(International Print/Online Journal)

SJIF IMPACT FACTOR: 5.565
PUBMED-National Library of Medicine ID-101739732

ISSN (Print): 2209-2870
ISSN (Online): 2209-2862

International Journal of Medical Science and Current Research (IJMSCR)
Available online at: www.ijmscr.com
Volume 6, Issue 4 , Page No: 326-340
July-August 2023

IJMSCR

# Comparative Evaluation of Physical Properties of Provisional Restorative Materials Reinforced with Glass and Aramid Fibres- An In-Vitro Study

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Type of Publication: Original Research Paper
Conflicts of Interest: Nil

**Abstract**

**Keywords**: NIL

## Introduction

Fixed Prosthodontic treatment is well established for maintaining proper harmony of the occlusion and the function of the stomatognathic system in partially edentulous patients ranging from a single tooth restoration to the rehabilitation of entire arches. Being an essential part of fixed prosthodontic treatment, provisional restorations provide patients with the ability to keep using their teeth until and unless the definitive restorations are made indirectly in dental laboratory.

Therefore, a provisional restoration, commonly referred to as a temporary or interim restoration, is described as a fixed restoration designed to enhance aesthetics, to satisfy biologic requirements of pulp protection, to maintain the periodontal health as well as mechanical prerequisites such as resistance to functional loads, removal forces and maintenance of abutment alignment for a limited period [1,2].

As the word provisional means 'established for time being', usually for a short span, less attention is designated to their fabrication. The patients tolerate the mild discrepancies unless the 'provisional' becomes 'longstanding' (more than 2 weeks). Provisional restorative materials must be durable enough to withstand the masticatory forces in the long-term cases like full mouth rehabilitation, long-span FPD cases, in patients having parafunctional habits and in complex interdisciplinary cases [3].

Materials commonly used to fabricate provisional restorations are Polymethyl Methacrylate (PMMA), Polyethyl Methacrylate (PEMA), Bis-Acryl Composite (BAC) resin, and Epimine resins. [3] Polymethyl methacrylate has been in use for the longest period of time as a provisional restorative resin [4]. Though polymethyl methacrylate has the advantages of easy manipulation, ease of finishing and polishing, good marginal fit and acceptance by intraoral tissues, it lacks certain physical properties, making it prone to fracture during service [5-7].

Bis acryl composite resin has come to the field of dentistry to overcome the shortcoming of polymethyl methacrylate, having low exothermic setting reaction and good abrasion resistance than polymethyl methacrylate [8]. However, bis acryl composite resin is more brittle than polymethyl methacrylate and has the disadvantage of low surface hardness [9]. Because of dissimilar chemistry, flowable composite or dentin adhesives do not readily bond to the Bis-acryl material, making repair or modification difficult [10].

Several methods and materials have been attempted to reinforce provisional restorative resins such as, a stainless-steel wire [11], cast metal on lingual side, a processed acrylic resin [12] and fibers such as polyethylene, glass, nylon, carbon, and aramid fibre [13-16]. Fiber reinforcements have become relatively popular and a comparatively easier method to increase the strength of the provisional restorations. Carbon fibers have been shown to improve the physical properties of the resin to a great extent. However, having a dark colour is the biggest disadvantage of it [13]. Transverse strength was not improved by polyethylene fibers in the absence of surface treatment because of poor adhesion between the fibers and the polymer matrix [16]. Glass fibers and Aramid fibres have been studied individually as a strengthening material after being added to polymethyl methacrylate resin. It was also understood from different studies that the position, quantity, and direction of the fibers and the degree of adhesion between the fibers and the polymer affect the degree of reinforcement [17,18].

For assessing the mechanical properties, fracture mechanics is a reliable indicator for brittle materials used for fabrication of provisional restoration which are exposed to complex masticatory stresses in the oral cavity. Fracture toughness is the ability of a material to resist crack propagation, flexural strength is the ability to resist bending under stress, and hardness is the resistance to indentation; these properties can accurately determine the potential of fracture of the restoration clinically [19,20].

