CHARACTERIZATION AND PROCESSING OF COMPOSITE PP/UHMWPE FILAMENT FOR FUSED DEPOSITION MODELLING APPLICATION

ABDULADIM SALEM AHMED BALA

A thesis submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

SEPTEMBER 2017

To the souls of my beloved mother and my great father

They are truly being missed

ACKNOWLEDGEMENTS

First of all, I deeply thank Allah, for his guidance and blessings. This thesis is the culmination of my journey of PhD which was just like climbing a high peak step by step accompanied with encouragement, hardship, trust and frustration. At this moment of accomplishment, I am greatly indebted to my research guide, ASSOC. PROF. DR MD SAIDIN BIN WAHAB, who accepted me as his PhD student and offered me his mentorship, brotherly love and care. Under his guidance I successfully overcame many difficulties and learnt a lot. The time spent with him will remain in my memory for years to come. Also, I greatly appreciate and acknowledge to Co Supervisor, DR. MAZATUSZIHA BINTI AHMAD, for her help, guidance, encouragement and friendship throughout my research progress.

I am highly grateful to Dr. Johari Y. Abdullah, staff of Universiti Sains Malaysia in Kelantan, for his academic support which gives me the chance to finish my research in the best form.

I would like to acknowledge the members of my examination committee who have guided my research and made it stronger. Many of them also wrote letters of recommendation for me and I thank them for their part in my success securing an academic position.

I would like to take this opportunity to thank the faculty administration and departments staff particularly the staff of Polymer lab for their constant support along doing my research experiments.

Finally, I acknowledge the people who mean a lot to me, my dear wife, for her patience along years that she stayed with me away from her parents. I would never be able to pay back the love and affection showered upon by my wife; Hanan. And my lovely kids; Ibrahim, Khaula, Omima, and my little angels; Albaraa and Raseel. And not to forget my friends.

May Allah bless us all!

Abduladim Salem Bala

June 2017

ABSTRACT

In this thesis Polypropylene/Ultra-high Molecular Weight Polyethylene (PP/UHMWPE) biomaterial composite was employed to manufacture implant to reconstruct large skull bone defect using Fused Deposition Modelling (FDM). This effort aimed to reduce the cost and processing time of manufacturing of a product like this and make it available to all. The effects of addition UHMWPE on the mechanical, thermal, rheology and toxicity of PP were investigated. All the blends composition were compounded using melt blending in an internal mixer and then extruded into single filaments characterized according to FDM filament specification. Subsequently, the prepared filament was underfed to FDM to manufacture tensile, flexural, and impact samples. This was done under the default setting of process parameters in order to investigate the mechanical behaviour of the composite. Structural morphology of the fracture surfaces of impact samples were investigated to explore microstructure changes related to UHMWPE content. Furthermore, thermal and rheological characterizations were conducted to explore the degradation temperature and process ability of the composites in order to accomplish successful processing in both filament extrusion and FDM processes. MTT assay was also conducted to investigate the composite toxicity. Full and Fractal Factorial Design were employed to investigate the effect of process parameters on the process response for filament extrusion and FDM processes respectively. The study results proved that the addition of 10% of UHMWPE resulted in 57% improvement in impact strength, 9.6% improvement in thermal stability, and 17.9 % in biocompatibility compared to pure PP. In addition, the impact strength improved once again at an estimation of 40.6% increment due to optimization of FDM setting parameters. As a case study, a skull implant was manufactured for a patent in USM-University Hospital with 88.13%-dimensional accuracy.

Keywords: Biomaterials melt blending, Polymer extrusion, Fused Deposition Modelling (FDM), Bone reconstruction,

ABSTRAK

Dalam tesis ini, komposit biomaterial *Polypropylene/Ultra-high Molecular Weight Polyethylene* (PP/UHMWPE) telah digunakan untuk pembuatan implan bagi tujuan pembinaan semula sebuah rangka tengkorak yang telah rosak dengan menggunakan kaedah *Fused Deposition Modeling* (FDM). Ini adalah untuk mengurangkan kos dan masa pembuatan sesebuah produk seperti ini serta membolehkan kaedah ini digunakan secara meluas. Kesan-kesan pertambahan UHMWPE (daripada 10% hingga 50%) ke atas aspek mekanikal, termal, reologi dan ketoksikan PP telah dikaji. Semua komposisi adunan telah disebatikan dengan menggunakan kaedah adunan leburan dalam sebuah pengadun dalaman yang disemperitkan kepada filamen-filamen individu yang setiap satunya mengikut ciri-ciri spesifikasi filamen FDM. Seterusnya, filamen-filamen ini telah melalui proses FDM untuk menghasilkan sampel-sampel yang mempunyai tegangan, lenturan dan impak. Ini dilakukan dengan mengikut tetapan asas proses parameter bagi mengkaji sifat mekanikal komposit berkenaan. Struktur morfologi pada permukaan yang telah pecah pada sampel impak telah dikaji untuk meneroka perubahan struktur mikro berkaitan isi kandungan UHMWPE. Berikutnya, proses pencirian termal dan reologi telah dijalankan untuk mengetahui penurunan suhu dan kemampuan komposit untuk diproses bagi menjayakan kedua-dua proses penyemperitan filamen dan FDM. Cerakin MTT juga telah dilaksanakan untuk mengkaji ketoksikan komposit. Rekabentuk *Full and Factorial* telah digunakan untuk mengkaji kesan proses parameter ke atas proses tindakbalas terhadap proses penyempritan filamen dan FDM. Hasil kajian menunjukkan, berbanding dengan PP tulen, penambahan 10% UHMWPE telah menghasilkan 57% peningkatan kekuatan impak, peningkatan 9.6 % kestabilan termal dan peningkatan 17.9% pada aspek keserasian bio. Kekuatan impak juga telah meningkat sekali lagi pada jangkaan sebanyak 40.6% disebabkan tetapan FDM yang telah dioptimakan. Sebagai sebuah kajian kes, sebuah implan tengkorak telah dibina sebagai sebuah paten di Hospital Universiti di USM.

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF SYMBOLS AND ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
AFD	-	Adaptable Filament Deposition
AG	-	Air Gap
Ag-SiO2	-	Spherical Silica Containing Immobilized Nano-Silver
AM	-	Additive Manufacturing
ANOVA	-	Analysis of Variance
ASA	-	Acrylonitrile Styrene Acrylate
ASTM	-	American Society for Testing and Materials
ATOS	-	3-D Scanner Software
BD	-	Bone Density
°C	-	Degree Centigrade
CAD	-	Computer Aided Design
$CaSt_2$	-	Calcium Stearate
CIM	-	Conventional Injection Moulded
Cu-SiO2	-	Spherical Silica Containing Immobilized Nano-Copper
DICOM	-	Digital Imaging and Communications in Medicine
DMSO	-	dimethylsulfoxide solution
DOE	-	Design of Experiment
DSC	-	Differential Scanning Calorimetry
3DP	-	Three-Dimensional Printing
E_{PP}	-	Young's Modulus for Pure PP
FDM	-	Fused Deposition Modelling
FETI	-	Finite Element Tearing and Interconnecting
FRFD	-	Fractional Factorial Design
FUFD	-	Full Factorial Design
g	-	Gram
GPa	-	Gigapascal
HBSS	-	Hank's Balanced Salt Solution

iPP	-	Isotactic polypropylene
J	-	Joule
LDPE	-	Low Density Polyethylene
LLDPE	-	Linear Low Density Polyethylene
LT	-	Layer Thickness
M	-	Molar
m	-	Meter
M_{ai}	-	Weight under Air Pressure
MFI	-	Melt Flow Index
Min	-	minute
mM	-	Milli-Molar
mm	-	Millimetre
Mpa	-	Mégapascal
MRI-	-	Magnetic Resonance Imaging
MTT	-	3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide
M_w	-	Molecular Weight
M_{water}	-	Weight under Water Pressure
N	-	Newton
NMWPE	-	Normal Molecular Weight Polyethylene
OSIM	-	Oscillatory Shear Injection Moulding
PC	-	Polycarbonate
PCL	-	Poly(ε-caprolactone)
PCL/MMT/HA-		Polycaprolactone/Montmorillonite/Hydroxyapatite Composite
PDLA	-	Poly-D Lactic Acid
PEEK	-	Poly(etheretherketone)
PEI	-	Polyetherimide
PGA	-	Polyglycolide
PIII	-	Plasma Immersion Ion Implantation
PLA	-	Polylactic Acid
PLLA	-	Poly-L Lactic Acid
PLT	-	Paper Lamination Technology
PMMA	-	Polymethylmethacrylate
PP	-	Polypropylene
PP-b-LLDPE	-	Polypropylene-Linear Low Density

