INDONESIAN JOURNAL OF PROSTHODONTICS

ORIGINAL ARTICLE

Influence of immersion in heat-cured resin acrylic in chitosan solution to hardness, transversal strength and modulus of elasticity

Silvia Naliani,* Angela Evelyna, Gabriella Jessica Suherman, Fransella Praisy Trinity Maramis

Keywords: Chitosan, Hardness, Heat-cured acrylic, Modulus of elasticity, Transversal strength.

ABSTRACT

Heat-cured acrylic resin is a commonly used material for removable denture bases but has a low mechanical strength. Heat-cured acrylic resin used as a denture base must be kept clean by immersing the denture in a cleaning agent. Denture cleaning materials on the market generally come from chemicals. Immersion of heat-cured acrylic resin as denture base in chitosan solution can inhibit the growth of Candida albicans better than oxygenizing denture cleaning solution. Biologically, chitosan is safe because it has biocompatible and biodegradable properties. To determine the effect of immersion of heat-cured acrylic resin in chitosan solution on hardness, transverse strength, and modulus of elasticity. 25 acrylic resin plates measuring 65x10x2.5mm divided into five groups. Each group was immersed in a solution of 1%, 2%, 3% chitosan, distilled water, and 1% ascorbic acid, then tested for transverse strength using the Universal Testing Machine. The values of transverse strength and modulus of elasticity were calculated using the formula. Hardness test pre and post-test used 15 acrylic resin plates measuring 12mmx12mmx3mm were divided into five groups with each group immersed in 1%, 2%, 3% chitosan solution, distilled water, and 1% ascorbic acid. Statistical analysis used one-way ANOVA for each test. The only significant difference was the modulus of elasticity between the immersion groups. The value of transverse strength, modulus of elasticity, and hardness was higher in the group with a 3% chitosan solution, with no difference statistically in transverse strength and hardness between groups. There was a significant difference in the effect of elastic modulus from the immersion of heat-cured acrylic resin in solution distilled water and 1% ascorbic acid as a control and 1%, 2%, and 3% chitosan solutions with ascorbic acid as a solvent. (IJP 2024;5(1):55-58)

INTRODUCTION

Acrylic resin is a polymer used in the manufacture of removable partial dentures and full dentures.[1,2] Based on the polymerization, acrylic resins are divided into three classifications: heat-cured acrylic resin, self-cured acrylic resin and light-cured acrylic resin.[3] Heat-cured acrylic resin is often used because it is non-toxic, non-irritating, insoluble in oral fluids and esthetics, easy to manipulate and repair, and has minimal dimensional changes.[4] Heat-cured acrylic resin has good enough strength to be used as a base for full and partial dentures but often fractures.[5,6] Transverse strength and modulus of elasticity of acrylic resin is one of the properties that affect the material's resistance to fracture.[5]

Acrylic resin is a material with a low level of hardness and elasticity and can be abraded. Heat-cured acrylic resin generally improve the weakness of the acrylic resin denture base material so that its mechanical properties increase for long-term use by adding reinforcing materials. The addition of reinforcing materials can be in the form of chemicals, metal, or fibre.[7] However, nowadays, using natural materials is more desirable because it does not cause side effects on the body. One of the uses of these natural ingredients is to use chitosan.[8]

Research by adding other materials to acrylic resin has been carried out by mixing chitosan into heat-cured acrylic resin before heating but did not produce significant changes. The addition of chitosan has a high viscosity value, making it difficult for chitosan to diffuse and decrease its mechanical strength.[9] The lower the molecular weight of chitosan and the lower its viscosity, the more easily chitosan is absorbed into the acrylic resin.[10] In

[1]Department of Prosthodontics, Faculty of Dentistry, Maranatha Christian University
[2]Department of Dental Materials, Faculty of Dentistry, Maranatha Christian University
[3]Clinical Clerkship Student, Faculty of Dentistry, Maranatha Christian University

*Corresponding author: silvia.naliani@dent.maranatha.edu

Table 1. Mean and standard deviation of hardness.

