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Mechanical Properties of PMMA-Based Biocomposites with Polyamide and Polyvinylpyrrolidone Blends for Denture Applications

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ABSTRACT

By blending heat-cured polymethylmethacrylate (PMMA) resin with two different types of polymers, which are polyamide (PV) type (6) and polyvinylpyrrolidone (PVP) type (K30), added separately with various weight fractions (0, 2, 4 and 6%) to heat-cured PMMA resin as blend matrix, attempts have been made in this study for developing the PMMA resin properties employed for prosthesis complete denture. Sisal powder and coconut powder, two different types of natural powders, were added separately to the polymer blend matrices with varying weight fractions (2%, 4%, and 6%) to prepare composite specimens. Hand lay-up methods were used for preparing all specimens. This study covered the flexural test using the 3-point bending method, the impact test using the Izod method, and the maximum shear stress test using the 3-point bending method. According to the results, adding polymer blends and reinforcing powders boosts the impact strength, while lowering flexural modulus, flexural strength, and maximum shear stress. The composite specimens made of (PMMA-2% PVP-6% sisal) manifested the best impact strength and value (11.875 KJ/m^2). These findings lead to the conclusion that using PMMA-based biocomposites with polyamide and polyvinylpyrrolidone blends improved impact strength for denture applications, which is one of the most important properties of these applications.

1. INTRODUCTION

The causes of tooth loss included dental trauma, periodontal disease, tooth rot, and others [1]. In the field of dentistry, prosthetics refers to the process of using either fixed or removable dentures, depending on a range of criteria, to replace the missing teeth that may have been lost due to several reasons [2]. Biomaterials should be nontoxic and they shouldn't trigger inflammatory or hypersensitive reactions given that they are frequently employed in biotechnology, medicine, and dentistry [3]. The four primary categories of dental biomaterials are polymers, metals, composites, and ceramics [4]. Polymeric materials have been utilized extensively in regenerative medicine due to their ease of manufacture, flexibility, biocompatibility, and good mechanical, chemical, and thermal qualities when mixed with other materials as composites [5]. The ability for producing materials with desired qualities that are challenging to obtain with plain polymers and the potential to generate such materials with lower research and development costs are the two main factors that have raised the interest in polymer blend technologies during the last 20 years. Some materials with improved mechanical qualities, chemical resistance, fracture resistance, barrier, thermal, and other properties are available due to the polymer blending technique which is a combination of two or more polymers combined for producing a novel material having various characteristics [6-9]. Utilizing composite polymer materials is essential for the expansion and increased productivity of key industries [10]. A composite material is composed of two or more materials each have unique features that are combined to create new properties that cannot be achieved by using any one of the constituent parts separately [11]. Natural materials can offer an excellent combination of beneficial features, such as rigidity, strength, and low weight when compared to materials manufactured by humans [12]. To boost the mechanical and tribological uses of polymer composites, recent years have seen a lot of interest in natural particles [13]. Small-sized natural particles have been elucidated to improve the mechanical characteristics of polymers [14]. Additionally, using natural particles creates secure and healthy working environments [15]. The literature survey includes several studies that have been conducted in this area, involving:

Salih et al. [16] added two different types of particles to PMMA resin used to prosthesis complete denture, which were nano-hydroxyapatite (nHA) particles and micro-zirconia (ZrO_2) particles mixed in various volume fractions (1%, 2%, and 3%) with (PMMA) cold-cured resin type matrix. PMMA composites were simultaneously reinforced by woven Kevlar fiber type (49) and woven glass fiber type (E-glass), both were used at a constant volume percentage of (5%). Impact, flexural, and Maximum Shear Stress tests were conducted. Results portrayed that the majority of characteristic values were augmented together by the volume percentage of nHA and ZrO_2 powders in the polymer composites, whereas the impact strength decreased. Oleiwi et al. [14] examined the effects of adding rice husk and bamboo having practical sizes (25 µm and 75 µm) and varying concentrations (2, 4, 6, and 8 wt.%)

to heat-cured acrylic resin for improving the flexural and impact properties. The findings demonstrated that the reduced particle size and high concentration improved the flexural and impact properties. Adnan Hamad [17] studied the influence of incorporating nano-silicon dioxide (nano-SiO_2) particles into polymethylmethacrylate (PMMA) resin at different volume fractions (0.5%, 1%, and 1.5%) and randomly woven fiberglass at a constant volume fraction (3%) during the flexural, impact, and shear stress tests of prosthesis complete denture base composite. According to the results, the flexural modulus, flexural strength, impact strength, and shear stress properties all raised as the volume percent of nano-silica powder increased. Al Nakash [18] examined how adding polyvinylpyrrolidone (PVP) affected the impact strength of acrylic resin that was auto-polymerized. The investigational group used 80% PMMA and 20% PVP to make their preparations. According to the study's findings, the modified auto-polymerized acrylic had no noticeable variations for impact strength. Yang et al. [19] evaluated the effect of adding polyimide (PI) to the PMMA denture base material on its flexibility. The results illustrated that compared to the control set, the supplement of (0.6%) of polyimide considerably augmented the PMMA denture base material's flexural strength via 13.5% and then reduced as the content of PI progressively increased as a result of the agglomeration of particles. Mohammed [20] analyzed the influence of adding (0%, 1%, 3%, and 5%) polyamide weight concentrations upon the impact strength of a heat-cured acrylic resin denture base material (PMMA). Experimental results depicted that polyamide has several interesting advantages, but its properties need to be enhanced beyond those of PMMA. To create a denture base with high resistance to breakage, Nylon 6 was added to PMMA. Salih et al. [21] used a blend of polymer consisting of PMMA resin as well as (2%) Natural Rubber (NR) and utilized it as a matrix reinforced via (2) nanoscale size natural powder types, including Clove Powder (CP) and Pomegranate Peels Powder (PPP) separately, with a selected weight fraction percentage of (0, 0.1, 0.3, 0.5 and 0.7 %wt.). For the two kinds of specimens of hybrid composite, the results revealed significantly higher fracture toughness, impact strength, ultimate shear stress, flexural modulus, and flexural strength values, in comparison with (PMMA: 2% NR) matrix. Hameed et al. [22] studied the effect of natural powder addition on denture base materials. Three groups of specimens were used, the first group included the control group, which consisted of 30 heat-cured PMMA specimens without additives; the second and third experimental groups each consisted of 60 heat-cured PMMA specimens with salinized sisal fiber powder, with weight percentages of 1% and 3%, respectively. The findings explained that there was no obvious change in the impact strength between the control set and the strengthened sets. And, the flexural strength was increased by the reinforcement with the natural sisal fiber powder although the impact strength was not significantly changed.

