Applied Adhesion Science

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Effect of surface treatments on the bond repair strength of resin composite to different artificial teeth

Amanda Maria de Oliveira Dal Piva, João Paulo Mendes Tribst*, Paula Carolina Komori de Carvalho, Eduardo Shigueyuki Uemura, Tarcisio José de Arruda Paes Junior and Alexandre Luiz Souto Borges

*Correspondence: joao.tribst@ict.unesp.br; joao.tribst@gmail.com
Post-Graduate Program in Restorative Dentistry (Prosthodontic), Department of Dental Materials and Prosthodontics, São Paulo State University (Unesp/SJC), Engenheiro Francisco José Longo Avenue, 777, São José dos Campos, SP 12245-000, Brazil

Abstract

The purpose of this study was investigate the influence of different surface treatments on the shear bond strength of two different type of artificial resin teeth repaired with composite resin. Fifteen (15) artificial teeth of each material (CR-composite resin and AR-acrylic resin) were divided into four parts and then embedded in acrylic resin. After, the teeth were separated into eight groups according to the surface treatments prior to the repair: control group (c), adhesive application (a), sandblasting (S) and sandblasting followed by adhesive application (Sa). Next, a composite resin cylinder (Ø = 0.95 mm e h = 2 mm) simulating a repair was built onto each surface. The specimens were submitted to a microshear bond test after 24 h, using a universal testing machine (1 mm/min, 50 kgf) until fracture. The data was subjected to two-way analysis of variance (ANOVA) and Tukey test, with a significance level of 5%. ANOVA showed statistical difference for the interaction artificial teeth material* surface treatment ($p = 0.001$). CR teeth (29.79 ± 11.54 MPa) showed higher bond strength mean values than AR (18.48 ± 9.73 MPa). Regardless the artificial teeth material, Sa (36.92 ± 6.16 MPa) treatment showed the higher bond strength values. The highest bond strength value was found in CRSa (45.93 ± 7.13 MPa) and the lowest was found in ARc (5.38 ± 0.90 MPa). Based on the results, tooth material should be taken in account in order to choose the best surface treatment and achieve suitable bond strength values when a repair is necessary. For artificial teeth in acrylic resin, applying an adhesive system is the best procedure, with or without sandblasting the alumina particles. However, for artificial teeth in composite resin, an association of sandblasting followed by applying an adhesive system showed more promising bond strength values.

Keywords: Surface treatment, Shear bond strength, Composite resin, Acrylic resin, Artificial teeth

Introduction

Full arch prosthesis is one alternative to rehabilitate edentulous patients. This prosthesis consists of artificial teeth mounted on a mucus supported acrylic resin base with the purpose to restore aesthetics, phonetics and mastication [1]. During chewing, the stresses induced in the denture may cause injury to the support tissue, if equilibrium conditions suitable for occlusal adjustment are not created [2]. The most common material used for artificial teeth is acrylic resin with acceptable mechanical properties and durability [3]. Acrylic resin is easily adjusted and concentrates less stress compared to ceramic teeth [4]. Furthermore, there is a chemical interaction between the resin base and artificial teeth [3]. Regarding disadvantages, acrylic resin artificial teeth exhibit often-occlusal wear, which leads to decreased masticatory efficiency and loss of vertical dimension [5].They also present clinical problems, as they suffer remolding of worn occlusal surfaces in denture teeth [5, 6], and fractures or debonding from the prosthesis base [7].

In spite of this, artificial teeth in composite resin have been used with the purpose of improving aesthetics and to enable the repair of worn occlusal surfaces with composite resin [5, 8]. Repairing the occlusal surfaces from posterior artificial teeth with composite resin allows for controlling the vertical occlusion dimension and the maintenance of occlusal contacts. The possibility to repair the prosthesis in the clinic eliminates the need for time-consuming procedures, thus reducing costs and prolonging the prosthesis lifetime [8].

The success of these procedures mainly depends on the composite resin adhesion to the artificial teeth [7]. Various methods have been reported to improve the reactivity of highly converted composites; these methods include acid etching [9], air abrasion [10] and the use of adhesives [11]. There is no consensus on the results obtained with the different procedures. Therefore, this study aimed to analyze the effect of surface treatment on the microshear bond strength between two type of artificial teeth and a composite resin repair. The study hypothesis was that there would be no influence of the artificial teeth material and surface treatments on the bond strength between composite resin and repaired teeth.

