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Transverse strength measurements of repaired acrylic resin modified with different surface treatments

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Abstract

Aim: the purpose of this study was to evaluate the effect of chemical and mechanical surface treatments on repaired acrylic resin in terms of transverse strength.

Materials and methods: seventy acrylic specimens were fabricated and divided into 7 groups according to kind of reinforcement materials. Thesespecimenswere cut in the mid and a space of 3 mm was created. The repair was done with various surface treatments and specimenswere then subjected to loads till fracture. Data were analysed and compared via ANOVA and Tukey tests.

Results: the transverse strength of repaired acrylic resin had been influenced by the type of surface treatment used.The repaired samples withglass fibers,stainless steel wire and monomerimproved significantly the bond strength than untreated group ($P<0.05$).Statistically, there were significant differences between control group and repaired groups ($P<0.05$); and among all repaired groups ($P<0.05$) with exception no significant differencesbetween fiber and monomer, and wire and monomer groups ($P > 0.05$).

Conclusion:A combination of chemical and mechanical treatments has a significant effect on transverse strengths. The repaired joints with monomer, wire, or glass fibers had significantly improved the strength of repaired acrylic resin.

Keywords: transverse strength, acrylic, repair.

Introduction

In dentistry, removable dentures are commonly utilized for partially and completely edentulous patients for restoring function and aesthetics[1]. These appliances are usually made from poly methyl methacrylate materials due to their cost and ease of fabrication[2,3]. Acrylic materials, however, have some drawbacks such us poor strength and may prone to fracture[4,5]. A fractured denture base, which may be due to denture drooping or masticatory forces, must be repaired as fabrication of new denture requires time and cost[6,7]. Various types of acrylic resin (i.e. heat cured, cold cured and light cured materials) have been used for repairing the denture bases [8, 9,10]. For repairing a fractured denture, numerous reinforcement materials (i.e. acetone, chloroform, acrylic cement, liquid monomer, metal wires, and glass fibers) have been utilized to improve the process of repair[11,12,13,14]. The form of joint (i.e. Butt, round, 45 degree, and rabbet) between the fractured pieceshave considerablyenhanced the mechanical properties of repairedacrylic [15, 16, 17]. The aim of this study was to assess the effect of using both chemical (i.e. monomer) and mechanical surface treatments (i.e. stainless steel wire and glass fibers) on transverse strength of repaired acrylic base. The null hypothesis indicated that there were no significant differences among the transverse strengths of unrepaired and repaired heat cured acrylic resin.

Materials and methods

1. Fabrication of acrylic samples

In this study, seventy acrylic specimens were fabricated for transverse test. Three plastic stripswith dimensions of (65mmX 10mmX 2.5 mm) length, width and thickness respectively, were used to construct the acrylic specimens. Themetal flask was painted withVaseline before filling the lower half of it with a dental stone (Spofadental, Czech Republic). Plastic strips were then embedded in dental stone (Fig. 1). After final set of stone, the separating medium was used to paint the stone surface andupper half was filled with stone, and its counterpart gently inverted over this half and left to set. Once setting, the flask was opened andplastic stripswere removed. The stone mould was lubricated with separating mediumand left to dry for 30 minutes. The heat cured acrylic resin (Spofadental, Czech Republic) was mixed according to manufacturer instructions and then packed into the mould, pressed and cured[18]. Once curing, the flask was left to cool and acrylicspecimens were then removed from the mould, finished and polished (Fig. 2). The specimens were ready for repair process.

