Advances in adhesive dentistry have increased the use of indirect restorations. They are indicated for extensive cavities because the anatomic form, proximal contacts, and interproximal contour are more easily and accurately obtained than with direct composite resin restorations. Moreover, indirect restorations are less prone to fracture and ensure a better seal because the impact of polymerization shrinkage on adhesion is insignificant.

Several properties of indirect composite resins have contributed to their selection by practitioners over ceramic materials. Composite resins induce less wear of the opposing tooth and are easier to repair intraorally. Moreover, better marginal quality has been reported, as well as greater fatigue resistance and fracture resistance, especially before the luting procedure. However, the additional polymerization of indirect composite resins, that enhances their physical and mechanical properties, also lessens their potential for chemical bonding because the...
Clinical Implications

Treating the surfaces of indirect composite resin onlays with airborne-particle abrasion with alumina or silica-coated alumina particles followed by Scotchbond Universal application produces the greatest bond strength after 6 months of artificial aging.

quantity of residual free carbon double bonds decreases.16

Several surface treatments have been proposed to increase composite resin roughness to provide mechanical interlocking of the adhesive15,17-27 and to increase the number of unreacted methacrylate groups in the larger surface area created.28 Specifically, airborne-particle abrasion with alumina has been shown to improve bond strength to repaired composite resin29-32 and to indirect composite resin restorations.20,33 Also, tribochemical silica coating has achieved promising results as it provides a silica deposit on the composite resin surface together with micromechanical retention.34 This silica-modified surface is reactive to silane coupling agents that also react with the methacrylate groups of the adhesive resins.30-32,35 Nevertheless, when both airborne-particle abrasion treatments have been compared, the results are controversial and the advantage of these chemical interactions has not been clearly demonstrated.29,31,36 Moreover, the benefit of silane agents application, alone or followed by a bonding agent, to indirect composite resins is not completely clear5,31,37 and would imply additional clinical steps.

Recently, a new family of dental adhesives known as “universal” or “multimode” adhesive systems has been introduced. These adhesives can be applied either with the etch-and-rinse or the self-etch technique.38-41 In the case of Scotchbond Universal (3M ESPE), it contains silane in order to allow the luting of indirect restorations with fewer clinical steps.42,43

The purpose of this in vitro study was to evaluate the influence of different surface treatments, including alumina airborne-particle abrasion and tribochemical silica coating combined with an adhesive application, preceded or not by a silane coupling agent, or using a universal adhesive, on the microtensile bond strength (μTBS) of composite resin onlays after 24 hours and 6 months of artificial aging. The effect of such treatments on composite resin roughness and morphology was also determined. The null hypothesis was that the bond strength of indirect composite resins would not be influenced by the intaglio surface treatment or by 6 months of water storage.

MATERIAL AND METHODS

The composition and application technique of the materials tested are listed in Table 1. All were used according to the manufacturers’ instructions.

Two-mm thick increments of a microhybrid composite resin (Filtek Z250, A3 shade; 3M ESPE) were layered into a Teflon mold (8 mm diameter × 4 mm high) to obtain composite resin onlays (n=36). Each increment was then photopolymerized for 40 seconds (Elipar S10; 3M ESPE, output of 1200 mW/cm²). The specimens were removed from the mold and polymerized in a unit (Lumamat 100; Ivoclar Vivadent AG) with program 3 at 104°C and high light intensity for 25 minutes. The surfaces to be bonded were wet ground on a polishing machine (Beta; Buehler) using 600 grit SiC abrasive papers and then ultrasonically cleaned for 10 minutes in distilled water and air-dried. After 24 hours of dry storage, the composite resin onlays randomly received 1 of the 6 treatments listed in Table 2. Software (Excel; Microsoft Corp) was used to generate random numbers from 1 to 6, according to the experimental treatment, that were assigned to each composite resin onlay.

