EVALUATION OF A NEWLY FORMULATED AUTO-POLYMERIZED ACRYLIC RESIN PERMANENT DENTURE BASE MATERIAL
(In Vitro Study)

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ABSTRACT

INTRODUCTION: Auto-polymerizing acrylic resin with pour technique provides an alternative method to conventional compression-molding processing for denture base resin. This technique offered improved adaptation, dimensional stability, reduced cost and simplicity of procedure.

OBJECTIVES: To investigate some of the physico-mechanical properties of a newly formulated auto-polymerized pour resin permanent denture base material and compare them with conventional heat cured resin.

MATERIALS AND METHODS: The study was conducted on two parallel groups according to the denture base material used Group (I) conventional heat cured resin (control group), Group (II) newly formulated auto-polymerized pour resin (study group) of 35 specimens each (14 for impact strength test, 14 for flexural strength test, 7 for warpage test and grinded powder from the cured material for estimation of residual monomer test). Will be examined in this in vitro study. Each group was divided into 2 subgroups: (A) Zero-thermo-cycling (no thermo-cycling) and (B) Thermo-cycling, then subjected to 4 different tests, impact strength, flexural strength, warpage and quantitative analysis for estimation of residual monomer test. All data from both groups in this in-vitro study was gathered, tabulated and statistically analyzed.

RESULTS: The results showed that denture bases processed from auto-polymerized pour resin exhibit high adaptation (low warpage) comparable to those heat cured, and this adaptation significantly increased after thermo-cycling, on other hand, results revealed significantly high amounts of residual monomer of pour resin in both condition (before & after thermo-cycling) in comparison with heat cured resin with significant reduction in these levels after thermo-cycling for both materials. While the impact strength of pour resin was significantly lower than heat cured with no significant increase of flexural strength.

CONCLUSIONS: Auto-polymerized pour resin exhibit high adaptation accuracy which is related to the investing medium & technique of processing. On the other hand, containing high amount of residual monomer affecting the physico-mechanical properties. Generally, thermal-cycling improve the mechanical and bio-compatibility of the material.

KEYWORDS: Auto-polymerized, pour resin technique, impact strength, flexural strength, warpage, residual monomer.

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INTRODUCTION

The denture base is part of a denture that rests on the foundation tissues and to which teeth are attached (1). A variety of resins have been introduced into dental treatment for the construction of dental prostheses and their efficacy has been based on physical, chemical, and biological properties (2).

Polymethyl methacrylate (PMMA) are capable of providing an excellent balance of features and characteristics needed for use in oral environment (3). Several techniques are utilized in resin polymerization method, such as heat polymerization method, pouring method, injection pressing method and microwave activated polymerization method. Improvements have been made in each method to strive toward a system with high accuracy and reliability (4).

Compression molding technique with heat activation in tempered water path for resin polymerization is the conventional method being followed for processing the dentures (5). Several processing methods have been proposed to simplify the technique and to reduce the manufacturing time (6).

The pouring method of denture base resin was developed in 1960s using agar hydrocolloids as investment material and has been one of the most popular polymerization techniques because of three merits. It is simple to use, less time consuming, and it offers better adaptation accuracy than heat polymerization method (7).

There is difference in the size of the polymer powder or beads of auto-polymerized resin. Small particle size results in fluid mix. The mix is quickly poured into the mold and allowed to polymerize under pressure. These offered improved adaptation, dimensional stability, reduced cost and simple procedure but had higher solubility and high residual monomer levels (8).

The principle difference between heat curing and auto-polymerized acrylic denture base resin is the method used to activate the benzoyl peroxide catalyst which initiates polymerization of the monomer. With heat cured resins, polymerization is started by free radicals from the benzoyl peroxide, which are activated by heat. In auto-polymerized resin, a tertiary amine chemical accelerator, usually dimethyl-p-toluidine is added to the monomer so that polymerization can be completed at room temperature (9).

Despite the various methods used to initiate the polymerization of denture base resin, the conversion of monomer to polymer is never complete; some unreacted (residual) monomer is always present (3).

The present study was aimed to evaluate some of the physico-mechanical properties of a newly formulated auto-polymerized pour resin denture base material and compare them with conventional heat cured PMMA and test the hypothesis that those properties could be affected by thermo-cycling. Thermo-cycling is an in vitro process where test materials are subjected to temperature extremes using water baths in an attempt to simulate conditions in the oral cavity (10).

