

Mechanical and Numerical Analysis of Polymer-Natural Fiber Composites for Denture Applications



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ABSTRACT

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Removable complete dentures are still a therapy of choice for a variety of medical professionals and patients even in an era of implant and fix prostheses. This article focuses on comparing complete dentures manufactured using various denture base materials. Heat-cured polymethylmethacrylate, used for prosthetic complete denture composites, was blended separately with Polyamide (PA) type 6 and Polyvinylpyrrolidone (PVP) type K30. These blends were prepared with various weight fractions (0%, 2%, 4%, and 6%) and reinforced with sisal and coconut powders, each added individually with varying weight fractions (2%, 4%, and 6%). The tensile test was carried out to achieve tensile strength, modulus of elasticity, and elongation percentage values. The numerical part depends on the Finite Element Method (FEM), conducted by using Ansys Workbench-2020 R2. According to the experimental data, the tensile strength, elastic modulus, and elongation of polymer blends increase at a 2% weight fraction of PA and PVP particles, and then decrease with higher PA and PVP particles' weight fraction. However, they decrease with increasing weight fraction of coconut and sisal particles. The highest tensile strength and elastic modulus are 86 MPa and 2.531 GPa, respectively, for PMMA-2% PA, and the greatest elongation percentage is 5.28% for PMMA-2% PVP. These findings lead to the conclusion that the addition of polymer blend materials to PMMA resin is a promising approach for improving tensile properties in applications such as complete or partial denture bases, addressing an ongoing challenge.

1. INTRODUCTION

A manufacturing device called a denture is used for replacing the missing teeth [1]. In the medical and dental professions, there are numerous biomaterials available [2]. Polymeric-based material is often used in the manufacture of dentures [3]. Acrylic resin is the polymer that is most frequently employed in biomedical and dental applications, especially as denture base materials [4]. When reinforced with several particles or fibers, the properties of polymethylmethacrylate are altered [5]. Numerous studies have been conducted on denture bases made of composite materials prepared from different particles and a matrix of the polymer [6]. Natural materials can offer an excellent combination of beneficial features when compared to materials manufactured by humans [7, 8]. To enhance the mechanical properties of polymer composites, researchers have increasingly turned their attention to natural particles in recent years, aiming to create secure and healthy working environments [9, 10]. Particularly in the area of dental care, finite element numerical analysis has been increasingly effective. Numerical simulation can, as a first step, offer a solution for the dentures' efficient operation and enable the validation of various theories relating to the incidence of denture fractures [11, 12]. The literature survey includes several studies that have been conducted in this area, involving

Craciunescu et al. [13] who used PMMA (polymethylmethacrylate resin) or polyamides to create partial dentures and simulate the solid bodies' conduct beneath the thermal or structural burdening circumstances by using a three-dimensional CAD solid geometry in combination with ANSYS. Also, the FEA was automated by ANSYS, which produced the outcomes stated. Barão et al. [14] used four edentulous mandibular models: (1) a complete denture, (2) an over-denture supported via two splinted implants and a bar-clip regime, (3) an over-denture supported via two unpainted implants and an O-ring regime, and (4) an over-denture supported via two splinted implants and a bar-clip and two distally located O-ring systems. Besides, a perpendicular stress of 100 N was exerted using the Ansys software. An over-denture supported via two unpainted implants displayed the lowermost ultimate stress magnitudes. Salih et al. [15] added nano-hydroxyapatite (nHA), micro zirconia (ZrO₂), with 1%, 2%, and 3% volume fractions, and the different types of woven fibers-Glass fiber, Kevlar fiber-was added with 5% to PMMA composites. Computational analysis based on the FEM method of the PMMA composite denture materials was carried out using ANSYS-15. Several investigational outcomes agreed with the FEA numerical outcomes. Cheng et al. [16] used 3D FEA and evaluated the strain distribution in dentures through the use of occlusal stress FEA, and a 230 N occlusal force was applied to the posterior teeth. The denture

fracture during the clinical service is probably caused by the elevated concentration of tensile strain at the incisal notch.

The objective of this study is to fabricate the complete lower denture from new composite material using hand layup method. This new composite consists of PMMA-PA and PMMA-PVP polymer blends as matrix, separately reinforced by sisal and coconut powder. Additionally, this research is being done to how tensile properties of composite material are affected by adding sisal and coconut powder separately to the polymer blend matrix. Whereas, the numerical analysis of such denture via employing FEM for confirming the investigational outcomes is performed via utilizing a program Ansys Workbrnch-2020 R2.

2. EXPERIMENTAL WORK

2.1 Materials used



Figure 1. PMMA resin type used in the present work

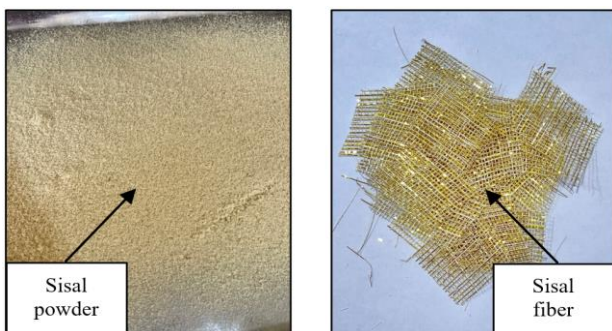


Figure 2. The sisal powder before and after the grinding process

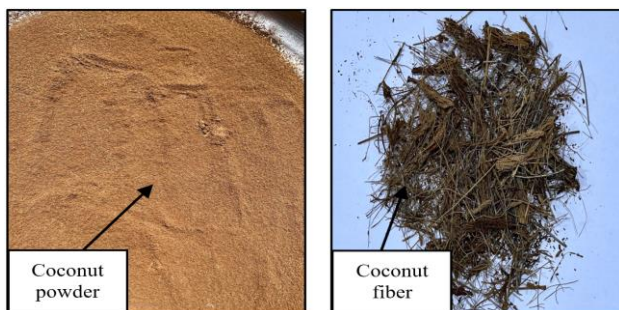


Figure 3. The coconut powder used before and after the grinding process

PMMA material was used as powder, type (Spofa Dental Company, the Czech Republic), as displayed in Figure 1. The blending materials were polyamide and polyvinylpyrrolidone, both in white color and micrometer size. The reinforced materials were sisal powder and coconut powder, both in micrometer size, where the former had an average value of diameter of 36 μm , while the latter had an average value of diameter of 195 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 included 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.

