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Efficiency of different repair kits on bonding to aged dental resin composite substrates

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ABSTRACT

Objective: To assess the efficiency of intraoral repair kits on the tensile bond strength (TBS) of resin composites (RCs) to aged RC substrates.
Methods: 840 aged (six months, 37 °C, distilled water) RC substrates (Tetric EvoCeram) were air-abraded (CoJet) with and without following phosphoric acid contamination or treated with silicon carbide (SiC) grinding paper. Seven repair kits were used as intermediate agents (Embrace First-Coat, CLEARFIL CERAMIC PRIMER, Tokuso Ceramic Primer, Monobond Plus+Heliobond; Scotchbond Universal, One Coat Bond and visio.link) for conditioning. Specimens were repaired using two direct RCs (Clearfil Majesty ES2 and Clearfil Majesty Posterior), stored in distilled water (37 °C, 24 h) and thermal aged (5 °C/55 °C, 10,000 cycles). The cohesive strength of the repair RCs ($N=40$) served as control and was determined by applying the RCs on the fresh polymerized substrates, followed by thermal-aging procedure. TBS and failure types were determined and evaluated with three-/one-way ANOVA, and chi-square test ($p<0.05$).
Results: The highest influence on the TBS was exerted by the intermediate agent (repair kit) (partial eta squared $\eta_P^2=0.320$, $p<0.001$), while the impacts of the repair RC ($\eta_P^2=0.017$, $p<0.001$) and surface pre-treatment ($\eta_P^2=0.015$, $p=0.003$) were significant but low. Except for Embrace First Coat and Tokuso Ceramic Primer, phosphoric acid contamination after air-abrasion maintains the TBS.
Conclusions: Air-abrasion induced superior TBS compared with grinding the surface with SiC paper prior to repair. Tested universal adhesives as well as the combination between a universal primer and an adhesive were in-vitro efficient intermediate agents for repairing aged RCs.

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1. Introduction

Recent systematical reviews on the longevity of posterior resin composite (RC) restorations confirm that secondary caries and fracture are typically failures that appear after a longer time of service [1]. Restoration repair rather than replacement is a valuable treatment modality [2] that is in agreement with the concepts of minimal invasive dentistry [3] which is taught in most universities [4]. Restoration repair is more economical to the patient in terms of treatment time-saving and reduces tooth structure loss to the bur [5] compared with replacement and the fabrication of new restorations. In-vivo studies have also shown that restoration repair results in a higher survival probability than restorations replacement [6].

In repairing RC restorations, the surface pre-treatment and the intermediate agent were proved to be significant factors of influence on the repair bond strength [4]. However, it is not compulsory to combine identical RCs in terms of repair [7,8]. Particularly challenging, but of high clinical relevance, is the repair of aged RC substrates. In-vitro studies generally indicate inferior repair bond strength of aged RC substrates compared with the cohesive strength of the original RCs [9,10], a fact attributed to the increased water sorption and saturation of the aged material.

The clinical procedure for repairing resin restoration usually implies a surface pre-treatment method to create mechanical retention by means of roughening with diamond burrs, or air-abrasion of the surface, followed by cleaning the surface with phosphoric acid and the use of silane and adhesives as intermediate agents previously to bonding to RC [4,11]. Different universal repair kits are available on the market, questioning their efficiency in repairing RC restorations as well. Moreover, universal adhesive systems were recently launched on the market, with fewer steps and less chances of error in the application process. Their chemical

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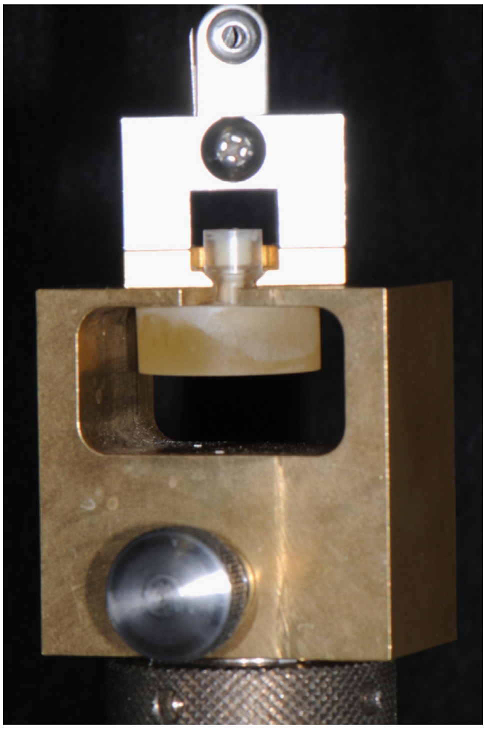

Fig. 1. Design of the tensile strength test.

composition includes - in addition to methacrylic monomers - silane or phosphate monomers, allowing them to prime metal, silica-based ceramics, and zirconia restorations.

