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THE EFFECT OF CHEMICAL AND MECHANICAL TREATMENT OF THE DENTURE BASE RESIN SURFACE ON THE SHEAR BOND STRENGHT OF DENTURE REPAIRS

Efeito do tratamento químico e mecânico da superfície da resina de bases de dentaduras nas forças de cisalhamento em reparos de dentaduras

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Abstract

OBJECTIVE: This study was aimed to evaluate the effect of three surface treatment methods on the shear bond strength of denture repairs. **MATERIAL AND METHOD**: 40 specimens (15 x 15 x 7mm) were fabricated according to the manufacturers' instructions from each of three denture base materials: a heat-cured acrylic resin (Veracril™), a rapid-setting heat-cured acrylic resin (QC-20™), and a pourable resin (Selecta Plus™). The samples of each material were divided into four groups of ten. One of the groups served as a control and underwent no surface treatment. The other groups received one of three surface treatments: air blasting with 50 μm aluminum oxide particles at 0.5 MPa pressure for 5 seconds; immersion in methyl methacrylate (MMA) for 180 seconds or immersion in acetone for 3 seconds. An autopolymerizing repair resin (Rapid Repair™) was applied to the bonding area (6 mm in diameter, 2 mm in height) and polymerized at a pressure of two bar for 30 minutes using a pressure pot. All specimens were subjected to 10,000 thermal cycles. The shear bond strength (MPa) of the specimens was measured in a universal testing machine at a 1 mm/min crosshead speed. The effect of the mechanical and chemical treatments on the surface of the base resins was examined using SEM. Statistical tests used were 2 way ANOVA and Kolmogorov-Smirnov. The level of statistical significance was established at ($p<0.05$). **RESULTS**: There were statistically significant differences between bond strength in surface treatment levels across acryl level categories ($p=0.042$). The results also showed differences between treatment levels ($p=0.0001$).Abrasive blasting significantly increased the bond strength of the repair material, but there were no significant differences between the bond strengths of the control group and the experimental groups treated with MMA or acetone. Examination by SEM revealed that chemical treatment with MMA or acetone produced a smooth surface similar to the control group, while airborne-particle abrasion produced a porous surface. **CONCLUSION**: Mechanical surface treatment prior to denture base repair resulted in a significant improvement in the shear bond strength of the base material.

Keywords: Denture repair. Chemical surface treatment. Mechanical surface treatment. Shear bond strength.

Resumo

OBJETIVO*: O presente estudo foi dirigido para avaliação do efeito de três métodos de tratamento de superfície na reparação de resinas-base de dentaduras.* ***MATERIAL E MÉTODO****: 40 espécimes (15 x 15 x 7 mm) foram fabricados de acordo com as instruções dos fabricantes de cada um de três materiais-base de dentaduras: uma resina termopolimerizada (Veracril™); uma resina de termopolimerização rápida (QC-20™) e uma resina autopolimerizável (Selecta Plus™). Cada material foi dividido em quatro grupos de dez corpos de prova. Um dos grupos serviu como controle, não recebendo tratamento de superfície. Os outros grupos receberam três tipos de tratamento de superfície: jato abrasivo com partículas de óxido alumínio (50) com pressão de 0,5 MPa durante cinco segundos; imersão em metil metacrilato (MMA) por 180 s; imersão em acetona por três segundos. Uma resina de reparo autopolimerizável (Rapid Repair ™) foi aplicada na área de adesão (6 x 2 mm) e polimerizada sob pressão de duas atmosferas por 30 minutos, utilizando um frasco de pressão. Todos os espécimes foram sujeitos a 10.000 ciclos térmicos. A resistência às forças de cisalhamento foi medida numa máquina universal de testes a uma velocidade de 1 mm/min. O efeito do tratamento químico e mecânico das superfícies da resina base foi avaliado usando SEM. Testes estatísticos utilizados foram ANOVA e Kolmogorov-Smirnov. O nível de significância estatística foi estabelecido a $p<0.05$.* ***RESULTADOS****: Houve diferenças estatisticamente significantes na resistência ao cisalhamento entre as categorias de tratamento de superfície (p=0,042). Os resultados também mostraram diferenças entre níveis de tratamento (p=0,0001). O jato abrasivo aumentou significativamente a resistência ao cisalhamento do material de reparo, mas não houve diferenças significativas entre a resistência do grupo controle e dos grupos experimentais tratados com MMA ou acetona. O exame com microscopia eletrônica demonstrou que o tratamento químico com MMA ou acetona produziram uma superfície lisa similar ao grupo controle, enquanto que a abrasão por jato de ar com partículas produziu uma superfície porosa.* ***CONCLUSÃO****: O tratamento mecânico da superfície da resina-base de dentaduras resultou em melhora significativa na resistência a forças de cisalhamento do material.*