There are many problems associated with PMMA denture base. To enhance the mechanical characteristics of PMMA resin. Natural materials reinforcements have many better properties compared with nonreinforced, for example, these natural reinforcements have higher impact strength compared with PMMA resin.

The focus of this research was to enhance PMMA resin by using the polymer blending technique and additional natural reinforcement. The goal of this study is to attempt to improve PMMA properties employed for denture bases and how adding PA and PVP polymers individually to the PMMA resin matrix affects the flexural strength, flexural modulus, impact strength, and maximum shear strength properties of the polymer blend material used for dentures. Additionally, this research is conducted on how these properties of composite material are affected by adding (sisal and coconut) powder separately to the polymer blend matrix.

2. EXPERIMENTAL WORK

2.1 Materials used

Heat-cured polymethylmethacrylate (PMMA) resin was used as powder, type (Spofa Dental Company, the Czech Republic), as displayed in Figure 1. The blending materials were polyamide (PA) type (6) and polyvinylpyrrolidone (PVP) type (K30), both in white color and micrometer size. The reinforced materials were sisal powder and coconut powder, both in micrometer size, where the former has an average value of diameter (0.936 μm), while the latter has an average value of diameter (1.3195 μm). Sisal powder has a light-yellow color, as depicted in Figure 2, while coconut powder has a brown color, as revealed in Figure 3. The blend materials include PMMA resin mixed with (0, 2, 4, and 6%) weight fractions for each of the PA and PVP particles, individually. The matrix of composite materials included polymeric blends (PMMA + 2% for each PA and PVP) reinforced by sisal and coconut powder, individually, in a weight fraction of (0, 2, 4, and 6%) after being treated via a salinization treatment, where the saline agent used was 3-(Trimethoxysilyl) propyl methacrylate.

Figure 1. PMMA resin type used in the present work

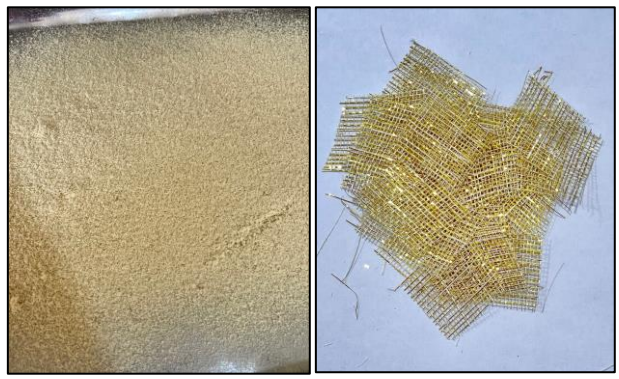

Figure 2. The sisal powder before and after the grinding process

Figure 3. The coconut powder used before and after the grinding process

2.2 Salinization treatment

30 grams of natural powder with 200 ml of toluene were placed into a glass beaker and then sonicated at room temperature for 20 minutes at 300 rpm, as shown in Figure 4(a). Then, this solution is equipped with a magnetic stirrer viewed in Figure 4(b) at room temperature for 30 minutes. 1.5 grams of saline (5% wt. of natural powder) was added dropwise by sterile syringe under a rapid stirrer, as illustrated in Figure 4(c). The glass beaker has been concealed via parafilm as well as the slurry has been soaked in the flask for 48 hr. Toluene has been eliminated via a rotary evaporator device beneath a vacuum at a temperature of 60℃ and a (150 rpm) rotational speed for thirty minutes, as evinced in Figure 4(d). Then, the modified powder was dried in a vacuum oven at 60℃ for 20 hours. After that, the powder was stored at room temperature before use.

