3D printing of surface characterisation and finite element analysis improvement of tensile properties for PEEK-HAP-GO in bone implant

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Abstract

Research and development on PEEK composites with high thermal conductivities and ideal thermal stabilities have become one of the hot topics in composites. However, not all PEEK composites have the necessary characteristics adequate fracture toughness to resist forces and crack propagation, with an improved mechanical and structural properties. This research evaluates a novel computational surface characterisation, and Finite Element Analysis (FEA) of polyetheretherketone and hydroxyapatite Graphene oxide (PEEK-HAP-GO) in the process of 3D printing to improve fracture toughness to resist forces and crack propagation. It also focuses on increasing the hydrophilicity, surface roughness, and coating osteoconductive of PEEK-HAP-GO for the bone implant. Compression and tensile tests were performed to investigate the mechanical properties of the PEEK-HAP-GO structure. The addition of calcium phosphate and the incorporation of porosity in PEEK-HAP-GO has been identified as an effective way to improve the osseointegration of bone-implant interfaces of PEEK-HAP-GO. The further analytical structure of the particle was performed, evaluating the surface luminance structure and the profile structure of composite material in 3D printing, analysing the profile curve of the nanostructure from the scanning electron microscope (SEM). The results of the uniaxial compression tests in new PEEK-HAP-GO biodegradable materials show good compressive strength suitable for loading applications. It shows Melt-blending with bioactive nanoparticles can be used to produce bioactive nanocomposites like HAP-GO and is used to modify the surface structure of PEEK implants in order to make it more bioactive.

Keywords: Additive Manufacture; Finite Element Analysis; Surface Characterisation; PEEK-HAP-GO; biomedical applications;

1. Introduction

Poly-ether-ether-ketone (PEEK) is of great interest for closure due to its excellent mechanical properties, biocompatibility and a flexibility module of human bones. One of the most capable bone repair materials [1] as the demand for PEEK increases, the production of additives (AM) is used in the process of forming the PEEK components. In the last decade, selective laser sintering (SLS) is the most commonly used additive manufacturing technology for PEEK [2]. However, the high cost, the low penetration and the concentrated laser beam avoid the sintering of large surfaces or laminates. To date, Fused Deposition Modelling (FDM) is one of the most sophisticated, accessible and fastest-growing three-dimensional (3D) printing methods used in the production of large medical implants. A researcher reported that FDM is an alternative method to treat PEEK fragments. The mechanical properties of the FDM parts depend mainly on the production parameters, such as the printing temperature, the printing speed, the scanning path, the diameter of the nozzle, the thickness of the layer, the camera [3]. The critical element of PEEK is an excellent material with many unique features that can be used in medical applications. Reliable and robust construction allows PEEK to improve sterilisation. [4] Suitable for surgical instruments and dental equipment. Also, biocompatibility and stability in the body showed that PEEK

is an embedded material and can be expected to be reused. PEEK is an alternative metal material in the bone and joint region [5] Orthopedic implants will increase to fit individual differences. These microparticle leaching techniques have been used to make porous PEEK with sintering by heat and compression, treatments with micro-sulphonates and SLS. The formation of pores in PEEK results within the natural tissue, cellular penetration and the physical forms of permissive integrated replication that surround the tissue migration of the preventive device in more detail [6,7]. Particle leaching from PEEK's current porous manufacturing technology is shown as an economically flexible platform, but with less micro/macro monitoring the porosity and structure, lack of flexibility and still suffer from restrictions, such as interference manual and irregularity. In addition to the PEEK of the biologically active materials, it can be suggested that the porosity of PEEK used in conjunction with the porosity control of the fully interconnected porosity is used to produce a more detailed description. PEEK is an efficient semicrystalline thermoplastic alternative to implant materials and materials that combine excellent biocompatibility with rigidity and functional strength. The injection of elasticity PEEK is similar to the reduction of cortical bone after protection against stress. It is also radiation permeation that allows radiological evaluation [8,9]. The grouping has created a potential for orthopaedic applications in PEEK. Medical-grade PEEK-OPTIMA has been developed by Invivo to comply with the requirements of the medical for teeth, which is a total replacement and craniomaxillofacial in several clinical applications of these boxes of spinal fusion [8-10]. Despite the advantageous properties described, the biologically based PEEK is relatively inert in vivo and shows the following infusion of infusion. The introduction of porosity in PEEK implants adds complexity to conventional fabrication but is an effective way to improve osseointegration. Physical form is more related to the natural organisation of cells in nature and allows better orientation of the orientation and fixation of the cell [11,12]. Due to the different types of free extrusion, AM technology has been identified as the most efficient way to make fabrics such as porous scaffolds of Tissue Engineering with porous three-dimensional structures capable of handling various materials like ceramics, cells Superior and thermoplastics are reproducibilities, excellent control over macro/microarchitecture and critically low cost [13,14]. Also similar to this method can also be used to print out non-skeletal three-dimensional structures. Fig. 1 show that the representation of poly-ether-ether-ketone composite is one of the most critical biocompatible polymers.

