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Acrylic denture base repair (Part II): Strength of acrylic denture base cured by four different techniques.

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ABSTRACT

Aim: To investigate the effect of repair techniques, surface treatment, and repair space design (3 mm space and no repair space) on the transverse, and tensile strengths of repaired denture base. **Materials and methods**: Four hundred and sixteen samples of two brand heat cured acrylic resin were repaired by four different techniques (water bath, microwave, thermo press, and chemically cured acrylic resin), treated and untreated with monomer, and repaired with 3 mm space, or no space at fracture area. The samples were tested to measure transverse, and tensile strengths, of repaired, and intact (control) samples. **Results**: Showed that transverse strength of acrylic denture base repaired by chemically cured acrylic resin was significantly lower ($P<0.001$) than that of water bath, microwave and thermo press. Transverse strength of repaired acrylic denture base was significantly improved ($P<0.001$) by monomer surface treatment for 180 seconds, and no space repair design showed the lowest transverse strength compared to 3 mm space repair design. The tensile strength of acrylic denture base repaired by microwave was significantly higher than that of water bath, thermo press, and chemically cured acrylic resin. Acrylic denture base treated with monomer for 180 seconds showed the highest tensile strength compared to untreated acrylic denture base. **Conclusion**: Acrylic denture base with 3 mm space and treated with monomer that repaired with microwave and water bath techniques were better than other techniques. The samples repaired by chemically cured acrylic resin without surface treatment showed significantly the lowest mean tensile strength. And microwave repairing technique was more time saving and more clean process than water bath technique.

Key words: Repair acrylic denture base, microwave, thermo press.

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INTRODUCTION

Heat cured Poly methyl methacrylate resin is the most common 'plastics' used in the production of denture bases and the repair of dentures. The curing is carried out through polymerizing the liquid monomer (MMA) to a solid (PMMA). In this instance the polymerization is brought about the application of external heat by hot water bath or microwave.[1,2]

Acrylic resin denture base materials are brittle and susceptible to fracture after periods of clinical use or accidentally.[3,4]

The repair of the fractured acrylic denture base can be accomplished using acrylic resins that are light–polymerized, auto polymerized, or heat–polymerized (by water bath or by microwave).[5,6]

Many studies have been conducted to compare several properties of acrylic denture base repaired by different repairing techniques. These studies showed that acrylic denture base repaired by heat cured acrylic resin (processed by water bath and microwave) had higher properties to that repaired by chemically cured acrylic resin.[7,8] Denture bases processed with conventional heating and microwave energy exhibited the same level of accuracy. [9]

An effective repair procedure should restore the original strength of denture base, avoid further fracture, have a short dur-

ation of curing, possess high strength and durability, and should be simple to use, cheap, good aesthetics, non–allergenic and does not distort the existing denture.[8,10] So, the study of transverse strength, and tensile strength of repaired acrylic denture base cured by different curing techniques has valuable clinical implications.

MATERIALS AND METHODS

Four hundred and sixteen heat cured denture base samples were prepared. Half of them from major base 2 **(**Major Prodotti Dentari S.P.A, ITALY), and the other half from Quayle Dental heat cured denture base material (Ouayle Dental, England). The specimens were prepared by cutting the hard elastic foil (master model) by electrical saw with 65 $\pm$ 0.3×10 $\pm$ 0.03 ×2.5 $\pm$ 0.03 mm (length, width and thickness respectively) for transverse strength test.[11] For tensile test the control group dimensions were 90×10×3 mm (length, width and thickness respectively).[12]

Acrylic resin specimens were prepared in a mold made by investing a hard elastic foil with specific dimensions according to each test as mentioned previously in dental stone against glass slab which was considered as the polished surface and the other side was considered as the tissue surface. The acrylic resin was cured by two steps polymerization of water bath, 70 ˚C for 30 minutes, then proceed at 100˚C for 30 minutes (according to the manufacturer's instructions). For repairing procedure the fractured acrylic denture pieces were made by preparing a mold for the two fractured denture base pieces as in part I of this research. The selected designs and spaces are; lap rabbit with no space (intimate contact), and 3mm space left between the two fracture ends**.** Fractured denture base pieces were cured by conventional water bath technique.[13] The repair procedure was done according to the following techniques: -

