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Adhesion between zirconia and indirect composite resin

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ABSTRACT

Purpose: The purpose of this study was to determine the bond energy using the strain energy release rate of three indirect restorative composite veneering systems to YZr.

Materials and methods: Three indirect composite veneering systems (Ceramage – Shofu Inc.; Signum – Heraeus Kulzer GmbH; Sinfony- 3M ESPE) were bonded to YZr stabilized zirconia plates with and without sandblasting and manufacturer's recommended bonding agents per the method described by Cheng et al. [32] consisting of two opaque layers on the YZr plate at the bond surface interface and a 12 mm composite rod. The specimens were brought to failure with a universal testing machine and *G*-values calculated. One-way ANOVA and Dunnetts's test ($P=95\%$) were performed. Homogeneity of the variables was confirmed with Bartlett's test.

Results: No significant difference was observed between the *G*-values for the control groups of Ceramage, Signum and Sinfony. Within the Ceramage group, there was no significant difference between the surface treatments. The Signum group showed a significant difference between the control and sandblasted groups as well as the sandblasted surfaces in combination with bonding agent groups, but no significant difference between control and bonding agent alone. The Sinfony group, showed no significant difference between the control and sandblasted groups, but a significant difference between the control and sandblasted with bonding agent groups (Rocatec).

Conclusion: The application of acidic functional phosphate monomer MDP or silicatising the YZr surfaces before veneering with indirect composite veneering material produced higher bond energy. Sandblasting the YZr surfaces with 120 grit AlO_2 only, did not increase the bond energy.

1. Introduction

Yitrium stabilized Zirconia Ceramic (YZr) has been developed as a framework material for tooth-supported or implant-supported all-ceramic restorations and implant abutments. This is due to its biocompatibility, low bacterial adhesion, high strength and natural esthetic properties [1–5].

Failures, with and without exposing the underlying framework, in the form of chipping within the veneering porcelain have been reported in the literature [5–12]. As an alternative to porcelain, Komine et al. reported on the use of composite resin as a viable veneer system. An additional advantage of using composite resin was the energy absorption of composite resulting in a preferable tactile response in natural teeth opposing an implant [1,12,13].

However, due to the chemical inertness of YZr, bonding remains problematic [11,14,16–23]. Limited research is available on the bond strength between proprietary indirect composite systems and YZr; published results from which were predominantly obtained by using the shear bond test [1,14]. Yet, data from these measurements, using the concept of nominal stress, are inconsistent and contain large deviation in test results between laboratories [15]. In fact, the mechanics of the nominal shear bond test, draws more criticism than approval. In a study done by Della Bona and van Noort finite element analysis (FEA) was used to demonstrate that tensile and shear bond strength measurements were highly dependent on the geometry of the test arrangement; the nature of the load applied; film thickness of the adhesive; as well as the elastic modulus of the materials involved [15].

By using the fracture energy release rate approach, it is possible to determine the potential power of stable crack propagation within an interface. This can be achieved using G_{Ic} (strain energy release rate) which is the amount of energy required to separate two bonded materials [25]. This approach takes into account, the mechanical properties of the adhesive material and the geometries of the test arrangement and adhesive surface.

Therefore, the purpose of this study was to determine the bond energy using the strain energy release rate, of three proprietary indirect restorative composite veneering systems to YZr.

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2. Materials and method

Three proprietary indirect composite veneering systems, incorporating their dentine and opaque, were bonded to zirconia plates using their manufacturer's recommended bonding agents (Table 1) and preparation techniques (Table 2). 132 YZr rectangular plates were sectioned from milling blocks, using a diamond grit blade on a low speed cutting machine (DTQ-5, Laizhou Huayin Testing Instrument Co., Ltd., Shangdong, China) under water irrigation. Prior to sintering the plates were hand polished using 400 grit Silicon Carbide abrasive paper (Struers, Denmark) to ensure a flat veneering surface.

All the plates were veneered according to each individual manufacturer's instructions with a composite rod as described by Cheng et al. [32] consisting of two opaque layers at the bond surface interface and a 12 mm composite rod. The geometry of the chevron shaped bond interface (Fig. 1) was adapted from Tantbirojn et al. [33]. The chevron shaped bonding surface was created by applying a custom-made cutout sticker, peeled off a preprinted sheet of ~50 micron non-stick polymeric transparent PVC film (Grafiprint; Houthalen, Belgium) produced by a commercial printing company, ensuring that each chevron notch shape was exactly the same for each specimen. A precision glass tube, inside diameter of 4 mm, lined with a thin film of petroleum jelly to prevent adhesion, was positioned over the chevron-shaped bonding area and incrementally filled with indirect composite resin. After polymerization, the glass tube was removed.

The specimens were loaded (Fig. 2) 10 mm from the bonded interface at a cross-head speed of 0.5 mm/min in a universal testing machine (Instron, model 3369, Instron Corp. Canton, MA, USA). The load at failure (F_{max}) was recorded using a 1 kN load cell and Istron Bluehill 3 software (Instron Corp. Canton, MA, USA).

