Acrylic denture base repair (Part III): Influence of repair procedure on color and residual monomer

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ABSTRACT

Aims: To evaluate the effect of repair techniques, surface treatment with monomer, and additional curing cycle on the color change, and residual monomer of the repaired denture base. **Materials and methods**: Two hundred and seventy two samples of two brands 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 at fracture area. The samples were tested to measure color change and residual monomer of repaired, and intact (control) samples. **Results**: Color change of acrylic denture base repaired by chemically cured acrylic resin was significantly higher than that of water bath, microwave, and thermo press. Microwave repairing technique had lower residual monomer than other techniques. The highest content of residual monomer was released in water after the first 24 hours and decreased in the subsequent days. Acrylic denture base that has additional curing cycle showed a residual monomer content lower than those with single curing cycle. **Conclusion**: Color changes of repaired denture with chemically cured resin are high and the lower adverse effect of monomer are shown with microwave and water bath curing cycle. Long storage period of repaired denture base are beneficial to reduce monomer release.

Key words: residual monomer, Color of acrylic resin, denture base.

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INTRODUCTION

Denture fractures occur all too frequently resulting in great inconvenience to both the patient and dentist.[1] The construction of a new denture is a time consuming and expensive. The greatest inconvenience to the patient is that the patient may be without prosthesis for an extended period of time. Thus the decision to repair the denture whether as a temporary or definitive measure is a common one. Most repairs are carried out with auto–polymerized poly methylmethacrylate. An effective repair material should be cost–fective, simple to use, have a short duration of curing, and no significant differences in optical density (color properties)[2], possess high strength, and durability, good aesthetics, be non–allergenic, and does not cause distortion to the existing denture.[3] The microwave polymerized resin had lower residual monomer levels than conventionally cured resin, yet had similar physical properties. The auto–polymerized resin had higher residual monomer levels compared with microwaveable resin.[4] They concluded 'the results suggesting that the residual monomer level does have an effect on the strength of repaired specimens'. That is, the lower the residual monomer levels, the stronger the repair. Moreover, lower residual monomer levels reduce the incidence of mucosal irritation and allergic reactions.[3]

The color of denture base acrylic resin is another important property. Discoloration of acrylic resin may occur which result in aesthetic problem.[5] The researches showed that the main two factors that have a major role in color property of acrylic resin are residual monomer content and porosity caused by over heating[6, 7], so that color and translucency should be maintained during processing stages.[8, 9] So the aim of this study was to select the proper additional curing cycle to repair acrylic denture base with good esthetic (minimum color change), and low residual monomer.

MATERIALS AND METHODS

Two hundred and seventy two (272) heat cured denture base specimens were prepared. Half of them from major base 2 **(**Major Prodotti Dentari S.P.A, ITALY), and the other half from Quayl Dental heat cured denture base material (Ouayle Dental, England).

The procedures of preparing and curing the control specimens and repaired specimens were mentioned previously as in part II of this research.

Color Change test: Eighty acrylic specimens were prepared from two brands of heat cured acrylic resin (40 specimens from major2 acrylic denture base, and 40 specimens from QD acrylic resin). These acrylic denture bases were divided into one control group and four repaired groups (figure 1) each one contains 8 samples repaired by different curing techniques.

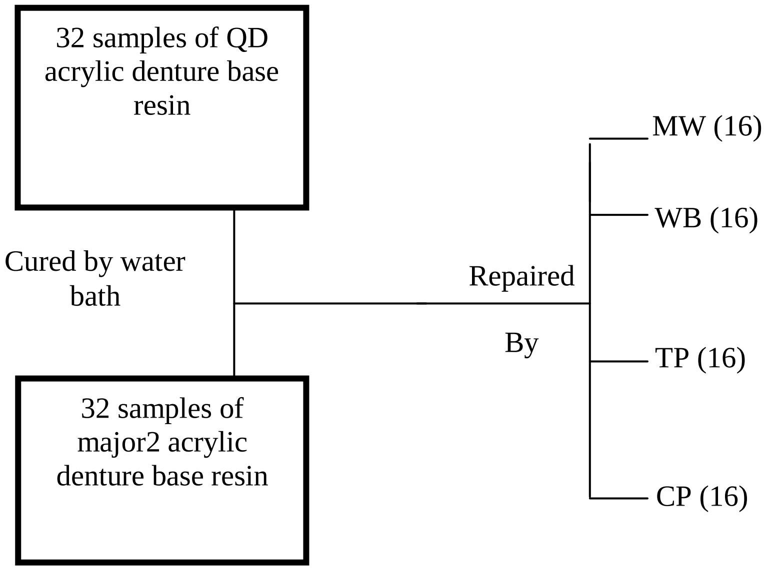

Figure (1): Diagram demonstrate the color change sample distribution. MW: microwave polymerization; WB: water bath polymerization; TP: thermopress polymerization; CP: chemically polymerization resin.

