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Effect of methyl methacrylate monomer on bond strength of denture base resin to acrylic teeth

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ABSTRACT

Bond failures at the acrylic teeth and denture base resin interface are still a common clinical problem in prosthodontics. The effect of methyl methacrylate (MMA) monomer on the bond strength of three types of denture base resins (Acron MC, Lucitone 550 and QC-20) to two types of acrylic teeth (Biotone and Trilux) was evaluated. Twenty specimens were produced for each denture base resin/acrylic tooth combination and were randomly divided into control (acrylic teeth received no surface treatment) and experimental groups (MMA was applied to the surface of the acrylic teeth for 180 s) and were submitted to shear tests (1 mm/min). Data (MPa) were analyzed using three-way ANOVA/Student's test ($\alpha = 0.05$). MMA increased the bond strength of Lucitone denture base resins and decreased the bond strength of QC-20. No difference was detected for the bond strength of Acron MC base resin after treatment with MMA.

1. Introduction

One of the primary advantages of acrylic teeth is their ability to adhesively bond to the denture base resins. Although the bonding seems satisfactory, clinical failures are still common [1–3]. Previous studies have demonstrated that debonding of teeth from the base resin is the most frequent repair in the laboratorial practice for conventional prosthodontics [4–6].

This failure between tooth and denture base resin may occur because of wax residue remaining on denture teeth [6], tin-foil substitute contamination [6–9], and variations in laboratory processing [9–11].

Several attempts have been made to improve the bonding at the interface of acrylic teeth and denture base resin. Examples of mechanical treatments include grinding the ridge-lap surface of acrylic teeth, cutting retention grooves in the ridge-lap surface, and placement of diatorics in denture teeth (cavities to improve mechanical retention between denture base resin-acrylic tooth) [4,7,12,13]. The basal area of the artificial tooth is called ridge-lap surface. Surface treatments include painting the tooth surface with monomer, nonpolymerizable solvents, dissolved polymethyl methacrylate (PMMA), or a combination of these [7,10,14]. However, these treatments have been reported effective by some researches [12,15–17] and ineffective by others [6,10,13].

The ability of acrylic teeth to bond to denture base resins may also be affected by the type of tooth material (conventional acrylic teeth or cross-linked teeth) [14,18]. Some authors have reported that teeth made from conventional acrylic resins achieve a higher bond to denture base resins than cross-linked teeth [14,18].

Different types of processing methods applied to the base resins can also affect the bond between acrylic teeth and denture base resins [2,19–21]. Several studies comparing the bonding of acrylic teeth to microwave polymerized with the bonding of acrylic teeth to heat-polymerized denture base resins have reported that heat-polymerized denture base resins revealed the highest bonding values [14,22,23]. By contrast, other studies reported that microwave-polymerized resin demonstrated significantly higher bond strengths with acrylic teeth than did heat-polymerized resin [17].

As described above, many factors can contribute to the failure at acrylic tooth–denture base resin interface. In recent years, the wide variety of new materials, the different types of denture base resins and different materials used for artificial teeth have added to the variety of processing methods to produce wide variability in reported results. This variability of results highlights the need for

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further examination techniques for improving the bond strength between acrylic teeth and denture base materials.

The purpose of this study was to evaluate the effect of surface treatment with methyl methacrylate (MMA) monomer on the shear bond strength of three denture base resins to two acrylic teeth. The null hypotheses were that MMA monomer would not affect the interface of acrylic teeth and different acrylic teeth would have similar bond to denture base resins.

2. Materials and methods

Three PMMA resins were used (Table 1): a conventional water-bath, heat-activated acrylic resin (Lucitone 550), a rapid polymerizing acrylic resin (QC-20), and a microwave-activated acrylic resin (Acron MC).

