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The Utilization of Eggshell as Reinforcing Material of Heat Cured Acrylic Resin Denture Base

Pemanfaatan Cangkang Telur Sebagai Bahan Penguat Basis Resin Akrilik Polimerisasi Panas

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Abstract

Heat-cured acrylic resin is easily fractured and can be prevented by adding reinforcing materials of duck eggshell powder. Furthermore, it can be used as a biocompatible reinforcing material due to the high content of $CaCO_3$. This study aims to determine the effect of adding 2.5% and 5% duck eggshells as reinforcement for the denture base with heat-cured acrylic resin on the transverse strength. The method is an laboratory experiments with a post-test only control design conducted on January 2022. The samples were made by adding a reinforcing agent of 2.5% and 5% heat-cured acrylic resin powder's weight in a mould sized 65 x 10 x 2.5 ± 0.5 mm with 11 samples in each group. The curing process was executed at a temperature of 70°C for 90 minutes before increasing to 100°C for 30 minutes, and the transverse strength of acrylic resin was measured using the Universal Testing Machine. The sample tested using univariate analysis with the results of the average transverse strength in the control group 66.59 ± 1.88 MPa, after adding 2.5% duck eggshell 72.61 ± 3.05 MPa and 5% duck eggshell 86.14 ± 4.09. The one-way ANOVA and LSD tests showed significant results with p-value = 0.001 ($p < 0.05$) and 0.001 ($p < 0.05$). The highest transverse strength value of heat-cured acrylic resin was found in the 5% duck eggshell group, followed by 2.5%, and lastly, the control group.

Keywords: Heat cured acrylic resin, reinforcement material, fracture, biocompatible

Abstrak

Resin akrilik polimerisasi panas mudah mengalami fraktur dan dapat dicegah dengan menambah bahan penguat berupa bubuk cangkang telur bebek. Tingginya $CaCO_3$ menjadikan cangkang telur bebek berpotensi sebagai bahan penguat yang biokompatibel. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh penambahan cangkang telur bebek 2,5% dan 5% sebagai bahan penguat basis gigi tiruan resin akrilik polimerisasi panas terhadap kekuatan transversal. Metode pada penelitian ini adalah eksperimental laboratoris dengan desain *post test control only*. Penelitian ini dilakukan pada bulan Januari 2022. Sampel pada penelitian ini ditambahkan bahan penguat berupa bubuk sebesar 2,5% dan 5% dari berat bubuk resin akrilik polimerisasi panas pada mold berukuran 65 x 10 x 2,5 ± 0,5 mm sebanyak 11 sampel setiap kelompoknya, setelah itu dilakukan proses kuring dengan suhu 70°C selama 90 menit dan dinaikkan pada suhu 100°C selama 30 menit. Kekuatan transversal resin akrilik diukur menggunakan *Universal Testing Machine*. Sampel tersebut di uji menggunakan analisis univarian dengan hasil rerata kekuatan transversal pada kelompok kontrol 66,59 ± 1,88 MPa, kelompok setelah penambahan 2,5% cangkang telur bebek 72,61 ± 3,05 MPa dan kelompok setelah penambahan 5% cangkang telur bebek 86,14 ± 4,09. Uji Anova satu arah didapatkan hasil yang signifikan dengan nilai p = 0,001 ($p < 0,05$) dan uji LSD yang signifikan dengan nilai p = 0.001 ($p<0.05$). Nilai kekuatan transversal resin akrilik polimerisasi panas yang paling tinggi terdapat pada kelompok setelah diberi 5% cangkang telur bebek sebagai bahan penguat diikuti dengan kelompok setelah diberi 2,5% cangkang telur bebek dan yang terakhir adalah kelompok kontrol.