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 min, as shown in Figure 4(a). Then, this solution is equipped with a magnetic stirrer viewed in Figure 4(b) at room temperature. 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 was covered with Parafilm, and the slurry was left to soak in the flask for 48 h. Toluene has been eliminated via a rotary evaporator device beneath a vacuum at a temperature of 60°C 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°C for 20 h. After that, the powder was stored at room temperature before use.

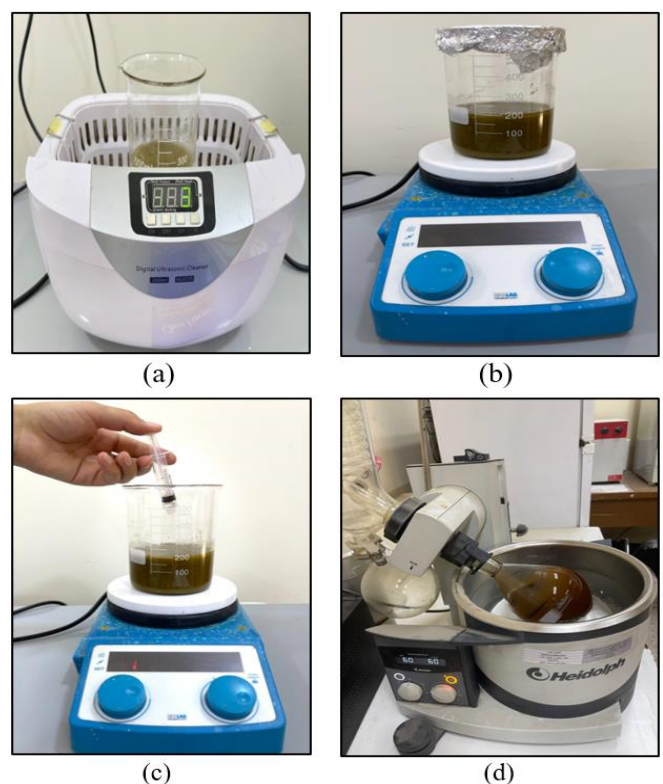


Figure 4. The sonication treatment of sisal and coconut powder: (a) sonication device (b) magnetic stirrer (c) adding saline agent to the solution, and (d) rotary evaporator device

2.3 Preparation method of specimens

The standard ratio of 2.25:1 (powder: liquid) has been used to combine the acrylic powder (PMMA) and liquid monomer (MMA), respectively. The PMMA powder was continuously mixed at room temperature with one type of blend powder (Polyamide and Polyvinyl pyrrolidone) at each time, and then the blend matrix was mixed with one type of reinforcing natural powder, i.e., sisal and coconut, at each time before adding this mixture to the liquid monomer MMA. The mixture was mixed in a glass beaker while being constantly shaken. Subsequently, the beaker was covered and left for 20 min, following the manufacturer's instructions. This is the point at which the samples are shaped using 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 placed in a water path where the temperature gradually increased to reach 70°C over 30 minutes and was maintained at this temperature for approximately 30 minutes. Subsequently, the temperature was gradually raised to reach 100°C over a span of 30 minutes, and it was held at this temperature for an additional 30 minutes. 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. TENSILE TEST OF SAMPLES

The tensile test is a significant conventional material testing method for evaluating the toughness and strength of polymers. In this test, a sample is subjected to tension until it reaches failure [17]. Tensile tests are useful for assessing the material quality and comparing them when the designers have to select one among several grades available in the market [18].

This tensile test was carried out at the lab temperature 25±2°C via employing universal testing equipment Type Instron available in the Department of Materials Engineering at the University of Technology. The machine was equipped with a load cell (5 KN), operated at a strain rate of (5 mm.min⁻¹), a gauge length of (60±0.5), and a total of 3 specimens were utilized for each proportion added. In total, 57 specimens were subjected to this test, with a gradual application of tensile load until fracture occurred. Then, the specimens were prepared according to the standard ASTM D638-03. The standard tensile test specimen is displayed in Figure 5(a), while specimens of the tensile test and universal testing machine are displayed in Figure 5(b) and Figure 5(c), respectively [19, 20]. The tensile properties (tensile strength, elastic modulus, and elongation percentage) can be calculated according to the following equations [21]:

$$\sigma = P / A \quad (1)$$

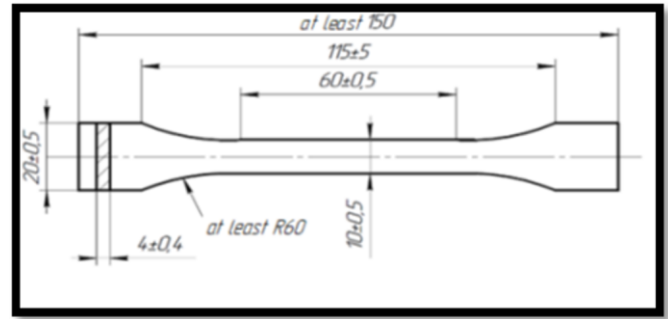
where, σ : is tensile strength (MPa); A : Original cross-sectional area of the specimen (m²); P : The applied force (N).

