Research Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2021;11:2s:93-100.

Evaluation of the Effect of Addition of Aluminium Oxide in Different Percentages on Hardness and Surface Roughness of Heat Polymerized Conventional Acrylic Resin and Its Comparison with High Impact Acrylic Resin: An In-Vitro Study

Hemant Sharma[1*] Shubham Jain[2] Garima Gothwal[3] Ajay Gupta[4] Syed Noorani[5] Nimit Jain[6]

[1]Senior Lecturer, Department of Prosthodontics, Mahatma Gandhi Dental College, Sitapura, Jaipur, Rajasthan, India.
[2]Senior Lecturer, Department of Prosthodontics, Mansarovar Dental College, Bhopal, MP, India.
[3]Senior Resident, Sardar Patel Medical College, Bikaner, Rajasthan, India.
[4]Senior Lecturer, Department of Prosthodontics, Mahatma Gandhi Dental College, Sitapura, Jaipur, Rajasthan, India.
[5]Reader, Department of Prosthodontics, Mansarovar Dental College, Bhopal, MP, India.
[6]Reader, Department of Prosthodontics, People's College of Dental Sciences, Bhopal, MP, India.

ABSTRACT

Background: Aim of this study was to evaluate the effect of addition of 2.5, 5, 7 wt% aluminum oxide on the surface hardness and roughness of heat polymerized acrylic denture base resin and compare it to commercially available high impact acrylic resin.

Material and method: A total of 150 specimens were prepared which were divided into 5 groups. Group 1 consisted of conventional heat cure denture material DPI. In group-2, 2.5%alluminium oxide was added. In group 3. 5% aluminium oxide was added. In group 4. 7% aluminium oxide was added. In group 5. high impact heat polymerized denture base material (Lucitone199) was used. One Way ANOVA test with Post. Hoc. Tukey. HSD test was used. p value < 0.05 was taken as significant, Med Cale. 14.6-version software was used for all statistical analysis

Result: It is evident from the study that mean surface roughness value was highest in Group 2 and lowest in Group 5. One Way ANOVA test found that mean surface roughness of all groups were not alike. (p> 0.001). On application of Post Hoc Tukey HSD test, It was found that the Mean surface roughness of group- 5 was significantly lower in comparison to all other groups except group-1. Further, Mean surface roughness of group - 2, 3 and 4 were alike. The Mean surface roughness of groups 4 did not differ significantly from group – 1 (p<0.001).

Conclusion: The results of SH evaluation revealed that High impact denture base resin (group-5) showed the least surface roughness (0.0629µm) and denture base resin added with 2.5% Al_2O_3 (Group-2) showed the maximum surface roughness (0.198µm). One Way ANOVA test reviled that Surface Roughness values were not alike.Multiple comparison using Tukey HSD revealed that addition of Al_2O_3 in concentration of 2.5, 5, 7% wt Al_2O_3 significantly increased the SH.

Keywords: Impact strength, Heat polymerized acrylic resin, One Way ANOVA test, Aluminum oxide powder, Hardness, surface roughness.

Received: Nov. 21, 2020: **Accepted**: Dec. 15, 2020
*Correspondence **Dr. Hemanth Sharma.**
Department of Prosthodontics, Mahatma Gandhi Dental College, Sitapura, Jaipur, Rajasthan, India.
Email: hemantsharma7@yahoo.com

pISSN 2278-0076
eISSN 2321-9270

INTRODUCTION

Currently, acrylic resin and rubber reinforced acrylic polymers represent approximately 95% of the denture base materials used in Prosthodontics, Acrylic resins, introduced in 1937 by Dr.Walter Wright, have been successful as denture bases because of their ease of processing, low cost, light weight, and color matching ability[1,2].

The denture base resin is subjected to various stresses during function; these include compressive, tensile, and sheer stresses. Some of the factors responsible for denture fracture include stress intensification, increased ridge resorption leading to an unsupported denture base, deep incisal notching at the labial frenum, sharp changes at the contours of the denture base, deep scratches, and induced processing stresses[3].

