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The Effect of Surface Treatment on the Transverse and Tensile Bonding Strength of Relined Acrylic Resin Denture Base (Part I)

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الخلاصة

الأهداف: تهدف هذه الدراسة إلى تقييم تأثير سمك مواد تبطين، طريقة معالجة (حمام مائي أو الموجات الدقيقة) ، والمعالجة السطحية بالمثيل ميثاكريلات على قوة الشد العرضي والطولي على قاعدة طقم الأسنان المبطن. **المواد وطرائق العمل:** أجريت دراسة رائدة من خلال إعداد (65) عينة لتقييم تأثير سماكة تبطين المواد فيما يتعلق قوة الشد العرضية والطولية من الراتنج الاكريلي لقاعدة أسنان، ودراسة تأثير المعالجة السطحية بالمثيل ميثاكريلات . وكان عمله الرئيس في الدراسة بإعداد (٣٢٠) عينة وتنقسم إلى قسمين لدراسة الخواص الميكانيكية للعينات التي تمثل قاعدة الطقم المبطنة و علاجه عن طريق حمام ماء والمجموعة الأخرى عن طريق تقنية المعالجة بالموجات الدقيقة، ومن ثم تأثير إعادة تبطينها بواسطة طريقتين، تم تقييم تأثير المعالجة السطحية. وتم استخدام تحليل التباين (ANOVA) واختبار دنكن مجموعة متعددة من أجل التحليل الإحصائي. **النتائج:** أظهرت هذه الدراسة عدم وجود اختلاف في الخواص بين سمك قاعدة الطقم المبطنة المواد. كان هناك اختلافا كبيرا على قوة الشد العرضية في قاعدة الطقم المبطن بالمعالجة . وتحسنت بشكل كبير على قوة الشد العرضي وقوة الترابط من العينات المبطنة (P = ٠.٠٥) عن طريق المعالجة السطحية مونيمر لمدة (١٨٠) ثانية. **الاستنتاجات**: تأثرت قوة الشد العرضية من قاعدة الراتنج الاكريلي بواسطة التبطين. أعطى طريقة المعالجة بالموجات الدقيقة طريقة علاج أفضل الخصائص الميكانيكية لقاعدة الراتنج الاكريلي المبطن.

ABSTRACT

Aims: To investigate the effect of the thickness of relining material, curing method (water bath or microwave), and the surface treatment by methyl methacrylate on transverse and tensile strength of relined acrylic resin denture base. **Materials and methods:** A pilot study was done by preparing 65 samples to evaluate the effect of the thickness of relining material in relation to denture base on the transverse strength of acrylic resin denture base, and to study the effect of surface treatment by methyl methacrylate on the transverse strength of acrylic resin denture base. The main study was done by preparing 320 samples and divided into two parts to study the mechanical properties of samples representing a denture base cured by water bath and other group cured by microwave curing technique, and then the effect of relining by the two curing methods and the effect of surface treatment were evaluated. Analysis of variance (ANOVA) and Duncan's multiple range tests were used for statistical analysis. **Results:** of this study showed that the different thickness of relining material in relation to denture base had no significant difference on the transverse strength of the relined denture base. The transverse strength and tensile bonding strength of the relined samples were significantly improved (P=0.05) by monomer surface treatment for 180 seconds. **Conclusions**: Transverse and tensile strength of the acrylic resin denture base were affected by relining. Microwave curing method gave better mechanical properties of the relined acrylic resin denture base.

Key words: Relining denture base, Thickness of relining, Microwave curing.

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INTRODUCTION

In 1937, polymethyl methacrylate (PMMA) was introduced, and used widely as a denture base material. PMMA provided enhanced physical, and esthetic properties; in addition it was readily available, inexpensive, and easily manipulated.[1- 3] Polymethyl methacrylate had an accepta(flexural strength), and impact strength of a material is a measure of stiffness,[4] and resistance to fracture. Flexural strength tests were undertaken as these were considered relevant to the loading characteristics of a denture base in a clinical situation.[5,6] Among the favorable properties of poly methyl methacrylate denture base resin is its ability to bond to new resin even after complete polymeriza-

tion. However, one common problem with relining is failure in adhesion between the reline material and the denture base material.[2]

Aims of this study were to investigate the effect of the thickness of relining material, curing method (water bath or microwave), and the surface treatment by methyl methacrylate on transverse and tensile strength of relined acrylic resin denture base.