A handful of studies have compared the physical properties of Polymethylmethacrylate resin and Bis acryl composite resin as a provisional restorative resin material reinforced with glass and aramid fibre. In this in-vitro study, fibres of Glass and Aramid were incorporated in Polymethylmethacrylate resin and Bis acryl composite resin in a particular weight percentage. The blocks of non-reinforced and reinforced resin were prepared and tested for physical properties i.e.- fracture toughness, flexural strength and hardness considering the null hypothesis, that there will be no effect of fibre reinforcement in improving the physical properties of polymethyl methacrylate and bis acryl composite resin.

## Materials And Methods

Three mechanical properties were tested in this study. For flexural toughness testing, test specimens were fabricated according to ASTM (American Society for Testing and Materials) D790 [21] standards and for fracture toughness testing specimens were fabricated according to ASTM E-1820 [22] standards. In each test, unreinforced resin samples were used as controls. A total of 180 (n=180) samples were fabricated including fibre reinforcement groups.

### Study Technique:

### Step 1.1 - Specimen Preparation without Fibre Reinforcement

For testing fracture toughness, a mould was fabricated having the dimensions [22] of 30×30×4 mm and shape as shown in Fig 1. Compact test specimens were fabricated in the pattern of a double cantilever beam, with a slot extending from the center of one edge to the specimen's center line to a 60° terminal apex, located slightly beyond the midpoint of the specimen. Two loading holes penetrated the specimen. For testing hardness, the same dimensional specimens were used. For testing flexural strength, a rectangular mould [21] was fabricated, with the dimensions of 25×2×2 mm.

For the fabrication of PMMA samples, polymer, and monomer (DPI, India) were mixed according to the manufacture's guideline of 1.8-2.0 gm/ml in a silicone cup. Separating medium was applied on both the moulds. When the mixture reached the dough stage, it was packed into the moulds and placed in a hydraulic press (SIRIO DENTAL Srl,47014 Meldola FC- Italy), under a pressure of 1 MPa for 15 minutes at room temperature for sufficient polymerisation of the resin. The mould was then opened and the specimens (Fig 2,3) were removed and checked for any voids. The excess in the specimens was then trimmed using a tungsten carbide bur, ground with an



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emery paper and polished with pumice powder in a polishing machine (Apex Industrial Electronics, India). The bis-acryl (Coltene Whaledent, Switzerland) specimens were formed in the same manner, except that the material was supplied in an auto mixing cartridge (Coltene Whaledent, Switzerland). The mix was packed directly into the mold cavity using application tips supplied with the kit.

1. PMMA (cont.

**Step 1.2 – Fibre Reinforced Specimen Preparation**

6mm pre-cut Glass fibres (K.K. Packing, Mumbai, India) with a dimension of 10-12 µm were soaked in a silane coupling agent (Angelus, Brazil) for 5 minutes in a petridish for better bonding with the resin matrix. The fibres were removed and excess silane was completely air dried. 2% by weight fibre was mixed with polymer thoroughly to disperse the fibres. Monomer and Polymer containing fibers (Fig 4) were mixed in the same ratio and packed into the mold after reaching the dough stage. The specimens were checked properly after retrieval of the samples and any exposed fibers at the peripheral border of the specimens were trimmed with the diamond bur at slow speed by Micromotor Lab Handpiece (Guangdong, China.) to prevent delamination of the reinforcement. With the help of a dispensing gun, (Coltene Whaledent, Switzerland) base and catalyst of equal amount was dispensed on a small glass slab, and 2% by weight of silane treated glass fibre was mixed well with the help of a broad ended spatula for 30 seconds and immediately transferred to the mould and placed under the hydraulic press.

Aramid fibres (K.K. Packing, Mumbai, India) used in this study, with a dimension of 12-24µ were chopped in 6 mm length by a sharp scissors. For incorporation in PMMA, it was soaked in monomer for 10 minutes. The fibers were then removed from the monomer and excess liquid was allowed to be dried off. 2% by weight of fibre was mixed well with the polymer and same procedure was followed. For BAC samples, the 2% by weight of chopped fibre was directly mixed and placed into the mould. (Fig 5)

All the Specimens were stored in saline at 37º C in an incubator for 24 hours, before testing. Specimens were also labelled on each end prior to testing so that fractured pieces could be reunited and examined after testing.