Fig. 1. Poly-ether-ether-ketone composite is one of the most critical biocompatible polymers [16]

Due to its excellent resistance to tribology, PEEK is a potential candidate to produce several types of high-standard biomedical implants, due to its mechanical and chemical resistance [17]. The main limitation of PEEK is related to biomedical applications such as prostheses and implants, and they are relatively deep integrations with bone. It was

disclosed that the formation of the bioceramic extrusion process at low temperatures could penetrate fibres less than 60min using a minimum soil composition. PEEK has been added to the extrusion field in the AM extrusion field in many types of publications in the extrusion area. Despite these problems, a comprehensive survey was conducted to bring the PEEK components to the same level as the product suppliers. Probes are the main problems in PEEK material. Usually mechanical, tribological and PEEK material can be changed by adopting two approaches, including physics and chemistry.

In the comparison of physical methods, the chemical modification does not mean that PEEK is chemically ineffective [18,19]. Coating, strengthening, plasma processing, surface modification, [20-22] are commonly used methods that can improve the performance of PEEK material standards. Table 3 lists the different activities that may benefit PEEK components based on biomedical components. Both 3D printing and PEEK have found useful applications in the field of biomedical and tissue engineering applications, including the development of orthopaedic implants, scaffolds, artificial organs, surgical guides and gauges, prostheses and medicine containers. It is also true that previous medical devices with PEEK-based production using conventional manufacturing technologies are complicated due to the presence of patient-specific parameters that often require specificity. This is only possible with 3D printing since adjustments are possible at each stage of the production process. In this section, interesting PEEK biomedical applications, 3D printing and their combinations are explained. However, earlier studies on the effects of thermal parameters have focused on the partial deformation or deterioration of materials in search of more significant mechanical properties. Take various concentrations of non-thermal parameters, such as the layers and angles of the bone plate between thermal factors and mechanical strength. If it has not yet been identified, this study aims to confirm whether the PEEK treated with HAP-GO can be administered in the actual treatment area. The objective of this research is to propose an evaluation of novel computational surface characterisation, and FEA of PEEK-HAP-GO in the process of 3D printing to improve fracture toughness to resist forces and crack propagation. Also, it focuses on increasing the hydrophilicity, surface roughness, and coating osteoconductive of PEEK-HAP-GO for the bone implant. Compression and tensile tests were performed to investigate the mechanical properties of the PEEK-HAP-GO structure. The addition of calcium phosphate and the incorporation of porosity in PEEK-HAP-GO has been identified as an effective way to improve the osseointegration of bone-implant interfaces of PEEK-HAP-GO. The further analytical structure of the particle was performed, evaluating the surface luminance structure and the profile structure of composite material in 3D printing, analysing the profile curve of the nanostructure from the scanning electron microscope.