Materials and methods

Thirty (30) artificial molars were selected and divided into two groups (n = 15): Group CR—composite resin artificial teeth (Soluut, KotaImports, São Paulo, SP, Brazil) and Group AR—Acrylic Resin artificial teeth (Yamahachi New Ace; Yamahachi Dental Mfg., Co., Aichi Pref., Japan). All teeth occlusal portions were cut with a diamond blade under water-cooling (Isomet 1000, Buehler, Lake Bluff, IL, USA), and subjected to a polishing machine (Erios—Technical and Scientific Equipment Ltda, São Carlos, Brazil) with 600 grit sandpaper for regularizing and standardizing the surface roughness. After, each tooth was sectioned into 4 parts that were embedded in chemically activated acrylic resin (Jet—Classic, São Paulo, Brazil) prior to receive different surface treatments. The groups were randomly assigned according to the surface treatment: subgroup c—did not received any surface treatment; subgroup a—application of an adhesive system layer (Signum Connector, Heraeus Kulzer, GER) polymerized for 40 s as per the manufacturer's instructions (1200 mW/cm^2—Radii Cal, SDI, Australia); subgroup S—sandblasting with Al_2O_3 particles (50 µm) [12] for 10 s with a distance of 10 mm and a pressure of 2.8 bar; and subgroup Sa—sandblasting followed by an adhesive system application. The group's distribution is summarized in Table 1, and Fig. 1 shows a schematic illustration of the specimen preparation.

Next, composite resin (Venus, Heraeus Kulzer, GER) cylinders (0.95 mm diameter and 2.0 mm high) were prepared using a rubber mold (Lamedid—an infusion device intravenous number 21 G) on the surface of each sample and light cured for

Table 1 Group distribution, descriptive statistical analysis (bond strength mean values in MPa and standard deviation) and Tukey test for the interaction "artificial teeth material*surface treatment"

Groups	Artificial teeth material	Surface treatment	Mean ± Std
ARc	Acrylic resin	No treatment	5.38 ± 0.89[a]
CRc	Composite resin		19.41 ± 4.62[bc]
ARa	Acrylic resin	Adhesive system application	23.76 ± 3.88[cd]
CRa	Composite resin		28.40 ± 6.22[d]
ARS	Acrylic resin	Sandblasting with Al_2O_3 particles	17.23 ± 5.64[b]
CRS	Composite resin		25.39 ± 5.75[cd]
ARSa	Acrylic resin	Sandblasting and adhesive system application	27.91 ± 6.27[d]
CRSa	Composite resin		45.93 ± 7.13[e]

Same superscript letters are not significantly different ($p < 0.05$)