The dimensions of specimens prepared for color change were 45 ×10 ×2.5 mm length; width and thickness respectively (according to spectrophotometer use instructions) Figure (2).

The fracture acrylic denture base specimens were repaired by four curing techniques (conventional water bath, microwave oven, thermo press, and chemically cured resin).

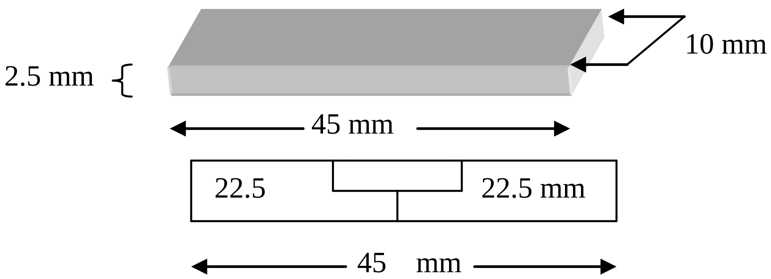

Figure (2): diagram of control, and repaired specimens of color change test.

All specimens were stored in distilled water for 7 days at 37 ºC in an incubator for conditioning the specimens. The specimens were dried by tissue paper before being tested for color change. The assessment of the color of acrylic denture base was performed using a computerized ultraviolet –visible spectrophotometer.[2, 10, 11]

Before testing, a single clear acrylic denture base sample was prepared (with the same dimensions of the tested samples) to make the computerized scale of spectrophotometer zero. This procedure was done to identify the absorbency of light by colored acrylic denture base pigments from that absorbed by other acrylic denture base components.

The determination of **λmax** of ea-ch type of acrylic denture base materials was performed by using ultraviolet–visible spectrophotometer. For the Quayle-Dental heat cured acrylic resin the recorded **λmax** was 304nm, while for the medicus chemically cured acrylic resin and major base heat cured acrylic resin the **λmax** was 345nm.[11]

Residual monomer test: One hundred ninety two specimens of heat cured acrylic resin of two brands were prepared (96 specimens of Major2 acrylic resin, and 96 specimens of QD acrylic resin). These acrylic denture bases were divided into one control group, and eleven repaired groups (Figure 3) each group contains 8 samples.