$$\varepsilon = (L_f - L_o) / L_o \quad (2)$$

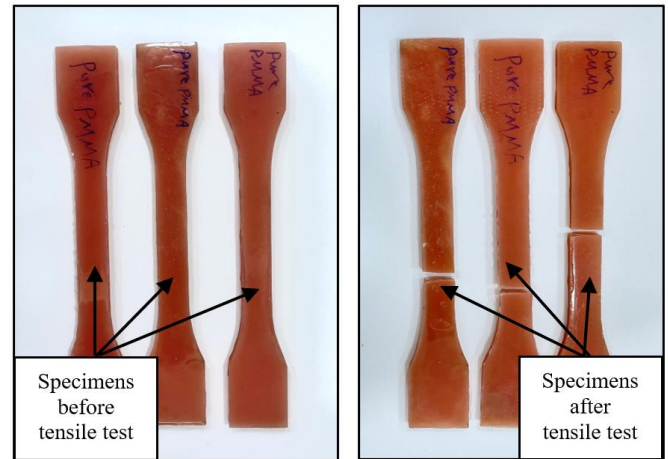
where, ε : strain (%); L_f : Final gauge length of the specimen (mm); L_o : Original gauge length of the specimen (mm).

$$E = \sigma / \varepsilon \quad (3)$$

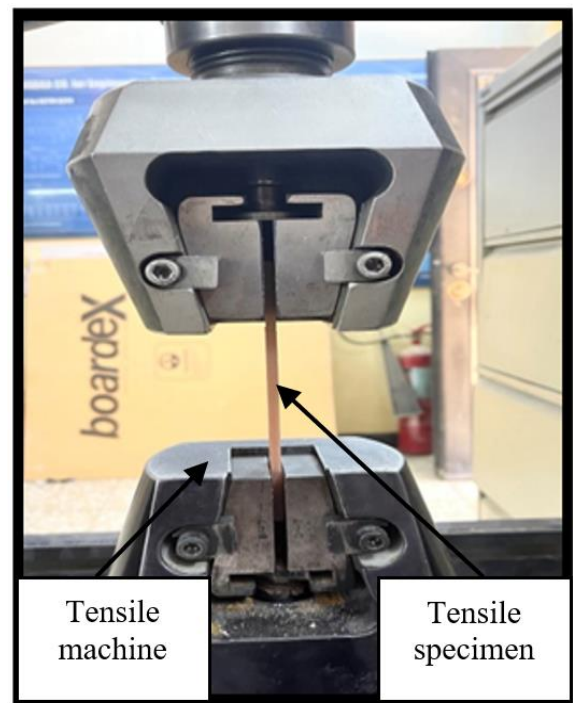
where, E : Young's modulus (GPa).



(a)



(b)



(c)

Figure 5. (a) Representation of the standard specimen of the tensile test [20], (b) Investigational specimens of the tensile machine prior as well as beyond the test, and (c) Universal testing machine

4. NUMERICAL ANALYSIS OF DENTURE

The numerical simulation-based methods take a significant part in engineering research due to their unique features, like rapid process, low price, and dependable performance [22]. And, the wide analysis via employing Ansys possesses three separate steps: the first step is building the geometry as a model, the second step is stratifying the boundary conditions load and attaining the solution, and lastly the third step is revising the outcomes [23]. This research developed the models of numerical simulation for various characteristics like deformation, strains, stresses, and factors of safety utilizing the ANSYS-2020 R2 package software under static loads.

4.1 Analysis procedure

4.1.1 The geometry

A three-dimensional finite element model of a lower complete denture is constructed in the ANSYS program using the actual geometrical dimensions of the prosthetic denture. Using Auto CAD software, the lower complete denture's x, y, and z measurements were taken and recorded. According to Figure 6, the lower complete denture geometry was generated for the Ansys Workbench-2020 R2.

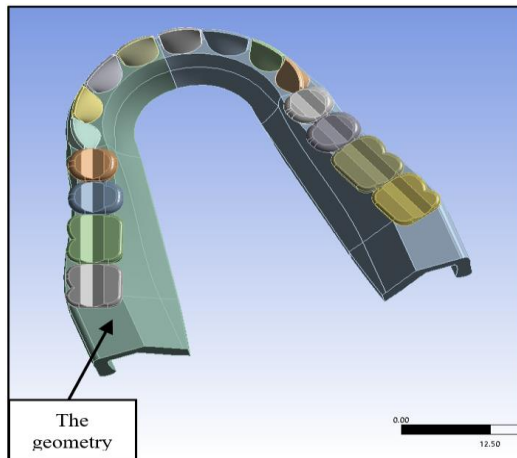


Figure 6. The complete prosthetic lower denture's FE model

4.1.2 Mesh generation

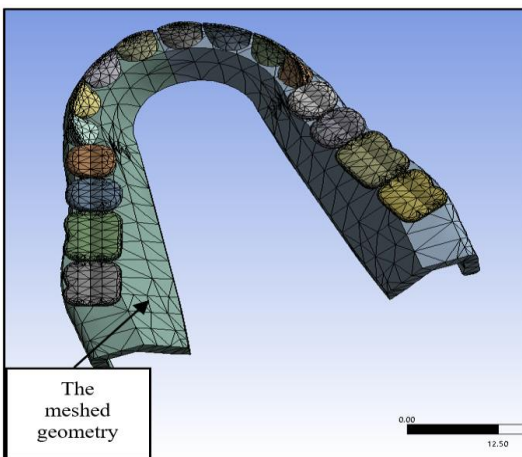


Figure 7. The meshed prosthetic lower denture

To get an acceptable accurate result, it is important to divide an object like a prosthetic denture into an adequate element

number. The entire no. of elements as well as nodes in the denture model were 9836 and 20988, respectively. Figure 7 depicts the mesh creation of the composite denture of the base materials.

