Proceeding of the 12th International Conference on QiR (Quality in Research)
Bali, Indonesia, 4-7 July 2011
ISSN 114-1284

Physical Properties and Fracture Surface of Acrylic Denture Bases Processed by Conventional and Vacuum Casting Fabrication Technique

Noraniah Kassim[a], M. Saidin Wahab[a], Yusri Yusof[a], Zainul A. Rajion [b], A. Jumali Sahar [c]

[a] *Faculty of Mechanical and Manufacturing Engineering*
Universiti Tun Hussein Onn Malaysia , 86400Parit Raja, batu pahat, Johor, Malaysia
Tel : (607) 4537875 Fax: :(607) 4536080
E-mail :noraniahkassim@gmail.com
Tel :(607) 4537714 Fax :(607) 4536080
E-mail :saidin@uthm.edu.my

[b]*School of Dental Science, helth Campus,*
Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, malaysia
Tel : (609) 7673000 ext 5824. Fax : (609) 7650431
E-mail :zar5057@gmail.com/ zainul@kck.usm.my

[c]*Dental clinic Ministry of Health Malaysia*
83000 Batu Pahat,Johor, Malaysia
Tel : (607) 4341619. Fax : (607) 4311997
E-mail :ahmadjumali_jt@yahoo.com

ABSTRACT

The purpose of this paper is to present the different properties and the fractured surface of denture base resin using different process fabrication technique, it also aims to determine the suitablality denture material used in vacuum casting technique. Thirty rectangular specimens were fabricated by conventional denture fabrication for (Impact rapid repair material) heat cure in water bath polymerized and cold cure in autiopolymerized, then specimences were fabricated by using vacuum casting technique for cold cure resin (Vertex Castavaria) with condition of no degassing, degassing at 20 sec and 40 sec. The mechanical properties; impact strength, flexural strength and hardness of the fabricated samples were evaluated using Impact Charpy test, three point bending test and Vickers hardness test respecticely. The fractured surface were observed by using SEM. The results were analyzed by one way ANOVA with (α=0.05). It was found that the cold cure resin produced in vacuum casting process has a lower impact strenght as compared to autiopolymerized process. However, the flexural strength had increased and the porosity also deacreased when the degassing time condition increased. The finding shows that the cold cure resin (Vertex castavaria) had longer pouring time than other cold cure material. This makes the material is suitable for vacuum casting technique.

Keywords
Denture base; physical properties; Conventional technique; vacuum casting technique; fracture surface

1. INTRODUCTION

According to review of dental material in dentistry area, the acrylic resins were so well received by the dental profession, There are different type of resins such as heat cure, cold cure, light cure, rapid heat polymerized, high impact resin, reinforcement resin etc. [1]. The conventional fabrication technique (compression flask) with variable polymerization method were most used in the current denture manufacturing [2]. As a result, a stronger and tougher acrylic resin of high impact acrylic has been developed. The material is able to absorb a greater amounts of energy at the higher strain rate before fracture [3], especially on heat cure material and polymerized by conventional water bath [4]. By exploring technology in the advanced manufacturing process such as CAD, Rapid Prototyping (RP) and Rapid Casting, a new fabrication technique has been explored and it was successful to produce removable denture components in the oral cavity. The approaches aspired to improve the current denture fabrication process which involved so many procedures and required a longer time to complete. Most importantly, it does not preserve any quantitative information for future retrieval.

ISSN 114-1284

2. MATERIALS AND METHODS

In this study, the differences of denture material properties and microstructures produced by using conventional and vacuum casting process have been verified. Several testing and experiments had been conducted such as flexural test, impact test and hardness test. The fractured surface has been observed by using SEM.

2.1 Experimental materials.

The Impact Rapid Repair material (Dental export of London) types heat cured and cold cured were used in the study. The materials were fabricated using conventional technique known as a Compression Flask process. The cold cure material (VERTEX™ Castavaria, Netherland) was used in vacuum casting process because of its pouring time is longer than high impact cold cure as used in conventional technique. The materials were available in powder and liquid form. The powder contains mainly PMMA modified with copolymer and the liquid contains ingredients such as MMA monomer and ethylene glycol dimethacrylate which acts as the crosslinking agent.

