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Effect of different surface treatment techniques on the repair strength of indirect composites

B.A.C. Loomans[a,*], M.E. Mesko[b], R.R. Moraes[b], J. Ruben[a], E.M. Bronkhorst[a], T. Pereira-Cenci[b], M.C.D.N.J.M. Huysmans[a]

[a] Radboud university medical center, Radboud Institute for Health Sciences, Department of Dentistry, Nijmegen, The Netherlands
[b] Graduate Program in Dentistry, School of Dentistry, Federal University of Pelotas, Pelotas, Brazil

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ABSTRACT

Objectives: Composite resin restorations present high survival rates and when a failure occurs repair is often possible. The aim of this study was to assess the effect of various repair techniques on indirect restorations.
Methods: LAVA Ultimate (3M), and Clearfil Estenia blocks (Kuraray) were repaired with our without surface roughness treatments, silane application and artificial ageing. Micro-shear bond stress tests were performed, while cohesive strength served as positive control. ANOVA was used for cohesive strength and effect of ageing, and linear mixed models to evaluate the effect of treatment variables on repair strength.
Results: Both materials reacted differently on surface treatments. Untreated (no treatment, no silane) repair strength was 16.3 ± 6.3 MPa for LAVA Ultimate and 19.0 ± 4.3 MPa for Estenia. Thermal cycling resulted in a 14–58% reduction of cohesive strength. Without cycling, all treatments resulted in a significant increase of bond strength in LAVA Ultimate ($p < 0.003$). After cycling use of air-abrasion showed a positive trend for both substrates, significantly effective for LAVA Ultimate ($p < 0.04$), and silane and CoJet for Estenia ($p < 0.024$). The positive effect of HF treatment disappeared after cycling.
Conclusion: It may be concluded that (1) the effect of surface treatment procedures on the repair bond strength of indirect composites is depended on the substrate and ageing. (2) Silane did not have a clear overall positive effect on bond strength and (3) artificial ageing had a strong negative influence on the stability of the adhesive interface and on the cohesive strength of one indirect composite resin material, but not the other.

1. Introduction

Improvements in quality of materials and placement techniques made the clinical application of resin-based composites feasible and predictable even in complex clinical situations such as cusp replacing restorations or rehabilitation of severely worn dentitions [1–6]. Even though the annual survival rates of composites are satisfactory, the restorations may also present failures that can be inherent to the materials, (e.g. material fracture) [7], to the operator (e.g. improper placement technique and individual criteria for failure assessment) [8–10], or to the individual risk factors of the patient (caries risk or bruxism) [11,12]. Overall, secondary caries and fracture are the predominant failure reasons of composite restorations [12]. Repairing failed restorations may be more advantageous and less invasive than replacement [13–15]. However, when repairing a restoration, one must often obtain adhesion to different substrates such as composite resins, metals, ceramics and tooth materials at the same time. Therefore, it is important to understand the possibilities of restoration repair, where only the missing or defect part is replaced [16–18].

Numerous in vitro studies have reported on the effect of different surface treatments on repair strength of composite restorations [19–25]. Unfortunately, no conclusion could be drawn on which (universal) repair technique was the best, as the used materials and methods of all these studies varied strongly. Overall, these studies confirmed a positive role of air abrasion, but still only scarce information of repair on indirect restorations is available.

Therefore, the aim of this in vitro study was to investigate the effect of different surface roughening treatments, silane application and artificial ageing on the repair bond strength of two

* Corresponding author at: Department of Preventive and Restorative Dentistry, Radboud university medical center, P.O. Box 9101, NL 6500 HB Nijmegen, The Netherlands.
E-mail address: bas.loomans@radboudumc.nl (B.A.C. Loomans).

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indirect composite resin-based systems. The hypotheses of this study were: (i) different surface treatment techniques will result in different repair strengths, (ii) application of a separate silane layer will enhance the repair strength and (iii) artificial ageing will decrease the stability of the repair adhesive interface.

2. Materials and methods

2.1. Production of samples

To obtain standardized samples of indirect composite resin, industrial pre-polymerized blocks of LAVA Ultimate for CAD-CAM use (color A3-LT, 3M ESPE Dental Products, St. Paul, Minnesota, USA) were cut with a diamond blade (Buehler Ltd., Lake Bluff, IL, USA) of 0.4 mm thick, resulting in 96 cubical samples of 6 × 6 mm in width and 4 mm in height. Additionally, using a custom Teflon mold, 96 similar sized cubical samples were obtained of Clearfil Estenia C&B (color DA3, Kuraray, Okayama, Japan). This composite was applied in two layers of 2 mm thick and each layer was separately photocured for 20 s with a Bluephase 16i LED polymerization unit (Ivoclar Vivadent, Liechtenstein; light intensity >1200 mW/cm^2), then blocks were complementary cured with Palatray CU (wavelength 400–500 nm; Heraeus Kulzer, Hanau, Germany) for 12 min. Finally, samples were covered with glycerin-based Air Barrier paste (Kuraray) and exposed to thermal curing in a heat curing oven (Multimat Mach 3, Dentsply De Trey, Hanau-Wolfgang, Germany) at 110 °C for 15 min according to the manufacturers' instruction. All blocks of LAVA Ultimate and Clearfil Estenia were immersed in 70% ethanol for 5 min for cleaning and then air-dried. To obtain a standardized surface roughness, similar to a rough dental diamond bur, samples were grinded by hand for 10 s with a dry 150-grit silicon carbide grinding paper (Siawat, Frauenfeld, Switzerland). Finally, samples were cleaned ultrasonically for 15 min in distilled water and stored dry at room temperature.