4.1.3 Element type selection

More than a hundred various element types can be found in the library of ANSYS elements. Depending on the application and the kind of results that must be calculated, the element is selected. The selected element type is ANSYS "185-brick".

4.1.4 Properties of materials

Most element types need materials properties according to the application of these materials. Now, these materials were presumed uniform as well as linear elastic. Experimental results from the tension test were used to determine the mechanical property "modulus of elasticity" of the composite material employed in the present work. The values of the properties of Young's modulus and Poisson's ratio employed in the Ansys Workbench-2020 R2 software are shown in Table 1.

Table 1. Composite materials properties used in the F.E.M.

Materials	Modulus of Elasticity (GPa)	Poisson's Ratio
Tooth [24]	2.65	0.35
Pure PMMA	2.162	0.4
PMMA+2% PA	2.531	0.3998
PMMA+4% PA	2.378	0.3996
PMMA+6% PA	2.316	0.3994
PMMA+2% PVP	2.313	0.3986
PMMA+4% PVP	2.291	0.3972
PMMA+6% PVP	2.2	0.3958
PMMA+2% PA+2% Sisal	2.235	0.3980
PMMA+2% PA+4% Sisal	2.175	0.3964
PMMA+2% PA+6% Sisal	2.077	0.3948
PMMA+2% PA+2% Coconut	2.457	0.3976
PMMA+2% PA+4% Coconut	2.424	0.3956
PMMA+2% PA+ 6% Coconut	2.229	0.3936
PMMA+2% PVP+2% Sisal	2.206	0.3970
PMMA+2% PVP+4% Sisal	2.141	0.3954
PMMA+2% PVP+6% Sisal	2.074	0.3938
PMMA+2% PVP+2% Coconut	2.254	0.3966
PMMA+2% PVP+4% Coconut	2.195	0.3946
PMMA+2% PVP+6% Coconut	2.148	0.3926

4.1.5 Boundary conditions

The load was exerted in a unit length as well as a displacement in this step, and the FE solution then started. And, the exerted load upon the whole denture is equal to 10% from a perpendicular force in the normal denture which is equal to 90 Kg, thus the fixed exerted load upon the whole prosthetic denture is equal to 104 N [25]. Also, the whole prosthetic denture's constant reinforced is upon the stone cast from a single side at the x, y, and z axes, but it stayed free at the z-axis on the else side. Further, the exerted occlusal load (biting force) upon the particular locations was chosen at the final four teeth of a prosthetic denture, as elucidated in Figure 8. Additionally, the occlusal load applied values and the positions of the denture are illustrated in Table 2 [15].

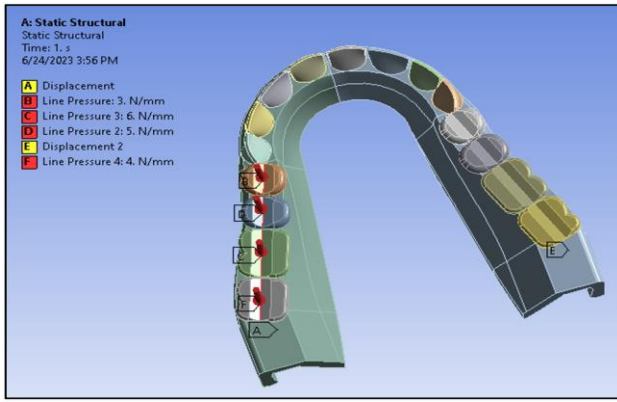


Figure 8. The boundary conditions applied to the prosthetic lower denture

Table 2. The values of an occlusal load applied and its selected position on the denture

Position of Load Applied	Fourth Tooth	Fifth Tooth	Sixth Tooth	Seventh Tooth
A load applied (N)	9	35	42	18
Length (mm)	3	7	7	4.5
Load per length unit (N/mm)	3	5	6	4

4.1.6 Obtaining the results

The Ansys Workbench-2020 R2 package program's results can be obtained for all materials used in this study. The finite element method was used to find the values of total deformation, stress, strain, safety factor, and Tsai-Hill failure theory in the lower denture.

4.1.7 Failure theory

The elastic-plastic solution for the composite materials is based on the Tsai-Hill composite structural strength theory, which is used as a yield criterion [26]. The failure theory used in this study was the Tsai-Hill theory. It was applied to polymer blends and composite specimens.

5. EXPERIMENTAL RESULTS

The relation between the weight fraction of (PA and PVP) in the PMMA resin and the specimens' tensile strength is depicted in Figure 9. Tensile strength readings for both types of blends increased at 2% of the weight fraction. This is a result of the blend's constituents' strong adhesion bonds, as seen by the fact that tensile strength improved noticeably as PA and PVP content increased, as opposed to values of more than 3%, which decreased drastically [27, 28]. Additionally, a reduction in tensile strength was noted with an increase in the weight fraction for both types of blends. This phenomenon can be attributed to the formation of agglomeration caused by the incorporation of blending powder exceeding 2% weight fraction into the matrix. The values of tensile strength rose from 75 MPa for PMMA as referenced to 86 MPa for PMMA-2% PA polymer blend material.

Figure 10 and Figure 11 reveal the relation between the weight fraction of sisal and coconut powder for each of the 2% PA-PMMA and 2% PVP-PMMA blend matrices and the tensile strength of composite specimens, respectively, where the tensile strength values for these matrices dropped when the content of sisal and coconut powders was increased. This

phenomenon is attributed to the fact that sisal and coconut powders possess lower tensile strengths compared to the blend matrix, and it is further compounded by the occurrence of agglomeration within the matrices [29, 30]. Thus, the lower value of tensile strength is 73 MPa for 2% PVP-PMMA-6% coconut composite material.