Palavras-chave*: Reparo de dentaduras. Tratamento químico de superfície. Tratamento mecânico de superfície. Resistência a forças de cisalhamento.*

INTRODUÇÃO

Removable dentures made of acrylic resin are subject to fracture if dropped or stressed beyond their fracture strength. Fabrication of a new denture is an expensive and time consuming procedure, and for this reason the decision to repair a denture is a common one (1).

Several techniques exist for restoring fractured dentures to their original strength. Surface preparation of the sites to be joined is of paramount importance in ensuring a long service life. Chemical or mechanical treatments change the morphology or surface chemistry of the acrylic resin base material to promote better adhesion (1). Etchants such as acetone, methyl methacrylate (MMA), chloroform and methylene chloride are used for improving the bond between the base and repair materials (1-8).

The objective of this was to evaluate the effect of three surface treatments (mechanical treatment by abrasive blasting or chemical treatment with MMA or acetone) on the shear bond strength of denture repairs.

MATERIAL AND METHOD

A total of 40 specimens (15 x 15 x 7 mm) were fabricated from each of three denture base materials: a heat-cured acrylic resin (Verasil™, New

Stetic S.A., Colombia), a rapid-setting heat-cured acrylic resin (QC-20™, Dentsply, England), and a pouring resin (Selecta Plus™, Dentsply, England). The samples were prepared according to the manufacturers' instructions. The test surface of the specimens was finished with 600-grit silicon carbide abrasive paper to remove surface irregularities.

Before surface treatment all specimens were stored in water at 37°C for 7 days and then ultrasonically cleaned in distilled water and dried with compressed air. The specimens of each resin material were divided into four groups of ten. One of the groups served as a control and underwent no further surface treatment. The other groups received one of three surface treatments:

1. Airborne particle abrasion with 50 aluminum oxide particles at a pressure of 0.5 MPa for 5 seconds;
2. Immersion in methyl methacrylate for 180 seconds;
3. Immersion in acetone for 30 seconds.

After treatment a small square of paper with a 6mm diameter hole in the center was glued to the top surface of each block. A small dam 6mm in diameter and 2mm in height was applied to the paper with sticky wax. The paper adhesive prevented flashing of repair material to the remaining sample surface.

An autopolymerizing repair resin (Rapid Repair™, Dentsply, England) was applied to the bonding area (6mm in diameter, 2mm in height) and polymerized in a pressure pot for 30 minutes at a pressure of 2 bar.

The specimens were placed in a water bath and subjected to 10,000 thermal cycles between and 5 and 55°C with a 1 minute dwell time. The shear bond strength (MPa) was measured in a universal testing machine (Zwick/Roell Z020) at a crosshead speed of 1mm/min. A 2-way analysis of variance and multiple-comparison Tukey test were performed to identify significant differences. The nature of the failure was observed using a stereomicroscope at a magnification of 20x and recorded as adhesive (at the interface), $cohesive_1$ (fracture of the base material), $cohesive_2$ (fracture of the repair material), or mixed ($cohesive_1$ and $cohesive_2$). The effects of the mechanical and chemical treatments on the surface of the base resins were examined using SEM. Photomicrographs of the surfaces were obtained at a magnification of 2000x.

