

# Effect of water absorption and solubility on dimensional change of self-cure acrylic resin using Ultraviolet visible spectrophotometer; an in vitro study

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## Abstract:

**Objective:** The objectives of this study are to evaluate the effect of different powder-liquid ratios and water temperatures on the levels of absorption and solubility of an auto-polymerizing resin material and its effect on dimensional stability of self-cure acrylic resin.

**Methodology:** 60 self-cure acrylic discs (39 x 4mm) were fabricated and divided into 3 groups, each having 20 specimens. Group 1 consisted of discs fabricated according to manufacturer's recommendations at a powder-liquid ratio of 5.1:2.8 this served as the control group. Group 2 and 3 also consisted of 20 samples each with slight variations in powder-liquid and post-cure soaking temperatures. Specimen from group 2 were soaked in water baths at temperatures of 37°C, 47°C, 57°C and 67°C for 24 hours. Specimens from the temperature-controlled group 3 were fabricated at four different powder-liquid ratios by increasing monomer liquid volume by 10%, 15%, 20% and 25%. The acrylic discs from control groups 1 and 3 were soaked at a constant temperature of 37°C for 24 hours the change in dimension was noted before and after immersion by weighing the samples. Residual monomer leached out from disc into water was analyzed using Ultraviolet spectrophotometer.

**Results:** A linear regression model was generated in order to investigate the impact of these three predictors on dimensional change. Pearson's correlation was employed for evaluating the association between the independent predictor variables (PLR, PST and residual monomer) and the dependent outcome variable dimensional change (DC).

**Conclusion:** A moderately weak positive correlation was calculated for the association between PLR and Dc ( $r = 0.15$ ,  $p < 0.001$ ) suggesting a proportional relationship between PLR and DC. The correlation between the DC and the PST association was found to be weakly positive ( $r = 0.23$   $p < 0.001$ ), indicating a proportional relationship. The association between residual monomer and dimensional change had a weak negative correlation ( $r = -0.01$ ,  $p < 0.001$ ). As the liquid ratio was increased there was a decrease in absorption (except for ratio controlled) and an increase in solubility.

**Index Terms:** polymethyl-methacrylate (PMMA), self-cure acrylic resin, residual monomer, dimensional change, water absorption, ultraviolet spectrophotometer

## 1. Introduction:

The use of acrylic resins in dentistry has been on the rise ever since their advent by 1937 and almost 98% of denture bases nowadays are constructed from polymethyl methacrylate (PMMA)(1).

Despite the extensive use of acrylic resins in dentistry, their long term predictability has been questionable due to inadequate flexural strength and reduced fatigue life exacerbated by notch sensitivity. Acrylic resin has also been known to absorb water followed by a release of moisture upon drying. Such a cyclic process if continued can lead to minute but multiple crack formations called 'crazing' which can lead to further weakening of the denture(2, 3).

Literature indicates that absorption followed by solubility of water from auto-polymerizing resins not only has negative implications on physical properties, but the leached products may lead to harmful tissue reactions(4). When water interacts with the polymer chains it may produce some mild reversible loosening or effective plasticization of the structure. It can also lead to rupture of weak inter-chain bonds and irreversible disruption of the polymer matrix may occur(5). Takahashi et al found that water molecules spread between the material forces them apart effecting the structural integrity and dimensional behavior, indicating that water absorption and solubility of these materials should ideally be as low as possible(6, 7).

The presence of residual, un-converted monomers physically entangled within the matrix and not strongly bonded to polymer chains, have the propensity of leaching out into the oral cavity. These monomers have been identified as a cause of adverse tissue reactions(8, 9). An optimum powder/liquid ratio is recommended in the fabrication of dental appliances which not only adequately satisfies the reaction, but also reduces residual monomer load capable of leaching out during service. Fletcher et al additionally recommended that a dental appliance should be soaked in water for at least 24 hours before delivery to a patient, in order to reduce the possible adverse effect(10).

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For auto-polymerizing resins, associated with higher residual monomer levels compared to heat-cured resins, soaking the appliance at elevated temperatures (65°C for 60 minutes), would reduce the residual monomer content more efficiently than at room temperature(4).