MATERIALS AND METHODS
Materials:
The materials that have been used in this study were:

- Conventional heat cured polymethyl methacrylate (PMMA) (Vertex^{TM} regular, Vertex-dental B.V.3705HJ Zeith the Netherland).
- Auto-polymerized pour resin (Vertex^{TM} Castavatia, Vertex-dental B.V.3705HJ Zeith the Netherland).

The following laboratory tests have been performed for evaluation of some physico-mechanical properties were done:

1- Impact strength test.
2- Flexural strength test.
3- Warpage test.
4- Quantitative analysis for estimation of residual monomer test.

A total of 70 specimens were prepared according to the international standard specifications for each test. The specimens were divided into two groups according to the following:

Group (I) (control group): 35 specimens of conventional heat cured acrylic resin denture base material PMMA (14 specimens for impact strength test, 14 for flexural strength test and 7 specimens for warpage test).

Group (II) (study group): 35 specimens of a newly formulated auto-polymerized pour resin material (14 specimens for impact strength test, 14 for flexural strength test and 7 specimens for warpage test).

Each group was divided into two subgroups:

Subgroup A: 7 specimens for each test were stored in the incubator at 37°C for 24 hours (called no thermo-cycle or zero-thermo-cycle).

Subgroup B: 7 specimens for each test were thermo-cycled to examine the effects of temperature variations.

N.B: For warpage test the same number of specimens (7 specimens for control group &7 for study group) after being stored in the distilled water in the incubator (zero-thermo-cycle) and subjected to testing, were then thermo-cycled in thermo-cycling machine, and subjected again to the test because this test is non-destructive.

For quantitative analysis for estimation of residual monomer test, pieces from the fractured specimens from each sub-group of any of the previous tests were grinded into fine powder then pressed to form a disc in order to be subjected to testing.

1. Impact strength test
Specimens preparation
Metallic molds having bar shape constructed according to the method described in the ISO standard (ISO 179-1;2010) (11) with dimensions of 75 mm length, 10 mm width, 10mm thickness, with 2mm depth notch at the middle. Base plate wax softened and poured into the mold. After cooling and hardening of the wax, it was removed. A total of 28 wax specimens were prepared. For auto-polymerized pour resin the waxed specimen placed on the plate of the flask and the flask was closed. Then the hydrocolloid gel (agar) of 48°C was poured in the flask gently. The flask then cooled down and the gel was hardened. The bottom plate of the flask was opened and the wax specimen had been taken out very gently. The pouring channels (sprues) were made by using sharp canal cutter (Figure 1.A). 17g of powder and 10 ml of liquid were mixed thoroughly in the jar for 20 seconds, the acrylic resin mix was poured through the sprues in the investing material (agar) with straight thin line in the flask (Figure 1.B). The flask was left for 8 minutes until the surface of pouring channels became matt. The flask placed in the pressure vessel (curing machine) and polymerized at 55°C for 30 minutes at 2.5 bar pressure. After polymerization, the flask was allowed to cool down outside the pressure vessel for 30 minutes; finishing and polishing of specimens were done (Figure 2.A). The specimens for conventional heat cured PMMA were constructed using compression molding technique as instructed by the manufacture. The 28 specimens were equally divided into two groups (I&II) of 14 specimens each. Subgroup A: 7 specimens were stored in distilled water at 37°C in the incubator. Subgroup B: 7 specimens were thermo-cycled using thermo-cycling machine for 500 cycles between 55°C and 5°C with a dwell time (time taken by the specimens to be transferred from one bath to another) of 30 seconds (12).

The specimens were accurately mounted on the vice of the pendulum testing machine (Charpy's type impact tester). The specimen was supported horizontally at its ends and it was struck by free swinging pendulum which was released from a fixed height. A pendulum of 15 J capacity was used. The scale reading gave the impact energy absorbed to fracture the specimen in Joules when struck by sudden blow.

