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DAFTAR PUSTAKA

Ahmed, Y.M.Z., El-Sheikh, S.M. and Zaki, Z.I. (2015) "Changes in hydroxyapatite powder properties via heat treatment," *Bull. Mater. Sci*, 38(7), pp. 1807–1819.

Åkerlund, E., Diez-escudero, A. and Grzeszczak, A. (2022a) "The Effect of *PCL* Addition on 3D-Printable *PLA* / HA Composite Filaments for the Treatment of Bone Defects," *Polymers*, 14, p. 3305. Available at: https://doi.org/doi.org/10.3390/polym14163305.

Åkerlund, E., Diez-escudero, A. and Grzeszczak, A. (2022b) "The Effect of *PCL* Addition on 3D-Printable *PLA* / HA Composite Filaments for the Treatment of Bone Defects," *Polymers*, 14(3305). Available at: https://doi.org/10.3390/polym14163305.

Alanis-gómez, R.P., Hernández-rosas, F., Olivares-hernández, J.D., Rivera-muñoz, E.M., Zapatero-gutiérrez, A., Méndez-lozano, N., Alanis-gómez, J.R. and Velázquez-castillo, R. (2024) "Magnesium Doped Hydroxyapatite Nanofibers for Medicine Applications : Characterization , Antimicrobial Activity , and Cytotoxicity Study Magnesium Doped Hydroxyapatite Nanofibers for," *International Journal of Molecular Sciences*, 25(22), p. 12418. Available at: https://doi.org/10.3390/ijms252212418.

Alanis-Gomez, R.P., Hernandez-Rosas, F., OlivaresHernandez, J.D., Rivera-muñoz, E.M., Zapatero-Gutierrez, A., Mendez-Lozano, N., Alanis-Gomez, R. and Velazquez-Castillo, R. (2024) "Magnesium-Doped Hydroxyapatite Nanofibers for Medicine Applications : Characterization , Antimicrobial Activity , and Cytotoxicity Study," *International Journal of Molecular Sciences*, 25, p. 12418. Available at: https://doi.org/https://doi.org/10.3390/ijms252212418.

Anggraini, R.M., Supii, A.I., Suparta, G.B. and Yusuf, Y. (2019) "The Effect of pH on the Characteristics of Carbonate Hydroxyapatite Based on Pearl Shell (Pinctada maxima)," *Key Engineering Materials*, 818, pp. 44–49. Available at: https://doi.org/10.4028/www.scientific.net/KEM.818.44.

ASTM (2016) *ASTM F1635: Standard Test Method for In Vitro Degradation Testing of Hydrolytically Degradable Polymer Resins and Fabricated Forms for Surgical* Implan*ts*. West Conshohocken, PA.

Badan Pusat Statistik NTB, B.-N. (2024) *Berita Resmi Statistik: Perkembangan Ekspor dan Impor Provinsi Nusa Tenggara Barat Bulan Juni 2024*. Mataram.

Baino, F. and Yamaguchi, S. (2020) "The Use of Simulated Body Fluid (SBF) for Assessing Materials Bioactivity in the Context of Tissue Engineering : Review and Challenges," *Biomimetics*, 5(57). Available at: https://doi.org/10.3390/biomimetics5040057.

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Baskaran, T., Mohammad, N.F., Saleh, S.S.M., Nasir, N.F.M. and Daud, F.D.M. (2021) "Synthesis Methods of Doped Hydroxyapatite : A Brief Review," *Journal of Physics: Conference Series*, 2071. Available at: https://doi.org/10.1088/1742-6596/2071/1/012008.

Bauer, L., Ivanković, M. and Ivanković, H. (2018) "MAGNESIUM SUBSTITUTED HYDROXYAPATITE SCAFFOLDS HYDROTHERMALLY SYNTHESIZED FROM CUTTLEFISH BONE," *Materials, Tribology, Recycling*, 2.