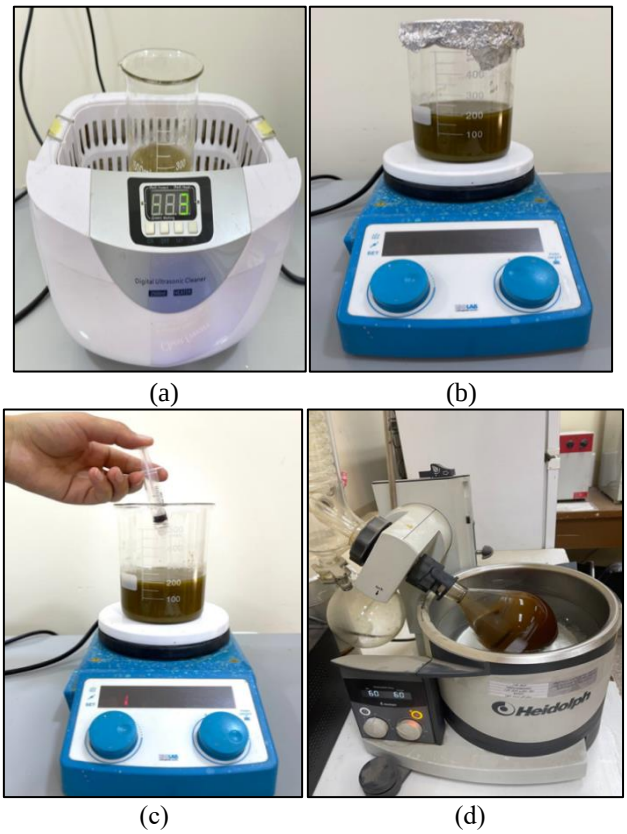

Figure 4. The sonication Treatment of sisal and coconut Powder (a) Sonication device (b) Magnetic stirrer (c) Adding saline agent to the solution, and (d) Rotary evaporator device

2.3 Preparation method of specimens

The standard ratio of 2.25:1 (powder:liquid) has been used to combine the heat-cured polymethylmethacrylate (PMMA) as powder and methyl methacrylate (MMA) as liquid, respectively. The PMMA powder was continuously mixed at room temperature with one type of blend powder (Polyamide (PA) and Polyvinyl pyrrolidone (PVP)) at weight fractions of (0, 2, 4, and 6%), and then the blend matrix was mixed with one type of reinforcing natural powder (Sisal and Coconut) at weight fractions of (2, 4, and 6%) then adding this mixture to the liquid monomer (MMA). The mixture was then mixed in a glass beaker and constantly shaking, and the beaker was finally concealed and kept for (20 min) under the guidance of the manufacturer, that's where the samples are shaped via (the hand lay-up) technique. The mold was concealed via a metallic plate and secured via ten screws for obtaining the required pressure recommended, which was (2.5 bars). The mold was positioned in a path of water where the temperature of water gradually raised till it reached (70℃) for (30 min) and remained at such temperature for around (30 min), then this temperature gradually raised till it reached 100℃ during 30 min, and such temperature installed for another 30 min. After that, the mold was removed from the path of water and left on the open air-track for some hours, where it was cooled gradually.

3. EXPERIMENTAL TESTS

The impact, flexural, and maximum shear strength tests were done for evaluating the fracture toughness properties for polymer blend and composite specimens.

3.1 Flexural test

Materials properties, like the resistance to fracture as well as the elasticity, beneath the stress, are assessed by obtaining the fracture toughness, flexural modulus, and flexural strength properties [23]. This test was carried out following the standard (ASTM D790). The whole data was measured from 3-Point Bending Testing Machine via employing the alike tensile testing machine at room temperature (25 ± 2℃), the number of specimens used in this test is (5) and using a (5 $mm.min^{-1}$) cross-head speed (strain's rate) and an exerted load equal to (5 kN) until breaking the specimen occur [24]. Figure 5 views the standard specimens of the flexural test and the specimens before and beyond the flexural test [25]. The sample's flexural modulus (E_B) and flexural strength (F.S) are obtained from the subsequent formulas [26]:

$$F.S = 3ps / 2bt^2 \quad (1)$$

$$E_B = \frac{mL^3}{4bt^3} \quad (2)$$

where:
S: The span that means the distance between the sample's (2) supported points of (mm).
(t & b): The specimen's thickness and width, correspondingly (mm).
p: The exerted load (N).
m: The slope of the tangent in the Load-Deflection curve (N/mm).

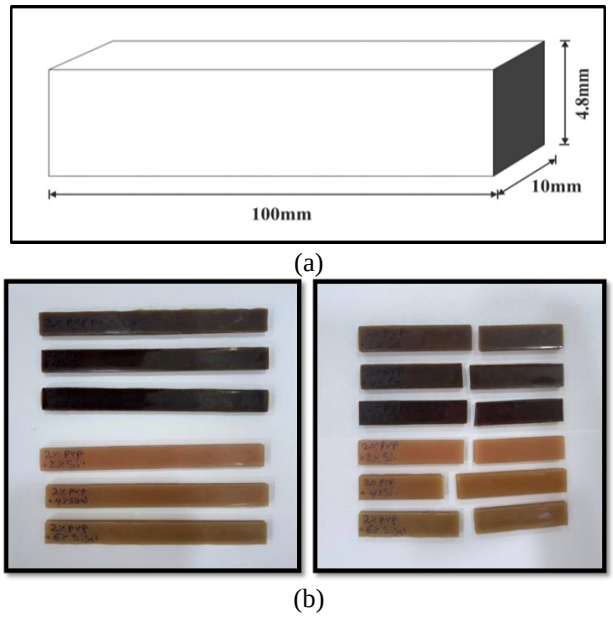

Figure 5. (a) The standard specimen of a flexural test [23], and (b) Specimens before and beyond the flexural test

3.2 Impact test

The force of impact can be well-defined as an elevated force or a shock exerted over a short time. This force may be created in a body via the moving bodies' collision or easily via the abrupt force exertion or motion to the body [27]. This test was conducted following the standard ISO-180 via employing Izod impact testing equipment (Type XJU series pendulum Izod/Charpy equipment). In the test of Izod, a specimen was fastened at a single termination as well as positioned perpendicularly cantilevered beam and it was fractured at a (5.5 Joul) pendulum impact energy and a (3.5 m/s) impact speed. Also, this test was performed at room temperature (25 ± 2°C) and the number of specimens used in this test is (5) without notching upon the specimens [28]. Figure 6 presents the standard specimen of the impact test and the specimens before and beyond the impact test [29]. Impact strength (I.S.) is calculated by applying the relationship [30]:

$$\text{I.S.} = \frac{U_c}{A} \quad (3)$$

$$A = b \times t \quad (4)$$

where:
U_c: The fracture energy (KJoule) which is determined from the Charpy impact test instrument.
A: The cross-sectional area of the specimen.