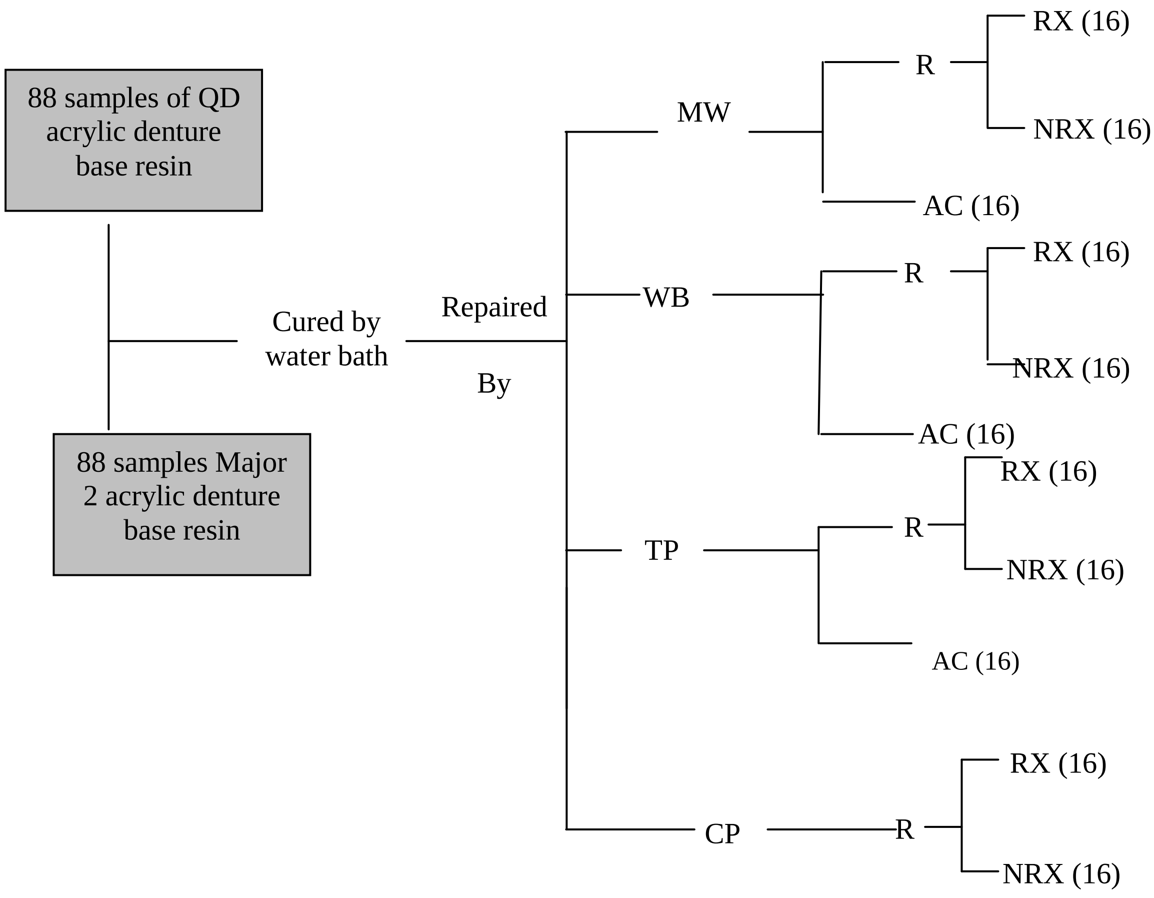

Figure 3: Diagram demonstrates the sample distribution of residual monomer. MW: microwave polymerization; WB: water bath polymerization; TP: thermopress polymerization; CP: chemically polymerization resin; R: repair; AC: Additional curing cycle.

The dimensions of acrylic resin specimens prepared for residual monomer test were 20×20×3mm length × width × thickness respectively.

The master model of fractured denture base specimens was prepared by reduction along the middle of control master model, for 1.5 mm from the thickness to a width of 10 mm to produce a room for repairing material (Figure 4).

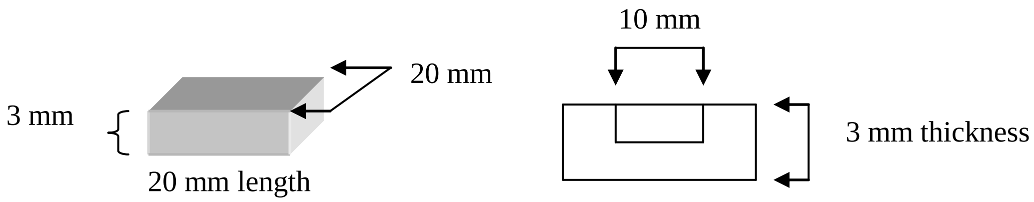

Figure (4): Diagram of control and Repaired residual monomer specimen

The specimens prepared for this test were repaired with, and without surface treatment and without treatment by monomer, and polymerized by different repair techniques (conventional water bath, microwave oven, Thermo press, and chemically cured resin). Other specimens with the same dimensions of control group were cured with conventional water bath, and then cured again by water bath, microwave and thermo press.

Each specimen was introduced in a sealed glass flask containing 10 ml of distilled water at 37 ºC for 7 days in an incubator, the supernatant were removed and rep-laced daily by fresh distilled water. The time –dependant monomer concentration was followed by monitoring the amount of monomer present in supernatant medium using (CECIL 2000) ultraviolet visible spectrophotometer (λ= 254nm) compared with pure monomer.

