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# Fracture Response of Acrylic Resin Denture Base Material to Different Heat Curing Cycles Modalities

[1]Mohamed M. Sh. Mohamed, [2]Ahamed Alassal, [3]Saad Eldosry, [4]Magdy M. M. Mostafa, [5]Hatem K. Amin and [6]Ahmad Basalah

*[1]Professor, Dental Biomaterials Division, Conservative Dentistry Dept., Faculty of Dentistry, King Abdulaziz,University, Jeddah, Saudi Arabia.*
*[2]Professor of Mechanical Engineering, Benha University, Egypt.*
*[3]Associate Professor of Production Engineering and Mechanical System Design. Dept., Faculty of Engineering, King Abdulaziz, University, Jeddah, Saudi Arabia.*
*[4]Professor, Removable Prosth. Division, Oral and Maxillofacial Prosth. Dept., Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.*
*[5]Professor, Removable Prosth. Division, Oral and Maxillofacial Prosth. Dept., Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.*
*[6] Mechanical Engineering Dept., Faculty of Engineering, Umm Al Quraa University, Macca, Saudi Arabia.*

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## ABSTRACT

The usage of Polymers in different fields is enormous and crucial. One of the most important working load effects on Polymers is the fracture, which constitutes very important potential for research and study.
***Statement of problem***. properties of denture acrylic resins are important for the clinical success of multiple types of prostheses Acrylic resin denture bases must be strong enough to withstand loading stresses at the oral cavity.***The purpose of this research*** was to investigate the fracture behavior of PMMA denture base material cured by commonly used long and short curing cycles. ***Materials and methods***: Tensile, three-point bending, and fatigue tests were carried out in this study for short and long curing cycles specimens of one commercial brand of polymethylmethacrylate, acrylic resin material. ***Results*****:** Results showed that a slight improvement in the tensile strength of the long curing process specimens compared with short curing specimens. However, the mean values of the two curing process specimens were closely matching for the three-point bending test, but the fatigue strength of the short curing specimens showed higher values compared to long curing cycles processed specimens. ***Conclusion:*** fracture behavior of acrylic resin materials showed no significant mechanical differences behavior for both curing cycles.

**Key words:** Polymers, fracture, denture acrylic resins, clinical .

## Introduction

Polymethylmethacrylate (PMMA)acrylic resin materials are commonly used for the fabrication of denture bases, owing to their good aesthetics, simple processing, and relative ease of repair (Cheng *et al.,* 2010) (1). However, insufficient mechanical properties render them non-ideal (Seo *et al.,* 2006)(2) . High flexural strength is crucial to the success of denture wearing, as alveolar absorption is a gradual and irregular process that causes uneven prosthesis support (Diaz-Arnold *et al.,* 2008).

Despite its popularity in satisfying aesthetic demands whereby, with an appropriate degree of clinical expertise and with the careful selection and arrangement of artificial acrylic teeth, it is possible to produce a prosthesis which defies detection, it is still far from ideal in fulfilling the mechanical requirements of a prosthesis. The impact and fatigue strength of PMMA are not entirely satisfactory and this is reflected by the expenditure on a large number of a denture repair annually (Dental Practice Board, 2005-2006)

Denture base acrylic resins are subjected to many different types of stresses. Intra orally, repeated mastication forces lead to fatigue phenomena, while extra orally high- impact forces may occur as a result of dropping the prosthesis, as a consequence, fracture of the denture base can result. Clinical studies have shown midline fractures to be a common problem in maxillary complete dentures (Zappini *et al.,* 2003)

The fracture of dentures is a common clinical occurrence in prosthetic service but still remains an unsolved problem. Denture fractures often occur by fatigue mechanism whereby relatively small flexural stresses over a period of time may eventually lead to the formation of small cracks propagating through the denture base. Therefore, flexural fatigue resistance is the primary factor being an important mechanical property

**Corresponding Author:** Magdy M. M. Mostafa. Removable Prosth. Division, Oral and Maxillofacial Prosth. Dept., Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.
E-mail: dr_magdy2000@yahoo.com

of a denture base polymer, while considering the length of use and clinical durability of the denture (Gurbuz *et al.,* 2012.).