The relation between the weight fractions of PA and PVP in the PMMA resin and the specimens' modulus of elasticity is shown in Figure 12. Because PA and PVP increase the elastic modulus due to the strong adhesion bonds between the blend's constituents, it is noticed that the modulus of elasticity values first augmented at 2% weight fraction for both types of blends and then decreased with increasing weight fraction. This occurs when the quantity of blending powder incorporated into the matrix surpasses a weight fraction of 2%, leading to the phenomenon of agglomeration [31]. The modulus of elasticity values augmented from 2.162 GPa for PMMA as referenced to 2.531 GPa for PMMA-2% PA polymer blend material.

Figure 13 and Figure 14 evince the relation between the weight fraction of sisal and coconut powders for each of the 2% PA-PMMA and 2% PVP-PMMA blend matrix and the modulus of elasticity of the composite specimens, respectively. And, it can be seen that when adding the sisal and coconut powders for each of 2% PA-PMMA and 2% PVP-PMMA composite materials, the modulus of elasticity decreases. This could be ascribed to the truth that the coconut and sisal powders are described as having a lower modulus of elasticity than the matrix. Thus, this results in the stiffness decreasing of the composite specimens [29, 30]. The lower value of modulus of elasticity is 2.074 GPa for composite PMMA-2% PVP-6% sisal.

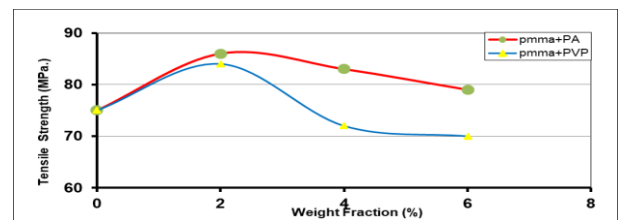


Figure 9. Tensile strength of polymer blends as a function of PA and PVP

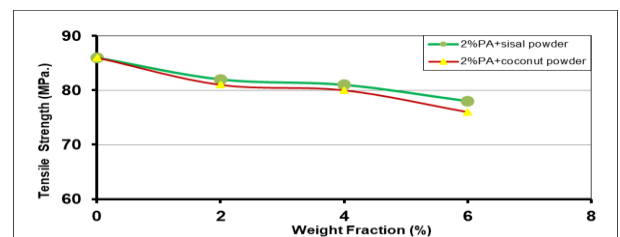


Figure 10. Tensile strength of 2% PA-PMMA composite as a function of sisal and coconut powder

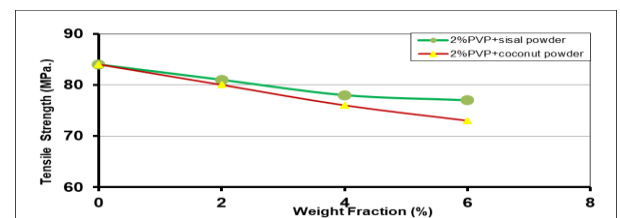


Figure 11. Tensile strength of 2% PVP-PMMA composite as a function of sisal and coconut powder

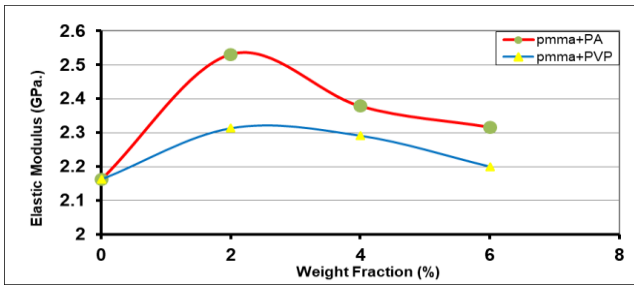


Figure 12. Modulus of elasticity of polymer blends as a function of PA and PVP

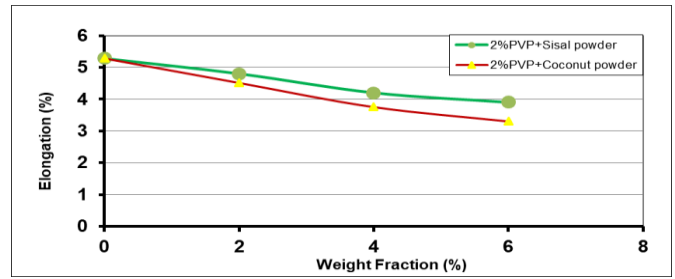


Figure 17. Elongation (%) of 2% PVP-PMMA composite as a function of sisal and coconut powder

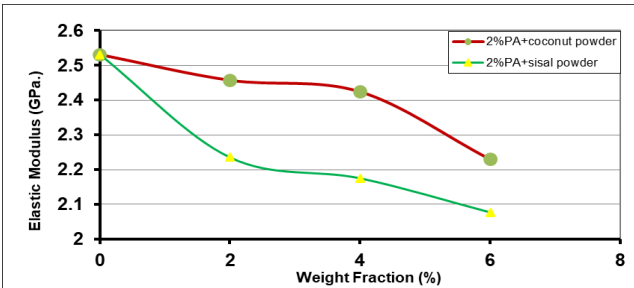


Figure 13. Modulus of elasticity of 2% PA-PMMA composite as a function of sisal and coconut powder

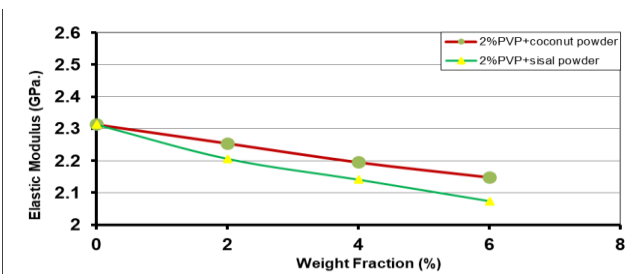


Figure 14. Modulus of elasticity of 2% PVP-PMMA composite as function of sisal and coconut powder

