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Evaluation of Fracture Resistance for Autopolymerizing Acrylic Resin Materials Reinforced with Glass Fiber Mesh, Metal Mesh and Metal Wire Materials: An *in Vitro* Study

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Abstract

Statement of problem: Many processes have been applied to improve the fracture resistance of acrylic resin dentures by reinforcing them. The maximum goal of any denture repair is to restore the main strength of the denture and to avoid further fracture. **Purpose:** This study investigated the ability of self-curing acrylic resin to be strength and deflection of repaired acrylic resin joints reinforced with various reinforcement materials to resist fracture. **Material and methods:** Transverse strength of polymethyl methacrylate acrylic resin reinforced with glass fiber mesh, metal mesh, and metal wire was evaluated with a 3-point load test on 40 intact specimens (n = 10 for control group) (n = 10 per each reinforcement material group). Fractured joint margins were rounded, a 4-mm gap was placed between them, and then they were repaired with autopolymerizing acrylic resin and retested. **Results:** Transverse strength for the polymethyl methacrylate acrylic resin samples has showed fracture at the side of sample rather than in the middle area of reinforcement materials and some other samples showed bending statue rather than fracture. **Conclusion:** Reinforcement with glass fiber mesh, metal mesh, and metal wire produced transverse strength in the side area of resin denture base material rather than in the middle of reinforcement area with bending samples rather than fracture response.

Keywords

Denture Base Material, Flexural Strength, Glass Fibers, Reinforcement, Metal Mesh

1. Introduction

Since the introduction of polymethyl methacrylate (PMMA) in dentistry in 1937, it has become the material of choice as a denture base material. PMMA has some clinically desirable properties such as good strength, durability, dimensional stability, chemical stability, biocompatibility, cost effectiveness, and an acceptable taste [1] [2] [3].

Today, most denture bases are made of acrylic polymers and have gained wide patient acceptance. However, dentures are known to undergo failures such as polymerization shrinkage, weak flexural, lower impact strength, low fatigue resistance, midline fractures of complete dentures, de-bonding of teeth, and other types of failures in complete or partial dentures [4] [5].

Although clinician's skills and experience play a major role in designing and fabricating an optimum prosthodontic restoration, the selection of denture resins is equally important, especially when the patient has to use the prostheses for long period of time [6] [7].

In a survey on the causes of repairs involving complete and partial dentures, it was reported that 29% of all repairs to dentures were associated with midline fractures of complete dentures. Therefore, there is a clear need to understand why such fractures occur, and to find ways to reinforce the dentures to prevent such failures [8] [9] [10].

The properties of denture base materials are typically evaluated under ANSI/ADA Specification; (ISO 1567) for Denture Base Resins [11]. The specification lists the requirements and testing methodology for evaluation of materials including acrylics, carbonate, and other plastics used as denture base materials.

Dentures are exposed to different forces intra- and extra-orally. Intraoral stresses are generated by chewing hard food repeatedly overtime or by chewing on poorly adapted dentures; the fracture line usually occurs around a fulcrum, which is considered the weak point, and it is anticipated that the denture will fracture at that spot. For the mandibular denture, the fracture line usually occurs in the midline due to lateral flexure of the denture upto 1.3 mm. Extra oral stress can occur from accidental dropping of the denture on a hard surface. The result in high impact shock loading can also be atypical source of fracture in a denture [9] [12].

The incidence of frequent fractures necessitated a search for methods to improve fracture resistance properties in denture base materials. High impact strength acrylic was introduced to increase the fracture resistance of the denture base against the sudden drop of the denture or unexpected high forces [10]. This acrylic was also believed to solve the problem of acrylic dimensional shrinkage and ensure better denture-tissue adaptation [13].

Currently, in clinical practice, metal frameworks are primarily used as reinforcements to improve the fracture resistance, volume stability, and precision of complete dentures. Im *et al.* reported that metal frameworks reduced the functional deformation and problems of the supporting tissue [14]. However, metal frameworks are heavier and require more complicated fabrication processes compared to resin bases. Further, because they are made from alloys, the possibility of hypersensitivity cannot be excluded. Glass fiber has been used as a reinforcement material in many fields. Because the material can bend without breaking, studies have focused on the use of glass fiber as a replacement for metal framework in dentures to improve the reparability of failed dentures [15]. A complete denture with a glass fiber framework has a shorter fabrication time, lighter weight, and better aesthetic features than one using a metal framework, benefiting dental technicians, dentists, and patients [15] [16].

The aim of this study was to evaluate the fracture resistance for PMMA as denture base material that reinforced with metal mesh, glass mesh and metal wire materials that were embedded in self-cure acrylic resin to compare between them *in vitro*.