Group (VHN)	Mean ± SD Before	After
Aquades	18.769±1.040	19.196±1.290
Ascorbic Acid 1%	18.281±0.629	19.630±0.678
Chitosan 1%	18.850 0.493	19.860±1.639
Chitosan 2%	19.013±0.496	19.854±1.532
Chitosan 3%	19.223±1.355	20.151±0.788
Total	18.827±0.890	19.738±1.232

Table 2. One Way ANOVA of hardness.

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	3.976	4	0.994	0.419	0.794
Within Groups	94.918	40	2.373		
Total	98.894	44			

*p<0.05

Table 3. Mean and standard deviation of transversal strength.

Group	Aquades	Ascorbic Acid 1%	Chitosan 1%	Chitosan 2%	Chitosan 3%
Mean±SD	128.46 ±23.03	138.05 ±12.87	117.11 ±15.03	136.24 ±12.75	143.72 ±10.35

Table 4. One-Way ANOVA of transversal strength.

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	2118.69	4	529.673	2.22	0.103
Within Groups	4771.077	20	283.554		
Total	6889.767	24			

*p<0.05

Table 5. Mean and standard deviation of modulus easticity.

Group	Aquades	Ascorbic Acid 1%	Chitosan 1%	Chitosan 2%	Chitosan 3%
Mean±SD	2102.15 ±209.14	2371.42 ±276.48	1736.51 ±225.31	2095.97 ±300.66	2499.17 ±216.89

Table 6. One-Way ANOVA of modulus elasticity.

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	1732598.12	4	433149.531	7.023	0.001
Within Groups	1233587.74	20	61679.387		
Total	2966185.87	24			

*p<0.05

research on the toxicity test of resin mixtures. Acrylic resin with chitosan as antifungal denture material stated that the greater the concentration of chitosan, the smaller the average value of absorbance and cell viability, acrylic resin with chitosan at concentrations of 0.5%, 1%, and 2% was not toxic.[11]

Chitosan is chitin's main derivative, which can be isolated from various living things such as shrimp, crabs and several other animals. Chitosan is a copolymer of D-glucosamine and N-acetyl-D-glucosamine with B-(164) bonds, obtained by enzymatic deacetylation of the polysaccharide chitin. Removing the acetyl group of chitin increases its solubility, so chitosan is used more than chitin. In addition, chitosan is non-toxic, biocompatible and biodegradable, so it is safe to use.[8] Chitosan is insoluble in water and most organic solvents but soluble in acids with a pH of less than 6.5. The solvents usually used to dissolve chitosan are formic acid, acetic acid, lactic acid, and glutamic acid.[12]

Chitosan can be dissolved in ascorbic acid, and the best chitosan solubility is found at 1%.[8] Ascorbic acid, or vitamin C, is a water-soluble and the most unstable vitamin. Vitamin C is stable in the dry state but in the form of a solution and is easily oxidized, especially by the influence of oxygen, light, and pH. Vitamin C is safe for the body and is used in carbohydrate metabolism and synthesizing proteins, lipids, and collagen. Unlike fat-soluble vitamins, vitamin C is not stored in the body and is excreted in the urine.[13]

MATERIAL AND METHODS

Preparation of 1% ascorbic acid solution

Mix 1 gram of ascorbic acid powder into 100 ml of distilled water, then stir with a magnetic stirrer for about 4 minutes until it is completely mixed and there are no deposits.

Procedure for making chitosan solution

A 1% chitosan solution was prepared by mixing 1 gram of chitosan powder in a 1% ascorbic acid solution, then stirred using a magnetic stirrer for about 30 minutes until all the chitosan powder was dissolved and there was no precipitate. For 2% and 3%, the same procedure was carried out only with different concentrations of chitosan powder, namely 2 grams and 3 grams, respectively.

