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Enhanced the Antibacterial and Mechanical properties of UHMWPE by Addition Sort Fibers of Polyacrylonitraile PAN, Graphene Nanoplate (GNP) and Hydroxyapatite (HAp)

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Abstract

The UHMWPE is a gold material in total joint replacement due to excellent properties but with the time was degradation therefor, In present study it was reinforced with 5% short fibers of polyacrylonitriale (PAN) and different weight fraction (0.3, 0.8 and 1.3)% of graphene nanoplate (GNP) and hydroxyapatite (HAp) to increase the mechanical properties (flexural strength, flexural modulus, compression strength and hardness) due to good bonding between fibers and nanoparticles (GNP, HAp) with polymer which improved the loud transfer from matrix to reinforcement phases, and also attributed to good mechanical properties of reinforcement fillers. Moreover, these fillers maintained the antibacterial properties to avoid infection which can happened per implantation of knee joint replacement.

Keyword: *UHMWPE; PAN; GNP; HAp; Antibacterial Properties and Flexural Strength.*

Introduction

Ultra high molecular weight polyethylene, UHMWPE have been used as bearing components in total joint replacements due to their excellent properties. Such as low friction coefficient against metallic components, high impact strength, and good chemical resistance, was widely investigated as a biomaterial especially as a bearing material in the total joint prostheses [1]

The great success of surgically-implanted biomaterials may be compromised in every case by the challenging complication of bacterial per implant infection [2]. Approximately 2.6 million orthopedic biomaterials are implanted annually in the USA, hence the incidence of implant-associated infections is also increasing [3]. Most important in the pathogenesis of infection is the colonization of the device surface and the consecutive formation of a biofilm [4], in which *Staphylococcus aureus* and *koagulase –negative Staphylococci* are most frequently implicated as the etiologic agents [5]. Systemic antibiotic prophylaxis and various local antibiotic delivery techniques have been proven to reduce the rate of infection [6]

Polyacrylonitraile PAN hollow fibers are already used as dialyzers that eliminate proteins and low molecular weight compounds. PAN fibers have high surface area, very high mechanical strength, abrasion resistance and had insect resistance. However, PAN has various greater properties, the existence of nitrile groups along with the fiber backbone deals multidirectional methods to alter fibers for definite applications dissimilar artificial films which can be damaged during the alteration [7].

Graphene is a one-atom-thick sheet of carbon atoms arranged in a 2D honeycomb structure. The strong carbon-carbon bonding in the plane, the aromatic structure, the presence of free p electrons, and reactive sites for surface reactions make graphene a unique material with excellent properties [8].

The polymer composites reinforced with graphene had better elastic modulus, toughness, hardness and fatigue strength. The main benefits of graphene as reinforce phase improved load transfer from a matrix to reinforcement due to have excellent in-plane strength and actual high surface area. [9,10]

Nano-hydroxyapatite who the main mineral constituent of bone, is one of the greatest interesting inorganic materials for applications in bone re-forming, thus it has been broadly used in hard tissue engineering to stimulate biological properties of bio-inert polymer by compound process. [11]

Hydroxyapatite- reinforced polymer composites display attractive properties for biomedical uses because of the existence of HA increases the biological properties of the material [12].

In current study, the hybrid nanocomposite of UHMWPE reinforced by 5%PAN with different weight fraction of nanoparticles (GNP , HAp) were prepared and examined mechanical properties (flexural and compression strength) and anti-bacterial properties for prepared hybrid nanocomposites to use in knee joint replacement.

Experimental Procedure

Ultra high molecular weight polyethylene (UHMWPE) was gained as a powder from LUOYANG MAX PIPE INDUSTRY with Molecular weight 600-700(10^4g/mol.), density (0.093-0.94) (g/cm^3) and Granularity (≥99%)20-40 Mesh

Polyacrylonitraile (PAN) is a short fiber was obtained from TENGZHOU TUOLDUO INDUSTRIAL &TRADE CO.,LTD, with length 3mm, diameter (15 ± 2) µm and density 1.18±0.01 g/cm^3.