Ultraviolet Visible Spectroscopy is a widely used quantitative analytical technique that is routinely applied to detect the presence and extent of residual monomers within a substance. UV/Vis spectroscopy is also used in analytical chemistry for the quantitative determination of different analytes, such as transition metal ions, highly conjugated organic compounds, and biological macromolecules. The spectroscopic technique is used to obtain an infrared spectrum of absorption, emission, it is commonly carried out in solutions but solids and gases may also be studied. Molecules containing  $\pi$ -electrons or non-bonding electrons (n-electrons) can absorb the energy in the form of ultraviolet or visible light to excite these electrons to higher anti-bonding molecular orbital(11). The more easily excited the electrons (i.e. lower energy gap between the excitation states), the longer the wavelength of light it can absorb. The Beer-Lambert law states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length(12). Thus, for a fixed path length, UV/Vis spectroscopy can be used to determine the concentration of the absorber in a solution. It is necessary to know how quickly the absorbance changes with concentration. This can be taken from references or more accurately, determined from a calibration curve.

This makes infrared spectroscopy useful for several types of analysis. In dentistry, infrared spectroscopy has been used extensively for various reasons such as identification of bone density, the determination of residual monomer, degree of conversion of polymethyl methacrylate, degree of conversion of composites etc. Infrared spectroscopy results in positive identification (quantitative analysis) of materials. In addition the size of peak in spectrum is indicative of the amount of material present.

A relationship exists between the levels of residual monomer and water absorption(13). Various studies have been conducted in the past to identify the effect of powder/liquid ratio on the degree of conversion of heat cure denture base resins (4, 14, 15). Kalachandra and Patel conferred the water absorption characteristics of resins and concluded that water absorption was affected by the plasticizer content. Wong et al discussed the effects of different processing methods on the dimensional accuracy and water absorption of acrylic resin dentures. The study proposed that different curing methods showed variations in dimensional shrinkage at water saturation(16). Hargreaves and Ristic discussed the equilibrium between denture base behavior and water uptake, the results

confirmed the influence of water on the behavioral properties of denture bases (17-20).

There, however, remains a paucity of literature available that identifies the effects of variations in power/liquid ratio on water absorption and the residual monomer content in self cure denture base resins.

## 2. Objective of the study:

The objectives of this study are:

1. To evaluate the effect of different powder/liquid ratios and water temperatures on the levels of absorption and solubility of an auto-polymerizing resin material.
2. To measure residual monomers as a consequence of variations in powder/liquid ratios and water temperatures and its effect on dimensional stability of self-cure acrylic resin.

### 2.1 Hypothesis:

The null-hypothesis states that there is no difference in absorption and solubility in auto-polymerizing resin material soaked in water at different temperatures with variations in powder/liquid ratios.

### 2.2 Materials and methods:

#### a) Sample preparation:

The methodology for the absorption and solubility experimentation followed was done according to the ISO Standard 1567 (1999) for the ratio-controlled experiment. For the temperature-controlled experiment the recommended temperature of 37°C was used as the control. The manufacturer's instructions of the material that was used for the experiments were followed, except when the powder/liquid ratios were changed. In this instance, the recommended ratio was used as the control. Teflon discs having a standard diameter of 39mm and a thickness of 4mm were initially used as templates to create moulds for the fabrication of self-cure acrylic samples as specified by ISO Standard 1567 (1999).

TABLE 1  
Study design for experiment.

Control Group			Group 01 (Temp controlled)			Group 02 (Composition controlled)		
S.No	Powder/liquid ratio	Temp	S.No	Powder/liquid ratio	Temp	S.No	Powder/liquid ratio	Temp
01	5.1 / 2.8	37°C	01	5.1 / 2.8	37°C	01	5.1 : 3.1	47°C
02	5.1 / 2.8	37°C	02	5.1 / 2.8	47°C	02	5.1 : 3.2	47°C
03	5.1 / 2.8	37°C	03	5.1 / 2.8	57°C	03	5.1 : 3.42	47°C
04	5.1 / 2.8	37°C	04	5.1 / 2.8	67°C	04	5.1 : 3.5	47°C

A total of 60 moulds were created and divided into 3 groups each consisting of 20 moulds. Self-cure acrylic powder and liquid (Meadway Selfcure/Supercure/Cold Curing Pour Type denture base material, England) was mixed according to the ratio mentioned in Table 1. The powder was dispensed and weighed on a digital weighing scale (UniBloc Analytical Balances ATY 224, Shimadzu, Japan) and the liquid volume was measured using a pipette (370710-10, PYREX VISTA, USA). The templates were filled with the mixed resin material and allowed to bench sit for 60 minutes before being carefully removed. Group 1 consisted of 20 discs fabricated at a powder-liquid ratio of 5.1:2.8 as recommended by the manufacturer. Groups 2 and 3 also constituted 20 acrylic specimens each with variations in curing temperatures and powder-liquid ratios respectively. Specimens from Group 2 were soaked in four water baths after curing at temperatures of 37°C, 47°C, 57°C and 67°C for 24 hours such that each water bath simultaneously received 5 specimens. Similarly specimens from the temperature-controlled Group 3 were fabricated at four different powder-liquid ratios as indicated in Table 1 by increasing monomer liquid volume by 10%, 15%, 20% and 25%. The acrylic discs from control Group 1 were cured at a constant temperature of 37°C.