PPSF	-	PolyPhenylSulfone
PU	-	Polyurethane
PVC	-	Polyvinyl Chloride
R^2	-	Coefficient of Multiple Correlations
RA	-	Raster Angle
RM	-	Malaysian Ringgit
RP	-	Additive Manufacturing
RPM	-	Revolution per Minute
RPS	-	Roller Pulley Speed
S^{-1}	-	Per Second
SLA	-	System Stereolithography Apparatus
SL	-	Single Laser Beam
SLS	-	Selective Laser Sintering
SS	-	Screw Speed
SSSP	-	Solid-State Shear Pulverization
STL	-	Stereolithography
$T_{10\%}$	-	Initial Decomposition Temperature
$T_{99\%}$	-	Temperature at 99% Weight Loss
TEM	-	Transmission Electron Microscopy
T_c	-	Crystallization Temperature
TGA	-	Thermogravimetric Analysis
Ti	-	Titanium
T_m	-	Melting Temperatures
T_P	-	Peak of Decomposition Temperature
UHMWPE	-	Ultra-high Molecular Weight Polyethylene
		Polyethylene Compatibilizer
UV	-	Ultraviolet
VE	-	Vitamine E
VGCF	-	Vapour-Grown Carbon Fibres
VLDPE	-	Very Low-Density Polyethylene
WHO	-	World Health Organization
wt%	-	Percentage of weight
χ	-	Crystallinity
ρ	-	Density

ΔH_f	-	Fusion Heat
μL	-	Micro-litter

LIST OF APPENDICES

REFERENCES

3D Printing for Beginners.com. (2016). *FDM spool*. Retrieved on June, 2017, from http://3dprintingforbeginners.com/how-to-make-diy-filament-for-your-3d-printer/

Abu Bakar M. B., Leong Y. W., Ariffin A., Z. A. M. I., & School (2013). Mechanical, flow, and morphological properties of talc- and kaolin-filled polypropylene hybrid composites. *Polymers and Polymer Composites*, *21*(7), 449-456.

Ansari, F., Ries, M. D., & Pruitt, L. (2016). Effect of processing, sterilization and crosslinking on UHMWPE fatigue fracture and fatigue wear mechanisms in joint arthroplasty. *Journal of the Mechanical Behaviour of Biomedical Materials*, *53*, 329-340.

Afrose, M. F., Masood, S. H., Iovenitti, P., Nikzad, M., & Sbarski, I. (2016). Effects of part build orientations on fatigue behaviour of FDM-processed PLA material. *Progress in Additive Manufacturing*, *1*(1-2), 21-28.

Alamaria, A., & Nawawi, G. (2015). Dehydration pervaporation of ethyl acetate-water mixture via sago/PVA composite membranes using response surface methodology. *Chemical Technology*, *9*(4), 479-484.

Albert, C., Jameson, J., Toth, J. M., Smith, P., & Harris, G. (2013). Bone properties by nanoindentation in mild and severe osteogenesis imperfecta. *Clinical Biomechanics*, *28*(1), 110-116.

Alharbi, N., Osman, R. B., & Wismeijer, D. (2016). Factors influencing the dimensional accuracy of 3D-Printed full-coverage dental restorations using stereolithography technology. *The International Journal of Prosthodontics*, *29*(5), 503-510.

An, Y., Bao, R.-Y. Y., Liu, Z.-Y. Y., Wu, X.-J. J., Yang, W., Xie, B.-H. H., & Yang, M.-B. B. (2013). Unusual hierarchical structures of mini-injection molded isotactic polypropylene/ultra high molecular weight polyethylene blends. *European Polymer Journal*, *49*(2), 538-548.

An, Y., Gu, L., Wang, Y., Li, Y.-M., Yang, W., Xie, B.-H., & Yang, M.-B. (2012). Morphologies of injection molded isotactic polypropylene/ultra high molecular weight polyethylene blends. *Materials & Design*, *35*, 633-639.

Anthony, J. (2014). *Design of experiments for engineers and scientists*. 2nd ed. London: Elsevier.

Antony, J. (2014). *Design of experiments for engineers and scientist*. 2nd ed. London: Elsevier.

Arcos-Novillo, D. A., & Güemes-Castorena, D. (2017). Development of an additive manufacturing technology scenario for opportunity identification – The case of Mexico. *Futures*, *90*, 1-15.

Ariff, Z. M., Ariffin, A., Rahim, N. A. A., & Jikan, S. S. (2012). Rheological behaviour of polypropylene through extrusion and capillary rheometry. In Dr. Fatih Dogan (Ed.), *Polypropylene*, *InTech* (pp. 3-48).

Arora, M., Chan, E. K., Gupta, S., & Diwan, A. D. (2013). Polymethylmethacrylate bone cements and additives: A review of the literature. *World Journal of Orthopedics*, *4*(2), 67-74.

Arrakhiz, F. Z., Malha, M., Bouhfid, R., Benmoussa, K., & Qaiss, A. (2013). Tensile, flexural and torsional properties of chemically treated alfa, coir and bagasse reinforced polypropylene. *Composites Part B: Engineering*, *47*, 35-41.

Asa, A., Abazary, S., & Masomi, A. (2013). Experimental study of the effect of the build direction on the compressive strength of components made of fused deposition modelling (FDM) method and a three-dimensional printer. *International Journal of Current Engineering and Technology*, *1*, 81-84.

Babík, O., Czán, A., Sajgalík, M., & Zausková, L. (2017). Machining of new biomaterials for implants. *Acta Technica Corviniensis-Bulletin of Engineering*, *10*(1), 35.

Baena, J. C., Wu, J., & Peng, Z. (2015). Wear performance of UHMWPE and reinforced UHMWPE composites in arthroplasty applications: A review. *Lubricants*, *3*(2), 413-436.

Barwinkel, S., Seidel, A., Hobeika, S., Hufen, R., Mörl, M., & Altstädt, V. (2016). Morphology formation in PC/ABS blends during thermal processing and the effect of the viscosity ratio of blend partners. *Materials*, *9*(8), 659.

Bashree, M., Bakar, A. B. U., Masri, M. N., Hazim, M., Amini, M., Mohamed, M., & Mohd, A. (2016). Mechanical and morphological properties of meranti wood flour filled polypropylene composites. *Materials Science Forum*, *8*(40), 91-96.

Basir I. E., Tu, A., Porwal, W., Zhang H., Liu H., Y., … Bilotti, E. (2016). Effect of mixed fillers on positive temperature coefficient of conductive polymer composites. *Nanocomposites*, *2*(2), 58-64.

Bikas, H., Stavropoulos, P., & Chryssolouris, G. (2016). Additive manufacturing methods and modelling approaches: A critical review. *The International Journal of Advanced Manufacturing Technology*, *83*(1-4), 389-405.

Binford, L. R. (2014). *Bones: Ancient men and modern myths*. Academic Press.

Bitar, D., & Parvizi, J. (2015). Biological response to prosthetic debris. *World Journal of Orthopedics*, *6*(2), 172.

Black, J., & Hastings, G. (1998). *Handbook of biomaterial properties*. UK: Springer.

Blokhuis, T. J., Termaat, M. F., den Boer, F. C., Patka, P., Bakker, F. C., & Haarman, H. J. (2000). Properties of calcium phosphate ceramics in relation to their in vivo behavior. *The Journal of Trauma*, *48*(1), 179-186.