- Heat cured acrylic resin cured by thermostatically controlled water bath using metal flask and curing cycle mentioned previously.[7,13,14]
- Heat cured acrylic resin cured by microwave oven. Iraqi fiberglass flask [15] was used to repair the specimens by microwave oven. The curing cycle of acrylic resin was done by placing the fiber reinforcement plastic (FRP) flask in the microwave oven for 30 minutes at low setting (80 watts), 15 minute presides, followed by 1.5 minutes at the high setting (500 watts) [16]. Then the flask was left aside for slow bench cooling before opening.
- Heat cured acrylic resin was polymerized by using thermo press machine (MINI 2000). This device polymerized the heat cured acrylic resin by pressure (6 bar) at 80ºC applied heat for 25 minute (according to manufacturer's instructions).
- Chemically cured resin in which the cellophane paper was placed above the dough between the two halves of the flask, then the flask was pressed and access resin was removed by a sharp wax knife. The flask was left in a clamp holder under pressure for 15 minutes till the resin set completely.[17]

The repaired acrylic resin specimens were stored in distilled water at 37 $\pm$ 1 ºC for 48 hours.[11] The following tests were done: - Transverse strength, and tensile strength.

*Transverse Strength***:** Two hundred seventy two acrylic denture base specimens were prepared from two different brands of heat cured acrylic resin cured by water bath. These acrylic denture bases were divided into, one control group and sixteen repaired groups each subgroup contains eight samples. The samples of transverse strength test were prepared from two fractured acrylic denture base parts which were repaired by different curing techniques (conventional water bath, microwave oven, Thermo press, and chemically cured resin), with, or without surface treatment with monomer, and with, or without space (3 mm space, and no space).

The two fractured acrylic denture bases were placed in a stone mold which had been prepared previously for control group and repair procedure was carried out as mentioned above to form acrylic resin specimens for transverse strength with dimensions 2.5 $\pm$ 0.03 × 10 $\pm$ 0.03 × 65 $\pm$ 0.3mm (thickness × width × length respectively) (Figure 1). All specimens were incubated in distilled water for 48 hours at 37 $\pm$ 1ºC.

The transverse strength of the repaired acrylic resin was measured by three–point transverse testing machine.[11] The

sample was supported at each end by a roller of 3.2 mm diameter. The distance between the two rollers was 50 mm (repressenting the average molar to molar distance). The load was measured by using compression machine (Inc. Model CN, 472 EVANSTON I11–USA) at cross–head speed of 0.5 cm per minute.[18] Transverse strength (TS) was calculated according to the following equation: $TS = 3WL/2bd^2$ [2] (TS: Transverse strength (MPa), W: Maximum load at midpoint of the sample (Kg), L: Distance between the supports (50 mm), b: Width of the sample (10mm), d: Thickness of the sample (2.5mm)).

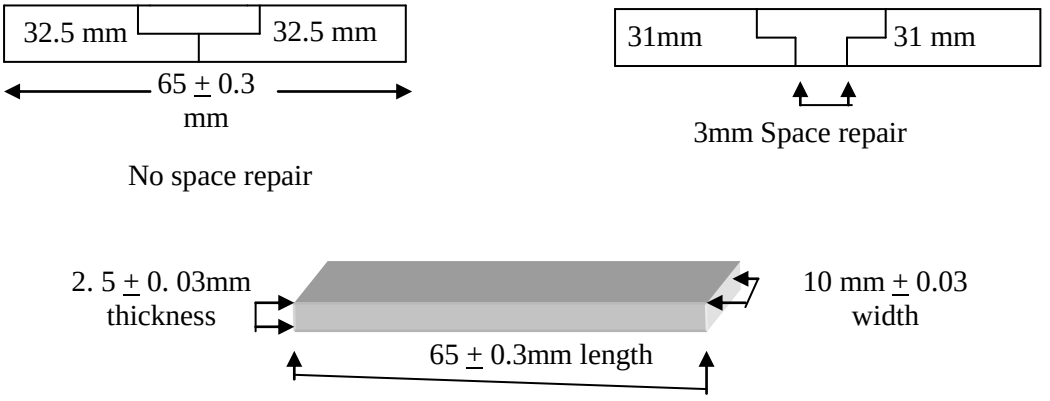

Figure (1): Dimensions for control and repaired acrylic resin specimens for transverse strength test

Tensile Strength: One hundred forty four specimens were prepared from two different brands. These acrylic denture bases were divided into one control group, and eight repaired groups each one contains 16 samples.

The dimensions of acrylic resin specimens prepared for tensile strength were 3 × 10 × 90 mm (thickness × width × length respectively).

These specimens were prepared from two heat cured acrylic denture base (each piece was prepared separately with 3 × 10× 43.5 mm thickness × width × length respectively), and stored in distilled water at 37 ± 1ºC for 48 hours in an incubator. Then the two pieces were placed in a stone mold prepared for control group with maintaining 3 mm gap between two prepared acrylic denture bases at the midway, (Figure 2).

