curing light with ~1470 mW/cm2 irradiance was used, while the other side of the cement interface was different substrates including human dentin, enamel, ***IPS e.max CAD*** and ***KATANA™ STML*** The critical bond interface we were interested in was on the side of the prepared substrate of dentin, enamel, lithium disilicate and zirconia, while the zirconia disc we were cementing to it, simulated a worst-case scenario of light attenuation to determine if the cements can cure with only ~80% of the applied light reaching the cement.

Thermocycling: The bonded specimens were then subjected to artificial aging by cycling the specimens between 5°C and 55°C for 5000 cycles and a 20-second dwell time. This stresses the bond due to the contraction and expansion of the two temperatures and is estimated to simulate about 6 months of in vivo use. This is a helpful screening test for determining if there is inefficient polymerization or compatibility issues between the products, as well as highlighting differences in performance between products.

Bond strength is calculated by dividing the overall force required to dislodge the disc from the surface by the surface area of the bonded interface to give a final result in MPa. While this may make it seem that the bond strength should be independent of the bonded area, we shouldn't directly compare the numerical results from different bond strength test methods as many factors can affect the overall value of the bond strength. However, the rankings of the materials should be consistent between tests assuming factors such as the surface treatment, and curing mode are consistent.

Bond Strength Results



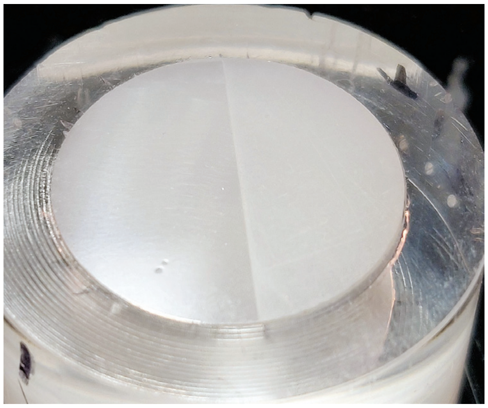


Panavia™ Veneer LC with ***CLEARFIL Universal Bond Quick*** and ***CLEARFIL Ceramic Primer Plus*** had equivalent or higher bond strength to the Dentin, Enamel and Lithium Disilicate substrates tested after six months of thermocycling simulated aging to the other two cement systems. ***Panavia™ Veneer LC*** with ***CLEARFIL Ceramic Primer Plus has the highest bond strength to zirconia (ANOVA and Tukey multiple comparison test, p>0.05). All cement systems showed good adhesion after thermocycling, indicating sufficient curing light penetration through the zirconia disc used in this study.***

Wear Resistance after Toothbrush Abrasion:

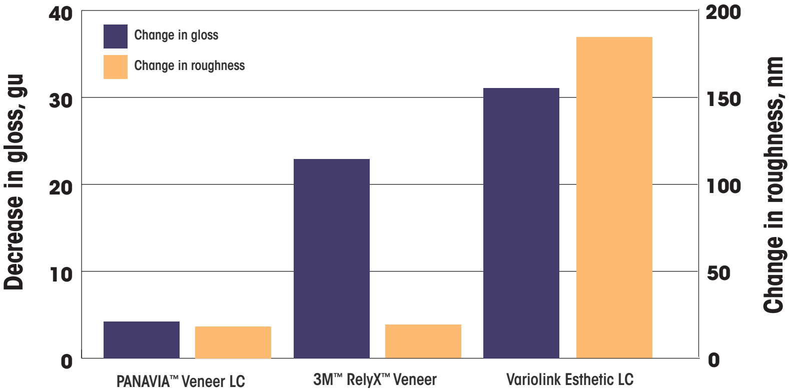
We prepared large discs of the cement and polished them with very fine-grit paper and then polished them with the ***3M™ Soflex Diamond Polishing System*** to produce a baseline of ideally polished specimens. Vickers hardness indents were made on the side to be brushed as the change in dimensions of the indent can be used to estimate how much wear was produced. Half of the cement discs were then covered with single sided tape to preserve the original surface, and the gloss was measured. The specimens were subjected to 30,000 strokes (5.5 years) of toothbrush abrasion which brushed the surface in a figure-8 pattern, with an average 180 g load and ***Colgate Optic White Enamel*** toothpaste.

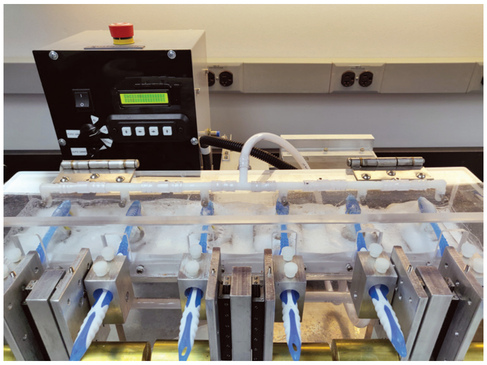
After toothbrush abrasion, the surfaces were analyzed. We remeasured the gloss to determine how the wear of the surface changed the reflection of light. Having a cement margin that is less glossy than the tooth and ceramic around it may be more apparent as a matte line, as well as being an indication of increased wear. Surfaces were measured using an Atomic Force Microscope (Veeco Dimension Icon), which is a kind of surface profilometer with an extremely fine stylus of ~20 nm in width that traces over the surface to generate a 3D map of the surface. This is the most accurate way to characterize the surface roughness change on both sides of the specimen. We also measured about 40 microns on either side of the interface created by the tape in the middle which showed less overall wear than the large flat surfaces due to the tape protecting it as the figure-8 is traced from one side or the other. This interface may more accurately represent the situation in the mouth as a circular toothbrushing pattern wouldn't necessarily be directly applied to the cement margin.



