Tikrit Journal for Dental Sciences 13(2) (2025) 397-408
https://doi.org/10.25130/tjds.13.2.12

Tikrit Journal
for
Dental Sciences

https://tjds.tu.edu.iq
Print ISSN:2073-1213
Online ISSN:3105-9384

Effect of Adding Glass Fiber with Different Concentrations on Surface Hardness and Color of Acrylic Denture Base Material

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Keywords:
heat-cured acrylic resin, fiberglass, hardness, color change, color recognition.

Article Info.:

Article History:
Received: 13/11/2024
Received in revised form: 25/11/2024.
Accepted: 9/12/2024
Final Proofreading: 9/12/2024
Available Online: 1/12/2025

Citation: Turki *SA*. Effect of Adding Glass Fiber with Different Concentrations on Surface Hardness and Color of Acrylic Denture Base Material. Tikrit Journal for Dental Sciences 2025; 13(2): 397-408.

https://doi.org/10.25130/tjds.13.2.12

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Abstract

One of the most popular biomaterials, particularly in dentistry, is acrylic resin, often referred to chemically as polymethyl methacrylate, which is used to make dental restorations. Recent research indicates that adding glass fiber to acrylic resin materials has enhanced the mechanical and biological characteristics of the polymer. The study's goal was to ascertain how various glass fiber concentrations affected the heat-cured acrylic resin's surface hardness and color change. The main objective of hardening the acrylic resin that was used to make the denture base was to reduce smoothness loss, pigmentation, plaque retention, and aesthetic problems to extend the denture's serviceability. Ten samples of acrylic resin were made for each of the four groups. The grouping was based on glass fiber concentration in the resin (Control, 1.5%, 2.5%, and 5%). The present study's results indicate significant variations across surface hardness and color change test groups. Glass fiber reinforcing materials improved the hardness of acrylic resin that has been heat-cured compared with specimens that had no glass fiber added to them (control group). **Also, glass** fibre has significant results on the color change of PMMA materials and allows light transmittance efficiently.

Introduction:

The most common material used in denture production is polymethyl methacrylate due to its suitable mechanical qualities, affordability, correct fit, stability in the oral environment, simplicity of handling, and enough operating feature [1, 2]. Lately, there has been a lot of interest in incorporating inorganic nanoparticles into PMMA in order to improve its mechanical and physical qualities[3, 4] .Several methods have been developed to enhance PMMA's mechanical properties increase the impact strength of PMMA dentures, one method is to replace it with a different denture base material (such as polyamides or epoxy resins) or add a rubber copolymer within the material. Fiber reinforcement or metallic wires are alternative options for fortifying PMMA dentures. Poor adherence between the wire and the acrylic resin matrix is the main issue with employing metal wire. Since numerous studies have shown that glass fibers improve the mechanical qualities of denture resins, they have recently attracted a lot of attention as denture base reinforcement material. They can also be easily customized to the desired form and length, making them excellent for use in denture base polymer materials. These fibers are available in a variety of shapes, thicknesses, and qualities, Expire Glass fibers can be employed in roving or fiber bundles, as well as woven, loose, and continuous forms [5-7]. Research of [8, 9] verified that glass fibers are also easily manipulable in the lab or clinic, have a suitable capacity for attaching to other resins and the tooth structure, and have high biocompatibility. As a result, they've gained a lot of popularity recently. Acrylic resin's flexural strength can also be increased by adding fiber since the pressure applied to a plate made of fiber and acrylic resin will be evenly distributed. For this reason, glass fiber can be utilized as a reinforcing material to prevent the spread of fractures[10, 11].