**b) Absorption, solubility and dimensional change:**

The poured templates were allowed to bench sit for 60 minutes. After setting the specimens were carefully removed wearing latex powder-free gloves and using a stainless steel instrument, the edges removed with a scalpel and stored in polythene to prevent possible evaporation of monomer during transport from the dental laboratory. After fabrication, the specimens were transferred to a desiccator based with silica gel for drying. The specimens were weighed using a Mettler A240 analytical scale with an accuracy of 0.0001 g. The room temperature and humidity were monitored. The cycle of incubating at 37°C and cooling off before weighing was repeated every 23±1hr until a constant weight/mass or state of equilibrium was reached, which is referred to as m1 or "conditioned mass 1". A constant weight was achieved.

After dry weight was determined, the thickness and width of the specimens were measured in order to calculate the volume (mm<sup>3</sup>) of each sample. For the diameter, an electronic digital Vernier caliper (Mitutoyo Digimatic caliper, Japan) to an accuracy of 0.01mm was used and three diameter measurements were recorded. The mean of these three measurements was calculated. Using an electronic digital micrometer (Model no., EOSAMO-24-IP54) to an accuracy of 0.01mm, four thickness measurements were taken at four equally spaced locations at the circumference of the specimen, together with a centre measurement. The mean of these five thickness measurements was calculated and recorded for each specimen.

Volume was recorded as follows:

$$V = \pi .r^2 .h \quad (1)$$

Where:

- $\pi = 3.14;$
- Radius (r) = mean diameter of sample;
- Height (h) = mean thickness of the sample

The specimens were then immersed in distilled water at 37°C ± 1°C, which was retrieved after 24hours for weighing (m2 – "wet" weight). The initial measurement for height was denoted as h1.

The specimens were wiped with a clean dry towel to remove all visible moisture. They were waved in the air for 15±1 seconds and then weighed 60±10 seconds after removal from the distilled water. Each individual specimen was transferred to the measuring pan in the scale. Care was taken not to contaminate the samples with skin moisture. Before each individual specimen reading, the display screen was reset to zero, the sample placed on the measuring pan and the sliding glass door closed. After closing the sliding glass door, the stability light flickers, indicating that the weight is stable, and the sample's weight recorded to an accuracy of 0.001 g.

When the m2 of all specimens was established, the specimens were returned to a desiccator with freshly dried silica crystals. Specimens were again stored and weighed using the same sequence as described earlier for m1, until a constant weight (m3) or "reconditioned mass" was reached at this point the height of the specimen were measured again (h2). The difference between h2 and h1 gave the change in dimension for the specimen post water absorption.

- H1 = initial height of specimen pre immersion
- H2 = final height of specimen post immersion
- m1 = "Dry" weight / pre-immersion weight
- m2 = "Wet" weight / at removal from water
- m3 = "Dry" weight / post immersion

$$\text{Water absorption (Wsp)} = (m2 - m3) / V$$

$$\text{Water solubility (Wsl)} = (m1 - m3) / V$$

$$\text{Change in dimension} = (h2 - h1)$$

**c) Ultraviolet-visible Spectrophotometry:**

Ultraviolet-visible spectrophotometer (JIR-100, JEOL Co.Ltd, and Tokyo Japan.) was used to detect the residual monomer in all samples. Eight solutions of MMA monomer in distilled water (solvent) were produced with concentration of 5%,4%,3%,2%,1%,0.5%,0.25%, and 0.1% for which UV spectra was obtained. The calibration curve was prepared based on these eight known samples. This served as standard or control curve Beer Lambert equation was applied and graph was plotted to obtain fig 1.