From results of the study (Part I), a linear calibration curve of methyl methacrylate (MMA) concentration as a function of absorbency at 254 nm was obtained using MMA standard aqueous solutions ranged 0.005 – 0.125 mg/ml. One thousand and eight measurements were expressed as a percentage of released monomer mass with respect to the weight of specimens (% W/W).[12, 13]

RESULTS

Colour change (Curing Technique): The mean color changes in nm and standard deviation of samples repaired by different techniques are given in Table (1) and Figure (5).

Table (1): Means and Standard deviation, and Duncan's multiple of color change for two brands of repaired acrylic denture base resin.

curing technique	**Duncan's groups**	**Materials**			
		Major base		**QD**	
		Mean ±SD (nm)	**Number**	**Mean ± SD (nm)**	**Number**
Control group (intact)	A	1.185 ±0.035	8	1.823 ± 0.038	8
Water bath	B	1.354 ± 0.119	8	1.874 ± 0.032	8
Microwave energy	B	1.335 ± 0.081	8	1.899 ± 0.078	8
Thermo press	C	1.401 ± 0.019	8	1.997 ± 0.061	8
Chemically cured resin	D	1.866 ± 0.054	8	2.161 ± 0.048	8

SD= standard deviation.

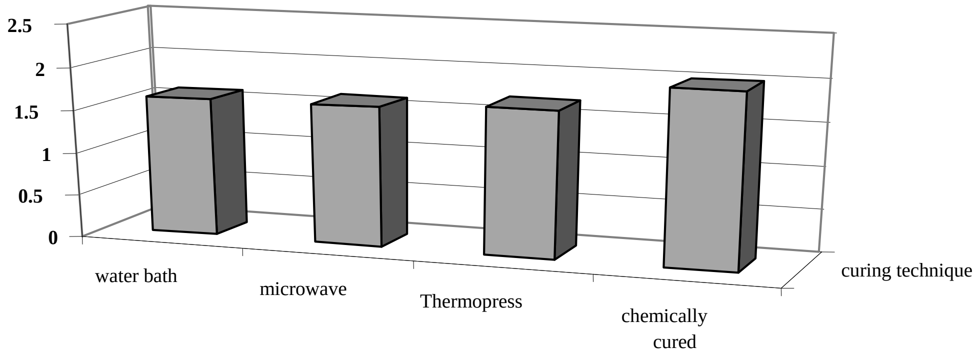

Figure (5): Mean of colour change for acrylic denture base repaired by different curing techniques.

The mean of samples repaired by chemically cured acrylic resin was significantly higher than the mean of samples repaired by water bath technique. Analysis of variance (ANOVA), Table (2), showed that there was a significant difference (P< 0.001) in samples repaired by different techniques. Duncan's multiple range test for the four repair techniques, Table (1), showed that repair by chemically cured acrylic resin had significantly higher mean followed by thermo press repair technique, but there was no significant difference between that of water bath, and microwave repair technique. All repair techniques showed color change means higher than that of the intact (control) samples mean.

Table (2): Analysis of variance (ANOVA) of color change for different curing techniques.

Source of variances	DF	Sum of square	Mean square	F -value	*P* – value
Curing technique	3	1.6741	0.5580	7.53	Significant
Error	60	4.4491	0.0742		
Corrected total	63	6.1232			

DF: Degree of freedom

*Residual Monomer (Effect of Repairing Technique):*The mean of residual monomer is expressed as a percent of released residual monomer mass with respect to the weight of the specimen (% w/w). The mean RM, and standard deviation of samples repaired by chemically cured resin was significantly higher than the mean RM of samples repaired by microwave, Table (3), and Figure (6).

Table (3): Mean and Standard deviation, and Duncan's multiple range test of residual monomer for different curing techniques.

Curing techniques	Duncan's groups	Mean $\pm$ SD (%w.w)	Number
Control group	B	$0.85 \times 10^{-3} \pm 0.68 \times 10^{-3}$	112
Water bath	A	$0.72 \times 10^{-3} \pm 0.57 \times 10^{-3}$	224
Microwave energy	A	$0.47 \times 10^{-3} \pm 0.45 \times 10^{-3}$	224
Thermopress	B	$0.91 \times 10^{-3} \pm 0.58 \times 10^{-3}$	224
Chemically cured resin	C	$1.41 \times 10^{-3} \pm 0.92 \times 10^{-3}$	224

10^{-3} : 1/1000; SD = standard deviation.