MATERIALS AND METHODS

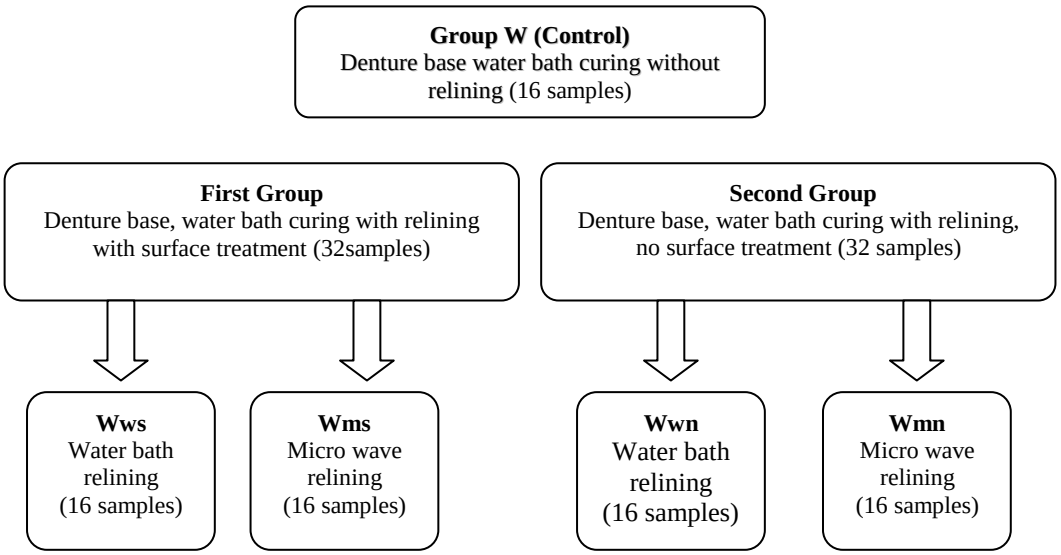
A pilot study was done to determine the best thickness of relining material in relation to denture base on (65) samples prepared from major heat cured resin in dimensions of 65×10×2.5±0.03mm for transverse strength test according to ADA specification No. 12 with different relining thicknesses (0.5mm, 1mm, 1.5mm).The results showed that there was no significant difference (Table 1).

Table (1) Mean, Standard Deviation and Significance of the Transverse Strength (N/mm²) of the Relined Samples of the pilot study.

	Sum of square	Df	Means square	F	Sig.
Between group	1594.341	9	177.149	85.946	0.000
within group	144.281	70	2.061		
Total(Major)	1738.622	79			
Between group	1874.675	9	208.297	99.997	0.000
within group	145.813	70	2.083		
Total (QD)	2020.488	79			

Df= degree of freedom, F= F value, Sig.= Significance

Main Study: Three hundred twenty samples were prepared; half of them were prepared from Major heat curing resin, while the other half was prepared from Quayle dental heat curing resin. Two curing cycles were used in this study, water bath (30 min. at 73°C then 30 min. at 100°C according to manufacture instructions), and Microwave (15 min. at 80 Watt. Per side then 1.5 min. at 500.[7] The study was divided into two parts (Figure 1):