2.2 Specimen preparation.

Specimens with size of (80x10 x4 mm, ISO-No.178:93) were prepared for 3-point bending test. Similar size of specimens with the notches cut edgewise in the middle (c=2, ASTM D6110-02) were also prepared for the impact Charpy test. These specimens were produced by difference materials and different fabrication technique i.e heat cure and cold cure acrylic resin for compression flask while and cold cure with no degassing, degassing 20 sec and 40 sec for vacuum casting process.

2.2.1 Compression flask process

The heat cure acrylic (Impact rapid repair, inc. London) used in the specimens preparation was followed the standard procedures for conventional fabrication by compression flask technique. Specimens with the size 80x10x4mm and 80x10x4mm with notches 2mm were wax up. Each half of the wax up thickness was placed on mould separation made from plaster of paris (POP). While the heat cure resin was in the dough stage, it was packed into two moulds after the wax boiled out and flushed. The halves of the flask were pressed together in a pneumatic press. The pressure was then increased up to 40kN in order to remove the excess resin. Then, a domestic water bath curing unit as used to cure the specimens at temperature of 100^{o}C in 60 minutes.

2.2.2 Vacuum casting technique

Auto polymerizing or cold cure acrylic resin (VERTEX Castavaria, Netherland) material was used in the vacuum casting technique. A box with a size of 22x16x9.5cm was created to setup samples for bending and impact test. Silicone rubber was used as the mold material and prepared in the vacuum chamber of the vacuum casting machine (MCP 4/01) as shows in Figure 1a. The Vertex Castavaria s cold cure resin with the ratio of (1ml/0.95g monomer: 1.7g polymer). Then the mixed resin was poured into the mould without degassing. It was then cured in an oven with a temperature of 55^{o}C as shown in figure 1b.

Figure 1: a. Vacuum casting machine

Figure 1b.Self cure resin (Vertex Castavaria) in silicone mould.

2.3 Test preparation

Impact strength was measured through Charpy impact test equipment. The test specimens were cut to a final dimension of 80x10x4mm. The notches were cut edgewise in the middle of the specimens (c=2 mm). The specimens were placed in the centre and perpendicular to the impact force. The specimens were propped up to 60 mm and the hammer is released from initial angle 15^o on the back surface of the notches. 3-point bending test was conducted to measure the Flexural strength using universal testing machine (UTM) conducted at room temperature and the crosshead speed was 1 mm/min. Maximum force, maximum stress, maximum strain, maximum elastic and maximum displacement result has been observed. Hardness test also was conducted on Shimadzu hardness tester (HMV-2000) with a load of 1.961N and loading time of 5 s. Measurements of 3 areas along uniformly selected points of each specimen. The Morphological of the fracture surface was observed using scanning electron microscopy (SEM). Samples were coated with a layer of platinum/palladium at 5nm thick, using an Agar high resolution sputter coater (Auto fine coater, JFC-1600, JEOL, Japan). The SEM was operated with the electron gun set at 20kV.

3. RESULT

Table 1 shows absorbed energy value for heat cure specimens 15.4 kj/m^2 higher than cold cure specimens 14.74 kj/m^2 in conventional technique. However they had similar performance amongst themselves, without significant statistical difference between both material ($p>0.05$) as shows in (Table 2). Therefore in vacuum casting technique absorbed energy is comparable between no degassing, 20sec and 40sec degassing are 13.5(0.5), 13.5(0.4) and 13.8(0.5) W/A respectively. It is proved in (Table 3), shows no statistical difference ($p>0.05$) to each group compared. The comparative analysis of cold cure acrylic according to the process technique (Table 4) revealed that, the cold cure materials used in conventional technique had better than vacuum casting technique in maximum degassed time (40 sec), with significant statistical difference ($p<0.05$).

In conventional fabrication technique, heat cure acrylic resin gives higher result of flexural strength with 68.4(0.1)Mpa than cold cure resin with result 57.7(0.4)Mpa respectively as shows in (Table 1). The result of one way ANOVA in (Table 2) shows there were statistical significant different ($p<0.05$). While in vacuum casting technique (Table 1) shows the flexural strength increased on degassing time, which 61.3(0.7), 67.8(0.2) and 84.9(0.5)Mpa respectively with (no degassing, 20 sec and 40 sec degassing), result from (Table 3) also shows that, there were statistical significant different ($p<0.05$) to each group of degassing time. The comparison of cold cure acrylic materials according to the process technique (Table 4) presented, the vacuum casting technique in maximum degassed time (40 sec) had better than conventional technique in with significant statistical difference ($p<0.05$).