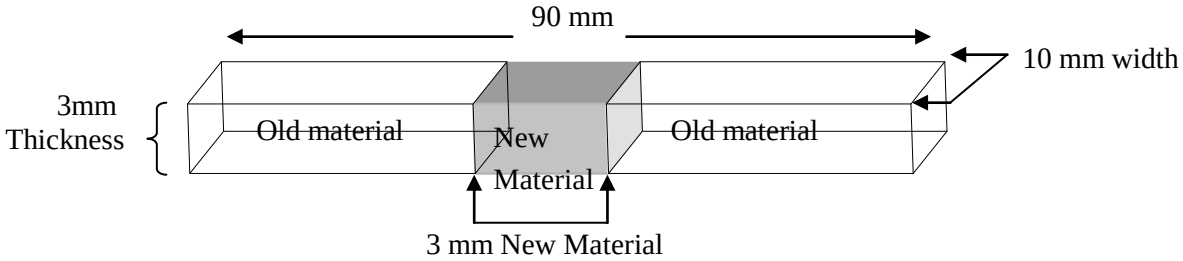

Figure (2) Diagram of tensile test samples

These two acrylic denture bases were treated, or untreated with monomer at the two faced surfaces. Then a new acrylic resin material cured by a different technique (conventional water bath, microwave oven, thermo press, and chemically cured resin) was pressed at the midway to replace the 3 mm space. The specimens were stored in distilled water at 37 ± 1ºC in an incubator for 48 hours. Then Instron tensile testing machine was used to test the specimens. The samples were

grasped by the two arms of the universal tensile testing machine and the tension force was applied in opposite direction till the fracture occurred at cross head speed of 5 mm/minute. The values were recorded from clock like gage for each specimen and the tensile bound strength was calculated by the following equation.[19] Tensile strength= F (N)/ A (mm^2) (F: Tension force, A: Cross section of the specimens).

RESULTS

Transverse Strength (TRS): The mean of transverse strength and standard deviation of samples repaired by water bath, microwave energy, thermo press, and chemically cured acrylic resin (irrespective to surface treatment and repair space design) are shown in Table (1–3) and Figure (3).

Table (1): Means and Standard deviation of transverse strength for two brands of acrylic resin curd by different curing techniques.

Curing technique	Materials			
	Major base		QD	
	Mean ± SD (MPa)	Number	Mean ± SD (MPa)	Number
Control group	81.3 ± 3.33	8	81.06 ± 1.37	8
Water bath	64.2 ± 4.97	32	64.016 ± 0.59	32
Microwave energy	64.7 ± 4.93	32	64.355 ± 0.59	32
Thermo press	60.4 ± 3.17	32	59.867 ± 0.38	32
Chemically cured resin	47.3 ± 2.99	32	46.961 ± 0.38	32

MPa: Mega Pascal; SD: Standard deviation.

Table (2): Means and standard deviation of transverse strength for acrylic denture base material repaired with or without surface treatment.

Surface treatment	Mean ± SD (MPa)	Number
Control group	81.219 ±3.474	16
Treated	60.937 ±7.803	128
Untreated	56.666 ±7.888	128

MPa: Mega Pascal; SD: Standard deviation.

Table (3): Means and standard deviation of transverse strength for repair space design of heat cured acrylic denture base resin.

Repair space design	Mean ± SD (MPa)	Number
Control group	81.219 ±3.474	16
3 mm space	61.226 ±8.120	128
No space	56.337 ±7.358	128

MPa: Mega Pascal; SD: Standard deviation

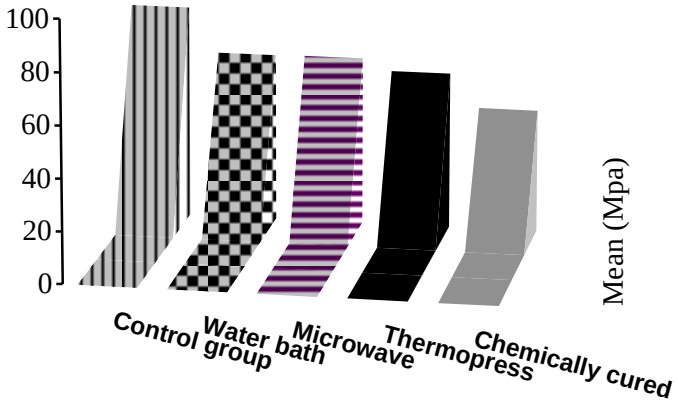

Figure (3): Mean transverse strength of control group and different repair techniques of acrylic denture base.

