Effects of Water Immersion at Different Temperatures on Dimensional Stability and Flexural Strength of Self-Cured Acrylic Resin

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Abstract

To study the effects of water immersion at different temperatures on dimensional stability and flexural strength of self-cured acrylic resin. Forty-five rectangular specimens size 10 x 65 x 3.5 mm^3 were prepared. The specimens were divided into three groups, 15 pieces each, immersed in water for 30 days at constant temperature of 5, 37, and 57 degrees Celsius respectively. Dimensional change in vector of the specimens were measured using a stereomicroscope before and after immersion. Then, the flexural strength of all specimens was tested using a universal testing machine and statistically analyzed using Wilcoxon and the Kruskal-Wallis and Mann Whitney Test at a confidence level of 95%. The result showed mean values of linear dimensional change of three groups were 0.075, 0.064, and 0.045 mm, respectively. After statistical analysis, each group was found to have statistically significant difference. The mean values of flexural strength of the three groups were 137.759, 137.376, and 141.171 N, respectively. In addition, each group was found not to have statistically significant difference. In conclusion, the immersion of self-cured acrylic resin in water for 30 days at constant temperatures of 5, 37, and 57ºC was found to have statistically significant differences in dimensional stability but not in flexural strength.

Keywords: *flexural strength, linear dimensional stability, self-cured acrylic resin, temperature*

บทคัดย่อ

เพื่อศึกษาผลของการแช่น้ำที่อุณหภูมิแตกต่างกันที่มีต่อเสถียรภาพเชิงมิติและค่าแรงดัดขวางของเรซินอะคริลิกชนิดบ่มได้เองเตรียมชิ้นงานที่ทดสอบให้มีรูปร่างสี่เหลี่ยมผืนผ้าขนาด 10 x 65 x 3.5 มิลลิเมตรจำนวน 45 ชิ้นโดยแบ่งกลุ่มการทดลองเป็น 3 กลุ่มกลุ่มละ 15 ชิ้นคือแช่น้ำที่อุณหภูมิคงที่เป็นระยะเวลา 30 วันที่อุณหภูมิ 5, 37 และ 57 องศาเซลเซียสตามลำดับวัดค่าการเปลี่ยนแปลงเชิงมิติในรูปเวกเตอร์ของชิ้นงานทั้งก่อนและหลังแช่น้ำด้วยกล้องจุลทรรศน์ชนิดสเตอริโอไมโครสโคปจากนั้นทดสอบค่าแรงดัดขวางของชิ้นงานทุกชิ้นด้วยเครื่องทดสอบสากลใช้สถิติวิเคราะห์ด้วยวิลคอกซัน, ครัสคาล-วัลลิสและแมนท์วิทนีย์ที่ระดับความเชื่อมั่นร้อยละ 95 พบว่าค่าเฉลี่ยของการเปลี่ยนแปลงเชิงมิติของทั้งสามกลุ่มคือ 0.075 , 0.064 และ 0.045 มิลลิเมตรตามลำดับเมื่อวิเคราะห์ทางสถิติพบว่าแต่ละกลุ่มมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติและค่าเฉลี่ยของค่าแรงดัดขวางของทั้งสามกลุ่มคือ 137.759, 139.376 และ 141.171 นิวตันตามลำดับเมื่อวิเคราะห์ทางสถิติพบว่าไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ โดยสรุปการแช่เรซินอะคริลิกชนิดบ่มได้เองที่อุณหภูมิคงที่ที่แตกต่างกันเป็นเวลา 30วัน ที่อุณหภูมิ 5, 37 และ 57 องศาเซลเซียส มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในแง่ของเสถียรภาพเชิงมิติแต่ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในแง่ของค่าแรงดัดขวาง การแช่เรซินอะคริลิกชนิดบ่มบ่มได้เองที่อุณหภูมิคงที่เป็นเวลา 30 วันที่อุณหภูมิ 5, 37 และ 57 องศาเซลเซียสมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในแง่ของเสถียรภาพเชิง มิติแต่ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในแง่ของค่าแรงดัดขวาง

คำสำคัญ: *เรซินอะคริลิกชนิดบ่มได้เอง แรงดัดขวาง เสถียรภาพเชิงมิติ อุณหภูมิ*

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1. Introduction

Normally acrylic resin denture base is made from heat-cured acrylic resin because of its strength, color stability, less polymerization shrinkage, and low residual monomer when compared with self-cured acrylic resin. However, when denture is broken or needs to reline, self-cured acrylic resin is usually used instead because it is easy to use and takes little time to set. These are the reasons for this study.