2. Repair process

All Acrylic specimens (except control group A) were cut from the middle into two pieces with presence of a gap of 3 mm between two fractured pieces. After lubricating the mould with separating medium, the fractured pieces were positioned onto stone mould with a butt joint in which there was no further change of the specimens as shown in the Fig.3. The first group was left intact and considered as control. The Group B was repaired without any manipulation with chemical and mechanical surface treatments. The Group C was treated with applying of a liquid monomer for 3 minutes using a fine brush (No: zero) before repairing process. The Group D was surface treated using a stainless steel wire with diameter of 0.7 mm, which formed as zigzag shape and positioned between two fractured pieces (Fig. 4). The group E was repaired viaa glass fiber (FiberForce, SYNCA, Canada), which positioned after preparation of cavity between two fractured pieces (Fig.5). The group F was repaired with both liquid monomer (for 3 minutes) and wire (diameter of 0.7 mm with zigzag shape). The Group G was repaired with a combination of monomer (for 3 minutes) and glass fibers.All repaired acrylic specimens (with control group) then kept into distal water to prevent acrylic shrinkage and ready for transverse testing[18]. Athree point bending testin a universal testing machine (Instron, Germany) was utilized for measuring transverse strength (Fig. 6). The load was applied with a constant speed of 5 mm/min until fracture occurred. The values were recorded in kilogram andthen converted to Newton via this formula Newton= 9.80 Kilogram.The values of transverse strength (MPa) was obtained by usingthis formula $T=3PT/2BD^{2}$[19],Where T = transverse strength (N/mm^2=MPA),P= Fracture load (Newton), T=Span length (millimeter), B=Sample width (millimeter), and D = sample thickness (millimeter).All samples data were analyzed using SPSS 12.1 software and summarized by providing values of mean, standarddeviation, standard error, 95% confidence intervals, minimum and maximum loads for bothcontrol and repaired groups.Among all groups, the comparisons were recorded using ANOVA (Analysis of variance) and Tukey tests with considering the significant findings whenP value < 0.05.

Results

In this study, the transverse strength of repaired acrylic resins had been influenced by the type of surface treatment used.The values of transverse strength of all groups (control & repaired groups) were demonstrated in Table 1. The results showed that the wire with monomer group had the highest mean of transverse strength followed by fiber and monomer group. In addition to above, the use of glass fibers only improved significantly the bond strength. Similarly, the transverse strength of heat cured acrylic resin following repairing process had significantly been improved after using a stainless steel wire with diameter of 0.7 mm. On the other hand, the group which was not treated with any surface treatment had the lowest value of transverse strength. In our study, the results revealed that the use of both a liquid monomer and placement of glass fibers or stainless steel wires enhanced significantly the bond strength when compared to groups of monomer, glass fiber and wire as shown in Table 1. More specifically, the use of a liquid monomer and stainless steel wire created a higher bond strength for repaired acrylic samples in comparison to monomer group and wire group. Similarly, the bond strength of repaired acrylic specimens had been increased when using monomer and fibers compared to monomer group and fiber group. In this study, Tukey test was utilized for multiple comparisons for control group and all repaired groups. The results indicated that there were statistically significant differences between control group and all repaired groups where ($p < 0.05$) as shown in Table 2. As well, the samples groups which were repaired with various surface treatments (untreated, monomer, metal wire and glass fibers) were statistically assessed and compared using Tukey test. The results indicated that there were highly significant differences between the repaired groups ($P < 0.05$) as shown in Table 3. On the other hand, there were no significant differences between fiber & monomer and wire & monomer groups ($P > 0.05$).

Among all tested groups,ANOVA test was performed and it was found that there were highly significant differences between groups with different surface treatments ($P < 0.05$) as shown in Table 4.

Discussion

For repairing a fractured denture, several approaches exist to restore its original strength and function[20]. The acrylic denture base is assessed by transverse test, which depends on three point loading system, where it reflects the loading arrangement in the clinical situation[21]. For this reason, transverse strength test was chosen in this study.In this study, the findings showed that all acrylic specimens, which were treated chemically and/or mechanically, presented significantly a higher value of bond strength in comparison to specimens that were repaired without surface treatment (untreated group). For instance, coating the acrylic samples with a liquid monomer for 3 minutes improved significantly the transverse bond strength when compared to untreated group. These results are in accordance with Abdul Hadi (2007)[22]study, which stated that a new interwoven polymer chains are formed with a repair material because of dissolving the outer layer of repaired denture base by monomer. On the other hand, our results disagree with the results of both (Belyi and VonFrunhofer, (1980) [23] and Grajower and Goultschin(1984)[24] ,where they stated that the application of a liquid monomer had no effect on the bond strength.Besides, in this study the transverse strength of repaired acrylic samples was increased after using a stainless steel wire (0.7mm) since the capability of metal wire to resist a higher force and support the materials used for repair. Our results were similar to Golbidi and Mousavi (2010)[8] study, which indicated that the acrylic samples repaired with a metal wire displayed a higher bond strength than untreated samples.