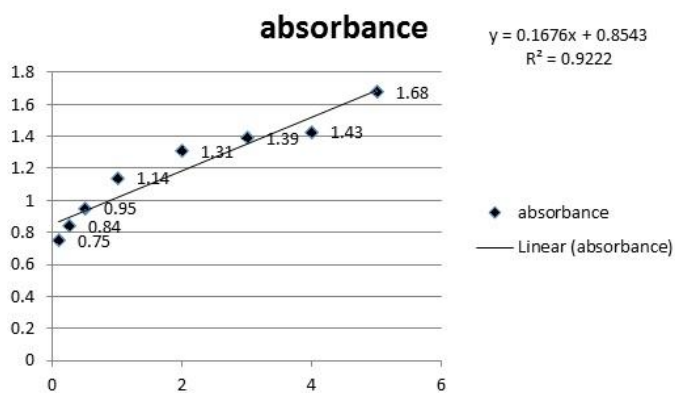


Figure 1: Standard calibration curve

The samples were tested on the basis of either being temperature controlled or composition controlled. For the temperature controlled experiment the powder liquid ratio of all the specimens was kept same as per manufacturer’s instructions ( 5.1g : 2.8ml) and the samples were divided into 03 groups of 20 samples each and immersed in water at temperatures of 37°C,47°C,57°C and 67 °C as shown in table 1. For the composition controlled experiment the temperature was kept standard at 47°C and the powder at 5.1g for all samples while the monomer was incrementally increased for each group starting at 10% (3.1ml), 15% (3.2ml), 20%(3.42), and 25% (3.5) as shown in table 1. Samples following manufactures recommendations that were kept at 37 were considered as the control sample.

In this study Ultraviolet-visible spectrophotometer was used to identify the level of residual monomer that leeches out of the denture sample into the water bath after immersion for 24 hours. This will help identify the solubility of dentures and also the level of residual monomer.

### 3. Results:

This study was designed to assess the effect of different powder/liquid ratios and water temperatures on the levels of residual monomer, absorption and solubility of an auto-polymerizing resin material And its effect on dimensional change of self-cures acrylic resin.

A total of 60 samples with varying powder-liquid ratios (PLR), post-set temperature (PST) and absorption were analyzed for residual monomer using UV spectrophotometer. A linear regression model was generated in order to investigate the impact of these three predictors on dimensional change.

Pearson’s correlation was employed for evaluating the association between the independent predictor variables (PLR, PST and residual monomer) and the dependent outcome variable dimensional change (DC). The DC values for each powder-liquid ratio and post-set temperature (PLR

and PST) settings have been illustrated in table 2. A moderately weak positive correlation was calculated for the association between PLR and Dc ( $r = 0.15, p < 0.001$ ) suggesting a proportional relationship between PLR and DC. The correlation between the DC and the PST association was found to be weakly positive ( $r = 0.23, p < 0.001$ ), indicating a proportional relationship. The association between residual monomer and dimensional change had a weak negative correlation ( $r = -0.01, p < 0.001$ ).

Pearson’s correlation showed a weak negative correlation between dimensional change and level of residual monomer and for every unit change in monomer concentration a dimensional change of 0.001mm was seen.

The linear regression models for the predictors (PLR, PST and residual monomer) of DC have been shown in table 2. For dimensional change, weak associations ( $p < 0.001$ ) were found with powder/liquid ratio [ $\beta = -0.05 (-0.93 - 0.93)$ ], post-set temperature [ $\beta = 0.223 (0.00 - 0.02)$ ] and residual monomer concentration [ $\beta = -0.71 (-0.57 - 0.39)$ ].

Table 2. Linear Regression Coefficients (95% Confidence Intervals) for the Association of Powder/Liquid Ratio, Post-set Temperature and Residual monomer concentration with change in dimension

	Dimensional Change
<b>Powder/Liquid Ratio</b>	-0.05 -0.93 – 0.93
<b>Post-set Temperature</b>	0.223 0.00 – 0.02
<b>Residual monomer concentration</b>	-0.71 -0.57 – 0.39

This would suggest that that the change in powder/liquid ratio and post-set temperature directly affected the water level of residual monomer concentration which in turn had a weak effect on change in dimension of the sample.

Table 3a: Mean values of absorption, solubility, dimensional change and concentration.

Control group	Absorption in $\mu\text{g}/\text{mm}^3$	Solubility in $\text{g}/\text{mm}^3$	Dimensional change (height)mm	Residual monomer concentration
	2.81	2.59	0.26	0.95
	2.79	1.54	0.25	0.93
	2.80	2.17	0.26	0.95
	2.84	2.92	0.36	0.93

Table 3b: Mean values of solubility.

