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Flexural strength of heat polymerized acrylic resin repaired with different reinforcing materials

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***Abstract*---**Purpose: Heat cure methyl methacrylate has been the denture base material of choice for the fabrication of conventional complete dentures and transitional removable partial dentures. One of the factors that cause fracture is considered to be low resistance to impact, flexural or fatigue. However, dentures repaired with auto-polymerizing acrylic resin alone often experience a re-fracture at the repaired site. This study aimed to evaluate flexural strength of heat

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polymerized acrylic resin repaired with different reinforcing materials. Methods: 48 samples were prepared and divided into four groups. 12 samples were considered as controls, and 36 were divided into 3 experimental groups. The samples were sectioned into two halves from the middle, and were then repaired with rapid repair material, and reinforcing material. Each group was divided into 4 subgroups: unreinforced, reinforced with metal wire, metal mesh, and glass fiber. All specimens were subjected to a 3-point bending test, and the flexural strength was calculated. Results: all the reinforcement groups namely Stainless steel wire, metal mesh and glass fiber improves flexural strength of heat cured acrylic resin samples and glass fiber reinforced samples had the greatest flexural strength when compared with all other groups. Conclusion: Repairing denture base with heat cure acrylic resin, reinforced with glass fibers increases the flexural strength of denture base.

***Keywords*---**Denture repair; Acrylic resins; Reinforcement; PMMA.

Introduction

The loss of teeth by an accident or disease has plagued mankind throughout the ages. Removable complete and partial dentures aid in restoring function and appearance[1]. Heat cure methyl methacrylate has been the denture base material of choice for the fabrication of conventional complete dentures and transitional removable partial dentures[2]. Poly-methyl methacrylate (PMMA) resin was introduced by Dr. Walter Wright in 1937 and since then it is in continuous use because of its multiple advantges[3]. Biocompatibility, ease of handling, dimensional stability in oral conditions, low density, ability to stain and low cost of production made it popular in the field of prosthodontics[4]. PMMA has some unfavorable mechanical properties such as poor thermal conductivity, low flexural, fatigue strengths and low impact strength[5]. The fracture of acrylic resin dentures is an unresolved problem in prosthodontics because of its lower toughness and strength[6]. One of the factors that causes fracture is considered to be low resistance to impact, flexural or fatigue[7]. Denture breakage is usually related to faulty design, faulty fabrication or poor materials choice. Denture failure outside the mouth occurs from impact due to accidents and as a result of expelling the denture from the mouth while coughing or dropping the denture. Inside mouth, excessive biting force may also cause fracture. Furthermore, fracture of repaired dentures often occurs at the junction of an old and new material rather than through the centre of the repair[8]. Most fractures of the denture occur primarily because of resin fatigue[9]. Fabrication of a new denture is time-consuming and costly for patients, denture repair is considered an alternative. Repaired dentures should have adequate strength, dimensional stability and color match; moreover the repair should be easy and quick to perform and must be affordable[10]. Although various materials have been proposed for repairing fractured denture bases, the use of auto-polymerizing resin is the most popular[11]. However, dentures repaired with auto-polymerizing acrylic resin alone often experience a re-fracture at the repaired site. One of the reason for this unfavorable phenomenon is the insufficient transverse strength of auto-polymerizing acrylic resin, which is lower than that of heat-polymerizing acrylic resin[12]. Poly-methyl methacrylate is often reinforced with different types of metal wire[13]. It is well known that acrylic resin exhibits a low potential for adhesion to non-acrylic materials. Different methods exist for improving the adhesion between metal and acrylic resin, namely sandblasting of the surface of the wire. Silanization of the surface of the metal with different techniques or the use of a metal bonding resin[14]. Another approach is the reinforcement of acrylic resin dentures with fibers. Different fiber types have been added to acrylic resin dentures to improve their physical and mechanical properties[15]. Glass fibers are advantageous because of their specific strength and high specific modulus, which receive stress without deformation. They also provide better esthetics, as they do not alter color[1]. Flexural strength of the denture base, repaired with different reinforcing materials has not been extensively studied. Therefore, the current study is aimed at evaluating and comparing the flexural strengths of denture base repaired with glass fibers, stainless steel wire and metal mesh.

2. Materials and method

Metal die will be fabricated by computerized milling which will be used as a standard mold, with the dimensions of 65x10x3 mm3 according to ADA specification no.12 with central groove of 30x3x2 mm3. Die and base of flask will be coated with a thin layer of petroleum jelly. The base will be poured with dental plaster and the die will be sealed in the lower half of the flask until the plaster will be in level with the whole depth of die. Once it sets, separating medium will be applied over metal die and dental plaster. Thereafter, second pour will be done. After the final set of dental plaster, the flask will be deflasked and the die will be removed. A heat cure acrylic resin will be taken in polymer-monomer ratio of 3:1 by volume and will be mixed as per manufacturer's instructions. When mixture will attain a dough form, it will be placed in the flask. The flask will be closed, pressed and bench cured and long curing cycle will be done. After curing, the flask will be bench cooled slowly to room temperature and samples will be retrieved. Finishing will be performed using sandpaper.