In 1937, chemical activators were used to induce denture base polymerization at a room temperature. These were also referred to as cold-curing, self-curing or autopolymerizing resins. Chemical activation is accomplished through the addition of a tertiary amine, such as dimethyl-para-toluidine, to the monomer, which upon mixing causes decomposition of benzoylperoxide. This releases free radicals to initiate polymerization (Anusavice et al., 1996). The disadvantage of chemically activated PMMA are incompleted polymerization which leads to a greater amount of unreacted monomer in the denture base causing decreased transverse strength and is a potential tissue irritant. Water storage reduces the level of residual monomer. The colour stability is generally inferior (Tandon et al., 2010).

The dimensional change in dentures indicates the correlation of clinical fit retention and resistance of the denture (Wong et al., 2000, Darvell and Clark, 2000). Many factors may influence the base dimensional accuracy, such as the flasking method used and time-temperature correlation during polymerization process. An important and essential factor in the retention and stability of the denture is the dimensional changes may happen due to polymerization shrinkage.These changes may be partially compensated by water absorption and by the saliva formed between the denture base and the soft tissues (Skinner et al., 1943, Vallittu et al., 1995). Some studies reported that dentures possibly changed dimensionally but were clinically successful (Mowery et al., 1958). The accuracy of the adaptation of a denture base to the bearing area has been cited as important and influenced by many factors. Previous studies explained various factors, such as, processing methods, polymerization shrinkage, thermal shrinkage, water sorption, sizes and shapes of acrylic resin as well as the presence of teeth.

Flexural strength is a physical property that determines the material's resistance to bending. When a flexural force is applied, the material suffers an elastic deformation followed by plastic deformation and eventually fractures. Flexural testing can be conducted using three-point or four-point loading (Telles et al., 2009). Many factors may influence the strength of the denture, such as temperature and time for curing, post polymerization heat treatment, and residual monomer (Vallittu et al., 1995, Machado et al., 2012).

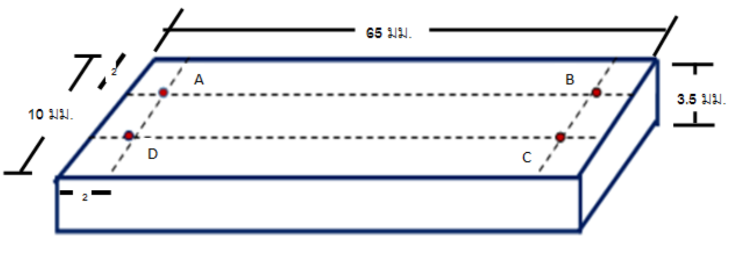
When dentures are provided to patients, they are suggested how to take proper care of the dentures. The recommended method to keep a denture is storing it in water so that its dimensional accuracy is retained (Naeem et al., 2015). However, it depends on where a patient is from such as countries with different weather condition, high or low temperature, etc. Some patients keep their dentures in different weather condition, e.g. in a car that is parked outdoor and exposed to the sunlight whole day, in cold weather, etc. All these various methods of storing the dentures are the causes leading to the conduct of this research to study the effects of different temperatures on the change of the dimensional stability and flexural strength of self-cured acrylic resin.

2. Objective

The objective of this research was to study the dimensional stability and flexural strength of self-cured acrylic resin during its immersion in water at different temperatures for 30 days.

