OPEN ACCESS
Saudi Journal of Oral and Dental Research
Abbreviated Key Title: Saudi J Oral Dent Res
ISSN 2518-1300 (Print) |ISSN 2518-1297 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/sjodr/

Original Research Article

Influence of Acrylic Resin Polymerization Methods on Residual Monomer Release and Porosity

Khaled Rateb Al-Hallak[1*], Mohammad Zakaria Nassani[2], Bilal Mourshed[3], Mohammad Kinan Seirawan[3]
[1]DDS, MSc, Prosthetic Dental Sciences Department, AlFarabi College for Dentistry and Nursing, Riyadh, Saudi Arabia
[2]DDS, PhD, Prosthetic Dental Sciences Department, AlFarabi College for Dentistry and Nursing, Riyadh, Saudi Arabia
[3]DDS, MSc, Prosthetic Dental Sciences Department, AlFarabi College for Dentistry and Nursing, Riyadh, Saudi Arabia

***Corresponding author:** Khaled Rateb Al-Hallak
| **Received:** 15.01.2019 | **Accepted:** 25.01.2019 | **Published:** 30.01.2019
DOI:10.21276/sjodr.2019.4.1.8

Abstract

Polymerization methods of acrylic resins have considerable effect on physical and mechanical properties like release monomer and porosity. The aim of this study was to investigate the release of residual monomer and porosity for acrylic denture base materials processed by different polymerization methods (heat and pour cured). Ten specimens were fabricated for each test. For release monomer test the samples were analyzed using gas chromatography with a flame ionization detector and for porosity test it was calculated by measurement of the specimen weight before its immersion in water and 7 days following immersion in water. Student t- test was performed to study the differences between the mean ratio of release monomer and porosity in heat-cured and pour-cured acrylic resin. The statistical analysis indicated highly significant differences in the mean rate of release monomer and porosity between pour-cured and heat-cured acrylic resin ($P<0.001$). As a conclusion, pour-cured acrylic processing method was significantly higher than heat-cured one in both residual monomer content and porosity.

Keywords: Porosity, release monomer, polymerization, acrylic resin.

INTRODUCTION

Acrylic resin has been widely used as a denture base material since the late 1930s [1, 2]. It is by no means a completely ideal material as it has its own advantages and disadvantages but is still one of the most frequently and extensively used materials in dentistry.

It is composed of polymethyl methacrylate (PMMA) powder particles, which are mixed with monomers of methyl methacrylate (MMA) and cross-linking agent [3, 4]. However, although the acrylic resins are widely used up to date, it has their own shortcomings such as residual monomer content and porosity.

The processing or polymerization of acrylic resin is the conversion of the monomer to the polymer regardless the methods used. However, this process is not complete and there is a certain amount of monomer, called residual MMA monomers, are left in the denture base polymers [3, 5].

There are many studies reported that residual MMA in a dental acrylic resin has baleful effects on many of its properties and leaching concentrations in water and saliva may be potentially high enough to elicit irritation and inflammation of the mucosal tissues [3, 5-8] and responsible for various degrees of cytotoxicity [9]. Because of that, it is desirable to reduce the residual monomer content in the dental acrylic resin to as low level as possible before it is placed in the oral cavity.

In addition, porosity in denture base resins remains to be a long standing problem and undesirable characteristics of PMMA that affect the mechanical properties of denture. This has been related to different factors including the following: air entrapped during mixing, monomer contraction during polymerization, monomer vaporization associated with the exothermic reaction, and the presence of residual monomer [10, 11]. In past few years, acrylic resin polymers and monomers have been modified not only to improve physical and mechanical properties, but also to improve the working properties that facilitate laboratory techniques such as microwave curing, visible light curing, and vacuum plus pressure at low temperature curing systems. However, it is important also to select an appropriate resin for the chosen method of processing to obtain the best results [12].

Pour- type technique is one of the processing methods used to process the autopolymerized denture base resin. It is recently used to process denture base resin with acrylic stains [13] and augmentation for lip support [14]. It's noted that many researches have studied the release of residual monomer and porosity in several types of acrylic resins because of their importance in the assessment of the biocompatibility as well as their role in the impact on physical and mechanical properties for acrylic resins. However, it's also noted that studies on these properties is very rare for pour cured acrylic resin.

Fletcher investigated two self-curing acrylic denture-base materials (compression type, and pourable material). He concluded that both exhibited higher residual monomer levels than did heat-cured acrylics, with thick sections having lower values than did thin sections. The pourable material showed lower values than did the compression variety [15].