2. Methodology

The professional 3D printer used in this study was the Inmate HPP 155/Gen 2, explicitly designed for PEEK FFF AM has a weight volume of 225×200×200 mm and thermally insulating support in an insulated manufacturing chamber. The diameter of the extruder was 0.4 mm. The second layer of Dimafix® solution was applied to a hotbed before printing to increase the adhesion between the cages and the thermal layer. The printing conditions were also maintained in all cohorts, except for the X/Y axis (extruder) transition speed of the X/Y axis of the nozzle, also referred to as "print speed" [23,24]. Four pressure groups were produced at a print speed of 1000, 1500, 2000 and 3000mm/min using the PEEK-OPTIMA™ LT1 filament. Print time and filament usage were recorded in FFF cohorts. In addition to the printed groups, the control samples were processed from the pulled PEEK-OPTIMA™ LT1 jacket.

Table 1 Manufacturing time and weight of cohorts depending on the manufacturing method.

Cohorts	Weight (g)	Mean	Standard Deviation	Time (Min)
Printing (mm/min)	1100	1.49	0.008	61.82

	145	1.52	0.009	39.98
	1950	1.51	0.011	32.97
	2950	1.27	0.023	21.04
Machined		1.45	0.018	16.98

ANSYS offers a complete additive manufacturing (AM) simulation workflow, which allows AM metal to move for a successful manufacturing operation. Additive Manufacturing is a technology to produce three-dimensional pieces, layer by layer, from various materials. It quickly gained popularity as an actual production procedure in recent years. In the AM process, a digital data file is transmitted to a production machine, which ends up translating a technical project into a 3D printed part. Primarily, AM was used as a rapid prototyping method, an accelerated process of creating pieces mainly plastic before manufacturing using well-accepted methodologies, such as injection moulding, moulding, modelling, assembly [24]. The best ANSYS solution for additional production provides simulation in all stages of the AM process. This will help optimise the configuration of the material and the configuration of parts and machines before starting to print. The mechanical printing simulation of ANSYS is an automatic feature of ANSYS designed primarily for users familiar with this environment. The automated printing simulation facilitates the configuration and resolution of print simulations, which provides maximum flexibility to adjust workflow settings as needed. The Workbench additive process simulation has a four-sided network option, which provides a significantly more accurate geometric representation without an associated increase in the size of the model. This is especially useful for models with narrow channels, thin walls or thin support geometry [25]. The Additive Machine also provides post-processing simulation capability. This help to model the steps of the heat treatment such as the annealing process after the construction process while remaining in the familiar environment of the mechanical machine. It can also perform parametric studies on the positions of the pieces and the orientations to determine the configuration of the optimal structure.

3. Mechanical printing and simulation

It allows to simulate the AM operations in the automated environment and optimise the facilitation topology based on physics with production restrictions incorporated for AM. A rough estimation of the current lattice structures and simulate the thermomechanical construction process to predict the distortions and stresses of the parts were done. It provides simple process parameters to define the AM creation process and the use of temperature-dependent properties of non-linear materials without assumptions of natural deformation. Furthermore, it gives full access to the user for personalisation settings for performance scale with ANSYS products.

3.1. Surface Stress distortion and thermal strain prediction

A stress analysis evaluations, final residual stress and maximum stress positions throughout the structure were carried out which provides a graphical visualisation of the stress build-up of the layer and the high voltage regions throughout the structure. This help to calculates the possible locations of the impact of the blade using colour maps that allow knowing the shape of the pieces during construction. It provides a visualisation that will enable users to evaluate how the assumptions of deterioration and residual tension affect the components, how to select the orientations of the pieces successfully, and how to implement their support strategies [26]. It allows the visualisation of the differences between the original, non-deformable geometry and the last deformed geometry before and after the images are compatible. Also, the thermal voltage based on a full section thermal analysis to predicts anisotropic effects based on the scan vector and the scan vector on the scan vector and thermal stress was calculated. The stress patterns using the uniform default voltage, the application of scanning patterns or the thermal tension options was calculated.