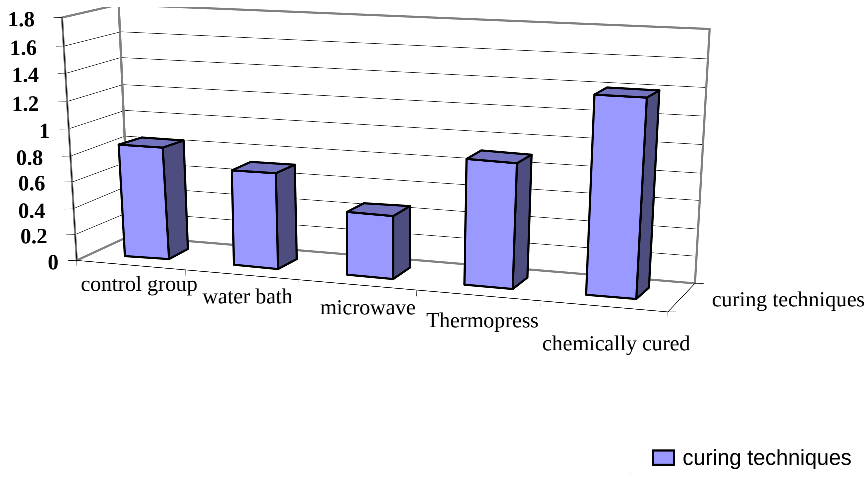

Figure (6) M:ean for residual monomer of supernatant solution of repaired acrylic denture base by different curing techniques

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

Duncan's multiple range test of RM, Table (3), showed that samples repaired by microwave, and water bath were significantly lower than samples repaired by thermo press, and control samples, followed by samples repaired by microwave, and water bath.

Table (4): Analysis of variance (ANOVA) of residual monomer for different curing techniques.

Source of variances	DF	Sum of square	Mean square	F -value	*P*–value
Curing techniques	4	0.107×10^{-3}	0.02×10^{-4}	51.50	Significant
Error	1003	0.521×10^{-3}	0.005×10^{-4}		
Corrected total	1007	0.628×10^{-3}			

DF: Degree of freedom.

Effect of Surface Treatment: The mean of RM and standard deviation of samples repaired without surface treatment were not significant to samples repaired with surface treatment table (5). Analysis of variance (ANOVA), Table (6), showed that there was no significant difference in RM between samples repaired with, and without surface treatment.

Table (5): Mean and standard deviation of residual monomer for treated and untreated samples.

Surface treatment	Mean $\pm$ SD (%w/w)	Number
Untreated	$0.88\times10^{-3}\pm0.80\times10^{-3}$	448
Treated	$0.87\times10^{-3}\pm0.81\times10^{-3}$	448

10^{-3}: 1/1000; SD: Standard deviation.

Table (6): Analysis of variance (ANOVA) of residual monomer of repaired samples with surface treatment, and without surface treatment.

Source of variances	DF	Sum of square	Mean square	F -value	*P*–value
Surface treatment	1	0.1×10^{-6}	0.1×10^{-7}	0.00	Not significant
Error	894	0.579×10^{-3}	0.6×10^{-6}		
Corrected total	895	0.579×10^{-3}			

10^{-6}: 1/1000000; 10^{-7}: 1/10000000; 10^{-3}: 1/1000; SD: Standard deviation

Effect of Immersion Time: The mean RM and standard deviation for supernatant solution of repaired samples for first day were significantly higher than those of supernatant solution at the 7th day of immersion, Figure (7). Analysis of variance (ANOVA), Table (7), showed that there was a significant difference (P<0.001) in RM of upernatant solution of repaired samples for seven days. Duncan's multiple range test of RM, Table (8) showed that the me-an of supernatant solution of the first day (%w/w) was significantly higher than that of the 2nd day, followed by the 3rd, 4th, 5th, 6th, and 7th day which is the lowest mean residual monomer.

Table (7): Analysis of variance (ANOVA) of residual monomer of repaired samples immersed in water for seven days.

Source of variances	DF	Sum of square	Mean square	F -value	*P*–value
Immersion time	6	0.346×10^{-3}	0.057×10^{-3}	332.15	Significant
Error	791	0.137×10^{-3}	0.002×10^{-4}		
Corrected total	798	0.483×10^{-3}			

10^{-3}: 1/1000; 10^{-4}: 1/10000; DF= degree of freedom.