The prepared testing specimen were divided into 2 main groups :-

1. Poly Methyl Methacrylate samples (PMMA)
2. Bis Acryl Composite samples (BAC)

Each group was again divided into three subgroups.

1. BAC with 2%wt Glass Fibre (BG)
2. BAC with 2%wt Aramid Fibre (BA)

**Step 2 – Testing of Specimens for Physical Properties**

**Flexural Strength Test:**

Flexural strength of the specimens was evaluated using a 3-point bend test in a Universal Testing Machine (Tinius Olsen, England). Each specimen was positioned on the bending fixture, consisting of 2 parallel, 2-mm–diameter supports, 20 mm apart. The load (Fig 6) was applied with a crosshead speed of 1 mm/min, with a third 2-mm rod placed centrally between the supports. The peak force (F) in Newtons, from the stress strain curve of each specimen, was recorded and was used to calculate the flexural strength in MPa from the following Eq. 1 [23]:

$$\delta\beta = 3FI/2Bh^2 \quad (1)$$

where δβ is the flexural strength in MPa; F is the maximum applied load in newtons; I is the supporting width in millimetres; B is the breadth of the test specimens in millimetres; and h is the height of the test specimen in millimetres.

**Fracture Toughness Test:**

After preparation of the specimens, a pre-crack was formed to standardize the direction of the force application, with hand pressure on a straight scalpel blade placed at the apex of the slot. Specimens were tested in tension in the same universal testing machine with the direction of the force perpendicular to the plane of the preformed crack with a crosshead speed of 1mm/min. Each specimen was held in a specially designed tension device (Fig 7) consisting of steel rods and screws, extending from steel fixtures attached to the loading apparatus, passed through the loading holes of the specimens. When actuated, the



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apparatus controlled the gradual separation of the fixtures and transmitted tensile load to the specimens. The peak force in Newtons, which caused fracture of the specimens, was recorded, and used to calculate the fracture toughness ($K_{1c}$) in MPa. $m^{1/2}$ from the following equation: [24]

$$K_{1c} = pc/bw^{1/2}. F(a/w) \quad (2)$$

Where pc is the maximum load before crack advance (KN); b is the average specimen thickness (cm); w is the width of the specimen (cm) and

$$F(a/w) = \frac{\{(2+a/w)(0.886+4.64a/w-13.32a^2/w^2+14.72a^3/w^3-5.6\,a^4/w^4)\}}{(1-a/w)^{1/2}} \quad (3)$$

where (a) = crack length (cm).

**Hardness Test:**

The Rockwell hardness (RHN) of the specimens 30×30×4 mm was measured using a hardness testing machine (Wilson, USA) for all specimens. Load (Fig 8) was applied to the specimens using a round shaped indenter. Next, the hardness values were assessed directly from the meter attached with the machine. A total of three indentations were made at different points (the same selected areas for each specimen), on each specimen, and the means of individual specimens were calculated.

**Step 3: Statistical Analysis**

For statistical analysis, data was entered into a Microsoft excel spreadsheet and then analysed by SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and for Graphs, M.S office 2013 was used. For numerical variables, the data had been summarised using the mean and standard deviation, and for categorical variables, count and percentages. For comparison of mean values of fracture toughness, flexural strength, and hardness values, among the groups, ANOVA one way test was used. For multiple mean comparisons, Tukey's post hoc test was applied and for inter-group comparison independent sample t test was done. If the calculated P-value is below the threshold chosen for statistical significance (usually the 0.05), then the null hypothesis is rejected in favour of the alternative hypothesis.