3.3 Maximum shear strength test

In this test, a shear force tends to create a sliding failure upon a specimen alongside a plane parallel to the direction of the shear force. And, such a test was achieved following the standard (ASTM D2344). The whole measured data from a 3-point bending test device was obtained at room temperature (25 ± 2°C) and the number of specimens used in this test is (5) via utilizing a hydraulic press (Type Leybold Harris No. 36110) employing a short beam as well as applying gradually a load till the occurrence of specimen fracture [31]. Figure 7 shows the standard specimen of the maximum shear strength test and the specimens before and after the maximum shear strength test [32]. The sample's shear stress (τ_{max}) is obtained from the subsequent formula [26]:

$$\tau_{max} = 3p / 4bt \quad (5)$$

where:
(t & b): The specimen's thickness and width, correspondingly (mm).
p: The exerted load (N).

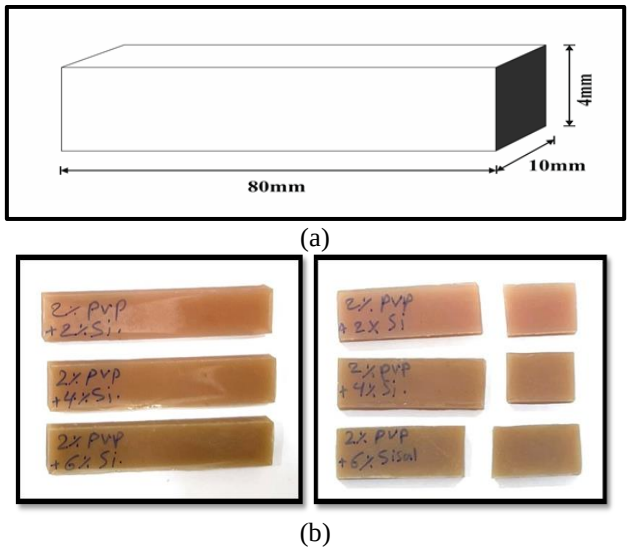

Figure 6. (a) The standard specimen of the impact test [29], and (b) Specimens before and beyond the impact test

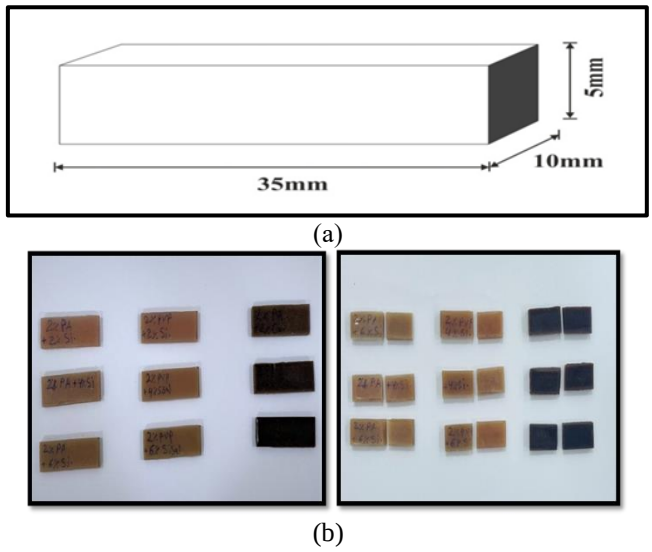

Figure 7. (a) Standard specimen of maximum shear strength test, and (b) Specimens before and beyond the maximum shear strength test

4. RESULTS

4.1 Results of flexural text

4.1.1 Results of the flexural strength

The relation between the weight percentage of (PA and PVP) in PMMA resin and the specimens' flexural strength is depicted in Figure 8. As the weight fraction of the two blend

kinds increased, it was observed that the flexural strength values decreased. This is because the flexural strength of denture base material reduced owing to the particle aggregation when PVP content increased and when PA content increased as well [19]. Additionally, it is clear from this figure that the addition of PA has a more pronounced influence than the addition of PVP on the flexural strength of composite specimens. This is because adding PA particles improves the mechanical characteristics of the material. The value of flexural strength is therefore decreased from (108.8 MPa) for (pure PMMA) to (71.3 MPa) for (PMMA-6% PVP).

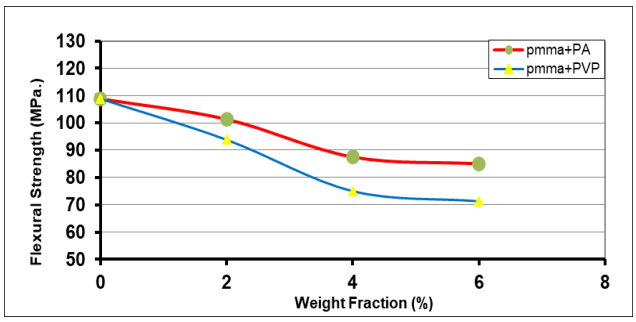

Figure 8. Flexural strength of polymer blend as a function of PA and PVP

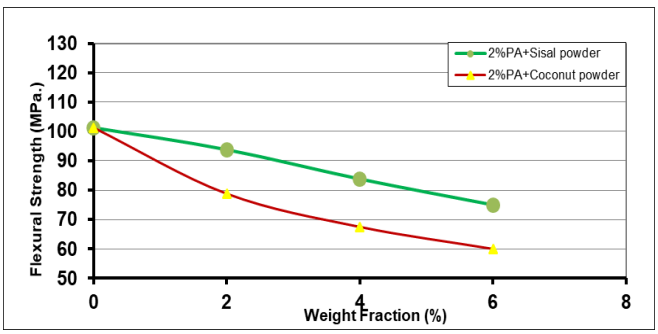

Figure 9. Flexural strength of 2% PA-PMMA composite as a function of sisal and coconut powder

