STUDYING THE FLEXURAL PROPERTIES AND MAX.SHEAR STRESS OF SELF CURE PMMA RESIN FOR DENTURE APPLICATIONS .

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ABSTRACT

Poly Methyl Methacrylate were widely accepted material in dental and medical field due to the excellent biocompatibility and easy fabrication, however exhibit inferior mechanical properties. Therefore, the present study conducted to determine the flexural properties of PMMA based material by reinforcing PMMA with two different natural fibers (bamboo & siwak fibers). Discontinuous random fibers used in three lengths (2, 6 & 12 mm) and three weight percentage (3, 6 & 9 wt. %) of the both types of fibers. Results indicated that Flexural modulus, flexural strength and max.shear stress increase with increasing weight fraction and fiber length of fibers (bamboo & siwak) and reach the maximum amount at addition of weight fraction of (9 wt.%) and (12mm) length of fibers. The highest value of flexural modulus, flexural strength and max.shear stress were (10.09GPa), (112MPa), (6MPa) respectively, for composite specimens with bamboo fibers, while for composite specimen with siwak fibers (9.71GPa),(101MPa),(4.44MPa) at the optimum condition of (9wt.%) and (12mm) length . All composite specimens reinforced with bamboo fibers showed the highest flexural strength and flexural modulus among the composite specimen reinforced by siwak fibers.

KEYWORDS- Flexural, Max.Shear Stress, Self cure, PMMA, Weight fraction, Fiber length, Denture .

دراسة خصائص الانحناء واجهاد القص الاعظم لراتنج البولي مثيل ميثا اكريليت المبلمر ذاتيا لتطبيقات طقم الاسنان .

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الخلاصة :

ان مادة البولي مثيل ميثا اكريليت مادة مقبولة بشكل واسع في تطبيقات طقم الاسنان والتطبيقات الطبي نظرا للتوافق الطبي وسهولة التصنيع على الرغم من الخواص الميكانيكية الضعيفة. لذلك فان الدراسة الحالية تهدف لحساب خصائص الانحناء لبوليمر البولي مثيل ميثا اكريليت المقوى بنوعين من الالياف الطبيعية (الياف السواك والخيزران) والتي استخدمت بشكل متقطع عشوائي الترتيب بثلاث اطوال (2 و 6 و12 ملم) وثلاث كسور وزنية (3 و6 و9 %) لكلا النوعين من الالياف. ولقد بينت النتائج ان معامل الانحناء ومقاومة الانحناء واجهاد القص الاعظم تزداد مع زيادة الكسر الوزني وطول الليف لالياف الخيزران والسواك وتصل الى اعظم قيمة عند (9%) و (12 ملم).وان اعلى قيم لمعامل الانحناء ومقاومة الانحناء واقصى اجهاد قص للعينات المتراكبة المقواة بالياف الخيزران (10.09 GPa, 112 MPa , 6MPa) بينما للعينات المتراكبة المقواة بالياف السواك (4.44 MPa,101MPa,9.71GPa) على التوالي عند افضل ظروف (12 ملم و 9%).كل العينات المتراكبة المقواة بالياف الخيزران تكون لها قيم معامل انحناء ومقاومة انحناء اعلى من المواد المتراكبة المقواة بالياف السواك .

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INTRODUCTION

poly (methyl methacrylate) (PMMA) is the most popular material used in removable denture base material and it remains the most well-known of all the polymeric denture base materials due to its easy laboratory manipulation, ease in polishing and finishing, inexpensive apparatus's, stable in the oral environment, and good appearance. It commonly consists of (PMMA) as powder form and (MMA) as liquid form of cold cured polymerization technique. One of the main problems associated with PMMA is low in strength, as well as brittle on impact, and fairly resistant to fatigue. The geometry of the denture base is complex and stresses can be concentrated in notches, cracks might occur in the denture base. Problems in the field of prosthodontics and are mainly represented by high-impact forces due to dropping and biting forces (A.O. Alhareb et.al., 2015).

Inoue K.et.al.,(2000), study some mechanical properties of PMMA used for denture reinforced by glass fibers. The results showed that the bending and impact properties for PMMA increased when the layers of fiber glass increased.

S. Eskimez et.al., (2006), researchers studied the resistance to fracture and bending strength of acrylic resin reinforced by glass fibers. Result illustrated that the flexural strength of the resins decreased with the fibers but the flexural resistance increased. Thus resin reinforced with fiber may be the material of choice when high impact acrylic resins are needed.

