ORIGINAL RESEARCH

Evaluation of Surface Topography of Heat Cure Acrylic Denture-base Resin before and after Reinforcement with Different Fibers Using Stylus-based Profilometer

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Abstract

Aim: The aim of this *in vitro* study was to evaluate the effect of glass and nylon fiber reinforcement on surface topography of polymethyl methacrylate (PMMA) denture resin after polishing.

Materials and methods: Stainless steel dies were used for preparation of specimens and were divided into three groups of 30 specimens each. Group A: Control group, Group B: PMMA reinforced with glass fibers, Group C: PMMA reinforced with nylon fibers. All specimens were finished and polished by a single operator to eliminate any inadvertent bias and ensure a constant pressure when polishing. The surface roughness of all the acrylic samples was measured with the help of profilometer (SURFCOM 130A).

Results: Glass-reinforced PMMA showed higher mean surface roughness (0.16817 µm) as compared to unreinforced PMMA (0.10203 µm). Nylon-reinforced PMMA showed lower mean surface roughness (Ra) of 0.09177 µm as compared to unreinforced PMMM (0.10203 µm). Glass-reinforced PMMA showed a higher mean surface roughness (Ra) of 0.16817 µm as compared to nylon PMMA (0.09177 µm).

Conclusion: Reinforcement with glass and nylon fibers affects the surface roughness of the PMMA resin, i.e., glass fibers increase the surface roughness of PMMA resin, whereas nylon fibers slightly decrease the surface roughness of PMMA resin. Hence, the use of nylon fiber may be justified to obtain a denture with increased fracture resistance, acceptable esthetic properties, and better denture hygiene and plaque accumulation.

Clinical significance: Two important parameters are essential for ensuring the durability of a restorative material, which include surface roughness and color stability. Surface roughness may be the major cause of discomfort for the patient and it may be associated with complications by promoting the deposition of biofilm and microbial growth. The use of nylon fiber increases fracture resistance and provides acceptable esthetic properties and better denture hygiene and plaque accumulation.

Keywords: Denture resin, Glass fiber reinforcement, Nylon fiber reinforcement, Polymethyl methacrylate, Surface roughness.

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Introduction

Over the past few decades, there has been tremendous development in the field of dentistry, particularly there has been great advancement in the field of dental materials.[1] Currently, PMMA is the material of choice recommended for denture-based prosthetic material. This material was introduced by Dr Walter Wright in 1937. This is the preferred material for denture-based fabrication as this material has favorable working characteristics, easy to process, fit accurately, provide stability and is stable in oral environment, has better esthetic properties, and is affordable.[2] The only disadvantage of this PMMA is its low fracture resistance, which needs to be improved.[3,4]

Over the period of many years, efforts have been made to improve the mechanical properties of these denture materials PMMA by providing maximum bulk to the material in regions most heavily stressed and by reinforcement with certain materials.[5] There are three approaches to improve the impact properties of PMMA which have been investigated. The first approach was chemical modification of PMMA by rubber-reinforced or high-impact resin, which absorb greater amount of energy at a higher strain rate before fracture than the standard resins. The second approach includes the use of an alternative material to PMMA such as polyamides, epoxy resin, polystyrene, vinyl acrylic, rubber graft copolymer, and polycarbonate. The third approach was incorporation of materials to PMMA by various types of fibers.[6]

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Fiber glass is an inorganic substance suggested as denture-based materials, which gets converted into a rigid structure when gets cooled without crystallization. Commercially, various glass fibers are produced such as Cemfil, S-glass, V-glass, E-glass, R-glass, etc. Among the above-mentioned glass fibers, E-type glass fiber has the highest flexural strength as compared to other glass fibers as it has high level of alumina and low levels of alkaline and borosilicate.[6] However, silanated glass fibers have been recommended as the fibers of choice for dental reinforcement as they have well-documented flexural properties and fatigue resistance with good esthetic quality.[6] Recently nylon polymer has been suggested as reinforcement material with denture-based resin as their use overcomes the disadvantage of PMMA resins.[7] Nylon belongs to a polyamide group which has low melting point and it provides a satisfactory polish. The chief advantage associated with the use of nylon polyamide includes the resistance to shock and repeated stressing.[8]