3.2. Mechanical and Image testing

Some samples from each MTS Mini Bionix 858 system cohort in about 20 tests and calibrated load and with a digital surface supplied with ASTM F207726 transfer and compression sensor by ISO 17025 quality system requirements have been tested for Shear and torsion test. The load cell had a capacity of 25kN, and a basic rate of 25 mm/min for compression and shear tests and the parameter setting can be seen in table 1 and 2 the equivalent result in table 3 section 4. The capacity of the torque cell was 100Nm, and the torsion tests were carried out at 60 °/min. The load and torque displacement curves were extracted from the data. Hardness, final displacement angle and loading final torque curves using ANSYS 19.1 were calculated from specific scripts [27]. Fig. 2a-b. Represent the SEM and analysis platform of PEEK-HAP/GO of MG-63 cell attachment and proliferation scaffolds and the surface KL transformed. Fig 2c-d shows a surface conversion of the luminance and waviness filter of Daubechies

Fig. 2. The SEM and analysis platform of PEEK-HAP/GO (a) MG-63 cell attachment and proliferation scaffolds [6] (b) The surface KL transformed (c) Surface conversion of the luminance (d) waviness filter of Daubechies

The assay, three cages each cohort using Scancode μ ct 80 10mm isotropic resolution was tracked by micro-CT. Both extremities of the framing design were defined as fixed cubes. Interesting to measure the porosity in a cage. The adjustment volume for porosity calculations has been created $5 \times 5 \times 2 \text{ mm}^3$ limited to the standard framing design [28]. To

compare the average porosity and the pore size of the specified area of the cage between the groups, two measurements of control volume was made a n=6per group produced as a result of the grayscale value histogram corresponding to intensity appeared in the form of two bright peaks. The limit selected for the segmentation threshold was the average of the two peaks. The evaluations were performed using the Scanco software Medical, Switzerland, for control volumes. The values of "solid volume / total volume" were obtained to estimate the percentage of porosity. The percentage of control porosity was calculated using the value of the equation (1) which is given in section 4.1 and table 3.

$$\text{Percentage of Porosity} = 1 - \frac{\text{Volume}_{\text{solid}}}{\text{Volume}_{\text{total}}} \% \quad \dots\dots\dots(1)$$

Also, the result of assessments of average pore size is a volume-based thickness. The software uses a volume-based local thickness algorithm introduced by Hildebrand and Rüegsegger²⁸. The mechanical tests, review that the fracture surfaces of the printed groups were visualised using optical microscopy to visualise the fracture morphology of different groups. Under the same loading conditions. The crack and the width of the layer were also calculated from the optical microscopy images of the compression samples. Also, detailed surface micrographs of printed cohorts were taken to analyse the porosity and surface structure of the scanning electron microscope (SEM). Before SEM, platinum and palladium were sprayed into the cages to obtain a conductive surface [29]. The filament-based device is defined as being more stable and effective than the syringe-based method for determining the appropriate nozzle temperature range as a function of mass. The temperature of the nose was tested at a rate of 2.2mg/sec at an exit rate of 350°C to 450°C; this has been adapted to printing having a layer thickness of 0.2mm and an ambient temperature of 80°C. Compression temperature There is neither fouling nor deterioration of the polymer.

3.3. Daimler Lead twist Experimental Analysis

The information for the PEEK-HAP-GO has the same value of method Length-scale rows of the Parameters Value show number of points to be 200 ar SRC threshold of 1.0 with a maximum domain scale of 159mm at a constant line slope at a Domain maximum scale of 140mm. The Daimler Lead Twist analysis for the two samples has a Parameters Value of diameter 40.0mm with a continuous period length and evaluation length 2.0mm with a continuous theoretical supply cross-section measured in μm^2 of the maximum wavelength of 0.40mm. The supply cross-section per turn, which is measured $\mu\text{m}^2/\text{U}$, is constant. The number of threads, contact length in per cent, lead depth measured in μm and Lead angle ($D\gamma$) measured in the degree are kept constant in the test [30]. The profile surface profile is drawn horizontally at 100nm and horizontally at 1.4 μm , and drawn from the 200-micron line parallel to the fibres and channels to limit errors due to the shape of the joint. The PEEK/HA tests were reduced to a size of 6x6x6mm³ with a gemstone working tool and were developed to support optical research with optical instruments [31-33]. Fig. 3a-c Shows the value of the parameter of PEEK-HAP/GO of curve extracted the profile of length 144-159mm with Filtered extracted Waviness profile of Gaussian filter settings, of cut-off 2.50mm and Extracted profile of length 84.1mm. Extension electrons calculated at a target of 9 microns per pixel Computed tomography to control the volume flow of AH within the composite and calculate the rupture in the AASI system and as a result of the correction of the air distance within the composite.