3. Materials and Methods

Following ISO 20795-1:2013, a rectangular stainless steel mould with a size of 10x65x35 mm^3 was prepared. Rectangular specimens for testing were made out of self-cured acrylic resin (Vertex self curing, Vertex-Dental B.V., Soesterberg, Netherlands). The preparation followed the manufacturer's instructions. Each specimen was finished and polished by carbide burs and sandpapers and marked with four points (A, B, C and D).



Size 10 x 65 x 3.5 mm^3

Figure 1 The specimens were marked with four points as reference

Lines were drawn connecting the four points, and the intersection of these lines were the reference points for measuring the change of the linear dimensional stability at the end of the experiment. Before storing the specimens, the lengths of the intersection between A-B and C-D on the specimens were measured, using stereomicroscope (SZ61 OLYMPUS, Japan) and this formula (O'Toole et al., 1985).

$$\text{Norm} = \sqrt{AB^2 + CD^2 + BC^2 + AD^2}$$

Then, the specimens were immersed for 30 days at three different temperatures: 5ºC, 37ºC, and 57 ºC. At 37 ºC, the specimens were immersed in an incubator (Contherm 160M, Contherm scientific Ltd., New Zealand). At 5ºC and 57ºC, the specimens were stored in a thermocycling (Thermo Cycling unit, King Mongkut's Institute of Technology Ladkrabang, Thailand). After 30 days, the lengths between each point A-B and C-D were measured using stereomicroscope to determine the change on linear dimension of the specimens. After the dimensional stability test, the specimens were tested for flexural strength using Universal Testing Machine (EZ – S, produced by SHIMADZU., Japan) at a cross head speed of 5 mm/min while the distance between the cross head and the specimen is 50 mm, and the flexural strength values were recorded in Newton as shown in Figure 2. Finally, the linear dimensional change and flexural strength values were tested and statistically analyzed using Wilcoxon, Kruskal-Wallis and Mann Whitney test at a confidence level of 95% and 20.0. SPSS (SPSS, Chicago, IL, USA).

Figure 2 Flexural strength testing

4. Results

Table 1 The mean values and Standard deviations of dimensional change and flexural strength of all 3 groups

	Temperature (Celsius)	**N**	**Mean±SD**	**Minimum**	**Maximum**
Dimensional stability(mm)	5 ºC	15	0.075±0.050	0.029	0.174
	37 ºC	15	0.064±0.018	0.037	0.095
	57 ºC	15	0.045±0.043	0.000	0.157
Flexural strength (N)	5 ºC	15	137.759±15.978	101.880	157.850
	37 ºC	15	139.376±13.593	121.930	168.500
	57 ºC	15	141.171±9.412	121.980	156.530

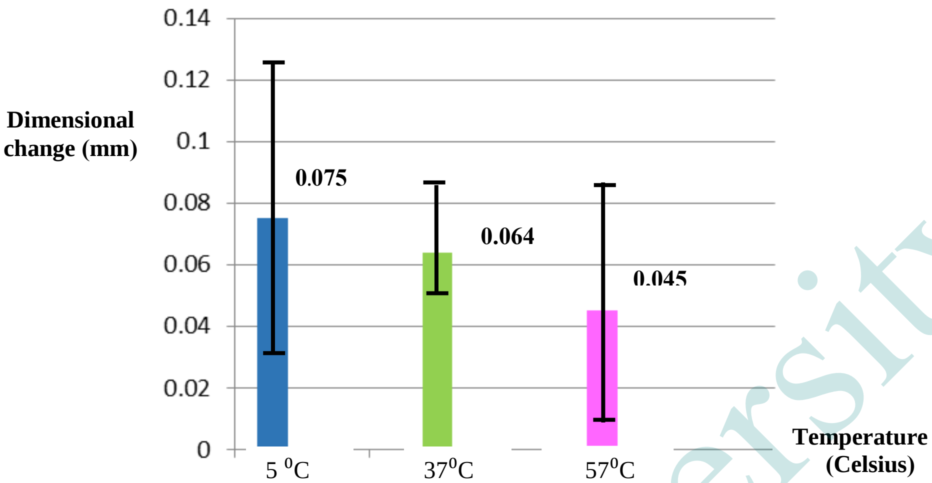


Figure 3 Mean of dimensional change of self-cured acrylic resin I The vertical line represent standard deviations in each groups

According to Figure 3, the self-cured acrylic resin at 5 ^{0}C shows the greatest dimensional change when compared with the 37 ^{0}C and 57 ^{0}C groups, respectively.

