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Development the Mechanical Properties of the Acrylic Resin (PMMA) by Added Different Types of Nanoparticles, Used for Medical Applications

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HIGHLIGHTS

- This research focuses on the development materials used for manufacturing prosthetic which used the new materials that are eco-friendly and low - cost.
- Used the natural particles and synthetic particles to manufacturing prosthetic.
- A comparison of mechanical properties between environmentally friendly materials and industrial materials.

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ABSTRACT

This research is studying the effect of reinforcement the acrylic resin (PMMA) by two types of nanoparticles, which included: Walnut shell (WSP) and Talc particles (TP) that practical sizes are (40.8 and 29.2 nm) in individually form, and utilize at three various concentrations (0.1, 0.2 and 0.3wt.%), to improve in the mechanical properties of composite materials. The results showed that the Tensile and Hardness shore D properties became better with increasing the concentration of nanoparticles. The highest value of (tensile strength, modulus of elasticity and elongation at break) was (28 MPa. 1.28 GPa and 2.35%) for (PMMA: 0.3% WSP) composite specimens. And the highest value of hardness shore D was (77) for (PMMA: 0.3% WSP) composite specimen.

1. Introduction

Polymer Nano composites are the outcome of the mix of natural/synthetic fillers and polymers at the nanometer level [1]. The mechanical properties of the Nano composite are upgraded when contrasted with traditional micro composites because of the association between Nano filler segments of Nano composites at the nanometer level, which enables them to function as molecular bridges in the polymer matrix material [2].

Polymer–nanoparticle composite materials have also attracted the interest of various researchers, because of their synergistic and hybrid properties. The simplicity of the process ability of natural polymers got together with the best mechanical and optical properties of nanoparticles has prompted the creation of numerous devices. These are the Nano composites depending on the polymer filler in any matrix, better depicted as Nano-filled polymer composites that can be readied utilizing polymers [3]. The researches incorporate a few investigate, which are practiced in this field, it's:

Hanan et al. researched the effect of the expansion of soak powder with various weight ratios on some mechanical attributes of PMMA resin. The results indicated that the expansion of soak powder leads to a diminishing in compressive strength, impact strength, and tensile strength [4].

Salah et al. explored the effect of the addition of changing Nano-zirconia ($nZrO_2$) particles in various weights on some mechanical qualities of PMMA acrylic resin. It's showing that the flexural and impact strength expanded with expanded weight division and reach extreme qualities in the composite material that containing (5wt %) of ($nZrO_2$) particles [5].

Hamad contemplated the effect of including (nano-$AL2O_3$) and nano-SiO_2) particles with various volume divisions on the physical properties of PMMA composite materials. The result demonstrated that the thermal conductivity and thermal diffusivity expanded with expanding the volume portion of both sorts of particles [6].

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Salih et al. contemplated the effect of including various kinds of nanoparticle powders (fly ash, fly dust, zirconia, and aluminum) with various volume divisions to PMMA, Result indicated that the compression property expanded with expanding the volume division of all sorts of nanoparticle powders [7].

Salloum. Examined the effect of a various division ratio of Basalt Powder (BP) into a customary heat-cured acrylic resin on the Flexural Strength (FS). It was shown that adding basalt powder up to 2%wt may improve the flexural strength of the acrylic resin [8].

Zidan et al. This examination explored the effect of the various weight ratios of yttrium-settled zirconia (ZrO_2) nanoparticles on mechanical properties. This investigation showed that the mechanical properties expanded with expanding ratio (ZrO_2) nanoparticles, with an ideal centralization of 3–5 wt. % zirconia's' [9].

Bacali et al. estimated the effect of two different weight ratios (1 and 2 wt. %) of Gr-Ag on the mechanical properties (PMMA) matrix. This strengthening brought about an improvement in all mechanical properties, with slight changes being gotten from the filler content variety [10].