Beć, K.B., Grabska, J. and Huck, C.W. (2020) "Near-Infrared Spectroscopy in Bio-Applications," *Molecules*, 25, p. 2948. Available at: https://doi.org/10.3390/molecules25122948.

Bernardo, M.P. and Cristina, B. (2021) "Development of three-dimensional printing filaments based on poly (lactic acid)/ hydroxyapatite composites with potential for tissue engineering," *Journal of Composite Materials*, 55(17), pp. 2289–2300. Available at: https://doi.org/10.1177/0021998320988568.

Bernardo, M.P., Silva, B.C.R., Hamouda, A.E.I., Toledo, M.A.S. De, Schalla, C., Rütten, S., Goetzke, R., Mattoso, L.H.C., Zenke, M. and Sechi, A. (2022) "OPEN *PLA* / Hydroxyapatite scaffolds exhibit in vitro immunological inertness and promote robust osteogenic differentiation of human mesenchymal stem cells without osteogenic stimuli," *Scientific Reports*, 12, p. 2333. Available at: https://doi.org/10.1038/s41598-022-05207-w.

Bilgili, H.K., Aydin, M.S., Sahin, M., Sahin, S.B., Cetinel, S. and Kiziltas, G. (2025) "3D-Printed Functionally Graded *PCL*-HA Scaffolds with Multi-Scale Porosity," *ACS OMEGA*, 10, pp. 6502–6519. Available at: https://doi.org/10.1021/acsomega.4c06820.

Bird, J. and Ross, C. (2020) *Mechanical Engineering Principles Fourth*. Fourth Edi. New York: Routledge Taylor & Francis Group.

Borciani, G., Fischetti, T., Ciapetti, G., Montesissa, M., Baldini, N. and Graziani, G. (2023) "Marine biological waste as a source of hydroxyapatite for bone tissue engineering applications," *Ceramics International*, 49(2), pp. 1572–1584. Available at: https://doi.org/https://doi.org/10.1016/j.ceramint.2022.10.341.

Budi, M.N.S., Kariem, M.A., Dwinata, B., Hidayat, Y.M., Sutiono, A.B., Fathurachman, F., Ismail, W.F.N.W., Dwitama, Y.G. and Nugraha, P. (2026) "3D-Printed *PLA*/HA Composite Scaffolds: Balancing Mechanical Properties for Bone Tissue Engineering," *Materials*, 19(10). Available at: https://doi.org/10.3390/ma19102083.

Bulina, N. V, Eremina, N. V, Makarova, S. V, Borodulina, I.A., Vinokurova, O.B., Avakyan, L.A., Paramonova, E. V, Bystrov, V.S. and Logutenko, O.A. (2024) "Influence of Magnesium Source on the Mechanochemical

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Synthesis of Magnesium-Substituted Hydroxyapatite," *Materials*, 17, p. 416. Available at: https://doi.org/10.3390/ma17020416.

Bystrov, V.S., Paramonova, E. V, Avakyan, L.A., Eremina, N. V, Makarova, S. V and Bulina, N. V (2023) "Effect of Magnesium Substitution on Structural Features and Properties of Hydroxyapatite," *Materials*, 16, p. 5945. Available at: https://doi.org/10.3390/ma16175945.

Cahyati, N., Sari, M. and Yusuf, Y. (2024a) "Biological and physicochemical characterization of carbonated hydroxyapatite-honeycomb-polyethylene oxide bone scaffold fabricated using the freeze-drying method," *Advances in Natural Sciences: Nanoscience and Nanotechnology*, 15(3), p. 35004. Available at: https://doi.org/10.1088/2043-6262/ad6b7b.

Cahyati, N., Sari, M. and Yusuf, Y. (2024b) "Properties of Carbonated Hydroxyapatite-Based Scaffold from Oyster Shells Composited with Honeycomb and Polyethylene Oxide for Bone Tissue Engineering Applications," *Key Engineering Materials*, 977, pp. 103–108. Available at: https://doi.org/10.4028/p-mH0PTj.