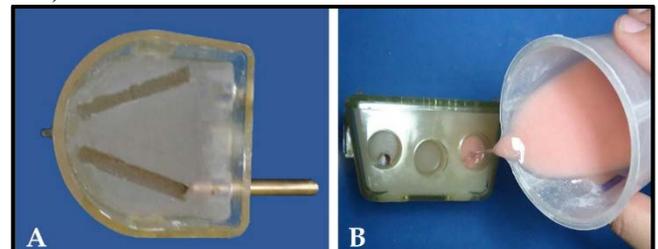The impact strength for the specimens was calculated in KJ/mm^2 as given by the following equation (13).

$$\text{Impact strength} = \frac{E}{bd} \times 10^3$$

Where:
E: Is the impact absorbed energy in joules.
b: Is the width in millimeters of the test specimen (10 mm).
d: Is the thickness in millimeters of the test specimen (10 mm).

Figure 1: **(A)** Showing the pouring channels made by using canal cutter.
(B) Showing the mix of acrylic resin poured with a thin line in the flask.

2. **Flexural strength test:** The specimens for this test were prepared in (65mm length, 10mm width and 2.5mm thickness) in accordance to the American Dental

Association Specification No.12 for denture base polymer in preparing the test specimens (14), metallic mold was used, the standard wax specimens were obtained by pouring the melted wax into the mold and the same steps for processing resin material in impact test were followed regarding to the type of denture base material used in this study (Figure 2.B). Individual specimens were placed on supports of the universal testing machine. During placement of the specimens on the testing device, care must be taken that the central loading plunger was touching the midline of the samples. The force in Newton was applied perpendicular to the center of specimen and it was gradually loaded at a crosshead speed of 0.5mm/min. The load was applied till the maximum capacity of the three-point device was recorded.

The flexural strength will be calculated according to the following equation (15):

$$\text{Flexural strength} = \frac{3PL}{2bd^2} \text{ (Mpa)}$$

Where:
P: Load at fracture (or load at maximum deflection)
L: Distance between the two supporting points (50mm).
b: Width of the test specimen (10mm).
d: Thickness of specimen(2.5mm).

3. **Warpage test**: A sectional maxillary metal cast which nearly represent the dimensions of the edentulous ridge was constructed. Five fine parallel lines were inscribed on the posterior aspect of the metal cast to be used as reference measuring locations. A rubber base mold was prepared for this metallic cast. Mix of dental stone with a constant water/powder ratio 3:1 was maintained for all casts. Then the stone mix poured in the rubber mold which was placed on a vibrator to remove any air bubbles present in the mix. After setting, the stone cast was removed. Following the previous steps identical standardized sectional stone casts were prepared for all the experiment. A uniform baseplate wax of 2 mm thickness was adapted upon each cast and sealed at the peripheries. Processing of the denture base materials was performed according to type of resin used in this study. De-flasking was done carefully to avoid damage of the casts. The posterior peripheral seal area displays the greatest discrepancy of adaptation after processing due to shrinkage of denture base material and strain release induced thermal change (16).

The discrepancy or space observed between the denture bases and their casts. The vertical distance between the end of the finished plate and the original standardized casts were measured at "five locations" at the posterior palatal border. Location (C) represents nearly the center of the palate. Location(R) and (L) Represent nearly the right and left of the crest of the ridge. Location (A) and (B) represent nearly the intermediate points between the center of the plate(C) and the crest of the ridge (R, L) (Figure 2.C) (17). The measurements were carried out using stereo-microscope with attached camera used to photograph the specimen at 18x magnification.

The measurement of warpage (for each specimen in different groups) were carried out at the following stages

1. Immediately after processing, de-flasking and finishing of the plates.
2. After stored in distilled water at 37°C in the incubator for 24 hours.

3. After the specimens thermo-cycled for 500 cycles between 55°C and 5°C (16).

The captured photographs were loaded on Cell-A software that was used to measure the distance in microns between the predetermined location on the cast and the base plate in vertical direction.

4- **Quantitative analysis for estimation of residual monomer:** After preparation of specimens according to the different curing techniques, 7peices from fractured specimens from each sub-group from control & study groups of any of previous tests, the pieces were grinded by using dry and clean blinder machine to fine powder. 10 mg of grinded powder was weighted using electronic balance of 0.0001accuracy. The yielded powder was then mixed with ten times of its bulk with potassium bromide (KBr). The mixture then pressed using mini-press machine to form a disc (Figure 2.D). The disc was mounted on holder of Fourier Transform Infra-Red spectroscopy and placed in the lenses of the device in order to study the specimen (18).