Nuhad H. M., (2009), calculated the effect of addition glass fibers and carbon fibers on bond strength of the heat cure acrylic resin (pink and clear). The results showed the acrylic resin reinforced by fibers of glass gives higher bonding strength than that of acrylic resin reinforced by carbon fibers**.**

Rahamneh A., (2009), investigated the effect of addition of different ***types*** of fibers (carbon, glass, polyethylene, silk fibers) on impact strength of PMMA material. The results indicated that the PMMA reinforced by carbon fibers, glass fibers and polyethylene fibers give high impact strength.

Yu, T. et.al. (2013), the researchers studied effect of short ramie fibers in length of (1.5 mm & 3 mm) and volume fraction (4 & 10 vol. %) on denture base resin. The results showed that the denture acrylic resin reinforced by short fibers had higher value of bending modulus compared with unreinforced acrylic resin.

Intisar J. Ismail et.al.,(2014), studied the effect of Alumina (Al_2O_3) Nano particles in three different percentages (1,2,3 wt %) on some physical and mechanical properties of heat cured polymethylmethacrylate denture base material. The results showed that the transverse strength increases with addition of (1 & 2wt %) Al_2O_3 to heat cured PMMA denture base material and reduces with addition of 3%. In addition, a significant increase in surface hardness and non-significant differences in surface roughness were observed for all percentages. **Zainab S. et.al., (2014),** evaluate the effect of polyester fibers and polyethylene fibers on some properties of acrylic denture resin (flexural strength, impact strength and hardness). The specimens were divided into seven test groups. The first group is the Control without fiber reinforcement), second group reinforced with 2mm polyester fibers, third group reinforced with 4mm polyester fibers, fourth group reinforced with 2mm Polypropylene fibers, fifth group reinforced with 4mm Polypropylene fibers, sixth group reinforced with 2mm of both fibers. Result showed that the addition of different fibers (polyester and Polypropylene) to acrylic resin make denture more resistance to break and more resistance to bend.

S.I. Salih et al., (2015), improve the properties of PMMA resin that reinforced with many values of volume fraction of nano hydroxyapatite and micro zirconia powders in addition to E-glass and Kevlar fibers. The results showed that the maximum properties of flexural modulus and impact strength happened for PMMA reinforced by ZrO_2 powder and Kevlar fibers. And the maximum values for properties of flexural strength and max.shear stress happened to PMMA reinforced by ZrO_2 powder and glass fibers.

S.I. Salih et al., (2016), develop PMMA properties by addition of four kinds of nanoparticles, which are fly ash, fly dust, zirconia and aluminum in different ratios of volume concentration to PMMA resin. The results show that the values of the hardness, flexural strength, Maximum shear stress and flexural modules increased and with the addition of Nano powders (fly ash, fly dust, zirconia, and aluminum).

The aim of this study is determine flexural properties (flexural strength, flexural modulus, flexural strain) and max. shear stress of the self-cure PMMA reinforced by two kinds of fibers (siwak and bamboo) fibers used for denture applications.

MATERIALS AND METHODS

Material Used

In this research the DURACRYL PLUS self-curing base resin, manufactured by Spofa Dental Company. This type of material characterized by many properties compared with other kind of PMMA polymer, such as: softer feel, low molecular weight, color stable in the long run, minimized shrinkage, stable polymerization cycle with a perfect end result, the acrylic is long pourable and model able for a long period of time (W.J.O Brien, 2002). Table 1 shows the properties of PMMA as obtain from the company. Figure 1 shows the methyl methacrylate powder and monomer that are used to fabricate composite specimens in this study . **Two** types of fibers (bamboo fibers and siwak fibers) were used in this study as reinforcing materials with weight fraction of (3, 6 and 9%) and length (2, 6 and 12 mm) it was added to PMMA. These types of fibers has a yellow color. Figure (2 & 3) show bamboo fibers and siwak fibers **.**

Preparation of acrylic (PMMA) Specimens

Self-curing base resin is mixed in the volumetric ratio 3:1 (three parts of powder, 1 part of liquid). The mixing ratio is important because it is affect the acrylic resin cytotoxicity, setting dimensional changes and control the mixture workability.

The mixture was mixed using wood stick to prevent the chemical interaction at room temperature continuously using hand in one direction for around 20 seconds and then poured into the metallic mold. The inner face of the mould was covered with a layer of smooth thermal nylon papers to ensure non adhesion of acrylic with the mould inner face and to obtain smooth lower surface with maximum time around (4 min) after pouring completion into the metallic mould the upper surface of the mould was covered with smooth thermal nylon and pressed using metallic plate to obtain samples with smooth upper surface and prevent the vapor entry to acrylic resin during curing process inside Ivo met. The samples were finished with using special hand grinder to remove the cracks from the specimen's sides as a result of the specimen's adhesion with the metallic mould cavity sides.