The maxillary molars Trubyte Biotone and Trilux Ruthinium were chosen for this study (Table 2). Trubyte Biotone is essentially PMMA beads and color pigments in a partially cross-linked polymer matrix. Trilux is composed of conventional tooth acrylic resins and color pigments. First, the ridge-lap surface (basal area of the tooth—Fig. 1A) of each acrylic tooth was planed with 320-, 400- and 600-grit silicon carbide paper (Norton; Saint-Gobain Abrasivos Ltd., Vinhedo, SP, Brazil) successively in a polishing machine (Arotec Ind. e Com. Ltd., Cotia, SP, Brazil) (Fig. 1B). Each acrylic tooth was embedded in autopolymerizing polymer PMMA (Jet, Artigos Odontológicos Clássico Ltd., Sao Paulo, SP, Brazil) with an embedding machine (Arotec Ind. e Com. Ltd., Cotia, SP, Brazil) (Fig. 2A).

A silicone rubber mold frame (Zetalabor, Zhermack S.A. Rovigo, Italy) with a 5.0 mm in diameter hole was obtained from a stainless steel mold to standardize the dimensions of the denture base resin cylinders and for controlling the bonding area. Cyanoacrylate glue (Super Bonder, Loctite Henkel Ltd., Diadema, SP, Brazil) was applied to the silicone rubber mold frame/polymer interface so that the hole of silicone mold coincided with the ridge-lap surface of the embedded tooth (Fig. 2B). Then, the hole of silicone mold was sealed with a small amount of silicone (Zetalabor, Zhermack S.A. Rovigo, Italy) before the investing. Investing is the process of forming molds by dental stone (α-hemihydrate of calcium sulfate). The embedded tooth with the silicone rubber mold frame was then invested in denture flasks with dental stone (Herodent, Vigodent S.A. Ind. Com., Rio de Janeiro, RJ, Brazil). Heat polymerization (Lucitone 550 and QC-20) and microwave polymerization (Acron MC) were conducted in metal flasks (OGP, Produtos Odontológicos Ltd., Sao Paulo, SP, Brazil) and plastic flasks (Onda Cryl, Artigos Odontológicos Clássico Ltd., Sao Paulo, SP, Brazil), respectively. Flasks are containers specially designed for denture base resin packing and processing. After the stone was set, the two halves of the flasks were separated and the silicone was carefully removed from the hole of silicone rubber mold frame. Two coats of sodium alginate (Cel-Lac, SSWhite, Rio de Janeiro, RJ, Brazil) were applied to the stone surfaces. Care was taken at all stages during subsequent handling to avoid contamination. Twenty specimens were produced for each denture base resin/acrylic tooth combination and were randomly divided into control and experimental groups. The control group contained acrylic teeth that received no surface treatment. For the experimental groups, the MMA was applied with a small brush to the surface of the acrylic teeth for 180 s. The acrylic resins Lucitone, QC-20 and Acron were mixed in a powder/liquid ratio of 21/10, 23/10 and 14.7/7 g/ml, respectively. The acrylic resin was then packed and polymerized according to the manufacturer's instructions (Table 2). After polymerization, the flasks were kept overnight on the lab bench. Each specimen composed of a denture base resin cylinder (5.0-mm diameter $\times$ 2.5-mm height) bonded to the ridge-lap surface of an acrylic tooth embedded in autopolymerizing polymer (Fig. 3) was carefully removed from the flasks and was cleaned and stored in distilled water at 37 °C for 50 $\pm$ 2 h [24].

After storage, the specimens of each denture base/acrylic tooth combination were submitted to shear tests. A universal testing machine (EMIC-DL 3000, EMIC Ltd., Curitiba, SP, Brazil) with a 2-KN load cell was used. Shear loading was applied at a crosshead speed of 1 mm/min [25]. The maximum stress (MPa) required to shear the denture base resin from the tooth was considered to be the shear bond strength.

Statistical analysis of the results was carried out with three-way analysis of variance (ANOVA). The three factors analyzed were denture tooth, acrylic resin, and surface treatment. The Student–Newman–Keuls test was used to determine differences between mean values ($\alpha = 0.05$).