Dentures physical and mechanical properties could be affected by the type of denture base material and its polymerization methods , as well as, the distinction in processing technique (Sahin *et al.,* 2015).

The purpose of this research was to investigate certain mechanical properties and the fracture behavior of PMMA denture base materials according to two different curing cycles approaches, and as a result of this research, more accurate data about fracture and mechanical properties of this widely used material for dental applications will be available for dental practioners.

## Materials and Methods

One commercially available, heat-polymerised acrylic denture base resin material (Ivoclar –Vivadent /triplex, Germany) Meliodent; Heraeus Kulzer Ltd, Newbury, UK) was used in this study. A type II dental stone (Moldano; Heraeus Kulzer GmbH, Hanau, Germany) was used for investing procedures.

*Methods*

Brass plates used for preparing test specimens were flasked by the conventional water bath method. After the setting of the investing stone, the plates were removed, leaving mould cavities in the stone, used for the fabrication of heat-cured acrylic resin specimens.

*Specimens Preparation*

Heat cured PMMA was used for fabricating the test specimens. The proper monomer polymer ratio as recommended by manufacturer was used (23.4 g powder to 10 ml liquid), and was thoroughly mixed and allowed to reach the dough stage in air-tight mixing Jar, then it was packed into the mold space and the two halves were closed under pressure using a hydrolytic press apparatus(OL57, Manfredi, Turin, Italy) under pressure 8 MPa. The flasks were submersed in tap water then the desired temperature was set on the temperature controller which was 73 C$^o$, for nine hours ( long curing cycle) and 73 C$^o$ for two hours followed by one hour at the boiling temperature ( short curing cycle).After the curing stage was finished, the moulds were raised from the water path and left for bench cooling . The moulds were deflasked and the specimens were derived from the mould and were thoroughly finished and polished and were stored in the distillate water prior to testing. Eight specimens for each test were gained and thorough finishing and polishing was performed to gain specimens ready for testing

*Testing equipments*

Universal testing unit( Instron 4502,U.K) was used to perform tensile and three point bending tests.

*Testing procedures*

*Tensile test*

Tensile test was performed according to American Standard Test Methods ASTM D638. The tensile test gives a measure of the Young's modulus of the material as well as the tensile strength and yield point. Tensile properties may vary with specimen preparation and with speed and environment of testing. Specimens dimensions in mm, were107mm as full length of the bar, 41mm as working length, 10mm as diameter of dumbbell head, and 6mm for ??the working bar. The cross head speed was maintained 5mm/min

*Three point bending test*

Three point bending test was performed according to American Standard Test Methods ASTM D79060 . Flexural tests on beams are usually made to determine strength and stiffness in bending. The bending test is often used as a control test for brittle materials. Three point bending test specimen dimensions were 60mm,L, 12mm,b,and 3.5 mm, d . The cross head speed was maintained at 1.3 mm/min. The width and depth of the specimen were measured at the center of the support span. The loading nose and supports were aligned so that the axis of cylindrical surfaces is parallel and the loading nose is midway between the supports. The specimens were centered on the supports, with the long axis of the specimen perpendicular to the loading nose. The load was applied to the specimen at the specified crosshead rate, and load deflection data was taken simultaneously. The stress-strain can be calculated from the following formula:

$$\text{Stress} = \frac{3PL}{2bd^2}$$

Where:

P= Applied load

L= support span, mm

b= width of beam, mm
d= depth, mm

*Fatigue Testing equipment and procedures*

Fatigue test specimen dimensions were, 150 mm, full length of the bar, 50 mm, working length, and 19 mm diameter. Test specimens were stressed and tested in the rotating bending machine ( AVK, Budapest, Hungary, 1980.). The specimens are supported by the pull-rod, the bending moment is applied on the PMMA specimen and the test was begun by the on-off push button. The number of cycles were recorded by the counter after the failure was occurred and the machine shutdown automatically. The same procedures were repeated for different specimens and the graphs were plotted the stress against the number of cycles.

## Results

### Tensile Test

Results of tensile test are presented in Table (1) for long and short curing cycles.