The displacement result of cold cure specimens are 3.3(0.5) is lower than heat cure specimens are 4.2(0.1) mm in conventional fabrication technique (Table 1). The Table 2 shows both of group specimens were statistically significant different ($p<0.05$) but in the small value change. For vacuum casting technique was resulted displacement also increased on degassing time where 4.1(1.1), 4.9(0.3), 6.1(0.8) mm respectively (table 1) for (no degassing, 20 sec and 40 sec degassing), however there were quite similar performance between themselves which is that no significant different ($p>0.05$) as show in (table3). The comparison of cold cure acrylic materials according to the process technique (table 4) presented, the vacuum casting technique in degassed time 40 sec had higher than conventional technique with significant statistical difference ($p<0.05$). Flexural modulus in (table 1) show the highest value is 2574.2(165.1)Mpa for impact cold cure material had processed in conventional fabrication technique. However (table 2-3-4) show no significant difference to each group comparison.

The mean Vicker's Hardness between heat cure specimens and cold cure specimens had processed by canventional technique shown in (table 1) is 20.9(0.4) and 19.4(1.6)VHN, with no statistical difference ($p>0.05$) when compared between both materials (table 2). While the mean vicker's hardness to cold cure material specimens had processed by vacuum casting technique with (no degassing, 20 sec and 40 sec degassing) were 24.2(1.1), 21.8(1.5) and 20.83(2.2)VHN respectively. However the result is comparable with no statitical significant different ($p>0.5$) to each group specimens as shows in (table 3). The hardness to cold cure materials between conventional technique and vacuum casting technique in maximum degassed time (40 sec) shows in (table 4) are comparable, where no significant different ($P>0.05$) observed of each group.

Table 1: The mean (standard deviation) of mechanical properties of all groups test

Fabrication Technique \ Properties		Impact Strength (W/A)(kj/m2)	Flaxural Strength (Mpa)	Flaxural modulus (Mpa)	Displacement (mm)	Hardness (VHN)
Conventional Technique	Heat Cure	15.4(0.5)	68.4(0.1)	2443.1(80.8)	4.2(0.1)	20.9(0.4)
	Cold Cure	14.7(0.1)	57.7(0.3)	2574.2(165.1)	3.3(0.5)	19.4(1.6)
Vacuum Casting Technique	No Degassing	13.5(0.5)	61.3(0.7)	2478.9(73.3)	4.1(1.1)	24.2(1.1)
	Degassing 20 sec	13.5(0.4)	67.8(0.2)	2274(138.9)	4.9(0.3)	21.9(1.5)
	Degassing 40 sec	13.8(0.5)	84.9(0.5)	2068.6(105.0)	6.1(0.8)	20.8(2.2)

Table 2: Properties in conventional technique (Heat cure vs Cold Cure)

Variables	*Sum of Square*	*df*	*Mean of Square*	*F-value*	*P-value*	*(P < 0.05)*
Impact strength (kJ/m2)	0.632	1	0.632	5.481	0.079	No
Flaxural strength (Mpa)	170.996	1	170.996	9.206	0.039	Yes
Flaxural Modulus (Mpa)	0.007	1	0.007	0.615	0.477	No
Displacement (mm)	1.115	1	1.115	8.364	0.044	Yes
Hardness (VHN)	3.375	1	3.375	2.567	0.184	No

Table 3: Properties in vacuum casting technique between (no degassing, degassing 20 sec, degassing 40sec)

Variables	*Sum of Square*	*df*	*Mean of Square*	*F-value*	*P-value*	*(P < 0.05)*
Impact strength (kJ/m2)	0.155	2	0.077	0.364	0.709	No
Flaxural strength (Mpa)	896.924	2	448.462	7.548	0.023	Yes
Flaxural Modulus (Mpa)	0.1221	2	0.0611	5.1674	0.050	No
Displacement (mm)	5.936	2	2.968	4.667	0.060	No
Hardness (VHN)	17.847	2	8.923	3.369	0.105	No

Table 4. Properties conventional technique (cold cure) vs vacuum casting technique (40 sec).