3. Results

The three-way ANOVA and the indication of significance for the different factors and interactions are shown in Table 3. It can be seen that significant differences were found for denture base resin ($P<0.001$), the interaction between surface treatment and denture base resins ($P<0.001$), and between denture base resins

Table 2
Acrylic teeth used in this study

Tooth	Type	Manufacturer
Trubyte Biotone/30M	Cross-linked acrylic resin artificial tooth	Dentsply Ind. e Com. Ltd., Rio Janeiro, RJ, Brazil
Trilux Ruthinium/M5	Conventional acrylic resin artificial tooth	RuthiBras Imp. Exp. e Com. De Odontológicos Ltd., Pirassununga, SP, Brazil

Table 1
Denture base resins used in this study

Denture base resin	Manufacturer	Type	Composition	Polymerization cycle
Acron MC	GC Lab Technologies, Inc., Alsip, IL, USA	Microwave-polymerized	Powder: PMMA Liquid: MMA and difunctional methacrylate	3 min at 500 W
Lucitone 550	Dentsply Ind. e Com. Ltd., Rio de Janeiro, RJ, Brazil	Heat-polymerized	Powder: PMMA Liquid: MMA and EGDMA	90 min at 73 °C and 100 °C for 30 min
QC-20	Dentsply Ind. e Com. Ltd., Rio de Janeiro, RJ, Brazil	Heat-polymerized	Powder: PMMA Liquid: MMA, EGDMA and (dimethyl-*para*-toluidine)	20 min at 100 °C

PMMA: polymethyl methacrylate; MMA: methylmethacrylate; EGDMA: ethylene glycol dimethacrylate.

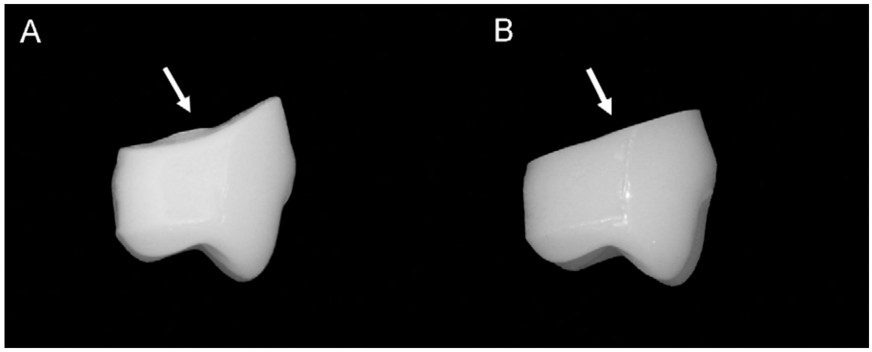

Fig. 1. Side view of an acrylic tooth. (A) The arrow indicates the ridge-lap surface and (B) the arrow indicates the ridge-lap surface after polishing.

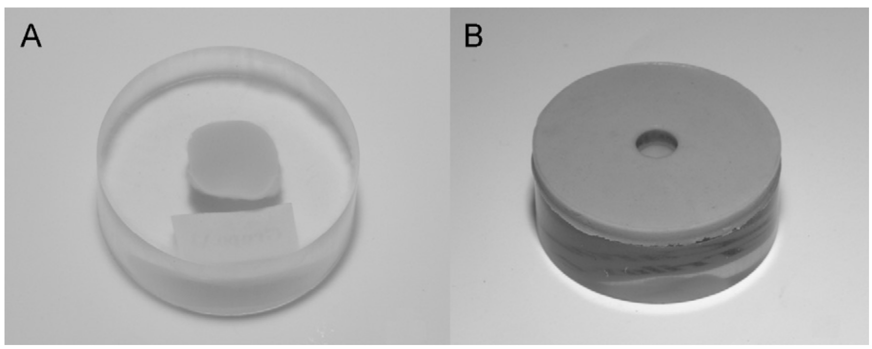

Fig. 2. (A) Acrylic tooth embedded in autopolymerizing polymer and (B) silicone pattern circular opening coincided with the ridge-lap surface of the acrylic tooth.