	Temperature	Absorption in $\mu\text{g}/\text{mm}^3$	Solubility in $\text{g}/\text{mm}^3$	Dimensional change (height)mm	Residual monomer concentration
Temperature controlled composition (5,12,8)	37°C	2.80	1.67	0.28	0.94
	47°C	2.50	6.28	0.24	1.05
	57°C	2.30	7.88	0.22	1.18
	67°C	2.88	3.82	0.30	2.84

Table 3c: Mean values dimensional change and concentration.

	Composition	Absorption in $\mu\text{g}/\text{mm}^3$	Solubility in $\text{g}/\text{mm}^3$	Dimensional change (height)mm	Residual monomer concentration
Composition controlled temperature at 47	10%	2.79	2.89	0.34	1.17
	15%	2.59	3.32	0.26	1.24
	20%	2.50	3.45	0.25	1.40
	25%	1.29	4.51	0.19	1.83

The group with the highest mean absorption was observed at 67°C in the 0% group (control) and the group with the lowest mean absorption was the 25% group. The highest solubility was observed at 57°C in the 25% group and the group with the lowest solubility was the 0% group. The maximum amount of residual monomer was obtained at 67°C and the lowest values were obtained in the control group (0%). The maximum amount of change in dimension was seen in the control group and the lowest dimensional change was observed for the 25% group.

One way analysis of variance ANOVA with a 95% confidence interval of means showed insignificant differences among absorption, solubility, residual monomer and dimensional change ( $p > 0.94$ ).

Table 4. ANNOVA

		Sum of squares	df	Mean square	F	significance
Sorption	Between groups	9.24	4	2.32	265	0.00
	Within groups	0.17	20	0.009		0.00
	Total	9.42	24			
Solubility	Between groups	0.005	4	0.001	2.34	0.90
	Within groups	0.10	20	0.001		0.64
	Total	0.15	24			
Residual monomer	Between groups	2.26	4	561	106.5	0.00
	Within groups	0.10	20	0.005		0.00
	Total	2.35	24			
Dimensional change	Between groups	0.105	4	0.26	0.535	0.712
	Within groups	0.987	20	0.49		0.921
	Total	1.092	24			

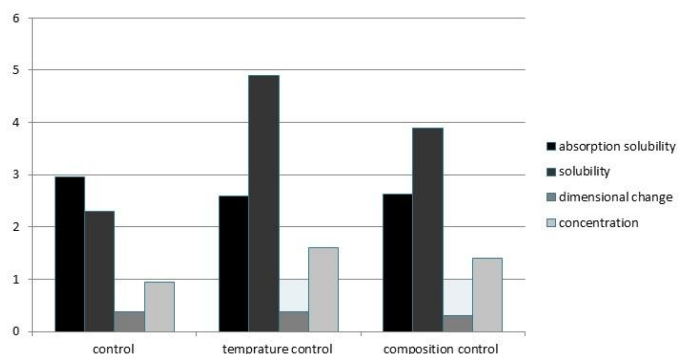


Fig 2: overview

#### 4. Discussion:

Auto-polymerizing or self-cure acrylic is commonly used for denture repairs, chair side temporary denture relines, fabrication of obturators, custom trays and orthodontic appliance(21, 22). Even though the use of autopolymerizing resins is declining world over due to its residual monomer content and its inherent properties which may be inferior than heat cure resin (23-25). It is still considered one of the common materials in the developing countries such as Pakistan, India, Bangladesh due to easier clinical handling, less chair side time and affordability. Upon mixing, activators present in the liquid monomer component immediately start the polymerization reaction by releasing free radicals from initiator break down. The reaction propagates fast resulting in a set polymer with shorter polymer chains and weaker cross linking. A lower average molecular weight of the self-cured acrylic chains indicates the possible higher existence of residual monomers(26).

The autopolymerizing acrylic resin is now commonly used in processing of dentures. For both the denture base resin; heat cure and autopolymerizing resin, the level of residual monomer in the resin and its mechanical properties are closely related to curing conditions(27). It is also a general belief that tissue sensitivity to acrylic resin denture base materials depends on the level of residual monomer and increases with an increase in percentage of residual monomers in the resin(28, 29). McCabe and Baskerg have reported that methyl methacrylate monomer is an irritants sensitizer to tissues. Therefore the level of residual monomer must be controlled carefully when using these materials(10). It has also been reported that a high level of residual monomer is detrimental to mechanical properties of the resin(26). However, there remains a paucity of literature on the relationship between conditions of material preparations and material properties of cured resin(30).