**Results**

The data in Table no 1 depicts the comparison of mean values of flexural strength the, Control Group (n=15) of PMMA samples and the Glass and Aramid fiber reinforced PMMA samples (n=15 each). Statistically, by using Tukey's post hoc test, it was revealed that the mean difference values were statistically significant (P<0.05) among the groups for multiple comparison, shown in Table no 2. From the Table no 3, it was evident that multiple comparison values of mean difference among the BAC control, glass fibre reinforced and aramid fibre reinforced group were statistically significant (P<0.05). Table no 4 and graph no 1 show the inter group comparison of flexural strength values between glass and aramid fibre reinforcement of PMMA and BAC samples which were also statistically significant.

Multiple comparison values of mean difference of fracture toughness among the groups of PMMA showed statistically significant value (Table no 5). In Table No 6-mean difference value between BAC control and glass fibre reinforced group were not significant statistically. Table no 7 and graph no 2 showed that the inter group comparison of fracture toughness values between glass and aramid fibre reinforced PMMA and BAC samples were statistically significant.

Table no 8 depicted that there was no significant difference present among the mean difference of hardness values of PMMA group. Table no 9 showed, only the mean difference values between BAC control and glass fibre reinforced group which was statistically significant.

**Discussion**

A provisional restorative material should withstand the greatest occlusal stresses varying from 200-300 N during mastication [25,26]. No interim material meets the ideal requirements for each situation. For a successful outcome, interim restorations must withstand the stress where the provisional are kept intraorally for a longer duration (more than 2 weeks) [3].

In literature the fibers reinforcement in provisional restoration shows acceptable success rate [27]. In this in vitro study, enhancement of physical properties in terms of flexural strength, fracture toughness and hardness of polymethyl rnethacrylate resin and bis



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acryl composite resin reinforced with glass fibre and aramid fibre in 2% weight percentage was evaluated.

Both the fibres are available in either continuous or woven forms. Though the continuous fibres showed superior results over randomly oriented fibres, incorporating them in a specific part of the material is difficult, according to the studies done by Ladizesky et al. [28] , Goldberg et al. [29]. Vallittu et al. [30] found another problem with the longitudinal fibres that it was spread out laterally in the mould when they are placed under press. Therefore, specimens containing randomly distributed, short lengths of fibres were investigated in this current study in accordance with the studies by Chung et al. [31], Keyf et al. [32]. In this current study, both the fibres which were incorporated randomly, significantly increased the flexural strength and fracture toughness.

Fibre reinforcement works by transferring the stress from the weak resin matrix to the fibres that have a high tensile strength [33-35]. According to the study by Fonseca et al. [36] the strengthening effect of reinforcement depends on some of the properties like the position, length, quantity, form, orientation, degree of adhesion between the fibres and the polymer, impregnation with the resin and the type of resin.

According to study done by Kamble et. al [37] 2% by weight of glass fiber and polyethylene fibre was added to PMMA and BAC for reinforcement and mentioned that fibre content more than 3% would affect the flow of the dough and represents a large volume of material to be wetted by the monomer during the mixing and produce dry friable dough. In the study by He X et al. [38] the mechanical properties of PMMA reinforced with aramid pulp (AP) and modified aramid pulp (MAP) were measured and compared with those of unreinforced PMMA. A significant reinforcing effect was measured at a fiber content of 2.5% for MAP but beyond that concentration, a declining value was shown. So, in this current study fibre content was selected at a 2% level for optimum effect on mechanical properties.

The strengthening effect of fibre is effective when the adhesion with matrix is strong. During load transfer poorly bonded fibers are almost equivalent to voids. According to Naveen et al. [39] the chemical bond should be covalent in nature. Most common modes of surface treatment of glass fibre include silanes and plasma, where they condition the fibres to bond with the resin matrix in a mechanical way. Wetting the fibres with monomer is also usually used since it improves adhesion. But it may impair other properties of the material because of residual monomer [39,40]. So, in this invitro study glass fibre was impregnated by silane coupling agent (Angelus, Brazil) and aramid fibre was impregnated by the monomer (DPI, India) of PMMA.