Thirty-six additional fresh composite resin cylinders (Filtek Z250, Shade A1; 3M ESPE) (8 mm in diameter and 4 mm high) were luted to the pretreated substrates with resin cement (RelyX Ultimate, Shade A1; 3M ESPE). Each composite resin specimen was cemented maintaining a constant force of 9.8 N during the first 5 minutes to standardize the luting agent thickness.44 Photopolymerization was carried out with the same polymerization unit for 20 seconds buccally, 20 seconds lingually, and thereafter for 40 seconds from the occlusal surface.

Specimens were randomly distributed using the Excel software program, according to the storage period, 24 hours or 6 months, and, in both cases, kept at 37°C and 100% relative humidity until μTBS testing. The bonded assemblies were sectioned perpendicularly to the adhesive interface in the x and y directions (IsoMet 5000; Buehler), and beams with a cross-sectional area of approximately 1 mm² were obtained. The exact dimensions of the beams were determined with a digital caliper (Mitutoyo Corp). Specimens were glued (Loctite Super Glue-3 gel; Henkel) to the fixtures of a universal testing machine (Instron 3345; Instron Co) and stressed at a tensile load of 0.5 mm/min until failure. The bond strength values were calculated in megapascals (MPa).

A single operator (I.G.-G.) determined the failure modes using a stereomicroscope (Olympus SZX7; Olympus Corp) at ×40 magnification to classify them as cohesive (in cement, in fresh composite resin, or in composite resin onlay); adhesive (between cement and fresh composite resin, composite resin onlay and cement, or both); or mixed (simultaneous adhesive and cohesive fractures). The percentage for each failure mode was then
calculated. After tensile testing, specimens with representative fracture patterns of each group were selected and also observed under a scanning electron microscope (XL30 ESEM; Philips) after gold sputter-coating (SCD).

Additional composite resin specimens (n=6) were prepared to determine the surface roughness and topographic changes induced by the following surface treatments: polishing with 600 grit SiC papers; airborne-particle abrasion with 27 μm alumina particles (RONDOflex; Kavo); and tribochemical silica coating with 30 μm particles (CoJet Sand). The surface roughness was determined by the parameter average roughness (Ra). Five successive measurements in different directions were made on each treated specimen with a contact profilometer (Mitutoyo Surf test SJ 301; Mitutoyo); the cutoff value for surface roughness was 0.8 mm, and the sampling length for each measurement was 2.4 mm.

Another 3 specimens corresponding to the surface treatments described earlier were sputter-coated with gold and observed under the same scanning electron microscope. Also, 10 quantitative elemental analyses were carried out per specimen using energy-dispersive x-ray spectroscopy (EDS) (XL-30; EDAX) at ×5000 magnification.

A 2-way ANOVA was performed to analyze the effect of the composite resin surface treatment and the aging period on the μTBS of luted onlays. Multiple comparisons were evaluated using the Tukey-Kramer test. The Student t test was applied to compare the μTBS values before and after aging for each surface treatment. The Ra was analyzed by 1-way ANOVA and the Tukey test. All statistical tests were performed with software (IBM SPSS v19; IBM Corp) (α=.05).

**RESULTS**

The means and standard deviations of the μTBS values yielded for each experimental group are summarized in **Table 3**. The 2-way ANOVA revealed that bond strength values were significantly influenced by the intaglio surface treatment (P<.001), the aging period (P<.001), and the interaction between these factors (P<.001).

Post hoc comparisons among the experimental groups showed that 24 hours after the luting procedure, airborne-particle abrasion with alumina particles followed by Adper Scotchbond 1XT or Scotchbond Universal adhesive application yielded the highest μTBS mean values. However, the lowest results were obtained