The purpose of these experiments was to investigate the influence of different Powder/Liquid ratios and different water soaking temperatures on absorption and solubility of self-cure acrylic resin and its effect on dimensional change due to the residual monomer content. The methodology chosen here was based on a study by A. Latief (2012) with few modifications. An incubation period of 24 hours was considered for all the specimen groups as the largest amount of residual monomer is usually leached from acrylate within first 24 hours(5). Control group specimens had fixed powder-liquid ratios and post cure soak temperatures. The selected variations in powder-liquid ratios and post-cure soak temperatures in Groups 2 and 3 were identified from literature based on the commonly used values by technicians and operators.

Powder-liquid ratios were prepared with an incremental increase of 10%, 15%, 20% and 25% in liquid. The variations in the powder-liquid ratio of PMMA resins was justified by the common practice of increasing the liquid content to improve flow of the material thereby enhancing the capability of reproducing fine detail.

The rate and extent of water absorption into polymer networks are controlled by resin polarity, which is in turn dictated by the availability of polar sites available to form hydrogen bonds with water(31). Water is absorbed into polymer by the polarity of the molecules by means of unsaturated bonds or unbalanced intermolecular forces(31, 32). The results of this experiment indicated lower water absorption levels with an increase in liquid monomer content in our temperature controlled group. It may be assumed that specimens fabricated with lower powder-liquid ratios presented with a lower mean water absorption levels and hence better dimensional stability due to the saturated bonds of the polymer chains containing unfavorable amounts of residual monomer. The residual monomers after polymerization occupies spaces within the matrix, thereby preventing the occurrence of voids capable of being filled by water.

Polymerization of resin can be achieved by using different polymerization methods during the mixing period and dough state the monomer penetrates into the powder particles. The liquid wets the powder particles and forms a binder when it hardens. After polymerization, a multiphase polymer is formed but despite the various methods used to initiate polymerization the conversion of monomer to polymer is seldom complete and some unreacted monomer remains. Lamb et al suggested that due to the nature of additional polymerization at the sites of active radicals, monomer molecules would disperse at a more rapid rate if stored at increased temperatures, thereby increasing the rate at which free monomer and water soluble additives are reduced. Since the conversion of MMA to PMMA is seldom complete for autopolymerizing resins it is recommended to store the appliance in hot water at higher temperature thus promoting the release of residual monomer and increasing the solubility of resin material. A decrease in water absorption will be observed thereby preventing the possible weakening and change in dimension of the appliance(33).

Water absorption and solubility are two different phenomenon involving different molecules. Monomer has a large molecular structure than water, the values of sorption and solubility, show considerably more matter is "absorbed" than "solved" and it is clear that residual monomer is not simply replaced by water upon immersion.

Vallutu et al explained that the rate of dispersion between PMMA and water may be enhanced, and is also dependent on, an increase in temperature(34) The influence of water

immersion temperature on absorption, solubility and residual monomer was therefore examined within this experiment.

Over the period of time, several physical and chemical methods have been employed to detect the level of residual monomer in resin. The most accurate method is gas liquid chromatography but our experimental design has employed the use of UV spectrophotometer to detect the residual monomer content which is also a reliable and accurate method.

Theoretically, a low absorption and low solubility value would result in a clinical superior product. However, the inverse relationship between absorption and solubility means that this cannot be achieved clinically. Therefore a decision needs to be made based on the consequences and impact of both properties and residual monomer content. Low absorption would lead to a more durable and dimensionally stable product or low solubility leading to a more biologically acceptable product. Martin et al reported that several studies have shown that residual monomer is a primary irritant to denture wearers which is localized to the immediate soft tissue area contacting the dental appliance and this notion is also backed by literature(35). Martin et al emphasized that delayed hypersensitivity is rare and can occur in and around some patients' mouths. Allergic hypersensitivity reactions can either be immediate or delayed, and with MMA, the reaction is usually delayed (9, 36). This delayed reaction is referred to as stomatitis venenata(36). From a clinical standpoint, proper powder/liquid ratios are therefore recommended in order to minimize reactions to the dental appliance, thereby minimizing possible trauma and denture discomfort, and improving patient satisfaction.