Graphene nanoplate are two dimension Nano particles obtained from TIANRUN SUNSHINEGRAPHITE CO.,LTD with purity >95wt.% , Thickness (1.0-1.7) nm, diameter (0.5-5) µm, (2-5) layers and SSA (360-450 m^2/g)

Hydroxyapatite (HAp 04) is a nanopowder were used in this research are acquired from N&R INDUSTRUIES, INC with purity 99% and Average Particle Size (20nm)

The two groups of hybrid composite material were prepared by addition 5%PAN short fibers and addition different weight fraction (0, 0.3, 0.8 and 1.3%) of graphene nanoplate GNP for first group and hydroxyapatite for second group. the nanoparticals are dispersion in ethanol by sonication instrument for 30 min for HAP and 15 min for GNP after that the nanoparticles were mixing by mechanical mixing the PAN fibers are added gradually and also dispersion in the sonication instrument for 15 min, the mixture are mixing by mechanical mixing and the powder of UHMWPE are added gradually. the mixing process were continued for 30 min. After that, the mixture was put in an oven with vacuum for drying at (60°C). After that the mixture was put in mold and press in hydraulic press at temperature 180 °C and pressure 12 MPa for one hour. Then the mold left to cool in air up to room temperature to get the sheet of composite material which was cut by CNC laser machine according to ASTM standard of each test in present study.

The samples of flexural properties test are cut from sheet according to ASTM D790 [13], the sample dimensions (100×10×4) mm. the test (three point - type) is achieved after fixed the ends of sample the loud applied at midpoint at strain rate 5mm/min. also The five sample are tested each time.

The samples of compression strength test are cut from sheet according to ASTM D695-02a. the test is achieved at velocity 1.3mm/min and the loud applied until the sample is failed. The data of stress-strain are obtained. each time The five sample are tested and the mechanical properties are the average of the data of sample [14].

Hardness test is required to measure the resistance of material to indentation, shore D instrument model (TH 210 FJ) made in Germany, the specimen is Cylindrical shape, the test was being done according to ASTM (D2240) [15]. To obtained correct readings the surface of sample must be smooth and clean and the minimum thickness of sample is 4mm, the position at which the test is proceed is far at least from the edge is 12mm.Each specimen was tested five times at different positions and the final hardness is average of them.

By using the Agar Well Diffusion Method was being used to determinate antibacterial activity of the samples. the Muller Hinton agar plates were prepared and were inoculated with Escherichia coli (E. coli), staphylococcus aureus (*S. aureus*) as test organisms which spreading on the surface of the media with the help of sterile swab.

Neat Polymer and polymer nanocomposites samples have been inserted to the plates at two state (solid after press, liquid state before evaporate the ethanol and also pure ethanol) to determine the inhibition zone. Finally, these plates were incubated at 37°C, and after 24 hours of incubation; zones of inhibition were visualized and measured the diameter of the inhibition zone and recorded in mm.

Results and Discussion

Figure (1) described the relationship between the flexural strength with different weight fraction of nanoparticles (GNP and HAp) w.t %. the figure illustrated the flexural strength was increased with addition PAN short fibers and increased with increased weight fraction of HAp% and also increased with weight fraction of GNP% up to 0.8% due to good interfacial bonding between matrix and reinforcement phases (PAN fibers and nanoparticles) thus impeded the growth of cracks within polymer, but at1.3%GNP slightly decreased due to agglomeration of GNP. The flexural strength was increased from (16.2) for neat UHMWPE, (20.4075MPa) for (UHMWPE+5%PAN) to (28.317 MPa) for (UHMWPE +5%PAN+0.8%GNP) and to (27.228 MPa) for (UHMWPE+5%PAN+1.3% HAp). Generally, the increment in flexural strength at addition GNP was higher than at addition of HAp [16-18]