Boboulos, M. A. (2010). *CAD-CAM & Rapid prototyping application evaluation*. Bookboon.

Bose, S., Vahabzadeh, S., & Bandyopadhyay, A. (2013). Bone tissue engineering using 3D printing. *Materials Today*, *16*(12), 496-504.

Brevnov, P. N., Zabolotnov, A. S., Krasheninnikov, V. G., Pokid'ko, B. V., Bakirov, A. V., Babkina, O. N., & Novokshonova, L. A. (2016). Catalytic activation of layered silicates for the synthesis of nanocomposite materials based on ultra-high molecular weight polyethylene. *Kinetics and Catalysis*, *57*(4), 482-489.

Brian, E. (2015). *Practical 3D printers the science and art of 3D printing*. New York: Apress.

Brihault, J., Navacchia, A., Pianigiani, S., Labey, L., De Corte, R., Pascale, V., & Innocenti, B. (2016). All-polyethylene tibial components generate higher stress and micromotions than metal-backed tibial components in total knee arthroplasty. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(8), 2550-2559.

Brooks, H. L., Rennie, A. E. W., Abram, T. N., McGovern, J., & Caron, F. (2012). Variable fused deposition modelling – Analysis of benefits, concept design and tool path generation. In *Innovative Developments in Virtual and Physical Prototyping*: *Proceedings of the 5th International Conference on Advanced Research and Rapid Prototyping* (pp. 511-517).

Campbell, I., Bourell, D., & Gibson, I. (2012). Additive manufacturing: Rapid prototyping comes of age. *Rapid Prototyping Journal*, *18*(4), 255-258.

Carneiro, O. S., Silva, A. F., & Gomes, R. (2015). Fused deposition modelling with polypropylene. *Materials & Design*, *83*, 768-776.

Chae, M. P., Rozen, W. M., McMenamin, P. G., Findlay, M. W., Spychal, R. T., & Hunter-Smith, D. J. (2015). Emerging applications of bedside 3D printing in plastic surgery. *Frontiers in Surgery*, *2*.

Changhui, S., Aibing, H., Yongqiang, Y., Di, W., & Jia-kuo, Y. (2016). Customized UHMWPE tibial insert directly fabricated by selective laser sintering. *The International Journal of Advanced Manufacturing Technology*, *85*(5-8), 1217-1226.

Celenk, C., & Celenk, P. (2012). Bone density measurement using computed tomography. *Computed Tomography-Clinical Applications*, 123-136.

Chen, Q., & Thouas, G. A. (2015). Metallic implant biomaterials. *Materials Science and Engineering Reports*, *87*, 1-57.

Chia, H. N., & Wu, B. M. (2015). Recent advances in 3D printing of biomaterials. *Journal of Biological Engineering*, *9*(1), 4.

Choi, J. W., & Kim, N. (2015). Clinical application of three-dimensional printing technology in craniofacial plastic surgery. *Archives of Plastic Surgery*, *42*(3), 267-277.

Cohen, A., Laviv, A., Berman, P., Nashef, R., & Abu-Tair, J. (2009). Mandibular reconstruction using stereolithographic 3-dimensional printing modelling technology. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *108*(5), 661-666.

Collins, M. N., Barron, D., & Birkinshaw, C. (2015). Ultra-High Molecular Weight Polyethylene (UHMWPE) for orthopaedic devices: Structure/property relationships. *Polyethylene-Based Blends, Composites and Nanocomposities*, *21*.

Cunico, M. W. M. (2013). Study and optimisation of FDM process parameters for support-material-free deposition of filaments and increased layer adherence. *Virtual and Physical Prototyping*, *8*(2), 127-134.

Dawoud, M., Taha, I., & Ebeid, S. J. (2016). Mechanical behaviour of ABS: An experimental study using FDM and injection moulding techniques. *Journal of Manufacturing Processes*, *21*, 39-45.

Dearmitt, C., & Rothon, R. (2017). Particulate fillers, selection, and use in polymer composites. *Fillers for Polymer Applications*, 3-27.

Dechow, P. C., Nail, G. A., Schwartz-Dabney, C. L., & Ashman, R. B. (1993). Elastic properties of human supraorbital and mandibular bone. *American Journal of Physical Anthropology*, *90*(3), 291-306.

Deshmukh, R. M. & Kulkarni, S. S. (2015). A review on biomaterials in orthopedic bone plate application. *Int. J. Curr. Eng. Technol*, *5*(4), 2587-2591.

Diop, M. F., Burghardt, W. R., & Torkelson, J. M. (2014). Well-mixed blends of HDPE and ultrahigh molecular weight polyethylene with major improvements in impact strength achieved via solid-state shear pulverization. *Polymer (United Kingdom)*, *55*(19), 4948-4958.

Domingos, M., Chiellini, F., Gloria, A., Ambrosio, L., Bartolo, P., & Chiellini, E. (2012). Effect of process parameters on the morphological and mechanical properties of 3D Bioextruded poly(?-caprolactone) scaffolds. *Rapid Prototyping Journal*, *18*, 56-67.

Dong, Y., Ghataura, A., Takagi, H., Haroosh, H. J., Nakagaito, A. N., & Lau, K. T. (2014). Polylactic acid (PLA) biocomposites reinforced with coir fibres: Evaluation of mechanical performance and multifunctional properties. *Composites Part A: Applied Science and Manufacturing*, *63*, 76-84.

Ducheyne, P., Healy, K., Hutmacher, D. E., Grainger, D. W., & Kirkpatrick, C. J. (Eds.) (2015). *Comprehensive biomaterials* (Vol. 1). Newnes.

Duck, F. A. (2013). *Physical properties of tissues: A comprehensive reference book*. Academic Press.

Durairaj, R. B., Borah, P., & Thuvaragees, Y. (2015). Characterisation of peek coated SS316 l for biomedical application. *Journal of Engineering and Applied Sciences*, *10*(11). 4794-4798.

Durgun, I., & Ertan, R. (2014). Experimental investigation of FDM process for improvement of mechanical properties and production cost. *Rapid Prototyping Journal*, *20*(3), 228-235.

Eda, M., Yashima, S., & Inoué, T. (2015). Medullary bone in goose remains: A reliable indicator of domestic individual in non- breeding regions. *International Journal of Osteoarchaeology*, *25*(6), 849-854.

Egorov, S. A. (2012). Microphase separation of mixed polymer brushes physisorbed on cylindrical surfaces. *Soft Matter*, *8*(14), 3971-3979.

El Mechtali, F. Z., Essabir, H., Nekhlaoui, S., Bensalah, M. O., Jawaid, M., Bouhfid, R., & Qaiss, A. (2015). Mechanical and thermal properties of polypropylene reinforced with almond shells particles: Impact of chemical treatments. *Journal of Bionic Engineering*, *12*(3), 483-494.

Farahani, R. D., Dubé, M., & Therriault, D. (2016). Three- dimensional printing of multifunctional nanocomposites: Manufacturing techniques and applications. *Advanced Materials*, *28*(28), 5794-5821.

Farooqui, J. M., Chavan, K. D., Bangal, R. S., Syed, M. M. A., Thacker, P. J., Alam, S., & Kalakoti, P. (2013). Pattern of injury in fatal road traffic accidents in a rural area of western Maharashtra, India. *Australasian Medical Journal*, *6*(9), 476-482.

Farzadi, A., Waran, V., Solati-Hashjin, M., Rahman, Z. A. A., Asadi, M., & Osman, N. A. A. (2015). Effect of layer printing delay on mechanical properties and dimensional accuracy of 3D printed porous prototypes in bone tissue engineering. *Ceramics International*, *41*(7), 8320-8330.

FDM Group. (2015). *Fused deposition modelling*. Retrieved on June 10, 2017, from http://www.cs.cmu.edu/~rapidproto/students.03/rarevalo/project2/Translation.html

Fernandez-Ballester Ma, Z., Cavallo L., Gough D., T., & Peters, G. W. M. (2013). High-stress shear-induced crystallization in isotactic polypropylene and propylene/ethylene random copolymers. *Macromolecules*, *46*(7), 2671-2680.