Fig. 3. Parameters value of PEEK-HAP/GO (a) Curve extracted the profile of length 144-159mm (b) Filtered extracted Waviness profile of Gaussian filter settings, of cut-off 2.50mm (c) Extracted profile of length 84.1mm

The spacing parameters roughness profile (RSm) is 1.35mm at Gaussian filter, 0.8 mm in ISO 4287 on amendment 2 (Rdq) of 0.000232degree and Peak parameters roughness profile (RPC) of 0.474mm^{-1} with a tolerance of $\pm 0.5\text{nm}$. The material ratio parameters for the first profile (Pmr) is 100% at Pdc of 40.8nm for the second sample. The amplitude parameters roughness profile (Rp) is 0.323nm with several motifs of 87 and height mean 8.04 nm at area mean value of 219mm^2 at pitch mean 16.5 mm. The equivalent diameter means 12.0mm. The roundness means 0.503 at compactness mean 0.703 with several motifs of 641, parameters height mean 12.1 nm and the area mean 25.3mm^2 . The mean pitch 5.41mm at equivalent diameter mean 4.38mm and Roundness mean 0.527 and compactness mean 0.721.

Table 2 Characteristics influence experimental test of converted luminance of the tissue engineering for scaffolding in 3D printing of PEEK-HAP-GO.

Parameters	PEEK-HAP-GO	Parameters	PEEK-HAP-GO
ISO 25178: Height		Feature Parameters	
Root-mean-square height (Sq)	25.3nm	Density of peaks (Spd)	0.136mm^{-2}
Skewness (Ssk)	0.605	Arithmetic mean peak	$2.39 \times 10^{-4} \text{mm}^{-1}$
Kurtosis (Sku)	2.72	Ten-point height (S10z)	82.3nm
Maximum peak height (Sp)	66.0nm	Five-point peak height	54.3nm
Maximum pit height (Sv)	34.nm	Five-point pit height (S5v)	28.0nm
Maximum height (Sz)	100	Density of peaks (Spd)	0.136mm^{-2}
The arithmetic mean height (Sa)	20.8		
Functional Parameters		ASME B46.1: 3D	
Areal material ratio (Smr)	100%, c = 1000nm	Mean height in absolute	$8.66 \times 10^7 \text{nm}$
Inverse areal material ratio	34.4nm, p = 10%	Developed area (Sdar)	$1.61 \times 10^4 \text{mm}^2$
Extreme peak height (Sxp)	31.0nm, p = 50%, q	Projected area (Spar)	$1.61 \times 10^4 \text{mm}^2$
Spatial Parameters of s = 0.2		Hybrid Parameters	
Autocorrelation length (Sal)	18.5mm	Root-mean-square gradient	5.06×10^{-5}
Texture-aspect ratio (Str)	0.309	Developed interfacial area	$1.28 \times 10^{-7} \%$
Texture direction (Std)	124°		

Volumetric Functional		Stratified surfaces	
Material volume (Vm)	$1.57 \times 10^{-6} \text{ mm}^3/\text{mm}^2$	Core roughness depth (Sk)	3.19nm
Void volume (Vv)	$3.6 \times 10^{-5} \text{ mm}^3/\text{mm}^2$	Reduced summit height	3.75nm
Peak material volume (Vmp)	$1.57 \times 10^{-6} \text{ mm}^3/\text{mm}^2$	Reduced valley depth	3.68nm
Core material volume (Vmc)	$2.57 \times 10^{-5} \text{ mm}^3/\text{mm}^2$	Upper bearing area (S _{mr1})	18.3%
Core void volume (Vvc)	$3.52 \times 10^{-5} \text{ mm}^3/\text{mm}^2$	Lower bearing area (S _{mr2})	83.0%
Pit void volume (Vvv)	$8.35 \times 10^{-8} \text{ mm}^3/\text{mm}^2$	Material ratio at Plateau-	95.4