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**Table 1. Chemical composition and application technique of tested materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Chemical Composition</th>
<th>Application Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adper Scotchbond 1XT Adhesive (3M ESPE)</td>
<td>Bis-GMA, HEMA, dimethacrylate resins, ethanol, water, photoinitiator, 5 nm spherical silica particles, methacrylate copolymer of polyacrylic and polyitaconic acids</td>
<td>Apply adhesive for 20 seconds with vigorous agitation. Gently air-thin for 5 seconds. Photopolymerize for 20 seconds.</td>
</tr>
<tr>
<td>Scotchbond Universal Adhesive (3M ESPE)</td>
<td>MDP monomer, dimethacrylate resins, HEMA, Vitrrebond copolymer (3M ESPE), filler, ethanol, water, initiators, silane</td>
<td>Apply adhesive for 20 seconds with vigorous agitation. Gently air-thin for 5 seconds. Photopolymerize for 20 seconds.</td>
</tr>
<tr>
<td>ESPE Sil (3M ESPE)</td>
<td>3-methacryloxypropylmethoxysilane, ethyl alcohol, methyl ethyl ketone</td>
<td>Apply and allow volatile silane solution to dry for 5 minutes</td>
</tr>
<tr>
<td>Filtek Z250 Shade: A3, A1 (3M ESPE)</td>
<td>Organic matrix: Bis-GMA, UDMA, Bis-EMA, TEGDMA. Filler: 60% in volume (range of 0.19-3.3 μm) zirconia and silica</td>
<td>Photopolymerize for 40 seconds</td>
</tr>
<tr>
<td>ReliaX Ultimate (3M ESPE)</td>
<td>Base paste: methacrylate monomers, radiopaque, silanated fillers, initiator components, stabilizers, rheologic additives Catalyst paste: methacrylate monomers, radiopaque alkaline (basic) fillers, initiator components, stabilizers, pigments, rheologic additives, fluorescence dye, dark polymerization activator Scotchbond Universal adhesive</td>
<td>Automix cement Photopolymerize for 80 seconds</td>
</tr>
</tbody>
</table>

**Table 2. Experimental treatments**

<table>
<thead>
<tr>
<th>Surface Treatment</th>
<th>Application Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al2O3+1XT</td>
<td>Airborne-particle abrasion with an intraoral device (RONDOflex Plus 360; Kavo) filled with 27 μm alumina particles (RONDOflex; Kavo) for 10 seconds at a pressure of 0.25 MPa from a distance of 10 mm. Following surface conditioning, they were rinsed copiously with water and dried with air. Adper Scotchbond 1XT adhesive (3M ESPE) was applied and photopolymerized for 20 seconds with the same LED unit.</td>
</tr>
<tr>
<td>Al2O3+Si+1XT</td>
<td>Airborne-particle abrasion was performed as described for the preceding group and a silane agent (ESPE Sil; 3M ESPE) was applied and left undisturbed for 5 minutes. Adper Scotchbond 1XT adhesive was applied and photopolymerized.</td>
</tr>
<tr>
<td>Al2O3+Universal</td>
<td>Specimens were airborne-particle abraded as described earlier followed by Scotchbond Universal adhesive application according to manufacturer’s instructions. Subsequently, the solvent was gently evaporated and photopolymerized for 20 seconds.</td>
</tr>
<tr>
<td>Silica+1XT</td>
<td>Tribochemical silica coating with 30 μm particles (CoJet Sand; 3M ESPE) using the parameters described for the Al2O3+1XT group, followed by Adper Scotchbond 1XT adhesive application.</td>
</tr>
<tr>
<td>Silica+Si+1XT</td>
<td>Tribochemical silica coating, followed by the same silane agent and Adper Scotchbond 1XT adhesive application.</td>
</tr>
<tr>
<td>Silica+Universal</td>
<td>Tribochemical silica coating, followed by Scotchbond Universal adhesive application.</td>
</tr>
</tbody>
</table>
for specimens subjected to tribochemical silica coating and Scotchbond Universal application.

After 6 months of water storage, the highest bond strength values corresponded to those of specimens airborne-particle abraded with alumina particles before Scotchbond Universal adhesive application, followed by composite resins treated with silica coating and the use of the same adhesive.

The Student t test showed significant differences in the $\mu$TBS after 24 hours and 6 months of aging for all the experimental groups, except for specimens treated with Scotchbond Universal after airborne-particle abrasion, regardless of the powder selected.

No failures occurred before testing for any of the experimental groups evaluated. The failure mode distribution observed for the different experimental groups is shown in Figure 1. After 24-hour storage, failures were primarily cohesive in resin cement, as can be seen in Figure 2A, followed by mixed failures. However, after 6 months of artificial aging, mixed failure was the predominant type for all the experimental groups (Fig. 2B), except for specimens treated with Scotchbond Universal adhesive, which for the most part, showed cohesive failures in the cement (Fig. 2C).