Glass and nylon fibers are documented to have better potential to be used in prosthetic materials but are difficult to be impregnated in PMMA. There are many studies showing improved mechanical properties of acrylic resin polymer, but none of the study has documented their superiority in improving roughness of the surface of denture. Very few studies have been carried out to determine the effect of reinforcement of PMMA with fibers on surface topography of polymethyl methacrylate. Hence the present study was conducted to assess the impact of glass and nylon fibers reinforcement on surface topography of polymethyl methacrylate denture resin after polishing.

Materials and Methods

This study was conducted as an *in vitro* study in the Department of Prosthodontics, Tertiary Care Center, and technical assistance regarding surface roughness measurement was obtained from QS Metrology, New Delhi.

Fabrication of Stainless Steel Dies

Stainless steel dies in this study for preparation of mold were made by the Mechanical Engineering Department of SGSITS College of Engineering, Indore. Ninety test specimens were prepared with stainless steel dies of dimensions 30 mm × 20 mm × 3 mm of polymethyl methacrylate (heat) cure denture resin material to evaluate the surface roughness.

These specimens were divided into three groups of 30 specimens each:

- *Group A*: Control group—unreinforced conventional polymethyl methacrylate heat cured acrylic resin.
- *Group B*: Polymethyl methacrylate reinforced with glass fibers.
- *Group C*: Polymethyl methacrylate reinforced with nylon fibers.

In fabrication of all these specimens, two criteria were kept constant:

- *Polymer*: Monomer ratio for each specimen was 2.4 g:1.0 mL for all the groups. Powder was weighed on analytical weighing machine and a 2 mL syringe was used to measure monomer.
- *Polymerization cycle*: Polymerization of the entire specimen was carried out in acrylizer. Initially the temperature was raised slowly up to 73°C for 90 minutes and then to 100°C for next 40 minutes.

So the standardized polymerization cycle was kept constant for all the specimens.

Preparation of Mold

The stainless steel dies were used to prepare dental plaster molds. The molds were made as follows. A smooth homogenous mix of dental plaster was prepared and vibrated into the base of the dental flask. Petroleum jelly-coated stainless steel dies were carefully embedded in plaster in such a manner that only half of the thickness of the dies was submerged. The superficial surface of the die was wiped free of plaster. After the initial set the excess plaster was removed with the help of carver in order to facilitate its removal. Then cold mould seal was applied on the plaster; the die again also coated with petroleum jelly.

Care was taken to maintain the edges of the mold spaces which we used to fabricate test specimens of three groups.

Group A: Control Group Unreinforced Conventional Heat Cured Acrylic Resin

Acrylic heat cure resin was used for the fabrication of control test specimen. Polymer and monomer for each specimen were mixed in the standard ration in porcelain jar and at the dough stage it was placed into the mould. For next 30 minutes, the flask was bench cured so as to allow the penetration of monomer into the polymer powder properly. The flask was kept at room temperature immersed in acrylizer to allow the polymerization to complete in two stages.

Group B: Heat Cured Acrylic Resin with Glass Fiber

About 2% of the glass fiber was added in each specimen and weighed on analytical balance. The denture material was cut into 5 mm pieces each.

Initially for the first 5 minutes, the glass fibers were soaked in the saline solution. This was done to allow the bonding of the glass fibers with PMMA matrix. The fibers were then removed from the solution and allowed to dry. This was followed thoroughly to allow polymerization and retrieved.

Group C: Heat Cured Acrylic Resin with Nylon Fibers

Similar to glass fibers, nylon fibers (2%) were weighed and then cut into 5 mm long pieces. These fibers were soaked with PMMA in petridish, removed after 10 minutes, and allowed to dry. Both polymer- and monomer-treated nylon fibers were mixed thoroughly at the dough stage and packed into the mold. The flask was closed and then bench pressed for 30 minutes. After 30 minutes they were placed in the curing unit and the polymerization cycle was completed. Deflasking was done after bench cooling the flask to the room temperature.