The specimen disc was placed in the sample beam of the spectrophotometer device, then the beam was passed to the detector for final measurement, 6 scans were accomplished. The measured signals were digitized and sent to the computer where the Fourier transform took place. Each specimen studied by this device gave us an Infra-Red chart which shows peaks, the range of spectrum used between 4000cm^{-1} at high frequency and 650cm^{-1} at low frequency. The Degree of Conversion (DC) (%) of monomer-to-polymer was calculated by comparison of the absorbance ratio using a standard baseline technique of the C = C peak from the methacrylate group at 1640 cm^{-1} to that of the unchanging C = O peak from the ester group at 1720 cm^{-1}, which was used as a reference peak, before (monomer) and after polymerization (19).

An appropriate base line was drawn; the intensity of absorption was determined by calculating the area of peaks by Auto-CAD software. By taking the ratio between the two absorbance, the fraction of unreacted double bonds could be calculated from the formula: (18)

$$DC = 1 - \frac{\{Abs(C=C)/Abs(C=O) \text{ polymerized samples}\}}{\{Abs(C=C)/Abs(C=O) \text{ monomer}\}} *100\%$$
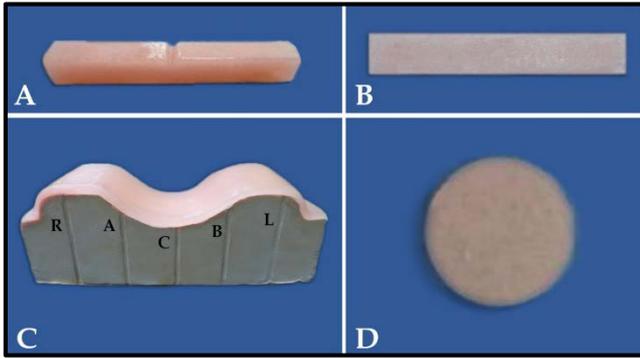
Where:
DC: degree of conversion
Abs (C=C): absorbance peaks of the carbon to carbon bond from the methyl- methacrylate group at 1640cm^{-1}
Abs(C=O): absorbance peaks of the carbon to oxygen from ester group at 1720cm^{-1}.
After that the amount of residual monomer was calculated by subtracting the obtained degree of conversion out of 100%.

Figure 2: (A): Showing impact strength test specimen.
(B): Showing flexural strength test specimen.
(C): Showing the sectional stone cast with five locations used for measurement of warpage.
**(D):** Showing the specimen for testing the amount of residual monomer.

STATISTICAL ANALYSIS

Data were fed to the computer and analyzed using IBM SPSS (Armonk;NY:IBM Crop) software package version 20.0. Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. The Kolmogorvo-Smirnov test was used to verify the normality of distribution of quantitative variables. Student t-test and paired t-test were used for normally distributed variables. For abnormally distributed variables Mann Whitney test was used and Wilcoxon signed ranks test was used for comparing between them. Friedman test was used for abnormally distributed variables to compare between more than two periods. Significance of the obtained results was judged at the 5% level (20).

RESULTS

1- Impact strength test

During performance of testing, all the specimens of all groups fractured immediately after first strike of the Charpy's impact machine and producing a shiny clean fracture surface. In all specimens of the tested groups the fracture line started from the base of the V-shaped notch and extended downward. All the fractured specimens could be reassembled with great ease and the line of fracture was not easily seen. The results of impact strength of the investigated acrylic resin and the thermo-cycling effect on them are given in table (1. A) and represented graphically in (Figure 3). Man Whitney test was used for comparing between the two studied groups at both condition. It revealed that the auto-polymerized pour resin had significantly low impact strength in comparison with heat cured PMMA in both conditions (zero thermo-cycling & after thermo-cycling) respectively with (U=5.000*) (P=0.011*) at zero thermo-cycling) and (U=7.000*) (P=0.021*) after thermo-cycling.
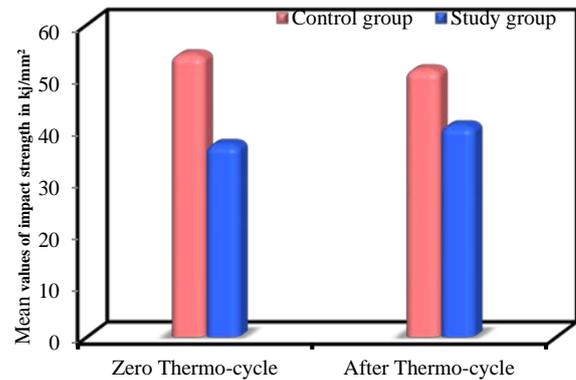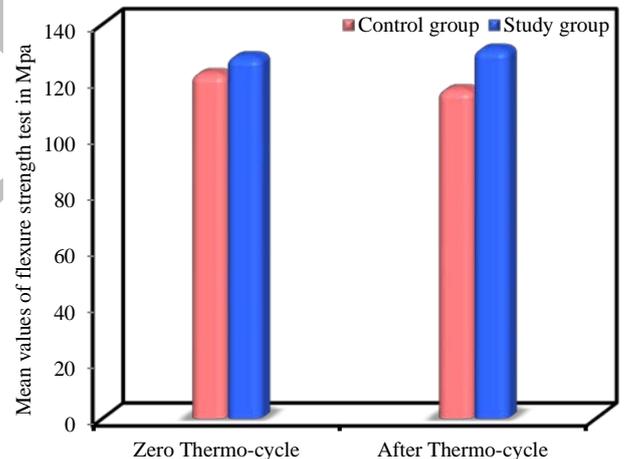