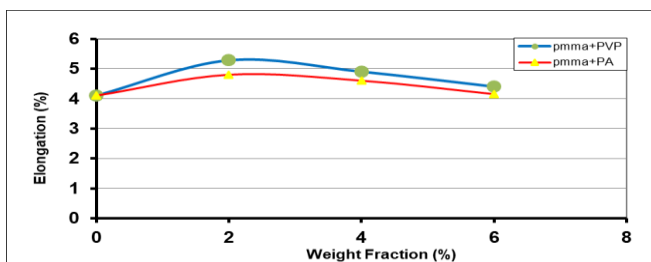


Figure 15. Elongation (%) of polymer blends as a function of PA and PVP

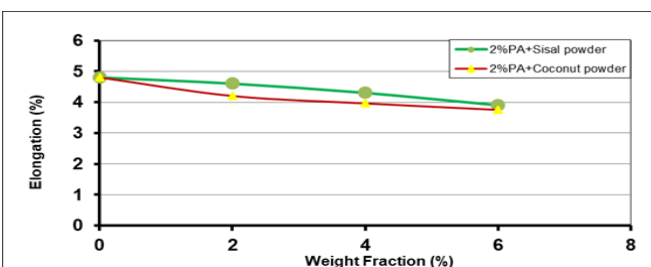


Figure 16. Elongation (%) of 2% PA-PMMA composite as a function of sisal and coconut powder

Figure 15 manifests the relation between the weight fraction of PA and PVP in PMMA resin and the elongation percentage of specimens. And, it can be noted that the elongation percentage values first increased at 2% weight fraction for the two types of blends, due to the good adhesion bond between the constituents of the blend, and then reduced with the raising of weight fraction for the two of blends. This is due to the occurrence of agglomeration as the amount of blending powder exceeds a weight fraction of 2%. It can be observed that the elongation decreases with increased PA and PVP ratios 4% or more, which is related to the properties of PA and PVP that increase the interfacial adhesion between the blend components and improve the stability and decrease the chain sliding [32]. The elongation value increased from 4.1% for PMMA as referenced to 5.28% for PMMA-2% PVP polymer blend material.

Figure 16 and Figure 17 elucidate the relation between the weight fraction of sisal and coconut powder for each of the 2% PA-PMMA and 2% PVP-PMMA blend matrix and the elongation percentage of the composite specimens, respectively. And, it can be seen that when adding the sisal and coconut powders to these matrices, the elongation percentage decreases. This could be ascribed to the truth that the sisal and coconut powders are described via their higher stiffness compared with the matrix, and this leads to an increase in the mechanical stiffness of the composite. This is because sisal and coconut powders possess lower tensile strength compared to the blend matrix, resulting in a reduction in composite elongation as the percentage of coconut increases [29, 30]. The elongation decreased to a lower value (3.3%) for the composite (PMMA-2%PVP-6% coconut).

6. NUMERICAL RESULTS

Numerical analysis was conducted to determine the values of total deformation, stress, strain, safety factor, and Tsai-Hill failure theory in the lower denture. Table 3 presents these values for pure PMMA, polymer blends, and composite prosthetic denture specimens prepared in this study, under a fixed occlusal load of 104 N. Furthermore, it is evident from the table that total deformation decreased at 2% PA and PVP, followed by an increase with higher weight fractions of polymer blending materials, which is shown in Figure 18(a). Additionally, it increased with rising weight fractions of powder strengthening materials as seen in Figure 18(b) and Figure 18(c). Notably, the lowest total deformation value was observed in the PMMA-2% PA polymer blend specimen, measuring 0.009876mm, as illustrated in Figure 19(a). Such outcomes coincide with those of the experimental ones, where

the tensile properties have optimum values at (PMMA-2%PA) polymer blend material.

It can be observed from Table 3 that the values of equivalent stress and equivalent elastic strain for all materials were equal, which were 46.535 MPa and 0.022832 mm/mm, respectively at the point of exerted load upon the tooth in Figure 19(b) and Figure 19(c). The safety factors of the polymer blend and composite materials were calculated, and the general behavior illustrates the rising safety factor values when the weight fractions of polymer blend and reinforcing materials rise, as revealed in Figure 20 (a)-(c). It was found that the highest value of safety factor belongs to PMMA-2% PVP-6% sisal composite material, as illustrated in Figure 19(d).

The values of the Tsai-Hill failure theory equation were also calculated for all materials as listed in Table 3, and the general behavior explains the increasing of Tsai-Hill equation values when the weight fractions of polymer blend and reinforcing materials rise, as evinced in Figure 21 (a)-(c), and the lowest value is for the PMMA-2% PA polymer blend material.

Furthermore, the PMMA blend exhibits minimal total deformation and better adherence to the Tsai-Hill failure theory equation, particularly with the inclusion of polyamide particles. The increased bonding forces between PMMA and polyamide particles in PMMA-2% PA contribute to this effect. The improvements observed in the numerical values align with the enhanced tensile properties demonstrated in the experimental portion of the study. This result can give suitable characteristics for denture base material.