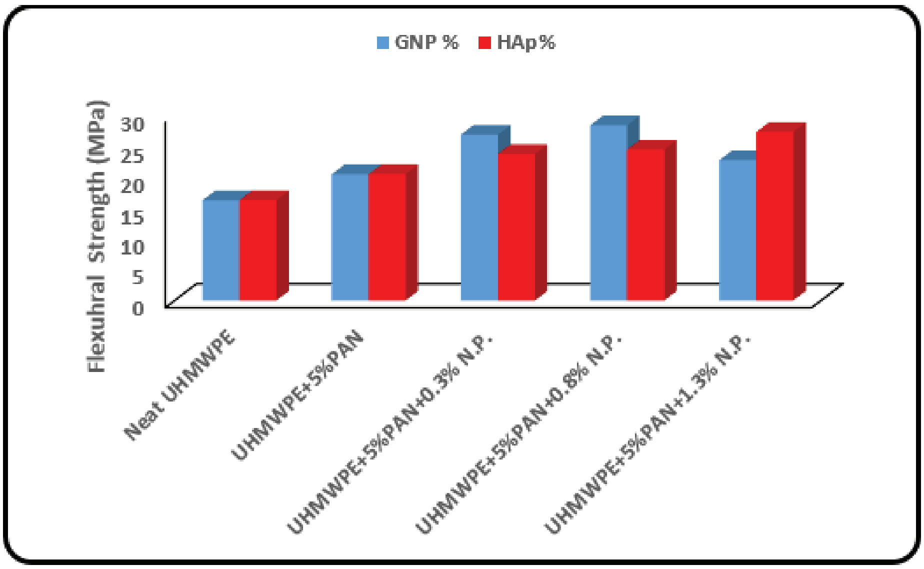

Figure (1) The Flexural Strength of Nanocomposite materials as function of Nanoparticles wt.% content in Nanocomposite

Figure (2) described the relationship of flexural modulus with weight fraction of nanoparticles (GNP+HAp) %. This figure showed the flexural modulus increased with addition of PAN fibers and with increased weight fraction of HAp% , also increased with increased weight fraction of GNP% up to 0.8% due to the properties of nanoparticles which had flexural modulus higher than UHMWPE and also due to good interfacial bonding between matrix and reinforcement phases (PAN fibers and nanoparticles) [16]

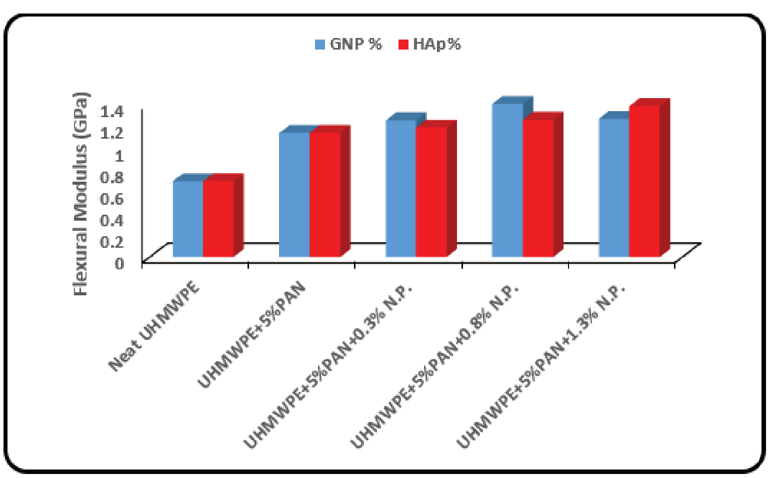

Figure (2) The Flexural Modulus of Nanocomposite materials as function of Nanoparticles wt.% content in Nanocomposite