Figure 3: Showing comparison between the mean values of the two studied groups according to impact strength in (KJ/mm2), before and after thermo-cycling.

Wilcoxon signed rank test was used for comparing between zero and after thermo-cycling for each group, it revealed that thermo-cycling increased the impact strength for group II by 11.93% with (Z=0.736) (P=0.461) but with no statistical significant.

Flexural strength test

During testing, the acrylic plates of all the specimens for all groups showed gradual bending and finally they were broken. The fracture line was found straight, sharp, clean and shiny. In all specimens of the tested groups, the fracture line was located nearly at the center of the specimen where the load was applied. Which all the fractured specimens could be reassembled, and the line of fracture was not clearly seen.

Table (1.B) and figure (4) show the mean flexural strength values for both studied groups (I&II) at both conditions (i.e. zero thermo-cycling and after thermo-cycling).

Figure 4: Showing comparison between the mean values of the two studied groups according to flexural strength in (Mpa), before and after thermo-cycling.

When compare the two groups using student t-test we found that the auto-polymerized pour resin had slightly higher flexural strength than conventional PMMA in both conditions (zero and after thermo-cycling) and this was not statistically significant at P level of 0.05 where the (t$_1$=0.437) (P=0.670) at zero thermo-cycling and (t$_1$=1.110) (p=0.289) after thermo-cycling.

According to Paired t-test for comparing between zero and after thermo-cycling for each group, it revealed reduction in flexural strength for both groups had not affected significantly by thermo-cycling.

Table 1: Showing comparison between the two studied groups according to (A) impact strength test &(B) flexural strength test, before and after thermo-cycling.

	Subgroups A&B	Group I Control group (n= 7)	Group II Study group (n= 7)	U(P)
(A) Impact strength test values in (KJ/mm²)	**No thermo-cycling** Min. – Max. Mean ± SD. Median	40.0 – 110.0 54.29 ± 24.90 45.0	30.0 – 45.0 37.14 ± 4.88 35.0	5.000*(0.011*)
	After thermo-cycling Min. – Max. Mean ± SD. Median	45.0 – 70.0 51.43 ± 9.45 45.0	35.0 – 55.0 40.71 ± 7.32 40.0	7.000*(0.021*)
	Z(P)	0.106(0.916)	0.736(0.461)	
	% of Change	↓5.67	↑11.93	
	Subgroups A&B	Group I Control group (n= 7)	Group II Study group (n= 7)	t_1(P)
(B) Flexural strength test values in(Mpa)	**No thermo-cycling** Min. – Max. Mean ± SD. Median	92.28–146.76 122.62±19 127.68	82.68–159 128.62±30.95 141.48	0.437(0.670)
	After thermo-cycling Min. – Max. Mean ± SD. Median	73.20–143.64 116.90±23.69 116.40	85.20–156.36 131.30±24.84 133.44	1.110(0.289)
	t_2(P)	0.512(0.627)	0.168(0.872)	
	% of Change	↓2.43	↓9.61	

U,P: U and P values for **Mann Whitney test** for comparing between the two studied groups.
Z,P: Z and P values for **Wilcoxon signed ranks test** for comparing between before and after thermo-cycling for each group.
t_1,P: t_1 for **Student t-test** for comparing between the two groups.
t_2,P: t_2 for **Paired t-test** for comparing between before and after thermo-cycling for each group.
*: statistically significant at P≤ 0.05

Warpage test

Warpage appears in the form of separation of the plate from stone cast at the posterior palatal seal area. The mean values of spaces between the plates and their stone casts at different locations measurement for two groups in all observational stages are presented in (Table 2. Figure 5).