The curing process of acrylic performed by placing the closed metallic mould inside the Ivo met at temperature equal to around (55 °C), and pressure equal to around (2.5 bar), the closed mould remained inside Ivo met device (curing device) for around (30 min) in order to complete polymerization process of acrylic specimens and to improve physical properties, the characteristic of this process is the residual monomer will be at minimum level and the polymerization process might be completed in short time **.**

Preparation of Composites specimens

According to required selection ratio of weight fractions of the reinforcement materials weighing (evaluating) the amount of reinforced material (siwak fibers, Bamboo fibers) using electronic balance with accuracy (0.0001) digits depending on total weight of the matrix material PMMA required for filling the mould cavities using theory of rule of mixture. The fibers alkali treated with 5% (w/v) alkali (sodium hydroxide) solution at 25 °C for 24 h, maintaining a fiber-to-liquor ratio of 1:30 (w/v). The fibers which alkali treated washed several times with distilled water to remove excess alkali sticking on their surface, then neutralized (PH-7) with distilled water containing a few drop of acetic acid and finally washed with distilled water ,then the treated fibers were dried at room temperature for 5 days and finally kept in hot air oven at (50-60 °C) until dry .The liquid monomer (MMA) with one type of reinforcement fibers (Bamboo or siwak) should be mixed together at room temperature homogeneous and continuously, so it must be sure of homogeneity of the mixture ,before added powder to it to produce composite materials .The powder then added to the mixture and gradually mixed, then cured in same manner which indicated above . **The** acrylic resin samples were de-molded to remove from the metallic mould cavities with very smooth upper and lower surface, followed by heat treatment at 55°C for 3 hr to remove residual stresses as a result of de-molding of the specimens from the metallic mold cavity.

Flexural test.

A three point flexural test was carried out at universal test machine in material engineering department laboratories. The vertical force was applied at the center of the composite flexural specimens to obtain the curve that represents the relationship between the force (N) and displacement (mm) for each composite specimen. The properties obtained from this test are the flexural modulus of elasticity and flexural strength for each laminated composite specimens which were prepared according to the ASTM (D-790 standard) (Annual Book of ASTM Standard,2002). Figure (4 & 5) show the standard dimension of specimens and the flexural test machine, respectively.

Flexural properties determination .

Flexural strength

Flexural strength can be determined by the following equation (Annual Book of ASTM Standard, 2002):

$$\text{Flexural Strength } \sigma_f = \frac{3PL}{2bd^2}$$

Where:

σ_f = Flexural strength (MPa).

P= Load at fracture (N).

L=Length of specimen (mm).

b= Width of specimen (mm).

d= Depth of specimen (mm)

1) flexural modulus

The flexural modulus (E_F) can be determined by using:

$$\text{Flexural modulus } E_F = \frac{L^3 P}{4bd^3\delta}$$

Where:

E_F= Modulus of elasticity in flexural test (MPa).

L=Length of specimen (support span) (mm).

b= Width of specimen (mm).

d= Depth of specimen (mm).

δ= Specimen deflection (mm).

2) flexural strain

Flexural strain can be calculated and expressed by the following equation (D.R. Askeland and P.P. Fulay):

$$\varepsilon_F = 6Dd/L^2$$

Also the maximum shear stress is determined by using equation below (Annual Book of ASTM Standard, 2002):

$$\tau_{max} = 0.75\frac{P}{bd}$$

Where:

P= Load at fracture (N).

b = Width of specimen (mm).

d= Depth of specimen (mm).

Flexural (3-point bending) Test .

The maximum value of stress happened at failure point to composite specimens is known as “flexural strength “(P.K. Mallick, 2007 & E.Soliman et.al.,2015).

The values of flexural strength for specimens reinforced by (bamboo and siwak fibers) are illustrated in figures (6 &7), respectively.

The pure PMMA specimens have flexural strength equal to (69 MPa). If the pure PMMA specimens are compared with the additional reinforcing fibers, it’s found that flexural strength for both composite specimens with (bamboo and siwak) reinforcing fibers is higher than pure PMMA **. Also** the flexural strength for specimens is increase with fiber length, this can be attributed to the increasing fiber-to-fiber contact when the fibers were impregnated (M.Sumaila et.al, 2013).