The aim of this study was therefore to analyze the efficiency of repairing aged RC substrates by using different surface pre-treatment and conditioning methods and different RCs as repair material. Since a contamination of the air-abraded surface with phosphoric acid might occur clinically during a restoration procedure, the study aims to simulate these conditions and to determine their impact on repair efficiency.

The null-hypotheses tested were that (1) the pre-treatment method (air-abrasion, air-abrasion with phosphoric acid contamination and grinding with silicon carbide [SiC]-paper); (2) the conditioning method (comprising of seven different repair kits); and (3) the repair RC shows no impact on the tensile bond strength (TBS) to aged RC substrates. Fig. 1

2. Material and methods

This study analyzed the TBS of aged RC substrates (Tetric Evo Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) in combination with different methods of conditioning for repair with two different RCs (CLEARFIL MAJESTY ES 2 and CLEARFIL MAJESTY Posterior, Kuraray, Japan). The compositions and batch number of all tested materials are shown in Table 1.

2.1. Specimen preparation

A total of 840 substrates were prepared by filling the composite with a plastic filling instrument into a shaped cavity (2 mm in depth, 6 mm in diameter) of an acrylic cylinder (ScandiQuick, ScanDia, Hagen, Germany; Lot.No: 542125/142125) surrounded by a stainless steel cylinder. The specimens were cured with the LED-curing device Elipar S10 (3 M ESPE, Seefeld, Germany) for 20 s with a light intensity of 1,200 mW/cm^2. Surfaces were polished during water-cooling with a series of SiC papers up to SiC P2400 (Tegramin-20, Struers). Thereafter, all polished surfaces were aged for six months in distilled water at 37 °C while the storage media was changed weekly.

The specimens were then randomly divided into three pre-treatment methods (n=280): (1) CoJet air-abrasion (3 M ESPE), (2) CoJet air-abrasion followed by phosphoric acid contamination and (3) grinding with SiC paper (Gritt 400, LECO). For air-abrasion with CoJet, silicatized sand (30 μm, Lot.No. 516365) was applied for 10 s at a distance of 10 mm from the specimen's surface and a pressure of three bars. Thereafter, specimens were cleaned with distilled water for 30 s. The phosphoric acid (34%, 3 M ESPE, Seefeld, Germany, Lot.No. 520594) contamination was simulated by acid application for 30 s followed by cleaning with distilled water for 30 s.

Thereafter, the specimens were randomly divided into seven main groups for different conditioning methods (n=40), as follows: (1) Embrace First Coat, (2) CLEARFIL CERAMIC PRIMER, (3) Tokuso Ceramic Primer included in the Bistite II DC kit, (4) Ceramic Repair System Kit: Monobond Plus+Heliobond, (5) Scotchbond Universal, (6) One Coat Bond; and 7) visio.link.

The application steps are described in Table 1. Subsequently, the conditioned specimens were repaired using two different RCs (CLEARFIL MAJESTY ES 2 and CLEARFIL MAJESTY Posterior, n=20 per RC). The specimens were positioned into a holding device and an acrylic cylinder (SD Mechatronik, Feldkirchen-Westerham, Germany) with an inner diameter of 2.9 mm and a height of 4.5 mm for repairing, which was fixed on the conditioned RC surface, filled with RC and axially loaded with 100 g. Light polymerization was performed with the same LED-curing device as the substrates, with three sequences of 20 s each, by applying the curing unit perpendicular directly onto the acrylic cylinder from three directions. Subsequently, the specimens were stored for 24 h at 37 °C in distilled water to allow for post-polymerization and then additionally aged for 10,000 thermal cycles between 5 °C and 55 °C with a dwelling time of 20 s (Thermocycler THE-1100, SD Mechatronik). The cohesive strength of the three RCs was used as control. Therefore, substrates were prepared as described above in a shaped cavity (2 mm in depth, 6 mm in diameter) of an acrylic cylinder, followed by an immediate (directly after polymerization) application of the same repair material. Specimens were thereafter stored and aged as the repaired specimens.

2.2. Tensile bond strength measurement

The Universal Testing Machine (MCE 2000 ST, Quicktest, Langenfeld, Germany) was used for tensile strength measurements by positioning the specimens in a special device that provided a moment-free axial force application. A collet held the acrylic cylinder, while an alignment jig allowed for the self-centering of the specimen. The device was attached to the load cell and pulled apart by the upper and lower chain, allowing the whole system to be self-aligned. The specimens were loaded at a crosshead speed of 5 mm/min until debonding of the cylinders occurred. Values were recorded at the time of the debonding of the cylinders. Bond strengths were expressed by dividing the force by the bonded surface area.

2.3. Fracture analysis

The fracture pattern was determined by analyzing the specimens under a stereomicroscope (Axioskop 2MAT, Carl Zeiss Microscopy, LLC, Thornwood, NY, US). The fracture mechanism was divided into three different types: (1) adhesive, when the failure occurred in the interface between the substrate and the repair RC; (2) cohesive, when the failure was in the substrate ore repair RC; and (3) mixed. Fractures occurring during the thermal

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