The specimen was removed from mould and assessed for the presence of air bubbles. The specimens which were defective were excluded.

Finishing and Polishing the Specimens

All the obtained specimens were kept in wet environment for 15 seconds and abraded by means of a low-speed polishing device (Marathon-4 Sae yang co. Korea) with a light pressure using 600 grit fine sand papers at front and back motion. After each use sand paper was discarded. Then the specimens were polished for next 20 seconds with the help of dental polishing lathe (Unident Instrument Ltd., New Delhi) with pumice powder mixed with water in ratio of 2 g:2 mL. The measured amount of pumice and distilled water was individually dispensed to obtain consistent slurries.

After polishing, each specimen was rinsed under distilled water and placed in an ultrasonic bath for 10 minutes.

All specimens were finished and polished by a single operator to eliminate any inadvertent bias and ensure a constant pressure when polishing. All the specimens were polished in the same orientation, and they were analyzed for surface roughness along the same orientation.

Parameter of Measurement of Surface Roughness: Roughness Average (Ra)

It is also called as AA (arithmetic average) and CLA (center line average). It is defined as the arithmetic mean of the departure of profile from the mean line. It is the most commonly used parameter because it is a very stable, repeatable parameter.

The various parameters of the instrument were set as follows:

- *Radius of stylus:* 2 µ (diamond)
- *Applied force:* 0.75 mN
- *Evaluation length:* 4.0 mm
- *Speed:* 0.3 mm/second
- *Cut-off value:* 0.8 mm
- *Measurement range:* ±400.0

The surface roughness of the all acrylic samples was measured with the help of profilometer (SURFCOM 130A). While measurement, the samples were stabilized over modeling clay to prevent any inadvertent movement. Surface roughness measured in µm was determined by the instrument's diamond stylus as it moved across the specimen surface under contact pressure.

Statistical Analysis

The data obtained for all the samples were subjected to statistical analysis using IBM SPSS software, version 20. Continuous variables were expressed as mean and standard deviation. Three groups were compared using one-way ANOVA test; subgroup analysis was done using Tukey HSD test. *p* value of less than 0.05 was considered statistically significant.

Results

The study was conducted on a total of 90 samples, i.e., 30 samples from each group. All the three groups showed different surface topography. The mean surface roughness of unreinforced PMMA, glass reinforced PMMA, and nylon reinforced PMMA were 0.10203, 0.16817, 0.09177 µm, respectively (Table 1).

Glass-reinforced PMMA showed higher mean surface roughness (0.16817 µm) as compared to unreinforced PMMA (0.10203 µm). Nylon-reinforced PMMA showed lower mean surface roughness (Ra) of (0.09177 µm) as compared to unreinforced PMMM (0.10203 µm). Glass-reinforced PMMA showed higher mean surface roughness (Ra) of (0.16817 µm) as compared to nylon PMMA (0.09177 µm) (Table 2).

Table 1: Surface roughness of the specimen of the groups

Group	*Mean*	*SD*
Group A	0.10203	0.047540
Group B	0.16817	0.070178
Group C	0.09177	0.028704
p-value	0.001	

Table 2: Comparison of surface roughness of the specimen between the groups

	Group A vs Group B	*Group A vs Group C*	*Group B vs Group C*
Mean difference	−0.066133	0.010267	0.76400
p-value	0.010	0.02	0.001

The inference of the study results indicates that the glass fiber increases the surface roughness whereas nylon fibers slightly decrease the surface roughness of PMMA resin.