When increasing the fibers weight fraction in the composite specimen leads to increasing the flexural strength. Also when the basalt fibers weight fraction reached values above limit values affect the interaction between fibers and matrix. The results of high flexural strength coming from strong interaction between fibers and matrix. The failure of composite specimens indicated the debonding between the reinforcement and matrix (P.A. Muthakkannan et.al, 2013) **. Also** can be seen from curves that flexural strength value for bamboo specimen is higher than siwak specimen **. (9%)** weight fraction and (12mm) fiber length shows the higher value for composite reinforced by both kinds of fibers. The value of flexural strength of composite specimens with bamboo fibers and siwak fibers reach (112 MPa & 101 MPa), respectively .

The relationship between flexural modulus and weigh fraction for composite specimens reinforced by bamboo fibers or siwak fibers are shown in Figures (8 & 9), respectively.

The specimens of composite reinforced by “bamboo fibers” have flexural modulus higher than the composite specimens reinforced by ”siwak fibers” because of bamboo fibers have mechanical properties higher than siwak fibers. Also, the increased the weight fraction and fiber length of (bamboo and siwak) fibers led to higher value of properties than PMMA alone (agree with Sihama I.Salih et.al, 2015) **. Flexural** modulus was (10.9 GPa & 9.71GPa) for specimens reinforced with bamboo fibers and siwak fibers, respectively at optimum condition of weight fraction (9%) and fiber lenght (12 mm) **. PMMA** resin has lower flexural modulus was (2.66 GPa), because of PMMA have higher value of extension compared with reinforcing specimens **. If** PMMA specimens are compared with that additional bamboo or siwak fibers, it is found that the improving percentage is (279 % & 265%), respectively**. Figures** (10 & 11) show the relationship between flexural strain and the weight fraction of reinforcing fibers (bamboo and siwak) in PMMA resin. It can be noticed that the flexural strain decreased when the fiber length and weight fraction of fiber increased **. It** can be seen from the figures that, PMMA matrix have the highest flexural strain value equal to (0.0259 %) while the lower value was found with specimens at (12 mm) length and (9%) weight fraction for both bamboo and siwak fibers. The flexural strain for composite specimen with bamboo fibers reach (0.0104%), while for composite specimen with siwak fibers reach (0.0111%) **. Specimens** with siwak fibers have higher flexural strain value than specimens with bamboo fibers .

Maximum Shear Strength Test

The shear test is performed according to (ASTM D2344). All data measured from three points bending test machine by using (Hydraulic press) type (Leybold Harris No. 36110) with used short beam and gradually load applied (Annual Book of ASTM Standard,1997). Figure (12 & 13) shows the standard specimen for this test and instrument of the test.

The relationship between the weight fraction of (bamboo and siwak) fibers in PMMA resin and Max. Shear stress of the specimens are shown in figures (14 & 15), respectively.

It can be noticed that when weight fraction increased lead to increasing the max.shear stress for both types of fibers and reach maximum value at (9%) weight fraction. This is due to the ability of these fibers to hinder the crack propagation inside PMMA matrix according to strengthening mechanism additionally to the strong bonding between the PMMA matrix and these fibers as a result of alkine treatment of fibers (Sihama I.Salih et.al,2015). Also, observed that the Max.Shear stress for composite specimens reach maximum value with fiber length (12mm) for both types of reinforcing fibers .
The composite specimens reinforced by bamboo fibers and siwak fibers have (6 MPa. and 4.44 MPa.) respectively at maximum condition of (12mm) fiber length and (9%) weight fraction .While the maximum shear stress for pure PMMA (2.25 MPa.) .
It can also be seen in these figures that the addition of bamboo fibers has a noticeable effect on the Max.shear stress of composite specimens more than the siwak fibers.

CONCLUSIONS

1) Pure PMMA had the lower value of flexural modulus and flexural strength which equal (2.66GPa & 69 MPa), respectively.
2) Flexural modulus, flexural strength and Max. shear stress increase with increasing weight fraction and length of fibers (bamboo and siwak) and reach the maximum amount at addition of weight fraction of (9 wt.%) and (12mm) length of fibers.
3) Flextural strain decrease with increasing weight fraction and length of fibers (bamboo and siwak) fibers.
4) The highest value of flexural modulus, flexural strength for bamboo specimens are (10.09 GPa), (112 MPa) respectively, while for siwak specimens are (9.71 GPa), (101 MPa) at optimum condition of (9wt. %) and (12mm) length.
5) The highest value of max shear stress for bamboo composite specimen are (6 MPa), while for siwak composite specimen (4.44 MPa) at (9%) and (12mm) .

Table 1: shows the properties of PMMA.