Sadamori studied the effect of thickness and location of acrylic resin plates on the residual monomer content after processing by three methods (conventional method, fluid resin technique, microwave curing method). He concluded that the levels of residual monomer were influenced by the processing methods and thicknesses of acrylic resin samples [16].

Up to date there is no recent study on porosity and release residual monomer of denture base resins with pour type processing technique. Therefore, this study evaluated porosity and release residual monomer of two brands of denture base resins, which are processed by conventional heat and pourable type.

MATERIALS AND METHODS

Preparation of Specimens

Relevant details of the resins used are presented in (Table-1).

Table-1: Materials used in this study

Information of the Denture Base Acrylic Resin				
Denture Base Material	Manufacture	Batch No	Material type	Composition
Respal NF	Roncomarzo-Mulazzano , Italy	I 26837	heat cured acrylic resin	Methacrylate copolymers and a liquid with a cross-linked effect
Vertex Castapress	Vertex – soesterberg, Netherlands.	YK 393P02 YK 401L01	cold- curing Pour-Type	Polymer based on Methyl methacrylate and monomer (mixing ratio10 ml liquid / 15 g powder)

Heat-Cured Acrylic Resin

The heat polymerizing resin (Respal NF, Roncomarzo- Mulazzano, Italy) was mixed according to the manufacture's instructions and cured according to the traditional method (short curing cycle) in a curing Hanau temperature of 74 º C for two hours and then at a temperature 100 º C for one hour.

Pour-Cured Acrylic Resin

The cold cure resin (Vertex Castapress, soesterberg, Netherlands) was mixed in the ratio of 15 g powder to 10 mL liquid by weight. The mixing time is 20 seconds and the pouring time was up to 3 minutes. After 6 minutes waiting, the flask was put in a curing temperature of 55 º C for 30 minutes (Fig-1).

Fig-1: Vertex curing machine

Preparation of Specimens for Porosity Test

Metal plates were used to prepare ten Samples of each material in parallel rectangles (65 × 40 × 5 mm) dimensions by using heat-cured and pour-cured technique. In order to calculate the percentage of porosity, the weight of the samples was measured in the air and then in water. After that it saved in the incubator temperature of 37 ° C for one week (Fig-2) [22].

Fig-2: Preparation the Specimens for porosity test and saving it in the incubator

Digital analytical balance was used to weigh each specimen in air and water. The absolute density of acrylic resin (1.198 ± 0.01 gm/cc) was used to calculate the percent mean porosity by use of various equations.

Wa = g (dr - da) (vsp - vip) --- 1

Ww = g (dr - dw) (vsp - vip) + g (da - dw) vip --- 2

% of porosity = vip / vsp × 100 --- 3

Where Wa = specimen weight in air, Ww = specimen weight in water, g = gravitational constant, dr = density of acrylic resin, da = density of the air, dw = density of water, Vsp = specimen volume, Vip = internal porosity volume.

In the first equation, specimen volume minus volume of internal porosity was determined using the following known values: d r = 1.198 6 ±0.01 g/ml, d a = 1.23 Kg/m 3, d w = 1000 Kg/m 3 and g = 9.8066 m/sec 2.

Release Monomer Test

Three specimens from each material were prepared in parallel rectangles (35 × 8 × 3 mm) dimensions then we split these specimens to small samples (ten samples of each material) with a weight of 0.2 g approx. Five mL of methyl ethyl ketone (MEK) was added into individual glass test tubes, each of which had a resin sample of about 0.2 g in mass, which were then kept in a dark place at 4°C for 96 hours. Ten µL of p-xylene was then added as an internal standard (2 µL per mL) and centrifuged at 2000 rpm for 15 min. The supernatant was then transferred into a vial awaiting analysis using gas chromatography with a flame ionization detector (Fig-3). The percentage of release monomer was calculated by dividing the amount of release monomer from each sample to sample weight multiplied by 100 (Fig-3).

Fig-3: The samples in centrifugation at 2000 rpm for 15 min

RESULTS

Release Monomer and porosity Test

The release monomer content and porosity results are presented in Table-2.

Student t- test was performed on samples to study the significance of differences between the average ratio of release monomer and porosity in heat-cured and pour-cured acrylic resin. There is highly significant differences in the average rate of release monomer and porosity between pour-cured and heat-cured acrylic resin (P<0.001).