Collins, M.N., Ren, G., Young, K., Pina, S., Reis, R.L. and Oliveira, J.M. (2021) "Scaffold Fabrication Technologies and Structure / Function Properties in Bone Tissue Engineering," *Advanced Functional Materials*, 31(2010609). Available at: https://doi.org/10.1002/adfm.202010609.

Colthup, N.B., Daly, L.H. and Wiberley, S.E. (2003) *Introduction to infrared and Raman spectroscopy*. Third. San Diego: Academic Press.

Correa-Piña, B.A., Gomez-Vaquez, O.M., Londoño-Restrepo, S.M., Zubieta-Otero, L.F., Millan-Malo, B.M. and Rodriguez-Garcia, M.E. (2021) "Synthesis and characterization of nano-hydroxyapatite added with magnesium obtained by wet chemical precipitation," *Progress in Natural Science : Materials International*, 31(June), pp. 575–582. Available at: https://doi.org/10.1016/j.pnsc.2021.06.006.

Cowie, J.M.. and Arrighi, V. (2007) *Polymers: Chemistry and Physics of Modern Materials*. Third. Scotland: CRC Press.

Custodio, C.L., Broñola, P.J.M., Cayabyab, S.R., Lagura, V.U., Celorico, J.R. and Basilia, B.A. (2021) "Powder Loading Effects on the Physicochemical and Mechanical Properties of 3D Printed Poly Lactic Acid / Hydroxyapatite Biocomposites," *International Journal of Bioprinting*, 7(1), pp. 112–122.

Dampang, S., Purwanti, E., Destyorini, F., Kurniawan, S.B., Rozaimah, S., Abdullah, S. and Imron, M.F. (2021) "Analysis of Optimum Temperature and Calcination Time in the Production of CaO Using Seashells Waste as CaCO 3 Source," *Journal of Ecological Engineering*, 22(5), pp. 221–228. Available at: https://doi.org/10.12911/22998993/135316.

Davis, J.. (2004) *Tensile Testing*. Second. New York: ASM International.

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Davoodi, E., Montazerian, H., Sadat, A., Kadkhodapour, J., Li, B., Khademhosseini, A. and Toyserkani, E. (2022) *Bioactive Materials Additively manufactured metallic biomaterials*, *Bioactive Materials*. KeAi Communications Co., Ltd. Available at: https://doi.org/10.1016/j.bioactmat.2021.12.027.

Dios-suárez, J. De, Pérez-escobar, B.L., Pérez-hernández, G., Lizama-tzec, F.I., Díaz-flores, L.L., Pérez-montejo, S., Dios-jiménez, J.P. De and Torres-ricárdez, R. (2026) "Influence of Thermal Treatment and Particle Size on the Physicochemical Properties and Filler Performance of Oyster Shell-Derived CaCO 3 in Mortar," *Materials*, 19(1656), pp. 1–13. Available at: https://doi.org/10.3390/ma19081656.

Dorozhkin, S. V and Epple, M. (2002) "Biological and Medical Significance of Calcium Phosphates," *Angewandte Chemie*, 41, pp. 3130–3146.

Farah, S., Anderson, D.G. and Langer, R. (2016) "Physical and mechanical properties of *PLA*, and their functions in widespread applications — A comprehensive review," *Advanced Drug Delivery Reviews*, 107, pp. 367–392. Available at: https://doi.org/10.1016/j.addr.2016.06.012.

Farzadi, A., Bakhshi, F., Solati-hashjin, M., Asadi-eydivand, M. and Osman, N.A.A. (2014) "Magnesium incorporated hydroxyapatite : Synthesis and structural properties characterization," *CERAMICS INTERNATIONAL*, 40, pp. 6021–6029. Available at: https://doi.org/10.1016/j.ceramint.2013.11.051.