Inter-group comparison of flexural strength from Table 3 revealed that glass fibre and aramid fibre reinforcement significantly increase the flexural strength of BAC when compared to PMMA as the mean difference was 32.55 for glass fibre and 11.25 for aramid fibre. Though the aramid fibre significantly increased the flexural strength value, the mean values for glass fibre reinforced samples (PMMA 76.88 MPa, BAC 109.43 MPa) were higher than aramid (PMMA 57.95, BAC 69.20). Study by Saygili et al. [41] also demonstrated flexural strength values of 80.35 MPa and 69.07 MPa in reinforced BAC and 138.44 MPa and 114.37 MPa in reinforced PMMA with glass fibre and aramid fibre reinforcement respectively. The possible explanation for this is poor bonding of aramid fibres with the resin matrix than in the glass fibres.

Table 6 shows the inter group comparison of fracture toughness of glass and aramid fibre reinforcement between PMMA and BAC. The mean difference value of 1.20 between glass fibre reinforced PMMA and BAC was statistically significant and the mean difference value of 0.50 between aramid fibre reinforced PMMA and BAC was statistically significant. From the Graph 2, it was revealed that fracture toughness was better in aramid fibre reinforcement as the mean fracture toughness values for aramid fibre were 3.22 MPa. $m^{1/2}$ and 2.72 MPa. $m^{1/2}$ and mean fracture toughness values for glass fibre were 2.47 MPa. $m^{1/2}$ and 1.27 MPa. $m^{1/2}$ for PMMA and BAC respectively.

Graph 3 shows that hardness value was slightly better in BAC group when glass fibre was incorporated (mean aramid 76.53, mean glass 78.27) and in PMMA group when aramid fibre was reinforced (mean aramid 63.33, mean glass 61.27).



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In the study done by Chen et al. [42] the result of the surface hardness test revealed no single pattern with either changes in length or concentration of the fibers. In the Kevlar fiber formulation in PMMA, hardness decreased with increasing fiber concentration from 1% to 3% whereas in the glass fibers formulations, hardness increased with fiber concentration. Whereas, Gad et al. [43] in their study demonstrated a decrease in the Vickers Hardness (VH) values of acrylic resins when glass fibre was added to the polymer matrix as compared to unreinforced groups. During fabrication of the specimens, there was a possibility of the fibres overlapping and clustering creating structural defects at the surface of the specimen, which might affect the integrity of the matrix and this may be the probable cause for decrease in hardness. Depending on the nature of the test, this current study showed that there was a difference in the results of both the fracture toughness and the flexural strength tests. Eliminating all the flaws during specimen fabrication was difficult and it could cause a direct effect on the flexural strength values obtained during the 3-point loading test. Because of these facts, researchers believe that fracture toughness is the best mechanical property measured to predict the wear and the fracture resistance of a restorative material [44].

Clinically, combination of fibres reinforcement can reduce patient discomfort by preventing catastrophic failure as the fractures segment are held together by the intact fibres.

To simulate the clinical environment the specimen can be tested under cyclic loading because in-vitro static loading does not mimic the intra oral conditions. Microcracks and defects that grow inherently during thermal and mechanical processes can significantly reduce strength measurements [45]. No cyclic loading in a moist environment was performed in the present study, which can be regarded as a study limitation.

## Conclusion

Within the limitations of this in vitro study, the following was found:

1. The flexural strength of PMMA and BAC provisional restorative material significantly increased after incorporation of 2% by wt. of glass and aramid fibre. For improving the flexural strength, effect of glass fibre was more in PMMA and BAC.
2. The fracture toughness of PMMA and BAC provisional material significantly increased after incorporation of 2% by wt. of glass and aramid fibre. For improving the fracture toughness, effect of aramid fibre was more in PMMA and BAC.
3. The hardness of PMMA provisional material was not significantly increased after incorporation of 2% by wt. of glass and aramid fibre. The mean hardness of BAC provisional material significantly increased after incorporation of 2% by wt. of glass and aramid fibre, though in-depth analysis revealed that only the mean difference between control and glass fibre reinforced BAC was statistically significant.

