JBAAR
Journal of Basic And Applied Research
ISSN 2413-7014

Effect of Phenol-Formaldehyde Bonding Agent on Acrylic Resin Impact Strength

Saja Ali Muhsin[a*] and Ayad Ibraheem Haddad[b]

[a] PhD Restorative Dentistry, UK; MSc., BSc. Prosthetic Dental Technology; Prosthetic Dental Technology Department, College of Health and Medical Technology, Middle Technical University (MTU), Baghdad, Iraq
[b] PhD, MSc, BSc. Chemistry, Al-Basra University; Prosthetic Dental Technology Department, College of Health and Medical Technology, Middle Technical University (MTU), Baghdad, Iraq

*Corresponding author: dr.sajaalshimmary@gmail.com, kaka.alshimmary@yahoo.com

Received: 16-8-2017
Revised: 28-8-2017
Published: 9-9-2017

Keywords:
Phenol-Formaldehyde; Novolac; Denture base; Impact strength; Charpy test; Bonding agent

Abstract: Objective: evaluating the impact strength of heat-cured acrylic resin material after adding Phenol-formaldehyde (Novolac) as bonding agent material. Materials and Methods: Phenol-formaldehyde blocks were ground into powder, sieved to fine particles to be mixed up with the liquid monomer for 15 minutes, then filtered to be added to the powdered polymer, then the heat-cured acrylic resin was polymerized according to the manufacturer recommendation. Sample of 40 specimens were divided into four main groups (no= 10), Group (A) for heat-cured acrylic resin processed without any additive agent (control group); Group (B): heat-cured acrylic resin processed after adding of 2.5gm of Phenol-formaldehyde powder, Group (C): heat-cured acrylic resin processed with 5gm of Phenol-formaldehyde powder, and Group (D): heat-cured acrylic resin processed with 10gm of Phenol-formaldehyde powder. All the specimens were processed and polymerized by water-bath curing technique and using short curing cycle of 3h. The statistical analysis of variation (ANOVA) and (Games-Howell) test was used at P-value of ($P \leq 0.05$). Results: there was a statistically significant difference between the heat-cured acrylic denture base resins that polymerized without additives and that cured with adding of Phenol-formaldehyde as a chemical agent. Conclusion: the heat-cured acrylic resin that polymerized with 2.5gm of Phenol-formaldehyde have the same effect on the impact strength as that polymerized with 5gm of Phenol-formaldehyde.

Cite this article as: Muhsin, S.A and Haddad, A.I. (2017). Effect of Phenol-Formaldehyde Bonding Agent on Acrylic Resin Impact Strength. Journal of basic and applied Research, 3(3): 127-132
Like us on Facebook - CLICK HERE Join us on Academia - CLICK HERE Visit JBAAR on Google Scholar - CLICK HERE

1. INTRODUCTION

In the early 1930s, the polymethylmethacrylate (PMMA) was first introduced as a denture base material. It employed as a true thermoplastic material being moulded by injection method under heat and pressure from a completely polarized blank into the shape of a denture (Van Noort, 2013). While, as the modern method of using acrylic resin is the form of liquid monomer and powder polymer which was introduced in 1937 (Tandon, Gupta, & Agarwal, 2010). Impact strength is considered as one of the most crucial mechanical properties of the polymers, and it can be significantly improved by the incorporation of the elastomeric and other chemical additives (Diaz-Arnold, Vargas, Shaull, Laffoon, & Qian, 2008; McCabe & Walls, 2013). Among the desirable properties of the denture base material is the possession of an adequate mechanical strength. This is to withstand the load of mastication**.** The impact bond strength is one of the mechanical properties that estimate the quality of the processed denture base materials (Phoenix, Mansueto, Ackerman, & Jones, 2004). It is measuring the energy that absorbed by a material when is suddenly broken (Faot, Costa, Del Bel Cury, & Rodrigues Garcia, 2006; Harrison, Huggett, & Jagger, 1978; Jagger, Jagger, Allen, & Harrison, 2002; Kanie, Fujii, Arikawa, & Inoue, 2000; Karacaer, Polat, Tezvergıl, Lassıla, & Vallıttu, 2003)**.** In the past few years, the synthesis of polymers from renewable resources has been the object of significant research (Williams & Hillmyer, 2008). This effort was due to the increasing the prices of petrochemical products associated with growing environmental concerns**.** Phenol formaldehyde resins (PF) or phenolic resins are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. In order to obtain materials which will be applicable for many fields, the impact strength of the cured PMMA with the adding of the chemical bonding agent of Phenol formaldehyde were studied. Phenolic resins comprise a large family of Oligomers and polymers, which are various products of Phenols, react with formaldehyde (Oliveira, Gardrat, Enjalbal, Frollini, & Castellan, 2008; Ruyter, 1980; Yousef, El-Eswed, & Ala'a, 2011). So, this study is undertaken to exam how Phenol-formaldehyde chemical material ($C_8H_6O_2$)