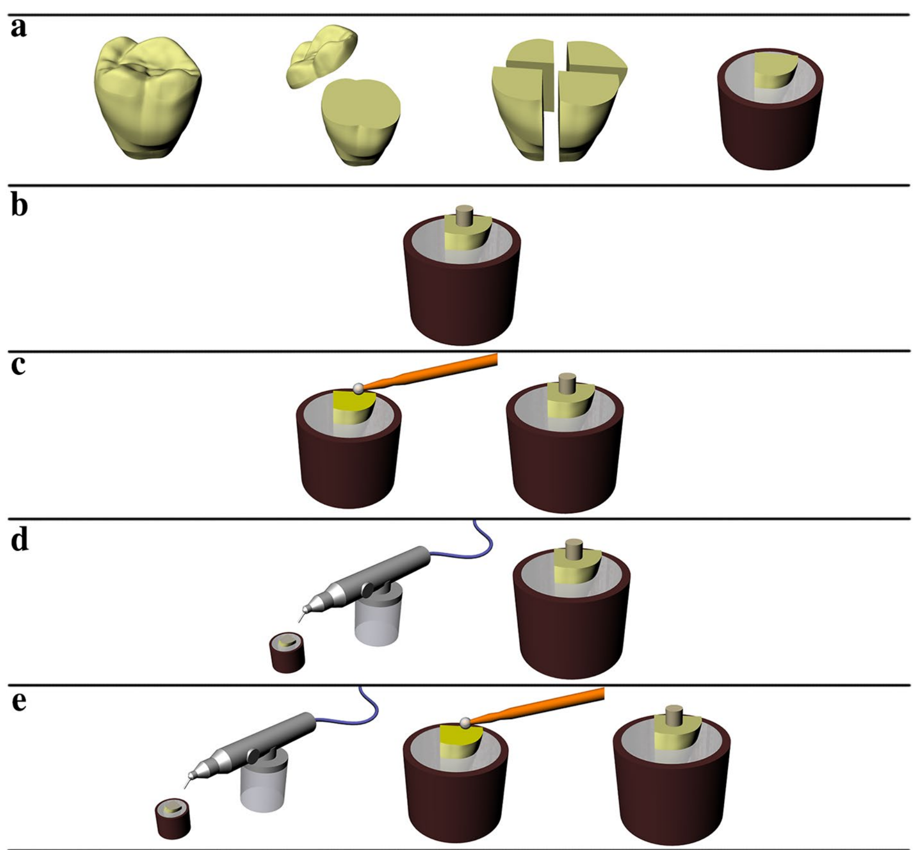

Fig. 1 Schematic representation of methodological procedures. **a** Sample preparation prior to surface treatment protocols: artificial teeth, planed occlusal surface, sectioned teeth and sample embedded into acrylic resin; **b** control protocol without surface treatment; **c** groups with adhesive prior to composite repair; **d** groups with sandblasting prior to composite repair; and **e** groups with sandblasting and adhesive prior to composite repair

40 s (1200 mW/cm^2—Radii Cal, SDI, Australia) [13]. The molds were gently removed and the samples were stored in distilled water at 37 °C for 24 h before the mechanical test. The microshear bond strength test was performed in a universal testing machine (DL1000, EMIC, São José dos Campos, SP, Brazil) and the load was applied at the

cylinder base by a steel wire (0.2 mm in diameter) at a speed of 0.5 mm/min and a load cell of 50 kgf until specimen fracture [14, 15]. Bond strength mean values were calculated by the formula: R = F/A, where R corresponds to the adhesive strength (MPa); F corresponds to the maximum load (N); and A corresponds to the adhesive area (1.41 mm^2), as calculated by the formula: $2\pi r^2$. Statistical analysis was performed using two-way analysis of variance (ANOVA) according to the factors "artificial teeth material" and "surface treatment". The Tukey test was performed for group comparison, while all tests considered a significance value of 5% [15].

Results

Two-way ANOVA showed statistically significant differences for both isolate factors and for their interaction, with p value = 0.001. Independent of the surface treatment, thus considering only the factor "artificial teeth material", teeth in composite resin (29.79 ± 11.54) showed higher bond strength values than teeth in acrylic resin (18.48 ± 9.73). And, regarding the "surface treatment" factor independent of the artificial teeth material, the bond strength values increased in the ratio: no treatment $(12.40 \pm 3.38)^d$ < sandblasting $(21.31 \pm 4.82)^c$ < adhesive system application $(26.08 \pm 5.74)^b$ < sandblasting followed by adhesive system application $(36.92 \pm 6.16)^a$. Table 1 summarizes the descriptive statistical analysis and the multiple comparison between groups. The repaired composite resin artificial teeth showed the highest bond strength mean values when treated with sandblasting and adhesive system application. While for acrylic resin teeth, the application of the adhesive system significantly improved the mean bond strength values, preceded or not by sandblasting.

Discussion

The results showed that composite resin teeth presented higher mean bond strength values than acrylic resin teeth during the repair of occlusal surfaces with composite resin. Also, the sandblasting surface treatment followed by applying an adhesive improved these results for artificial teeth in composite resin, thus rejecting the study hypothesis.

In order to achieve durable bond strength between composite resin and artificial teeth, it is essential to know the effects of different surface treatments that can modify the interaction between these materials [8]. Shear, microshear, tensile and microtensile tests can be used to evaluate bond strength. Despite the limitations of the shear test, sample standardization and easy preparation, as well as suitable laboratory equipment make this test a commonly used methodology to determine the adhesive strength of dental materials [12, 15].