4. Results

The extrusion rate was determined, ambient temperature, and fibre size of the feedstock, including the maximum extrusion temperature range to protect the PEEK fibres. After the deposit. Moreover, avoid the deterioration of polymeric raw materials, chewing and removal of the breast. The melting temperature of PEEK is 390-450°C but is generally injection moulded at a temperature of 360-400°C. A viscosity of about 77×10^3 to 66×10^3 Pa.s (Pascal-second) of the extrusion temperature between 350°C and 450°C with a PE diameter of 1.75 mm and a flow rate of 2.2mm/s of ambient temperature 80°C. Degradation of PEEK can be considered both a colour change and a formation. Cavities in PEEK bowel after release This fibre can retard and deform [34-35]. Fig. 4a-b is a representation of parameters value of PEEK-HAP/GO of wavelet filter of Daubechies of 10 and Peak count distribution of compatibility. Fig. 4. c-b show threshold of -60.8nm of 39.1nm and Abbott firestone curve of KL transformed. The evaluation of the view and microscope samples Depending on the results, the temperature between 400 and 430°C is defined as the dynamic range. Temperatures below 400°C result in clogging or cracking of the nozzle and temperatures above 430°C result in significant deformation or deterioration of the nozzle, mechanical properties and biological performance [36,37]. By adjusting the appropriate temperature for pressing PEEK parts, additional size analysis with high accuracy, maximum mechanical strength and suitable biological compatibility, including mechanical and physiological experiments, is essential.

Fig. 4. Parameters value of PEEK-HAP/GO (a) wavelet filter of Daubechies of 10 (b) Peak count distribution of compatibility (c) Threshold of -60.8nm of 39.1nm (d) Abbott firestone curve of KL transformed

Table 3. Experimental parameters result of Resampled series in ISO 25178

Description	Mean	Std	Sum	Range	Varianc
Height Parameters					
Root-mean-square height (nm)	6.30	4.80	37.8	13.9	23.0
Skewness	1.28	1.88	7.66	5.47	3.52
Kurtosis	26.3	33.4	158	94.6	1114
Maximum peak height (nm)	48.1	12.3	289	40.8	151
Maximum pit height (nm)	42.8	6.22	257	15.8	38.7
Maximum height (nm)	90.9	12.7	546	41.6	160
Arithmetic mean height (nm)	4.02	3.76	24.1	11.4	14.1
Functional Parameters					
Areal material ratio (%)	100	0.00	600	0.00	0.00
Inverse areal material ratio	6.43	7.05	38.6	21.2	49.8
Extreme peak height (nm)	9.00	4.37	54.0	14.0	19.1
Spatial Parameters					
Autocorrelation length (nm)	5.50	9.57	33.0	26.6	91.6

With a nozzle temperature of 0.2 mm and a temperature of 410°C, 3D printed parts are of excellent quality, without distortion or deformation due to the strong adhesion. In this study, the use of a free extrusion structure makes it possible to control the size of the pores and the interconnections necessary for the development of the bones [38,39]. General techniques such as particle extraction have little control over porosity and may have limitations such as inconsistencies and manual intervention. By using non-extrusion methods, can quickly print porous PEEK implants, controlling high levels of external production and porosity, which is the essential requirement for medical device production. The main advantage of the extrusion-free moulding process is the comparison with other traditional techniques, such as thermal discharge and die compression. The typical 3D printed human bone for implantology and structure test produce are shown in fig. 5.