One-way ANOVA showed that surface roughness was statistically different for the 3 treatments tested ($P<0.001$). The ranking of the surface roughness values (Ra, $\mu$m) from the lowest to the highest was as follows: 600-grit SiC paper polishing (0.21 $\pm$0.77) < tribochemical silica coating (0.65 $\pm$0.09) < alumina airborne-particle abrasion (1.70 $\pm$0.6).

The effect of the 600 grit SiC paper polishing and airborne-particle abrasion either with 27 $\mu$m alumina powder or 30 $\mu$m silica-coated alumina particles on the composite resin topography is shown in Figure 3. As shown in Figure 3A, the polishing procedure produced scratches in the same direction. In contrast, airborne-particle abrasion with alumina or silica-coated alumina powder significantly altered the composite resin surface creating undercuts, grooves and edge-shaped microretentions (Fig. 3B, C). However, these modifications were slightly more irregular and noticeable after airborne-particle abrasion with alumina (Fig. 3B).

EDS microanalysis showed an identical element distribution on composite resin surfaces airborne-particle abraded with alumina or CoJet Sand, with 30% of Zr and with 34% of Si. For composite resin surfaces polished with SiC paper, the composition was essentially the same, 31% Zr and 35% Si.

**DISCUSSION**

The present study examined the effect of 6 surface treatments of an indirect composite resin on its adhesive properties when luted to a direct one by means of a resin cement and on stability after 6 months of artificial aging. According to the results, the null hypothesis

<table>
<thead>
<tr>
<th>Surface Treatment</th>
<th>24 hours $\mu$TBS</th>
<th>6 months $\mu$TBS</th>
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<tbody>
<tr>
<td>Al$_2$O$_3$+1XT</td>
<td>98 (18)* A</td>
<td>36 52.8 (12.9)* C</td>
</tr>
<tr>
<td>Al$_2$O$_3$+Si+1XT</td>
<td>76.9 (19.9)* BC</td>
<td>52 54.6 (16.2)* C</td>
</tr>
<tr>
<td>Al$_2$O$_3$+Universal</td>
<td>97.5 (18.9) A</td>
<td>45 91 (19.15) A</td>
</tr>
<tr>
<td>Silica+1XT</td>
<td>74.3 (13.5)* BC</td>
<td>46 55.7 (20.5)* C</td>
</tr>
<tr>
<td>Silica+Si+1XT</td>
<td>83.3 (15.6)* B</td>
<td>44 68.3 (24.8)* B</td>
</tr>
<tr>
<td>Silica+Universal</td>
<td>71.2 (18.3) C</td>
<td>64 76.6 (15.8) b</td>
</tr>
</tbody>
</table>

$n$, number of microbars tested. Different letters indicate statistically different $\mu$TBS values among groups ($P<0.05$) for each evaluation period (24 hours or 6 months). *Statistical differences between $\mu$TBS results after 24 hours and 6 months of water storage.

**Table 3. Mean $\mu$TBS values in MPa (standard deviation) to different treated indirect composite resins after 24 hours and 6 months of water storage**
was rejected as the composite resin surface conditioning and the aging period did affect bond strength results.

Figure 2. Representative micrographs of debonded composite resin surfaces (original magnification ×150). A, Large area of cement layer from specimen airborne-particle abraded with alumina particles before Adper Scotchbond 1XT application and fractured after 24 hours. B, Cement remnants layering on composite resin surface from specimen treated by tribochemical silica coating before Adper Scotchbond 1XT application and fractured after 6 months of aging. C, Large cement layer from experimental group in which composite resin onlay was silica coated before Scotchbond Universal adhesive application and fractured after 6 months of aging.

Figure 3. Scanning electron micrographs of treated resin composite resin surfaces (original magnification ×1000). A, Polished with 600 grit SiC papers. B, Airborne-particle abraded with 27 μm alumina particles. C, Tribochemical silica coating with 30 μm particles (CoJet Sand).