Artificial teeth in composite resin are commonly used due to the physical composite resin properties such as abrasion resistance, color stability, lower water sorption and chemical bonding to acrylic resin. According to the results, composite resin repair adhesion is not effective without any surface treatment, regardless of the material used in the artificial teeth. Results show that, for composite resin teeth, it is necessary to perform mechanical retention to achieve more suitable bond strength values [4], allowing the adhesive and composite resin repair to penetrate into the surface micro irregularities and yield mechanical bond strength [8, 16–18]. The sandblasting procedure increased the mean bond strength values compared to no surface treatment. And, when followed by the application of the adhesive system, the higher bond strength values were achieved. A bonding agent has long been used with composite resin in restorative dentistry [12]. It improves surface wettability by causing the resin infiltrate into microscopic surface irregularities [8, 17]. Some studies have shown that a bonding agent was essential for achieving adequate bond strength between light-activated and polymerized resin [5, 8, 17]. For AR teeth, higher bond strength values were found when an adhesive system was applied, regardless of sandblasting. This mean values were similar to the repair bond strength of CR treated only with adhesive system application. Sandblasting was required to increase the tooth surface roughness and therefore to verify if its presence would benefit the adhesion between the repair and the tooth. Likewise, the adhesive itself for this situation was chosen to test its effectiveness in enhancing bond strength. Furthermore, teeth in composite resin and acrylic resin were selected because they are the most common artificial teeth used. The combination of a rougher surface/sandblasted surface and bond agent application significantly improved the shear bond strength between the repair and the tooth in composite resin. Nevertheless, this protocol showed similar result to only applying bond agent for acrylic resin teeth [7, 19].

Santos et al. [20] evaluated the influence of adhesives on the bond strength between artificial teeth and a thermally activated acrylic resin. The authors also associated a sandblasting protocol of aluminum oxide particles with the bond agents. The results showed that the use of adhesives significantly affected the tooth/prosthesis base union. In the present study, the bond strength between tooth and composite resin (repair) was tested. Regardless of tooth material, the presence of the bond agent was always beneficial.

It is important to notice that these results should be extrapolated with care since this was an in vitro study, with no variables found in the oral medium such as temperature and pH variations, as well as no aging methodology that could test the groups bond strength in the long term. However, based on these findings, the present study led to developing a protocol for more effective surface treatment, increasing the bond strength of artificial teeth repaired with a composite resin.

Conclusion

Notwithstanding the limitations of this study, the following conclusions can be made: (i) tooth material should be taken in account in order to choose the best surface treatment and achieve suitable bond strength values when a repair is necessary; (ii) for artificial teeth in acrylic resin, applying an adhesive system is the best procedure, with or without sandblasting the alumina particles; (iii) for artificial teeth in composite resin, an association of sandblasting followed by applying an adhesive system showed more promising bond strength values.

Clinical significance

The damaged artificial teeth material should be considered to determine the suitable surface treatment to promote acceptable bond strength values to a repair using composite resin.

Abbreviations

CR: composite resin; AR: acrylic resin; c: control group; a: adhesive application; S: sandblasting; Sa: sandblasting followed by adhesive application; Ø: diameter; h: high; ANOVA: one-way analysis of variance; Al_2O_3: aluminium oxide; ISO: International Organization for Standardization.

Authors' contributions

AMdeODP participated on the concepts, design, definition of intellectual content, literature search, data acquisition, data analysis, manuscript preparation, manuscript editing and manuscript review; JPMT participated on the concepts, design, definition of intellectual content, literature search, data acquisition, data analysis and manuscript review; PCKdeC participated on the concepts, design, data acquisition, data analysis and manuscript preparation; ESU participated on the concepts, design, definition of intellectual content, data analysis and manuscript editing; TJdeAPJ and ALSB participated on the concepts, design, literature search, data acquisition, data analysis and manuscript review. All authors read and approved the final manuscript.

Acknowledgements

None.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Funding

None.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 11 September 2018 Accepted: 20 November 2018
Published online: 28 November 2018

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