Example of a cement specimen after toothbrush abrasion, with the polished surface (~86 gu) on the left, and abraded surface (~63 gu) on the right.

Change in Gloss and Roughness after Toothbrush Abrasion

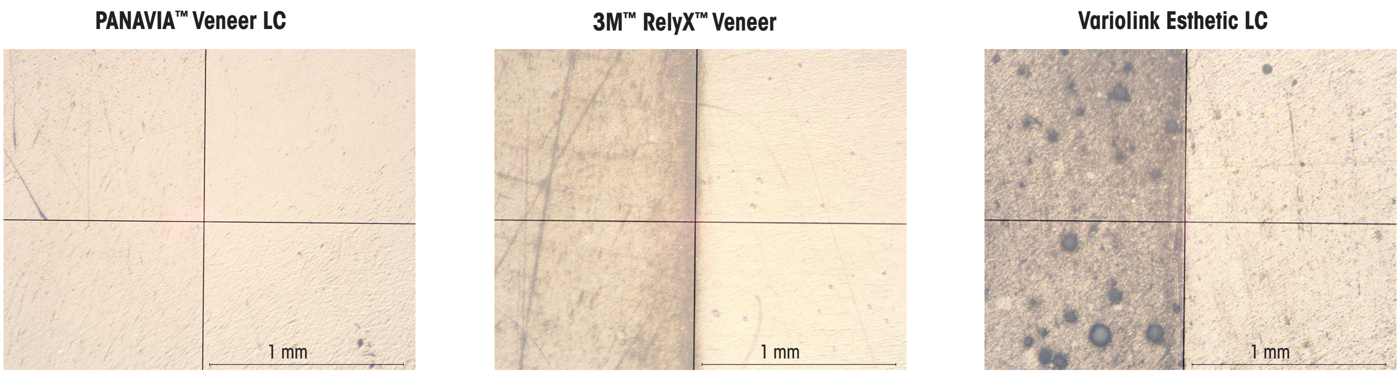




Proto-tech Advanced Toothbrush Simulator

PANAVIA™ Veneer LC had the best gloss retention of the three cements tested and a very even wear pattern. Having limited surface roughness after toothbrush abrasion can help lower staining and bacterial adhesion, with an average roughness of under 100 nm being ideal to prevent staining and bacterial adhesion. The final roughness after abrasion was under 50 nm for both PANAVIA Veneer LC and ***3M™ RelyX™ Veneer***, while ***Variolink Esthetic LC*** had a roughness of over 200 nm. ***Variolink Esthetic LC*** had the presence of up to 3-micron diameter surface voids after toothbrush abrasion, likely due to larger filler clusters being removed.

Gloss is the reflection of light measured by shining a fixed beam of light at an angle to determine how much light is reflected at an equal and opposite angle. A high gloss for restorative materials is generally considered to be >70 gloss units (gu).