The greatest overall increasing in residual monomer was Pour -cured acrylic resin samples by mean of 5.3 while the mean for heat-cured acrylic samples was 0.96. In addition, the mean percentage of porosity for pour-cured acrylic resin was 2.34 while for heat-cured acrylic resin was 0.89.

Table-2: Results of release monomer and porosity test in Heat and Pour cured acrylic resin samples

Processing method	Release Monomer Mean (SD)	Porosity Mean (SD)
Heat Cured	0.96(±0.18)	0.89(±0.11)
Pour cured	5.3(±0.33)	2.3(±0.11)

DISCUSSION

It is important to determine the residual monomer content and porosity of any acrylic material with different processing method, as these directly influence the properties of the material [6]. There have been few reports that investigated the residual monomer and porosity for pour- type processing method. Therefore, the present study investigated the impact of the curing method (pour- type and heat cured) on the proportion of release monomer and porosity. In our study, the residual MMA content of pour-cured acrylic processing method (5.3%) was significantly higher than heat-cured acrylic (0.96%). This finding was almost identical to the finding of Sadamori 1994 [16]. In addition, Fletcher AM *et al*., investigated two self-curing acrylic denture-base materials (compression type and pourable material). They concluded that both exhibited higher residual monomer levels than did heat-cured acrylics. However, the pourable material showed lower values than did the compression one [15]. The high proportion of residual monomer in pour-cured acrylic samples could be interpreted primarily for low temperature in curing, which is mainly processed through chemical activation compared with the thermal activation of heat-cured acrylic resin and that lead to the existence of a large amount of residual monomer which did not enter the formation of chains with polymer molecules [17, 18]. Another explanation could be the high proportion of pores formed in pourcured acrylic samples that facilitate infiltration and release the residual monomer from acrylic material.

The result of heat cured acrylic resin in our study is not surprising as this finding confirmed the previous studies which reported that polymerization temperature and time considerably affect the residual MMA content of denture base polymers [3, 18]. However, the longer period the acrylic samples it takes in the curing process with high degree of curing temperature the less proportion of release monomer from this acrylic. Moreover, in order to achieve such a low residual monomer level, the curing time should be more than 50 min [18]. There are many reports showed that residual MMA in acrylic resin is toxic to oral tissues. Although heat-polymerized resins showed lower cytotoxic effects than autopolymerizing denture base acrylic resins [9], Hensten-Pettersen and Wictorin reported that the cytotoxic potential of autopolymerized pour type and heat cured resins did not indicate any difference when manufactured by alternate processing methods [19]. However, new methods are recommended to reduce the residual monomer in auto and heat polymerized acrylic resin using ultrasonic treatment [20, 21]. During polymerization of acrylic resin, pores are formed in its mass leading to porosity. Porosity occurs due to the air trapped during mixing, monomer contraction and evaporation of the monomer during curing [18]. There are many variables influencing the porosity in acrylic resin samples such as; specimen thickness, curing method, curing time and curing temperature. In the present study, the porosity in pour-cured acrylic resin was higher than it in heat-cured acrylic resin. However, the effect of time and temperature might be the dominant. The curing temperature and time of pour-cured acrylic in our study was 55 º C for 30 minutes which is very less comparing with that of heat cure acrylic resin. This result was in agreement with Antonopoulos 1978 where the porosity in pour-cured acrylic resin was higher than it in heatcured acrylic resin. However, the porosity in our study is not as high as previous study [23] which might be due to the improvements to pour-cured acrylic resin within the thirty-year period.

CONCLUSION

Pour-cured acrylic processing method was significantly higher than heat-cured one in both residual monomer content and porosity.

REFERENCES

1. Peyton, F. A. (1975). History of resins in dentistry. *Dental Clinics of North America*, *19*(2), 211-222.
2. Sears, V. H. (1958). Developments in the denture field during the past half century. *Journal of Prosthetic Dentistry*, *8*(1), 61-67.
3. Vallittu, P. K., Ruyter, I. E., & Buykuilmaz, S. (1998). Effect of polymerization temperature and time on the residual monomer content of denture base polymers. *European journal of oral sciences*, *106*(1), 588-593.
4. Sadamori, S., Kotani, H., & Hamada, T. (1992). The usage period of dentures and their residual monomer contents. *Journal of Prosthetic Dentistry*, *68*(2), 374-376.
5. Botega, D. M., Machado, T. D. S., Mello, J. A. N. D., Garcia, R. C. M. R., & Del Bel Cury, A. A. (2004). Polymerization time for a microwave-cured acrylic resin with multiple flasks. *Brazilian oral research*, *18*(1), 23-28.
6. Lassila, L. V. J., & Vallittu, P. K. (2001). Denture base polymer Alldent Sinomer®: mechanical properties, water sorption and release of residual compounds. *Journal of oral rehabilitation*, *28*(7), 607-613.
7. Jorge, J. H., Giampaolo, E. T., Vergani, C. E., Machado, A. L., Pavarina, A. C., & Carlos, I. Z.