Table 2 Kruskal-WallisTest (Analysis Of Variance) for dimensional change of all 3 groups.

Self-cured	Temperature	N	Mean Rank
Dimensional change	5 °C	15	25.13
	37 °C	15	27.67
	57 °C	15	16.20
	Total	45	

Test Statistics[a,b]

	Different
Chi-Square	6.310
Df	2
Asymp. Sig.	.043*

a. Kruskal Wallis Test
b. Grouping Variable: Temperature
(* represents statistically significant difference between the groups)

According to Table 2, the self-cured acrylic resins immersed in water for 30 days at constant temperatures: 5, 37, and 57ºC were found to have statistically significant differences in dimensional stability.

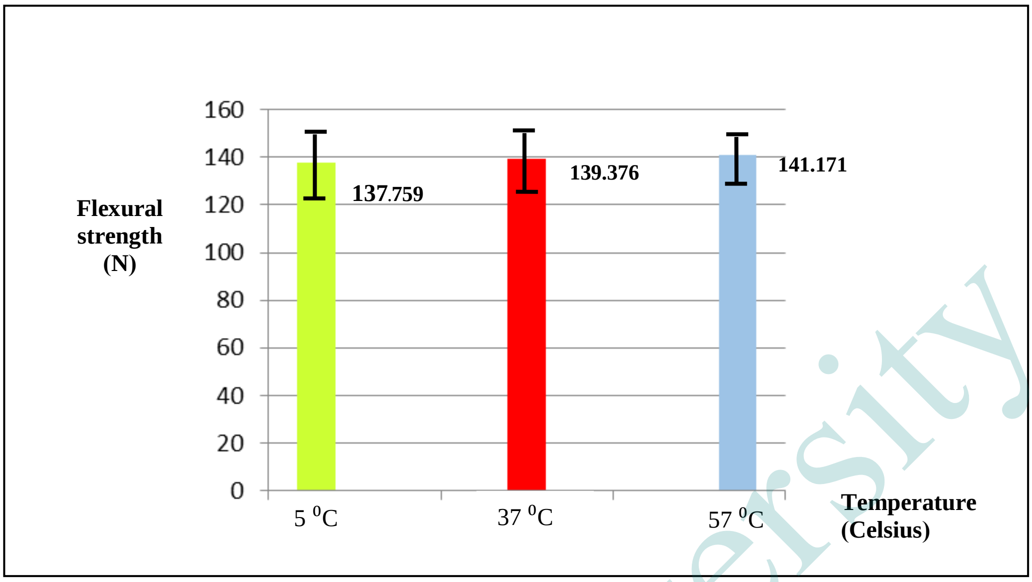


Figure 4 Mean of flexural strength of self-cured acrylic resinI The vertical line represents standard deviation in each groups

The self-cured acrylic resin at 57°C shows the greatest flexural strength when compared with the 37°C and 5°C groups, respectively.

Table 3 Kruskal-Wallis Test(Analysis Of Variance) for flexural strength of all 3 groups.

Self-cured	Temperature	N	Mean Rank
	5 °C	15	22.93
flexural	37 °C	15	21.33
strength	57 °C	15	24.73
	Total	45	

Test Statistics[a,b,c]

	flexural strength
Chi-Square	.503
Df	2
Asymp. Sig.	.778

a. Group = Self-cured
b. Kruskal Wallis Test
c. Grouping Variable: Temperature

From Table 3, the self-cured acrylic resins immersed in water for 30 days at constant temperatures: 5, 37, and 57°C were found to have statistically significant differences in flexural strength.