The aim of this study is to develop the mechanical properties of acrylic resin (PMMA) materials which are commonly used for the fabrication of the prosthesis, by adding different types of nanoparticle materials to improve the mechanical properties and reduce most problems that occur in the prosthesis base material. These composite materials consist of acrylic resin (PMMA) as matrix material and two types of nanoparticles, which include (walnut shells and talc) powders.

2. Materials and methods used

The acrylic resin (PMMA) reinforced with different percentage ratios of nanoparticles Walnut shell nanoparticle (WSP) taken from Walnut fruit with particle size (40.8118 nm) and Talc nanoparticle (TP) with particle size (29.214 nm) in individually form as reinforcement materials. Figures 1-2 show the distribution and average diameter for (walnut shell & talc) nanoparticles respectively by atomic force microscope AFM.

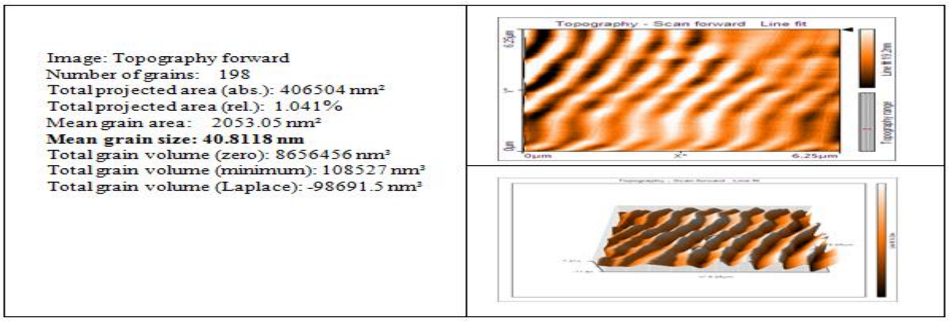

Figure 1: Illustrates the AFM test of Walnut shell nanoparticles

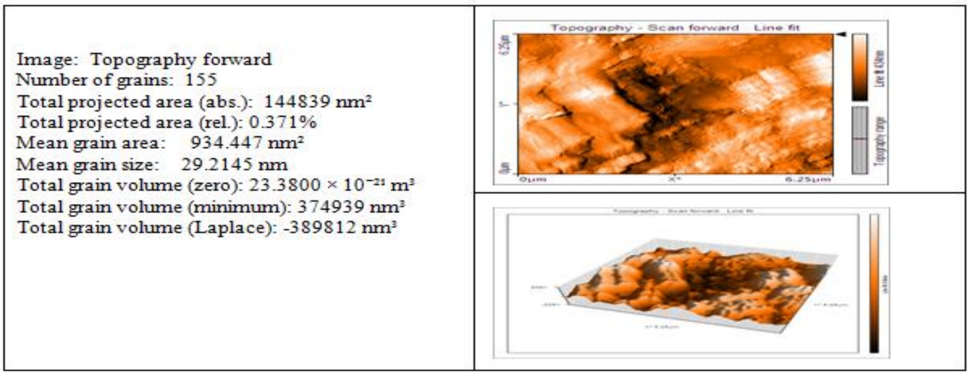

Figure 2: Illustrates the AFM test of Talc nanoparticle

2.1 Preparation of Nano Composite Samples

In this work, fabrication polymer Nano composites samples by utilizing (PMMA) acrylic resin as a matrix material reinforced with various rates proportions of nanoparticles (Walnut shell particles (WSP) and Talc particles (TP)) in exclusively structure as reinforcement materials, the mechanical mixing was utilized to get these samples.

The natural particles (Walnut shell powder) were first washed few times with distilled water to remove the duty. It was then soaked in alkali solution comprised of (5%wt) of (Na OH) in distilled water for (3hr) at (24℃), then washed with distilled water for few times so as to expel the remaining (Na OH) on the outside of powder until reached to neutralize (PH-7) after that the powder had been dried at room temperature (24℃) for (5 days). Eventually, it puts in the furnace at (50-60˚C) for 30min to emphasize the drying process.