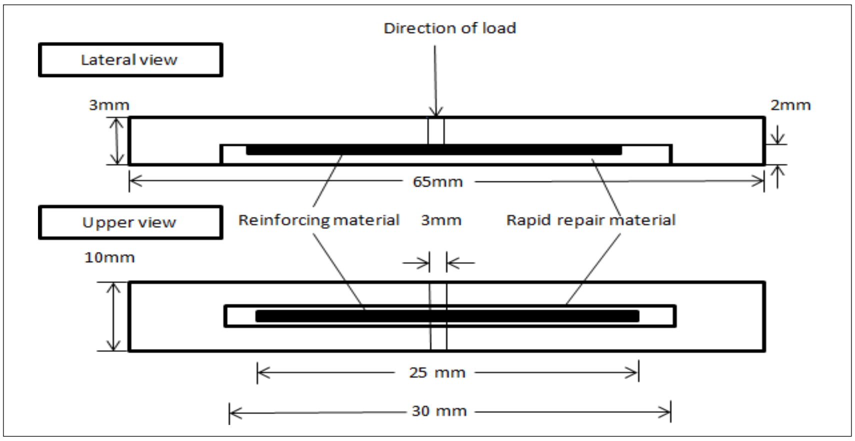

Fig. 1. Schematic presentation of 3-point bending test

All 48 specimens will be divided into three experimental groups; each will comprise of 12 specimens. The sizes of specimens will be accurately measured with a vernier caliper. Then specimens will be cut horizontally by a high speed diamond disk cutter until 3 mm space will be created between the two pieces. Stainless steel wire of gauge 19 will be cut to 25mm length and sandblast with aluminum oxide. Metal mesh will be cut to 25mm length. Glass fibers will be cut to 25mm length and soaked in monomer for better bonding with the acrylic resin; after the fibers will be removed from the monomer, excess liquid will be allowed to dry. The strip halves will be fixed to a stone mold and reinforced materials will be placed. These specimens will be repaired using a free flowing mixture of raid repair material as per manufacturer's instructions. Final finishing will be performed using sandpaper. Finally, the repaired specimens will be stored in distilled water at 37°c for 48 hours prior to testing. The specimens will be examined using a three-point bending test with a universal testing machine at a constant cross head speed of 5mm/min until fracture of sample. The distance between the two bases of the machine for the three-point deflection test will be 50mm.

3. Statistical analysis

All data were statistically analyzed with one-way and two-way ANOVA, and the differences among the groups were assessed using the Tukey's test and Dunnett's post-hoc test. P-val-ues less than 0.05 were considered statistically significant.

4. Result

The flexural strength with mean value and standard deviation given in the (Table 1)

Groups	Minimum	Maximum	Mean	Standard Deviation
Control Group	10.43	13.87	11.86	0.95
Wire Group	39.26	42.04	40.54	1.01
Mesh Group	17.43	20.12	18.67	0.91
Fibre Group	49.04	52.87	51.4	1.09

Table 1. Mean Flexural Strength in Control Group, Wire Group, Mesh Group and Glass Fiber

One-way ANOVA analysis showed the F value of 4121.28 and P value of <0.001. Since P < 0.05 there is a significant difference in the flexural strength among different groups. Hence a Post Hoc analysis was done to analyze the flexural strength among different groups. ANOVA between four groups showed high statistically significant difference in the flexural strength of heat polymerized acrylic resin which shows null hypothesis was rejected by each group that is control, wire, mesh and glass fibre. (F= 4121.28; p<0.001). Tukey's post hoc test for within group comparison showed highly significant difference Flexural strength of heat polymerized acrylic resin when Control group was compared with Wire, Mesh and Glass Fibre group.(p<0.001). Further when Wire group was compared with Mesh and Glass Fibre groups again showed high statistically significant difference in the Flexural strength of heat polymerized acrylic resin.($p<0.001$) The similar findings were also found when flexural strength in Mesh group was compared with Glass fibre group. ($p<0.001$). The results obtained in this study revealed that all the reinforcement groups namely Stainless steel wire, metal mesh and glass fiber improves flexural strength of heat cured acrylic resin samples and glass fiber reinforced samples had the greatest flexural strength when compared with all other groups.