Discussion

The present study was carried out to evaluate the effect of glass and nylon fibers reinforcement on surface topography of polymethyl methacrylate denture resin after polishing. Various materials have been in use for reinforcement, such as sapphire whiskers, ultrahigh molecular weight polyethylene (UHMWPF) fiber, carbon fiber, aramid fiber, nylon fiber, metal wire, to strengthen the acrylic resin denture-base materials. These materials have shown to have varying effects on the mechanical properties of resin.[9] The fibers are reinforced in resins in three ways: chopped, longitudinal, and woven form, each form having their own advantages and disadvantages.[10]

The choice of dental restoration procedure mainly lies upon its longevity and comfort to the patients. Apart from this, two important parameters are essential for ensuring the durability of restorative material, which include surface roughness and color stability.[11] Surface roughness may be the major cause of discomfort for the patient and it may be associated with complications by promoting the deposition of biofilm and microbial growth.[11] The reinforcement with glass fibers has been associated with certain advantages due to their flexural properties and fatigue resistance. Also, their use is associated with good esthetic quality.[6] Recently, nylon fibers reinforcement have been in use, with certain advantages due to their properties such as shock absorbing resistance and resilience to repeated stress. However, its use is associated with certain disadvantages as nylon absorbs water significantly affecting the mechanical properties of nylon.[7]

The quantity of both glass and nylon fibers used in this study is 2% by weight of the polymer-monomer mixture used for each specimen. Unlike glass fibers, preimpregnated nylon fibers are not available commercially. Therefore, in the our study, nylon fibers were wetted in methyl methacrylate monomer for 10 minutes to ensure proper bonding with acrylic resin and randomly oriented in the acrylic resin specimen. The present study evaluated the effect of fiber reinforcement on the roughness of surface of PMMA resin using profilometry analysis. The surface topography of acrylic specimen was measured in the form of roughness by contact-based profilometer. The main advantages of this method are that it is more accurate, easy to conduct, and mean surface roughness (Ra) of the surface can be directly measured.

In this study, surface roughness was measured after polishing. Zissis et al. in their study used unpolished tested surface of denture-based resin and documented the surface roughness to be 3.4–7.6 µm higher than the values found in the current study. This probably indicates that any kind of polishing technique, either mechanical or chemical, is important to reduce roughness.[12] The time consumed for polishing was evaluated by Berger et al. showed that conventional polishing with a lathe is superior to other techniques. In the current study, all finishing and polishing were done using a laboratory micromotor. The objective of the procedure is to produce an adequately smooth and glossy surface and thereby prevent bacterial plaque accumulation.[13]

The surface roughness (Ra) was determined to be 0.10203, 0.16817, and 0.09177 in group A (no fiber), group B (glass reinforced PMMA), and group C (nylon reinforced PMMA), respectively, with a statistically significant difference between three groups. However, we observed no statistically significant difference between unreinforced and nylon fiber group on subgroup analysis. Our results revealed that surface roughness of all groups was well under 0.2 µm. Although the reinforcement with glass fibers (0.16817) increased surface roughness, it is not significant clinically. Zortuk et al. reported that the reinforcement of FDP resin with glass fibers increases the roughness of the surface.[10] Kannaiyan et al. also reported higher utility of glass and nylon fibers as a reinforcement of conventional denture-base resin as compared to unreinforced high impact of denture base resin.[14]

Glass fibers, which make a positive contribution to the physical characteristic of PMMA resin, have a negative effect on surface roughness and plaque accumulation.[10] The nylon fiber-reinforced resin group showed slightly lower mean surface roughness as compared to unreinforced resin; this difference was not statistically significant. Although there were several studies promoting its use where flexibility is desired (as in cases with severe undercuts) or for patient who are allergic to PMMA resin,[15,16] no studies have been conducted to determine the impact resistance behavior and surface topography of nylon fibers. Therefore, no comparison was possible. Nylon fibers may be preferred over glass fibers as they increase the fracture resistance without increasing surface roughness also they do not have any negative effect on the esthetics.[11]

Some of the limitations of this study include lack of literature available regarding an acceptable Ra value for acrylic resin denture base and effectiveness of polishing depends on the polishing operator. Further study, investigation, and clinical trial should be carried out to conclusively prove the real utility of incorporation of nylon and glass fibers in the acrylic resin denture construction.