The Nano composite mixture is set up by the nanoparticles was added to acrylic resin (PMMA) and then combined till reach the homogenous mixture, at that point adding the hardener to acrylic resin (PMMA) at room temperature relative to the rate (100/2). At long last emptying the Nano composite materials into the silicon form and left them inside the shape at room temperature about (24 hrs.) as indicated by the guidelines of the provider organization. After the polymerization relieving finished, the examples as a plate were then expelled from the silicon shape, with a smooth upper and lower surface, then they were exposed to completing the procedure to be prepared for the ensuing tests.

3. Characterization and test methods

1) The tensile test of the samples was performed according to (ASTM D638) were to be tried. This test is finished by utilizing a universal tensile instrument in the department of materials engineering-university of technology with a crosshead speed of 5 mm/min [11].
2) The gadget Shore D hardness is utilized to assess the hardness of examples as indicated according to the (ASTM D-2240). The element of a round plate example was (6 mm) for the thickness and (25 mm) for a distance across. The applied load was (50N) and the discouraging time equivalent to (15 sec). The test was done in the department of materials engineering, university of technology [12].

4. Results and discussions

4.1 Tensile testing

The (tensile strength, modulus of elasticity and elongation at break) for acrylic resin (PMMA) when the expansion different proportions (0.1, 0.2 and 0.3 %) from two sorts of nanoparticles (Walnut shell particles (WSP)) and (talc particles (TP)) individually form showed up in Figures 3 (a, b and c). The resulted show, the expansion of the nanoparticles (WSP and TP) to the polymer matrix (PMMA) lead to expanded tensile strength and modulus of elasticity while elongation value diminished, Such conduct might be because of the great and uniform dissemination of nanoparticles and decreases agglomeration (grouping) of the nanoparticles and that may prompt lessen interior stress fixation in Nano composite materials close to the bunching nanoparticles and such little inner stress are insufficient to break the interactions at the area of the interface [13]. It was seen that the polymer Nano composites ((PMMA): X% WSP) get the higher estimations of (tensile strength and modulus of elasticity) separately, however, lower value of the elongation rate as contrasted and their partners of the other kind of nanoparticles (TP). This is because of the strengthening mechanism by this powder which plays to limiting the slipping of (PMMA) chains, additionally natural of the bond between the matrix and reinforced materials which relies upon capacity of PMMA to separate between strong particles as good wettability that led to the invigorating high bond between the matrix and reinforced materials [14].

Just as, the figures show that the most elevated value of (tensile strength & modulus of elasticity) can be obtained of the Nano composite content 0.3% proportion of walnut shell particles was reached to (28 MPa) and (1.28 GPa) respectively, while the most elevated value of (tensile strength & elasticity modulus) can be obtained of the Nano composite content 0.3% proportion of talc particles was reached to (27.5 MPa) and (1.2 GPa) respectively.

