Effect of Glass & Carbon Fiber Reinforcement on the Transverse Strength of Conventional Heat Cure Denture Base Resin Processed By Heat And Microwave Energy : A Comparative In-vitro Study

Dr. Meenu Garg
Senior Lecturer
Dept. of Prosthodontics Crown & Bridge
Sudha Rustagi College of Dental
Sciences & Research, Faridabad.

Dr. K.N Raghavendra Swamy
Professor
Dept. of Prosthodontics Crown & Bridge
J.S.S. Dental College
& Hospital, Mysore.

Dr. Anil Kumar Gujjari
Professor & H.O.D.
Dept. of Prosthodontics Crown & Bridge
J.S.S. Dental College
& Hospital, Mysore.

Dr. Ramesh Gupta
Senior Lecturer
Sudha Rustagi College of Dental
Sciences & Research
Faridabad, Haryana

Abstract

Purpose: The aim of this study was to evaluate and compare the transverse strength of conventional heat cure denture base resin reinforced with glass and carbon fibers processed by heat and microwave energy.

Materials and Methods: Total 48 specimens were fabricated. Out of these-24 specimens were processed by conventional heat & 24 specimens were processed by microwave energy. The specimens were divided into 6 groups (8 specimens in each group Group1: unreinforced, processed by heat. Group2: unreinforced, processed by microwave energy. Group3: Reinforced with glass fibers, processed by heat. Group4: Reinforced with carbon fibers, processed by heat.Group5: Reinforced with glass fibers, processed by microwave energy.Group6: Reinforced with carbon fibers processed by microwave energy. After processing, the specimens were subjected to transverse strength testing.

Results: Microwave polymerized group has greater mean transverse strength as compared to heat polymerized group. Among all the groups, group-5 has the highest mean transverse strength value. Whereas, group-1 has the least mean transverse strength value.

Conclusion: Within the limitations of this in-vitro study, glass fiber reinforced resin with microwave polymerization technique, significantly increases the transverse strength of heat cure denture base resin.

Key words: Glass fibers; carbon fibers; heat polymerization; Microwave polymerization; Transverse strength.

Introduction

Polymethylmethacrylate (PMMA) was introduced as a denture base material by Dr. Walter Wright in 1937. Presently it is the most widely accepted material because of its favorable working characteristics, superior esthetics, stability in oral environment, processing ease and use with inexpensive equipments[1].

The inherent disadvantage of its low strength causes an acrylic denture to fracture during service as a result of fatigue failure in mouth due to repeated masticatory forces or impact failure as a result of dropping the prosthesis[2]. To overcome these shortcomings, various approaches to strengthen the acrylic resin have been suggested. These include metallic reinforcement and synthetic fibers reinforcement by nylon, aramid, glass, polyethylene and carbon fibers[3].

Historically the polymerization of polymethylmethacrylate resin has been either heat or chemically activated[4]. Several researches have been done to improve the physical properties of denture base acrylic resin by varying the processing techniques. The use of microwave energy for polymerization of denture bases was first reported by Nisshi in 1968[5]. Several studies, found that microwave polymerization have lower residual monomer content, less porosity, better adaptation and better strength than conventional water bath. In addition, shorter curing cycle has made microwave curing an attractive processing technique[6].

But there are no studies on the effect of polymerization on fibers. Therefore, the purpose of this study was to evaluate and compare the transverse strength of conventional heat cure denture base resin reinforced with glass and carbon fibers processed by heat and microwave energy.

Materials And Methods

To make the Acrylic resin specimens of dimension 65mm×10mm×2.5mm according to ADA specification No. 12, following method was followed:

- Two stainless steel dies of dimension 65mm×10mm×1.25mm were fabricated. Both dies were aligned and joined together with minimal sticky wax. These dies were invested in a brass flask for conventional heat polymerization and microwavable flask for microwave polymerization. Dies were invested such that, one die was covered in the first pour of investment, separating media was applied and second pour of investment was poured to cover the second die. After investing, flask was opened and die in the lower base of the flask was removed, investment was coated with separating media. Resin was mixed in ceramic jar according to manufacturer's recommended ratio, (polymer and monomer 3: 1 by volume). The resin was left in the mixing jar until it reached the dough stage, then mix was kneaded thoroughly to a homogenous dough and packed in the mold space. A cellophane sheet was placed over resin and first trial closure was done.
- The flask was opened and excess flash was removed. The second die was removed and investment was coated with separating media. A layer of acrylic resin was packed in the space obtained by second die. A cellophane sheet was placed between the two layers of resin and second trial closure was done. This forms two layers of resin separated by cellophane sheet.