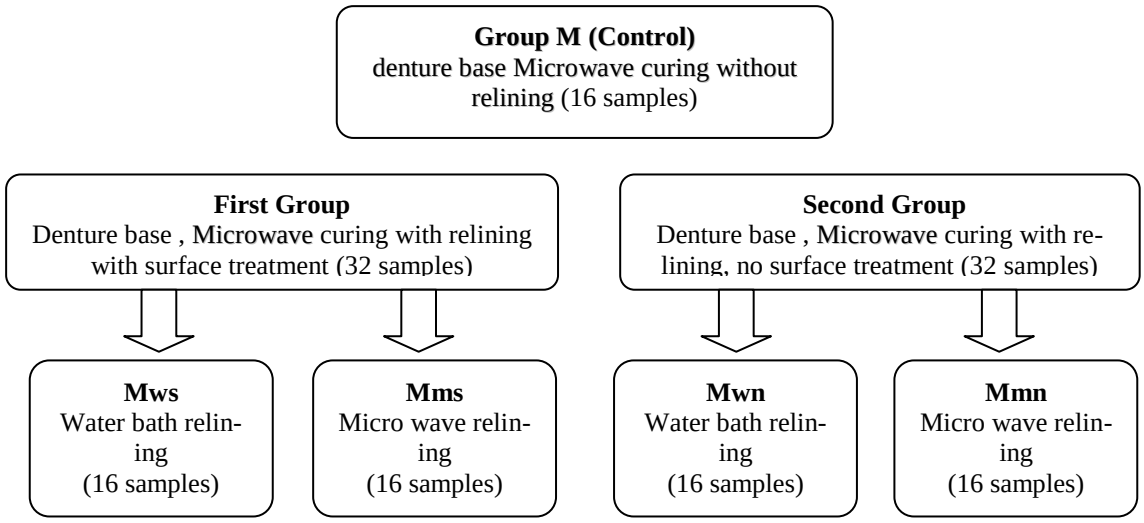


Figure (1): Experimental Design of the Study.

1. Part W : involved studying the transverse and tensile strength of samples representing a denture base cured by water bath curing method, then the effect of relining by two curing methods (water bath, and microwave), and the effect of surface treatment was studied.

2. Part M : involved studying the mechanical properties of samples representing a denture base cured by microwave curing method, then the effect of relining by two curing methods (water bath, and microwave) and the effect of surface treatment was studied.

Transverse Strength Test: One hundred sixty samples with dimensions of 65×10×2.5±0.03mm (length, width and thickness) respectively were prepared according to ADA specification no.12. Representing the control group, for relined samples, the ratio of relining to denture base was 1:1.5 mm. According to the results obtained from a pilot study (Table 1). So a thickness of 1 mm relining material: 1.5 mm of denture base was chosen in this study.[8-13] The acrylic specimens were prepared by using a sheet of wax with 1.5mm of thickness which represented the denture base to be relined. These samples were placed in moulds with 2.5 mm thickness, the polished surface faced downwards and the tissue surface faced upwards. The acrylic polymer and monomer were mixed according to the manufacturer instruction, half of the samples were surface treated by application of methyl methacrylate monomer by using a fine brush for 180 sec, [14-17] and the other half was not treated. The acrylic dough was applied over the tissue surface of the samples, and then packing, curing, and deflasking were proceeded. The cured samples were stored in distilled water at 37^{o}C for 48 hr. before testing.

The test was done by using an Instron testing machine. The devise was supplied with a central loading plunger, and two supports, with polished cylindrical surfaces of 3.2 mm in diameter and 50 mm between supports. The supports should be parallel to each other and perpendicular to the central line. The tests were carried out with cross head speed of 5mm/min. The surface of the denture base material was placed facing down for each of the relined specimens. The samples were deflected until fracture occurred. The transverse strength was calculated using the following equation:- [19]

$$S = \frac{3PI}{2bd^2}$$

S= transverse strength (N/mm^2) b= width of specimen (mm). d= depth of specimen (mm)

I= distance between supports (mm). P= maximum force exerted on specimen (N)

Tensile Bonding Test: One hundred sixty samples with dimensions of 90×10×3 mm (length, width, and thickness) respectively were prepared representing the control group samples, then for relined

samples a metal spacer was placed at the center of the mould with dimensions of 10×10×3 mm, then packing, and curing were done, after curing the two parts of the sample were removed and stored in distilled water at 37°C for 24 hr. before relining. Then the two acrylic parts of each sample were placed back into the moulds, surface treatment was done to half of the samples at the two surfaces facing the space made by metal spacer. After that, the relining material was packed into the space then curing was proceeded [20] (Figure 2).