2. Materials and Methods

2.1. Materials

For this study, heat cure acrylic resin (MELIODENT Heraeus) Kuzler, autopolymerizing acrylic resin (DPI RR Cold Cure Acrylic) (Resin dental stone), (Type III) (ELITE dental stone Zhermach), glass fibers (12 mm E-Glass Fiber Chopped Strand), metal mesh (BesQual Grid Strengtheners (Reinforcement Mesh) - Stainless Steel, 10/Box) and metal wire (semi-round wire diametered in 1.50 × 0.75 mm) **Table 1**.

Conventional cold cure denture base resin samples without reinforcement materials were used as control group.

2.2. Methodology

1) Specimen preparation:

40 specimens of dimensions 64 mm long, 10.0 mm width and 2.50 mm thick (64 × 10 × 2.5 mm) for fracture resistance strength (As per ADA specification No. 12) [17]. (4) mm space were used for reinforcement materials in the middle of each specimen were used. The widths and thicknesses of the specimens were measured by a digital vernier caliper (Mitutoyo, Kawasaki, Japan). These work samples were divided into 4 groups' acrylic resin denture material; (10) without reinforcement material as control group (10) for each reinforcement material.

Table 1. Materials used in this study.

Material	Product name	Manufacturer
Heat-polymerizing acrylic resin	MELIODENT	Germany, Heraeus
Autopolymerizing acrylic resin	DPI RR Cold Cure Acrylic	India
Dental stone Type III	ELITE	Zhermach
Glass fiber	YuNiu Fiberglass	BMC
Metal mesh	BesQual Grid	NJ 589
Metal wire	Quality Orthodontic silver wire	KC Smith, German

For the purpose of standardization of the fracture line the following measurements were done in the silicone base specimens (Figure 1, Figure 2).

All of these specimens were coated with a thin layer of petroleum jelly and three pair of plates was invested in dental stone (Type III) in the lower half of flask making sure that one half of the thickness was embedded in the stone put in base of the flask. Care was taken so that the plates were placed keeping sufficient distance between them and also from the walls of the flask.

The flask was then opened and the preformed silicon plates were separated from the stone. The molds were immersed in hot water to remove any traces of petroleum jelly and molds that obtained were used for the preparation of the denture base material test samples.

Acrylic denture base specimen preparation:

Powder and liquid for self-cure denture base material; PMMA was prepared and mixed according manufacture mixing recommendations, the dough was then packed into the mold, trial closure was performed and excess material was removed and final closure was done under a bench press at 40,000 N. After the final closure, the flask was left in the clamp for bench curing for 30 minutes at room temperature then immersed in boiling water bath of (100˚C) temp. After the curing was completed, the flask was removed and left for bench cooling.

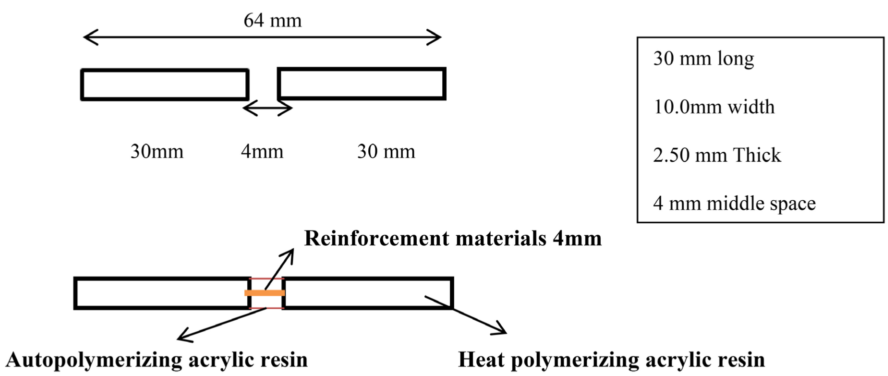

Figure 1. Dimensions of repaired test specimens and embedding position of reinforcement materials.

Figure 2. Silicone base specimens with petroleum jelly in the flask.

Once the flask was cooled, the samples were retrieved from the flask and necessary finishing was done. Minimum finishing was required just for remove excess acrylic and care was taken to maintain low heat during the procedure that not to damage or spoil the specimen.

2) Reinforcement procedure:

The specimens were stored in water at 37˚C for 14 days before the measurement procedure to simulate oral environment [18]. Control group I consisted of 10 rectangular plates of cold cure polymerized denture base resin which filled the 4 mm space area without any reinforcement. Specimens in group II, 10 for denture base material reinforced with glass mesh, while the specimens in groups III contained a metal mesh which was soaked in a saline for 5 minutes and allowed to air dry before using, group IV specimens were reinforced with metal wire **Table 2**. The different 3 groups were refilled each with its specific reinforcement material to full gap of about 4 mm to have total finished samples carefully restored.

Specimens were measured by a digital vernier caliper (Mitutoyo, Kawasaki, Japan).