Property	Value
Brinell hardness	min. 120 Mpa.
Bending strength	min.65.5 Mpa.
Setting time	max. 7 min
Time of solubility	max. 4 min
Time required to prepare nontacky plastic mixture	4-6 min
Resistance to impact	min. 0.40 J/cm^2
Absorbability	max. 32 mg/mm^3
Solubility	max. 8 mg/mm^3

Figure1: The Powder PMMA and Monomer MMA are used in This Study.

Figure 2: Sample of Bamboo Fibers .

Figure 3: Sample of Siwak Fibers .

Figure (4): Shows the standard dimension of specimens

Figure (5): The flexural test machine .

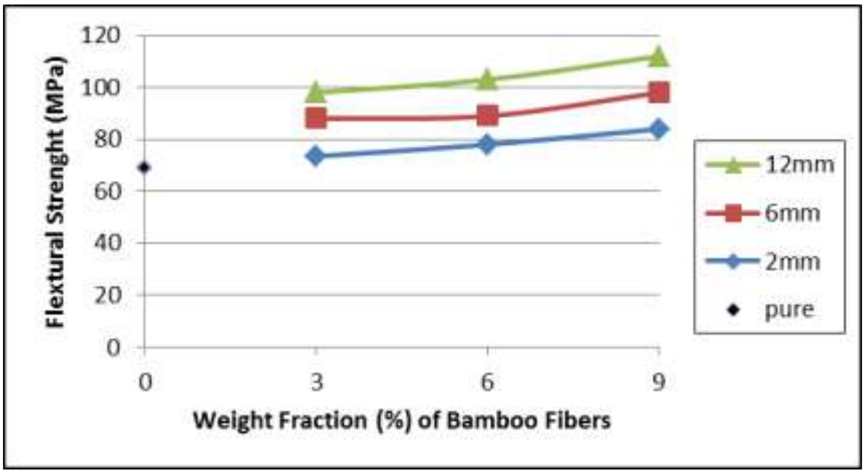

Figure (6): Flexural Strength for Composite Specimens with Weight Fraction of Bamboo Fibers .

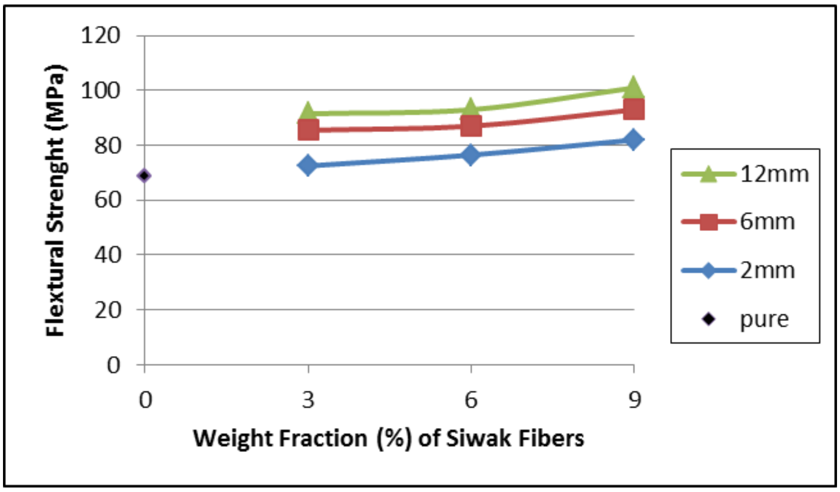

Figure (7): Flexural Strength for Composite Specimens with Weight Fraction of Siwak Fibers.

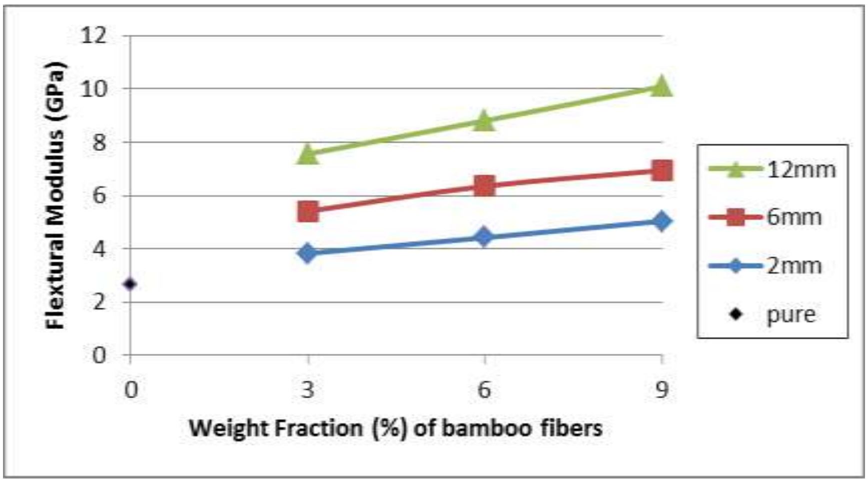

Figure (8): Flexural Modulus for Composite Specimens Having Bamboo Fibers in PMMA.