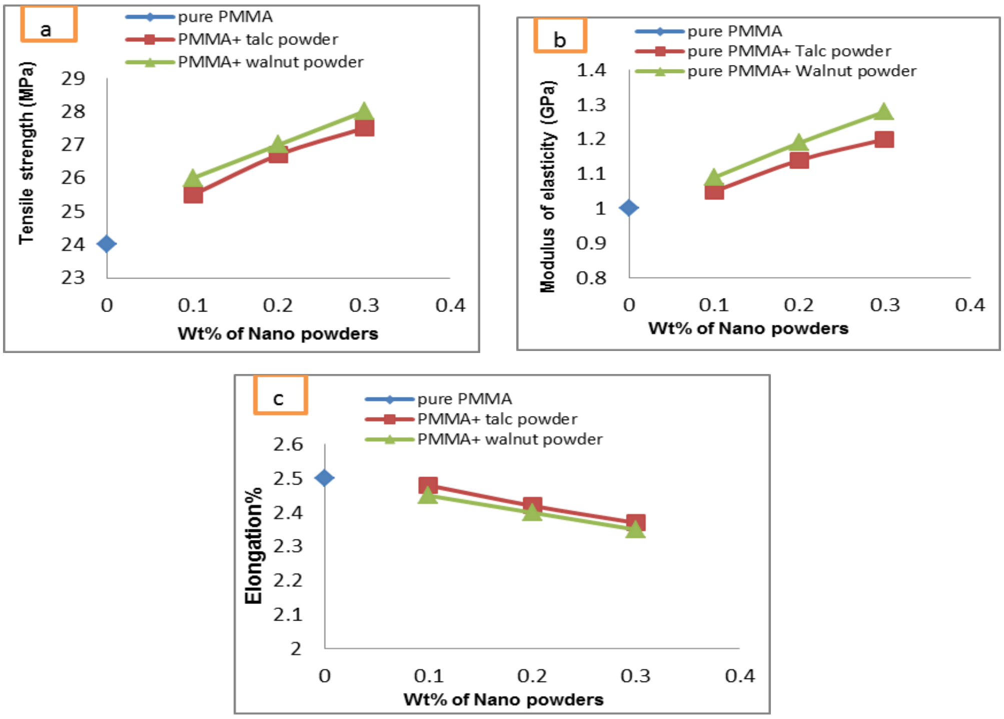

Figure 3: (a) Tensile Strength, (b) Modulus of Elasticity, and (c) Elongation at break of polymer Nano composite (PMMA: X% Nanoparticles) as a component of (WSP and TP) particles

4.2 Hardness test

In Figure 4, It can be noticed the value of hardness (shore D) for acrylic resin (PMMA) expanded with the expansion of nanoparticles to composite, and this value increment with expanding weight proportion of nanoparticles content in composite, and reach the most elevated value (77 shore D) at 0.3 % proportion of walnut shell particles, while for talc nanoparticles reach to the most elevated value (75 shore D) at 0.3%. Such conduct might be because of the strong bonding at the interfacial locale between the acrylic resin (PMMA) matrix and (walnut shell and talc particles) nanoparticles particles is a direct result of the formation of strong physical cross-joins (supra sub-atomic) bonding prompts moving the pressure through this strong interface, likewise the obstruction of polymers matrix to the plastic twisting mode by the controlled movement of the acrylic resin (PMMA) chains along the direction of stress by the (walnut shell and talc particles) nanoparticles (development of harder surface) [15,16].

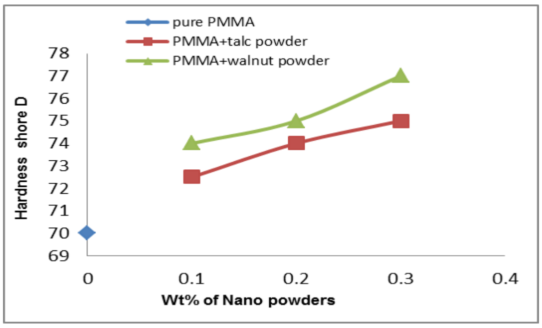

Figure 4: Hardness (shore D) of polymer Nano composite (PMMA: X% Nanoparticles) as a component of (WSP and TP) particles

4.3 Scanning electron microscopy SEM Test

SEM images of the polymer Nano composites with walnut shell and talc as nanoparticle in composites are shown in Figure 5 (b - c)) at a magnification (×2000). It was seen that a large portion of nanoparticles is installed inner the matrix material, which goes about as a basic bit of the acrylic resin (PMMA) structure, exhibiting the better interfacial bond between a compound of composite material and great compatibility between acrylic resin (PMMA) and the reinforcement nanoparticles, which improves the mechanical properties [17]. By adding nanoparticles (WSP and TP) to the polymer material acrylic resin (PMMA), the morphology of polymer Nano composite doesn't change the structure morphology like morphology of polymer material (PMMA) Figure 5 (a). During the mixing process, the associations among nanoparticle and polymer segments fundamentally happened through the melting of acrylic resin (PMMA), trailed by wetting of molten molecules with the nanoparticle. After mixing, Acrylic resin (PMMA) molecules melt epitomized the outside of nanoparticles and private interfacial bonding was formed in Nano composites as observed from the thick and solid surface, especially for polymer composites when reinforced with 0.3% of nanoparticles [18].