Because of the risk of fracture if patients drop their dentures, high impact strength is a desirable property. Given the function of a denture base in a removable prosthesis, high flexural strength, flexural modulus, and a large yield point distance would help resist torsional forces in function, leading to a longer clinical service life for the prosthesis[4,5]. There have been few studies concluded that incorporating Al_2O_3 powder from 5% to 20% by weight into conventional heat-polymerized denture base resin results in an increase in thermal diffusivity. Increasing thermal diffusivity of the acrylic resin base material could lead to more patient satisfaction[6].

Different mechanical reinforcements through the inclusion of metal inserts (in the form of wires, meshes, plates), carbon fibers, glass fibers, sapphire whiskers, silica fibers, aramid fibers, nylon fibers, ultra high modulus polyethylene fibers, **PMMA** fibers and beads of polyethylene and **PMMA** have been studied. Effective fiber reinforcement is dependent on many variables, including the type of the fibers, the percentage of fibers in the matrix, the modulus and distribution of the fibers, fiber length, orientation, form, and the interfacial bond. Small fibers can be added with relative ease[7,8].

Recent advances in the processing of ceramics have made thermally conducting ceramics, such as sapphire (single crystal form of Al_2O_3), silicon nitride, boron nitride, and aluminum nitride widely available. These ceramic powders have the advantage of being white, and therefore are less likely to alter the finished appearance of the denture base material than are metal powders[9,10].

Aluminum oxide, commonly referred to as alumina, possesses strong ionic interatomic bonding, giving rise to its desirable material characteristics. It can exist in several crystalline phases, which all revert to the most stable hexagonal alpha phase at elevated temperatures. This is the phase of particular interest for structural applications. Alpha phase alumina is the strongest and stiffest of the oxide ceramics. Its high hardness, excellent dielectric properties, refractoriness, and good thermal properties make it the material of choice for a wide range of applications[6,7,10].

However, reinforcement methods should not have adverse effects on the mechanical properties of denture base materials. The roughness of acrylic resin surfaces is a critical property because surface irregularities increase the likelihood of microorganisms remaining on the denture surface after the prosthesis is cleaned[6,7].

Another property that can influence the surface characteristics of acrylic resins is the hardness, which indicates the ease of finishing a material and its resistance to in-service scratching during cleaning procedures[8]. There have been few studies in the past to evaluate the effect of addition of aluminium oxide in different percentage by weight on the flexural strength of PMMA. However, there are very few studies to evaluate the effect on surface roughness & hardness of PMMA and compare it with commercially available high impact resin[7,8,9,12].

Hence, this study was conducted to evaluate the effect of addition of 2.5%, 5% and 7%, Al_2O_3 on the surface hardness and surface roughness of heat cure denture base acrylic resin & compare it to a commercially available high impact strength acrylic resin. The null Hypothesis was that there will not be any difference in the Surface Hardness and Surface Roughness of heat cure denture base acrylic resin after addition of 2.5, 5 and 7 wt% AL_2O_3.

AIM & OBJECTIVES

Aim of current study was to Evaluate and compare the effect of addition of 2.5, 5, 7 wt/wt% aluminium oxide on the surface hardness and roughness of heat polymerized conventional acrylic denture base resin and its comparison with high impact acrylic resin.

Objectives

1.To evaluate and compare the effect of addition of 2.5% by weight aluminium oxide powder on surface hardness and roughness of heat polymerized conventional acrylic denture base resin and its comparison with high impact acrylic resin.

2.To evaluate and compare the effect of addition of 5% by weight aluminum oxide powder on surface hardness and roughness of heat polymerized conventional acrylic denture base resin and its comparison with high impact acrylic resin.

3.To evaluate and compare the effect of addition of 7% by weight aluminum oxide powder on surface hardness and roughness of heat polymerized conventional acrylic denture base resin and its comparison with high impact acrylic resin.