Likewise, the bond strength was significantly improved when using glass fibers. This was in agreement to hanna (2010)[25] study where the bond strength was significantly increased when using glass fibers in comparison to untreated group.Furthermore, the use of both chemical and mechanical surface treatments improved significantly the strength of repaired acrylics as compared to groups treated only with chemicals and / or wires and fibers as shown in Table 1. This was similar to study which undertaken by hanna (2010)[25] regardless the type of materials used. They stated that the use of both glass fibers with saline coupling agents) enhanced significantly the bond strength as compared to fiber group without use of saline agent.Finally, the untreated group which were not chemically and mechanically surface treated displayed a lower value of bond strength in comparison to repaired groups with any surface treatment (Table 1). This was in accordance with Auda (2007)[12] study which indicated that the use of monomer enhanced significantly the transverse bond strength as compared to untreated surface.The current research evaluated the bond strength of repaired acrylic via transverse test. Patients with fractured dentures preferred the fabrication of new prosthesis. However, the main the challenges faced by the patients were cost and time consuming. In these situations, repairing of fractured dentures is necessary to restore denture strength. The current study suggested that both use of chemicals with both wires and glass fibershad a significant effect on transverse bond strength of repaired acrylics. The null hypothesis, therefore, was rejected since there were significantly differences among all groups of repaired acrylic samples. However, further investigation of different acrylic resins (i.e. cold cured, and light cured materials), various joint shapes (rabbet, bevel, round) with different surface treatments to accomplish the optimum bonding is required**.**From the present study, it has concluded that a combination of mechanical and chemical surface treatments exhibited higher values of transverse bond strength than other surface treatment groups.As well, the repaired specimens without any chemical and mechanical surface treatments produceda lower transverse strength when compared to other repaired groups.The repaired joints with monomer, stainless steel wire and fibers had significantly improved the transverse strength of the repaired acrylic specimens.

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and impact strength of denture base resin repaired by various methods. An In Vitro Study. Journal of American Science.2010. 6(9):115-125.

Tables

Table 1. Descriptive values of transverse strength of all tested groups

Groups	Mean	SD	Std. Error	95% Confidence Interval		Minimum	Maximum
				Lower bound	upper bound		
Control	114.8	2.27567	.71963	113.2171	116.4729	110.60	118.50
Untreated	53.4	1.59124	.50319	52.3227	54.5993	50.60	55.90
Monomer	77.7	2.01704	.63784	76.3021	79.1879	73.50	79.90
Wire	110.5	2.74403	.86774	108.6300	112.5560	106.16	114.48
Wire plus monomer	118.9	1.65973	.52485	117.7767	120.1513	115.66	121.12
Glass fiber	106.7	3.85255	1.21828	103.9801	109.4919	101.50	113.17
Monomer plus fiber	118.2	1.98827	.62875	116.7737	119.6183	115.46	121.42

Table 2. Multiple comparisons between control and repaired groups

P value	Mean	Groups	P value	Mean	Groups
0.000*	114.8 106.7	Control Fiber	0.004*	114.8 110.5	Control Wire
0.043*	114.8 118.2	Control Fiber monomer	0.006*	114.8 118.9	Control Wire & monomer
0.000*	114.8 76.10	Control Monomer	0.000*	114.8 53.4	Control Untreated