After 24 hours of water storage, airborne-particle abrasion with alumina particles followed by the application of Adper Scotchbond 1XT or Scotchbond Universal adhesives was the surface treatment that provided the highest μTBS mean values. Other authors have previously reported the effectiveness of this surface treatment as it creates micromechanical...
retentions and increases the wettability of the adhesive.14,21,31,33

Curiously, tribochemical silica-coated composite resins displayed lower μTBS mean values, although both powders were selected with a similar particle size (27 μm for alumina and 30 μm for silica-coated alumina), because a more relevant influence on bond strength has been attributed to different particle sizes than to their different chemical composition.29 Accordingly, micro-roughness results were significantly lower for tribochemical silica-coated composite resins than for airborne-particle abraded alumina, and, as shown in Figure 3, tribochemical silica coating produced a less uneven surface.29-31 Moreover, no differences in composite resin composition were detected between airborne-particle abrasion with alumina or silica-coated alumina powders29 by EDS analysis.

Therefore, the microretentive pattern created by the surface treatment would have a main function on composite resin bond strength at 24 hours after luting. Previous studies have reported similar bond strength values for both airborne-particle abrasion techniques,29-31,36 without any advantage for tribochemical silica-coating followed or not by a silane coupling agent application.30,31 Moreover, in a clinical situation, with the presence of enamel and/or dentin, silica coating may adversely affect composite resin bond strength22 or marginal quality.21 However, in the present study, the presence of natural tooth tissues was avoided as onlay composite resins were luted to fresh composite resin in order to detect the effect of the different surface treatments without the interference of microstructural variations of natural dental tissues.1 Furthermore, in a clinical situation the adhesive substrate is mainly composite resin, in that it is usually used as a base or liner underneath inlay and onlay preparations to avoid unnecessary tissue sacrifice to accommodate the geometric restrictions of indirect restorations and functions as pulpal protection during the interim restoration phase.2,3,46

The adhesive interfaces established during indirect composite resin luting should remain stable over time,5,34 although in most studies the specimens are tested shortly after the luting procedure.5,18,20 In the present study, the effect of the surface treatments tested on bond strength was evaluated not only after 24 hours but also after 6 months of water storage. This storage time was chosen as it is the one commonly used to analyze the degradation of resin dentin bonds.39-41 Moreover, specimens were not sectioned before their storage to simulate a clinical situation in which the inner part of the restoration is protected by the external one and to follow the methodology previously used.23

According to the results obtained, a significant decrease in bond strength values was registered after the aging procedure24,25 for all experimental treatments, except for specimens in which Scotchbond Universal adhesive was applied after alumina or silica-coated airborne-particle abrasion. Several studies have also reported a tendency for lower bond strength after an aging procedure,25 while other authors find adhesive interfaces stable for different evaluation periods.22,26

The better performance detected for composite resins treated with the universal adhesive is supported by previous studies that have found that the adhesive system used is a main influence on the composite resin bond strength after an aging procedure.17,22,26 In agreement with our results, Tantbirojn et al27 reported that the application of Scotchbond Universal adhesive to repair freshly polymerized or aged composite resin restored the cohesive strength of the original monolithic composite resin, unlike Adper Single Bond Plus.

The hydrophilicity of the adhesives has been suggested as a reason for interface degradation due to water absorption over time.47,48 A possible explanation for the stability of specimens treated with Scotchbond Universal could be the incorporation of 10-MDP monomer in its formulation. This functional self-etching monomer is considered hydrophobic and relatively hydrolytically stable, keeping water at a distance.48 It is also present in Clearfil SE Bond adhesive (Kuraray), which exhibited higher repair bond strength of composite resin than other adhesives such as AdheSE One F (Ivoclar Vivadent AG) and Adper Scotchbond Multi-Purpose (3M ESPE) after 1 and 12 months of storage.26 The 10-MDP molecule also has the ability to react with zirconia49 to obtain aging resistant adhesion.50 According to EDS microanalyses of the composite resin used, Filtek Z250, around a 30% of Zr a 32% of Zr was detected, regardless of the surface treatment performed (alumina or silica-coated alumina airborne-particle abrasion), which could allow a chemical interaction between them. Moreover, RelyX Ultimate resin cement incorporates a dark polymerization activator for Scotchbond Universal adhesive in the catalyst paste that may have contributed to its better performance; this would be especially true after aging as this dual polymerization has been described as slower.51,52