MATERIALS AND METHOD

The materials and methods used in the study has been described in the following order:

A. Materials
B. Armamentarium
C. Methodology

   a. Preparation of working moulds
   b. Preparation of PMMA resin specimens
   c. Surface hardness test
   d. Surface roughness test
   e. Statistical analysis

Materials used in the study:

- Conventional heat polymerized PMMA denture base resin in powder and liquid form (DPI-Dental Products of India limited, Mumbai)
- Aluminium oxide powder (5 – 22microns) BEGO
- Auto polymerizing acrylic tray material (SR Ivolen, IvoclarVivadent)
- Medium body Polyvinylsiloxane impression material, addition silicone. (Aquasil Ultra Heavy, Dentsply/ Caulk, USA)
- Tray adhesive (Medicept,UK)
- Die stone (Kalrock)
- Modeling waxes (DPI-Dental Products of India Limited, Mumbai)
- Dental stone (Gold stone), [Asian chemicals, Rajkot, India]
- Vaseline
- Cold mould seal (DPI-Dental Products of India Limited, Mumbai)
- Cellophane separating sheets (DPI-Dental Products of India Limited, Mumbai)

Armamentarium used for the study:

- Stainless Steel Mould (65mm x 10mm x 3mm)
- Rubber bowls
- Spatulas (plaster mixing, cement mixing)
- Denture trimming and polishing lathe with trimming burs, stones, sand paper mandrel, disks and polishing buffs
- Incubator for storing the sample at room temperature
- Porcelain Jar
- Denture Flasks (Jabbar& co.)
- Bench Press Unit
- Curing unit
- Caliper
- Hardness tester (Rockwell)
- Distilled Water
- Plastic bottles to store the specimens

Methodology:

a. Preparation of working mould

A custom tray made of yellow colour self cure acrylic material suitable for the stainless steel mold was fabricated. With the polyvinylsiloxane impression material, an impression of this mold was made and master cast was poured with improved dental stone. Wax was placed in each of the compartment. Master cast was invested in the flask, following manufacturer's instructions for water powder ratio, mixing time and setting time. Dewaxing procedure was carried out by keeping flask in boiling water for 5 minutes and mould was allowed to cool. A standard mold measuring 65 x 10 x 3 mm^3 (ISO 1567 standard) was obtained for the fabrication of the test specimens that were divided into 5 groups.

b. PREPARATION OF PMMA RESIN SPECIMENS

CONTROL GROUP (GROUP-1):

The material used was conventional heat polymerized denture base material (DPI) in a powder and liquid form.

GROUP-2:

The material used was conventional heat polymerized denture base material (DPI) with addition of 2.5% by wt. aluminium oxide powder. Aluminium oxide powder (2.5g) and resin powder (97.5 g) were measured using measuring balance and aluminium oxide powder was mixed with resin powder to make it into 100 g powder.

GROUP-3:

The material used was conventional heat polymerized denture base material (DPI) with addition of 5% by wt. aluminium oxide powder. Aluminium oxide powder (5 g) and resin powder (95 g) were measured using measuring balance and aluminium oxide powder was mixed with resin powder to make it into 100 g powder.

GROUP-4:

The material used was conventional heat polymerized denture base material (DPI) with addition of 7% by wt. aluminium oxide powder. Aluminium oxide powder (7g) and resin powder (93 g) were measured using measuring balance and aluminium oxide powder was mixed with resin powder to make it into 100 g powder.

GROUP-5:

The material used was high impact heat polymerized denture base material (Lucitone199).

Preparation Method Of Samples

Sodium alginate separating media (thin film) was applied on the die stone mould with the help of a brush and dried. The liquid (monomer) and powder (polymer) were mixed in porcelain jar according to manufacturer's instructions at room temperature for a minute and the jar was closed. When the resin had reached dough stage, it was packed into the molds prepared within the denture flasks. And the flask was kept under pressure in bench press unit for bench curing for 30 mins and curing was carried out according to manufacturer's instructions. Finishing and polishing was carried out using sandpaper and tungsten carbide bur. Specimens were stored in distilled water at 37 ^{0}C for 7 days.

No of samples – 150

In each group – 30 samples

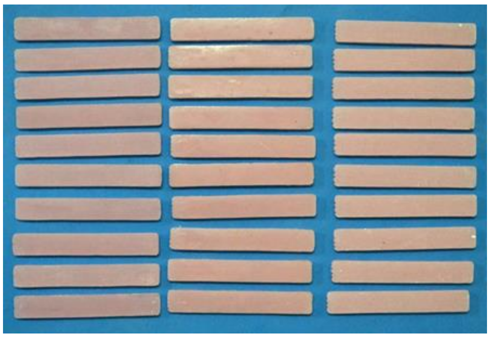


Fig 1: Total sample prepared.