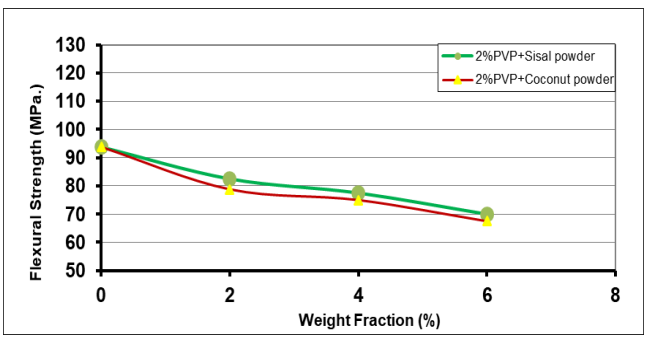

Figure 10. Flexural strength of 2% PVP-PMMA composite as a function of sisal and coconut powder

Figures 9 and 10 display the correlations between the composite specimens' flexural strength and the sisal and coconut powder weight fraction for the 2% PA-PMMA and 2% PVP-PMMA blend matrix, respectively. As can be observed, the flexural strength of composite materials reduces when the sisal and coconut powders are added in weight fractions. Because the sisal and coconut powders have lower flexural strengths than the matrix, in this case, as a result, the composite specimens' flexural strength is reduced, where the composite flexural strength weakens as the percentage of coconut content rises [33]. Also, the composite flexural strength decreases with increasing the sisal powder's weight fraction [34]. Additionally, Figures 9 and 10 elucidate that the specimens' flexural strength values when sisal powder is added are higher than those for flexural strength when coconut powder is added. This is because the addition of sisal powder to composite specimens improves their mechanical properties. Thus, the composite made of PMMA, 2% PA, and 6% coconut has a lower value of flexural strength (60 MPa).

4.1.2 Results of the flexural modulus

The (PA and PVP) weight percentage in PMMA resin and the specimens' flexural modulus are related, as manifested in Figure 11. As the weight fraction of both types of blends increased, it was observed that the values of flexural modulus decreased. Polyamide had a lower flexural modulus than PMMA material [35]. Additionally, it is clear from this figure that the addition of PA has a more pronounced impact than the addition of PVP on the composite specimens' flexural modulus. The value of flexural modulus is decreased from (4.05 Gpa) for (pure PMMA) to (2.362 GPa) for (PMMA-6% PVP).

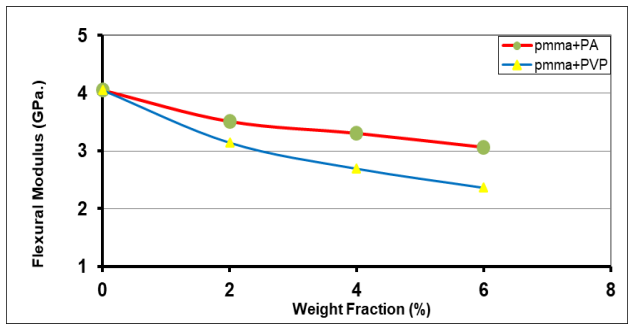

Figure 11. Flexural modulus of polymer blend as a function of PA and PVP

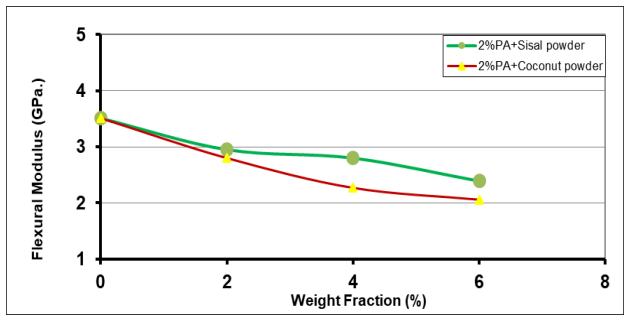

Figure 12. Flexural modulus of 2% PA-PMMA composite as a function of sisal and coconut powder

Figures 12 and 13 exhibit the relations between composite specimens' flexural modulus and sisal and coconut powders' weight fraction for the 2% PA-PMMA and 2% PVP-PMMA blend matrix, respectively. As can be observed, the flexural modulus of composite materials reduces when the sisal and coconut powders are added. Because sisal and coconut powders have lower flexural strengths than matrix, in this case, as a result, the composite specimens' flexural strength is reduced, where the flexural strength of the composite weakens as the percentage of coconut content rises [33]. Also, the composite flexural modulus decreases by increasing the sisal powder's weight fraction [34]. Additionally, Figures 12 and 13

appear that the specimens' values for flexural strength when adding coconut powder are higher than those for flexural modulus when sisal powder is added. This is because the addition of sisal powder to composite specimens improves their mechanical characteristics. Thus, the composite made of PMMA, 2% PA, and 6% coconut has a lower value of flexural modulus (2.06 GPa).