Preparation of the Fibers

A woven form of fiber was used in this study. Fibers of 63mm length and 8mm width were cut with scissor. This dimension of fibers ensured that the acrylic resin remains around the fibers. Before placing, the fibers were soaked in monomer for 10 minutes for better bonding with the acrylic resin. The fibers were placed on inclined glass slab to remove the excess monomer

For Experimental Group

After opening the flask, excess flash was removed and fibers (glass/carbon) were placed in between these two layers of acrylic resin. The flask was closed properly under 2000psi pressure in a bench press. In case of microwave flask, bolts were used to close the flask properly.

For Control Group

After opening the flask, excess flash and cellophane sheet were removed and the flask was closed properly under 2000psi pressure in a bench press. In case of microwave flask, bolts were used to close the flask properly. After final trial closure, flasks were bench cured for 30 minutes at room temperature.

Processing of Specimens using Conventional Heat Cure Method[7]

Acrylization of the specimens was done following the short cycle (74^{0}C for2 hrs then 100^{0}C for 1hr) in the electrical acrylizer. After completion of the polymerization cycle, flasks were bench cooled over night at room temperature before deflasking.

Processing of specimens using microwave energy[8]

This technique required, total 14.5 minutes of polymerization time to ensure proper curing. A glass of water was placed in the oven to protect the magnetron from over-heating. Then flask was placed on the oven turntable and irradiated for 13 minutes in a vertical position at 90 W and for 90 seconds at 500W in the horizontal position as recommended by flask manufacturer. The flask was removed from the oven, allowed to bench cool for 30 minutes and then cooled under running water.

Retrieval of the Test Specimens

After complete cooling, the test specimens were carefully retrieved, finished, numbered and stored in distilled water at 37^{0}C± 1^{0}C in an incubator for 48hrs.

Testing of Specimens

Transverse strength of the specimens was determined by three points loading with Hounsfield's universal testing machine. The specimen was centered on the device in such a way that the loading wedge, set to travel at a crosshead speed of 2mm/min, engaged the center of the specimen. The specimens were loaded until fracture occurred.

Statistical Analysis

Analysis of variance, Scheffe's Post Hoc Test, Independent samplest' test and Descriptive statistics were performed on the observed values for comparison between the groups.

Results

Tables 1 show the mean transverse strength values of different groups.

The transverse strength in increasing order was found to be as follows:

Without fiber reinforcement, processed by heat polymerization < Specimens reinforced with carbon fibers, processed by heat polymerization **<** Specimens reinforced with glass fibers, processed by heat polymerization < Without fiber reinforcement, processed by microwave polymerization < specimens reinforced with carbon fibers processed by microwave polymerization< Specimens reinforced with glass fibers, processed by microwave polymerization.

Graph 1- shows that among all groups microwave polymerized group has greater mean transverse strength as compared to heat polymerized group. This also shows that among all the groups, group-5 (Reinforced with glass fibers, processed by microwave polymerization), has the highest mean transverse strength value. Whereas, group-1 (Without fiber reinforcement, processed by heat polymerization), has the least mean transverse strength value.

Discussion

One of the problems inherent in providing any acrylic prosthesis is its low strength which causes an acrylic denture to break / fracture both outside and inside the mouth. Outside the mouth failure occurs most often through impact as a result of dropping the denture. Inside the mouth, fracture could be ascribed to unsatisfactory occlusion, excessive biting force and /or poor fit of the prostheses, ridge resorption and accidental trauma[2].

Numerous studies support the fatigue failure mechanism as the main cause of denture fracture. Midline fracture of a denture base is a flexural fatigue failure that results from cyclic deformation of the base during function[1].

To overcome these shortcomings, various approaches to strengthen the acrylic resin have been suggested. These include:

1. Chemical modifications by incorporation of butadiene styrene to produce graft copolymer high-impact resins [9].
2. Mechanical reinforcement through the inclusion of :

- Metals in the form of powder wire and mesh.
- Carbon, glass, aramid, nylon and ultra high modulus polyethylene fibers.

The incorporation of metal fillers into polymethylmethacrylate is difficult and technique sensitive with added risk of leaching out of toxic metal ions. It also leads to an increase of specific gravity and poor esthetics[10].

Aramid fibers are not esthetic, difficult to pack and polish [11].In case of polyethylene fibers, the surface treatment to improve the adhesion between fibers and denture base polymer is complicated[5].Studies have shown that the nylon fibers are not effective in increasing the strength of acrylic resin [1]. Carbon fibers have been shown to increase the resistance to flexural fatigue and prevent breakages in complete dentures, fixed partial and removable partial dentures [12]. Glass fibers are most often used for reinforcing polymers in prosthetic dentistry due to its superior esthetics and excellent mechanical properties[1].