Hardness Test

Fifteen heat-cured acrylic specimens measuring 12mmx12mmx3mm were divided into five groups. Group 1: 3 specimens immersed in aquadest/distilled water solution; Group 2: 3 specimens immersed in 1% ascorbic acid; Group 3: 3 specimens immersed in 1% chitosan solution; Group 4: 3 specimens immersed in 2% chitosan solution; Group 5: 3 specimens immersed in 3% chitosan solution.

All specimens were soaked for 10 minutes for each group, then dried and tested for hardness using a Shimadzu Micro Vickers Hardness Tester type HMV-G21ST (E, 230V) with an HVO load of 0.25 (245.2mN)/10 seconds. Each specimen carried out five different test points and averaged. Data analysis was carried out using a paired sample T-test to determine the difference between groups before and after immersion. The data were tested again using one-way ANOVA statistical analysis to compare the averages of more than two groups unrelated to the significance level of $p<0.05$.

Transversal Strength Test

Twenty-five acrylic plates with dimensions 65 x 10 x 2.5 mm were divided into five groups, five pieces each and soaked in the same way with the hardness test. The transversal strength test was carried out using the Universal Testing Machine (UTM), with the three-point bending method using the Shimadzu Autograph AGS-X Series, Japan. The load cell used in this study is 5 kN with a speed of 50 mm/min. Statistical analysis using One Way ANOVA test using SPSS software version 25 to compare the mean of each group.

DOI 10.46934/ijp.v5i1.270

RESULTS

The mean and standard deviation of hardness, transversal strength and modulus of elasticity of the five groups are as follows: All groups were tested for normality with the Shapiro Wilk test and showed normal results ($p>0.05$), which continued with the One-Way ANOVA test.

DISCUSSION

Immersion of heat-cured acrylic resin in each treatment group, namely the distilled water group, 1% ascorbic acid solution, 1% chitosan solution, 2% chitosan solution and 3% chitosan solution, all experienced an increase in hardness when compared to the hardness value before immersion. Immersion of heat-cured acrylic resin in a solution can affect its physical properties. Based on the study's results, it was found that heat-cured acrylic resin before and after immersion in various solutions experienced an insignificant increase in hardness because the chitosan solution could penetrate the microporosity cavity of acrylic resin and affect the intermolecular bonds. The longer the immersion time, the more solution particles will penetrate the microporosity cavity of the acrylic resin.[14] This is due to the heat-cured nature of acrylic resin, which can absorb water slowly over a certain period, with the absorption mechanism through the diffusion of water molecules according to the law of diffusion. The diffusion coefficient of water on the heat-cured acrylic resin is generally 1.08×10^{-12} m2/sec at 37°C. [15,16] In the results of this study, the hardness of heat-cured acrylic resin after immersion in several concentrations of chitosan showed an increase in hardness with increasing concentration. This result follows previous studies that discussed the effect of adding chitosan nano gel to the mechanical properties and colour stability of heat-cured acrylic resin denture base materials. The study stated that adding chitosan to heat-cured acrylic resin showed an increase in hardness and modulus of elasticity, which affected the fracture toughness of heat-cured acrylic resin. Chitosan has mechanical properties 2-3 times stronger than heat-cured acrylic resin.[17] The concentration of chitosan is directly related to the viscosity; the higher the viscosity, the friction between the particles in the chitosan solution increases and is more attached. The addition of chitosan to the denture base can reduce water absorption.[18]

The heat-cured acrylic resin group immersed in 3% chitosan solution has the highest average transversal strength and modulus of elasticity. The lowest average was the heat-cured acrylic resin group immersed in 1% chitosan solution. The standard transversal strength of acrylic resin used as a denture base should not be less than 65 MPa, and the modulus of elasticity ranges from 2000-2400 MPa.[4,19] In this study, there was an increase in the average transverse strength and modulus of elasticity of heat-cured acrylic resin immersed in chitosan solution. The increase started from 1% chitosan concentration, 2% chitosan concentration, and 3%. The highest average transversal strength and modulus of elasticity were in chitosan solution with a concentration of 3%. However, the average modulus of elasticity of heat the average modulus of elasticity of heat cured acrylic resin, which should equal 2400 MPa. The increase occurred in line with the increase in the concentration of chitosan, where the higher the chitosan concentration, the transverse strength and modulus of elasticity increased. Increasing the concentration of chitosan can cause more chitosan content in the solution, which results in physical and chemical interactions in binding molecules.[17]