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# List of Figures and Tables

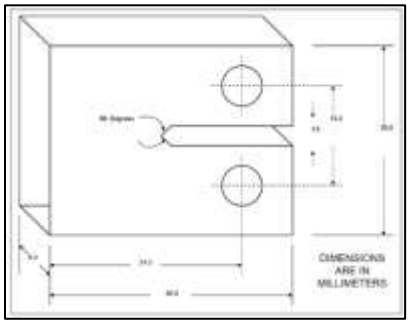
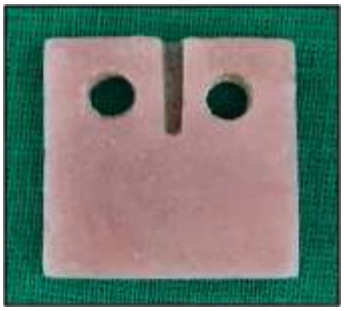



**Figure 1:** Dimensions of compact test specimens for



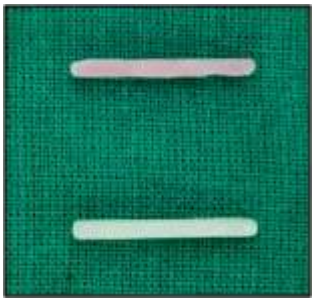


**Figure 2,3:** (Control Group Samples of PMMA and BAC)

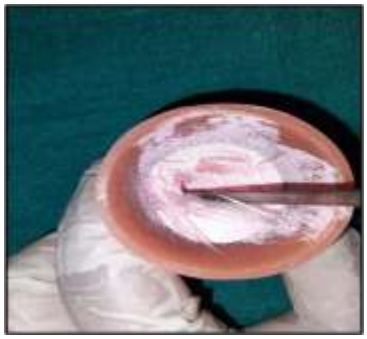


**Figure 4:** Glass fibre mixed with PMMA polymer

**Figure 5:** Aramid fibre mixed with bas and catalyst of BAC

**Figure 6:** Flexural Strength testing by 3-point bend test

**Figure 7**: Tensile Loading of Sample

**Figure 8:** Sample under load



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**Table 1: Mean comparison of Flexural strength (M. Pa) of PMMA samples among Control group, Glass fiber and Aramid fiber**

| PMMA | MIN | MAX | MEAN | SD | P value |
|---|---|---|---|---|---|
| Control | 42.00 | 51.00 | 46.38 | 2.49 | 0.000 S |
| Glass Fibre | 69.00 | 84.38 | 76.88 | 4.07 | |
| Aramid Fibre | 53.25 | 64.13 | 57.95 | 3.01 | |

Statistical Analysis: ANOVA one way test.

S: statistically significant if P≤0.05; NS: Not Significant if P>0.05

**Table 2: Multiple comparisons of Flexural strength (M. Pa) of PMMA samples between Control group, Glass fiber and Aramid fiber**

| Multiple Comparisons - Tukey HSD test | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| PMMA | Control | Glass Fibre | -30.50 | 1.189 | 0.000 | Significant |
| | | Aramid Fibre | -11.57 | 1.189 | 0.000 | Significant |
| | Glass Fibre | Control | 30.50 | 1.189 | 0.000 | Significant |
| | | Aramid Fibre | 18.93 | 1.189 | 0.000 | Significant |
| | Aramid Fibre | Control | 11.57 | 1.189 | 0.000 | Significant |
| | | Glass Fibre | -18.93 | 1.189 | 0.000 | Significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is statistically significant if P≤0.05.



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**Table 3: Multiple comparisons of Flexural strength (M. Pa) of BAC samples between Control group, Glass fiber and Aramid fiber**

| Multiple Comparisons - Tukey HSD test | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| BAC | Control | Glass | -49.59 | 2.259 | 0.000 | Significant |
| | | Aramid | -9.36 | 2.259 | 0.000 | Significant |
| | Glass | Control | 49.59 | 2.259 | 0.000 | Significant |
| | | Aramid | 40.23 | 2.259 | 0.000 | Significant |
| | Aramid | Control | 9.36 | 2.259 | 0.000 | Significant |
| | | Glass | -40.23 | 2.259 | 0.000 | Significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is statistically significant if P≤0.05.