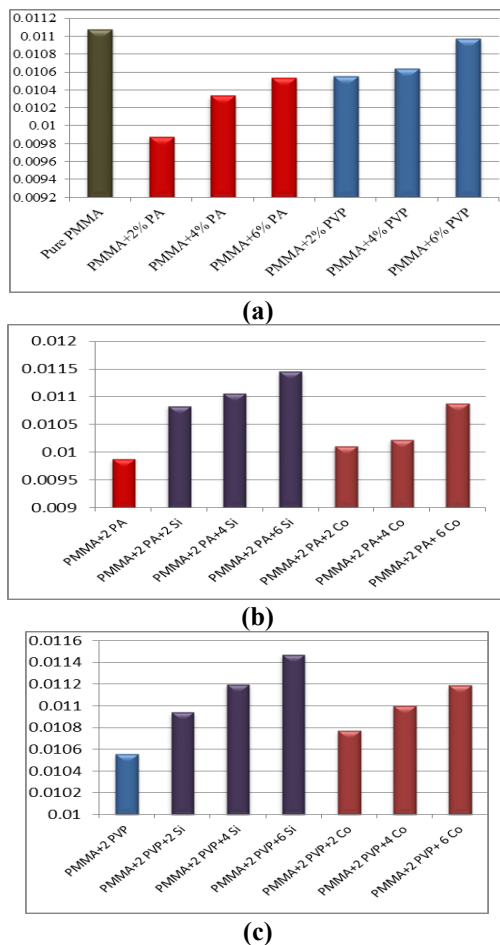


Figure 18. Total deformation of (a) polymer blends as a function of PA and PVP, (b) 2% PA-PMMA composite as a function of sisal and coconut, and (c) 2% PVP-PMMA composite as a function of sisal and coconut

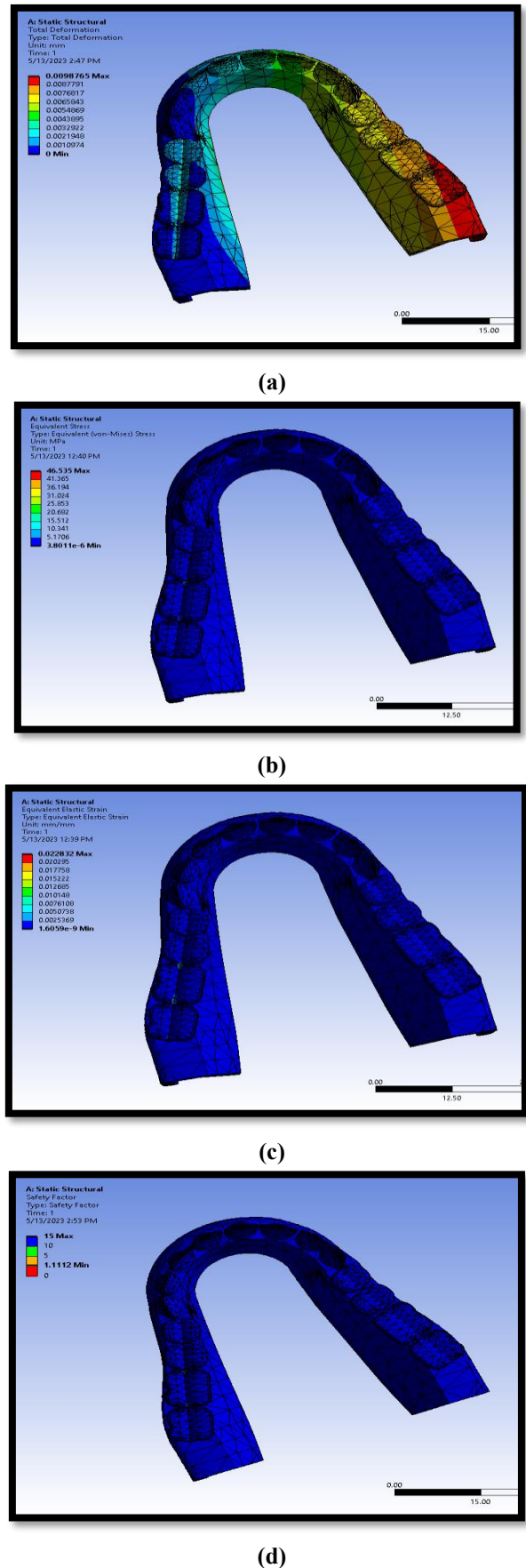
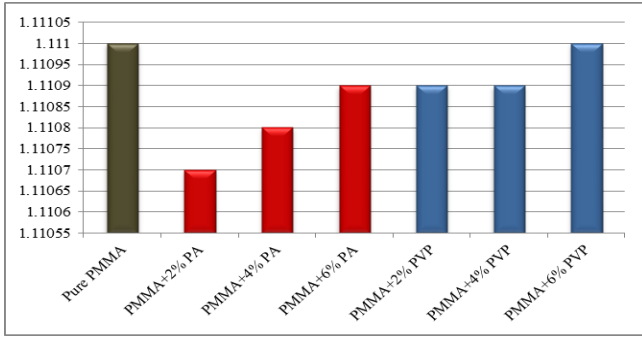
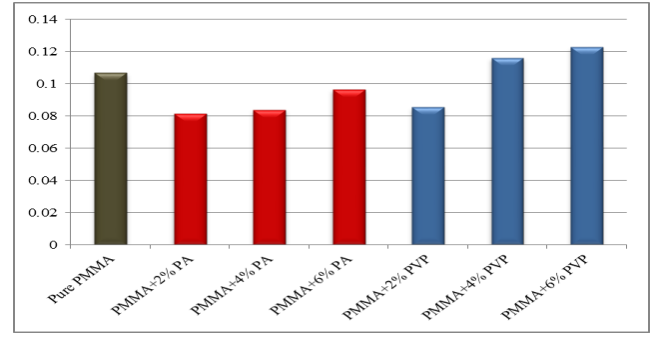