Kata kunci: Resin Akrilik Polimerisasi Panas, Bahan Penguat, Fraktur, Biokompatibel

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INTRODUCTION

The bases of dentures found on supporting tissue are usually made of metal or non-metallic materials. Non-metallic base materials have good aesthetics and are more affordable than metallic materials.[1] Based on the thermal reaction, and the bases can be divided into two thermoplastic types and thermoset. Thermoset polymers have the best abrasion resistance with very stable dimensions compared to thermoplastic polymers. Examples of these thermoset polymers are acrylic resin or polymethyl methacrylate. According to Yu et al. (2012), acrylic resin is widely used because it has many advantages, such as the price is relatively cheap, easy to repair, the manufacturing process uses simple equipment, the color matches the tissue around the oral cavity, good dimensional stability, and is easy to polish.[2,3,4]

Acrylic resin is divided into heat-cured, light-cured, microwaves, and acrylic resin. Heat-cured acrylic resin is easily permeable, lacks abrasion resistance, and is brittle. These disadvantages can be prevented by increasing the transverse strength of the mechanical properties. The transverse strength illustrates the object's resistance to gaining weight when mastication occurs. The strength of the denture base is affected by the molecular weight of the polymer, the content of the residual monomer, the composition of the plasticizer, the thickness of the denture base, the type of polish and the porosity. The problem of fracture can be prevented by increasing the strength of the heat-cured acrylic resin. The addition of reinforcing materials into the polymer content can increase the strength of various mechanical properties such as impact strength, transverse, tensile, and hardness.[5,6,7,8]

Acrylic resin reinforcing materials can be divided into inorganic and organic. The organic material used from eggshells is $CaCO_3$ in powder form. Eggshells contain (94-97)% $CaCO_3$, and this amount makes it a strengthening material used as a biocompatible starter. This occure by the bonding reaction of $CaCO_3$ and polymethyl methacrylate. The unsaturated group in methyl methacrylate copolymerizes covalently with the polymer to link with the $CaCO_3$ particles through chemical bonds. This linkage increases intermolecular adhesion and compatibility between inorganic $CaCO_3$ and the polymer matrix.[9,10,11]

MATERIALS AND METHODS

Research design. This is experimental laboratory study with a posttest-only control group design. Ethical clearance. It has received approval from the Ethical Committee of the Faculty of Medicine, Universitas Sumatera Utara, with decision letter 54/KEPK/USU/2022. Population and sample. The samples used are dental plaster (Maldano, Germany), Cold mold seal (QC 20, UK), Selopan plastic (Prima Jaya, Indonesia), sandpaper sizes of 400, 800, 1200 (Atlas, Indonesia), Sodium hypochlorite (Rofa, Indonesia) and heat cured acrylic resin (QC 20, UK) made in the form of a test plate with a size of 65 x 10 x 2.5 mm under the provi-sions of ADA specification no.12. The groups of the control, additional 2.5% duck eggshell group and 5% duck eggshell contain 11 samples each.[3]

The powder was made by soaking the eggshell in sodium hypochlorite for 6 hours before drying and burning the egg membrane in an oven at 250°C for 6 minutes. Subsequently, the duck eggshells were crushed into the powder using a blender, and grinding was conducted using a 10 mm ball mill. The samples were mashed for one hour with a ball mill rotation speed of 400 rpm, and the powder was sifted using mesh 100, followed by mesh 400.

The mould making began with making dental plaster dough with a ratio of 30 g: 900 ml of water, then the plaster was stirred until homogeneous using a spatula in a rubber bowl. Gypsum was put into the bottom cuvette while vibrating on a vibrator, and the test plate was immersed in the plaster surface and left until the cast hardened for 45 minutes.

The hardened dental plaster surface was coated with Vaseline, and the top of the cuvette was filled with dental plaster mixture in the same ratio as the lower cuvette filling. The bottom and top cuvettes were put together, pressed, and still for 45 minutes to harden. After the cast hardens, the cuvette is opened, and the parent model is removed. The dental plaster surface is treated with a cold mold seal and left for 20 minutes after drying.

Before filling the acrylic resin into the mould, duck eggshell microparticle reinforcement with a concentration of 2.5% and 5% was added to the acrylic resin polymer, and monomers were mixed with a weight ratio of 2 g: 1 ml and stirred until homogeneous. Subsequently, the mixed dough was put into the mold after reaching the stage, and the heat polymerized acrylic resin was covered with clear plastic before closing the cuvette.

A hydraulic press pressed the cuvette with a pressure of 1000 psi, then the cuvette was opened, and the excess acrylic resin was cleaned by a lecron and pressed with a pressure of 2200 psi. Furthermore, the cuvette was closed and locked with the bolts until it fused, then let for 15 minutes. The cuvette was put into a water bath with a temperature of 70°C for 90 minutes and was increased to 100°C for 30 minutes. The sample was trimmed using a micromotor and by removing the exces part of the acrylic. Meanwhile, the sample was smoothed using sandpaper sizes 400, 800, and 1200

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using a rotary grinder and was tested using the Universal Testing Machine to determine the transverse strength.