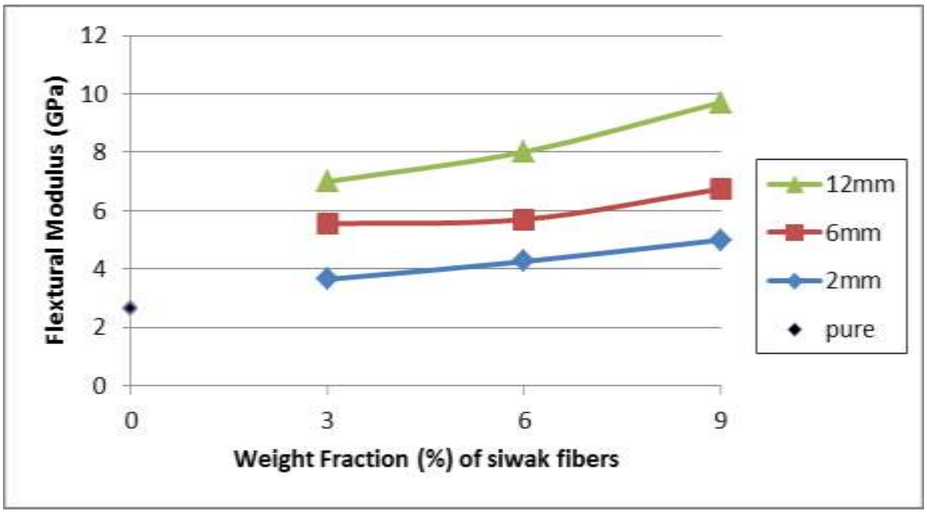

Figure (9): Flexural Modulus for Composite Specimens Having Siwak Fibers in PMMA.

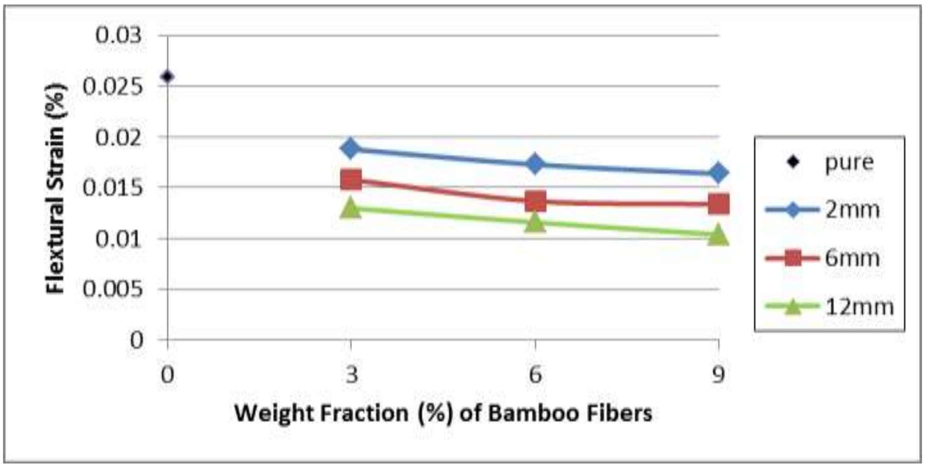

Figure (10): Flexural Strain for Composite Specimens having Bamboo Fibers in PMMA .

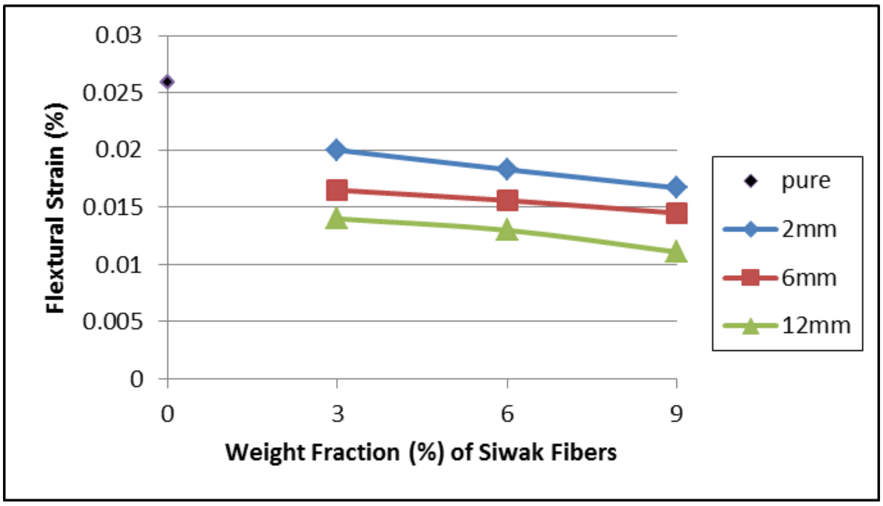

Figure (11): Flexural Strain for Composite Specimens having Siwak Fibers in PMMA.