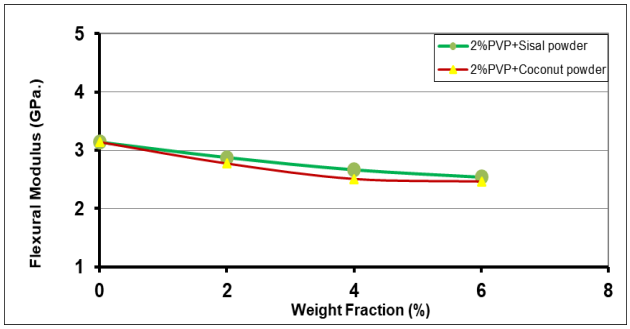

Figure 13. Flexural modulus of 2% PVP-PMMA composite as a function of sisal and coconut powder

4.2 Results of the impact strength and fracture toughness

One significant dynamic mechanical test that exposes the specimen to a rapidly moving load is the impact test. The energy required (Uc) to fracture the specimen, which was measured by the test device, and the flexural modulus (EB) that was obtained from the flexural test can be used to compute the impact strength (Gc) as well as the fracture toughness (Kc) of composite materials from this test. The relation between the weight percentage of PA and PVP in PMMA resin and the specimens' impact strength is revealed in Figure 14. It is obvious that the values of impact strength increased as the two blends' weight fraction increased. This is because PMMA, the basic material for dentures, has lower impact strength than PA [36]. As the weight ratio of PVP content increased, the impact strength values also increased [37]. Additionally, Figure 14 evinces that the impact strength values for composite specimens made of (PA-PMMA) are higher than those for composite specimens made of (PVP-PMMA). This is because the PA particles, as opposed to PVP particles, have a higher mechanical strength. As a result, the impact strength value for the composite of PMMA and 6% PA rose from 5 kJ/m² for PMMA (as specified) to 10.5 kJ/m².

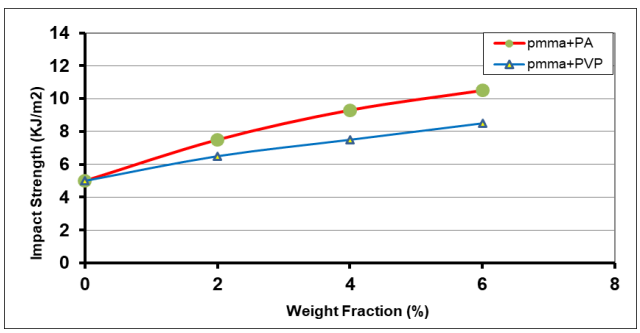

Figure 14. Impact strength of polymer blend as a function of PA and PVP

It can be seen that adding sisal or coconut powder to the blend matrix in composite material increases the impact strength for blend matrix composite, as illustrated in Figures 15 and 16, which respectively show the relation between the weight fraction of sisal and coconut powders for each of the 2% PA-PMMA and 2% PVP-PMMA blend matrix composite. And, this can be explained by the truth that the sisal and coconut powders have higher impact strength than blend matrices, which improved the composite specimens' impact strength. Also, the composite impact strength increases with an increment in the percentage of coconut because the higher compactness of composites is attained for the higher percentages of coconut, which produces the highest impact strength at a 6% weight fraction [33, 38]. Additionally, these figures indicate that for all composite materials, the impact strength values increased as the sisal and coconut powders' weight fraction increased. This is because they can withstand the impact loads better than the blend matrix materials. As a result, the impact strength of the composite (PMMA-2% PVP-6% sisal) increased to a higher value (11.875 kJ/m²).

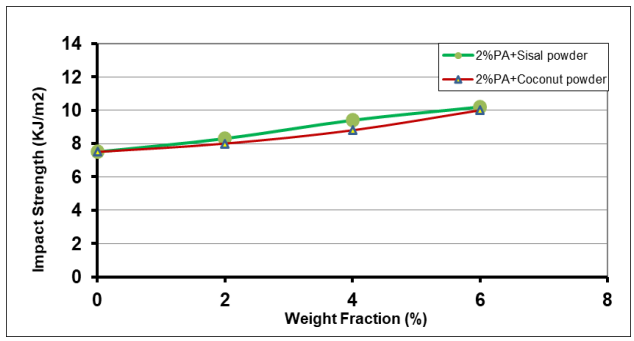

Figure 15. Impact strength of 2% PA-PMMA composite as a function of sisal and coconut powder

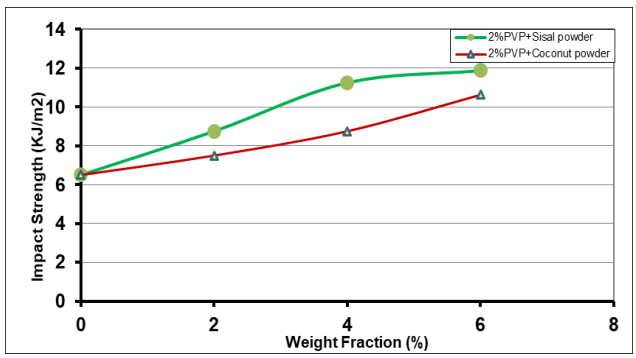

Figure 16. Impact strength of 2% PVP-PMMA composite as a function of sisal and coconut powder

Figure 17 depicts the relation between the weight fraction of (PA and PVP) in PMMA resin and fracture toughness. It is obvious that the fracture toughness values augmented as the PA weight fraction in PMMA resin raised; however, they marginally dropped as the weight fraction of PVP in the PMMA resin increased. This is because Figure 14, which shows how fracture toughness depends on the impact strength and flexural modulus values, also depicts how fracture toughness behaves similarly to how it does in this figure. Additionally, the addition of PA improves the composite specimens' ability to withstand fracture, whereas the addition of PVP makes them less resilient to fracture. Owing to the nature of PA particles, which possess a higher fracture toughness than PVP particles and have little to no effect on the fracture toughness, the mechanical properties associated with the inclusion of PA particles have improved. As a result, the

PMMA-6% PA blend's fracture toughness values increased from (4.5 MPa.m) for PMMA (as referenced) to (5.672 MPa.m).