Conclusion

Reinforcement with glass and nylon fibers affects the surface roughness of the PMMA resin, i.e., glass fibers increase the surface roughness of PMMA resin whereas nylon fibers slightly decrease the surface roughness of PMMA resin. Hence, the use of nylon fiber may be justified to obtain a denture with increased fracture resistance, acceptable esthetic properties, and better denture hygiene and plaque accumulation.

References

1. Tripathi P, Phukela SS, Yadav B, et al. An in vitro study to evaluate and compare the surface roughness in heat-cured denture-based resin and injection-molded resin system as affected by two commercially available denture cleansers. J Indian Prosthodont Soc 2018;18(4):291. DOI: 10.4103/jips.jips_335_17.
2. Craig RG. Powers JM. Restorative dental materials. St. Louis: Mosby; 2002.
3. Athar Z, Juszczyk AS, Radford DR, et al. Effect of curing cycles on the mechanical properties of heat cured acrylic resins. Eur J Prosthodont Restor Dent 2009;17(2):58–60. PMID: 19645305.
4. Ali IL, Yunus N, Abu-Hassan MI. Hardness, flexural strength, and flexural modulus comparisons of three differently cured denture base systems. J Prosthodont 2008;17(7):545–549. DOI: 10.1111/j.1532-849X.2008.00357.x.
5. Choksi RH, Mody PV. Flexural properties and impact strength of denture base resins reinforced with micronized glass flakes. J Indian Prosthodont Soc 2016;16(3):264. DOI: 10.4103/0972-4052.176532.
6. Hassan M, Asghar M, Din SU, et al. Thermoset polymethacrylate-based materials for dental applications. In: Materials for biomedical engineering. Elsevier; 2019. p. 273–308.
7. John J, Gangadhar SA, Shah I. Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. J Prosthet Dent 2001;86(4):424–427. DOI: 10.1067/mpr.2001.118564.
8. Kohli S, Bhatia S. Flexural properties of polyamide versus injection-molded polymethylmethacrylate denture base materials. Eur J Dent 2013;1:56–60. DOI: 10.4103/2347-4610.119792.
9. Kanie T, Arikawa H, Fujii K, et al. Impact strength of acrylic denture base resin reinforced with woven glass fiber. Dent Mater J 2003;22(1):30–38. DOI: 10.4012/dmj.22.30.
10. Zortuk M, Kılıc K, Uzun G, et al. The effect of different fiber concentrations on the surface roughness of provisional crown and fixed partial denture resin. Eur J Dent 2008;2(03):185–190. PMID: 19212545.
11. Sarand SH. Comparative evaluation of effect of tooth brushing on the surface roughness and colour stability of poly (methyl methacrylate) heat cure denture base resin with the application of denture surface sealant: an in vitro study [Doctoral dissertation]. Chennai: Ragas Dental College and Hospital.
12. Zissis AJ, Polyzois GL, Yannikakis SA, et al. Roughness of denture materials: a comparative study. Int J Prosthodont 2000;13(2):136. PMID: 11203622.
13. Berger JC, Driscoll CF, Romberg E, et al. Surface roughness of denture base acrylic resins after processing and after polishing. J Prosthodont Implant Esthet Reconstruct Dent 2006;15(3):180–186. DOI:10.1111/j.1532-849X.2006.00098.x.
14. Kannaiyan K, Sharashchandra MB, Kattimani S, et al. Comparison of flexural strength of Kevlar, glass, and nylon fibers reinforced denture base resins with heat polymerized denture base resins. J Pharm Bioallied Sci 2020;12(Suppl 1):S399. DOI: 10.4103/jpbs.JPBS_117_20.
15. Saeed F, Muhammad N, Khan AS, et al. Prosthodontics dental materials: from conventional to unconventional. Mater Sci Eng 2020;106:110167. DOI: 10.1016/j.msec.2019.110167.
16. Rickman LJ, Padipatvuthikul P, Satterthwaite JD. Contemporary denture base resins: Part 2. Dent Update 2012;39(3):176–187. DOI: 10.12968/denu.2012.39.3.176.