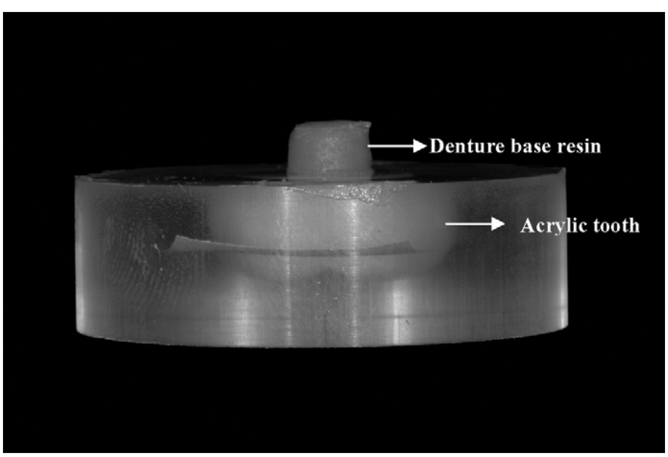

Fig. 3. Specimen.

and acrylic teeth ($P = 0.005$). The mean values ($\pm$S.D.) for the shear bond strength of denture base resins and experimental conditions evaluated and the results of Student–Newman–Keuls test are presented in Fig. 4. After treatment surface, the lowest shear bond strength was observed with denture base resin QC-20. However, surface treatment with MMA resulted in a significant increase in the bond strength of Lucitone 550. No significant difference was detected on the bond strength of Acron after monomer application. The mean values ($\pm$S.D.) for the shear bond strength of denture base resins and acrylic teeth interface evaluated and the results of Student–Newman–Keuls test are presented in Fig. 5. The interaction between denture base resins and acrylic teeth is shown in Fig. 4. The lowest shear bond strength values were found with QC-20 when bonded to both acrylic teeth (Biotone and Trilux) and the highest bond strength was seen with Lucitone denture base resin bonded to Trilux acrylic teeth. All the other combinations of denture base resins/acrylic teeth showed intermediate values of bond strength.

4. Discussion

In the present study, the effect of surface treatment of acrylic teeth with MMA was investigated. The hypotheses that surface treatment with MMA does not affect the interface of acrylic teeth and denture base resins and different acrylic teeth does not have similar bond to denture base resins were rejected. The method of polymerization of the denture base resin, as well as its composition, and the type of tooth material may help explain these findings.

Chemical bonding between acrylic resin teeth and polymers is based on the penetration of the acrylic resin monomers into the teeth and the formation of an interwoven polymer network [20,23]. According to Vallittu et al. [26], wetting the surface with MMA dissolves the structure of PMMA and improves adhesion between the acrylic teeth and the denture base resin. The strength of the bond depends on the degree of penetration of the solvent and the strength of the interwoven polymer network formed thereafter [14].

Our results demonstrated that Lucitone 550 denture base resin showed the highest mean shear bond strength value after surface treatment with MMA. Saavedra et al. [27] also observed similar results with the same denture base resin after application of an MMA-based surface treatment. Vallittu et al. [21] affirmed that the higher polymerization temperature of heat-polymerized resins enhances the diffusion of monomers of the denture base

Table 3
Results of three-way ANOVA

Source of variation	Sum of squares	d.f.	Mean square	*F*	*P*
Surface treatment	1.226	1	1.226	0.15	0.696
Acrylic teeth	0.044	1	0.044	0.01	0.941
Denture base resins	257.740	2	128.870	16.17	<0.001*
Surface treatment × acrylic teeth	0.004	1	0.004	0.00	0.982
Surface treatment × denture base resins	236.499	2	118.249	14.84	<0.001*
Denture base resins × acrylic teeth	87.912	2	43.956	5.52	0.005*
Surface treatment × denture base resins × acrylic teeth	28.280	2	14.140	1.77	0.175
Error	860.703	108	7.969		
Total	1472.407	119			

* $P<0.05$.

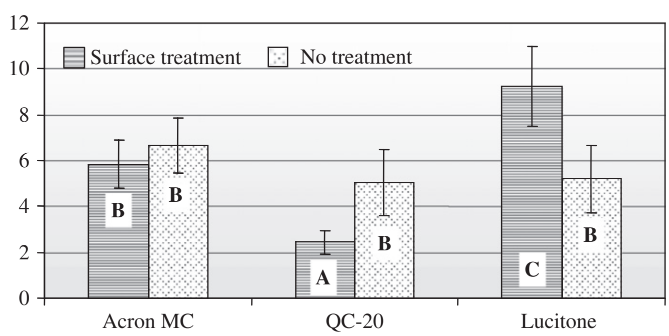

Fig. 4. Shear bond strength of surface treatment and no treatment groups of each denture base resin. Same capital letters indicate no significant difference (Student–Newman–Keuls test, $P<0.05$).