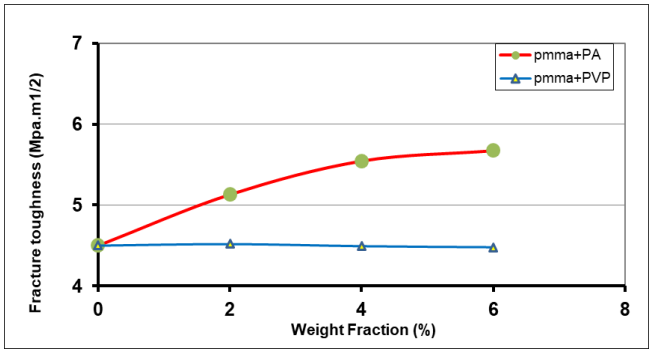

Figure 17. Fracture toughness of polymer blend as a function of PA and PVP

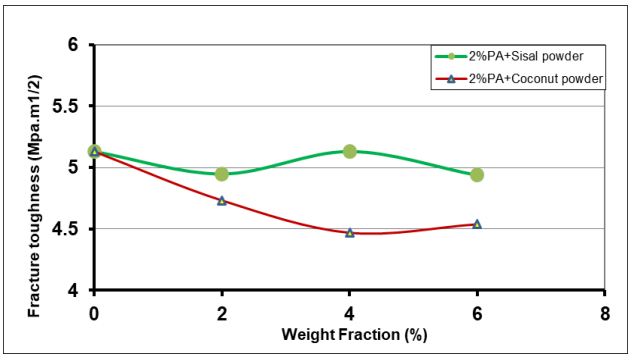

Figure 18. Fracture toughness of 2% PA-PMMA composite as a function of sisal and coconut powder

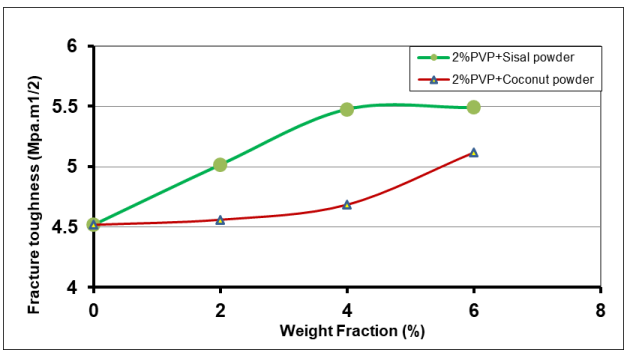

Figure 19. Fracture toughness of 2% PVP-PMMA composite as a function of sisal and coconut powder

Figures 18 and 19 portray the relation between the fracture toughness of the composite specimens and the weight fraction of sisal and coconut powders for the 2% PA-PMMA and 2% PVP-PMMA blend matrix, respectively. These figures demonstrate that the fracture toughness values dropped when the sisal and coconut powder containing 2% PA-PMMA was added; however, the fracture toughness values increased when the sisal and coconut powder containing 2% PVP-PMMA was added. This is a result of the fracture toughness being dependent upon the impact strength as well as flexural modulus values.

Figure 18 also shows that the values of fracture toughness somewhat decreased when the weight fraction of sisal and coconut powders in the composite specimens (2% PA-PMMA) increased. In general, the sisal powder reinforced (2% PA-PMMA) composite specimens had greater fracture toughness values than the PVP-PMMA (2% PA-PMMA) composite specimens with the coconut powder reinforcement. While (4% coconut 2% PA-PMMA) composite specimens have the lowest fracture toughness compared to other fractions, and (4% sisal 2% PA-PMMA) composite specimens have the highest fracture toughness. When the weight percentage of sisal or coconut powders is increased, the wettability and mixing between the (PA-PMMA) matrix and reinforcing material decreased, which results in a decrease in the adhesion force between these reinforcing materials and matrix, ultimately leading to a decrease in fracture toughness. In contrast, the increase in fracture toughness can be attributed to the (PVP-PMMA) matrix's increased adhesive force with the reinforcing material. Figure 19 further displays that the fracture toughness values are generally augmented by raising the sisal and coconut powders' weight fractions in composite specimens made from 2% PVP-PMMA. When 2% PVP-PMMA composite specimens reinforced with sisal powder are used, the values of fracture toughness are higher than when using coconut powder. This is because the addition of sisal powder to composite specimens improves their mechanical properties. The composite made of (PMMA-2% PVP-6% sisal) has the greatest value of fracture toughness (5.49 MPa.m).

4.3 Results of the maximum shear stress

Figure 20 elucidates the relation between the maximum shear stress of the specimens and the weight percent of PA and PVP in PMMA resin. As the weight fraction of both types of blends increased, it was observed that the values of maximum shear stress decreased. This is a result of the poor bonding between the components of blends, and the drop may also be brought on by the fact that PA and PVP particles have lower maximum shear stresses than the PMMA matrix. Where PA needs modification processes for producing consistently better properties than PMMA resin [35]. PVP has lower maximum shear stress at a weight fraction lower than 8% [39]. For composite (PMMA-6% PVP), the lower value of maximum shear stress is (5.06 MPa), while pure PMMA has a maximum shear stress value (7.312 MPa).