Analysis of variance (ANOVA), Table (4), showed that there was a significant difference (p < 0.001) in TRS of samples repaired by water bath, microwave, thermo press, and chemically cured acrylic resin. There was a significant difference (p < 0.001) in TRS of untreated, and treated samples.

Duncan's multiple range test for the four curing techniques, Table (5), showed that intact (control) acrylic denture base has significantly higher mean than all repaired denture bases. The acrylic denture base repaired by microwave, and water bath had significantly higher mean TRS, followed by thermo press, then chemically cured resin show the lowest mean.

The mean TRS and standard deviateon of 3 mm space samples was significantly higher than mean of no space samples Table (3). Analysis of variance (ANOVA), Table (4), showed that there was a signifycant difference (p <0.001) in TRS of no space and 3 mm space repaired samples.

Table (4): Analysis of variance (ANOVA) for curing techniques, surface treatment, repair space, and their interaction.

Source of variance	DF	Sum of square	Mean square	F-value	*P –value*
Curing technique	4	38503.094	9625.773	1643.95**	0.0001
Surface treatment	1	913.952	913.952	156.09**	0.0001
Repair space design	1	1251.362	1251.362	213.09**	0.0001
Curing technique × Surface treatment	4	250.279	62.569	10.69**	0.0001
Curing technique × repair space design	4	460.563	115.140	19.66**	0.0001
Surface treatment × repair space design	1	56.784	56.784	9.70**	0.0002
Curing technique × surface treatment × repair space design	4	102.459	25.614	4.37**	0.0019
Error	280	1639.472	5.855		
Corrected total	299	43177.97			

**&* Mean significant at 0.01& 0.05 respectively; DF: Degree of freedom.

Table (5): Duncan's multiple range test for interaction between curing techniques, surface treatment, and repair space design.

Curing technique	Treated		Untreated	
	No space Mean ± SD (MPa)	3mm space Mean ± SD (MPa)	No space Mean ± SD (MPa)	3mm space Mean ± SD (MPa)
Water bath	64.81 ± 3.35 D	68.96 ± 2.30 A	57.75 ± 2.04 F	65.62 ± 2.15 B C
Microwave energy	64.81 ± 2.59 D C	68.59 ± 1.60 A	57.35 ± 2.03 F	66.65 ± 2.04 B
Thermopress	59.75 ± 1.79 E	63.37 ± 1.50 D	56.12 ± 1.85 F	59.81 ± 1.36 E
Chemically cured resin	47.25 ± 1.34 H	50.59 ± 1.56 C	43.50 ± 1.54 I	46.50 ± 1.44 F

MPa: Mega Pascal; SD: Standard deviation; Means with different letters horizontally and vertically are statistically different.

Tensile Strength TS: The mean of tensile strength and standard deviation of samples repaired by water bath, microwave, thermo press and chemically cured acrylic resin techniques, (irrespective to surface treatment) are shown in Table (6, 7), and Figure (4), and demonstrated that the mean TS and standard deviation of samples repaired by microwave technique was significantly higher than mean TS of samples repaired by chemically cured acrylic resin.

Table (6): Means and Standard deviation of tensile strength for major base2 and QD acrylic denture base resin repaired by different curing techniques.

Curing technique	Materials			
	Major base		QD	
	Mean ± SD (N/mm²)	Number	Mean ± SD (N/mm²)	Number
Control group	74.90 ± 1.26	8	75.36 ± 1.27	8
Water bath	64.83 ± 1.33	16	63.36 ± 2.03	16
Microwave energy	67.27 ± 2.16	16	67.20 ± 2.13	16
Thermopress	59.42 ± 1.95	16	60.90 ± 1.88	16
Chemically cured resin	52.47 ± 1.90	16	51.42 ± 1.86	16

SD: Standard deviation;

Table (7) Mean and standard deviation of tensile strength for control samples, treated and untreated samples.

Surface treatment	Mean ± SD (N/mm²)	Number
Control group	75.13 ±1.252	16
treated	60.383 ±5.687	64
untreated	46.739 ±6.539	64

SD = standard deviation.

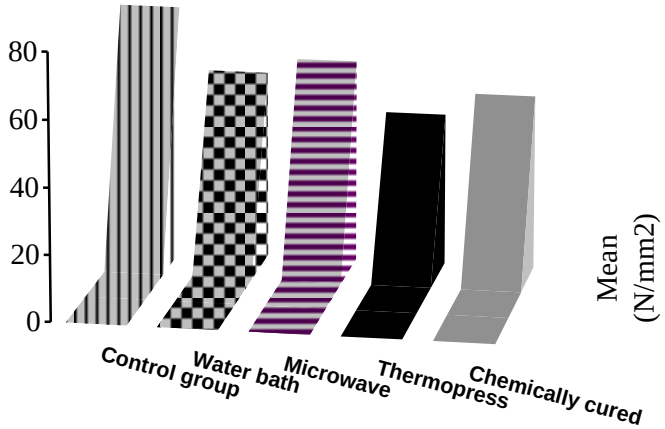

Figure (4): Mean tensile strength of control group and different repair techniques of acrylic denture base.