Strain energy release rates were calculated using the formula by Cheng et al. [32]

$$G_{Ic}\left(\mathrm{J/m^2}\right) = 104.5(F_{max})^2 L^3/ED^6$$

where F_{max}=Load at failure (N), L=Distance to loading point (mm), E=Elastic modulous of the composite cylinder (dentine

Table 2
YZr specimen preparation process (n=12 per test group) prior to veneering with indirect composite resin.

Material	Sandblasted with 120 μm grit ALO_2, 2 bar pressure.	Bonding agent
Ceramage		
CER1 (Control)	No	No
CER2	No	AZ primer
CER3	Yes	No
CER4	Yes	AZ primer
Signum		
SIG1 (Control)	No	No
SIG2	No	Zirconia bond 1&2
SIG3	Yes	No
SIG4	Yes	Zirconia bond 1&2
Sinfony		
SIN1 (Control)	No	No
SIN2[a]	N/A	N/A
SIN3	Yes	No
SIN4	Yes	Sandblasted again with Rocatec and ESPESil applied

[a] Sinfony incorporates the use of Rocatec (3M ESPE, USA) sandblasting as part of the bonding system. This process is reflected in group SIN4 and therefore no specimens where prepared for this surface treatment option as per CER_2 and SIG_2.

Table 1
List of proprietary indirect composite veneering systems (dentine, opaque and bonding agent) by material type/trade name (including dentine Elastic modulus), lot number, constituents, and reference for constituents and name of manufacturer.

Material/trade name	Lot	Constituents	Reference for constituents	Manufacturer
Zirconia ceramic				
Vita In-Ceram YZ for in lab (*E*-modulus 210 GPa)	35760	91% Zirconium oxide (ZrO_2), 5% yttrium oxide (Y_2O_3), 3% hafnium oxide (HfO_2), small amounts (1%) of aluminum oxide (Al_2O_3) and silicon oxide (SiO_2)	Bottino et al. [26]	VITA Zahnfabrik, Germany
Indirect composite materials				
Ceramage dentine (*E*-modulus 10.7 GPa)	041024	UDMA (Urethane dimethacrylate)	Soancă et al. [27]	Shofu Inc., Kyoto, Japan
Ceramage opaque	100906	UDMA, aluminum silicate, 2-HEMA, glass, pigment, others	Muratomi et al. [28]	Shofu Inc, Kyoto, Japan
AZ Primer (Ceramage)	071213	6-MHPA(6-methacryloxyethyl phosphonoacetate.), acetone, others	Ural et al. [16]	Shofu Inc, Kyoto, Japan
Signum dentine (*E*-modulus 3.5 GPa)	01300	Bis-GMA(2,2′-bis-[4-(methacryloxypropoxy)-phenyl]-propane) and TEGDMA (Tri (ethylene glycol) dimethacrylate)–SiO_2, Ba–Al–Si (1,0 μm) -	Janda et al. [29] Alves et al. [30]	Heraeus Kulzer GmbH, Hanau, Germany
Signum Opaque F	010209	Multifunctional dimethacrylates; Pyrogenic SiO_2 Photoinitiator Camphorquinone; TiO_2, iron oxides	Janda et al. [29]	Heraeus Kulzer GmbH, Hanau, Germany
Zirconia bond I+II	010021	Bond I: Acetone, 10-MDP (10-methacryloyloxy-decyl-dihydrogenphosphate), acetic acid 010106 Bond II: Methyl methacrylate, diphenyl(2,4,6- trimethylbenzoyl) phosphanoxide	Ural et al. [16]	Heraeus Kulzer GmbH, Hanau, Germany
Sinfony dentine (*E*-modulus 3.1 GPa)	449469	Microhybrid composite containing: strontium aluminum borosilicate glass, pyrogenic silica, glass ionomer, a mixture of aliphatic and cycloaliphatic monomers	Alves et al. [30] Özcan et al. [31]	3M ESPE, Minnesota, USA
Sinfony opaque powder	445066	3-(trimethoxysilyl)propyl, titaniumdioxide, calcium fluoride, dilauroylperoxide, 1,1,1-trimethyl-N-(trimethylsilyl), silaneamine, hydrolyzation products with silica, iron oxide	Özcan et al. [31]	3M ESPE, Minnesota, USA
Sinfony opaque liquid	518929	bis(methylene)diacrylate, MMA, vinylchloride–vinylacetate copolymer, trimethylbenzoyl-diphenylposphone oxide	Özcan et al. [31]	3M ESPE, Minnesota, USA
Rocatec	–	Silicatized aluminum oxide particles	Bottino et al. [26] Özcan et al. [31]	3M ESPE, Minnesota, USA
ESPE Sil	495219	3-methacryloxypropyltrimethoxysilane(MPS) in ethanol	Özcan et al. [21]	3M ESPE, Minnesota, USA