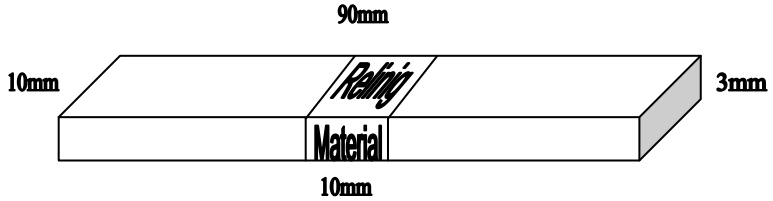


Figure (2): Sample of Tensile Bonding Test.

The samples were conditioned at 37°C for 48 hr. in distilled water before testing.[21] All samples were placed under tension until fracture occurred in a universal testing machine (WolPert, Germany) at a cross head speed of 5 mm/min. Tensile bond strength values were recorded for each specimen.Tensile bond strength calculated from the following equation:Tensile bonding strength = force of failure / cross sectional area. (Ozkan).[20] Then the mode of failure was evaluated and character ized as: a- Adhesive failure refers to total separation at the inter face between the relining material and denture base. b- Cohesive failure refers to fracture within the relining or denture base. c- Mixed failure refers to both.

RESULTS

Transverse Strength Test: The one way analysis of variance (ANOVA) is shown in Table (2)

Table (2): The One Way Analysis of Variance (ANOVA) of the Transverse Strength of the Control and Relined Groups.

Variables	Ratio of relining to denture base 1:1.5mm		Ratio of relining to denture base. 1.5:1mm		Ratio of relining to denture base 2:0.5mm	
	N	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**
Relining by water-bath with surface treatment	5	76.5 ± 1.5*	5	76.8 ± 1.25*	5	76.5 ± 1.06*
Relining by water-bath without surface treatment	5	68.7 ± 1.643*	5	69 ± 1.837*	5	69 ± 1.06*
Relining by microwave with surface treatment	5	82.2 ± 1.25	5	81.9 ± 0.82	5	82.2 ± 1.25
Relining by microwave without surface treatment	5	75.3 ± 1.25*	5	76.5 ± 1.5*	5	75.3 ± 0.67*

Control group (denture base without relining) M±SD = 82.8 ± 1.6. SD = standard deviation*= significant difference from the control group. N = number of samples

The Duncan's multiple range test of the transverse strength in (N/mm^2) of the control group and the relined groups (Table 3) showed that all the relined samples, except samples relined by using microwave curing method with surface treatment, had shown a significant decrease in the transverse strength when compared with the control group (at P=0.05).

Table (3): Mean and Duncan's Multiple Range Test of the Transverse Strength (N/mm^2) of the Control and Relined Groups.

Variable	Material	Denture base cured by water bath			Denture base cured by microwave		
		N	Means	DMRT	N	Means	DMRT
Control	Major	8	82.875	A	8	83.812	A
Without Relining	QD	8	83.438	A	8	83	A
Relining by water bath	Major	8	76.687	D	8	78.25	C
with surface treatment	QD	8	73.875	E	8	77.187	C
Relining by water bath	Major	8	69	F	8	73.125	E
without surface treatment	QD	8	68	G	8	71.062	F
Relining by microwave	Major	8	80.812	B	8	82.875	A
with surface treatment	QD	8	79.687	B	8	82.312	A
Relining by microwave	Major	8	76.125	D	8	77.625	CD
without surface treatment	QD	8	75.375	D	8	78	C

N = number of the samples. Different letters means the groups are significantly statistically different
DMRT = Duncan's multiple range test

Transverse strength of samples relined by microwave curing method had a higher transverse strength than samples relined by water bath curing method. The test also showed that samples relined by using surface treatment had a higher transverse strength than samples relined without using a surface treatment.

Tensile Bonding Test*:* One way analysis of variance (ANOVA) was used as shown in Table (4*).*

Table (4): The One Way Analysis of Variance (ANOVA) of the Tensile Strength of the Control, and Relined Groups.