Variables	*Sum of Square*	*df*	*Mean of Square*	*F-value*	*P-value*	*(P < 0.05)*
Impact strength (kJ/m2)	1.296	1	1.296	11.458	0.028	Yes
Flaxural strength (Mpa)	1111.039	1	1111.039	65.198	0.001	Yes
Flaxural Modulus (Mpa)	0.033	1	0.033	2.456	0.192	No
Displacement (mm)	11.141	1	11.141	26.922	0.007	Yes
Hardness (VHN)	3.082	1	3.082	0.873	0.403	No

According to SEM observation of impact fracture showed in x 400 magnification (figure 2a-b) the microstructure of heat cure and cold cure resin in conventional fabrication technique were smooth and homogenous. While (figure 2c-d-e) shows fracture surface of cold cure resin which fabricated in vacuum casting technique were improved smooth and the cracked more stable when degassing time had increased. However fracture surface of cold cure resin in conventional fabrication technique (figure 2b) had smoother than cold cure resin at maximum degassing time in vacuum casting technique. SEM observation in x 100 magnification in (figure 3a-b-c) shows, fabrication in vacuum casting technique found porous materials. However, the porosity had been reduced after the process of the degassing time was increased.

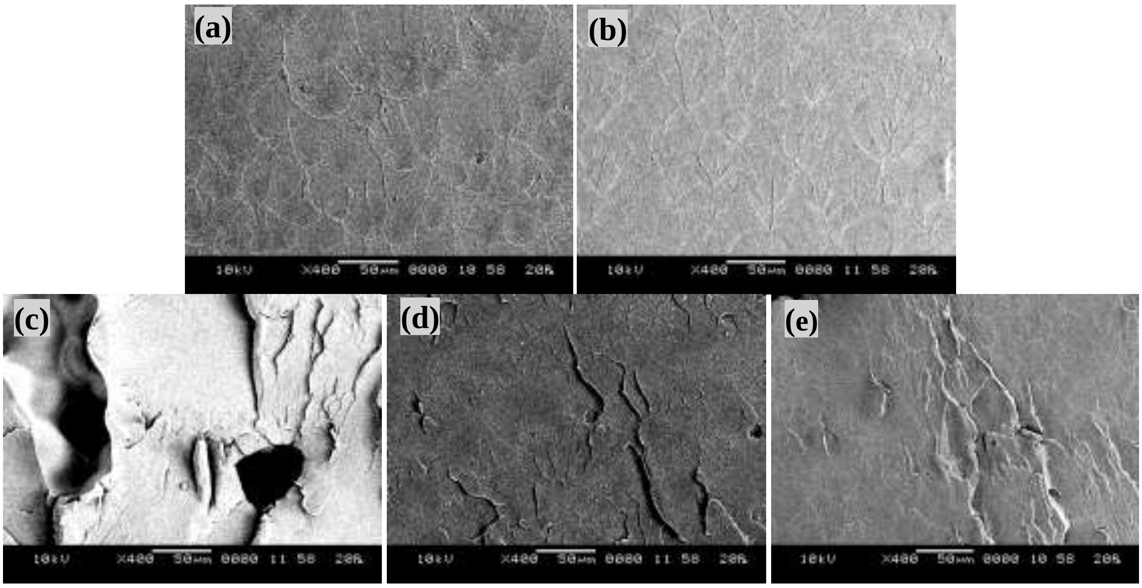

Figure 2: SEM of fracture specimen (x 400 magnification). a. Conventional technique; heat cure resin (Impact repid repair material), b. Conventional technique; cold cure (impact rapid repair material), c. vacuum casting technique; no degassing (cold cure, Vertex Castavaria), d. vacuum casting technique; 20 sec degassing (cold cure, Vertex Castavaria), e. vacuum casting technique; 40 sec degassing (cold cure, Vertex Castavaria)