**Table 4: Inter-group comparison of Flexural strength (M. Pa) of Glass fiber and ARAMID between PMMA and BAC**

| Variables | Samples | Mean | SD | Mean difference | P value | Result |
|---|---|---|---|---|---|---|
| GLASS | PMMA | 76.88 | 4.07 | 32.55 | 0.000 | Significant |
| | BAC | 109.43 | 7.78 | | | |
| | | | | | | |
| ARAMID | PMMA | 57.95 | 3.01 | 11.25 | 0.000 | Significant |
| | BAC | 69.20 | 6.44 | | | |

Statistical Analysis: Independent sample t test.

Statistically significant if P ≤0.05.



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**Graph 1: Inter-group comparison of Flexural strength (M. Pa) of Glass fiber and ARAMID between PMMA and BAC**

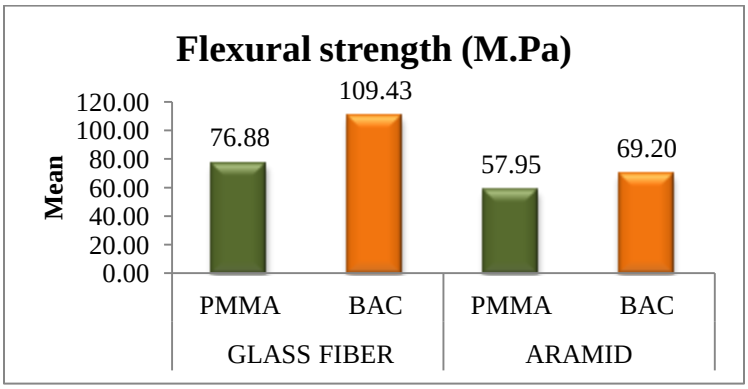


**Table 5: Multiple comparisons of Fracture toughness (MPa. m1/2) of PMMA samples between Control group, Glass fiber and Aramid fiber reinforced group**

| Multiple Comparisons -Tukey HSD test | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| PMMA | Control | Glass Fiber | -0.81 | 0.025 | 0.000 | Significant |
| | | Aramid Fiber | -1.56 | 0.025 | 0.000 | Significant |
| | Glass Fiber | Control | 0.81 | 0.025 | 0.000 | Significant |
| | | Aramid Fiber | -0.75 | 0.025 | 0.000 | Significant |
| | Aramid Fiber | Control | 1.56 | 0.025 | 0.000 | Significant |
| | | Glass Fiber | 0.75 | 0.025 | 0.000 | Significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is significant if P≤0.05.



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**Table 6: Multiple comparisons of Fracture toughness (MPa.m 1/2) of BAC samples between Control group, Glass fiber and Aramid fiber.**

| Multiple Comparisons -Tukey HSD test | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| BAC | Control | Glass | -0.08 | 0.047 | 0.243 | Not Significant |
| | | Aramid | -1.53 | 0.047 | 0.000 | Significant |
| | Glass | Control | 0.08 | 0.047 | 0.243 | Not Significant |
| | | Aramid | -1.45 | 0.047 | 0.000 | Significant |
| | Aramid | Control | 1.53 | 0.047 | 0.000 | Significant |
| | | Glass | 1.45 | 0.047 | 0.000 | Significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is statistically significant if P≤0.05.

**Table 7: Inter-group comparison of Fracture toughness (MPa.m 1/2) of Glass fiber and Aramid fibre between PMMA and BAC**

| Variables | Samples | Mean | SD | Mean difference | P value | Result |
|---|---|---|---|---|---|---|
| GLASS | PMMA | 2.47 | 0.07 | 1.20 | 0.000 | Significant |
| | BAC | 1.27 | 0.06 | | | |
| | | | | | | |
| ARAMID | PMMA | 3.22 | 0.05 | 0.50 | 0.000 | Significant |
| | BAC | 2.72 | 0.21 | | | |

Statistical Analysis: Independent sample t test.