Effective fiber reinforcement is dependent on many variables, including the type of fibers; form of fibers; percentage in the matrix; modulus and distribution of fibers; length and upon surface treatment. The type of fiber and its architecture is critical for the success of reinforcement. Fibers can be used in three forms namely continuous parallel, chopped and woven [2]. Woven fiber is a suitable form as reinforcing material for the partial fiber or total fiber reinforcement because the woven form is the form of cloth or tape in which fibers are oriented at 90^0 to each other. For this reason it is easy to cut woven form of fiber with scissors and can be readily placed in the desired location. Placing a single cut mat in the center of specimen is comparatively easier than placing continuous, parallel longitudinal fibers[3,13]. In case of chopped fibers, it is difficult to control the thickness and position of the fibers. Hence, in the current study woven form was used to reinforce acrylic resin and it is placed as close as possible in the middle of the thickness of the specimen i.e. midway between the compressive and tensile side.

Ideally to strengthen the polymer resin by reinforcing fibers, there should be good adhesion between the polymer matrix and fibers. The untreated fibers however, act as inclusion bodies and weaken the resin instead of strengthening .The chemical bond between the polymer and fiber should ideally be of covalent nature. Proper adhesion makes it possible to transfer the stresses from the matrix to fiber. A variety of techniques have been used to treat the fibers such as silanisation, plasma treatment and presoaking in monomer in an attempt to improve the bond between the fiber and the resin[14]. In the present study, fibers were treated with monomer for better bonding with acrylic resin, as this is commonly available material.

Several researches have been done to improve the physical properties of denture base acrylic resin by varying the processing techniques.

In conventional heat polymerization (water bath) technique, the monomer molecules are moved by thermal shocks, which they receive from other molecules; they are thus passively moved and their movements are only the consequence of the outside heat. This technique provides a constant temperature[6].

In the microwave polymerization technique, the monomer molecules are positively moved by a high frequency electromagnetic field; their movements are the cause of the internal heat and heat is only the consequence of their movement [6]. This results in reduced monomer content leading to decreased porosity, better adaptation and better strength of denture base resin. In addition this technique offers a shorter curing cycle for the fabrication of complete denture[11].

Taking all the above factors into consideration the present study, was done to “compare and evaluate the transverse strength of conventional heat cure denture base resin reinforced with glass and carbon fibers processed by conventional water bath and microwave energy”.

In this study, microwave polymerized specimens showed greater mean transverse strength compared to conventional heat polymerized specimens, because the monomer content is reduced in microwave polymerization. Microwaves act only on the monomer, which decreases in the same proportion as the polymerization degree increases. Therefore the same amount of energy is absorbed by less and less monomer, making the molecules increasingly active. This is important because a form of self-regulation of the curing program takes place and leads to complete polymerization of resin[15].

This result can also be compared with Stuart R et al (1989), who evaluated the transverse strength of PMMA denture base resin processed by conventional hot water bath and microwave energy. Testing was done without any fiber incorporation. They found that the transverse strength of test specimens was higher with microwave polymerization technique as compared to conventional hot water bath but there was no statistically significant difference between the two polymerization techniques[5].

No porosity was observed in the resin test strips polymerized by either technique.

In the present study, transverse strength of fiber reinforced specimens was greater as compared to unreinforced specimens. This result correlates with the study of John J et al (2001)[1], who observed that compared to conventional polymer materials, fiber-reinforced polymers are successful in their application primarily because of their high specific modulus and specific strength.

In the present study, transverse strength of glass fiber was greater as compared to carbon fiber. Because the modulus of elasticity of glass fibers is very high, most of the stresses are received by them without deformation whereas; carbon fibers are flexible in nature. Thus in this study, glass reinforced specimens exhibited better transverse strength than other specimen group[1].

An increased strength was also reported by Schreiber CK (1971), who found 50% increase in the transverse strength of acrylic resin on reinforcement with surface treated carbon fibers[12]. Results of the current study have also shown that, the transverse strength of fiber reinforced heat cure denture base resin was greater when processed by microwave energy as compared to conventional heat.

Ih Tacir et al (2006), compared unreinforced and glass fiber reinforced acrylic resin polymers prepared under both conventional heat curing and microwave curing, techniques. Strengthening with the fibers decreased the flexural strength of the resins but increased flexural resistance[16].

Whereas in the present study, transverse strength of PMMA resin was increased with microwave polymerization technique .It was highest for group 5 (i.e. acrylic resin reinforced with glass fibers, processed by microwave polymerization) and the results were highly significant.

It is important to consider that there are no enough studies to evaluate and compare the effect of microwave polymerization technique, after incorporating different types of fibers into PMMA resin, so further studies are required to support the present study.