Lamb et al reported that residual monomer present in a dental appliance will eventually leach out in the oral cavity of the denture wearer(33). Based on cell culture studies by Cimpan et al it may be extrapolated that monomer has a direct cytotoxic effect on cells *in vivo*. Since toxic effects are usually time and dose dependent, lower solubility values are desired to minimize the release of harmful substances into the oral cavity, reducing cytotoxicity and allergic reactions. The results obtained from this experiment indicate that an increase in the liquid ratio produced increased solubility. A higher risk of cytotoxicity and allergic reactions could therefore be anticipated, and an accurate powder/liquid ratio as indicated by the manufacturer is therefore recommended.

Previous studies have established that storage time influences the level of residual MMA in processed specimens. However, it would be highly impractical and non-profitable to soak a newly processed appliance for periods even ranging up to one week before delivery to the dentist. Proper patient education related to handling their new appliance would be recommended instead. As

mentioned before, one of the aspects investigated in this study was the influence of increase in temperature on the water sorption and solubility of the resin material. Possible future studies could examine the effect storage time and storage temperature will have on absorption and solubility values.

## 5. Conclusion:

Autopolymerizing resins have higher monomer content as compared to heat cure resin. The residual monomer content would adversely affect the properties of the prostheses itself and therefore it can be controlled by using a pre set powder liquid ratio and soaking temperature so as to reduce the level of residual monomer in the product and also to improve the stability and other properties of the product.

Within the limitations of this study, the following conclusions and recommendations may be made

- For auto-polymerizing resins, it is recommended to store the appliance in water at moderately higher temperature ranges (under 67°C), thus promoting the release of residual monomer.
- When the fluid content in the mixture is increased, it is recommended to pre-soak the polymerized product longer to optimize pre-leaching of residual monomer and other possible harmful substances
- Soaking auto-polymerizing resins at higher temperatures (e.g. 67°C) increases solubility, but also absorption of water, hence this practice is not recommended.
- As the liquid ratio was increased there was a decrease in absorption (except for ratio controlled) and an increase in solubility. Therefore, an increase in fluid in the mixture does not affect the absorption and its negative consequence on the mechanical properties of the finished product, but it does affect the solubility. However, in terms of bio-compatibility, the use of the manufacturer's guidelines for powder/liquid ratios is recommended, resulting in the lowest solubility.