with three different weighted ratios could act as a bond strength agent to affect the impact strength of the heat-cured acrylic resin denture base material that polymerized by water-bath processing method.

2. MATERIALS AND METHODS

2.1. Metal Pattern Preparation:

According to ADA specification no.12 (Chow, Cheng, & Ladizesky, 1993; Ilbay, Güvener, & Alkumru, 1994; Koumjian & Nimmo, 1990), the following metal pattern was constructed, rectangular-shaped metal pattern of (10mm X 2.5mm X 3mm ± 0.5mm) length, width, and thickness was constructed to be used for impact strength test**.**

2.2. Mould Preparation

Mould was prepared using a conventional denture flask technique; the lower part of the dental flask was filled with the dental stone which mixed according to the manufacturer instruction (50ml/100gm). The metal pattern painted with separating medium to easy removal from the stone and then coating one side of the metal pattern with a layer of stone mix. This is to avoid trapping of air under the specimen when placing the metal pattern into the stone mix. After completely setting of the stone, both the stone surface and metal patterns were coated with separating medium, and another layer of stone was poured into the upper part of the flask with vibration to get rid of the trapped air. Dental stone was allowed to harden for 60min, then the flask was opened and the metal pattern was removed from the mould carefully to leave the mould cavity (John, Gangadhar, & Shah, 2001; Johnson & Wood, 2012; Phoenix et al., 2004).

2.3. Phenol-formaldehyde Powder Preparation

Some of the chemical agents such as phenol-formaldehyde ($C_8H_6O_2$) material present in nature as a stone called Novolac, figure (1) (Gil et al., 2013; Gusse, Miller, & Volk, 2006; Mutlu, Alma, Basturk, & Oner, 2005; Zoumpoulakis & Simitzis, 2001). The Novolac mass of block resin should be ground and sieved to achieve the finest and debris fewer particles, also to facilitate the process of material dissolving in a liquid medium. These stones are ground into smaller particles by using a mechanical grinding machine**.**

The resulted powder was sieved with an aid of electrical vibrator device. The ground powder was passed through consequent sieving steps, figure (2), and as described below (Cuthrell & Murch, 2016; Drummond, Hathorn, Cailas, & Karuhn, 2001; Ma, Wu, Wei, Liang, & Wu, 1998; Taira & Yamaki, 1995):

1st step: The powder sieved through sieve no. 40 and the resulted powder are will be of (240 µm/ inch^2) grid size.

2nd step: The powder resulted from the 1st step sieved using sieve no. 60 and the powder of (360 µm / inch^2) grid sizes were achieved.

3rd step: The powder resulted from the 2nd step then sieved by sieve no. 100 and the powder of (600 µm/ inch^2) grid size were finally achieved.

The fine Novolac powder is then measured by weight using precision electrical balance into three different ratios of 2.5gm, 5gm, and 10gm. The resulted powder kept in tight plane tubes for next experimental study.