Our goal in this study was to find out how adding glass fibers to acrylic resin for denture bases affected both its mechanical and cosmetic properties. Our specific objective was to determine the optimal proportion of glass fibers that would yield enhanced durability without sacrificing visual appeal. According to earlier research, adding 3% of glass fibers with a length of 6 mm can increase the strength of acrylic resin [12] .PMMA can be polymerized by a variety of techniques, including microwave, light, and heat. Nonetheless, a number of PMMA resins with different copolymer compositions are offered for sale. The mechanical qualities of the resin may be impacted by changes in its chemical composition[13]. When creating a denture base using polymers, specific mechanical and physical characteristics of the finished product are essential , and the choice of materials and curing conditions can affect the physical and mechanical parameters that indicated when producing a denture[14]. A denture base material's resistance to abrasion, scratches, polishing, and water sorption is correlated with its surface hardness level[15]. Numerous studies using various acrylic types and companies were conducted to assess the hardness of various acrylic resins for denture bases with and without the addition of glass fibers. The results showed that a high percentage of hardness was evident among them, particularly those that contained glass fibers in their composition.

Compared to the control specimen without glass fiber reinforcement, the heat-cured experimental specimen with extra glass fiber had a higher surface hardness [7, 16, 17]. The cross-linking substance (GF) can increase a denture foundation's surface hardness and decrease its amount of water absorption capability [18]. Furthermore, the chemistry and structure of the resins used in dental composites, as well as the nature of glass fiber reinforced systems, are examined in relation to their effects and characteristics, including mechanical, physical, thermal, and biocompatibility, technique sensitivity, and the mode and rate of restoration failure in clinical applications[19]. It is significant to remember that denture base acrylic's residual monomer content is still a cause for worry because it can alter the material's overall characteristics[20].

Long-term exposure to various circumstances can cause denture base resin to stain, discolor, and distort to differing degrees, issue can be solved by covering or immersing the resin in different materials[21]. Additionally, the kinds of filler components, storage time, and immersion solutions have a direct effect on the color stability of the PMM denture base resin [22].

By dispersing pressure, glass fibre may be used as a reinforcing material to stop fracture spread. In addition to being able to absorb pressure, acrylic resin plates may also be strengthened with fibres that are stronger than the plates. Because glass fibres link well to polymer matrix utilising saline coupling agents and have high cosmetic properties overall, they have shown to be the ideal alternative for dental applications. Glass fibres are selected for denture base polymer because they are more transparent than other fibres when utilized in light-curing type resin[11, 23].

In this study, we are studying and explaining the effect of adding fiber glass from two aspects: the mechanical aspect represented by measuring the hardness of the acrylic material, and the aesthetic aspect through how the acrylic maintains its color without changing or improving them after adding the fibers in different ratios. We are studying which ratio gives us results close to natural and is somewhat ideal.

Materials and Methods

Materials

In this experiment, forty samples of heat-cured acrylic material (Rodex, Turkey) were used. Following that, these samples as in figure 1 were divided into four groups: Control Group A, Group B, Group C, and Group D. Each group consisted of ten separate specimens. The distinguishing factor among the experimental groups (B, C, and D) lies in the varying quantities of added glass fiber. To fabricate the specimens, materials such as dental modeling wax (Polywax, Turkey), dental stone (Hiro die stone, Mutsumi, Japan), glass fiber (E glass fiber, 3nm, Jushi Group Co., China), and a separating medium (tinfoil, Germany) were utilized.

Sample Preparation

silicon models with a disc form (12 mm in diameter and 2 mm in thickness) were used to make wax pattern specimens [24]. In order to make it easier to remove the stone mold after deflasking, a separating material was first applied to the top and lower parts of the metal flask. Next, the mixed dental stone whose usual ratio of powder to water was (100g/25m1) was placed in a creamy state in the lower half of the flask, gently arranging it in the middle, keeping in mind that half of the patterns needed to be exposed for easy removal. Then, separating medium was applied and the upper half was positioned once the dental stone layers had fully set.