Table (8): Duncan's multiple range test of residual monomer of repaired samples immersed in water for seven days.

Days	Mean$\times10^{-3}$ $\pm$ SD$\times10^{-3}$ (%w/w)	Duncan's grouping	Number
First	2.05 ± 0.73	A	114
Second	1.40 ± 0.54	B	114
Third	1.05 ± 0.37	C	114
Fourth	0.78 ± 0.31	D	114
Fifth	0.33 ± 0.24	E	114
Sixth	0.16 ± 0.22	E	114
Seventh	0.13 ± 0.17	E	114

Means with different letters vertically are statistically significant

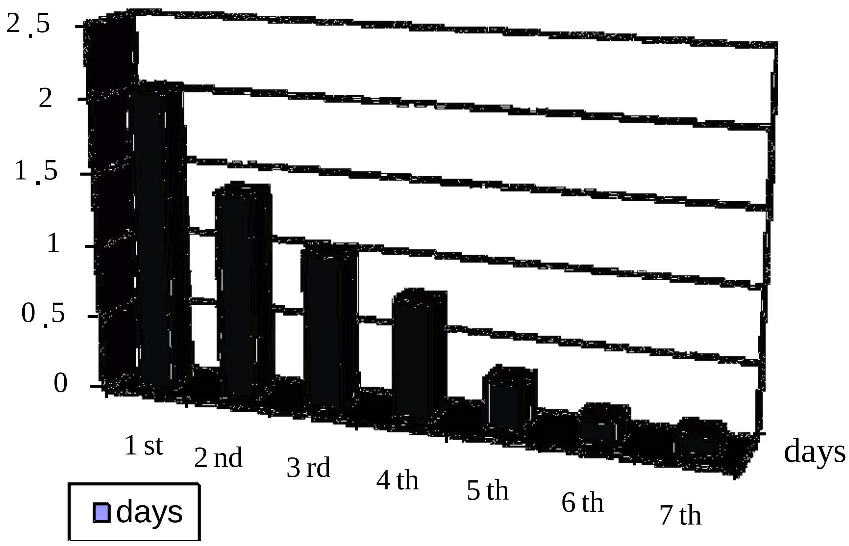

Figure (7): Mean for residual monomer of supernatant solution of repaired acrylic denture for seven days.

Effect of Additional Curing Cycle: The mean and standard deviation of RM, Figure (8), showed that mean RM of samples cured with additional curing cycle by microwave was significantly lower than the mean RM of samples with single curg cycle (control samples) by water bath. Analysis of variance (ANOVA), Table (9), showed that there was a significant difference ($P < 0.001$) in RM of samples cured with additional curing cycle, and samples with single curing cycle (control). Duncan's multiple range test of RM, Table (10), showed that samples with additional curing cycle by microwave and water bath were significantly lower than the samples with single curing cycle (control), and samples that had additional curing cycle by thermo press.

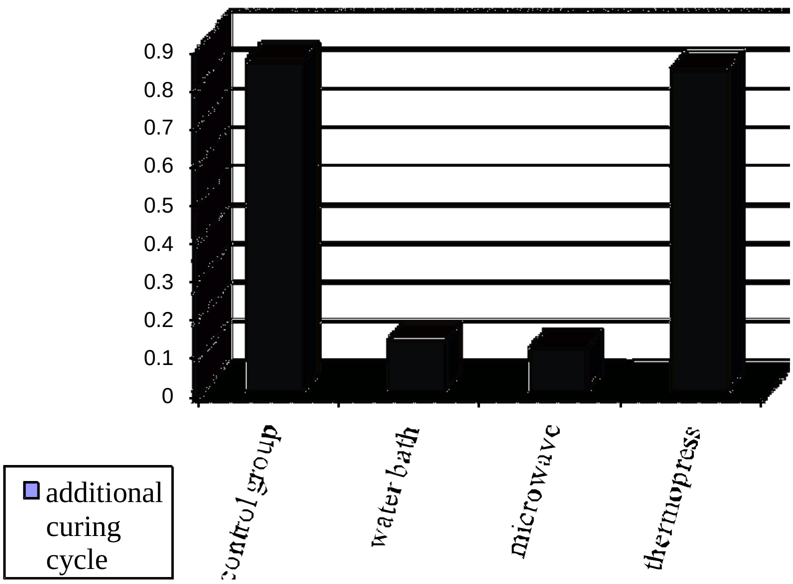

Figure (8) Mean for residual monomer of supernatant solution of acrylic denture base with additional curing ycles by different curing techniques.