Figure (3) demonstrated the effect of addition different weight fraction of nanoparticles w.t% (GNP and HAp) on compression strength. The compression strength increased with addition PAN fibers and with increased of weight fraction of HAp% also increased with GNP% up to 0.8%and after that the compression strength slightly decreased. Moreover, the increment in compression strength at addition HAp% was higher than at addition of GNP% due to the natural of nanoparticles and the Lubricant properties of GNP which made it more susceptible to compression than HAp nanoparticles

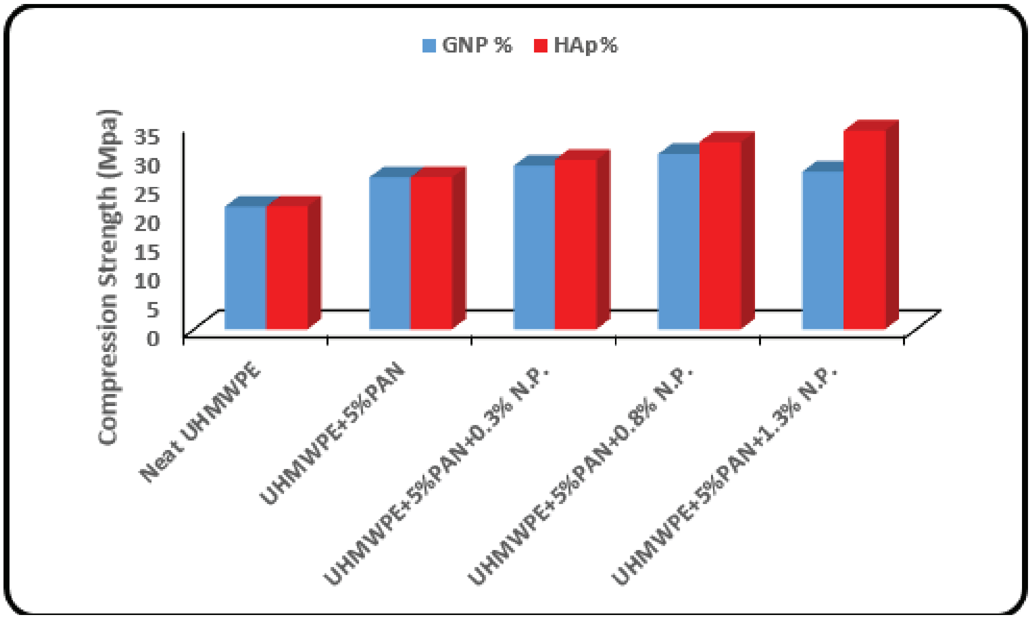

Figure (3) The Compression Strength of Nanocomposite materials as function of Nanoparticles wt.% content in Nanocomposite

The figure (4) illustrate the hardness increased with addition PAN fibers and increased weight fraction of GNP% and HAp% due to strong interfacial bond between the matrix and the reinforcement allowing efficient load transfer mechanism. Also nanoparticles have good mechanical properties that can influence the properties of the matrix positively thus lead to transfer the load from matrix to nanoparticles. [19,20]

The hardness at addition HAp was higher than at addition GNP due to natural HAP is a ceramic brittle material