Another quantity of dental stone was mixed, prepared and placed over both patterns and stone surfaces. The mold was left for one hour. After that, it was carefully opened to remove the designs to prevent mold deformation. Medium's second layer was put on the mold then allowed to dry after being coated with a separating medium. The in accordance with manufacturer instructions, the acrylic powder (100gm) and liquid (40ml) were combined and controlled for the control group, resulting in a main acrylic resin mixing proportion of 25g:10ml (P/L). Utilizing a sterile metal spatula, the mixing process was done in a glass jar. After that, the mixture was covered and let to stand until it solidified into dough. The mold was filled with acrylic dough. The flask was cured after being compressed with a hydraulic press for five minutes at 1500 psi [20]. As soon as the curing was finished, the flask was left to cool. After being removed from the flask, the samples were polished and completed. To prevent the acrylic from shrinking, they were then kept in distilled water at 37°C for 28 days [25]. Immediately after that the color change and the hardness tests were performed. The acrylic samples (groups B, C, and D) were fabricated using the above process by adding 1.5% glass fiber [3] to 24.625g acrylic powder for the B group, adding 2.5% glass fiber to 24.375g acrylic powder for the C group and adding 5% glass fiber to 23.75g acrylic powder for the D group [23] All glass fibre that adding to three groups were on size (3nm)[26]

Hardness Measurement Test

In this study, the hardness tests were applied using the durometer hardness device, type (Shore D) scales in accordance with (ASTM D2240) as in figure (2: A, B) was used to perform the hardness measurement. The testing value was determined by calculating the average of various readings that were obtained directly from the scale reading of the durometer by using a pointed dibbing tool; the pointed dibbing tool penetrated the material surface as a result of the pressure that applied on the instrument, the dibbing tool head coming into contact with the surface of the samples. In conducting the Shore D hardness test, each specimen was tested seven times at various positions, ensuring that tests were conducted in the middle of each specimen rather than at the edges. The average value of these measurements was subsequently calculated to yield a representative hardness value for each sample, the testing loads were applied equally to 50 N, and the specimen was found beneath the indenter region with a depressing time equal to 10Sec. The digital Shore D device's indenter is 0.8 mm in diameter and tapers to a 1.6 mm cylinder. The digital scale was utilized to obtain the reading once the indenter was firmly pressed down. Higher values indicate a harder substance. The hardest numbers for each scale run from (0 to 100). The thickness, size, and distance of the specimen from the edge (more than 12 mm) all have a significant impact on the hardness rating. The specimen's diameter should be greater than 30 mm and its minimum thickness should be 3 mm. Additionally, for the zone test, the specimen's surface has to be smooth [(20)] [(11)].

Color Recognition Test

The hardness and color change tests were applied using the color recognition sensor (TCS230, China) as in figure (2: C). The Arduino Uno microcontroller was utilized as the system's setup, and the assessment result was computed as an average of various readings that were recorded straight from the scale reading. Four LED lights at the PCP's corners and an RGP color sensor in the middle make up the sensor. The software code was changed to take readings every three seconds, and the system was configured to deliver the red, green, and blue color level readings[(25)]. The application code established the reading thresholds for each color between 0 and 1023. To accommodate the size of the sensor and the LEDs' light distribution, the color sensor box is made of a black piece of polymer that measures 2.5 x 3 x 2.5 mm. After every specimen was inspected, data was collected and stored in preparation for statistical analysis. IBM SPSS software was used to do statistical analysis for significant differences following the collection of data. For every color, an independent sample T-test was run between the groups.

Results

The results obtained from (40) experimental specimens of acrylic resin classify into four concentration groups of amounts of Glass fiber as in Table (1).

Hardness and color recognition tests were statistically analyzed using the Least Significant Difference (LSD) test and One-Way ANOVA (Analysis of Variance).

Results of Hardness Test

Descriptive statistics (mean, standard deviation, minimum and maximum hardness values) for each tested group are shown in Table (3) and Figure (4). According to the results, group D, which contains 5% glass fiber, had the highest mean hardness value (72.6), while the control group had the lowest value (57.55). The least significant difference test (LSD test) was also used to compare the means of each group at a significance level of 0.05. The findings indicated a substantial difference of 1.5% G.F. and 2.5% G.F. between group B and group C, as well as a high significant difference across the tested groups (Table 2).

Results of Colour Recognition Test

The descriptive statistics data for color proportions were illustrated in Table (3) as well as Descriptive and Statistical analysis results. Regarding the data from the control groups, the mean values indicated that they were greener than the groups under study. Figure (3), which displays a statistically significant difference (P-value<0.05), provided additional support for this conclusion. Additionally, the least significant difference test (LSD test) was used to compare the means of each group at a significance level of 0.05. Figures (3, 4&5) and (3&4) demonstrate Table (3) shows the collected data based on the RGB values, including the baseline readings, which are an empty black backdrop reading. The data has lower RGB values than the control data.