Fig 2: Samples divided in 5 groups.

Fig 3: Incubator.

Surface hardness testing

Surface hardness test was carried out at the Central Institute of Plastics Engineering & Technology, Jaipur. The surface hardness of the specimens was tested on Rockwell hardness tester. The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is applied to a sample using a diamond indenter. This load represents the zero or reference position that breaks through the surface to reduce the effects of surface finish. After the preload, an additional load, call the major load, is applied to reach the total required test load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This major load is then released and the final position is measured against the position derived from the preload, the indentation depth variance between the preload value and major load value. This distance is converted to a hardness number. The surface hardness was calculated using the test method ASTM D 785.

Fig 4: Rockwell hardness testing.

Surface roughness testing

Surface roughness test was carried out at the National Engineering Industries Ltd Jaipur.In this test 10 mm length of each sample were tested by a profilometer and the roughness value was given in Ra value. The surface roughness of the specimens was tested on Taylor Hobson profilometer.

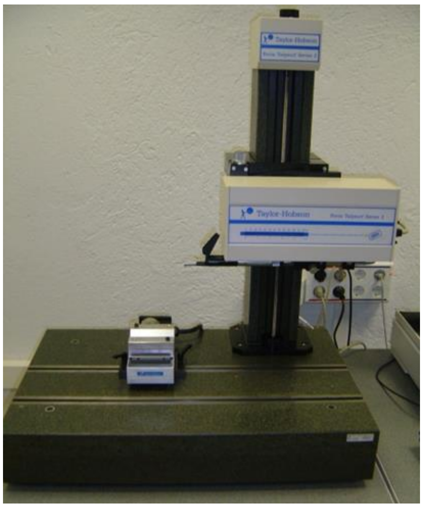


Fig 5: Taylor Hobson profilometer.

Statistical analysis

Data was obtained and was subjected for statistical analysis. All liner variables was summarized as mean and standard deviation and was analyzed by using One Way ANOVA test with Post. Hoc. Tukey. HSD test. p value < 0.05 was taken as significant, Med Calc. 14.6-version software was used for all statistical analysis

RESULTS

Table 1: Descriptive Statistics of all groups for Surface roughness (um).

Group	N	Mean	Std. Deviation	Minimum	Maximum	'p' Value*
1	30	0.0449	0.0251	0.0016	0.0937	<0.001
2	30	0.0873	0.0428	0.0061	0.1982	
3	30	0.0915	0.0491	0.0068	0.1814	
4	30	0.0795	0.0361	0.0124	0.1585	
5	30	0.0277	0.0165	0	0.0629	

It is evident from the above table that mean surface roughness value was highest in Group 2 and lowest in Group 5. One Way ANOVA test found that mean surface roughness of all groups were not alike. (p> 0.001)

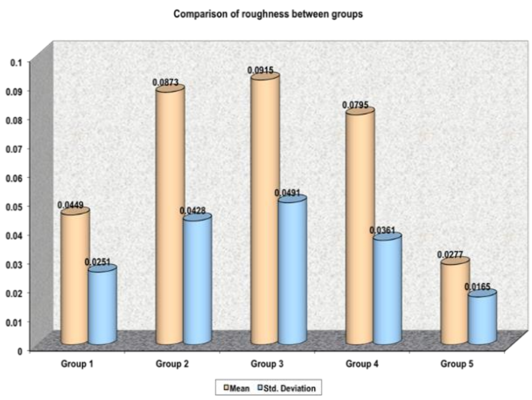
Table 2: Inter group multiple comparison for Surface roughness.

(I) Group	(J) Group	Mean Difference (I-J)	'p' Value*
1	2	0.0425	<0.001
	3	0.0467	<0.001
	4	0.0346	0.002
	5	0.0172	0.349
2	3	0.0042	0.991
	4	0.0078	0.916
	5	0.0596	<0.001
3	4	0.0120	0.693
	5	0.0638	<0.001
4	5	0.0518	<0.001

On application of Post Hoc Tukey HSD test, It was found that the Mean surface roughness of group- 5 was significantly lower in comparison to all other groups except group-1. Further, Mean surface roughness of group -2, 3 and 4 were alike. The Mean surface roughness of groups 4 did not differ significantly from group – 1 ($p<0.001$).