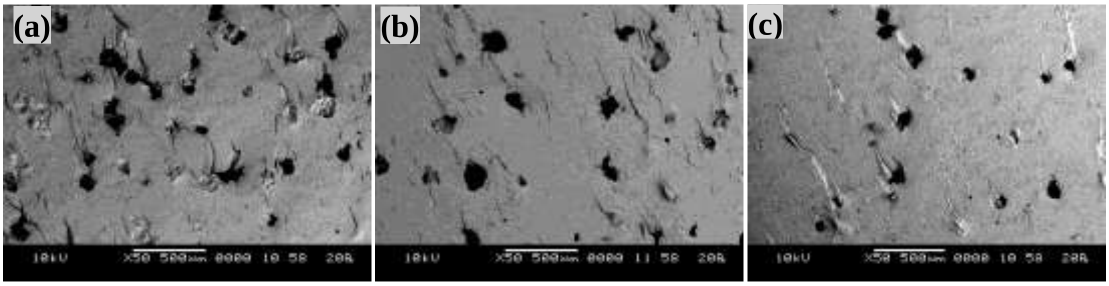

Figure 2: SEM (x 100 magnification) fracture specimen of cold cure (Vertex Castavaria) in vacuum casting technique, a. no degassing, (b) 20 sec degassing, (c) 40 sec degassing

4. DICUSSION

The research shows that the impact test specimens exhibited brittle fractures for all acrylic resins. The absorbed work or impact strength of heat cure resin has a slightly strength than cold cure resin. One way ANOVA showed no significant ($p>0.05$) interaction between both materials, because they were classified in impact rapid repair material. Turkey HSD revealed the Experimental PU exhibited cold cure impact rapid repair material was not significantly different from heat cure rapid repair materials [5]. However, Impact strength for (Vertex Castavaria) cold cure resin ($p<0.05$) significant lower than both materials, because it is not classified in high impact denture resin.

The flexural strength of three point bending test is one of the mechanical strength tests, useful in comparing denture base materials which is applied to the denture during mastication [6]. The transverse (flexural) strength is a combination of compressive, tensile and shear strengths, all of which directly reflect the stiffness and resistance of a material to fracture [7,8]. Several acrylic materials have been used in dentures fabrication, including autopolymerized acrylic resin and heat activated resin. This study demonstrates that in conventional fabrication technique, the autopolimerization curing of impact rapid repair cold cure resin shows the least flexural strength in term of break force, maximum stress, maximum strain and maximum displacement value than impact rapid repair heat cure resin which curing by microwave. As mention by B.H Naveen et al. (2003), the processed performed with autopolymerized resin do not require much time and are inexpensive and easy to perform. Unfortunately, the strength of autopolymerized resin has been lower than heat cured polymerized by hot water bath [9]. In this study also shows cold cure resin (Vertex castavaria) had fabricated in vacuum casting technique without degassing time has lower flexural strength. The reason for the lower transverse strength values of self-cured resin compared with the other materials might be due to the presence of large number of porosities in this material [10, 11]. It was concluded that these materials could not be kept under pressure during the polymerization process is common defects and internal voids often heppened[10]. It has been proposed that internal porosities concentrated stresses in the matrix and contributed to the formation of micro cracks under loading. It should also be noted that, consistent with manufacturer's recommendations, the urethane dimethacrylate material was polymerized on one side only, because the material was not packed into flask under pressure [12]. However the flexural strength were increased when the degassing time during vacuum casting process also increased, because the gasses in that material had been removed and gives less amount of porosity on the materials.

The effects of the impact fracture process on the acrylic resin microstructures observed in the SEM photomicrographs showed a true network polymer structure with the presence of homogeneous particle to heat cure and cold cure resin had fabricated in conventional fabrication technique. The microstructure of the deformed region between both materials showed a smooth and flat microstructure because the cold cure material was poured into flask and compressed under pressure. However in vacuum casting technique, according to SEM image (figure 7a) were found non homogenous microstructure and a lot of porosity had emerged after processed with no degassing time because the material was not packed into flask under pressure. Research from H.T suleyman et. Al (2008) proved that, the Vertex self cure resin had found porous materials than others [13]. However (figure 7b-c) shows the porosity of material had a decreased when increased the degassing time during vacuum casting process. It is proved that with increasing the degassing time more gasses in that material had been removed gives less porosity on the materials.