## 6. References:

- [1] Manappallil JJ. Basic dental materials: Jaypee Bros. Medical Publishers; 2010.
- [2] Bevan E, Earnshaw R. The role of water sorption in the solvent crazing of acrylic resins: Part I. Australian dental journal. 1968;13(4):265-73.
- [3] Hiromori K, Fujii K, Inoue K. Viscoelastic properties of denture base resins obtained by underwater test. Journal of oral Rehabilitation. 2000;27(6):522-31.
- [4] Latief A. Sorption and solubility of a denture base acrylic: Cape Peninsula University of Technology; 2012.
- [5] Tuna SH, Keyf F, Gumus HO, Uzun C. The evaluation of water sorption/solubility on various acrylic resins. European journal of dentistry. 2008;2:191.
- [6] Takahashi Y, Chai J, Kawaguchi M. Effect of water sorption on the resistance to plastic deformation of a denture base material relined with four different denture reline materials. International Journal of Prosthodontics. 1998;11(1).
- [7] Cucci ALM, Vergani CE, Giampaolo ET, Afonso MC. Water sorption, solubility, and bond strength of two autopolymerizing acrylic resins and one heat-polymerizing acrylic resin. The Journal of prosthetic dentistry. 1998;80(4):434-8.
- [8] Gosavi SS, Gosavi SY, Alla RK. Local and systemic effects of unpolymerised monomers. Dental research journal. 2010;7(2):82.
- [9] Keyf FA, Keyf AI. Harmful effects of methylmethacrylate and formaldehyde from acrylic resin denture base materials. Saudi Dental Journal. 1998;10(1):23-8.
- [10] Fletcher A, Purnaveja S, Amin W, Ritchie G, Moradians S, Dodd A. The level of residual monomer in self-curing denture-base materials. Journal of dental research. 1983;62(2):118-20.
- [11] Mehta A. Ultraviolet-Visible (UV-Vis) Spectroscopy-Woodward-Fieser Rules to Calculate Wavelength of Maximum Absorption (Lambda-max) of Conjugated Carbonyl Compounds.
- [12] Mehta A. Ultraviolet-Visible (UV-Vis) Spectroscopy-Derivation of Beer-Lambert Law. Analytical Chemistry Available at pharmaxchange info. 2012.
- [13] Ferracane JL. Hygroscopic and hydrolytic effects in dental polymer networks. Dental Materials. 2006;22(3):211-22.
- [14] Yunus N, Harrison A, Huggett R. Effect of microwave irradiation on the flexural strength and residual monomer levels of an acrylic resin repair material. Journal of oral Rehabilitation. 1994;21(6):641-8.
- [15] Moharamzadeh K, Brook IM, Van Noort R. Biocompatibility of resin-based dental materials. Materials. 2009;2(2):514-48.
- [16] Wong D, Cheng LY, Chow T, Clark RK. Effect of processing method on the dimensional accuracy and water sorption of acrylic resin dentures. The Journal of prosthetic dentistry. 1999;81(3):300-4.
- [17] Ristic B, Carr L. Water sorption by denture acrylic resin and consequent changes in vertical dimension. The Journal of prosthetic dentistry. 1987;58(6):689-93.
- [18] Hargreaves A. Equilibrium water uptake and denture base resin behaviour. Journal of Dentistry. 1978;6(4):342-52.
- [19] Kalachandra S, Turner D. Water sorption of plasticized denture acrylic lining materials. Dental Materials. 1989;5(3):161-4.
- [20] Patel M, Braden M. Heterocyclic methacrylates for clinical applications: III. Water absorption characteristics. Biomaterials. 1991;12(7):653-7.
- [21] Frazer RQ, Byron RT, Osborne PB, West KP. PMMA: an essential material in medicine and dentistry. Journal of long-term effects of medical implants. 2005;15(6).
- [22] Faltermeier A, Rosentritt M, Müssig D. Acrylic removable appliances: comparative evaluation of different postpolymerization methods. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(3):301. e16-. e22.
- [23] Huang F-M, Hu C-C, Chang Y-C, Chou M-Y. Residual monomer releasing from acrylic denture base in water. CHINESE DENTAL JOURNAL. 2000;19(1):17-22.
- [24] Jorge JH, Giampaolo ET, Machado AL, Vergani CE. Cytotoxicity of denture base acrylic resins: a literature review. The Journal of prosthetic dentistry. 2003;90(2):190-3.
- [25] Bholra R, Bholra SM, Liang H, Mishra B. Biocompatible denture polymers-a review. Trends in Biomaterials and Artificial Organ. 2010;23(3):129-36.
- [26] Ivković N, Božović D, Ristić S, Mirjanić V, Janković O. THE RESIDUAL MONOMER IN DENTAL ACRYLIC RESIN AND ITS ADVERSE EFFECTS. Contemporary Materials. 2013;1(4):84-91.

- [27] Doğan A, Bek B, Cevik N, Usanmaz A. The effect of preparation conditions of acrylic denture base materials on the level of residual monomer, mechanical properties and water absorption. *Journal of Dentistry*. 1995;23(5):313-8.
- [28] Devlin H. Acrylic monomer--friend or foe? Quintessence of dental technology. 1984;8(8):511.
- [29] Kallus T. Evaluation of the toxicity of denture base polymers after subcutaneous implantation in guinea pigs. *The Journal of prosthetic dentistry*. 1984;52(1):126-34.
- [30] Honorez P, Catalan A, Angnes U, Grimonster J. The effect of three processing cycles on some physical and chemical properties of a heat-cured acrylic resin. *The Journal of prosthetic dentistry*. 1989;61(4):510-7.
- [31] Malacarne J, Carvalho RM, Mario F, Svizero N, Pashley DH, Tay FR, et al. Water sorption/solubility of dental adhesive resins. *Dental materials*. 2006;22(10):973-80.
- [32] Arima T, Murata H, Hamad T. The effects of cross-linking agents on the water sorption and solubility characteristics of denture base resin. *Journal of oral rehabilitation*. 1996;23(7):476-80.
- [33] Lamb D, Ellis B, Priestley D. The effects of process variables on levels of residual monomer in autopolymerizing dental acrylic resin. *Journal of Dentistry*. 1983;11(1):80-8.
- [34] Vallittu PK, Miettinen V, Alakuijala P. Residual monomer content and its release into water from denture base materials. *Dental Materials*. 1995;11(5):338-42.
- [35] Martin N, Bell HK, Longman LP, King CM. Orofacial reaction to methacrylates in dental materials: a clinical report. *The Journal of prosthetic dentistry*. 2003;90(3):225-7.
- [36] Hochman N, Zalkind M. Hypersensitivity to methyl methacrylate: mode of treatment. *The Journal of prosthetic dentistry*. 1997;77(1):93-6.

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