	Sum of square	Df	Means square	F	Sig.
Major	9470.138	9	1052.238	409.610	0.000
Between group within	179.821	70	2.569		
group total	9649.959	79			
QD	10169.735	9	1129.971	365.058	0.000
Between group within	216.673	70	3.095		
group total	10386.407	79			

Df = degree of freedom, F = F value, Sig. = Significance.

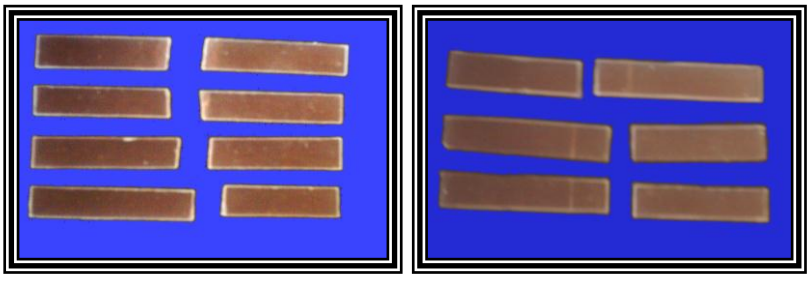
Duncan's multiple range test (Table 5) showed that all the relined groups had a tensile bonding strength significantly lower than the tensile strength of the control group (at P=0.05).

Table (5): Mean and Duncan's Multiple Range Test of the Tensile Strength (MPa) of Control Groups and Tensile Bonding Strength of Relined Groups

		Denture base cured by water bath			**Denture base cured by microwave**		
Variable	Material	N	M	DMRT	N	M	DMRT
Control	Major	8	75.05	A	8	75.175	A
Without Relining	QD	8	75.712	A	8	75.8	A
Relining by water	Major	8	65.15	C	8	62.687	D
bath with surface treatment	QD	8	64.325	C	8	62.062	D
Relining by water	Major	8	43.225	F	8	43.687	F
bath without surface treatment	QD	8	41.887	G	8	44.062	F
Relining by micro-	Major	8	67.275	B	8	67.275	B
wave with surface treatment	QD	8	67.9	B	8	67.675	B
Relining by micro-	Major	8	54.525	E	8	55.612	E
wave without surface treatment	QD	8	54.187	E	8	55.262	E

N = number of the samples, DMRT = Duncan's multiple range test,
MPa = mega Pascal. Different letters means the groups were significantly statistically different.

The samples relined by using microwave curing method with surface treatment showed the highest tensile bonding strength among the other relined samples. While samples relined by water bath curing method without surface treatment showed the lowest tensile bonding strength among all groups. Samples relined by using microwave curing method produced samples which had a higher tensile bonding strength than samples relined by using water bath curing method. The test also showed that samples relined by using surface treatment had a higher tensile bonding strength than samples relined without using a surface treatment. The type of failure was evaluated; the test showed that, the control group failure type was cohesive failure (Figure 3).



A **B**

Figure (3): A-Cohesive Type of Failure of the Control Groups. B- Adhesive Type of Failure of the Relined Groups.

All the relined samples showed adhesive type of failure only, whether with surface treatment, or without surface treatment.

DISCUSSION

Transverse Strength Test: The transverse (flexural strength) of a material is a measure of stiffness, and resistance to fracture. Flexural strength tests were undertaken as these were considered relevant to the loading characteristics of a denture base in a clinical situation.[6]

From the results of Tables (2 and 3), it is clear that the denture base material after relining possessed significant lower transverse strength (69 to 80.812 for Major, 68

to 79.687 for QD) than denture base material without relining, except the group which represent the denture base cured by microwave method and relined by using microwave curing method with surface treatment (82.875 for Major, 82.312 for QD). The decrease in transverse strength of the relined denture base samples could be mainly related to the adhesive failure under load between the reline and the denture base material.[22]

This could be better explained through the molecular interaction between the active sites of the two resin surfaces (the parent resin and the added resin). All the active sites of the parent resin (denture base) are occupied by the previous curing of the material, while the added resin (reline material) has fully activated active sites. As a result, the compatibility between the two resins is inadequate which leads to weakening of the molecular interaction between the two resins, consequently weakening the mechanical properties of the base - reline complex. [23,24] This is in accordance with Baily [25] who stated that the cross linkage of surface molecules between parent acrylic resin and new reline resin was not as complete as initially polymerization process but clinically acceptable.