Statistically significant if P ≤0.05.



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**Graph 2: Inter-group comparison of Fracture toughness (MPa.m 1/2) of Glass fiber and Aramid fibre between PMMA and BAC**

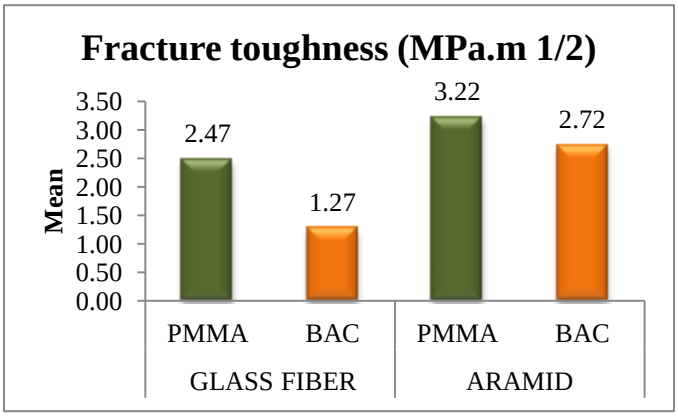


**Table 8: Multiple comparisons of Hardness value (RHN) of PMMA samples between Control group, Glass fiber and Aramid fiber**

| Multiple Comparisons - Tukey HSD | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| PMMA | Control | Glass Fibre | 1.40 | 1.565 | 0.647 | Not significant |
| | | Aramid Fibre | -0.66 | 1.565 | 0.905 | Not significant |
| | Glass Fibre | Control | -1.40 | 1.565 | 0.647 | Not significant |
| | | Aramid Fibre | -2.06 | 1.565 | 0.392 | Not significant |
| | Aramid Fibre | Control | 0.66 | 1.565 | 0.905 | Not significant |
| | | Glass Fibre | 2.06 | 1.565 | 0.392 | Not significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is significant if P≤0.05.



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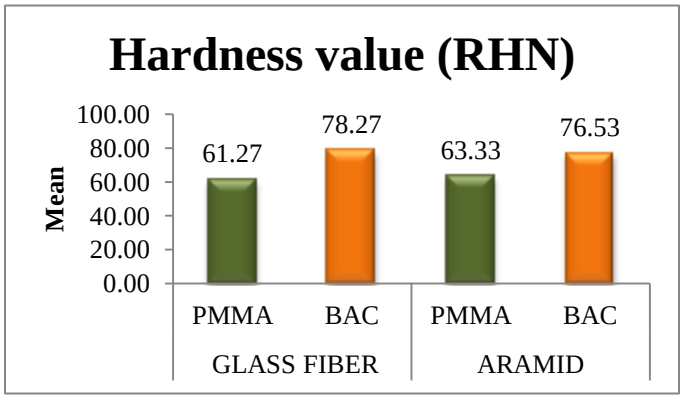
**Table 9: Multiple comparisons of Hardness value (RHN) of BAC samples between Control group, Glass fiber and Aramid fiber**

| Multiple Comparisons - Tukey HSD | | | | | | |
|---|---|---|---|---|---|---|
| Dependent Variable | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | P value | Result |
| BAC | Control | Glass | -3.33 | 1.218 | 0.024 | Significant |
| | | Aramid | -1.60 | 1.218 | 0.396 | Not significant |
| | Glass | Control | 3.33 | 1.218 | 0.024 | Significant |
| | | Aramid | 1.73 | 1.218 | 0.339 | Not significant |
| | Aramid | Control | 1.60 | 1.218 | 0.396 | Not significant |
| | | Glass | -1.73 | 1.218 | 0.339 | Not significant |

Statistical Analysis: Tukey's post hoc test.

Mean difference is significant if$P \leq 0.05$.

**Graph 3: Inter-group comparison of Hardness value (RHN) of Glass fiber and ARAMID between PMMA and BAC**



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