Table 2: Showing comparison between the mean values of warpage test in microns for the two studied groups, immediately, before & after thermo-cycling.

Studied groups (I&II)	Immediately	No Thermo-cycling	After Thermo-cycling	^{Fr}p
Group I control group (n= 7) Min. – Max.	159.6–1222.93	467.71–1617.7	659.20–1713.71	0.001*
Mean ± SD.	588.89±423.91	845.64±520.29	1148.5 ± 394.36	
Median	429.94	565.52	1030.02	
Sig. between periods	p_1= 0.016*,p_2 <0.423,p_3= 0.001*			
% of Change (Immediately)		↑53.44	↑197.83	
% of Change (before - after)		↑93.53		
Group II Study group (n= 7) Min. – Max.	208.95–491.64	486.12–792.07	238.07 – 1131.1	0.004*
Mean ± SD.	407.20±104.85	595.64±111.84	499.87 ± 320.42	
Median	465.10	559.11	382.80	
Sig. between periods	p_1=0.061,p_2= <0.001*,p_3= 0.061			
% of Change (Immediately)		↑73.86	↓3.95	
% of Change (before - after)		↓39.46		
U	24.0	22.0	5.0*	
P	0.949	0.749	0.013*	

^{Fr}p: ^{Fr}p value for **Friedman test**, Sig. bet. grps was done using Post Hoc Test (**Dunn's multiple comparisons test)**
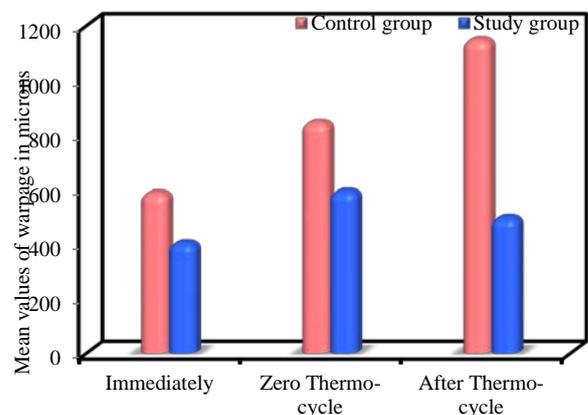U, p: U and p values for **Mann Whitney test** for comparing between the two groups
p_1: p value for comparing between immediately and before thermo-cycling
p_2: p value for comparing between immediately and after thermo-cycling
p_3: p value for comparing between before and after thermo-cycling
*: Statistically significant at p ≤ 0.05

Figure 5: Showing comparison between the mean values of the two studied groups according to warpage in (microns), immediately, zero thermo-cycling after thermo-cycling.

The analysis of data showed that the amount of space between the plates and their stone casts in both groups was greatest at center of plates and gradually decreased toward the crest of the ridge. A comparison of the overall spaces between the plates and reference points at different studied periods was conducted; the overall mean of spaces at different locations for each measurement stage was calculated. For (group I) significant increase in space was observed after 24h immersion in water by 53.44% with (p_1=0.016) and by 197.83% with (p_2=0.423) after thermo-cycling. In addition, there was no significant difference between zero and after thermo-cycling (p_3=0.061). While for (group II) the space was increased with no statistical significant when compared between immediately and before thermo-cycling by 73.86% with ($p1$=0.061) but the this space was decreased by 3.95% & (p_2=<0.001) with statistical significant after thermo-cycling, and the space was significantly decreased when compared between zero & after thermo-cycling by 39.46% with (p_3=0.001).

Mann Whitney test was used for comparing between the two groups, in general there was decrease in spaces for (group II) at three periods of measurement and this decrease was of statistical significant after thermo-cycling for with (U=5.0)(P=0.013).

Comparison between periods was done using Dunn's multiple comparisons test for Friedman test, it revealed statistical significant for both groups with (^{Fr}P=0.001) for group I and (^{Fr}P=0.004) for group II.