Given that every hue has a distinct wavelength, the results of the ANOVA LSD test for multiple comparisons indicate that there is a statistically significant difference (P-value < 0.05) between all color groups. Table (4) and Figures (4,5&6) indicate that group B has an intermediate mean value, whereas group C&D has the lowest mean value, and the control group has the greatest mean value (Table 3).

Discussion

In dentistry for many years, PMMA have been regarded as one of the most popular materials for denture fabrication. They also have many benefits, including their excellent looks, accuracy fit, stability within the patient's mouth, ease of work and handling in dental laboratories and clinics, and inexpensive working equipment [19]. Acrylic resins are suited for the creation of prostheses due to a number of characteristics, such as biocompatibility, relining capacity, low cost, manufacturing complexity, solubility, and specific weight. Additionally, because acrylic resin is visually appealing, inexpensive, easy to process, and reparable, it is the most widely utilized material for denture bases, according to(Sugianitri, 2021) [27] who carried out the search. The ease with which acrylic resin can crack is one of its drawbacks. According to the research of (Chen Liang and Yen, 2001) [23], inquiry, one of the efficient solutions is combining agave sisalana fiber with E-glass fiber. It is not, however, regarded as the perfect material since it has several drawbacks, such as its poor mechanical and physical qualities, which make it prone to fracture or deformation [21].

This study's primary objective was to examine the effects of varying glass fiber concentrations on the surface hardness and aesthetic properties of a special heat-polymerized denture base material. At first, important finding was increased surface hardness values after the addition of glass fiber of different concentrations into heat-polymerized acrylic material, and Group D which contains 5% by weight of glass fiber showed the highest hardness value. Surface hardness is an inherent property of a material that shows how its resistance to plastic deformation. Moreover, a material's resistance to wear is most frequently described by its mechanical characteristics; a material with a high surface hardness is said to have the strongest resistance to wear [14]. Many studies have used different fiber length measurements, and one of them(Al-Thobity, 2020)[26] that used fiber glass length ranging from 2 to 4 and 6 nm and different concentrations , but in this research, we chose an average length of 3 nm, based on a previous study Al-(Thobity, 2020) [26] that showed a positive effect of this length on the physical properties of acrylic. It should be noted that the effects of the aforementioned length measurements on the physical and aesthetic qualities of acrylic varied, and that concentration level was more useful than length measurement. The study's primary goal was to examine the impact of concentration rather than the fiber length unit.

Many studies[3, 4, 24, 28, 29] came to the same conclusion about how to use strengthening materials as additives to improve the mechanical and physical characteristics of PMMA. Glass, polyamide, ultra-high molecular weight polyethylene (UHMWPE), carbon/epoxy, and polyamide are a few examples of reinforcing fiber kinds. Each has both advantages and disadvantages. For instance, compared to UHMWPE fibers, which have weak adherence to the polymer matrix, glass fibers have become the most extensively utilized in dentistry because of their superior stickiness and attractiveness. Polyamide fibers, on the other hand, are challenging to work with and polish, whereas carbon/epoxy fibers have a high modulus of elasticity, fatigue strength, and tensile strength but a low visual appeal[13]. Different research has demonstrated that adding glass fiber to denture resins improves their mechanical properties and the appropriate ratio of polymer to monomer is either (2.5:1) by weight or (3 to 3.5:1) by volume; this ratio controls the workability of the mix and the dimensional changes that occur during setting [9]. Also,(Anderson et al., 2001) [6] discovered that, within the limitations of his research, using glass or aramid fibers as additives to heat-polymerized PMMA denture glue increased its flexural strength. Additionally, he stated that this procedure may be useful for both temporarily affixed partial dentures and distal extension partial denture bases.

Additionally, the study by [15] shown that the resin substance used to fabricate denture bases had varying degrees of toxicity in vitro while simultaneously exhibiting an allergic reaction in vivo.