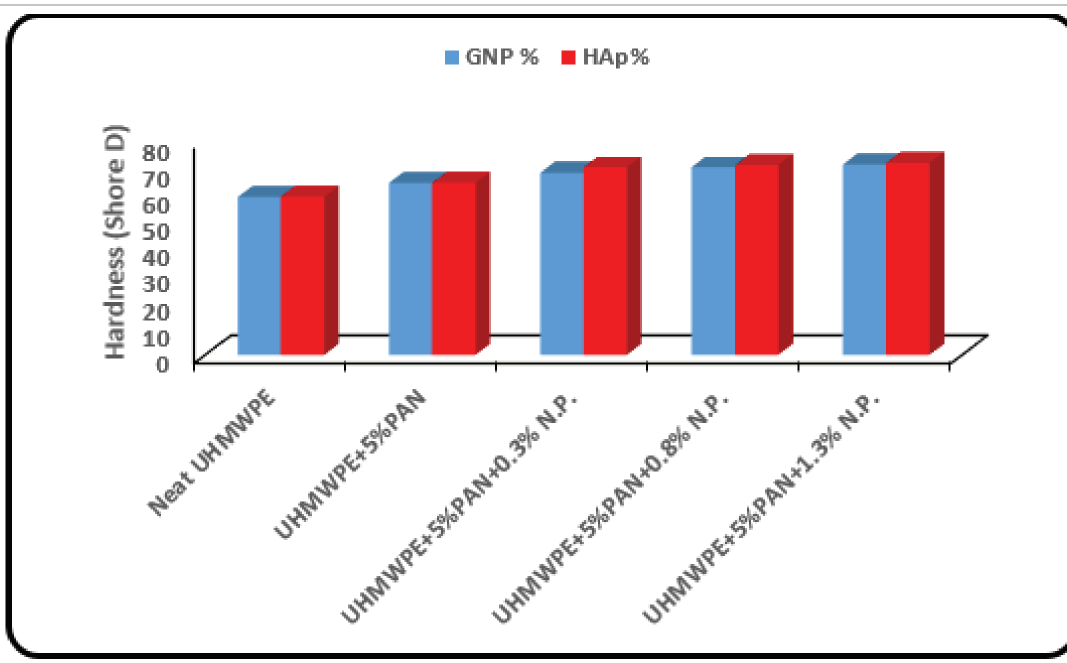

Figure (4) Hardness of nanocomposite material as function of nanoparticles wt.% content in composite

Figure (5) show the bacterial inhabitation area of pure ethanol (a) and neat UHMWPE, composite material (UHMWPE+5%PAN fiber) (b) and nanocomposite material reinforced with different weight fraction wt.% of GNP and HAp (c and d) respectively. which illustrated there was not inhibition of bacterial for all solid compressed samples because the agar needed to media to diffuse within it but the natural of UHMWPE had low absorbedly thus at compress sample the agar cannot diffusion within it. And also there was not inhibition area for ethanol alone. Table 1 exhibited the anti-bacterial activity of neat UHMWPE, composite material (UHMWPE+5%PAN fiber) and nanocomposite material reinforced with different weight fraction wt.% of GNP and HAp. The neat polymer had good antibacterial activity and the composite material (UHMWPE+5%PAN fiber) cause to increase the diameter of inhabitation of E-coli Bactria due to PAN fiber had antibacterial properties[21] .while, diameter of inhibition decreased at addition 0.3% of nano particles (GNP and HAp) but with increase the weight fraction of Nanoparticles, the diameter of inhibition increased and become more stable especially at 0.8% for GNP% and for HAp% start increased and stable after over 0.3 w.t% HAp [22]. Moreover, the antibacterial activity of HAp is more than GNP which attributed to the particles size of HAp is about 20 nm moreover, the HAP nanoparticles activate the bacterial grovel and spores so that the efficiency of bactericidal became higher [22].