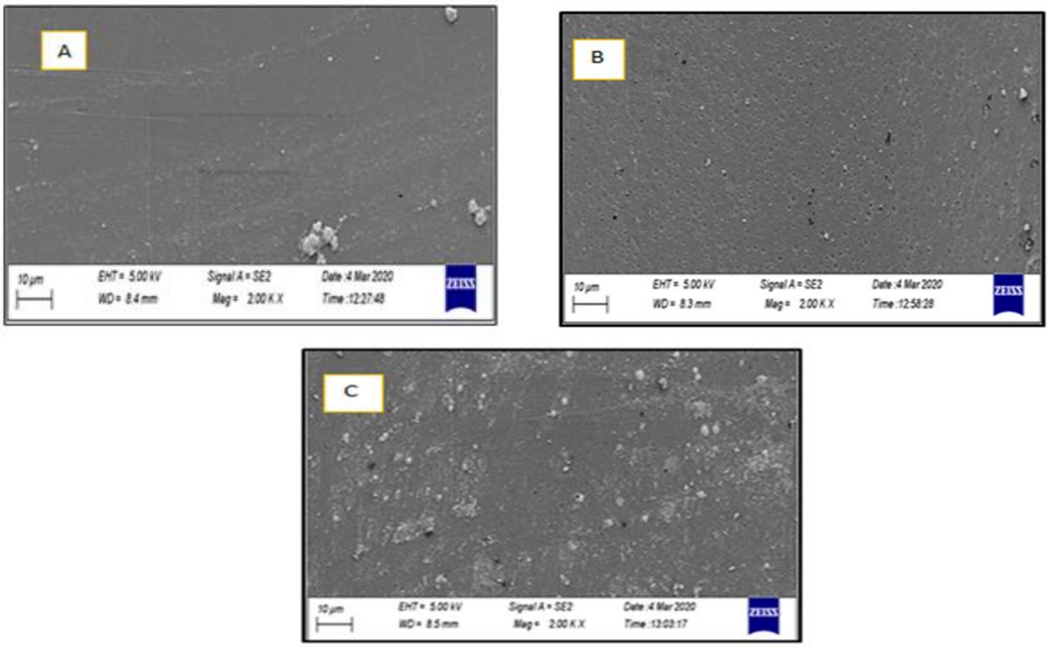

Figure 5: The Morphology of Surface for (a): pure acrylic resin (PMMA), (b) for polymer Nano composite (PMMA: 0.3% WSP) and (c) for polymer Nano composite (PMMA: 0.3% TP) at magnification (x2000)

5. Conclusions

From the experimental results of the fabrication polymer Nano composites with walnut shell nanoparticles (WSP), and talc nanoparticles (TP), it was concluded that: -

1) The tensile strength and modulus of elasticity for the polymer Nano composite (PMMA: X% Nano filler) increased with increasing expansion of (WSP, TP) in polymer, though the elongation at break is decreasing.
2) The most elevated estimation of tensile strength & modulus for Nano composite at (PMMA: 0.3% WSP) is (28 MPa) and (1.28 GPa) respectively, and the most elevated estimation of tensile strength & modulus at (PMMA: 0.3% TP) is (27.5 MPa) and (1.2 GPa) respectively.
3) The hardness (shore D) of polymer Nano composite increased with increasing the weight fraction of nanoparticles (WSP and TP).
4) In the SEM test, results showed the structural morphology of the polymer Nano composite like the morphology of polymer material, this means the morphology of polymer Nano composite doesn't transform. The SEM of the broken surface demonstrated every one type of polymer composites has a homogeneous structure. And the outcomes show that the advancement of properties of acrylic resin (PMMA) with expansion (WSP, and TP) can be utilized in the uses of medical applications.
5) This research focuses on the development materials used for manufacturing prosthetic as well as the need to provide new materials which are low - cost and eco-friendly for the prosthesis components.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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