The residual monomer losing is one of defects that causes the reduction in mechanical properties, which leaked out into either saliva or water, and to the water that absorbed which causes plasticization of the resin, and this case means the resin like to be more flexible and softer [13]. Furthermore, my research's findings are consistent with other methods used to reinforce the PMMA structure and enhance its mechanical qualities and among these methods were modifying the polymerization procedures and employing various approaches to include fibers into the PMMA powder [8, 14, 16].

Also, the finding of our study agreed with [30] It concluded that the experimental specimen with extra glass fiber that had been heat-cured had a harder surface than the control specimen without glass fiber reinforcement, the results were similar to those obtained by [18] who concluded that added glass fiber increased surface hardness of PMMA significantly. The cross-linking agent in the acrylic resin may be the reason for the increased surface hardness of heat-cured acrylic resin in reinforced groups. According to [12, 31], the cross-linking substance can increase a denture base's surface hardness and decrease the amount of water absorption capacity. While [28] found that a linear chain of a single cross-linking material combined with a crossed linking homopolymer forms a polymer cross-linking tie till a three-dimensional structure with strong chain connections is generated. In Addition [28] in his work it was demonstrated that, when glass fibers added to the hot PMMA there is a substantial result in the hardness test and this is due to the influence of silane-treated E glass fiber weight % and aspect ratio on the hardness number of PMMA.

The results of our search were consistent with their research,[10] , which found that "When glass fiber concentration was increased in acrylic denture base material, researchers discovered that the aesthetic appearance of the acrylic denture base was greatly impacted by the visual qualities of color and translucency". And in study of [13] said that the translucency is a characteristic by which the extent of light's ability to pass through a material can be determined. Denture base resin should also supply long term color stability and mimic oral tissue naturally in order to create visually agreeable outcomes [7]. In the practice of dentistry, two widespread methods are used to determine ,control and measure colors: instrumental and visual [22]. In my study I used Arduino Uno microcontroller. The outcomes of ANOVA test and the least significant difference LSD tests (Tables 3 and 4) assured that all examined groups showed significant degree of color length variation after adding glass fibres. However, the range of the discolouration different according to the varied percentages amount of glass fibre that added between groups. The results were highly significant. Nd according to [18], glass fibres efficiently permit light transmission since they have a refractive index comparable to resin. Consequently,[7] discovered that, in contrast to opaque-colored kelvin, carbon, or zirconia fibers, adding glass fibers to dental composite will enhance its mechanical qualities without changing the degree of conversion of the resin matrix.

The results of [32] also, detected that integrating E-glass fiber into PMMA obtained the ultimate stable color.

In conclusion, the current study's findings indicate that the addition of glass fibers enhanced PMMA's surface hardness as a denture base material and effectively permits light transmission. Additional testing techniques like as impact, fatigue, and fracture testing should be used to ascertain the therapeutic significance of including these compounds into PMM. Furthermore, it is suggested that we highlight the importance of conducting further research in our study regarding the effects of adding glass fibers on color changes. This is due to the scarcity of available studies in this field and the lack of explanations for the variations observed in the effects of these different concentrations of fibers on color aspects. This study may encourage more research to gain a better understanding of how glass fibers affect material color changes, which can be beneficial for the development and improvement of applications of this technology in the field of dentistry and dental manufacturing.

Conclusion

The following conclusions can be drawn from the results of this study:

1-The hardness of heat-cured acrylic resin was considerably increased by the inclusion of glass fibers when compared to specimens without glass fiber (control group).

2- Group D of 5% concentration by weight of glass fiber showed the highest surface hardness values.

3- The hardness values of the studied groups increased as the concentration of glass fiber increased.

4- Glass fiber reinforcing materials have significant results on the color change of PMMA materials and allow light transmittance efficiently.

Acknowledgements

I want to thank my beloved father and Atyaf Alnaser an assistant lecturer at the College of Health and Medical Technologies in Baghdad (prosthodontics department) for assisting with this project.