Fig. 5. A typical 3D printed human bone implant structure produce (a) knee cup (b) Finger (c) Femur Bone (d) Tensile test piece

Printed cohorts exhibited a similar final displacement under compression-shear force compared to machined cages $P = 0.08$. Also, the printing speed was not related to the final displacement under shear force. Likewise, the angular displacement of the printed cohorts was not significantly different from the processed cages $PCC = 0.02$, $P = 0.94$, no relationship between the print speed and the angular displacement of the cohort ($P = 0.94$). Fig. 6. Shows the FEA of the femur bone

Fig. 6. the FEA of the femur bone

4.1. Surface Imaging Characterization

Based on micro-CT scans, printed cohorts exhibited an average porosity of 2% to 20%. The correlation rate between the printing speed and the porosity of the printed boxes $PCC = 0.88$, $P < 0.001 > 0.01$ for all tests, means difference = 1.88%, 3.82%, 2.99% and 19.6% for the calculation processes, for the selected groups, respectively, 1000, 1500, 2000 and 3000mm/min. Fig. 7a-d shows the value of the parameter of PEEK-HAP/GO of 3D view of surface KL transforms with fractal compatibility analysis of enclosed scale of KL transform. The frequency spectrum of KL transformed, and average power spectrum density of KL transformed can be seen in fig.7c-d

Fig. 7. Parameters value of PEEK-HAP/GO (a)3D view of surface KL transform (b)Fractal compatibility analysis of enclosed scale of KL transform (c) Frequency spectrum of KL transformed (d)Average power spectrum density of KL transformed

The crack layer and the width were calculated and analysed of a bivariate analysis showed that leaf width increased significantly with printing speed at $Rho = 0.46$ and $P < 0.0001$. The layers of the faster printing cohort 3000 mm/min are significantly larger than the other published series for all tests, $P < 0.001$, mean difference = 34.2, 19.9 and 18.37 groups, 1000, 1500 and 2000mm respectively. Also, the width of the slower published cohort 1000 mm/min was significantly lower than that published from 1500 to 2000 mm/min at $P < 0.03$ and the mean difference = 14.3 and 15, 8, respectively. Moreover, no significant relationship was discovered for the width of the crack due to the increase in speed. Finally, the fastest printing cohort 3000mm/min had significantly higher retreats and 1500mm/min at $p = 0.009$ and mean difference = 35.5.

4.2. Surface crystallinity PEEK-HAP/GO

Both FTIR and XRD confirmed that crystallinity did not depend on the production method in PEEK cages. $P = 0.49, 0.98, 0.74$ and 0.98 , for cohorts 1000 of no significant difference between the groups of printed and values of calculated crystallinity coefficient processed by FTIR of average crystallinity average 10% found In addition, we did not observe correlation between the print speed and the crystallinity measured with FTIR at $PCC=0.12$ and $P = 0.46$. The Parameters value of PEEK-HAP/GO of Roughness of wavelet filter of Daubechies of 10 and Scatter compatibility of the study are shown in Fig. 8a-b. The Control chart of height motifs analysis and Histogram of compactness from the study of volume islands in 33 is represented in Fig. 8c-d. The printed and processed cohorts $P = 0.97, 1.0, 1.0$ and 1.0 for 1000, 1500, 2000 and 3000mm/min printed cohorts respectively at $PCC = 0.001$ and $P = 0.996$. however, there is a difference in the crystallinity between the top positions and lower by WAXS-related warm bed cohorts at $P = 0.68$.

Fig. 8. Parameters value of PEEK-HAP/GO (a) Roughness of wavelet filter of Daubechies of 10 (b) Scatter compatibility of the study (c) Control chart of height motifs analysis (d) Histogram of compactness from the study of volume islands in 33

4.3. Mechanical properties

The microstructure of the Victrex PEEK 450G compression test printed in 3D with a total width of 600, a height of 200 mm and a pore size of 450 mm, we can see that the accumulated species has a relatively smooth shape, allowing porous samples. 3D solid samples and PEEK porosity 0% with porosity yield of 10% to 38% yield 3s-1, stable at 102%, yield of 38 MPa and yield of 29.34 MPa and bound of elasticity of 0056 to 0044, substantial and modulus value at 38%, average compression modulus value adjusted to 1.82 GPa for stable PEEK close to the amounts reported in the literature for similar compressive conditions 7 MPa [35-38]. PEEK samples, printed in 3D with a porosity of 14% and 31%, have a lower resistance to stress compared to Ultem 9085 and PEEK injection moulded. The sample with 14% porosity showed a tensile strength at the break of approximately 75.06 MPa. 33% less than PEEK injection moulded at a rate of 113 MPa at the same standard of deformation [40]. On the other hand, PEEK printed in 3D has a higher UTS than Ultem 9085, but its extension is less long. It should be noted that the random formation of airbags and microbubbles in the PEEK test samples and the inconsistency in the solidification of the material after the accumulation led to a relatively inconsistent test result for UTS with a standard deviation of 4.1 MPa. Fig. 9. Shows the value of a parameter of PEEK-HAP/GO of Volumetric parameter KL transformed and Peak count distribution of KL transformation. A failed example of a typical