Statistical analysis

Summary statistical measures (mean, 5%trimmed mean and stand-ard deviation) were calculated for continuous variable (bond strength). For discrete variables, frequency distributions were stud-ied. Distribution normality assumption of bond strength in surface treatment levels across acryl level categories were assessed by the Kolmogorov-Smirnov test and results showed normality would hold ($p>05$). For comparison of bond strength in surface treatment levels between acryl level categories, 2way analysis of Variance (two-way ANOVA) was used. The level of statistical significance was established at $p<0.05$.

RESULTADOS

The mean shear strength values and standard deviations for each type of acrylic base material and treatment method are presented in Table 1. ANOVA testing suggested no significant difference in the shear bond strength of the acrylic resins ($P=0.233$), but the treatment method had a significant ($P<0.001$) influence on the shear bond strength (Table 2). On the other hand, significant differences were found in the behavior of the various base materials to the surface treatment ($P=0.042$).

TABLE 1 - Mean shear bond strength values (SD) for acrylic resins and different surface treatment

Acryl	Surface treatment	Mean ± SD	number	5% Trimmed mean *
Veracril	untreated	3.9450 ± 2.39951	10	3.782
	air abrasive	7.8430 ± 4.14725	10	7.93
	MMA	4.5390 ± 3.47517	10	4.34
	Acetone	2.0560 ± 0.89521	10	2.036
	sum	4.5958 ± 3.56887	40	
QC-20	untreated	1.9540 ± 1.41455	10	1.933
	air abrasive	9.1650 ± 4.16101	10	9.31
	MMA	2.8810 ±2.40606	10	2.706
	Acetone	1.7010 ± 1.16236	10	1.663
	sum	3.9253 ± 3.96097	40	
Selecta Plus	untreated	4.1380 ± 1.30569	10	4.066
	air abrasive	6.5130 ± 3.88405	10	6.377
	MMA	5.2130 ± 2.13086	10	5.11
	Acetone	3.9590 ± 2.28687	10	3.914
	sum	4.9558 ± 2.68224	40	
Total sum	untreated	3.3457 ± 1.98623	10	
	air abrasive	7.8403 ± 4.07499	10	
	MMA	4.2110 ± 2.81905	10	
	Acetone	2.5720 ± 1.81874	10	
	sum	4.4923 ± 3.44352	40	

*the arithmetic mean calculated when the largest 5% and the smallest 5% of the cases have been eliminated

TABLE 2 - Results of ANOVA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	611.418	11	55.583	7.507	.000
Intercept	2421.637	1	2421.637	327.058	.000
ACRYL	21.881	2	10.941	1.478	.233
TREAT	488.723	3	162.908	22.002	.000
ACRYL * TREAT	100.813	6	16.802	2.269	.042
Error	799.665	108	7.404		
Total	3832.720	120			
Corrected Total	1411.082	119			

No significant differences (P>0.05) were detected between the control group and specimens treated with MMA or acetone according to the multiple-comparison Tukey test (Table 3).

TABLE 3 - Multiple Tukey´s test for effect of kind of surface treatment and shear bond strength

subdivision		No	Treatment
2	1		
	2.5720	30	Acetone
	3.3457	30	Untreatment
	4.2110	30	Metylmethacrylate
7.8403		30	Air abrasive
1.000	0.097		Sig.

The shear bond strength of the mechanically treated samples was significantly higher than the control or chemically treated groups (P<0.05). The frequency of occurrence of each failure type (adhesive, cohesive$_1$, cohesive$_2$, and mixed) is listed in Table 4.

TABLE 4 - Multiple Tukey´s test for effect of kind of surface treatment and shear bond strength

Acetone	MMA	Air abrasive	Untreated	Surfacetreatment / Acrylic resin	
10(100)	8(80)	5(50)	10(100)	AD(%)	Veracril
—	10(10)	2(20)	—	CO1 (%)	
—	—	2(20)	—	CO2 (%)	
—	1(10)	1(10)	—	MI (%)	
6(60)	9(90)	4(40)	10(100)	AD (%)	QC-20
—	—	—	—	CO1 (%)	
4(40)	1(10)	2(20)	—	CO2 (%)	
—	—	4(40)	—	MI (%)	
2(20)	5(50)	4(40)	3(30)	AD (%)	Selecta Plus
8(80)	1(10)	4(40)	4(40)	CO1 (%)	
—	2(20)	1(10)	1(10)	CO2 (%)	
—	2(20)	1(10)	2(20)	MI (%)	