**Table 1:** Tensile test results of PMMA processed by long and short curing processes

| | Long curing process | | Short cyring process | |
|---|---|---|---|---|
| | Tensile strength (MPa) | Total strain (%) | Tensile strength (MPa) | Total strain (%) |
| x | 61.4 | 4.4 | 55.7 | 4.0 |
| S.D. | 4.56 | 0.23 | 4.89 | 0.60 |

### Three Point Bending (flexural strength) Test

The results of three point bending, yield strength, and youngs modulus tests were plotted in Table (2) and table (3) for long and short curing cycles.

**Table 2:** Three point bending test resultus of PMMA processed by long and short curing processes

| | Long curing process | | Short cyring process | |
|---|---|---|---|---|
| | Tensile strength (MPa) | Total strain (%) | Tensile strength (MPa) | Total strain (%) |
| x | 84.9 | 4.6 | 72.9 | 3.70 |
| S.D. | 6.89 | 0.93 | 6.31 | 0.82 |

**Table 3:** Yield strength and Youngs modulus of PMMA processed by long and short curing cycles

| | Long curing process | | Short curing process | |
|---|---|---|---|---|
| | S.D. | X | S.D. | X |
| Yield strength (Proof stress, MPa) | 2.88 | 38.0 | 2.50 | 35.4 |
| Young,s modulus (GPa) | 0.59 | 2.129 | 0.64 | 2.002 |

### Faigue test

Fatigue test results for both long and short curing cycles were represented in the S-N curve the next figure

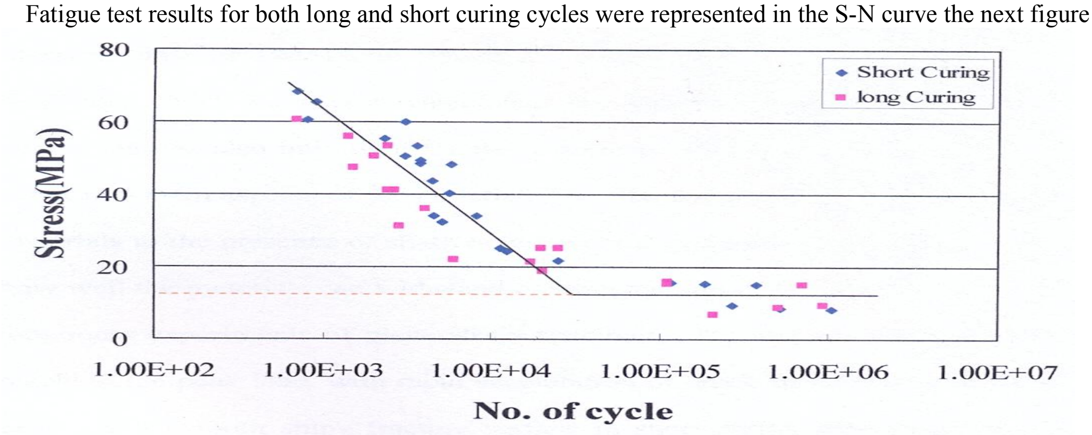


**Fig. 1:** Fatigue test profile for both long and short curing cycles

## Discussion

Acrylic resin denture bases are subjected to many different types of stresses during their services. Intra orally,repeated mastication for cesleadt of atigue phenomena, while extra orally high-impact forces may occur as a result of dropping the prosthesis due to its low tensile strength , as a consequence, fracture of the denture base can result. Our study was conducted to assess and compare the mechanical properties of denture base materials, the tensile, flexural, and fatigue strengths of a conventional PMMA based heat-cured acrylic resin material. Clinical studies have shown midline fractures to be a common problem in maxillary complete dentures were thought to be a flexural fatigue phenomena (Zappini *et al.,* 2003). The denture bases are subjected to a combination of tensile and compressive stresses during flexural forces. Our study did follow two curing cycles commonly applied in dental laboratories( short and long ) and mechanical tests were carried out to compare properties and the behavior of prepared specimens accordingly.

In our study, a slight improvement in tensile strength of the long curing specimens over the short curing was recorded and both showed a total elongation at failure of about 4% strain. This may be due to the higher temperature scheme that was followed, that may be contributed for a better cross-linking due to the thermosetting process which was reflected on the strength of specimens Visual examination of the fracture surface showed that there are two zones representing two types of facture as follow: Zone 1,represents brittle fracture (cleavage with shines surfaces) while Zone 2, which tends to represent ductile fracture as the surface appears with dimples are two zones representing two types of fracture. The average of the tensile strength results agree with the results of Craig and Powers (Craig, 2004).

