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Influence of thermomechanical fatigue on bond strength of repaired composites

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ABSTRACT

Objective: The aim of this study was to evaluate the influence of thermomechanical fatigue (TMF) and two adhesive systems on bond strength (BS) of repaired nanofilled composite. *Materials and Methods*: A hundred test specimens (8 mm diameter × 8 mm thickness) were obtained (Filtek Z350, 3M ESPE, St. Paul, MN, USA) and separated in 10 groups ($n=10$), according to the type of adhesive system for repair and TMF, after and before repair. Control groups: G1 – without repair and TMF (control); G2 – without repair+TMF. Groups repaired with total-etch adhesive system (ASB – Adper Scotchbond Multi-Purpose, 3M ESPE): G3 – repaired without TMF; G4 – TMF before repair; G5 – TMF after repair; G6 – TMF before and after repair. Groups repaired with self-etch adhesive system (CLB – Clearfil Liner bond 2V, Kuraray Dental): G7 – repaired without TMF; G8 –TMF before repair; G9 – TMF after repair; G10 – TMF before and after repair. After treatments, sticks (1 mm^2) were obtained and submitted to the microtensile test (0.5 mm/min). Failure modes were observed in Scanning Electron Microscopy (SEM-Jeol JSM 5600LV). *Results*: Statistical analysis (2-way ANOVA, Tukey, $p<0.05$) demonstrated that G2 presented highest BS values that differed statistically compared with those of other repaired groups submitted to TMF ($p<0.05$). Regarding control groups, G2 presented the highest BS values, different from G1 ($p=0.0087$). Fractographic analysis demonstrated that all repaired groups showed predominantly adhesive failures regardless of the adhesive system used. *Conclusions*: The TMF can improve the BS of repaired composites mainly when used self-etch adhesive, which demonstrated higher BS. The timing of TMF influences the BS of the repair on composite.

1. Introduction

Nowadays, composites are widely used due to their excellent esthetic properties and because they enable a more conservative approach to restoring anterior and posterior teeth [1]. However, composites are submitted to degradation and deterioration under the conditions in the oral medium [2], involving complex processes exemplified by mechanisms of abrasion, wear and fatigue; or chemical degradation resulting from thermal shock, and enzymatic, hydrolytic or acid action [2]. The action of these mechanisms may result in microleakage, discoloration, loss of marginal retention or fractures, which are frequently found in clinical situations and may require repair or replacement of the restoration [3].

The traditional treatment of these clinical situations consists of complete replacement of the restoration [4], which may remove enamel and dentin unnecessarily [5], and result in more extensive cavities during these procedures [6].

In the last few years, restoration repair has been proposed to reduce the destruction of tooth structure and pulp trauma [7]. This new approach has only been possible with the advent of bioactive adhesive restorative materials and new techniques [8]. The possibility of performing repair is recognized as a favorable feature of composites

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[9], as it requires less clinician time to perform, is great value for money as well as being a more conservative procedure [10].

In order to achieve a good composite repair, a stable bond between matured and fresh resin is required, and this can be obtained with the combination of micromechanical retention by surface treatment of the substrate [11] and physical–chemical strength promoted by an intermediate agent, such as adhesives, non-filled resins or silane [12–14]. Adhesive systems, very accessible and easily handled by the dentist [15], allow the use of a thinner layer of material and provide a closer link between the repair and the preexisting substrate.

During clinical function, dental restorations are not only subjected to high static loads, but also to low cyclic loads, leading to fatigue that creates a failure mode, in which the induction of cracks occurs in the material, eventually leading to fracture [16]. Mechanical failures of dental restorations in the majority of cases can be assigned to fatigue loading, which makes fatigue resistance one of the most important and clinically relevant properties of a dental material [16].

Therefore, the use of mechanical fatigue associated with thermal cycle testing allows simulation of the longevity of the material by providing a more faithful reproduction of the oral conditions [17]. It is known that oral cavity conditions can alter the properties of restorative materials, so it will be interesting to know how the TMF can change the longevity of repaired composites restorations, with different adhesive systems (simplified or not), even when submitted after and before the repair.

Thus the aim of this study was to evaluate the effect of TMF on the bond strength of composite repaired using two different adhesive systems. The null hypotheses tested were that adhesive system and TMF would not affect the bond strength between composite substrate and reparative composite.

2. Material and methods

The materials used in the study are described in Table 1. Eighty test specimens (8 mm in diameter × 4 mm thick) and twenty control samples (8 mm in diameter × 8 mm thick) of nanofilled composite (Filtek Z350, 3M ESPE, St. Paul, MN, USA), shade A3 were obtained, using a Teflon matrix. The composite was inserted into the matrix in increments (2 mm), the last being pressed with a glass slide to promote excess material runoff and prevent oxygen inhibition during polymerization, which was light activated with a LED device (Flash Lite 1401, Discus Dental, Culver City, CA, USA – 1100 mW/cm^2, wavelength in the range from 460 to 480 nm) for 40 s, following the manufacturer's instructions.

