The influence of salt solution as curing media towards curing time and compressive strength of heat cured acrylic resin

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ABSTRACT
Heat-cured acrylic resin is commonly used as denture base materials. The time needed for its polymerization makes the process less efficient. The salt solution has a higher boiling point and more stable molecular bonding, which is expected to shorten the curing time of HCAR. This article determines the influence of salt solution as curing media on curing time and compressive strength of HCAR. This experimental laboratory study used 25 samples of HCAR with 25.4x12.7x12.7 mm by dimension. Samples were boiled in water at 74ºC for 120 minutes as a control, in 35% salt solution at 74ºC for 30, 60, 90, and 120 minutes as treatment groups, and then all groups were boiled at 100ºC for 60 minutes. The compressive strength of each sample was tested using an *Autograph AG-10TE.* The highest compressive strength and fastest setting time were shown in samples boiled in a salt solution for 60 minutes. One-way Anova followed by a post hoc Tukey-HSD test showed no significant compressive strength differences in each group ($p>0.05$). It is concluded that salt solution usage as curing media fastens the curing time and results in the same compressive strength within all groups.
Keywords: heat-cured acrylic resin, salt solution, curing time, compressive strength

INTRODUCTION

Losing teeth can cause loss of mastication, speech and aesthetic function and cause many psychological problems. According to *Riset Kesehatan Dasar* (Riskesdas) data Ministry of Health Indonesian Republic, in 2013, it was reported that tooth loss was found at 5.65% in the group of age 45-54, 10.13% in age 55-64 and 17.05% for group age above 65 years old. The denture was made to rehabilitate intraoral function.[1]

The denture has two essential parts; the base and the artificial teeth. The denture base gains support through direct contact with the underlying intraoral tissue. A denture base can be made from acrylic resin or metal. One of the most popular materials for denture base is heat-cured acrylic resin. The most widely used material for denture base is polymethyl methacrylate HCAR because it has several advantages such as easy to get, cheap, non-toxic, not irritating, not soluble in oral fluids, easily manipulated, significant aesthetical aspect, biocompatible, easily repaired and slightly changed in its dimensional aspect.[2]

The HCAR needs to be heated at a specific temperature to help the polymerization process. The widely used method for curing is by boiling the resin in 74ºC water for about 120 minutes, and then the temperature is raised to the boiling point of water 100˚C for 60 minutes. This traditionally curing cycle needs a long time to reach the perfect setting phase of the acrylic resin. This condition should be reached so that there will be no dimensional change and mechanical strength decrease in the acrylic resin. The dimensional change in acrylic resin will disrupt the denture base making and the free monomer formed due to not achieving the setting phase of acrylic resin can irritate the oral mucosa.[3,4]

The problem over the curing cycle of the HCAR is the long time needed for the polymerization process that makes curing cycle and production cost of the HCAR being less efficient.[5] Salt solution has a higher boiling point than water because of its colligative properties.[6] Solutions' colligative properties depend on the concentration of molecules or ions of the solute but not on the identity of the solute. Besides boiling point elevation, colligative properties include lowering vapor pressure, depression of the freezing point, and osmotic pressure.[7] Salt solution has a stabler molecular bond, so it is assumed that salt solution can shorten curing time of the HCAR.

This article determines the influence of salt solution as curing media on curing time and compressive strength of HCAR.

METHOD

This is a post-control group design and experimental laboratory design. The HCAR used was 25 specimens with the size of 25.4x12.7x12.7 mm.[8] The specimens met criteria such as flat surface, not pored, and smooth.

This research was conducted at the Skill Laboratory Faculty of Dentistry Brawijaya University to produce the HCAR sample and *Laboratorium Dasar Bersama* (LDB) Airlangga University Surabaya

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for the compressive strength testing of the samples. The procedures were began with acrylic resin sample making. The molds were made by flasking the wax master model by the sample size in the cuvette filled with dental stone. After the mold was ready, the mix of PMMA and mono methyl methacrylate (ADM) was taken in a closed porcelain mixing jar for polymerization according to the manufacturer's instruction (polymer 4 grams : monomer 2 mL) at room temperature ±20-25°C. Mold was coated with a thin layer of petroleum jelly to remove the samples quickly. After reaching the dough stage phase at room temperature, the mold was filled with acrylic resin dough. The top and bottom part of the cuvette was put together, and was pressed with a pressure of 900 psi with hydraulic bench press. The cuvette was opened, and the excess material was removed during the closure trial that was done several times until there was no excess material and formed a metal-to-metal contact of the cuvette. Then, the cuvette was pressed by the manual hand press and ready to be cured.[9]