Regarding the effect of silane application on composite resin luting, no clear benefit was detected in the present study as previously reported.20,31,37,44 Specifically, a significant decrease in bond strength was observed after 6 months of water storage when it was included as a separate step, possibly related to the high hydrophilicity of silane coupling agents.52

Finally, no failures occurred before testing for any of the experimental groups evaluated, revealing a high μTBS of the luted indirect composite resins.36 Regarding the type of failure, higher numbers of cohesive fractures were observed in groups with higher bond strength.
values, which is in agreement with observations of Eliasson et al. For specimens tested 24 hours after the luting procedure, cohesive failure in resin cement predominated for all groups. This indicated that the bond strength after surface treatments approaches the fracture strength of the resin cement evaluated. However, specimens after 6 months of water aging exhibited more mixed failures (predominantly between cement and composite resin onlay), which is compatible with a higher hydrolytic degradation in the adhesive interface, except in specimens treated with Scotchbond Universal, which mostly showed cohesive failures in cement.

**CONCLUSIONS**

Within the limitations of this in vitro study, airborne-particle abrasion with alumina followed by Adper Scotchbond 1XT or Scotchbond Universal adhesive application obtained higher adhesive strength values after 24 hours of water storage. However, the selection of the adhesive acquires relevance after 6 months of water aging as airborne-particle abrasion with alumina particles, silica-coated or not, followed by Scotchbond Universal adhesive provided the highest bond strength values and better aging stability.

**REFERENCES**

8. Da Costa TR, Ferreira SQ, Klein-Junior CA, Logueiro AD, Resi AA. Durability of resin cement evaluated. However, the selection of the adhesive acquires relevance after 6 months of water aging as airborne-particle abrasion with alumina particles, silica-coated or not, followed by Scotchbond Universal adhesive provided the highest bond strength values and better aging stability.

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The concept of platform switching to preserve peri-implant bone level: Assessment of methodologic quality of systematic reviews

Monje A, Pommer B

Purpose. To assess the methodologic quality of systematic reviews on the effect of platform switching upon peri-implant marginal bone loss.

Materials and Methods. An electronic literature search of several databases was conducted by two reviewers. Articles were considered for quality assessment if they met the following inclusion criterion: systematic reviews that aimed at investigating the effect of platform switching/mismatch on marginal bone levels around dental implants. Two independent examiners evaluated the review publications using two quality-ranking scales (assessment of multiple systematic reviews [AMSTAR] and Glenny checklist). Descriptive statistics were used to summarize the results, and Cohen’s kappa coefficients were calculated to appraise interrater agreement of each checklist.

Results. Overall, five systematic reviews (including three of them with meta-analysis) were evaluated. The mean AMSTAR score ± standard deviation was 8.4 ± 2.6 (range, 4 to 11), and the mean Glenny score was 10.8 ± 2.9 (range, 6 to 14), showing high statistical correlation (rs = 0.98, P = .005). Cohen interexaminer test yielded values of $\kappa = 0.88$ and $\kappa = 0.86$ for the AMSTAR and Glenny checklist, respectively. The AMSTAR items rated positive in 78%, whereas 18% met the criteria for “no” and 4% were “not applicable.” Only one review article met all criteria. Items of the Glenny checklist rated positive in 73% and negative in 27%. All but one study with the lowest quality scores (finding no difference) demonstrated a clinical benefit of implant platform switching in preserving the peri-implant marginal bone loss.

Conclusion. According to the quality-ranking scales appraised, substantial methodologic variability was found in systematic assessment of benefits with the platform switching concept to preserve peri-implant bone level. High-quality systematic reviews, however, generally favored platform switching over platform matching.