2.4. Preparation of Liquid Solution

The solution for the study test was prepared using the MMA liquid monomer with the previously weighted Novolac powder as an additive chemical agent. The 125ml of MMA monomer (Pigeon dental, China) was placed in a clean and dry mixing beaker followed by slow addition of Novolac powder. The mixture was then stirred with mixing spatula and left for 15min at room temperature (25C°) to dissolute Novolac particles gradually. After 15min, the solution was filtered and kept in a dark brown container till the time of sample preparation. The process was repeated with different ratios of Novolac powder of 2.5gm, 5gm, and 10gm for the experimental groups.

2.5. Specimens Preparation

2.5.1. Packing

The pink heat-cured acrylic resin (Pigeon dental, China) was mixed according to manufacturer's instruction (3:1) by volume. The prepared MMA monomer-Novolac solution was placed in a clean and dry mixing vessel followed by slow addition of PMMA powder. The mixture was then stirred with a wax knife and left in a closed container at room temperature (23C°±5C°). The flask mould cavity was filled with the dough resin after the application of a separating medium. Then the flasks were closed together and placed under hydraulic press (4bar)**.** The pressure was slowly applied to allow even flow of the acrylic dough throughout the mould space, ADA specification no. 12.

2.5.2. **Curing Cycle**

Curing was done in a thermostatically controlled water-bath at a temperature of 74C° for 2½h then at 100 C° for ½h (Johnson & Wood, 2012; Sakaguchi & Powers, 2012; Van Noort, 2013). After heat-cured polymerization, the flask was allowed to cool slowly at room temperature. After deflasking, acrylic specimens were removed from the mould and kept in distilled water until finished and polished, figure (3).

2.5.3. **Finishing and Polishing**

According to the ADA specification no. 12, the sample was finished and polished using a water-

cooling system. This is to prevent the distortion of the specimens during procedures**.** Sand paper of 600 then of 1200 grit size was used, and the polishing was accomplished by bristle brush and pumice using dental lathe polishing machine at a speed of 1500rpm. The final glossy surface was obtained with wool brush and polishing soap. The specimen dimensions were measured for the testing procedure as shown in figure (4).

2.6. Impact Strength Testing Procedure

The impact strength test was accomplished using impact tester machine (TMI 43-1, USA) and according to the recommendation given by the ASTM D-6110 and ISO (179) using Charpy-type impact test (Deblieck et al., 2017; Haque, Rahman, Islam, Huque, & Hasan, 2010; Uzay, Boztepe, Bayramoğlu, & Geren, 2017; Yang, Sáez, Nagel, & Thomason, 2015), figure (5). In this procedure, the specimens were held horizontally and struck by the pendulum of (2J) capacity at the center of the tested specimen. The scale reading gives the impact energy in (KJ).

The value of Charpy impact strength was computed by the following formula and according to ASTM D-6110 and ISO (179) (Yang et al., 2015) for determination of impact strength.

Impact strength (KJ/mm^2) = $E / t\, w$

Where E is the absorbed energy in (KJ), while t is the thickness of the specimen and w is the width at the center in (mm^2).

The data were evaluated statistically using SPSS (Essex-Sorlie, 1995) and ANOVA-test at a confidence interval of 95% and P-Value of ($P \leq 0.05$).

3. RESULTS

The impact strength data were evaluated for the treated heat-cured resin that prepared in this study and after adding the phenol-formaldehyde as a bonding agent. The findings were presented depending upon the results in the following table (1) and figure (6):

Figure 1: Resin stones of Phenol-Formaldehyde material

Figure 2: Novolac powder was sieved gently with the aid of vibrator

Figure 3: Acrylic specimens after curing and deflasking.

Figure 4: Using of Vernier to standardize the dimensions of each acrylic specimen after finishing