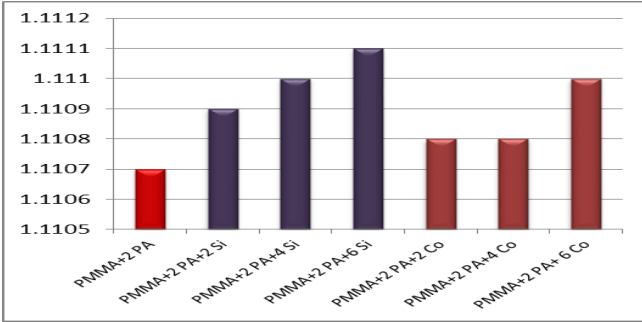
Figure 19. (a) The contour of total deformation distribution of PMMA-2% PA polymer blend denture, (b) The contour of equivalent (Von Mises) stress of PMMA denture, (c) The contour of an equivalent elastic strain of PMMA denture, and (d) The safety factor of 2% PVP-PMMA composite as a function of sisal and coconut powder



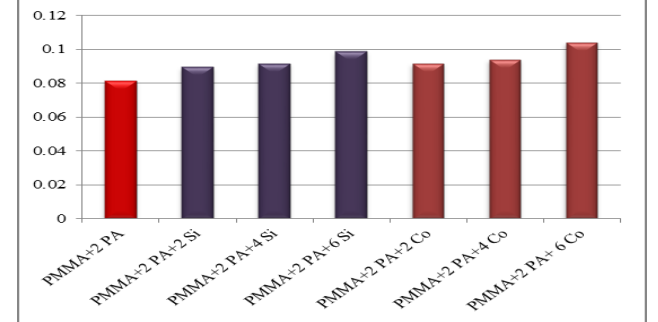
(a)



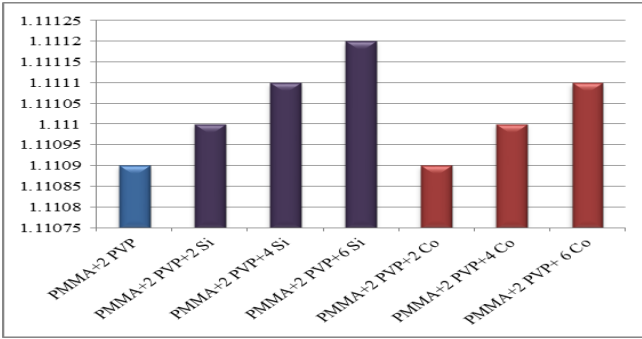
(a)



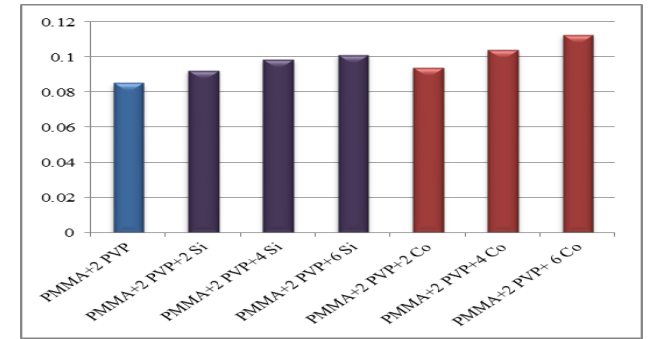
(b)



(b)



(c)



(c)

Figure 20. A safety factor of (a) polymer blends as a function of PA and PVP, (b) 2% PA-PMMA composite as a function of sisal and coconut powder, and (c) 2% PVP-PMMA composite as a function of sisal and coconut powder

Figure 21. Tsai-Hill equation of (a) polymer blends as a function of PA and PVP, (b) 2% PA-PMMA composite as a function of sisal and coconut powder and (c) 2% PVP-PMMA composite as a function of sisal and coconut powder

Table 3. Numerical results of tensile test for polymer blends and composite dentures

Materials	Total Deformation	Von Mises Stress (MPa)	Elastic Strain (mm/mm)	Safety Factor	Tsai-Hill Equation
Pure PMMA	0.011077			1.111	0.1068
PMMA+2%PA	0.009876			1.1107	0.0815
PMMA+4%PA	0.010337			1.1108	0.0837
PMMA+6%PA	0.010539			1.1109	0.0964
PMMA+2%PVP	0.010555			1.1109	0.0853
PMMA+4%PVP	0.01064			1.1109	0.1161
PMMA+6%PVP	0.01097			1.111	0.1227
PMMA+2%PA+2%Sisal	0.010827			1.1109	0.0895
PMMA+2%PA+4%Sisal	0.011058			1.111	0.0917
PMMA+2%PA+6%Sisal	0.01145	46.535	0.022832	1.1111	0.0987
PMMA+2%PA+2%Coconut	0.010107			1.1108	0.0917
PMMA+2%PA+4%Coconut	0.010221			1.1108	0.0940
PMMA+2%PA+6%Coconut	0.010882			1.111	0.1041
PMMA+2%PVP+2%Sisal	0.010939			1.111	0.0923
PMMA+2%PVP+4%Sisal	0.011194			1.1111	0.0988
PMMA+2%PVP+6%Sisal	0.011471			1.1112	0.1013
PMMA+2%PVP+2%Coconut	0.010771			1.1109	0.0940
PMMA+2%PVP+4%Coconut	0.010998			1.111	0.1041
PMMA+2%PVP+6%Coconut	0.011189			1.1111	0.1127

7. CONCLUSION

The tensile properties of PMMA blend and composite materials are affected by adding polymer blends and reinforcement powders. The tensile strength, elastic modulus, and elongation of polymer blends were increased at 2% PA and PVP and then reduced by raising the PA and PVP content, where the highest tensile strength and elastic modulus were 86 MPa and 2.531 GPa, respectively, for PMMA-2% PA and the highest elongation value was 5.28% for PMMA-2% PVP. These properties are reduced by raising the coconut and sisal particle weight fraction. The lowest total deformation in the Tsai-Hill equation values were 0.009876 mm and 0.0815, respectively for the PMMA-2% PA polymer blend material.

PMMA-2% PA polymer blend material gave the best numerical and experimental results which makes them the good choice of denture base material for denture fabrication with sufficient characteristics.

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