The heat-cured acrylic resin contains polymethyl methacrylate and a small amount of ethylene glycol dimethacrylate, both of which will form a functional group in the form of an ester group so that it easily absorbs the solution.[20] This causes chitosan to penetrate macromolecules of heat-cured acrylic resin and affect its chemical bonding.[4] Chitosan has elements $NH2$ and $NH3^+$, and polymethyl methacrylate from heat-cured acrylic resin has elements of COOH.[9] Bonds occur between polymer chains where CH3 in heat-cured acrylic resin will bind to chitosan polymer chains, namely -OH. In addition, the carbonyl group C = O in the poly (methyl methacrylate) chain will also bind to NH2 in chitosan.[17] The hydrogen bonding reaction between chitosan and acrylic resin can affect the hardness value of the denture plate so that a strong bond will occur. Another possibility that can occur is the presence of ionic bonds between $NH3^+$ chitosan and $CH3COO^-$.[21]

The transversal strength and modulus of elasticity of heat cured acrylic resin immersed in 1% ascorbic acid solution had higher values than 1% chitosan solution. This value is thought to occur because the acid compound contains a lot of H^+ ions which can lower the surface tension of the heat-cured acrylic resin so that the molecules in the solution easily enter between the acrylic resin molecules and diffusion occurs faster.[21] Denture bases exposed to acid solutions for a long time can experience a decrease in transverse strength.[22] However, the results of this study did not show a decrease in transverse strength and modulus of elasticity after immersion in 1% ascorbic acid solution. This result is because the acrylic resin has good resistance to weak acids, one of which is ascorbic acid.[23]

CONCLUSION

There was no significant effect on the hardness of heat cured acrylic resin before and after immersion in distilled water, 1% ascorbic acid solution, and chitosan solution with ascorbic acid solvent at concentrations of 1%, 2% and 3%, but there was an increase in hardness with increasing chitosan concentration.

There was no significant difference in the transversal strength effect of heat cured acrylic resin immersion in aquadest solution and 1% ascorbic acid as control and 1%, 2%, and 3% chitosan solution with the ascorbic acid solvent. However, there was an effect of a different modulus of elasticity.

REFERENCES

1. Rahal JS, Mesquita MF, Henriques GEP, Nobilo MAA. Influence of chemical and mechanical polishing on water sorption and solubility of denture base acrylic resin. Braz Dent J. 2004;15(4):225-230.
2. Patrick, Eakle, Bird. Dental material: Clinical application for dental assistants and dental hygienists. Philadelphia: WB Saunders Company; 2003. p.250-257.
3. Suguh BP, Yogiartono M, Titien HA. Perubahan kekuatan impak resin

DOI 10.46934/ijp.v5i1.270

akrilik polimerisasi panas dalam perendaman larutan cuka apel. Dentofasial Jurnal Kedokteran Gigi. 2010;9(1):13-20.