The 35% salt solution as curing media was done by dissolving kitchen salt (*Kapal Api, Indonesia*) in water with a mass ratio of 7:20 or calculating 350 g of salt in every 1 L of water. The salt solution used has a concentration of 35% because the maximum solubility of salt in water at room temperature is 357 mg/mL.[10]

The curing of the acrylic resin samples was carried out according to the treatment group. There are 5 groups of samples; they are the control group, the samples were cured 120 minutes in 2 L of water at 74°C and continued for 60 minutes at a boiling water temperature. The treatment groups A, B, C, and D were cured for 30, 60, 90, and 120 minutes in 2 L of 35% salt solution and followed by 60 minutes at 100°C for each group. The cuvette was immersed in curing media where a thermometer was set to measure the temperature of the water; then, the time was recorded accordingly with the help of the stopwatch. After the curing cycle, the cuvette was allowed to bench-cool before deflasking. Following the bench cooling procedure, the flask was opened, and acrylic resin samples were carefully retrieved. A laboratory micromotor trimmed the excess of the sample with fraser burs and polished stone burs.

The evaluation of compressive strength of all the specimens in this study was tested using Autograph AG-10TE. The load was applied to the center of the standing samples until they broke. The value listed on the tool was then recorded, then calculates the compressive strength by using the following formula:[11]

$$C = \frac{P}{A}$$

C = *compressive strength* (kg/mm^2)
P = *force shown on the tool* (kg)
A = *surface area* (mm^2)

The compressive strength data obtained are tabulated in tabular form. The normality of data was tested using the *Kolmogorov-Smirnov* test, while the homogeneity of the data was carried out using *Levene statistic* test. The study results were then analyzed using the *one-way* Anova statistical test to determine the difference in compressive strength values between the treatment groups. Then, a further difference test (*post hoc test*), namely Tukey HSD, was carried out to find further the value difference of compressive strength between each treatment group.

RESULTS

The compressive strength was obtained in units of kg/mm^2 using the Autograph (*Shimadzu, Japan*). The data is obtained from the magnitude of the load that presses the test sample until just before the sample breaks. After the data is obtained, the data is entered in the formula for compressive strength.

The results of the compressive strength test listed in table 1 show that there are differences in compressive strength between the treatment groups. The lowest average compressive strength is in group D of 6.982 kg/mm^2, while the highest average compressive strength is in group B of 7.896 kg/mm^2. The results also show an effect between curing time and compressive strength of HCAR. To clarify the effect of curing time on the compressive strength of HCAR (Fig.1).

The results of the study were then analyzed using several statistical tests. Based on the normality test of the data using the Kolmogorov-Smirnov test in this study, a significance value of p=0.2

Table 1 Mean of compressive strength value of HCAR with variation of curing time with water and 35% salt solution

Group	Curing cycle	Curing time	Average compressive strength (kg/mm^2)
Control	74°C + 60 minutes at 100°C in water	120 minutes	7.866
A	74°C + 60 minutes at 100°C in 35% salt solution	30 minutes	7.24
B	74°C + 60 minutes at 100°C in 35% salt solution	60 minutes	7.896
C	74°C + 60 minutes at 100°C in 35% salt solution	90 minutes	7.274
D	74°C + 60 minutes at 100°C in 35% salt solution	120 minutes	6.982

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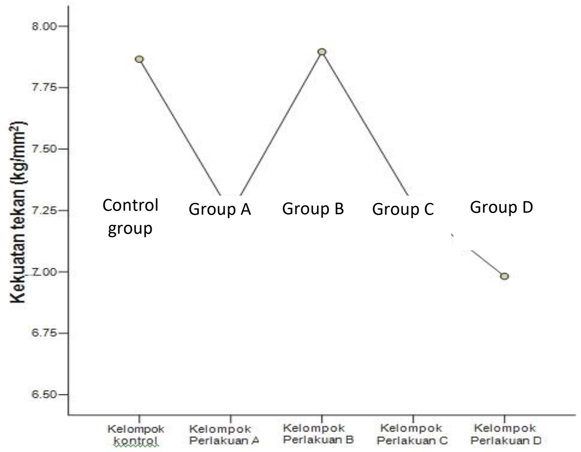

Figure 1 Line diagram of the effect of curing time on the compressive strength of HCAR

0.2 (greater than 0.05) in all groups was obtained. While testing the homogenity of variance with the Levene Statistic test, the significance value of p = 0.486 (greater than 0.05). Thus, it can be concluded that the data has a normal distribution and homogenous, so the data can be tested using one-way Anova.