3) Evaluation of Fracture resistance of the samples:

Fracture resistance for each of the four groups was evaluated using the Universal testing machine. To measure the compressive properties, different specimens were placed on a Universal testing machine and load was applied to the fracture place of the samples with a rod having a square shaped end. The maximum force that resisted fracture was recorded as fracture resistance in Newtons. For fracture strength measurement, samples were placed under inside a Instron 3344 machine (Instron Corp., 100 Royall St., Canton, Ma., 02021, USA) using a cross-head speed of cm/mm un'l failure occurred. (Başlık hızı yazılacak) The end of the test was determined either by fracture or when load dropped 30% from the maximum load. The fracture resistance of all the four groups was measured.

3. Pilot Study

Test samples with three different enforcement materials showed either bending with no fracture of acrylic or some other test specimens showed a side fracture rather than middle one According to these results we changed the dimensions of the sample specimens to (70 × 16 × 7); The widths and thicknesses of the specimens were measured by a digital vernier caliper (Mitutoyo, Kawasaki, Japan).

Table 2. Specimen groups.

Group no.	Reinforcement materials used
Control I	None
II	Autopolymerizing resin with glass fiber
III	Autopolymerizing resin with metal mesh
IV	Autopolymerizing resin with metal wire

These samples have showed fracture at the side of sample rather than in the middle area and some other samples showed bending statue rather than fracture when submitted to Fracture resistance test (**Figure 3**, **Figure 4**).

4. Results

The mean value of the transverse strength for the control group was 86.4 MPa. The lowest value (60.2 MPa) was recorded for group I (autopolymerizing acrylic only); the highest value (92.6 MPa) was recorded for group IV (metal wire). For the glass fiber–reinforced group II that exhibited significantly higher transverse strength than the control group I ($P \leq 0.05$). No significant difference was seen between group III (metal mesh) and group IV (metal wire) for the mean value of fracture strength in comparison to group I.

Typical fracture sites for the respective groups are presented in **Figure 4**. All specimens in group I fractured at the interface between the heat-polymerized and autopolymerized acrylic resins. On the other hand, all specimens in group II and group IV fractured at the side of the autopolymerized acrylic resin. **Figure 4**, while in group III the specimens showed bending in the middle site rather than fracture **Figure 3**.

5. Discussion

The current study evaluated the effect of the transverse strength of different reinforcement material embedded in autopolymerizing acrylic resin. Group A was the lowest among all groups which is generally proportionate with the results reported in former studies that used autopolymerizing acrylic resin for repairing specimens of heat-polymerizing resin [6] [19] [20]. In a reported reinforcement study with an autopolymerizing adhesive resin and 4 mm-long reinforcement material, the transverse strength was nearly 134% higher than that of intact heat-polymerizing acrylic resin specimens. In this study, all groups that were repaired with the use of reinforcement materials fractured at the side of the

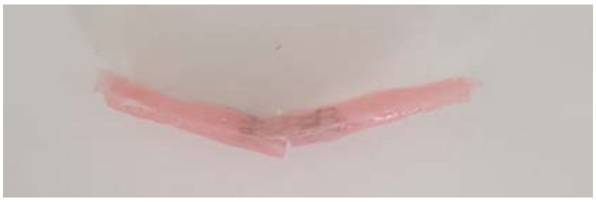

Figure 3. Bending of the sample.

Figure 4. Fracture at the side of reinforcement.

reinforcement apparatus. A higher value of transverse strength might have been obtained if a longer reinforcement apparatus had been embedded [7] [21] [22].

Irregular deformations that occur at side of the reinforcement area of denture base material indicated that fracture strength at the connection side between heat cure acrylic resin and reinforcement area within the autopolymerized acrylic resin was higher than middle area of reinforcement side which indicates the stress concentration against compressive loads at the side more than the center area [23].

Most of the previous studies were carried out in terms of improving the strength, rather than the rigidity, and studies aimed at improving rigidity remained insufficient even in experimental model and specimen studies [24] [25]. Furthermore, there were no randomized long-term clinical studies comparing prostheses with and without reinforcement. Therefore, further studies focusing on the rigidity of prostheses with reinforcement and its effect on underlying structures such as the residual ridge or implant as well as longitudinal clinical studies, are necessary to ensure the effect of reinforcement within dental prostheses.

The limitations of this study included using of bar specimens alternative to multifaceted denture shapes as well as the absence of environment that mimic oral conditions and absence of aging procedures as thermal cycling effects. Contamination by oral fluid like saliva may affect the bond between the repair material and denture base. However, this type of contamination is sometimes unavoidable when dentists attempt to repair inside the patient mouth. It is therefore questionable whether the findings of this research can be applied directly to clinical practice.

6. Conclusions

Within the limitation of this study, we can conclude that:

1) The transverse strength value was high when autopolymerizing acrylic resin was combined with the use of reinforcing glass fiber, metal mesh, and metal wire materials.

2) There was no difference in the transverse strength value when autopolymerizing acrylic resin was combined with the use of reinforcing metal mesh and metal wire.

3) Fracture tests showed fracture line at the side of reinforcement material rather than at the center of specimen.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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