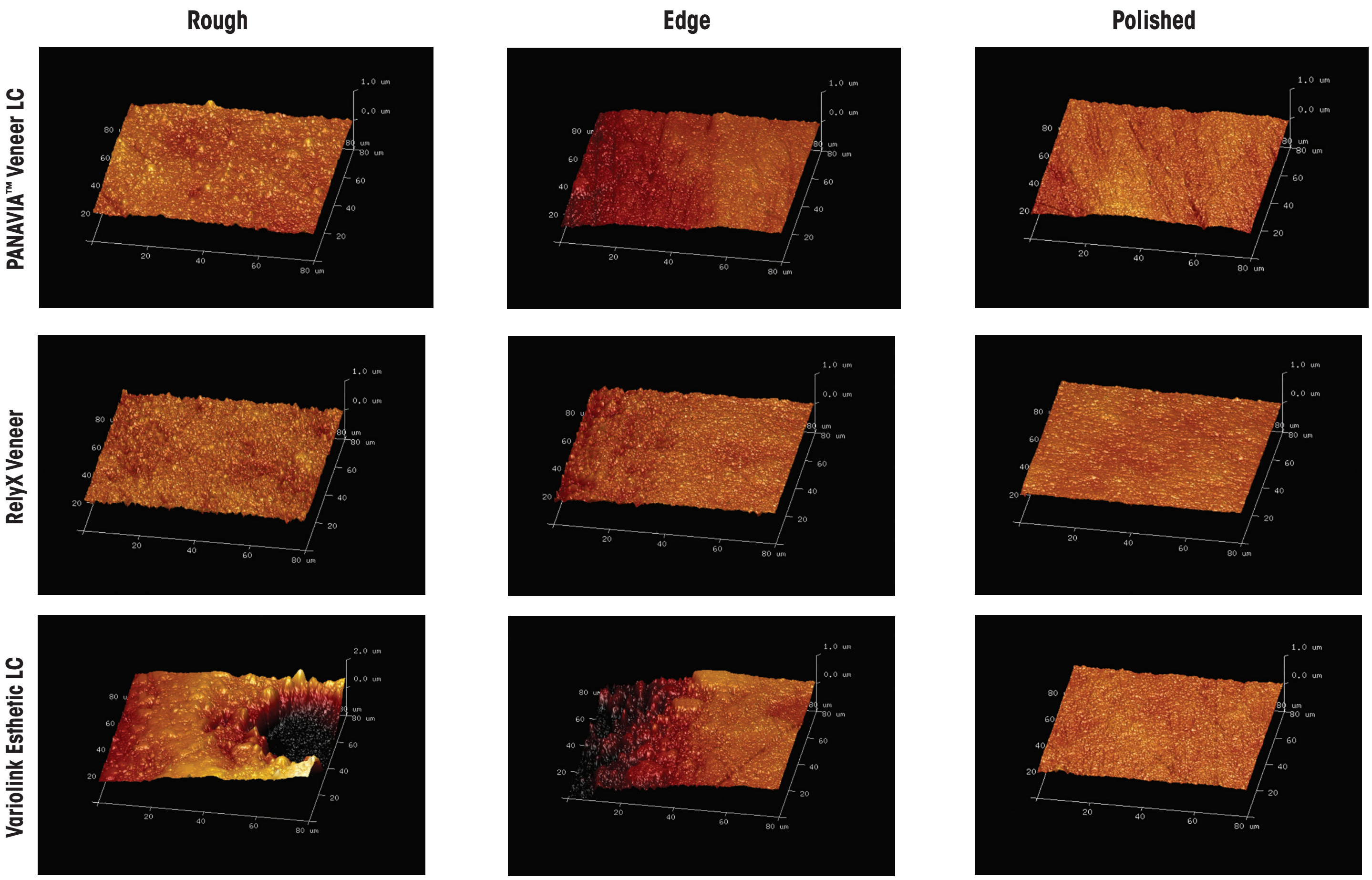
Appearance of surface gloss at 10X magnification after toothbrush abrasion (initial right, final left) ***PANAVIA™ Veneer LC*** has almost indistinguishable gloss difference after tooth brush abrasion.

PANAVIA™ Veneer LC and ***3M™ RelyX™ Veneer*** had similar depth of wear that was less than ***Variolink Esthetic LC***. The depth of wear at the interface of the tape may better represent the clinical situation of a cement margin than the larger flat areas. Given that cement margins can often be 20 – 100 microns in thickness, the wear depth of a few microns isn't going to affect the clinical situation as much as the change in surface roughness; however, these values can indicate the overall resistance to abrasion. Abrasion can potentially also come from mastication of food particles as well. ***PANAVIA™Veneer LC*** consists of spherical silica fillers and nano cluster fillers which allows a high overall filler load increasing the density to prevent excessive wear. The smaller diameter fillers have the added benefit of allowing easy application from the syringe and flowability for minimal film thickness. The Hardness of the cements are similar and within the range for flowable composites, cements and core materials.

Depth of Wear and Hardness

Cement	Edge Depth of Wear within 40 µm of tape, µm	Average Depth of wear from Hardness Indents, µm	Vickers Hardness, HV/0.1
PANAVIA™ Veneer LC	0.7	1.8	49 (2)
3M™ RelyX™ Veneer	0.7	1.9	56 (2)
Variolink Esthetic LC	2.3	3.3	53 (4)

As seen from the AFM scans, ***PANAVIA™ Veneer LC*** has a largely flat surface after abrasion with some bumps from filler clusters that haven't been removed yet. This allows it to have an even glossy surface after abrasion compared to ***3M™ RelyX™ Veneer*** which has a more regular bumpy pattern despite similar average surface roughness. Putting it another way, ***PANAVIA™ Veneer LC*** has higher peaks on a nanoscale (but small enough to not present a problem clinically), while ***3M™ RelyX™ Veneer*** has slightly lower peaks, but more of them, which scatters light more lowering the gloss.



Representative 80 x 80-micron AFM scans of the Rough, Edge and Polished regions. Note, the ***Variolink Esthetic LC*** rough example has a different scale to show features of filler cluster being removed from the surface.

CONCLUSION:

PANAVIA™ Veneer LC cement system showed excellent adhesion properties and exceptional gloss retention and wear resistance. Due to its excellent properties, ***PANAVIA™ Veneer LC Paste*** can meet the most challenging esthetic conditions of veneer cementation.

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