Another explanation for the reduction in transverse strength could be due to the reheating of the old resin (denture base) to cure the added reline resin that releases the internal stress inherent in heat cured acrylic base. This will result in a partial depolymerization and micro cracks formation within the resin from which crack propagation start, leading to decrease in strength and rigidity of the relined resin. [13] Heat stress may cause the water sorption of the polymer to increase because of an extension of the distance between the polymer chains. Water taken up into polymer acts as a plasticizer, thus the mechanical properties may be decreased. [12, 26] For this reason Anusavice. [27] stated that for relining low polymerization temperature is desirable to minimize distortion of the remaining denture base.

Table (3) showed that, the microwave curing method was better than water bath curing method in relining acrylic denture base. The microwave heating is energy conversion not conduction heating as in conventional water bath technique. In the microwave method, the monomer molecules are positively moved (rotated) by a high frequency electromagnetic field, their movements are the cause of the internal heat and the heat is only the consequence of their movements. So the microwave curing is much faster than a conventional water bath, and the degree of curing also increased.[28-30]

The surface treatment by MMA had a significant effect on increasing the transverse strength of the relined samples. Their effects were probably to increase the wet-ability of the denture base polymers and to increase the chemical bonding with the reline polymer.[12]

Tensile Bond Strength Test: A variety of tests had been developed to measure the bond strength between two materials. However, most of these tests were designed to place the bond in tension.[19] Tensile strength is defined as the resistance of the material to a tensile or stretching force.

The results of this test, Table (4 and 5) showed that the denture base without relining (control group by both curing methods) exhibited a higher tensile strength (75.05, 75.175 for Major, 75.712, 75.8 for QD) than the other groups (after relining). This is probably related to adhesive failure under load between the reline resin and denture base resin.[13]

The results of this test also showed that relining by microwave curing method had given higher tensile bonding strength values than the water bath curing method, this could be attributed to that the microwave curing method is much faster than the water bath curing method, the degree of curing is also increased, and the rate of monomer diffusion could be higher in microwave technique that provide higher bond strength.[12, 27]

The results also revealed that the use of surface treatment leads to a higher tensile bonding strength at $P = 0.05$. The MMA monomer has a relatively low ability to dissolve the denture base resin surface. However, they penetrate into the denture base resin and polymerize with the reline acrylic resin. In addition, this kind of primer makes the denture base resin surface

porous and a type of mechanical interlocking structure between the two materials would be established through this layer. When the denture base resin is dissolved by MMA, the bonding is based on the formation of new polymer chains between the heat polymerizing acrylic resin pieces.[16, 20, 30-32]

The bonding agent should include constituents, which will provide a chemically clean bonding surface that acts as a solvent, and provides a polymer cross linking agent.[33]

However, these bond strength values may not simulate the clinical situation because of difference between the geometry of test samples and the clinical application. Generally, the bond strength values typically overestimate the bond strength obtained in clinical usage. Nevertheless, laboratory tests are useful in comparing and ranking the bond strength of lining material.[24]

With respect to the nature of failure, all the relined samples failed adhesively across the denture base resin (Figure 3). This result is in agreement with many authors[24, 34, 35] who observed that all relined samples display an adhesive failure at the junction of the reline - denture base site.

CONCLUSIONS

There were no significance differences of transverse strength of relining thicknesses (0.5mm, 1mm, and 1.5mm). Relining the heat cure denture base material significantly decreases the transverse strength of the relined denture base. The microwave curing method in relining gives higher transverse strength, and tensile bonding values for the relined samples than water bath curing method. Surface treatment by MMA monomer significantly increases the transverse strength and the tensile bonding strength of the relined samples.

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