Figure (12): Schematic Specimen for Standard Specimen of max.shear test .

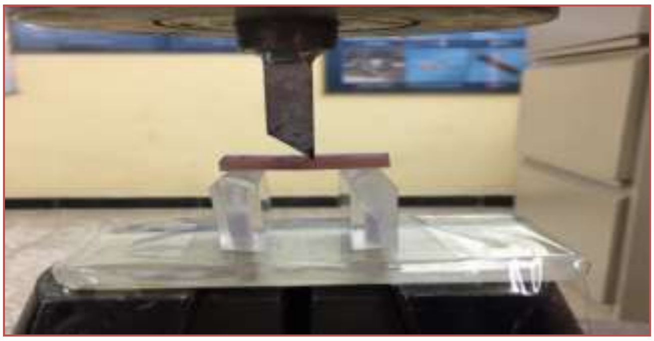

Figure (13): The max.shear test machine.

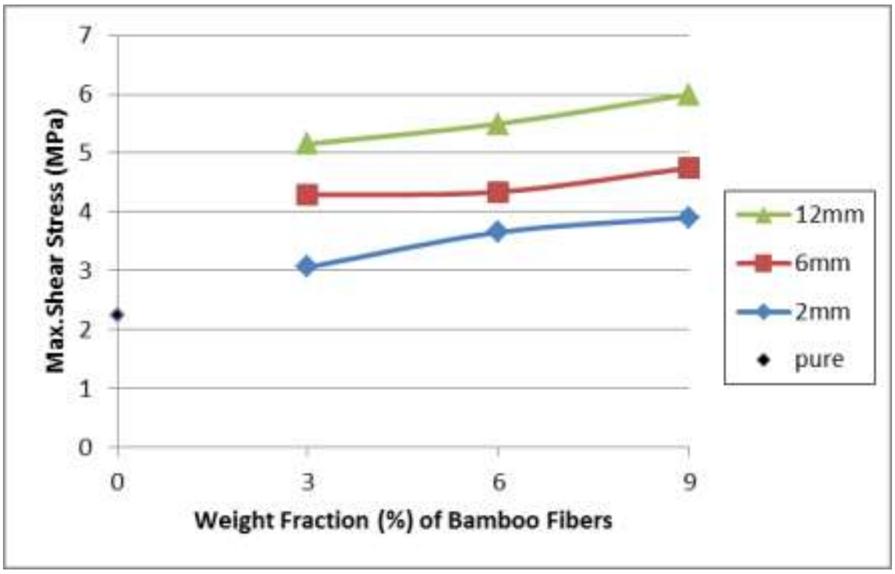

Figure (14): Max. Shear Stress for Composite Specimens with Bamboo Fibers.

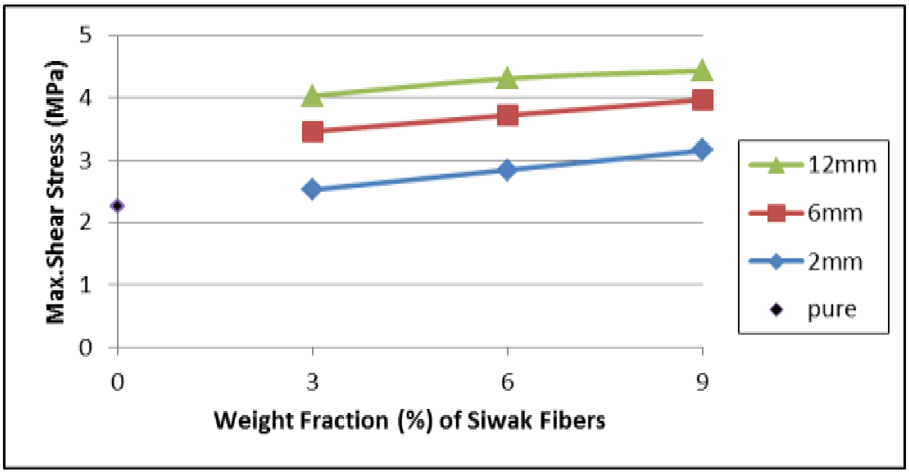

Figure (15): Max. Shear Stress for Composite with Siwak Fibers .