Filip Górskil & Wiesław Kuczko1, R. W. (2013). Influence of process parameters on dimensional accuracy of parts manufactured using fused deposition modelling technology. *Advances in Science and Technology Research Journal*, *7*(19), 27-35.

Firouzi, D., Youssef, A., Amer, M., Srouji, R., Amleh, A., Foucher, D. A., & Bougherara, H. (2014). A new technique to improve the mechanical and biological performance of ultra high molecular weight polyethylene using a nylon coating. *Journal of the Mechanical Behaviour of Biomedical Materials*, *32*, 198-209.

Fishero, B. A., Kohli, N., Das, A., Christophel, J. J., & Cui, Q. (2015). Current concepts of bone tissue engineering for craniofacial bone defect repair. *Craniomaxillofacial Trauma and Reconstruction*, *8*(01), 023-030.

Fung, Y. C. (2013). *Biomechanics: Mechanical properties of living tissues*. Springer Science & Business Media.

Gai, J.-G., & Zuo, Y. (2012). Metastable region of phase diagram: Optimum parameter range for processing ultrahigh molecular weight polyethylene blends. *Journal of Molecular Modeling*, *18*(6), 2501-2512.

Garg, A., Bhattacharya, A., & Batish, A. (2016). On surface finish and dimensional accuracy of FDM parts after cold vapor treatment. *Materials and Manufacturing Processes*, *31*(4), 522-529.

Gautam, R., Singh, R. D., Sharma, V. P., Siddhartha, R., Chand, P., & Kumar, R. (2012). Biocompatibility of polymethylmethacrylate resins used in dentistry. *Journal of Biomedical Materials Research - Part B Applied Biomaterials*, *100 B* (5), 1444-1450.

Ghasemi-Mobarakeh, L., Prabhakaran, M. P., Tian, L., Shamirzaei-Jeshvaghani, E., Dehghani, L., & Ramakrishna, S. (2015). Structural properties of scaffolds: Crucial parameters towards stem cells differentiation. *World Journal of Stem Cells*, *7*(4), 728.

Giannitelli, S. M., Accoto, D., Trombetta, M., & Rainer, A. (2014). Current trends in the design of scaffolds for computer-aided tissue engineering. *Acta Biomaterialia*, *10*(2), 580-594.

Gibson, I., Rosen, D., & Stucker, B. (2015). Direct digital manufacturing. In *Additive Manufacturing Technologies* (pp. 375-397). New York: Springer.

Gibson, R. F. (2016). *Principles of composite material mechanics*. CRC Press.

Goiato, M. C., Anchieta, R. B., Pita, M. S., & dos Santos, D. M. (2009). Reconstruction of skull defects: Currently available materials. *The Journal of Craniofacial Surgery*, *20*(5), 1512-1518.

Go, J., & Hart, A. J. (2016). A framework for teaching the fundamentals of additive manufacturing and enabling rapid innovation. *Additive Manufacturing*, *10*, 76-87.

Goodfellow, M. (2017). *Goodfellow facilitates scientific innovation*. Retrieved on June 10, 2017, from http://www.goodfellow.com/catalogue/GFCat4I.php?ewd_token=UAwGAejWId4by3P7dSlfCrbnJUi9hB&n=tw09yelOqVZkATwt674uRFSvrqHISC&ewd_urlNo=GFCat411&Catite=ET306010&CatSearNum=1

Górski, F., Kuczko, W., & Wichniarek, R. (2013). Influence of Process Parameters on Dimensional Accuracy of Parts Manufactured Using Fused Deposition Modelling Technology. *Advances in Science and Technology – Research Journal*, *7*(19), 27-35.

Granke, M., Grimal, Q., Parnell, W. J., Raum, K., Gerisch, A., Peyrin, F., … Laugier, P. (2015). To what extent can cortical bone millimeter-scale elasticity be predicted by a two-phase composite model with variable porosity? *Acta biomaterialia*, *12*, 207-215.

Guo, C., Zhou, L., & Lv, J. (2013). Effects of expandable graphite and modified ammonium polyphosphate on the flame-retardant and mechanical properties of wood flour-polypropylene composites. *Polymers and Polymer Composites*, *21*(7), 449-456.

Haq, R. H. A., Bin Wahab, M. S., & Jaimi, N. I. (2014). Fabrication process of polymer nano-composite filament for fused deposition modelling. *Applied Mechanics and Materials*, *465-466*, 8-12.

He, S., He, H., Li, Y., & Wang, D. (2015). Effects of maleic anhydride grafted polyethylene on rheological, thermal, and mechanical properties of ultra-high molecular weight polyethylene/poly (ethylene glycol) blends. *Journal of Applied Polymer Science*, *132*(43).

Hieu, L. C., Zlatov, N., Sloten, J. Vander, Bohez, E., Khanh, L., Binh, P. H., & Toshev, Y. (2005). Medical rapid prototyping applications and methods. *Assembly Automation*, *25*(4), 284-292.

Hossain, M., Ramos, J., Espalin, D., Perez, M., & Wicker, R. (2013). Improving tensile mechanical properties of FDM-manufactured specimens via modifying build parameters. *Utwired.Engr.Utexas.Edu*, 380-392.

Hsieh, P. C., Tsai, C. H., Liu, B. H., Wei, W. C. J., Wang, A. B., & Luo, R. C. (2016, March). 3D printing of low melting temperature alloys by fused deposition modelling. In *Industrial Technology (ICIT): 2016 IEEE International Conference on IEEE* (pp. 1138-1142).

Huan, S., Liu, G., Han, G., Cheng, W., Fu, Z., Wu, Q., & Wang, Q. (2015). Effect of experimental parameters on morphological, mechanical and hydrophobic properties of electrospun polystyrene fibers. *Materials*, *8*(5), 2718-2734.

Huang, S. H., Liu, P., Mokasdar, A., & Hou, L. (2013). Additive manufacturing and its societal impact: A literature review. *The International Journal of Advanced Manufacturing Technology*, *67*(5-8), 1191-1203.

Huang, W., Zhang, X., Wu, Q., & Wu, B. (2013). Fabrication of HA/ß-TCP scaffolds based on micro-syringe extrusion system. *Rapid Prototyping Journal*, *19*(5), 319-326.

Huang, G. J., Zhong, S., Susarla, S. M., Swanson, E. W., Huang, J., & Gordon, C. R. (2015). Craniofacial reconstruction with poly (methyl methacrylate) customized cranial implants. *Journal of Craniofacial Surgery*, *26*(1), 64-70.

Ivanova, O. O., Williams, C. C., & Campbell, T. T. (2013). Additive manufacturing (AM) and nanotechnology: Promises and challenges. *Rapid Prototyping Journal*, *19*(5), 353-364.

Jacob, G. C., Fellers, J. F., Simunovic, S., & Starbuck, J. M. (2002). Energy absorption in polymer composites for automotive crashworthiness. *Journal of Composite Materials*, *36*(7), 813-850.

Jardini, A. L., Larosa, M. A., de Carvalho Zavaglia, C. A., Bernardes, L. F., Lambert, C. S., Kharmandayan, P., … Maciel Filho, R. (2014). Customised titanium implant fabricated in additive manufacturing for craniomaxillofacial surgery. *Virtual and Physical Prototyping*, *9*(2), 115-125.

Jiang, Z., Chang, C. Z., Tang, C., Zheng, J. G., Moodera, J. S., & Shi, J. (2016). Structural and proximity-induced ferromagnetic properties of topological insulator-magnetic insulator heterostructures. *AIP Advances*, *6*(5), 055809.

Jikan, S. S., Arshat, I. M., & Badarulzaman, N. A. (2013). Melt Flow and Mechanical Properties of Polypropylene/Recycled Plaster of Paris. *Applied Mechanics and Materials*, *315*, 905-908.