structure-oriented cross-section with air spaces of $+45^\circ/-45^\circ$ in the first layer analysed in the previous section. Non-extruded shaped parts comprise a plurality of filaments, each of which can be treated as a single component for fracture analysis.

Fig. 9. Parameters value of PEEK-HAP/GO (a) Volumetric parameter KL transformed, (b) Peak count distribution of KL transformation

Therefore, it is essential to form and deposit PEEK filaments with minimal micro-air bubbles, which are considered the leading cause of the reduction of filament force. In addition to the strength of the individual filaments, excellent adhesion of the filament to the filament is essential for maximum structural integrity and absorption of energy under load in the free form of extrusion. The tensile strength of the extruded pieces is much more affected by the filament-filament bonding. The use of a high processing temperature is an entity to obtain enough filamentary bonding. This may also minimise air gap formed between the filament filler, as the extruded PEEK has a lower viscosity and therefore can affect dimensional accuracy as it propagates further in the lateral direction during deposition. The refractive surface of a typical PEEK freeform sample printed on extrusion of a $+45^\circ/45^\circ$ oriented web using a high extrusion temperature of 430°C . There is no weld line between the fill and the surrounding filaments, which shows that adhesion of the filament to the filament in each layer is excellent. The solder line may have formed between the layers, but there was enough bond between the layers. This strong filament-filament bonding at each layer affects the PEEK failure behaviour without extrusion. PEEK samples printed at low temperature, which have a clear weld line between the fill filaments, exhibit multiple fill filament errors in sliding and stretching. When drawing and possibly breaking individual filaments, breakdowns occur when filaments are separated by $\pm 45^\circ$ from the tensile load.

5. Conclusion

In this research, it can be concluded that novel investigation for possible reinforcement of different PEEKs composite and examine it nanoparticles and microstructural behaviour to enhance productivities of ADM. According to the results obtained in the tensile and compression tests, the resistance of the PEEK polymers was High when compared to the other commercial plastics. However, they presented fair values if the desired application were treated on the bone implant. According to the results obtained in differential scanning calorimetry and the analysis of the microstructure. The PEEK-HAP-GO showed different behaviour from the low-temperature state to the high-temperature state, which is typical of crystalline and semicrystalline PEEK composite polymers; it is reported that PEEK-HAP-GO formulated without too

high-temperature extrusion for biomedical applications. Nanoparticles such as HAP/GO was successfully combined with PEEK through the process of melt-blending to produce biomaterials nanocomposites for 3D printing. During the printing process, thermal management is defined as the necessary parameters for establishing an appropriate link between substrates and PEEK-HAP-GO layers and to avoid collisions and peeling. Also, the heat dissipation in the ambient environment can affect the level of crystallisation in the 3D PEEK printed structure: the temperature of the nozzle varies from 400-430°C, the ambient temperature of 80°C and the hot plate. The extrusion rate of 2.2 mg/sec is defined as a mandatory condition up to 130°C. The results show that the 3D pore PEEK-HAP-GO tends to have compressive properties. It was discovered that Hap/ help the PEEK to exhibit significantly higher tensile properties. The composite exhibited a load, which gives tensile and compression stress to be 102.38 MPa and 29.34 MPa and the resistance at 0.056 and 0.044 for porosity samples 0% and 38%, respectively. 3D printed examples with a fill rate of 100% and a porosity of 14% at 33% reduction in PEEK injection the PEEK-HAP-GO has a modulus of elasticity of 2.43GPa and bending strength of 132.37 MPa, superior to the sharp bending.

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