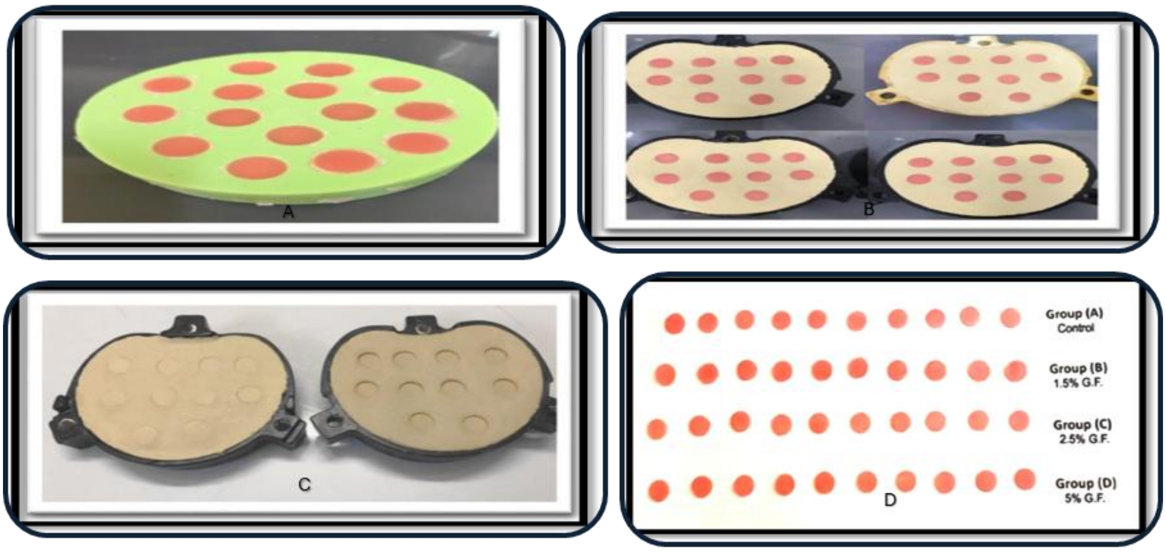

Figure (1): A: Silicon mold used for wax pattern Making, B: Inserting wax pattern in the stone, C: Stone mold after wax elimination and D: Samples ready for testing

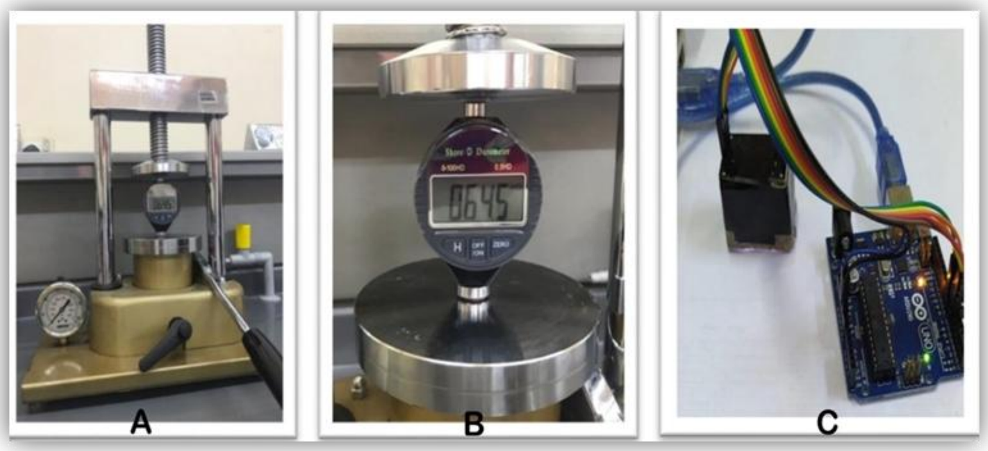

Figure (2): A and B: Hardness test using shore D surface hardness tester meter
C: color recognition sensor (TCS230, China).