(2004). Cytotoxicity of denture base resins: effect of water bath and microwave postpolymerization heat treatments. *International Journal of Prosthodontics*, *17*(3), 340-344.

8. Bayraktar, G., Duran, O., Bural, C., & Guvener, B. (2004). Effects of water storage of E-glass fiber reinforced denture base polymers on residual methyl methacrylate content. *Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials*, *70*(1), 161-166.
9. Chaves, C. D. A. L., Machado, A. L., Vergani, C. E., de Souza, R. F., & Giampaolo, E. T. (2012). Cytotoxicity of denture base and hard chairside reline materials: a systematic review. *The Journal of prosthetic dentistry*, *107*(2), 114-127.
10. Keller, J. C., & Lautenschalger, E. P. (1985). Porosity reduction and its associated effect on the diametral tensile strength of activated acrylic resins. *Journal of Prosthetic Dentistry*, *53*(3), 374-379.
11. Wolfaardt, J. F., Cleaton-Jones, P., & Fatti, P. (1986). The occurrence of porosity in a heat-cured poly (methyl methacrylate) denture base resin. *Journal of Prosthetic Dentistry*, *55*(3), 393-400.
12. Levin, B., Sanders, J. L., & Reitz, P. V. (1989). The use of microwave energy for processing acrylic resins. *Journal of Prosthetic Dentistry*, *61*(3), 381-383.
13. Pattanaik, B., & Pattanaik, S. (2013). Characterization of a denture base using autopolymerized pour-type denture base resin and acrylic stain. *Journal of prosthodontic research*, *57*(2), 145-146.
14. Shimizu, H., Nakahara, G., & Takahashi, Y. (2008). Use of soft wax and pour-type denture base resin to augment lip support for a removable prosthesis. *Journal of Prosthetic Dentistry*, *100*(3), 242-243.
15. Fletcher, A. M., Purnaveja, S., Amin, W. M., Ritchie, G. M., Moradians, S., & Dodd, A. W. (1983). The level of residual monomer in self-curing denture-base materials. *Journal of dental research*, *62*(2), 118-120.
16. Sadamori, S., Ganefiyanti, T., Hamada, T., & Arima, T. (1994). Influence of thickness and location on the residual monomer content of denture base cured by three processing methods. *Journal of Prosthetic Dentistry*, *72*(1), 19-22.
17. Vallittu, P. K. (1996). The effect of surface treatment of denture acrylic resin on the residual monomer content and its release into water. *Acta Odontologica Scandinavica*, *54*(3), 188-192.
18. Doğan, A., Bek, B., Cevik, N. N., & Usanmaz, A. (1995). The effect of preparation conditions of acrylic denture base materials on the level of residual monomer, mechanical properties and water absorption. *Journal of dentistry*, *23*(5), 313-318.
19. Hensten-Pettersen, A., & Wictorin, L. (1981). The cytotoxic effect of denture base polymers. *Acta Odontologica Scandinavica*, *39*(2), 101-106.
20. Charasseangpaisarn, T., & Wiwatwarrapan, C. (2015). The effect of various frequencies of ultrasonic cleaner in reducing residual monomer in acrylic resin. *Ultrasonics*, *63*, 163-167.
21. Charasseangpaisarn, T., Wiwatwarrapan, C., & Leklerssiriwong, N. (2016). Ultrasonic cleaning reduces the residual monomer in acrylic resins. *Journal of Dental Sciences*, *11*(4), 443-448.
22. Compagnoni, M. A., Barbosa, D. B., de Souza, R. F., & Pero, A. C. (2004). The effect of polymerization cycles on porosity of microwave-processed denture base resin. *The Journal of prosthetic dentistry*, *91*(3), 281-285.
23. Antomopoulos, A. N. (1978). Dimensional and occlusal changes in fluid resin dentures. *The Journal of prosthetic dentistry*, *39*(6), 605-615.