Discussion

The ultimate goal of denture repair is to restore the denture's strength to avoid recurrent fractures. In the present study, three different reinforcing materials; Stainless steel wire, Metal mesh, and glass fibers used to enhance the mechanical properties of acrylic resin. In this study, all reinforcing materials increase the flexural strength of acrylic resin. Glass fiber showed higher flexural strength than other materials. In literature, various methods have been reported to improve the mechanical properties of the heat-activated PMMA. Many research groups have introduced methods to strengthen the resin by embedding solid metal forms into the resin, incorporating of rubber phase into the polymer, and fiber reinforcement in the polymer matrix[16&17]. But, embedding the solid metal forms resulted in poor aesthetics[18&16]. A study conducted by Boone ME[19], regarding the use of metal wire for the first time to repair the denture with the help of modeling clay as stabilizing material. A study conducted by Reddy A et al[2], to compare the flexural resistance of conventional heat-cured denture base resins was done with and without using steel strengthners. In the study given by Carroll et al[20], the flexural strength of the denture base polymer reinforced with metal or glass rod was higher than that of the unreinforced denture base polymer. The diameter and shape of the rod directly influenced the flexural strength, but the shape or diameter also limited its use. Polyzois GL et al[14] showed the use of metal wires. The incorporation of metal wires allows greater deflection of heat cure acrylic resin strips before the fracture of the repair and combined with the increased fracture loads gives greater values of toughness, which means that more energy is necessary for breaking the denture. Metal wire improves the mechanical properties of acrylic resin. It strengthens the repaired bases and also increases the flexural strength of resin. Repair of fractured dentures with auto polymerizing acrylic resin using wire presents a challenge for clinicians to maintain the longevity of repaired dentures. Vallittu PK[13] Conducted a study in which cast metal plates have been used to replace some parts of the denture. Although metal plates increase the flexural and impact strength, they may be expensive, and prone to corrosion; moreover, metal-reinforced dentures may be unesthetic as well. Vallittu and Lassila[21], again renewed interest in the subject and found that result in the reduced effect of the reinforcement could be associated with ineffective coupling between the acrylic matrix and fiber, poor wetting of the fibers, the inclusion of voids, dry friable dough, non-uniform fiber distribution, or fiber breakage. The heat-activated resin reinforced with different types of fibers such as polyethylene, glass, carbon, and aramid has been successfully investigated by researchers[7,8&22]. It was found that the flexural strength of the denture base had increased by the glass fibers like aramid and polyethylene fibers. Compared to other fibers, carbon fibers showed the highest flexural strength. A study given by Ying-hui L & Gui-lan S[6], used the wire as reinforcement showed that embedding two to four wires can improve the flexural strength of dentures. Pre-treatment of wire was the limitation of the study. A study conducted by Fonseca RB et al[23], showed that the untreated steel wires may reinforce resin but its micromechanical interaction does not seem to be effective. On the other hand, they concluded that non-impregnated fibers irrespective of their length tend to improve the flexural strength of acrylic resin. Also, they said that fiber impregnation allows a better interaction between fibers and resin which results in higher flexural strength. In the last 30 years, polyethylene, carbon-graphite, and glass fibers were successfully used to reinforce with polymers to improve the mechanical properties[15]. Glass fibers are proved to be a good alternative to improve the mechanical properties of the denture base resin. Initially, glass fibers in long, parallel forms were tried. Then, woven and gritted fibers were investigated[8&15]. Before that, glass fiber in chopped form was tried to improve the transverse strength and impact strength of the denture base[24&25]. So, in this study, glass fibers have also been added for investigation. In general, the fibers are wetted in the monomer to improve the bonding properties. Even though the addition of a monomer could increase the adhesion of fibers to the polymer matrix, it will affect other properties because of the residual monomer. So then impregnation of fibers was made to bring contact with the surface of each fiber of the denture base. Glass fibers on their own are hydrophobic. They contain no polar groups, so their compatibility with PMMA resin is very poor. Untreated glass fibers act as inclusion bodies in the acrylic resin mixture; and instead of strengthening, actually they weaken the resin. John J et al[9] studied flexural strength of heat-polymerized PMMA denture resin reinforced with glass, aramid, or nylon fibers. They found that glass reinforcement increases the flexural strength of heat polymerized PMMA denture base materials. Anne G et a[l4] conducted a comparative study of flexural strength by using metal mesh and glass fiber. The metal mesh provides resistance to flexure as it is arranged at right angles to load application. Furthermore, as the mesh does not show water absorption, it is dimensionally stable. However, clinically it is difficult to reline or repair the denture. Acceptance by the patient is low due to the unesthetic metal display. The addition of glass fibers offers an aesthetic advantage as the fibers are invisible. It also provides a metal-free solution with no additional bulk of the prosthesis. It enhances the flexural strength of conventional acrylic due to increased filler content in the matrix that allows wider force dissipation. The use of stainless steel wire, metal mesh, and glass fiber as reinforcement material with rapid repair material present a viable solution for the successfully repaired denture.

Conclusion

In this study, the flexural strength of the PMMA resin in different forms was considered. Experimental tests were conducted on unreinforced heat polymerized PMMA resin, wire reinforced PMMA, mesh reinforced PMMA, and glass fibers reinforced PMMA. Within the limitations of the study, the following conclusions could be made:

All the reinforcement groups namely wire, mesh, and glass fiber improves the flexural strength of the heat-cured acrylic resin.

The flexural strength of heat activated PMMA resin reinforced with wire, mesh and fibers were statistically significant when compared to the control group.

The glass fiber reinforced samples had the greatest flexural strength than all other groups.

Conflict of interest: Nil

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