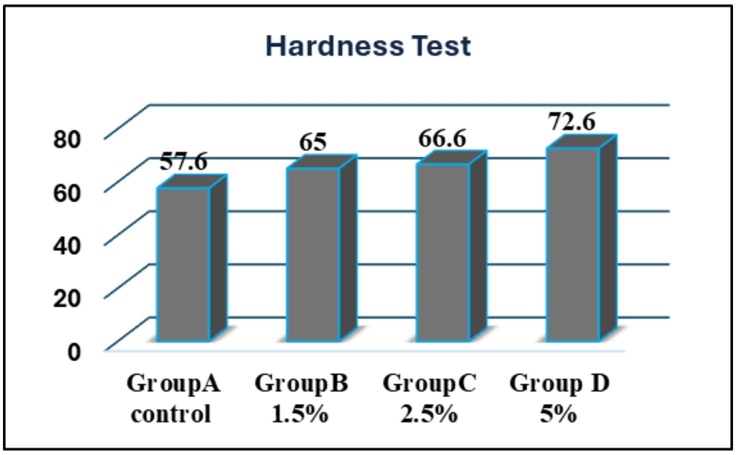

Figure (3) Bar chart of hardness test before and after added different percentage of glass fiber

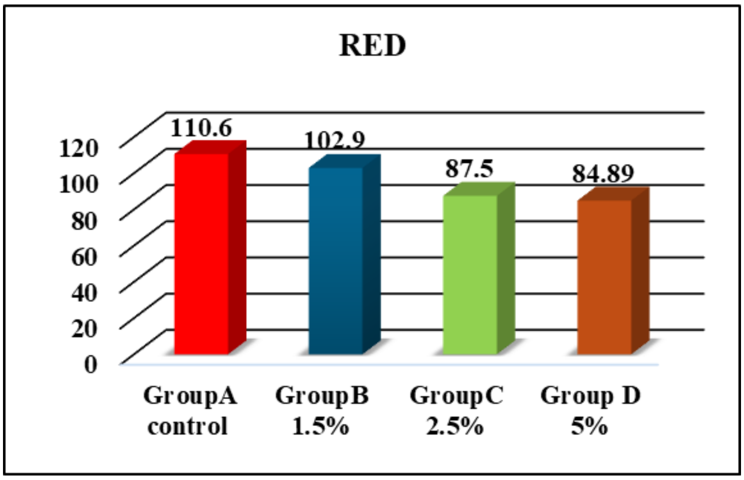

Figure (4): Bar chart of color change (Red color) before and after added different percentage of glass fiber.

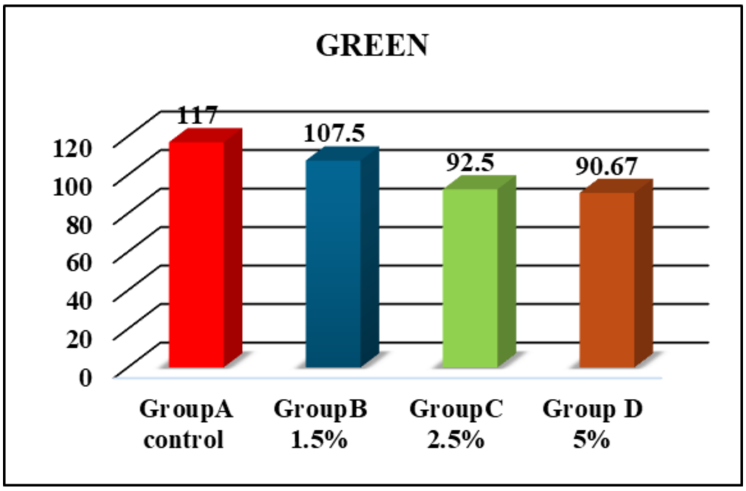

Figure (5): Bar chart of color change (Green color) before and after added different percentage of glass fiber