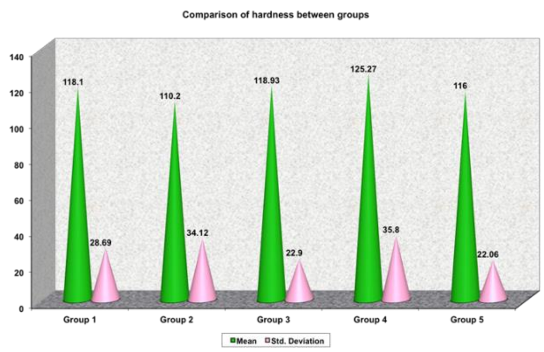
Table 3: Descriptive Statistics of all groups for Surface hardness (RHN).

Group	N	Mean	Std. Deviation	Minimum	Maximum	'p' Value*
1	30	118.10	28.69	64	173	0.392
2	30	110.20	34.12	17	187	
3	30	118.93	22.90	68	172	
4	30	125.27	35.80	53	191	
5	30	116.00	22.06	79	162	



Graph 1: Comparison of roughness between groups.

Graph 1 depicts the mean surface roughnessof group-1, group-2, group-3, group-4 and group-5. Group-E showed lowest mean surface roughness of 0.0277 Ra. Group-1, Group-2, group-3 and Group-4 showed mean surface roughness value of 0.0449 Ra, 0.0873 Ra, 0.0915 Ra and 0.0795 Ra.



Graph 2: Comparison of hardness between groups.

Graph 2 depicts the mean surface hardness of group-1, group-2, group-3, group-4 and group-5. Group- 4 showed highest mean surface hardness of 125.27 with addition of 7% by wt. Al_2O_3 powder. Group-1, group-2, group-3 and group-5 showed mean surface hardness of 118.1, 110.2, 118.93, and 116.

It is evident from the above table that mean surface hardness was highest in Group 4 and lowest in Group 5. One Way ANOVA test found that mean surface hardness of all groups were alike. ($p > 0.001$)

DISCUSSION

Acrylic resins have been used extensively for the fabrication of denture bases because they provide large number of advantages than any other material. Among them,the most widely used is PMMA. Since its introduction to dentistry, it has been successfully used for denture bases because of its ease of processing, low cost, light weight, and color-matching ability. However, acrylic resin denture base materials have poor strength, including low impact strength and low fatigue resistance[2].

It is well known fact that rough surface in the mouth promotes the formation of plaque, which is deleterious to oral hygiene. This is especially relevant in case of a prosthesis like complete denture, which is expected to function in the mouth for a long time. Another property that can influence the surface characteristics of acrylic resins is the surface hardness, which indicates the ease of finishing a material and its resistance to in service scratching during cleaning procedure[3,4,5].

There are three ways to improve the mechanical properties of PMMA: replacing PMMA with an alternative material; chemically modifying it; and reinforcing the PMMA with other materials[6,7]. One alternative to conventional PMMA is a rubber-modified acrylic polymer. By contrast, this material has relatively poor Fracture Strength, and shows long-term failure due to fatigue.[5]Moreover, the high costs of this material restrict its widespread use[8,9].

Other attempts made to improve the mechanical properties of denture base resins have been by incorporating glass fibers, aramid fibers, carbon fibers, nylon, and sapphire. Recently, aluminium oxide powder in various percentages by weight has been added to improve the physical properties of acrylic denture base resin. However, very few studies are available regarding the same[4,5,6,7,8]. In view of these facts, this study was planned to investigate the effect of adding 2.5%, 5% and 7% aluminum oxide on flexural strength, surface hardness and roughness of heat cure denture base resin and compare it to a commercially available high impact acrylic resin.

A study by Vojdani et al, however had showed that the FS of PMMA significantly increased after incorporating 2.5 and 5 wt.%Al_2O_3.This increase in FS was attributed to inherent characteristics of the Al_2O_3particles. Al_2O_3possesses strong ionic interatomic bonding, giving rise to its desirable material characteristics, that is, hardness and strength. The most stable hexagonal alpha phase $Al_2O_3$is the strongest and stiffest of the oxide ceramics[14].