Figure 5: Impact strength tester machine

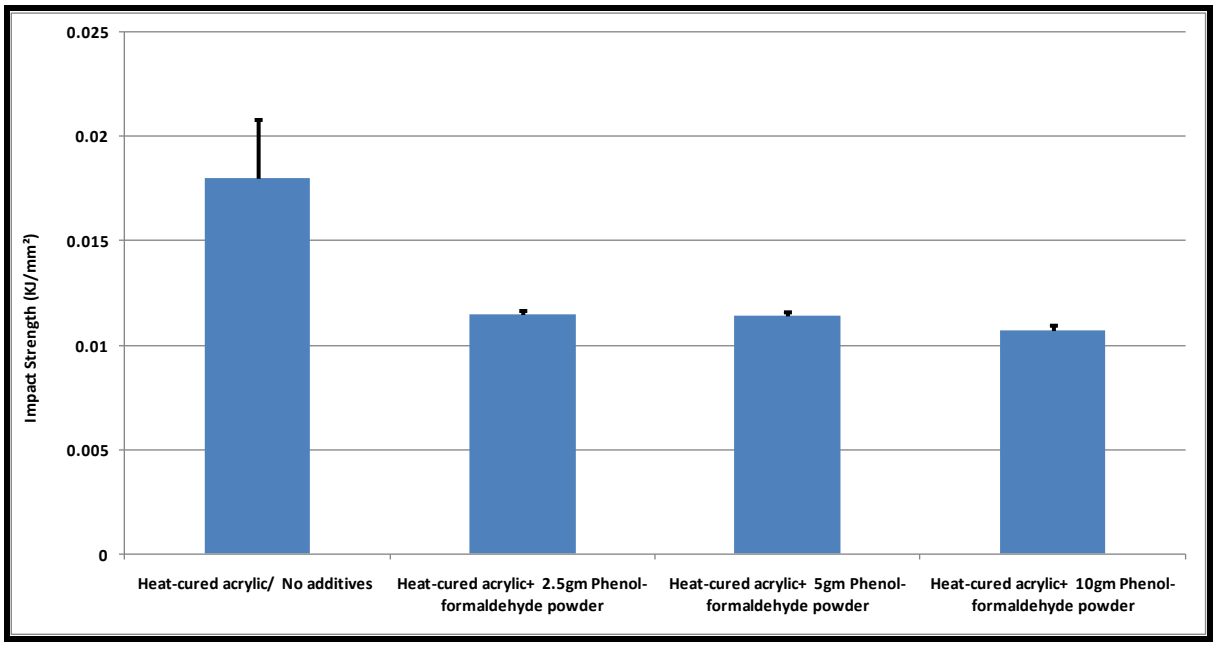

Figure 6: Diagram showing the mean distribution of the impact strength of heat-cured acrylic resin after adding the Phenol- formaldehyde powder as filler agents.

Table 1: ANOVA-test showing the impact bond strength in (KJ/ mm^2) among studied groups

Groups		No.	P-Value	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
A	**B**	10	0.000	S	.0037	.0093
A	**C**	10	0.000	S	.0038	.0094
A	**D**	10	0.000	S	.0045	.0101
B	**C**	10	0.632	NS	-.0001	.0003
B	**D**	10	0.000	S	.0005	.0011
C	**D**	10	0.000	S	.0004	.0010

(P≤ 0.05)
A= Heat-cured acrylic resin with no additives
B= Heat-cured acrylic resin with 2.5gm (Phenol-formaldehyde)
C= Heat-cured acrylic resin with 5gm (Phenol-formaldehyde)
D= Heat-cured acrylic resin with 10gm (Phenol-formaldehyde)

4. DISCUSSION

The value of impact strength may depend greatly on the ratios of Phenol-formaldehyde powder that added to the liquid monomer of acrylic resin components.

The heat-cured acrylic resin with the addition of 2.5gm revealed nearly the same effect as that of 5gm of bonding agent. However, these two powder ratios have shown an increase in the impact strength than that of 10gm powder. This could be related to the incorporation of Novolac powder as a filler material which may affect the final polymerization of resin polymer. This may agree with (Jagger, Harrison, & Jandt, 1999) who stated that the filler particles may affect the denture strength due to the incomplete wetting of the fillers by a resin which leads to the particles disorientation within the denture base. Also, it may depend on the graphical relationship between the impact strength and the adding of Phenol-formaldehyde with different measurements of weight to the network structure of resin. (Vuorinen, Dyer, Lassila, & Vallittu, 2008) found out that some PMMA specimens with low filler percentage such as rigid rod polymer (RRP) showed lower mechanical properties compared to that without fillers. However, the higher RRP filler percentage revealed an improvement in the mechanical properties.