The flexural strength test is thought to be useful in comparing denture base materials because it reflects the complex stresses applied to the denture during mastication and it provides an indication of a materials' rigidity (Jagger *et al.,* 1999; Doğan *et al.,* 2008; Kanie et al., 2000). Staford and Handley,1975 mentioned that the high flexural, tensile and compressive strengths exhibited may be related to the high degree of polymerization and crystalline nature of the formulation as well as less voids within the materials (Stafford and Handley,1975; Yunus et al., 2005).

The mean Flexural strength of PMMA specimens at our study, processed with long and short curing cycles corresponded well with previously reported values by Craig & Power and meet the ANSI/ADA Specification No. 12 (2002). testing requirements which mentioned that the flexural strength must be not less than 65 M Pa. Results showed some increase in the strain in case of long curing process which tends to increase ductility than the short curing process.

A denture base material with a high elastic modulus can withstand permanent mastication-induced deformation. Fracture of the upper dentures invariably occurs through the midline of the denture, due to flexure. Therefore, the denture base should have sufficient flexural strength to resist fracture.

The flexural strength is related to the distance between the two supporting bars, test speed, and dimensions (width and thickness) of the tested strip (Kenneth *et al.,* 2012)

Further studies are required to test the effect of large number of curing cycles with different equipments and techniques on the fracture behavior of acrylic resin material. In common engineering prospective, fatigue refers to the response of a material to repeated application of stress or strain. Denture bases as mentioned previously is subjected to repeated stresses caused by mastication forces that lead to fatigue phenomena. This repeated stress is equivalent to tensile stress on one side and compressive stress on the other which can cause failure of the material at a stress level less than the yield stress. During the present study, the fatigue life time was slightly decreased after long cycle, however it was slightly increased after short curing process with increasing the curing temperature. Stress was decreased for each succeeding specimen and the life time was increased. The highest stress at which a run out (non-failure) obtained, was taken as the fatigue limit or endurance limit in long curing cycle process, however it was increased in the short curing process. Both curing processes are close in the endurance limit at 13 MPa and showed that about two thirds of the tensile strength of the material , the test stress was decreased for each succeeding specimens and the life time increased. The highest stress at which a run out (non failure) was obtained, is taken as the fatigue limit or endurance limit.

Visual examination of the plane stress specimens after testing showed three kinds of surface-zones, (i) Initial crack (ii) Poisson contraction (iii) fracture onset. The plane stress samples that fractured at extremely low values showed some evidence of crazing followed the initial crack region, which leads to the Poisson contraction was happened which caused when a specimen thickness is small compared to the plastic zone region relieving stresses acting through the sample in the z direction that cause crazing of the specimens.

The material reflects its potential to resist catastrophic failure under a flexural load. High flexural strength is crucial to denture wearing success, as alveolar resorption is a gradual, irregular process that leaves tissue-borne prostheses unevenly supported. As a foundation, the acrylic resin materials should exhibit a high proportional limit to resist plastic deformation and also exhibit fatigue resistance to endure repeated mastication loads (John *et al.,* 2001; Kelly, 1969) An acrylic resin capable of sustaining higher flexure in combination with high resistance to cyclic loading may be less prone to clinical failure.

Materials of different compositions may not fracture under the same fatigue. Different processing techniques also may increase the fracture strength of acrylics (Craig *et al.,* 2004),so in our study we tested two different curing cycles. The resistance to flexural fatigue of denture base materials is of considerable importance for their functional evaluation (Diaz-Arnold *et al.,* 2008).

## Conclusion

This study presented a thorough investigation for long and short cured processes of a commonly used PMMA denture base material, Within the limitations of the conducted study, the following conclusion could be highlighted .Short curing process showed a slight improvement in the mechanical properties as compared to long curing process, this leads to a more effective guide of producing denture base in the laboratories since short cure consumes less time for construction of complete and partial acrlic denture bases.

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