5. Discussion

From According to the results, the specimens before and after immersion in water for 30 days at different temperatures (5 °C, 37 °C, and 57 °C) were compared, the acrylic was found to expand when observed using a stereomicroscope. This phenomenon was caused by the absorption of water into the resin influenced by the polarity of the PMMA molecules and diffusion of water molecules into the interstitial spaces between polymer chains. Increasing water absorption may also prevent the intermeshing of polymer chains, causing them to be progressively more mobile and resulting in relaxation of built-up internal polymerization stresses (Rimple et al., 2011). Water sorption effects can occur after a certain period of immersion in the aqueous solution or oral environment. This makes acrylic resin expand due to diffusion of water in between macromolecules and can affect dimensional stability. Acrylic resins absorb water and expand slowly over a period of time. This expansion is a volumetric change expressed in three dimensions. It is noticeable that water molecules act according to the laws of diffusion. The diffusion presumably occurs between the macromolecules, which are forced slightly apart. This separation renders the molecules mobile, and the inherent stresses created during curing of the acrylic resin can be relieved with consequent intermolecular relaxation and possible change in the shape of the denture (Ristic and Carr., 1987). When compared dimensional change in different temperatures, they show more significant expansion at a lower temperature. This suggested that at lower temperature there are more residual monomer (Vallittu et al., 1995). Vallittu (1995) indicated that the polymerization reaction continued longer in the chemical-cured PMMA. A constant level of MMA could be found even in a denture that had been used for 17 years. Another study clinically comparing self-cured to heat-cured acrylic resin stated that the dentures in the autopolymerized group continued to shrink throughout the entire testing period of 3 months. This continuous shrinkage of the autopolymerized denture group over a period of 3 months may be due to the greater volume of monomer employed in the acrylic resin mix (Vallittu et al., 1995, Mirza, 1961).

In terms of flexural strength, the results showed that, when the temperature is higher, the flexural strength value is also higher with no significance at a confidence interval of 0.05. According to Dogan (1995), when the amount of residual monomer is less, the flexural strength value is higher which can be described in this experiment that when the temperature is higher, the residual monomer increasing released. Therefore, lower residual monomer in the acrylic resin specimen and a higher flexural strength value relate to a higher temperature and more post polymerization (Dogan et al., 1995). Heat activates chemical reaction between the monomer and polymer components of the resin and produces more complete polymerization. This mechanism may explain why hot water conditions improves the mechanical properties of resin (Ogawa et al., 2000).

However, this study demonstrated temperature effects on linear dimensional stability and flexural strength. A higher temperature decreased dimensional change and increased greater flexural strength of rectangular acrylic resin. Consequently, residual monomer possibly facilitated the diffusion of water and reduced the absorption properties of acrylic at 57 °C, supported by Dogan's study showing a higher percentage of water absorption in samples containing a higher amount of residual monomer (Mirza, 1961). Although, this experiment showed temperature significantly caused dimensional change, the previous clinical study showed small dimensional changes of both heat-cured and self-cured resins, usually not exceeding 0.2 mm. Patients' reaction indicated that changes of this amount did not significantly affect the fit of the dentures (Mowery et al., 1958). Consequently, an amount of residual monomer and unreacted polymerization showed the porosity of internal material related to mechanical properties. However, the result of flexural strength after the immersion in a higher temperature was not significantly different.

From this research, rectangular acrylic resin specimens were used. However, for the clinical situation, it is necessary to consider other factors on the dimensional accuracy and flexural strength of dentures such as longer immersion period, oral temperature changing while having hot or cold beverages, improvement of the methods for the experiment.

6. Conclusion

This experiment was conducted to evaluate dimensional stability and flexural strength of self-cured resin when it was immersed in water at different temperatures. From this experiment, it can be concluded that:

1. The different temperatures (5, 37, 57°C) affect the dimensional stability of self-cured acrylic resins with statistical significance.

2. Difference in temperature does not affect the flexural strength of self-cured acrylic resins with statistical significance.

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