Analysis of variance (ANOVA), table (8), shows that there was a significant difference (P< 0.001) in TS of treated and untreated samples. Duncan's multiple range test of TS for different curing techniques Table (9), showed that samples repaired by microwave with surface treatment afforded significantly higher mean TS (67.2± 0.520 N/mm²). While the samples repaired by chemically cured acrylic resin without surface treatment showed significantly the lowest mean TS (39.4 ± 0.621 N/mm²), followed by water bath and thermo press, and the chemically cured resin (45.72 ± 6.69 N/mm²) is the lowest.

Table (8): Analysis of variance (ANOVA) for curing techniques, surface treatment and their interaction.

Source of variance	DF	Sum of square	Mean square	F–value	*P*–value
Curing technique	4	13121.542	4030.385	1294.29**	0.0001
Surface treatment	1	6216.295	6216.385	1996.26**	0.0001
curing techniques × surface treatment	4	1983.009	495.752	159.20**	0.0001
Error	140	435.956	3.113		
Corrected total	149	24756.804			

**&* Mean significant at 0.01& 0.05 respectively.

Table (9) Duncan's multiple range test of tensile strength for the interaction between different curing techniques, and surface treatment.

Curing technique	Surface treatment			
	Treated		Untreated	
	Mean ± SD (N/mm²)		Mean ± SD (N/mm²)	
Water bath	64.1 ± 0.457	B	44.7 ± 0.379	F
Microwave energy	67.2 ± 0.520	A	54.4 ± 0.228	D
Chemically cured resin	51.9 ± 0.476	E	39.4 ± 0.621	H
Thermopress	60.1 ± 0.501	C	42.4 ± 0.532	G

SD: Standard deviation; Means with different letters horizontally and vertically are statistically significant.

DISCUSSION

Transverse Strength (effect of curing technique): The result of this study showed that transverse strength of acrylic denture base repaired by water bath and microwave has no significant difference and both were significantly higher than thermo press and chemically cured acrylic resin.

The heat conduction of conventional water bath, and energy conversion of microwave heating would cause high degree of MMA conversion to PMMA and give rise to minimum, or no porosity, and stiffer resin. In addition to that the low plasticizer content of heat cured acrylic resin polymer beads results in good adherence between two similar acrylic resins.[2, 20]

The Effect of Surface Treatment with Monomer: The effect of surface treatment of the acrylic denture base with monomer for 180 seconds before repair procedure significantly enhanced the transverse and tensile strengths.

Painting the surface of acrylic resin by monomer softens and dissolves the acrylic resin surface to enhance the bond of repair material dough to the acrylic denture base material. Such surface treatment causes a superficial crack propagation, as well as formation of numerous pits. This surface morphologic change may enhance the mechanical retention between fractured surface and repaired material.[6, 21, 22]

Surface treatment is important to achieve acrylic denture base surface clean, and free of contamination of dental laboratory such as wax, and separating medium.[23, 24]

The Effect of Space Repair Design: The result of this study showed that fractured acrylic denture base repaired with 3 mm space at the fractured site significantly revised its transverse strength. The possible explanation for this result is related to the greater area of old resin to be brought into contact with the new material than if only reduction with no space repair between the two fractured denture base.[14, 25]

Tensile Strength (the effect of curing techniques): Microwave heating is energy conversion, in which the resin absorbs energy and converts it to a local heat, rising the temperature of the resin quicker and higher than that of conventional water bath technique.[1,26]

Therefore, the rate of monomer diffusion could be higher in microwave techniques that provide higher bond strength of repaired acrylic denture base. In addition, these results can be attributed to high rate of cross–linking between similar resin base materials.[5,22]

CONCLUSION

All repaired samples had lower transverse strength and tensile strength than control (intact) samples. Microwave repairing technique had superior tensile strength than other curing techniques. Microwave and water bath repairing technique showed higher transverse strength than thermo press technique and chemically cured resin. Acrylic denture base repaired with surface treatment by monomer exhibited repair strength that was superior to those repaired without surface treatment. Repairing acrylic denture base with 3-mm space at the fracture site has a superior transverse strength than those without space.

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