Quantitative analysis for estimation of residual monomer

(Table 3 & Figure6) represent the comparison between the two studied groups both before and after thermo-cycling. The results were analyzed using Student t-test, we found that the auto-polymerized pour resin had a higher residual monomer level than conventional PMMA with (t_1=14.415) (P≤ 0.001) & (t_1=15.603) (P≤ 0.001) before and after thermo-cycling respectively.

On analyzing the effect of thermo-cycling on both groups, Paired t-test revealed that both groups have statistical significant decrease in residual monomer levels after thermo-cycling by 18.45% with (t_2= 4.172) (P= 0.006) for group I, while for group II the decrease was by 12.69% with (t_2=6.591) (P= 0.001).
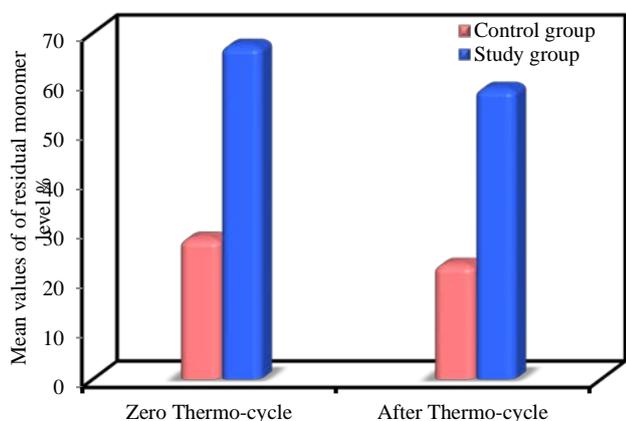
Figure 6: Showing comparison between the mean values of the two studied groups according to residual monomer levels in (%), before and after thermo-cycling.

Table 3: Showing comparison between the two studied groups according to residual monomer test, before and after thermo-cycling.

Subgroups A&B	Group I Control group (n=7)	Group II Study group (n=7)	t_1(P)
No thermo-cycling Min. – Max. Mean ± SD. Median	22.0 – 37.0 28.57 ± 5.32 28.0	61.0 – 76.0 67.57 ± 4.79 67.0	14.415*(<0.001*)
After Thermo-cycling Min. – Max. Mean ± SD. Median	18.0 – 35.0 23.29 ± 5.53 22.0	55.0 – 62.0 58.86 ± 2.41 59.0	15.603*(<0.001*)
(t_2P)	4.172* (0.006*)	6.591*(0.001*)	
% of Change	↓18.45	↓12.69	

t_1,P: t_1 values for **Student t-test** for comparing between the two groups.

t_2,P: t_2 values for **Paired t-test** for comparing between before and after thermo-cycling in each group.

*: Statistically significant at p ≤ 0.05

DISCUSSION

Classically, the polymerization of an acrylic resin for denture base is carried out by heating induction in hot water, and it is a slow process. Lately, with the aim of reducing working time, some polymerization techniques have been tried. However, acceleration process can result in greater porosity, dimensional changes and concentration of residual monomer (21).

The presence of unreacted monomer in denture base resin in undesirable because it impedes the resin's mechanical properties. Furthermore, this unreacted monomer may leach out into the saliva which actually causes the cytotoxic effects in the oral cavity (22).

Auto-polymerized pour resin has been used for denture base construction in order to simplify the process of denture fabrication and reduce the working time.

Impact strength is an important property for denture base material which have tendency to fracture if accidentally dropped onto a hard object (11).

Therefore, the impact strength test was conducted in this study as one of the tests for evaluation of mechanical properties of a newly formulated auto-polymerized pour resin denture base material.

As regard to our study when compare the mean values of impact strength of specimens for both groups at different conditions, and represent the effect of thermo-cycling on them, we found that auto-polymerized pour resin showed significantly lower impact strength than conventional PMMA in both situations. This decrease can be explained by lower degree of polymerization of auto-polymerized resin which lead to high concentration residual monomer which lower the impact strength (23). Our results are consistent with previous study by AbouDaya (24) in 1990.

Also the results obtained from this study showed that there was non-significant increase in the value of impact strength for group II after thermo-cycling, this increase may be explained by competing effects of post-polymerization and residual monomer release of the materials and gradual water sorption. It is likely that the further polymerization and residual monomer release mechanism overcome the plasticizing effect

of the water uptake consequently; an improvement in the mechanical properties can be expected (25). Our finding was agreed with Silva et al. (10) in 2013.