Yet, no studies have been published regarding the effect of the Phenol-formaldehyde chemical material as a denture base bonding agents. Therefore, more studies were needed in this direction.

5. CONCLUSION

The present study concluded that the heat-cured acrylic resin denture base that processed with the addition of 2.5gm or 5gm of phenol-formaldehyde powder to the liquid monomer as a chemical bonding agent has an impact strength value higher than that of 10gm which polymerized by the same processing conditions. However, it was lower than that polymerized without any additives. It showed that the impact strength value of heat-cured acrylic resin was decreased as Novolac powder ratios increased.

REFERENCES

Chow, T., Cheng, Y., & Ladizesky, N. (1993). Polyethylene fibre reinforced poly (methylmethacrylate)—water sorption and dimensional changes during immersion. *Journal of dentistry, 21*(6), 367-372.

Cuthrell, R. Q., & Murch, L. V. (2016). Archaeological laboratory extraction procedures and starch degradation: Effects of sonication, deflocculation, and hydrochloric acid on starch granule morphology. *Journal of Archaeological Science: Reports, 9*, 695-704.

Deblieck, R. A., van Beek, D., McCarthy, M., Mindermann, P., Remerie, K., Langer, B., . . . Grellmann, W. (2017). A simple intrinsic measure for rapid crack propagation in bimodal polyethylene pipe grades validated by elastic–plastic fracture mechanics analysis of data from instrumented Charpy impact test. *Polymer Engineering & Science, 57*(1), 13-21.

Diaz-Arnold, A. M., Vargas, M. A., Shaull, K. L., Laffoon, J. E., & Qian, F. (2008). Flexural and fatigue strengths of denture base resin. *The Journal of prosthetic dentistry, 100*(1), 47-51.

Drummond, J. L., Hathorn, R. M., Cailas, M. D., & Karuhn, R. (2001). Particle size analysis of amalgam powder and handpiece generated specimens. *Dental Materials, 17*(4), 322-332.

Essex-Sorlie, D. (1995). *Medical biostatistics & epidemiology: examination & board review*: McGraw-Hill/Appleton & Lange.

Faot, F., Costa, M. A., Del Bel Cury, A. A., & Rodrigues Garcia, R. (2006). Impact strength and fracture morphology of denture acrylic resins. *The Journal of Prosthetic Dentistry, 96*(5), 367-373.

Gil, M., Martínez, M., García, S., Rubiera, F., Pis, J., & Pevida, C. (2013). Response surface methodology as an efficient tool for optimizing carbon adsorbents for CO 2 capture. *Fuel processing technology, 106*, 55-61.

Gusse, A. C., Miller, P. D., & Volk, T. J. (2006). White-rot fungi demonstrate first biodegradation of phenolic resin. *Environmental science & technology, 40*(13), 4196-4199.

Haque, M., Rahman, R., Islam, N., Huque, M., & Hasan, M. (2010). Mechanical properties of polypropylene composites reinforced with chemically treated coir and abaca fiber. *Journal of Reinforced Plastics and Composites, 29*(15), 2253-2261.

Harrison, A., Huggett, R., & Jagger, R. C. (1978). The effect of a cross-linking agent on the abrasion resistance and impact strength of an acrylic resin denture base material. *Journal of dentistry, 6*(4), 299-304.

Ilbay, S., Güvener, S., & Alkumru, H. (1994). Processing dentures using a microwave technique. *Journal of oral rehabilitation, 21*(1), 103-109.

Jagger, D., Harrison, A., & Jandt, K. (1999). The reinforcement of dentures. *Journal of Oral Rehabilitation, 26*(3), 185-194.

Jagger, D., Jagger, R., Allen, S., & Harrison, A. (2002). An investigation into the transverse and impact strength ofhigh strength'denture base acrylic resins. *Journal of oral rehabilitation, 29*(3), 263-267.

John, J., Gangadhar, S. A., & Shah, I. (2001). Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. *The Journal of Prosthetic Dentistry, 86*(4), 424-427.

Johnson, T., & Wood, D. J. (2012). *Techniques in complete denture technology*: John Wiley & Sons.