Jin, M., Jin, B., Xu, X., Li, X., Wang, T., & Zhang, J. (2015). Effects of ultra-high molecular weight polyethylene and mould temperature on morphological evolution of isotactic polypropylene at micro-injection moulding condition. *Polymer Testing*, *46*, 41-49.

Jin, M., La, R., Zhang, Y., Liu, K., Li, X., & Zhang, J. (2015). Stratiform β crystals in ultrahigh molecular weight polyethylene and β-nucleating agent-nucleated isotactic polypropylene at micro-injection molding condition. *Polymer Testing*, *42*, 135-143.

Kadapa, C., Dettmer, W. G., & Perić, D. (2016). A fictitious domain/distributed Lagrange multiplier based fluid–structure interaction scheme with hierarchical B-Spline grids. *Computer Methods in Applied Mechanics and Engineering*, *301*, 1-27.

Kannan, S. (2013). Development of Composite Materials by Rapid Prototyping Technology using FDM Method. *IEEE*, 281-283.

Klammert, U., Gbureck, U., Vorndran, E., Rodiger1, J., & Meyer-Marcotty, P. (2010). 3D powder printed calcium phosphate implants for reconstruction of cranial and maxillofacial defects. *Journal of Cranio-Maxillo-Facial Surgery*, *38*, 565-570.

Kuang, X., Liu, G., Zheng, L., Li, C., & Wang, D. (2015). Functional polyester with widely tunable mechanical properties: The role of reversible cross-linking and crystallization. *Polymer*, *65*, 202-209.

Kumar, M. N., Venkatesh, S., & Hussain, M. M. (2017). Influence of 3D material properties on quality prototypes using SLS and FDM process of a 3D printer.

Kun, K. (2016). Reconstruction and development of a 3D printer using FDM technology. *Procedia Engineering*, *149*, 203-211.

Kurtz, S. M. (2016). *A primer on UHMWPE.*

Kurtz, S. M., Kocagöz, S., Arnholt, C., Huet, R., Ueno, M., & Walter, W. L. (2014). Advances in zirconia toughened alumina biomaterials for total joint replacement. *Journal of the Mechanical Behaviour of Biomedical Materials*, *31*, 107-116.

Lakin, B. A., Ellis, D. J., Shelofsky, J. S., Freedman, J. D., Grinstaff, M. W., & Snyder, B. D. (2015). Contrast-enhanced CT facilitates rapid, non-destructive assessment of cartilage and bone properties of the human metacarpal. *Osteoarthritis and Cartilage*, *23*(12), 2158-2166.

Lanzotti, A., Grasso, M., Staiano, G., & Martorelli, M. (2015). The impact of process parameters on mechanical properties of parts fabricated in PLA with an open-source 3-D printer. *Rapid Prototyping Journal*, *21*(5), 604-617.

Lederle, F., Meyer, F., Brunotte, G. P., Kaldun, C., & Hübner, E. G. (2016). Improved mechanical properties of 3D-printed parts by fused deposition modelling processed under the exclusion of oxygen. *Progress in Additive Manufacturing*, *1*(1-2), 3-7.

Lee, S. T. S. C., Wu, C. T., Lee, S. T. S. C., & Chen, P. J. (2009). Cranioplasty using polymethyl methacrylate prostheses. *Journal of Clinical Neuroscience*, *16*(1), 56-63.

Lee, J., & Huang, A. (2013). Fatigue analysis of FDM materials. *Rapid Prototyping Journal*, *19*(4), 291-299.

Lee, M. P., Cooper, G. J., Hinkley, T., Gibson, G. M., Padgett, M. J., & Cronin, L. (2015). Development of a 3D printer using scanning projection stereolithography. *Scientific Reports*, *5*, 9875.

Lee, J. Y., An, J., & Chua, C. K. (2017). Fundamentals and applications of 3D printing for novel materials. *Applied Materials Today*, *7*, 120-133.

Li, Y. M., Yu, Y. Z., & Wang, H. L. (2012). Study on morphology and property of UHMWPE/PP blends. *Advanced Materials Research*, *476*. 974-978.

Li, B., Li, M., Fan, C., Ren, M., Wu, P., Luo, L., … Liu, X. (2015). The wear-resistance of composite depending on the interfacial interaction between thermoplastic polyurethane and fluorinated UHMWPE particles with or without oxygen. *Composites Science and Technology*, *106*, 68-75.

Lillie, E. M., Urban, J. E., Lynch, S. K., Weaver, A. A., & Stitzel, J. D. (2016). Evaluation of skull cortical thickness changes with age and sex from computed tomography scans. *Journal of Bone and Mineral Research*, *31*(2), 299-307.

Liu, D., Kang, J., Xiang, M., & Cao, Y. (2013). Effect of annealing on phase structure and mechanical behaviours of polypropylene hard elastic films. *Journal of Polymer Research*, *20*(5), 126.

Liu, G., & Li, H. (2003). Extrusion of ultra-high molecular weight polyethylene under ultrasonic vibration field. *J. Appl Polym Sci.*, *89*, 2628-2632.

Lotte (2017). *Lotte chemical TiTAN*. Retrieved on June 10, 2017, from http://www.lottechem.my/main/main.asp

Lotte Chemical Titan (2015). *PP-sm240 data sheet*. Retrieved on June 25, 2017 http://www.matweb.com/search/datasheet.aspx?matguid=c2b924d70cbc40c7a256867161914523&ckck=1

Lukanina, Y., Khvatov, A., Kolesnikova, N., & Popov, A. (2016). Melting behaviour of polypropylenes of different chemical structure. *Chemical and Structure Modification of Polymers*, *9*, 51.

Lužanin, O., Movrin, D., & Plan, M. (2014). Effect of layer thickness, deposition angle, and infill on maximum flexural force in FDM-built specimens. *Journal for Technology of Plasticity*, *39* (1), 50-57.

Lyles, M. B., Hu, J. C., Varanasi, V. G., Hollinger, J. O., & Athanasiou, K. A. (2015). Bone tissue engineering. *Regenerative Engineering of Musculoskeletal Tissues and Interfaces*, 97.

Ma'ruf, M. T., Siswomihardjo, W., Soesatyo, M. H. N. E., & Tontowi, A. E. (2015). Effect of glutaraldehyde as a crosslinker on mechanical characteristics of catgut reinforced polyvinyl alcohol-hydroxyapatite composite as bone-fracture fixation material. *ARPN Journal of Engineering and Applied Sciences*, *10*(15), 6359-6364.

Mazatusziha A,Wahit M. U, Abdul Kadir M., & Dahlan K. Z. (2012). Mechanical, rheological, and bioactivity properties of ultra high-molecular-weight polyethylene bioactive composites containing polyethylene glycol and hydroxyapatite. *The Scientific World Journal*, 1-13.

Mable, C. J., Gibson, R. R., Prevost, S., McKenzie, B. E., Mykhaylyk, O. O., & Armes, S. P. (2015). Loading of silica nanoparticles in block copolymer vesicles during polymerization-induced self-assembly: Encapsulation efficiency and thermally triggered release. *J. Am. Chem. Soc*, *137*(51), 16098-16108.

Maddah, H. A. (2016). Polypropylene as a promising plastic: A review. *American Journal of Polymer Science*, *6*(1), 1-11.

Mahindru, D. V., & Mahendru, P. (2013). Review of rapid prototyping-technology for the future. *Global Journal of Computer Science and Technology Graphics & Vision*, *13*(4), 27-38.

Maitz, M. F. (2015). Applications of synthetic polymers in clinical medicine. *Biosurface and Biotribology*, *1*(3), 161-176.

Malligarjunan, S., Chandrasekaran, M., & Malliga, P. (2015). Diverse approaches in minimizing the build time for different rapid prototyping processes. *Journal of Engineering and Applied Sciences*, *10*(11), 5028-5033.

Maloul, A. (2012). *Biomechanical characterization of complex thin bone structures in the human craniofacial skeleton* (Doctoral thesis, Biomaterials and Biomedical Engineering University of Toronto).