REFERENCES

Abdalbasit A. F., Mithaq R.M., Yasameen T. and Zainab S.,"The Effect of Incorporation of Two Different Fibers on Some Mechanical Properties of Heat Cure Acrylic Resin", MDJ, Vol.11, No.1, PP.(48-56), (2014) .

Annual Book of ASTM Standard, "Standard Test Method for Apparent Inter laminar Shear Strength of Parallel Fiber Composites byShort-Beam Method", D 2344, PP.(64), (1997) .

A.O. Alhareb, H.M. Akil and Z.A. Ahmad, "Mechanical Properties of PMMA Denture Base Reinforced by Nitrile Rubber Particles with Al2O3/YSZ Fillers." Procardia Manufacturing, Vol.2, PP.(301-306), (2015) .

A. Rahamneh,"Impact strength of acrylic resin denture base material after the addition of different fibres", Pakistan oral & Dental journal, Vol.29, NO.1, (2009) .

B.S. Jasim and I. J. Ismail , "The Effect of Silanized Alumina Nano -Fillers Addition on Some Physical and Mechanical Properties of Heat Cured Polymethyl Methacrylate Denture Base Material", Journal of Baghdad Collage of Dentistry, university of Baghdad, Vol. 26, No.2, PP.(18-23), (2014) .

D. R. Askeland and P. P. Fulay, "Essential of Materials Science and Engineering", 2nded. Cengage Learning, (2010) .

E. Soliman, U. Kandil, and M.R. Taha, "Improved Strength and Toughness of Carbon Woven Fabric Composites with Functionalized MWCNTs", materials-open access material science journal, MDPI AG, Vol.7, (2014) .

I.H. Tacir, J. D. Kama, M. Zortuk and S. Eskimez, "Flexural Properties of Glass Fiber Reinforced Acrylic Resin Polymers", Australian Dental Journal, Vol.51, No.1, pp. (52-56), (2006) .

M. Sumaila, I. Amber, and M. Bawa, "Effects of fiber length on the physical and mechanical properties of random oriented, nonwoven short banana (Musa Balbisiana) fibre/epoxy composite" , Asian J. of Nat. & Appl. Sci., Vol.2, No.1, pp.(39-49), (2013) .

N.H. Mohammed, "The effect of fiber reinforcement on tensile bond strength of acrylic denture base resin", AL-Taqani Journal, foundation of technical education, Vol.23, No. 5, PP.(59-65), (2010) .

P. A. muthakkannan1, V. Manikandan, J. T. W. Jappes and M. Uthayakumar, "Effect of fiber length and fiber content on mechanical properties of short basalt fibre reinforced polymer matrix composites", Mater. Phys. and Mech. Journal, advanced center Co., Vol.16, pp. (107-110), (2013) .

P. K. Mallick, "Fiber-Reinforced Composite: Materials, Manufacturing, and Design", International Standard Book, 3rd edition, CRC press, (2007) .

Sihama I. Salih, Jawad K. Oleiwi and Qahtan A. Hamad , "comparative study the flextural properties and impact strength for PMMA reinforced by particle and fibers for prosthetic complete denture base",The Iraqi Journal For Mechanical And Material Engineering, university of Babylon, Vol.15, No.4, (2015) .

Sihama I. Salih, Jawad K. Oleiwi and Alaa M.T," Investigation of Hardness and Flexural Properties of PMMA Nano Composites and PMMA Hybrids Nano Composites Reinforced by Different Nano Particles Materials used in Dental Applications", Engineering and Technology Journal, Vol.34, Part (A), No.15, (2016) .

Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials D790-02", Annual Book of ASTM Standard, New York, (2002) .

Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates D2344/D2344M-00", Annual Book of ASTM Standard, New York, (2000)

T. Kanie, K. Fujii , H. Arikawa, K. Inoue, "Flexural properties and impact strength of denture base polymer reinforced with woven glass fibers", Dental Materials, official publication of the academy of dental materials , Vol.16, No.2, PP.(150-158), (2000). W.J. O'Brien," Dental materials and their selection", 3rd edition, Quintessence publishing Co, Inc., pp.(216-20), (2002) .

Xu J., Li Y., Yu T., Cong L.,"Reinforcement of Denture Base Resin with Short Vegetable Fiber", Dental Materials, official publication of the academy of dental material, Vol. 29, NO.12, PP.(1273-1279), (2013).