Kanie, T., Fujii, K., Arikawa, H., & Inoue, K. (2000). Flexural properties and impact strength of denture base polymer reinforced with woven glass fibers. *Dental Materials, 16*(2), 150-158.

Karacaer, Ö., Polat, T. N., Tezvergıl, A., Lassıla, L. V., & Vallıttu, P. K. (2003). The effect of length and concentration of glass fibers on the mechanical properties of an injection-and a compression-molded denture base polymer. *The Journal of Prosthetic Dentistry, 90*(4), 385-393.

Koumjian, J. H., & Nimmo, A. (1990). Evaluation of fracture resistance of resins used for provisional restorations. *The Journal of prosthetic dentistry, 64*(6), 654-657.

Ma, R., Wu, J., Wei, B., Liang, J., & Wu, D. (1998). Processing and properties of carbon nanotubes–nano-SiC ceramic. *Journal of materials science, 33*(21), 5243-5246.

McCabe, J. F., & Walls, A. W. (2013). *Applied dental materials*: John Wiley & Sons.

Mutlu, I., Alma, M., Basturk, M., & Oner, C. (2005). Preparation and characterization of brake linings from modified tannin-phenol formaldehyde resin and asbestos-free fillers. *Journal of materials science, 40*(11), 3003-3005.

Oliveira, F. B., Gardrat, C., Enjalbal, C., Frollini, E., & Castellan, A. (2008). Phenol–furfural resins to elaborate composites reinforced with sisal fibers—molecular analysis of resin and properties of composites. *Journal of applied polymer science, 109*(4), 2291-2303.

Phoenix, R. D., Mansueto, M. A., Ackerman, N. A., & Jones, R. E. (2004). Evaluation of mechanical and thermal properties of commonly used denture base resins. *Journal of Prosthodontics, 13*(1), 17-27.

Ruyter, I. E. (1980). Release of formaldehyde from denture base polymers. *Acta Odontologica Scandinavica, 38*(1), 17-27.

Sakaguchi, R. L., & Powers, J. M. (2012). *Craig's restorative dental materials*: Elsevier Health Sciences.

Taira, M., & Yamaki, M. (1995). Preparation of SiO2-Al2O3 glass powders by the sol-gel process for dental applications. *Journal of Materials Science: Materials in Medicine, 6*(4), 197-200.

Tandon, R., Gupta, S., & Agarwal, S. K. (2010). Denture base materials: From past to future. *Indian J Dent Sci, 2*(2), 33-39.

Uzay, C., Boztepe, M. H., Bayramoğlu, M., & Geren, N. (2017). Effect of post-curing heat treatment on mechanical properties of fiber reinforced polymer (FRP) composites. *Materials Testing, 59*(4), 366-372.

Van Noort, R. (2013). *Introduction to Dental Materials4: Introduction to Dental Materials*: Elsevier Health Sciences.

Vuorinen, A.-M., Dyer, S. R., Lassila, L. V., & Vallittu, P. K. (2008). Effect of rigid rod polymer filler on mechanical properties of poly-methyl methacrylate denture base material. *Dental Materials, 24*(5), 708-713.

Williams, C. K., & Hillmyer, M. A. (2008). Polymers from renewable resources: a perspective for a special issue of polymer reviews. *Polymer Reviews, 48*(1), 1-10.

Yang, L., Sáez, E., Nagel, U., & Thomason, J. (2015). Can thermally degraded glass fibre be regenerated for closed-loop recycling of thermosetting composites? *Composites Part A: Applied Science and Manufacturing, 72*, 167-174.

Yousef, R. I., El-Eswed, B., & Ala'a, H. (2011). Adsorption characteristics of natural zeolites as solid adsorbents for phenol removal from aqueous solutions: kinetics, mechanism, and thermodynamics studies. *Chemical Engineering Journal, 171*(3), 1143-1149.

Zoumpoulakis, L., & Simitzis, J. (2001). Ion exchange resins from phenol/formaldehyde resin-modified lignin. *Polymer international, 50*(3), 277-283.