The present study has its limitations because it was done under laboratory conditions. The properties of acrylic resin in the clinical situation still differ from the laboratory testing. Processing porosity, void spaces due to inadequate wetting, minor surface imperfections, bonding of fibers to the matrix and their location, all contribute to the variation in results of various studies. These factors also need further investigation to identify and predict which material will provide the best service clinically.

Conclusion

Within the limitations of this in vitro study the following conclusions were made from the data obtained:

1. (a) The transverse strength of heat cure denture base resin reinforced with glass fibers was 11% greater than unreinforced denture base resin when processed by conventional heat.
   (b)The transverse strength of heat cure denture base resin reinforced with glass fibers, processed by microwave energy was 29% greater than unreinforced denture base resin, processed by conventional heat.
2. (a) The transverse strength of heat cure denture base resin reinforced with carbon fibers was 5.4% greater than unreinforced denture base resin when processed by conventional heat.
   (b) The transverse strength of heat cure denture base resin reinforced with carbon fibers, processed by microwave energy was 26% greater than unreinforced denture base resin, processed by conventional heat.
3. (a) The transverse strength of heat cure denture base resin reinforced with glass fibers was 21.1% greater when processed by microwave energy as compared to conventional heat.
   (b) The transverse strength of heat cure denture base resin reinforced with carbon fibers was 21.8% greater when processed by microwave energy as compared to conventional heat.
4. Among all the specimens, glass fiber reinforced specimens, which were processed by microwave energy, have the highest mean transverse strength value. Whereas, unreinforced heat polymerized specimens, showed the least mean transverse strength value.

The mean values obtained from the above mentioned results were found to be highly significant.

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Legends

Fig 1: Standardized stainless steel dies to prepare mold.
Fig 2: Standardized dies invested in brass flask.
Fig 3: Standardized dies invested in microwave flask.
Fig 4: Glass fibers placed.
Fig 5: Carbon fibers placed
Fig 6: Glass fibers placed
Fig 7: Glass fibers placed
Fig 8: Fractured specimens
Graph: Comparison of mean transverse strength values among all groups Processed by conventional heat and microwave energy


Fig. 1


Fig. 2

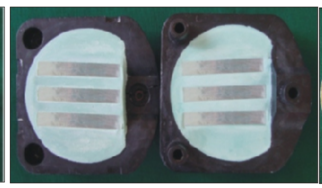
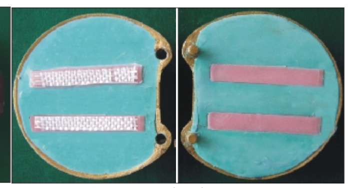


Fig. 3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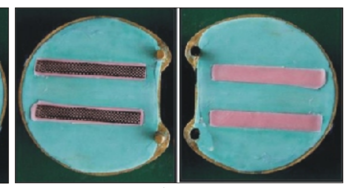


Fig. 5

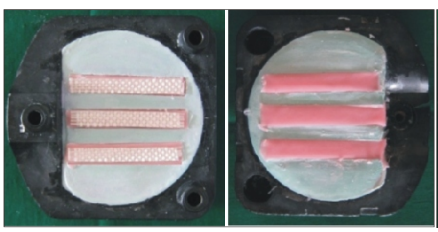
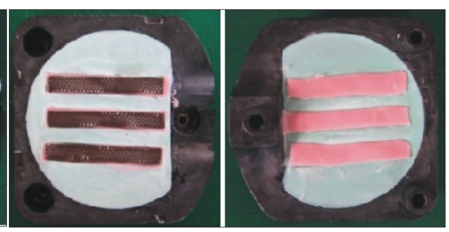


Fig. 6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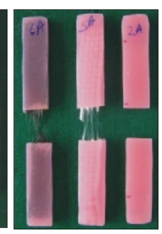
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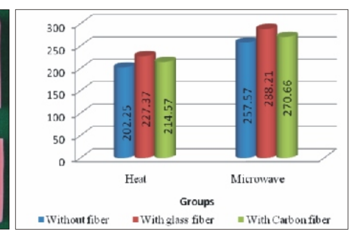

Graph

Table

Table 1-Comparison of mean transverse strength values among all group processed by conventional heat and microwave energy

Descriptive Statistics				
GROUPS	**SUBGP**	**Mean**	**Std. Deviation**	**N**
Heat	without fiber (gr-1)	202.2500	2.3534	8
	With glass fiber (gr-3)	227.3700	2.3214	8
	With carbon fiber (gr-4)	214.1100	2.6037	8
	Total	**214.5767**	**10.7352**	**24**
Microwave	without fiber (gr-2)	257.5688	3.4208	8
	With glass fiber (gr-5)	288.2100	1.9995	8
	With carbon fiber (gr-6)	270.6600	1.4443	8
	Total	**272.1463**	**13.0327**	**24**