4. Citra K, Evelyna A, Sutanto D. Perbedaan Kekuatan Transversa Resin Akrilik Heat Cured yang Direndam pada Larutan Eeffervescent dan Perasan Daun Salam (Eugenia Polyantha Wight). SONDE. 2019; 2(1): 12-23.
5. Manappallil J. Basic Dental Materials. 2nd ed. New Delhi: Jaypee Brothers Medical Publishers; 2003. p. 18-20,124.
6. Sundari I, Sofya PA, Hanifa M. Studi Kekuatan Fleksural Antara Resin Akrilik Heat Cured dan Termoplastik Nilon Setelah Direndam dalam Minuman Kopi Uleekareng (Coffea robusta). J Syiah Kuala Dent Soc. 2016; 1(1): 51-8.
7. McCabe JF, Walls A WG. Applied dental materials. 9th ed. Singapore: Blackwell; 2008. p. 110-5.
8. Amelia M. Studi kelarutan kitosan dalam larutan asam askorbat [Skripsi.]. Fakultas Matematika dan Ilmu Pengetahuan Alam: Universitas Sumatera Utara; 2010.
9. Widia DR. Pengaruh Kadar Kitosan dalam Resin Akrilik terhadap Kekuatan Transversal [Skripsi]. Fakultas Kedokteran dan Ilmu Kesehatan: Universitas Muhammadiyah Yogyakarta; 2018.
10. Evelyn A, Sutanto D, Tiffany E. Chitosan 2% effect on prohibiting the growth of candida Albicans on heat-cured acrylic resin. Jurnal Material Kedokteran Gigi. 2017; 6(2): 17-24.
11. Titik I, Widowati S, Marsetya HNE, Rochmadi. Uji sitotoksisitas campuran resin akrilik dengan kitosan sebagai bahan gigi tiruan anti jamur. Jurnal Teknosains. 2016;5(2):81-146.
12. Pratiwi R. Manfaat kitin dan kitosan bagi kehidupan manusia. Oseana. 2014;1(39):35-43.
13. Dewoto H. Vitamin dan Mineral. dalam Farmakologi dan Terapi. 5th ed. Jakarta: Gaya Baru; 2007. p. 769-792.
14. Dewi P, Debby S, Rizky N. Perbandingan kekerasan resin akrilik tipeheat cured pada perendaman larutan desinfektan alkalin peroksida dengan ekstrak seledri (apium graveolens l.) 75%. Odonto Dental Journal. 2016;3(1):34-41.
15. Melissa K. Perbedaan kekerasan resin akrilik heat cured sebelum dan sesudah perendaman dalam larutan tablet pembersih gigi tiruan [Skripsi]. Fakultas Kedokteran Gigi. Universitas Kristen Maranatha; 2014.
16. Anusavice KJ. Philips' science of dental materials. 12th ed. Missouri: Elsevier; 2012. p. 352-69, 738-47.
17. Ika DA. Pengaruh penambahan kitosan nano gel terhadap sifat mekanis dan stabilitas warna bahan basis gigi tiruan resin akrilik polimerisasi panas [Tesis]. Program Magister (S-2) Ilmu Kedokteran Gigi Fakultas Kedokteran Gigi: Universitas Sumatera Utara; 2016.
18. Hartini VO, Widodo HB, Purnama RB, Logamarta SW and Imam DNA. Absorption of heat cured acrylic resin reinforced with rice husk nanoceluloce. J Dentomaxillofac Sci. 2021;6(3):184-188.
19. Kostoulas I, Kavoura V, Frangou M, Polyzois G. Fracture force, deflection, and toughness of acrylic denture repairs involving glass fiber reinforcement. J Prosthodont. 2008;17 (4): 257-61.
20. Viona D, Sri F, Aldita D. Pengaruh durasi perendaman resin akrilik heat cured dalam minuman the rosella (Hibiscus sabdariffa) terhadap perubahan dimensi. Cakradonya Dent J. 2015; 7 (2): 807-868
21. Indah Wulandari. Pengaruh Konsentrasi Kitosan Dalam resin Akrilik Terhadap Modulus Elastisitas [Skripsi]. Fakultas Kedokteran dan Ilmu Kesehatan:Universitas Muhammadiyah Yogyakarta. 2018.
22. Soldiers J, Kiseleva T, Kaiminsh I. Influence of ascorbic acid on the stability of chitosan solutions. Carbohydrate Polymers. 2005;60 (2): 215-8.
23. Wulandari F, Rostiny, Soekobagiono. Pengaruh lama perendaman resin akrilik heat cured dalam eugenol minyak kayu manis terhadap kekuatan transversa. J of Prosthodont. 2012;3(1): 1-5.