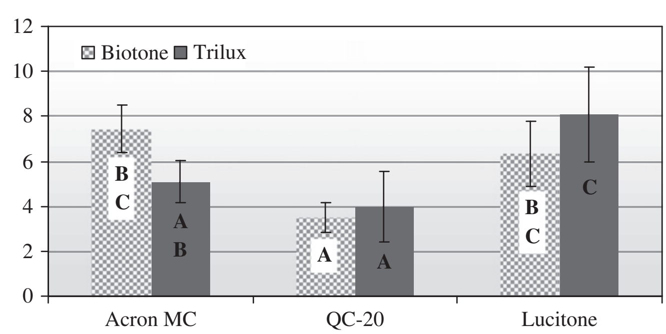

Fig. 5. Shear bond strength of each denture base resin/acrylic tooth combination. Same capital letters indicate no significant difference (Student–Newman–Keuls test, $P<0.05$).

resin into the acrylic resin polymer teeth. This could explain the improvement that MMA surface treatment brings about in the bond strength of Lucitone denture base resin and acrylic teeth interface.

Adversely, the lowest bond strength values were observed for both types of acrylic teeth adhered to QC-20 denture base resin after surface treatment with MMA. Although this denture base resin is classified as a heat-polymerized resin, its behavior was similar to that of autopolymerizing acrylic resins. The liquid component of QC-20 contains an activator (dimethyl-*para*-toluidine), which causes the decomposition of benzoyl peroxide to initiate polymerization [28]. Thus, less time is available before polymerization to adhere good contact between the acrylic tooth and denture base interface to produce a satisfactory bond [1,4].

The results of this study demonstrated that the application of monomer to the surface of acrylic teeth did not influence bond strength for microwave-polymerized denture base resin. Denture base resins especially designed for microwave polymerization contain a monomer formulated for microwave polymerization that could contain either a triethylene- or a tetraethylene glycol dimethacrylate. This modification is necessary for processing at elevated temperatures, due to the low vapor pressure of dimethacrylates [29]. However, in the present study, this fact did not affect the results. Different results were observed by Geerts and Jooste [17] and Takahashi et al. [14]. These authors concluded that the surface treatment resulted in a significantly better improvement in bond strength when compared with no treatment. These opposite results demonstrate that bond strength would appear to be multifactorial, including polymerization cycle, cross-linking of the materials, availability of the monomer, and degree of contamination during processing [2,30]. So, further studies are indicated to evaluate the effect of surface treatments on the strength of microwave-polymerized denture base resin.

Considering the interaction between denture base resin and acrylic tooth, the lowest bond strength values were found with QC-20 denture base resin with both types of acrylic teeth evaluated. However, for Lucitone, the type of tooth did influence the results, and it showed the highest mean bond strengths with Trilux acrylic teeth. Differences in the chemical structure of the acrylic teeth evaluated may explain this fact. Several studies demonstrated that the surface composition of the tooth's ridge lap can affect bonding to the denture base resin [1,9,31]. Conventional acrylic teeth usually achieve a better bond to denture base resins than highly cross-linked teeth [18]. The higher degree of cross-linking agents may restrict the diffusion of polymer chains into the denture base to form a polymer network [18].

It can be considered that the present study method and variables did not simulate all clinical conditions. Despite these limitations, the materials evaluated in this study are expected to perform similarly in the oral environment. Further studies are recommended to investigate other material combinations and to predict which materials would provide the best clinical service.

5. Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. After surface treatment with MMA, the shear bond strength of Lucitone acrylic resin was significantly increased.
2. Surface treatment with MMA significantly decreased the shear bond strength of QC-20 acrylic resin.
3. The shear bond strength of Acron MC acrylic resin was not significantly affected by surface treatment with MMA.

4. Lucitone acrylic resin/Trilux denture tooth combination exhibited the highest bond strength values and it is recommended for clinical use.

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