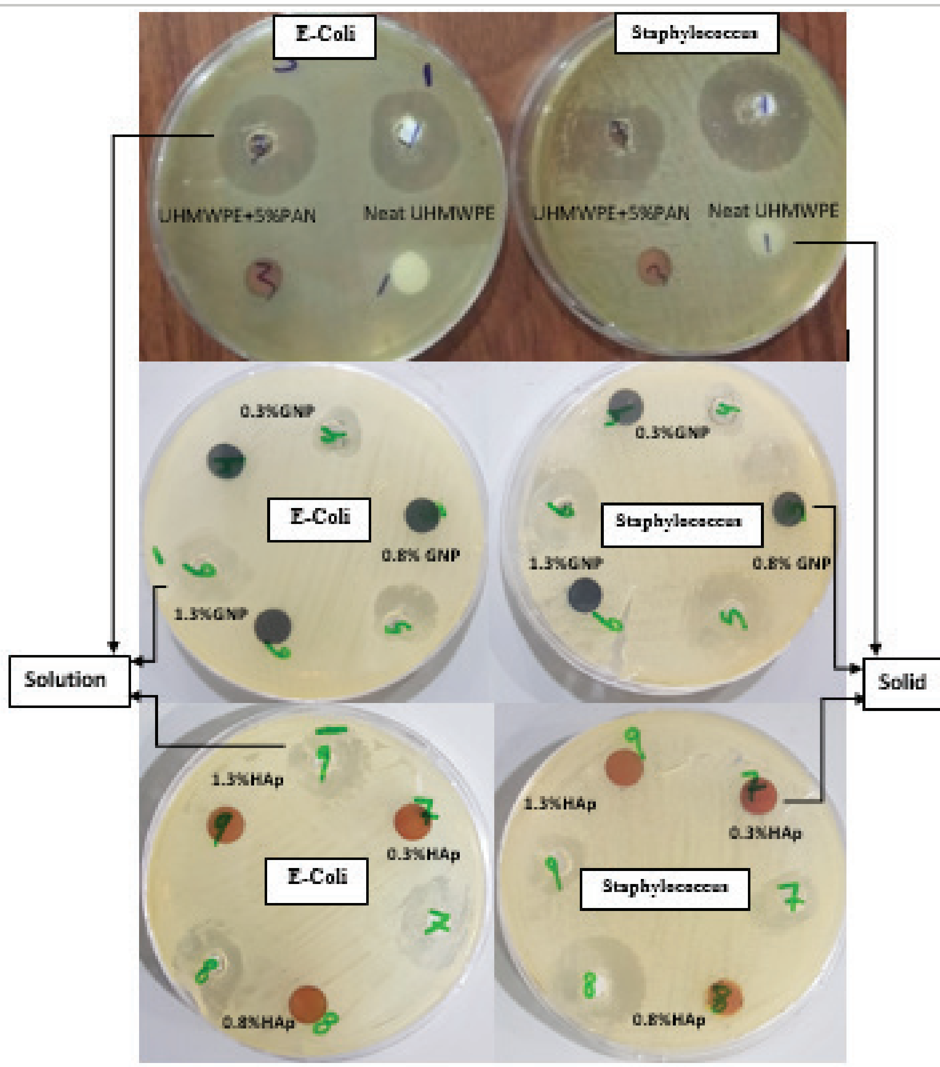

Figure (5) illustrated the inhibition area neat polymer and composite material for E. coli and Staphylococcus colony.

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Table (1) Inhibition Zone for Pure Ethanol and Hybrid Nanocomposites.

Samples	**Inhibition zone diameter (mm)**	
	E-coli	**Staphylococcus**
Pure Ethanol	0	0
Neat UHMWPE	25	30
UHMWPE+5%PAN	26	30
UHMWPE+5%PAN+0.3%GNP	14	15
UHMWPE+5%PAN+0.8%GNP	19	23
UHMWPE+5%PAN+1.3%GNP	20	21
UHMWPE+5%PAN+0.3%HAp	24	21
UHMWPE+5%PAN+0.8%HAp	23	28
UHMWPE+5%PAN+1.3%HAp	24	22

Conclusion

The hybrid nanocomposite was enhanced the mechanical properties (flexural strength, flexural modulus, compression strength and hardness) to support the weight of patient and improved the performance of knee joint replacement by develop the properties of cartridge and enhance the anti-bacterial properties to avoid the infection after implantation process that cusses the failed joint replacement.

Ethical Clearance: I am studied ten case of patient that proceed surgical operation to replace knee joint in (Medical City Hospital) for knowing the important notes, the defects of joint and the service life of synthetic joint before replacement.

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No **Conflict Interesting**

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