The one-way Anova method was analyzed to determine the difference in compressive strength values between treatment groups. Based on the one-way Anova test in this study, the significance value of p = 0.118 (greater than 0.05), so it can be concluded that there is no significant difference in the value of compressive strength between the treatment groups.

The results of further analysis using the Tukey-HSD Post Hoc Test serve as a further difference test to determine the difference in the compressive strength value between each treatment group. From the results of statistical tests obtained p-value > 0.05, it can be concluded that there is no difference in the value of significant strength between each treatment group.

DISCUSSION

Based on the measurement results shown in the table and graph above, there are differences in compressive strength value between each treatment group. The slightest difference in compressive strength values was found in the control group and treatment group B, and the treatment group was cured for 60 minutes at a temperature of 74ºC and 60 minutes at 100ºC in a salt solution. This indicates that using the salt solution can accelerate the curing time of HCAR with the same compressive strength in all groups.

Several things can also affect the setting level of HCAR, including polymerization temperature and molecular weight of HCAR.[12] Polymerization of HCAR can occur when heated above 60ºC. At this temperature, the molecules of benzoyl peroxide contained in the acrylic resin polymer/powder, which function as initiators, will be separated to produce molecules with a neutral electrical charge and containing unpairs electrons called free radicals. These free radicals rapidly react with the monomer molecule to stimulate polymerization.

In addition, at this study, the terminal temperature of the control group could not reach 100ºC. The water terminal temperature only reaches 94.5 ˚C. Meanwhile, the terminal temperature of treatment group B, which was heated using 35% salt solution, could reach 100ºC. This is due to the difference in air pressure at the water surface, which can be influenced by the altitude of an area above sea level.[11] This research was conducted in Malang City, which has an altitude of about 400-667 meters above sea level with an air pressure of 1015 hPa or equivalent to 0.01 atm. The higher a plateau, the lower the air pressure and the lower the boiling point of water in that area.[13] The boiling point is also affected by the type of substance dissolved in the water. The addition of salt, in this case, can increase the boiling point so that the terminal temperature of the treatment groups A, B, C, and D can reach 100˚C. The optimal temperature can produce a perfect HCAR dress polymerization reaction.

As the curing time of the HCAR was increased using a salt solution, the compressive strength of acrylic plate decreased. This shows that the addition of curing time of HCAR plate does not have a linear relation to its compressive strength. When the HCAR plate was heated for more than 60 minutes with a salt solution at a temperature of 74˚C, there was a decrease in the compressive strength of the HCAR due to the nature of the salt that can absorb the water content in a material, resulting in a decrease in the density value of the material.[14]

The salt content in water, both seawater, and rainwater can cause erosion of various materials in the wild. Erosion is the erasure of solids (sediment, soil, rock, and other particles) due to the transport of wind, water, or ice and the characteristics of rain.[15] In this study, the sample group of the HCAR cured in 35% salt solution for 120 minutes at 74˚C and added 60 minutes at 100˚C had the lowest average compressive strength compared to the other four treatments, which was 6.98 kg/mm2. This is because if a material is exposed to salt at high temperatures and for a certain period, salt can cause erosion of the material to become more brittle.[14]

It is concluded that curing time using salt solution media affects the compressive strength of HCAR, which can accelerate curing time with the same strength in all groups. The most effective curing time for the HCAR is 60 minutes at 74˚C plus 60 minutes at terminal temperature (100ºC) in 35% salt solution.

For further research, it is suggested 1) preparation of HCAR samples should use molds from metal plates so that the sample size is more uniform; 2) before the compressive strength test, the HCAR sample should be weighed first to ensure that the mass of the entire sample is the same; 3) it is necessary using a curing time interval of 30-60 minutes in a salt solution at a temperature of 74ºC plus 60 minutes at a temperature of 100ºC to see the relationship between the increase in curing time with the set level and the compressive strength of HCAR; 4) to examine the effect of using a salt solution as a curing medium on the transverse strength, impact strength, and discoloration of HCAR; 5) to examine the effect of different concentrations of salt solution as a curing medium on the curing time of the HCAR.

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