Table (9): Analysis of variance (ANOVA) of residual monomer of acrylic denture base with additional curing cycle.

Source of variances	DF	Sum of square	Mn square	F -value	*P*–value
additional curing cycle	3	0.069×10^{-3}	0.023×10	103.41	Significant
Error	444	0.099×10^{-3}	0.002×10^{-4}		
Corrected total	447	0.169×10^{-3}			

10^{-3}: 1/1000; 10^{-4}: 1/10000; DF= degree of freedom.

Table (10): Duncan's multiple range test for residual monomer of acrylic denture base with additional curing cycle.

Additional curing cycle	Mean$\times10^{-3}$ $\pm$ SD$\times10^{-3}$ (%w.w)	Duncan's Group	Number
Control group(single curing)	0.85 $\pm$ 0.68	A	112
Water Bath	0.13 $\pm$ 0.16	B	112
Microwave energy	0.11 $\pm$ 0.13	B	112
Thermopress	0.83 $\pm$ 0.61	A	112

Means with different letters vertically are statistically significant.

DISCUSSION

Color Change**:** The higher color change of chemically cured resin may be caused by several reasons. The chemically cured resin polymerized by the decomposition of dibenzoyl peroxide by tertiary amine such as dimethyl–para–toluidine, that is susceptible to oxidation and accompanying colour change.[14, 15]

In addition to the reasons mentioned previously, chemical discoloration has been attributed to the oxidation of the polymer matrix or oxidation of unreacted double bonds in the residual methyl methacrylate.

This unreacted monomer is the resin matrix because the degree of polymerrization by chemically cured resin is not complete as that achieved in heat cured acrylic system. This unreacted monomer could be another reason for the color change.[16, 17]

Another possible explanation for the discoloration is related to the higher porosity level associated with chemically cured resin.[18, 19]

Residual Monomer (Effect of Additional Cycle): The plausible explanation for such result is due to the fact the extent of monomer conversion into polymer is enhanced as a result of this additional heating, and then potentially leachable monomer is covalently bonded to the polymer network. The additional conversion observed with heating resulted in an increase in cross–link density; unreacted monomer remaining in the polymer matrix would find it much more difficult to diffuse out as a result of the decrease in diffusion channel size. Also, unreacted monomer could have been lost as a result of volatilization during the heating process.[20]

Effect of Curing Techniques: The repaired acrylic denture base consists of two parts, existing denture base, and new denture base material. Thus the existing denture base will have an additional curing cycle, and repair material will have a single curing cycle during repairing by water bath, microwave, and thermo press.

Therefore the lower residual monomer content of denture base repaired by water bath and microwave is due to that the additional curing cycle will reduce the residual monomer of the existed denture base (as explained previously). The majority of RM comes from new repair material.[14, 15, 19]

*Surface treatment***:** The mean RM of repaired acrylic denture base with surface treatment is the same as that of repaired without surface treatment. A rational explanation is that the monomer that was applied on the surface of repaired acrylic denture base softens and dissolves the acrylic resin surface. The monomer will diffuse into acrylic denture base and a new acrylic resin dough that participates in the acrylic resin polymerization.[20, 21]

Effect of Immersion time: This result may be explained by the diffusion of monomer into the water and by a continuous polymerization phenomenon caused by the existence of free radicals in the polymer chains.[22,23]

CONCLUSIONS

The mean color changes in nm of samples repaired by chemically cured acrylic resin was significantly higher than the samples repaired by water bath technique, and no significant difference between that of water bath, and microwave repair technique.

The mean residual monomer of samples repaired by chemically cured resin was significantly higher than samples repaired by microwave. Samples repaired by microwave, and water bath had significantly lower residual monomer than samples repaired by thermo press, and control samples. There was no significant difference in between samples repaired with, and without surface treatment. Highest amounts of residual monomer content of acrylic denture base were released at the first 24 hours and subsequently disappeared. Samples with additional curing cycle by microwave and water bath were significantly lower than the samples with single curing cycle (control), and samples that have additional curing cycle by thermo press.

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