*significant when P <0.05

Table 3. Multiple comparisons among repaired groups

P value	Mean	Groups	P value	Mean	Groups
0.012*	110.5 106.7	Wire Fiber	0.000*	53.4 77.7	Untreated Monomer
0.000*	77.7 110.5	Monomer Wire	0.000*	53.4 110.5	untreated Wire
0.000*	77.7 118.9	Monomer Wire & monomer	0.000*	53.4 118.9	Untreated Wire &monomer
0.000*	77.7 106.7	Monomer Fiber	0.000*	53.4 106.7	Untreated Glass fibers
0.000*	77.7 118.2	Monomer Fiber& monomer	0.000*	53.4 118.2	Untreated fiber &monomer
0.000*	110.5 118.9	Wire Wire &monomer	0.000*	106.7 118.9	Fiber Fiber & monomer
0.000*	118.9 106.7	Wire &monomer Fiber	0.000*	110.5 118.2	Wire Fiber & monomer
			0.991	118.9 118.2	Wire &monomer Fiber&monomer

*Significant when P <0.05

Table 4. ANOVA test among all tested samples

Sig.	F	Mean Square	df	Sum of Squares	
0.000	1.0653	6216.348	6	37298.090	Between Groups
		5.837	63	367.731	Within Groups
			69	37665.820	Total

Figures

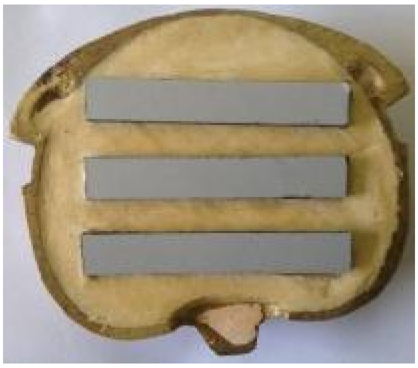

Fig.1. Plastic samples within stone mould

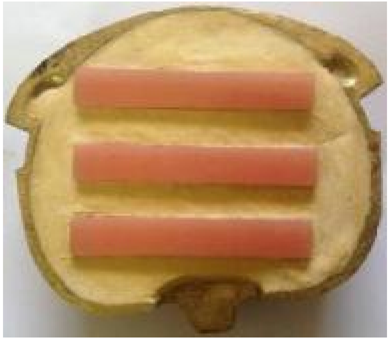

Fig.2. Acrylic samples were fabricated

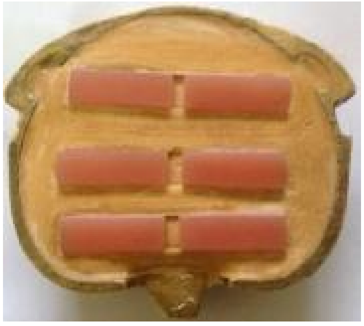

Fig.3. Preparation of butt joint

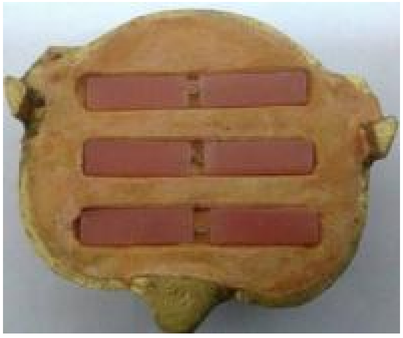

Fig.4. A piece of wire positioned in the gap

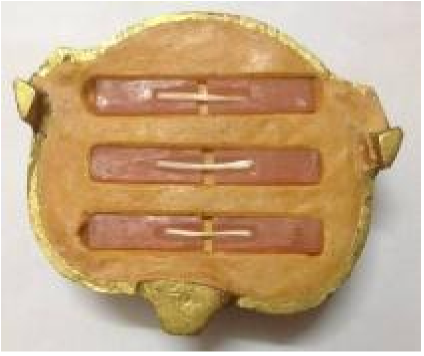

Fig.5.Glass fibers positioned in the gap

Fig.6 acrylic specimen under test