The results of SH evaluation revealed that High impact denture base resin (group-5) showed the least surface roughness (0.0629μm) and denture base resin added with 2.5% Al_2O_3 (Group-2) showed the maximum surface roughness (0.198μm). One Way ANOVA test reviled that Surface Roughness values were not alike[15.] Multiple comparison using Tukey HSD revealed that addition of Al_2O_3 in concentration of 2.5, 5, 7% wt Al_2O_3 significantly increased the SH[16].The SH of denture material is important, because it affects the oral health of tissues in direct contact with the dentures.[16]Bollen CM in a study concluded that the surface roughness threshold for acrylic resin is 0.2 um, below which no significant decrease in bacterial colonization occurs.[17]Quirynen M et. al have stated that dramatic colonization would be expected to occur on surfaces with a roughness value of 2.2 μm[18].

In our study, even though addition of 2.5,5,7 wt.%of Al_2O_3increased the SH significantly, it is well within the acceptable level of 0.2 μm. This also agrees with the study done by Vojdani at el and Saad-Eldenetal[14]. Results of the SH test revealed that denture base resin with 7 wt% Al_2O_3 (Group-4) showed the highest SH (Mean 191 RHN)and high impact resin (Group -5) showed the lowest SH (Mean 162 RHN). One Way ANOVA test revealed that there was no significant difference of SH values among all the groups tested. This is not in concurrence with the study done by Vijodani et al who found a significant increase in SH of conventional denture base resin on addition of 2.5 and 5 wt% Al_2O_3.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Eick J.D. Biological properties of denture base resins. Dent Clin North Am 1977;21:459-64.

2. Peyton F.A. History of resins in dentistry. Dent Clin North Am 1975;19:211-22.

3. Smith DC. Recent developments and prospects in dental polymers. J Prosthet Dent 1962;12:1066-78.

4. John J, Gangadhar S.A., Shah I. Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. J Prosthet Dent 2001;86:424-7.

5. Von Fraunhofer J.A. An investigation of self reinforced PMMR denture base resin using scanning electron and atomic force microscope. IJP 2000;13:526-31.

6. Ellakwa A.E., Morsy M.A., El-Sheikh A.M. Effect of aluminum oxide addition on the flexural strength and thermal diffusivity of heat-polymerized acrylic resin. Journal Of Prosthodontics 2008;17:439–444.

7. Schreiber C.K. Polymethylmethacrylate reinforced with carbon fibres. Br Dent J 1971;130:29-30.

8. Donovan T.E., Hurst R.G., Campagni W.V. Physical properties of acrylic resin polymerized by four different techniques. J Prosthet Dent 1985;54:522-4.

9. Yazdanie N, Mahood M. Carbon fibre acrylic resin composite: an investigation of transverse strength. J Prosthet Dent. 1985;54:543-7.

10. Braden M, Davy KWM, Parker S, Ladizesky N.H., Ward I.M. Denture base poly (methyl methecrylate) reinforced with ultra high modulus polyethylene fibers. Br. Dent J 1988;164:109-13.

11. Salem Sal. Some properties of reinforced denture base polymers. J Dent Res. 1989;68:909.

12. Dixon D.L., Ekstrand K. G. The transverse strengths of three denture base resin. J Prosthet Dent. 1991;66:510-3.

13. Dixon D.L., Breeding L.C. The transverse strengths of three denture base resin reinforced with polyethylene fibres . J Prosthet Dent 1992;67:417-9.

14. Vojdani M, Bagheri R, Khaledi A. Effects of aluminum oxide addition on the flexural strength, surface hardness, and roughness of heat-polymerized acrylic resin.Journal of Dental Sciences 2012: 7; 238-244.

15. Ladizesky NH, Cheng YY, Chow TW, Ward IM. Acrylic resin reinforced with chopped high performance polyethylene fibre-properties and denture construction. Dent Mater 1993;9:128-35.

16. Vallittu P.K. Acrylic resin fiber composite part 2: the effect of polymerization shrinkage of PMMA applied to fiber rowing on transverse strength. J Prosthet Dent 1994;71:613-7.

17. Vallittu P.K., Lassila V.P., Lappalainen R. Transverse strength and fatigue of denture acrylic glass fiber composite. Dent Mater 1994; 10: 116-21.