After this, the test specimens were separated ($n=10$) into ten groups according to the adhesive system used and the aging protocols to which they were submitted (Table 2). Samples from G1 and G2 were control groups and were not repaired. Repaired samples were submitted to protocols for repair described in Table 2.

When used ASB, (Adper Scotchbond Multi-Purpose – 3M ESPE, St. Paul, MN, USA), a thin layer of primer was applied on the surface to be repaired. The solvent was gently removed with air spray, followed by adhesive application and light activation (Flash Lite 1401, Discus Dental) for 10 s according to the manufacturer's instructions. When used CFB (Clearfil Liner bond 2V- Kuraray Co, Osaka, Japan), a thin layer of adhesive was applied followed by light activation (Flash Lite 1401, Discus Dental) (Table 2).

For the repair procedure, the samples returned into the Teflon matrix with the depth set to 8 mm by using a spacer. All samples were filled up completely with the same composite, but of a different shade (C3) in order to allow identification easily and orientation of the repaired interface during the microtensile test and when observing the fracture patterns [18].

The load cycling (ERIOS ER-37000, Erios, São Paulo, SP, Brazil) (Table 2) was set at 1.2×10^6 cycles, with load of 98 N (10 Kg) simulating clinical chewing [19] at a frequency of 2 Hz/s, using a rounded tip 6 mm in diameter as an antagonist. The frequency of 2 Hz/s simulates two cycles per second [20], which corresponds to five years of clinical use [21]. At the same time, samples were submitted to thermal cycling at temperatures ranging from 5 °C, 37 °C and 55 °C.

All the test specimens were cut with diamond disks (SYJ-150 Digital Diamond Low Speed Saw 4, MTI Crystal, Richmond, CA, USA) into stick shaped samples (1×1 mm^2), according to the non-trimming microtensile test technique [22]. Next, they were adapted to a metal device composed of two cylindrical parts. The sticks were fixed at the center of the device with cyanoacrylate ester adhesive gel (Super Bonder Flex Gel, Henkel Loctite Ltda., São Paulo, Brazil), at the union between the two parts of the device. Each segment was then linked to the Universal Test Machine (Emic-Model 1L-2000, São José dos Pinhais, PR, Brazil) and the microtensile test was performed at a speed of 0.5 mm/min.

The bond strength (BS) was calculated according to the formula $R = (F/A)/10$, where "R" is the resistance (MPa), "F" is the load required to rupture the test specimen (kgf) and "A" is the area of the test specimen interface (mm^2), measured before the test. After the microtensile test, the surfaces of the fractured sticks were observed by Stereomicroscope (Keyence Brasil, São Paulo, SP, Brazil) at 50× magnification [23] and classified as cohesive, adhesive or mixed. In addition, two sticks from each group were observed by Scanning Electron Microscopy (SEM-Jeol JSM 5600LV, Sony, Tokyo, Japan) to illustrate the failure patterns obtained [23]. The BS values obtained were submitted to statistical analysis (2-way ANOVA, Bonferroni test at a 95% level of significance).

3. Results

3.1. Bond strength analysis

The results of the microtensile bond strength are presented in Table 3. Analysis of the results (2-way ANOVA, Bonferroni, $p < 0.05$) demonstrated that there was statistical difference ($p < 0.05$) when

Table 1
Materials used, composition and manufacturer.

Material	Composition	Manufacturer
Universal Filtek™ Z350	Bis-GMA, Bis-EMA,UDMA with small amounts of TEGDMA. Silica nanoparticles non-clustered/non-aggregated, zirconia nanoclusters/silica, primary particles of zirconia/silica	3M ESPE, St. Paul, MN, USA
Adper Scotchbond Multi-Purpose	Primer: 2-HEMA, poly (alkenoic) acid copolymer Adhesive: Bis-GMA (60–70%), HEMA, dimethacrylates and photoinitiators	3M ESPE, St. Paul, MN, USA
Clearfil Liner bond 2V	Primer A: MDP, HEMA, dimethacrylates, photoinitiator, water, others Primer B: HEMA, dimethacrylates, accelerator, water Bond A: MDP, HEMA, Bis-GMA, dimethacrylates, photoinitiator, microfiller, others	Kuraray Co, Osaka, Japan

Bis-EMA, ethoxylated bisphenol-A dimethacrylate; Bis-GMA, bisphenol glycidyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate; MDP, methacryloyloxydecyl dihydrogen phosphate.