2.2. Surface treatment procedure and groups of treatment

Samples of LAVA Ultimate and Clearfil Estenia were assigned to six surface treatment protocols (n = 16): (1) no treatment, serving as negative control, (2) air-abrasion with CoJet (30 μm Al_2O_3-particles coated with SiO_2, 3M ESPE) for 10 s at a distance of 10 mm in a circular motion with a pressure of 3 bar (MicroEtcher II, Danville Materials, San Ramon, CA, USA), (3) air-abrasion with SilJet (30 μm Al_2O_3-particles coated with SiO_2, Danville Materials) with the identical procedure, (4) air-abrasion with SilJet Plus (silanized silica-coated 30 μm Al_2O_3-particles, Danville Materials) with the identical procedure, (5) air-abrasion with Aluminum Oxide particles (50 μm, Rønvig Dental, Daugaard, Denmark) with the identical procedure and (6) etching with hydrofluoric acid (Porcelain Etch Gel, 9.6% (Pulpdent Co., Watertown, MA, USA)) for 10 s. All materials used in this study are listed in Table 1. After the surface treatment, all blocks were assigned into different subgroups, identified with a waterproof mark and stored dry at 37 °C (Fig. 1a).

2.3. Repair procedure

Half the number of samples per group (n = 8) received a separate silane application (Relyx Ceramic Primer, 3M ESPE) before application of adhesive resin Scotchbond Multipurpose (3M ESPE) without using the primer. The other half of the samples (n = 8) was only treated with adhesive resin without silane. The adhesive was gently air-dried and photopolymerized for 10 s using the LED-polymerization unit (Fig. 1b and c). Using a silicone mold, 'fresh' direct composite resin (Filtek Supreme XTE, color A1D, 3M ESPE) was placed in 2 layers of 2 mm thick and each layer was

Table 1
Materials used in this study.

Materials	Category	Manufacturer	Origin	Lot code(s)	Composition
LAVA Ultimate CAD/CAM Restorative	indirect resin composite	3M ESPE	St. Paul, USA	N490227 A3-LT Shade	Hybrid composite with nanoceramic compounds (ZrO_2/SiO_2 nanoparticles) embedded in highly cross-linked polymer matrix
Estenia C&B	Indirect resin composite	Kuraray Noritake Dental Inc.	Okayama, Japan	Lot n. BS0007; DA3 Shade	UTMA, aromatic dimethacrylate, aliphatic dimethacrylate, di-comphorquinone. Alumina microfiller, silanized glass filler, pigments, 92% colloidal silica spheres, 16 wt% microfillers, grain size 0.02 μm, 76% wt microfillers, grain size 2 μm
Air-barrier paste	Insulating	Kuraray Noritake Dental Inc.	Okayama, Japan	6A0001	Glycerin paste
CoJet Sand	Air abrasion	3M ESPE	Seefeld, Germany	520953	30 μm Al_2O_3 particles coated with SiO_2
Siljet	Air abrasion	Danville Materials	San Ramon, USA	31624	30 μm Al_2O_3 particles coated with SiO_2
Siljet Plus	Air abrasion	Danville Materials	San Ramon, USA	116-168B	Pre-silanized 30 μm Al_2O_3 particles coated with SiO_2
Aluminium oxide	Air abrasion	Rønvig Dental	Daugaard, Denmark	Not informed	50 μm Al_2O_3
Porcelain etch gel	Etchant	Pulpdent Co.	Watertown, USA	100825	Hydrofluoric (3 ppm) 9.6%
RelyX Ceramic primer	Silane	3M ESPE	St. Paul, USA	N417664	Silane stabilized alcohol solution
Adper Scotchbond Multipurpose Plus	Adhesive (bonding)	3M ESPE	St. Paul, USA	N421442	Bis-GMA, HEMA, tertiary amines (light-cure and self-cure initiators), photo-initiator
Filtek Supreme XTE	Nanofiller resin composite	3M ESPE	St. Paul, USA	N272867; N433402; N437301; N4522993; A1D Shade	Combination of aggregated ZrO_2/SiO_2 cluster filler with primary particle size and a SiO_2 filler (nano agglomerated/nano aggregated), BisGMA, Bis-EMA, UDMA, TEGDMA, hydrophilic dimethacrylate, di-camphorquinone, *N*,*N*-Diethanol-*p*-toluidine, water

Al_2O_3 (aluminum trioxide); Bis-GMA (bisphenolA glycidyl dimetacrylate); Bis-EMA (bisphenol-A ethoxylated dimethacrylate); HEMA (2-hydroxyethyl methacrylate); SiO_2 (silicon dioxide); TEGDMA (triethyleneglycol dimethacrylate); UDMA (urethane dimethacrylate); UTMA (urethanetetramethacrylate); ZrO_2 (zirconium dioxide).