AD=failure in interfaceCO1=failure in base materialCO2=failure in repaired materialMI=failure in base material and repaired material(mixed)

Adhesive fractures were the most common type of failure for Verasil and QC-20. However, cohesive$_1$ fracture was the most prevalent failure mode for Selecta plus samples. SEM examination of the control group and the chemically treated specimens revealed a smooth surface, while mechanically treated specimens displayed a surface covered with scratches and depressions, which likely plays a role in the improved bond strength of these samples.

DISCUSSION

This study evaluated the effect of chemical and mechanical treatment of the denture base resin surface on the shear bond strength of denture repair. Shear strength is the maximum force that a material can tolerate before shear failure. Investigation of the shear bond strength of material interfaces is important (9).

Many studies examined the transverse strengths of repaired specimens of acrylic resin (2-4, 10, 11). Since, the numbers of interface failure were more than cohesive failure; therefore we evaluated bonding failure of repair resin to base material by measuring shear bond strength. The shear bond test applies a shear bond directly to the interface between repair material and denture resins which allows the results to be easily compared between material (12).

Mechanical surface treatment prior to denture base repair resulted in a significant improvement in the shear bond strength of the base materials. This finding is in agreement with a study by Minami (7). He reported a significant increase in bond strength between the denture base resin and an autopolymerizing resin. In addition, Jagger (13) found that a rough surface increases the friction between the denture base and the repair material, requiring more debonding force at the interface.

Organic solvents such as chloroform, Acetone, and Methylenchloride have also been used for this process, and increase the bond strength of a repair material to the denture base (1-5).

Chemical treatment with enchants (MMA, acetone, chloroform, or methylene chloride) alters the surface morphology by inducing the formation of cracks and pits approximately 2ìm in size. These changes can increase the mechanical bond strength, due to penetration of the monomer into the pits and cracks (1).

Chloroform and methylene chloride are toxic and potentially carcinogenic agents (14); for this reason we investigated only acetone and MMA. In our study chemical treatments using MMA did not result in a statistically significant increase in shear bond strength. Our experiments are also relevant to the cold-curing resin denture technique. The consistency of the resin mixture continuously becomes thicker during pressure curing. The thicker consistency results in less penetration and decreased wetting of the structure. Shen (4) found a statistically significant improvement in the success of repair procedures when using PMMA in a heat-cured process.

Leles (6) studied the effects of surface treatment with acetone on transverse strength and found that the treatment decreased the bond strength. However, the decrease was not significant. Acetone is a solvent for PMMA (15, 16), and the reduction in bond strength may be due to residual acetone trapped between PMMA chains. In our study the shear bond strengths observed for untreated or chemically-treated specimens were lower than previous reports, except for Ng (17), who reported similar values. He used three types of repair material including Rapid Repair ™, which we used as well. The type of repair material may also exert an effect on the bond strength.

The high level of residual monomer in heat-cure acrylic resin with short processing cycle may lead to lower mechanical properties. There is probably relationship between residual monomer and low bond strength of QC-20 ™ with or without treatment with MMA and Acetone, in compare to Veracil ™ and Selecta plus™ specimens. According our assessment the most type of bond failure in veracil and QC-20 were adhesive. Then we would conclude that bond strength between base and repaired material in compare to the base material is lower. We found most of bond failure in Selecta plus ™ were cohesive, therefore the bond strength between base material and repaired materials were better than base material.

The SEM observations of specimens were treated with acetone and MMA revealed a smooth and clear surface with few fissure and air abrasion group revealed surfaces with scratches and depression. Mechanical surface treatment resulted in a significant improvement in the shear bond strength of the base material. This finding is in agreement with a study by Rached et al. (2).

CONCLUSION

Mechanical surface treatment prior to denture base repair resulted in a significant improvement in the shear bond strength of the base material.

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