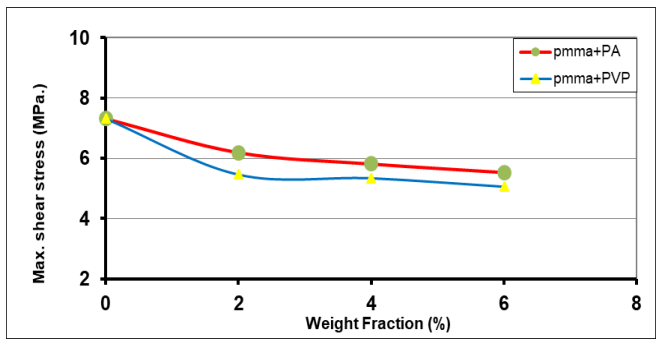

Figure 20. Maximum shear stress of polymer blends as a function of PA and PVP

Figures 21 and 22 exhibit the relation between the weight fraction of sisal and coconut powders for each of the (2% PA-PMMA) and (2% PVP-PMMA) blend matrices and the maximum shear stress of composite specimens, respectively. And, the maximum shear stress is shown to diminish when the weight fractions of sisal and coconut powders are added to the

composite materials. The sisal and coconut powders may have a lesser binding strength between the fibers and matrix, which could explain this. Figures 21 and 22 also manifest that for the composite materials, the values of maximum shear stress dropped as the weight fraction of sisal and coconut powders increased. This is because each particle of (coconut and sisal) has a lower maximum shear stress than the matrix.

Additionally, these figures demonstrate that, with each increase in the weight fraction of sisal or coconut powder, the values of maximum shear stress for the composite specimens blended by PA are higher than those of the maximum shear stress for the composite specimens blended by PVP. This is a result of the enhancement in mechanical properties brought on by the addition of PA particles. Additionally, Figures 21 and 22 demonstrate that the maximum shear stress values for the specimens when the sisal powder is added are higher than the maximum shear stress values for the specimens when the coconut powder is added. This is because the addition of sisal powder to composite specimens improves their mechanical properties. Therefore, the composite (PMMA-2% PVP-6% coconut) has a lower maximum shear stress value of (4.125 MPa).

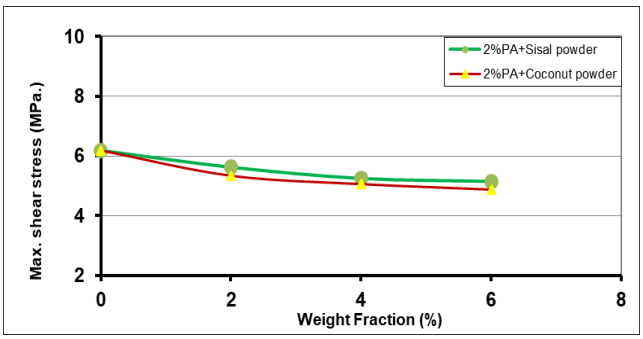

Figure 21. Maximum shear stress of 2% PA-PMMA composite as a function of sisal and coconut powder

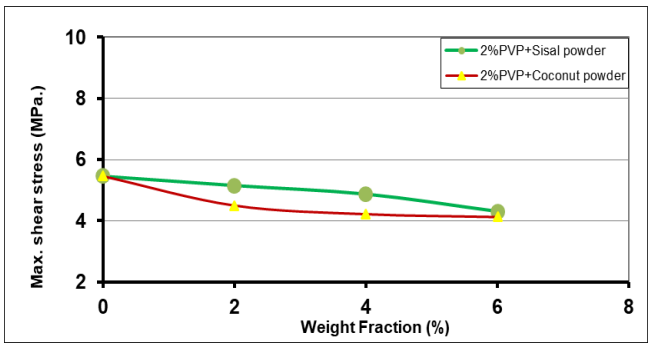

Figure 22. Maximum shear stress of 2% PVP-PMMA composite as a function of sisal and coconut powder

5. CONCLUSION

The study was performed on a denture base, which is used to compensate for missing teeth that may have been lost due to several reasons. Nineteen samples were prepared using a polymer blend consisting of PMMA with (PA and PVP) as matrix and the reinforcement powders were (sisal and coconut), and the most important tests for denture base were performed. To select the appropriate sample for fabricating the denture base, the following has been obtained:

- The impact strength of polymer blends and composite materials was increased by raising the (PA, PVP, Coconut, and Sisal) particles' weight fraction. And, the ultimate values of impact strength properties were (11.875 kJ/m²) for the (PMMA-2% PVP-6% sisal) composite materials.
- The flexural strength, as well as flexural modulus of polymer blends and composite materials, were reduced by raising the (PA, PVP, Coconut, and Sisal) particles' weight fraction. And, the lower value of flexural strength and flexural modulus were (60 MPa, 2.06 GPa), respectively, for (PMMA-2% PA-6% coconut) composites.
- The maximum shear stress of polymer blends and composite materials was reduced by raising the (PA, PVP, Coconut, and Sisal) particles' weight fraction. Also, the lower value of the maximum shear stress was (4.125 MPa) for (PMMA-2% PVP-6% coconut) composites.

We have found that the flexural and maximum shear stress properties decreased with increasing concentrations of materials used in this study. Wherefore, from the study outcomes, a complementary contemplation of the effect of matrix and natural reinforcing materials used in this study on the physical and thermal properties of the denture base may be accomplished for future research.

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