Martelli, N., Serrano, C., van den Brink, H., Pineau, J., Prognon, P., Borget, I., & El Batti, S. (2016). Advantages and disadvantages of 3-dimensional printing in surgery: A systematic review. *Surgery*, *159*(6), 1485-1500.

Mcknight, C. L., Doman, D. A., Brown, J. A., Bance, M., & Adamson, R. B. (2013). Direct measurement of the wavelength of sound waves in the human skull. *The Journal of the Acoustical Society of America*, *133*(1), 136-145.

Medeiros, C. C. G., Cherubini, K., Salum, F. G., De Figueiredo, M. A. Z., & Figueiredo, M. A. Z. (2014). PMMA complications after polymethylmethacrylate (PMMA) injections in the face: A literature review. *Gerodontology*, *31*(4), 245-250.

Melchels, F. P. W., Domingos, M. a N., Klein, T. J., Malda, J., Bartolo, P. J., & Hutmacher, D. W. (2012). Additive manufacturing of tissues and organs. *Progress in Polymer Science*, *37*(8), 1079-1104.

Melocchi, A., Parietti, F., Maroni, A., Foppoli, A., Gazzaniga, A., & Zema, L. (2016). Hot-melt extruded filaments based on pharmaceutical grade polymers for 3D printing by fused deposition modelling. *International Journal of Pharmaceutics*, *509*(1), 255-263.

Merritt, C. E. (2015). The influence of body size on adult skeletal age estimation methods. *American Journal of Physical Anthropology*, *156*(1), 35-57.

Michler, G. H., & Balta-Calleja, F. J. (Eds.). (2016). *Mechanical properties of polymers based on nanostructure and morphology* (Vol. 71). CRC Press.

Minev, E. M., Yankov, E., & Minev, R. M. (2015). The Reprap 3D printers for metal casting patternmaking–capabilities and application. In *On Innovative Trends in Engineering and Science (SFITES 2015)* (pp. 122-127). Kavala, Greece: Parnas Publishing House.

Mireles, J., Espalin, D., Roberson, D., Zinniel, B., Medina, F., & Wicker, R. (2012). Fused deposition modeling of metals. *Journal of Electronic Packaging*, 836-845.

Miron, R. J., Gruber, R., Hedbom, E., Saulacic, N., Zhang, Y., Sculean, A., & Buser, D. (2013). Impact of bone harvesting techniques on cell viability and the release of growth factors of autografts. *Clinical Implant Dentistry and Related Research*, *15*(4). 481-489.

Moazen, M., Peskett, E., Babbs, C., Pauws, E., & Fagan, M. J. (2015). Mechanical properties of calvarial bones in a mouse model for craniosynostosis. *PloS one*, *10*(5), e0125757.

Mohammadi, M. S., Bureau, M. N., & Nazhat, S. N. (2014). PLA Polylactic acid (PLA) biomedical foams for tissue engineering. *Biomedical Foams for Tissue Engineering Applications*, 313.

Mohamed, O. A., Masood, S. H., & Bhowmik, J. L. (2015). Optimization of fused deposition modelling process parameters: A review of current research and future prospects. *Advances in Manufacturing*, *3*(1), 42-53.

Mohamed, O. A., Masood, S. H., Bhowmik, J. L., Nikzad, M., & Azadmanjiri, J. (2016a). Effect of process parameters on dynamic mechanical performance of FDM PC/ABS printed parts through design of experiment. *Journal of Materials Engineering and Performance*, *25*(7), 2922-2935.

Mohamed, O. A., Masood, S. H., & Bhowmik, J. L. (2016b). Experimental investigations of process parameters influence on rheological behaviour and dynamic mechanical properties of FDM manufactured parts. *Materials and Manufacturing Processes*, *31*(15), 1983-1994.

Mohamed, O. A., Masood, S. H., & Bhowmik, J. L. (2016 c). Mathematical modelling and FDM process parameters optimization using response surface methodology based on Q-optimal design. *Applied Mathematical Modelling*, *40*(23), 10052-10073.

Monzón, M. D., Gibson, I., Benítez, A. N., Lorenzo, L., Hernández, P. M., & Marrero, M. D. (2013). Process and material behaviour modelling for a new design of micro-additive fused deposition. *The International Journal of Advanced Manufacturing Technology*, *67*(9-12), 2717-2726.

Mosleh, S., Gawish, S. M., Khalil, F. H., & Bieniek, R. F. (2005). Properties and application of novel amphoteric polypropylene fabrics. *Journal of Applied Polymer Science*, *98*(6), 2373-2379.

Mota, C., Puppi, D., Chiellini, F., & Chiellini, E. (2015). Additive manufacturing techniques for the production of tissue engineering constructs. *Journal of Tissue Engineering and Regenerative Medicine*, *9*(3), 174-190.

Murr, L. E. (2015). Additive manufacturing: Changing the rules of manufacturing. In *Handbook of Materials Structures, Properties, Processing and Performance* (pp. 691-699). Springer International Publishing.

Nagarajan, H. P., Malshe, H. A., Haapala, K. R., & Pan, Y. (2016). Environmental performance evaluation of a fast mask image projection stereolithography process through time and energy modelling. *Journal of Manufacturing Science and Engineering*, *138*(10), 101004.

Naghmouchi, I., Espinach, F. X., Mutjé, P., & Boufi, S. (2015). Polypropylene composites based on lignocellulosic fillers: How the filler morphology affects the composite properties. *Materials & Design (1980-2015)*, *65*, 454-461.

Nalin Ploypetcharaa, Panuwat Suppakula, B., & Duangduen Atongc, C. P. (2014). Blend of polypropylene-poly-lactic acid for medical packaging. *Energy Procedia*, *56*, 201-210.

National Highway Traffic Safety Administration. (2016). 2015 motor vehicle crashes: Overview. *Traffic Safety Facts Research Note*, 1-9.

Negi, S., Dhiman, S., & Sharma, R. K. (2014). Basics and applications of rapid prototyping medical models. *Rapid Prototyping Journal*, *20*(3), 256-267.

Oshkour, A. A., Pramanik, S., Mehrali, M., Yau, Y. H., Tarlochan, F., & Osman, N. A. A. (2015). Mechanical and physical behavior of newly developed functionally graded materials and composites of stainless steel 316L with calcium silicate and hydroxyapatite. *Journal of the Mechanical Behaviour of Biomedical Materials*, *49*, 321-331.

Ozkaya, N., Nordin, M., Goldsheyder, D., & Leger, D. (2012). Mechanical Properties of Biological Tissues. In Fundamentals of Biomechanics. In N. Ozkaya, *Mechanical Properties of Biological Tissues* (pp. 221-236). Springer Science+Business Media.

Pan, A., Huang, Z., Guo, R., & Liu, J. (2016). Effect of FDM Process on Adhesive Strength of Polylactic Acid (PLA) Filament. *Key Engineering Materials*, 667.

Pang, W., Ni, Z., Chen, G., Huang, G., Huang, H., & Zhao, Y. (2015). Mechanical and thermal properties of graphene oxide/ultrahigh molecular weight polyethylene nanocomposites. *Rsc Advances*, *5*(77), 63063-63072.

Panin, S. V, Kornienko, L. A., Poltaranin, M. A., Mandoung, T., & Ivanova, L. R. (2014). Mechanical and tribotechnical characteristics of nanocomposites based on mixture of ultrahigh molecular weight polyethylene and polypropylene. *Advanced Materials Research*, *872*, 36-44.

Peng, A., Xiao, X., & Yue, R. (2014). Process parameter optimization for fused deposition modelling using response surface methodology combined with fuzzy inference system. *The International Journal of Advanced Manufacturing Technology*, *73*(1-4), 87-100.

Plum, A. W., & Tatum, S. A. (2015). A comparison between autograft alone, bone cement, and demineralized bone matrix in cranioplasty. *The Laryngoscope*, *125*(6), 1322-1327.

Prospector (2016). *Plastic Materials (AA- - Acu)*. Retrieved on March 12, 2017, from https://plastics.ulprospector.com/materials

Raeisdasteh Hokmabad, V., Davaran, S., Ramazani, A., & Salehi, R. (2017). Design and fabrication of porous biodegradable scaffolds: A strategy for tissue engineering. *Journal of Biomaterials Science, Polymer Edition*, 1-29.