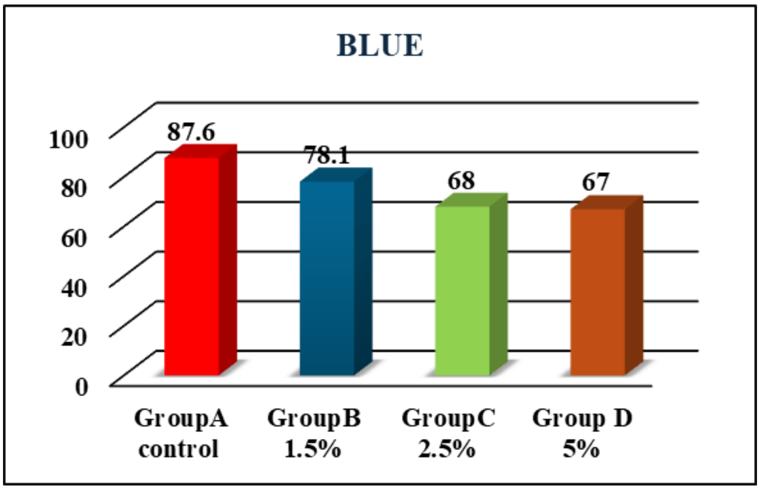

Figure (6) Bar chart of color change (Blue color) before and after added different percentage of glass fiber

Table (1): Mixing ratio of acrylic resin with different reinforcement material glass fiber:

Percentage	Amount of reinforcement (addition)	Amount of polymer	Amount of monomer
Group A: Control (0%)	**0g**	25g	**10ml**
Group B: Glass fibre (1.5%)	**0.375g**	**24.625g**	**10ml**
Group C: Glass fibre (2.5%)	**0.625g**	**24.375g**	**10ml**
Group D: Glass fibre (5%)	**1.25g**	**23.75 g**	**10ml**

Table (2): Descriptive statistics of the surface hardness for the four different groups foradding different percentages of glass fiber.

Different% of Groups	Groups	Mean	SD	Min.	Max.
Control (PMMA)	Group A	57.55	1.212	55.5	59
PMMA+1.5%G. F	Group B	65.	1.453	62	66.5
PMMA+2.5%G. F	Group C	66.6	0.46	66	67
PMMA+5%G. F	Group D	72.6	1.524	69	74.5

Table (3): Statistical analysis using the least significant difference test.

Groups	(J) Groups	Mean Difference (I-J)	P- Value	Sig
Group A	B	-7.45000-*	000	(HS)
	C	-9.05000-*	000	(HS)
	D	-15.05000-*	000	(HS)
Group B	C	-1.60000-*	.006	(S)
	D	-7.60000-*	000	(HS)
Group C	D	6.00000	.000	(HS)

*. The mean difference is significant at the0.05 level

Table (4): Descriptive statistics of the color change for the four different groups with different percentages of glass fiber adding.

Studied Groups		N	Mean	Std. D.	Std. Er	Min	Max	*P*-Value	Sig.
Red	A	10	110.6	5.854	1.851	83	92	000	(HS)
	B	10	102.90	11.580	3.662	104	121		
	C	10	87.50	3.837	1.213	88	122		
	D	10	84.89	3.060	1.020	82	94		
Green	A	10	117.00	5.333	1.687	110	127	000	(HS)
	B	10	107.50	12.678	4.009	92	129		
	C	10	92.50	4.301	1.360	86	100		
	D	10	90.67	4.093	1.364	87	99		
Blue	A	10	87.60	6.467	2.045	77	98	000	(HS)
	B	10	78.10	9.291	2.938	69	96		
	C	10	68.00	3.621	1.145	63	74		
	D	10	67.00	2.915	.972	64	73		

Table (5): Statistical analysis using the least significant difference

	(I) groups	(J) groups	Mean Difference (I-J)	*P*-Value	Sig
Red	A	B	7.700	.000	HS
		C	23.100*	.000	HS
		D	25.711*	.085	S
	B	C	15.400*	.000	HS
		D	18.011*	.000	HS
	C	D	-2.611	.849	NS
Green	A	B	9.500*	.039	HS
		C	26.333	.000	HS
		D	24.500*	.000	HS
	B	C	-15.000*	.000	HS
		D	16.833*	.000	HS
	C	D	1.833	.952	NS
Blue	A	B	9.500*	.008	HS
		C	19.600*	.000	HS
		D	20.600	.000	HS
	B	C	10.100*	.004	HS
		D	11.100*	.002	HS
	C	D	1.000	.985	NS

*The mean difference is significant at the0.05 level

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