It was found that, there were no significant differences in the surface hardness between different material which processed in conventional fabrication technique and vacuum casting technique. In previous study also had presented no significant difference in surface hardness (VHN) between the internal and external surfaces between heat cure and cold cure denture resins [14].

In further, to get a better microstructure for Self cure resin Vertex Castavaria had processed in vacuum casting technique, various pouring distance between mixed material and silicone mould should be change, because the higher distance will gives more amount of porosity [15].

5. CONCLUSION

This investigation evaluated the Impact strength; flexural strength and morphology of three different denture resin materials, heat cure resin (Impact rapid repair materials), and cold cure (Impact rapid repair materials and Vertex castavaria) between conventional fabrication technique and vacuum casting technique. Within the limitations of this study, the following conclusions were drawn:

- Heat cure resin fabricated using vacuum casting technique showed the highest mean impact strength and flexural strength when cured by hot water bath and flasked under pressure.
- Porosity amount were decreased when increase the degassing time during vacuum casting process.
- Cold cure resin (Vertex castavaria) had longer pouring time than other cold cure material is suitable use in vacuum casting technique when porosity improved after degassing process.

ACKNOWLEDGMENT

The research is support under Graduate Incentive Grant (GIS) of University Tun Hussein Onn Malaysia, the author would like to thank to dental school HUSM, dental clinic Parit Raja and all team members for supporting this research.

REFERENCES

[1] Nehal, Salahuddin and Mohamed Shehata, "Polymethylmethacrylate; montmorillonite composites: preparation, characterization and properties", Polymer, ScienceDirect. 2001, Vol42, No.20, Pp 8379-8385
[2] J.H Jorge et al., " Cytotoxity of denture base resin: a literature review, J. Prosthet Dent, 2003, vol 90, pp 190-193
[3] Rodford R, "The development and evaluation of high impact strength denture base material", J Dent, 1990, vol 18, pp 151-157
[4] CP Lai et al., " Morphology and properties of denture acrylic resins cure by microwave energy and conventional water bath", Dental Materials , 2004, vol 20, pp 133-141.
[5] Radzi Z et al, "Impact Strength Of An Experimental Polyurethane- Based Polymer", Annals of Dentistry,2007, 14 (1). pp. 46-51. ISSN 0128-7532
[6] Craig RG. *Restorative Dental Materials*. 11th ed. St Louis, MO: Mosby; 2002: pp. 87-88.
[7] Jagger DC, Jagger RG, Allen SM, Harrison A. An investigation into the transverse and impact strength of "high strength" denture base acrylic resins. Journal Oral Rehabilitation 2002; 29(3): 263-2
[8] Anusavice KJ. Phillips' Science of Dental Materials. 11th ed. St Louis, MO: Saunders; 2003: p. 737
[9] B.H. Naveen, B.P Sanjayagouda, and K. Kumaraswamy, " A study transverse strength of different denture base resins repaired by various material and method: An in-vitro study", Journal od dental sciences and research, vol. 1, issue 1, 2003, pp. 66–73.
[10] Machado C, Sanchez E, Azer SS, Uribe JM. Comparative study of the transverse strength of three denture base materials. Journal of Dentistry 2007; 35(12): 930-933.
[11] Tan HK, Brudvik JS, Nichols JI, Smith DE. Adaptation of a visible light-cured denture base material, Journal of Prosthetic Dentistry 1989; 61(3): 326-331
[12] Ozlem Gurbuz, Fatma Unalan, Idil Dikbas, "*Comparison of the Transverse Strength of Six Acrylic Denture Resins"*, OHDMBSC , 2010, Vol. 6, No. , pp 21-24
[13] H.T Suleyman et.al, " The evaluation of water sorption/ solubility on various acrylic resins", European Journal of dentistry, 2008, vol 2, pp 191-196.
[14] I.L Ali, N.Yunus, M.I Abu Hassan, " hardness, flexural strength and flexural modulus comparisons of three differently cures base systems, Journal Prosthodont., 2008, vol 17, No 7, pp 545-549.
[15] N. Mohamed Sutan, S. Hamdan and E.C.C. Jin, " The influence of porosity to the accuracy of ultrasonic pulse velocity method", NDT.net - November 2002, Vol. 7 No.11.