Rane, R. H., Jayaraman, K., Nichols, K. L., Bieler, T. R., & Mazor, M. H. (2014). Evolution of crystalline orientation and texture during solid phase die- drawing of PP- Talc composites. *Journal of Polymer Science Part B: Polymer Physics*, *52*(23), 1528-1538.

Raza, M. A., Westwood, A. V. K., Stirling, C., & Ahmad, R. (2015). Effect of boron nitride addition on properties of vapour grown carbon nanofiber/rubbery epoxy composites for thermal interface applications. *Composites Science and Technology*, *120*, 9-16.

Reazul Haq Abdul Haq (2015). *Characterization and development of polycaprolactone (PCL) / montmorillonite (MMT) / hydroxapatite (HA) nanocomposites for fused deposition modelling (FDM) process* (Doctoral Thesis, Universiti Tun Hussein Onn Malaysia).

Rengier, F., Mehndiratta, A., von Tengg-Kobligk, H., Zechmann, C. M., Unterhinninghofen, R., Kauczor, H.-U., & Giesel, F. L. (2010). 3D printing based on imaging data: Review of medical applications. *International Journal of Computer Assisted Radiology and Surgery*, *5*(4). 335-341.

Ribeiro, A. R., Gemini-Piperni, S., Travassos, R., Lemgruber, L., Silva, R. C., Rossi, A. L., … Borojevic, R. (2016). Trojan-like internalization of anatase titanium dioxide nanoparticles by human osteoblast cells. *Scientific Reports*, *6*, 23615.

Rieger, J. (2015). Guidelines for the synthesis of block copolymer particles of various morphologies by RAFT dispersion polymerization. *Macromolecular Rapid Communications*, *36*(16), 1458-1471.

Roozemond, P. C., van Drongelen, M., Ma, Z., Spoelstra, A. B., Hermida- Merino, D., & Peters, G. W. (2015). Self- regulation in flow- induced structure formation of polypropylene. *Macromolecular Rapid Communications*, *36*(4), 385-390.

Ruiz-Huerta, L., Almanza-Arjona, Y. C., Caballero-Ruiz, A., Castro-Espinosa, H. A., Díaz-Aguirre, C. M., & Echevarría y Pérez, E. (2016). CAD and AM-fabricated moulds for fast cranio-maxillofacial implants manufacture. *Rapid Prototyping Journal*, *22*(1), 31-39.

Saadah, B. (2013). *Saadah Central*. Retrieved on February 15, 2017, from http://saadahcentral.blogspot.my/2013/02/boneclassification-and-structure.html

Salehi, S., Naved, B. A., & Grayson, W. L. (2016). Three- dimensional printing approaches for the treatment of critical- sized bone defects. *Advanced Surfaces for Stem Cell Research*, 233-278.

Salem Bala, A., & bin Wahab, S. (2016). Elements and materials improve the FDM products: A review. In *Advanced Engineering Forum* (Vol. 16, pp. 33-51). Trans Tech Publications.

Saini, M., Singh, Y., Arora, P., Arora, V., & Jain, K. (2015). Implant biomaterials: A comprehensive review. *World Journal of Clinical Cases: WJCC*, *3*(1), 52.

Sánchez Comas, A., Troncoso Palacio, A., Troncoso Mendoza, S., & Neira Rodado, D. (2016). Application of Taguchi experimental design for identification of factors in influence over 3D printing time with fused deposition modelling. *IJMSOR - International Journal of Management Science & Operations Research*, *1*(1). 43-48.

Saqib, S., & Urbanic, J. (2012). An Experimental Study to Determine Geometric and Dimensional Accuracy Impact Factors for Fused Deposition Modelled Parts. In *4th International Conference on Changeable, Agile, Reconfigurable and Virtual Production* (pp. 293-298). Canada.

Scheirs, J. (2009). *A guide to polymeric geomembrances*. John Wiley.

Scott, D. W. (2015). *Multivariate density estimation: Theory, practice, and visualization*. John Wiley & Sons.

Senatov, F. S., Baranov, A. A., Muratov, D. S., Gorshenkov, M. V., Kaloshkin, S. D., & Tcherdyntsev, V. V. (2014). Microstructure and properties of composite materials based on UHMWPE after mechanical activation. *Journal of Alloys and Compounds*, *615*, S573-S577.

Setti, D., Sinha, M. K., Ghosh, S., & Rao, P. V. (2015). Performance evaluation of Ti–6Al–4V grinding using chip formation and coefficient of friction under the influence of nanofluids. *International Journal of Machine Tools and Manufacture*, *88*, 237-248.

Seyed Shahabadi, S. M., & Reyhani, A. (2014). Optimization of operating conditions in ultrafiltration process for produced water treatment via the full factorial design methodology. *Separation and Purification Technology*, *132*, 50-61.

Shacham-Diamand, Y., Mintz, M., & Taub, A. (2016). Metallic implant biomaterials. *Materials Science and Engineering: Reports*, *87*, 1-57.

Shang, X., Penchev, P., Guo, C., Lancaster, M. J., Dimov, S., Dong, Y., … De Rijk, E. (2016). $ W $-Band waveguide filters fabricated by laser micromachining and 3-D printing. *IEEE Transactions on Microwave Theory and Techniques*, *64*(8), 2572-2580.

Sharifzadeh, E., Ghasemi, I., & Safajou-Jahankhanemlou, M. (2015). Modulus prediction of binary phase polymeric blends using symmetrical approximation systems as a new approach. *Iranian Polymer Journal*, *24*(9), 735-746.

Shi, W., Li, X. Y., & Dong, H. (2001). Improved wear resistance of ultra-high molecular weight polyethylene by plasma immersion ion implantation. *Wear*, *250*, 544-552.

Sing, S. L., An, J., Yeong, W. Y., & Wiria, F. E. (2016). Laser and electron- beam powder- bed additive manufacturing of metallic implants: A review on processes, materials and designs. *Journal of Orthopaedic Research*, *34*(3), 369-385.

Singh, A. K., & Chauhan, S. (2016). Technique to Enhance FDM 3D Metal Printing. *Bonfring International Journal of Industrial Engineering and Management Science*, *6*(4), 128.

Singh, S., Ramakrishna, S., & Singh, R. (2017). Material issues in additive manufacturing: A review. *Journal of Manufacturing Processes*, *25*, 185-200.

Skinner, H. C. W. (2013). Mineralogy of bones. In *Essentials of Medical Geology* (pp. 665-687). Netherlands: Springer.

Smith, W. C., & Dean, R. W. (2013). Structural characteristics of fused deposition modeling polycarbonate material. *Polymer Testing*, *32*(8), 1306-1312.

Song, T., Qiu, Z. Y., & Cui, F. Z. (2015). Biomaterials for reconstruction of cranial defects. *Frontiers of Materials Science*, *9*(4), 346-354.

Sreekanth, P. R., & Kanagaraj, S. (2013). Assessment of bulk and surface properties of medical grade UHMWPE based nanocomposites using nanoindentation and microtensile testing. *Journal of the Mechanical Behaviour of Biomedical Materials*, *18*, 140-151.

Srithep, Y., Nealey, P., & Turng, L. S. (2013). Effects of annealing time and temperature on the crystallinity and heat resistance behavior of injection- molded poly (lactic acid). *Polymer Engineering & Science*, *53*(3), 580-588.

Su-Wen Lim, Hwei-San Loh, Kang-Nee Ting, T. D. B., & Z. N. A. (2015). Reduction of MTT to purple formazan by vitamin E isomers in the absence of cells. *Tropical Life Sciences Research*, *26*(1), 111-120.

Suñer, S., Tipper, J. L., & Emami, N. (2012). Biological effects of wear particles generated in total joint replacements: Trends and future prospects. *Tribology-Materials, Surfaces & Interfaces*, *6*(2), 75.