Flexural strength is important parameters that can reflect the ability of a denture base material to withstand functional masticatory forces. The three-point flexural strength test is useful in comparing denture base materials because it simulates the type of stress that is applied to the denture during mastication (26). Denture bases have been shown to flex under the forces generated during mastication subjecting the acrylic polymer to internal stresses that may result in crack formation and eventually, fracture of the denture (27). When compare the two groups (I&II) the auto-polymerized pour resin had slightly higher flexural strength than conventional PMMA in both conditions (zero and after thermo-cycling) and this was not statistically significant at P level of 0.05. This increase could be attributed to high amount of residual monomer which acts as plasticizer which reduce the polymer inter-chain forces and reduce the glass transition temperature which render the resin softer and more flexible (28). Our finding was in agreement with Mumcu et al. (29) in 2011.

Our results of comparison between two groups were consistent with Takahashi (30) in 2012 as he reported that thermo-cycling not significantly affect the flexural strength.

Warpage appears in the form of separation of the plate from the stone cast and was selected for testing the specimens since an accurate fit is relatively important because the distance between the base and supporting tissue is one of the principal factors in retention and control of the amount of forces necessary to dislodge the dentures (31).

Our study showed that the space in the middle was higher than the crest of ridge and this may due to the heat of polymerization process was transferred from the highest area to the midline area according to creep phenomenon in addition to the volume of acrylic resin was more in the midline area so greater volumetric changes and more internal stress release was documented as reported by Al-Taie (32) in 2008.

Our study revealed that the mean space for conventional PMMA was increased in the five points in all conditions, this can be explained that contraction of denture base due to compression of the material in the mold and further polymerization that occurred due to exposure to high temperature with reduction in spaces between the chains of polymer, and this was consistent with Al-Ameer (16) in 2012.

While for auto-polymerized pour resin the amount of spaces were significantly lower than conventional PMMA and this may due to that the induced stresses in auto-polymerized resin are less than those of heat cured resin, also the lower polymerization temperature tend to give less thermal contraction after polymerization, and the elastic limit of hydrocolloid investing material allow and compensate for volumetric changes occurred during polymerization and cooling (33) while after thermo-cycling the material showed significantly decreased spaces and this could be explained by the water sorption, in which water sorption forces the molecules apart and results in acrylic expansion, this expansion compensates the polymerization shrinkage of acrylic resin and improves the adaptation of denture base (34). This finding agreed with Frangou et al (35) in 1990 and Al- Alooni &Fatah (36) in 2012.

Polymerization of acrylic resin is followed by conversion of MMA to PMMA (curing process), during polymerization not all of the monomers are converted into polymers and therefore some unreacted monomers called residual monomers are left. Its conversion varies depending on the methods and the conditions of polymerizations. Residual monomers is left in the polymerization might leach into water as well as human or artificial saliva. Leached residual monomer is considered be responsible for various degree of in vitro and in vivo allergic response (37).

The results obtained from our study showed that the level of residual monomer for auto-polymerized pour resin was significantly higher than that of conventional PMMA, which responsible for electing immune response as reported by Abdelhamid et al (38) in 2016. The reason for this higher residual monomer content is the low degree of conversion achieved by the use of chemical activator in auto-polymerized resin as opposed to that generated by heat activation. Free radical polymerization reaction does not result in complete conversion of all carbon-carbon double bond and therefore, acrylic resins are known to contain and release un-polymerized monomers (39). Our results were in agreement with AL-Ali et al (18) in 2013.

The effect of thermo-cycling on both groups I&II revealed significant reduction in the residual monomer levels which agreed with Milena et al. (40) in 2011 as he stated that after additional polymerization in hot water bath, a significant reduction in the amount or residual monomer in the samples was observed.

CONCLUSION
Within limitations of this in vitro study, it could be concluded that:
1- The newly formulated auto-polymerized pour resin exhibited high adaptation accuracy (low warpage) which attributed to investing medium and technique of processing.
2- The newly formulated auto-polymerized resin with pour technique associated with high amount of residual monomer which affecting the physico-mechanical properties which resulted in decrease in the impact strength while the flexural strength is slightly increased.
3- The thermo-cycling has improved the bio-compatibility and physico-mechanical properties of auto-polymerized pour resin due to further polymerization and leaching out of residual monomer.

CONFLICT OF INTEREST
The authors declare that they have no conflicts of interest.

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