RESULTS

The results showed that the mean value of the transverse power was analyzed using the univariate test. The mean value of transverse strength in the control group was 66.59 MPa, with a standard deviation of 1.88. The group's mean value of transverse strength after adding 2.5% duck eggshell as a reinforcing material was 72.61 MPa, with a standard deviation of 3.05.

The group's mean value of transverse strength after adding 5% duck eggshell as a reinforcing material was 86.14 MPa, with a standard deviation of 4.09. Subse-quently, a one-way ANOVA test was conducted and obtained a significance of p = 0.001 (p<0.05), meaning that there is a significant effect between the control, the group after the addition of 2.5% duck eggshells as reinforcement and after the addition of 5 % of duck eggshell for transverse strength of denture base heat polymerized acrylic resin (Table 1).

The LSD (Least Significant Different) test was conducted to determine which groups had significant differrences. Based on the results of the LSD test, there is a significant difference in each control with the group after the addition of 2.5% duck eggshells as a reinforcing material with a p-value = 0.001 (p <0.05), the control and the group after the addition of 5% duck eggshells as a reinforcing material with p-value = 0.001 (p< 0.05) and the group after the addition of 2.5% duck eggshell as a reinforcing material with the group after adding 5% duck eggshell as a reinforcing material with a p-value = 0.001 (p<0.05) (Table 2).

The highest transverse strength value of the heat polymerized acrylic resin denture base was found in the group after adding 5% duck eggshell as a reinforcing material, followed by the group after adding 2.5% duck eggshell as a reinforcing material and followed by the control.

DISCUSSIONS

The results showed various transverse power values in the same group, and the varying results can be caused by several factors that affect the sampling process.[11] The presence of residual monomer content that acts as a plasticizer would weaken the polymer bond chain allowing deformation to occur more easily and altering the strength values. The second factor is due to the manual stirring technique and the possibility of air trapping in the heat polymerized acrylic resin matrix and internal porosity, which is not visible on the sample surface. However, it can affect the transverse strength of the heat polymerized acrylic resin, and mixing the denture base material should be conducted using a vacuum mixer to prevent air in the polymer matrix.[7,12,13]

Based on the data obtained in Table 1, the value of the transverse strength in the control group is (66.59 ± 1.88 MPa), and the value after adding 2.5% duck eggshell as a reinforcing material is (72.61 ± 3.05 MPa). Furthermore, the transverse strength value after adding 5% duck eggshell is equal to (86.14 ± 4.09 MPa). it showed that duck eggshell had significant effect with p value = 0.001 (p < 0.05) on each treatment group. It occurred due to adhesion $CaCo_3$ particle with polymer matrix re-sult in stronger bondage over its stress point threshold. [6,13,14]

This study is in line with Sri Handayani and Eddy Dahar (2017), where the addition of reinforcing material can increase the transverse strength because of the transfer of load and the polymer matrix. The increase in strength is due to the high strength of the surface shear between the particles and the matrix caused by the formation of cross-links or supramolecular bonds. [11,12,14]

The results of the LSD test in Table 2 show a significant difference with ha accepted between the control and the addition of 2.5% duck eggshell as a reinforcing material with p-value = 0.001 (p <0.05), the control with the addition of 5% duck eggshell as a reinforcing material with p-value = 0.001 (p <0.05) and the group after adding 2.5% duck eggshell as a reinforcing material with after adding 5% duck eggshell as a re`inforcing material

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TABLE

Table 1. The effect of adding 2.5% and 5% of duck eggshells as ingredients heat cured acrylic resin denture base reinforcement against transverse strength based on a one-way ANOVA test

Group	Transverse Strength (MPa)		
	N	$\bar{X} \pm SD$	p
Control	11	66.59 ± 1.88	
2.5%	11	72.61 ± 3.05	0.001 *
5%	11	86.14 ± 4.09	

Description: *significant

Table. 2 There was a significant difference in the addition of 2.5% and 5% duck eggshells as reinforcement for heat-polymerized acrylic resin dentures based on transverse strength based on the LSD test

	Control	2.5%	5%
Control	-	0.001*	0.001*
2.5%	0.001*	-	0.001*
5%	0.001*	0.001*	-

Description: *significant

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