Szost, B. A., Terzi, S., Martina, F., Boisselier, D., Prytuliak, A., Pirling, T., … Jarvis, D. J. (2016). A comparative study of additive manufacturing techniques: Residual stress and microstructural analysis of CLAD and WAAM printed Ti–6Al–4V components. *Materials & Design*, *89*, 559-567.

Szykiedans, K., & Credo, W. (2016). Mechanical properties of FDM and SLA low-cost 3-D prints. *Procedia Engineering*, *136*, 257-262.

Thomas, D. J. (2016). 3D Printing. *Printing on Polymers: Fundamentals and Applications*, 293-306.

Teoh, S. H., Tang, Z. G., & Hastings, G. W. (2016). Thermoplastic polymers in biomedical applications: Structures, properties and processing. In *Handbook of Biomaterial Properties* (pp. 261-290). New York: Springer.

Teramura, S., Sakoda, H., Terao, T., Fujiwara, K., Kawai, K., & Tomita, N. (2009). Reduction of wear volume from accelerated aged UHMWPE knee components by the addition of vitamin E. *Journal of Biomechanical Science and Engineering*, *4*(4), 589-596.

Ticona Engineering Polymers. (2009). *UHMWPE (GUR 1020) Celanese*. Retrieved on June 25, 2017, from http://www.gz-ideal.com/UploadFile/CoolSite/2013-11/2013111216311297.pdf

Tomashchuk, I., Grevey, D., & Sallamand, P. (2015). Dissimilar laser welding of AISI 316L stainless steel to Ti6–Al4–6V alloy via pure vanadium interlayer. *Materials Science and Engineering: A*, *622*, 37-45.

Torabi, K., Farjood, E., & Hamedani, S. (2015). Rapid prototyping technologies and their applications in prosthodontics: A review of literature. *Journal of Dentistry*, *16*(1), 1.

Torres, Y., Trueba, P., Pavón, J., Montealegre, I., & Rodríguez-Ortiz, J. A. (2014). Designing, processing and characterisation of titanium cylinders with graded porosity: An alternative to stress-shielding solutions. *Materials & Design*, *63*, 316-324.

Trojanowska-Tomczak, M., Steller, R., Ziaja, J., Szafran, G., & Szymczyk, P. (2014). Preparation and properties of polymer composites filled with low melting metal alloys. *Polymer-Plastics Technology and Engineering*, *53*(5), 481-487.

Tseng, A. A., & Tanaka, M. (2001). Advanced deposition techniques for freeform fabrication of metal and ceramic parts. *Rapid Prototyping Journal*, *7*(1), 6-17.

Turner, B. N., Strong, R., & Gold, S. A. (2014). A review of melt extrusion additive manufacturing processes: I. Process design and modelling. *Rapid Prototyping Journal*, *20*(3), 192-204.

Vaezi, M., & Yang, S. (2015a). A novel bioactive PEEK/HA composite with controlled 3D interconnected HA network. *International Journal of Bioprinting*, *1*(1).

Vaezi, M., & Yang, S. (2015b). Extrusion-based additive manufacturing of PEEK for biomedical applications. *Virtual and Physical Prototyping*, *10*(3), 123-135.

Vargas, K. F., Borghetti, R. L., Moure, S. P., Salum, F. G., Cherubini, K., & de Figueiredo, M. A. Z. (2012). Use of polymethylmethacrylate as permanent filling agent in the jaw, mouth and face regions–implications for dental practice. *Gerodontology*, *29*(2), e16–e22.

Wang, X., Tuomi, J., Mäkitie, A. A., Paloheimo, K.-S., Partanen, J., & Yliperttula, M. (2013). The integrations of biomaterials and rapid prototyping techniques for intelligent manufacturing of complex organs. *Advances in Biomaterials Science and Biomedical Applications*, *5*(3), 212-220.

Wang, H., Li, M., Huang, S., Zheng, J., Chen, X., Chen, X., & Zhu, Z. (2015). Deposition characteristics of the double nozzles near-field electrospinning. *Applied Physics A*, *118*(2), 621-628.

Wang, X., Li, J. T., Xie, M. Y., Qu, L. J., Zhang, P., & Li, X. L. (2015). Structure, mechanical property and corrosion behaviors of (HA+ β-TCP)/Mg–5Sn composite with interpenetrating networks. *Materials Science and Engineering: C*, *56*, 386-392.

WHO (2015). *Global Status Report on Road Safety 2015*. World Health Organization.

Wimmer, W., Gerber, N., Guignard, J., Dubach, P., Kompis, M., Weber, S., & Caversaccio, M. (2015). Topographic bone thickness maps for bonebridge implantations. *European Archives of Oto-Rhino-Laryngology*, *272*(7), 1651-1658.

Wong, K. V., & Hernandez, A. (2012). A review of additive manufacturing. *ISRN Mechanical Engineering*, 1-10.

Wong, W. H., Lee, W. X., Ramanan, R. N., Tee, L. H., Kong, K. W., Galanakis, C. M., … Prasad, K. N. (2015). Two level half factorial design for the extraction of phenolics, flavonoids and antioxidants recovery from palm kernel by-product. *Industrial Crops and Products*, *63*, 238-248.

Wu, G. H., & Hsu, S. H. (2015). Polymeric-based 3D printing for tissue engineering. *Journal of Medical and Biological Engineering*, *35*(3), 285-292.

Wypych, G. (2016). *Handbook of Polymers*. Elsevier.

XiaoHui, S., Wei, L., PingHui, S., QingYong, S., QingSong, W., YuSheng, S., … WenGuang, L. (2015). Selective laser sintering of aliphatic-polycarbonate/hydroxyapatite composite scaffolds for medical applications. *The International Journal of Advanced Manufacturing Technology*, *81*(1-4), 15-25.

Xin, C., He, Y., Li, Q., Huang, Y., Yan, B., & Wang, X. (2012). Crystallization behaviour and foaming properties of polypropylene containing ultra- high molecular weight polyethylene under supercritical carbondioxide. *Journal of Applied Polymer Science*, *119*(3), 1275-1286.

Xu, L., Huang, Y.-F., Xu, J.-Z., Ji, X., & Li, Z.-M. (2014). Improved performance balance of polyethylene by simultaneously forming oriented crystals and blending ultrahigh-molecular-weight polyethylene. *RSC Adv*, *4*(4), 1512-1520.

Yaghini, N., & Iedema, P. D. (2015). Branching determination from radius of gyration contraction factor in radical polymerization. *Polymer*, *59*, 166-179.

Yi, P., Locker, C. R., & Rutledge, G. C. (2013). Molecular dynamics simulation of homogeneous crystal nucleation in polyethylene. *Macromolecules*, *46*(11), 4723-4733.

Zavaglia, C. A. C., & Prado da Silva, M. H. (2016). Biomaterials. *Reference Module in Materials Science and Materials Engineering*.

Zhang, J. W., & Peng, A. H. (2012). Process-parameter optimization for fused deposition modeling based on Taguchi method. *Advanced Materials Research*, *538-541*, 444-447.

Zhang, K., Gong, W., Lv, J., Xiong, X., & Wu, C. (2015). Accumulation of floating microplastics behind the Three Gorges Dam. *Environmental Pollution*, *204*, 117-123.

Zhao, L., Lu, H., & Gao, Z. (2015). Microstructure and mechanical properties of al/graphene composite produced by high- pressure torsion. *Advanced Engineering Materials*, *17*(7), 976-981.

Zheng, Y., Xiong, C., & Zhang, L. (2014). Formation of bone-like apatite on plasma-carboxylated poly(etheretherketone) surface. *Materials Letters*, *126*, 147-150.

Zhou, C., Chen, Y., Yang, Z., & Khoshnevis, B. (2013). Digital material fabrication using mask-image-projection-based stereolithography. *Rapid Prototyping Journal*, *19*(3), 153-165.

Zhou, Y. G., Su, B., & Turng, L. S. (2017). Deposition-induced effects of isotactic polypropylene and polycarbonate composites during fused deposition modelling. *Rapid Prototyping Journal*.