Fernández-Penas, R., Verdugo-Escamilla, C., Triunfo, C., Gärtner, S., D'Urso, A., Oltolina, F., Follenzi, A., Maoloni, G., Cölfen, H., Falini, G. and Gómez-Morales, J. (2023) "A sustainable one-pot method to transform seashell waste calcium carbonate to osteoinductive hydroxyapatite," *Journal of Materials Chemistry B*, 10(July), pp. 7766–7777. Available at: https://doi.org/10.1039/D3TB00856H.

Garratt-Reed, A.J. and Bell, D.C. (2003) *Energy-Dispersive X-Ray Analysis in the Electron Microscope*. Oxford: BIOS Scientific Publishers Limited.

Gharibshahian, M., Salehi, M., Beheshtizadeh, N., Farahani, M.K., Atshi, A., Nourbakhsh, M.S. and Alizade, M. (2023) "Recent advances on 3D-printed *PCL*-based composite scaffolds for bone tissue engineering," *Frontiers in Bioengineering and Biotechnology* [Preprint], (June). Available at: https://doi.org/10.3389/fbioe.2023.1168504.

Gobbi, S.J., Reinke, G., Gobbi, V.J., Rocha, Y. and Sousa, T.P. (2020) "Biomaterial : Concepts and Basics Properties," *European International Journal of Science and Technology*, 9(2), pp. 23–42.

Goldstein, J.I., Newbury, D.E., Michael, J.R., Ritchie, N.W.M., Scott, J.H.J. and Joy, D.C. (2018) *Scanning Electron Microscopy and X-Ray Microanalysis*. Fourth. New York: Springer.

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Hammond, C. (2015) *The Basics of Crystallography and Diffraction*. Fourth. Oxford: Oxforf University Press.

Hamzah, M.S. (2016) "Perubahan Tekanan Media Pemeliharaan Larva Kerang Mutiara (Pinctada maxima) Terhadap Daya Reaksi Enzim Protease dalam Memacu Pertumbuhan dan Sintasan," *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 7(2), pp. 655–670. Available at: https://doi.org/10.29244/jitkt.v7i2.11032.

Hanafi, M.E.S., Sallam, S.M. and Mohamed, F.A. (2016) "Characterization of Hydroxyapatite Doped with Different Concentrations of Magnesium Ions," *International Journal of Research Studies in Science, Engineering and Technology*, 3(8), pp. 17–23.

Harrington, G.F. and Santiso, J. (2021) "Back - to - Basics tutorial : X - ray diffraction of thin films," *Journal of Electroceramics*, 41, pp. 141–163. Available at: https://doi.org/10.1007/s10832-021-00263-6.

Hassan, M.I., Sun, T. and Sultana, N. (2014) "Fabrication of Nanohydroxyapatite / Poly (caprolactone) Composite Microfibers Using Electrospinning Technique for Tissue Engineering Applications," *Journal of Nanomaterials* [Preprint]. Available at: https://doi.org/10.1155/2014/209049.

Hassanajili, S., Karami-pour, A., Oryan, A. and Talaei-khozani, T. (2019) "Materials Science & Engineering C Preparation and characterization of *PLA* / *PCL* / HA composite sca ff olds using indirect 3D printing for bone tissue engineering," *Materials Science & Engineering C*, 104(June), p. 109960. Available at: https://doi.org/10.1016/j.msec.2019.109960.

He, Z., Wang, S. and Xia, X. (2025) "Effects of *PCL* / *PLA* / HA nanocarrier on apoptosis , growth and functional metabolism of osteoblasts," *Pak. J. Pharm. Sci.*, 38(6), pp. 2031–2038. Available at: https://doi.org/10.36721/PJPS.2025.38.6.REG.14584.1.

Hebbar, K.R. (2020) *Basic of X-ray Diffraction and its Applications*. New Delhi: Dreamtech Press.

Hein, Z.M. and Thu, M. (2021) "STUDY ON SHELL MORPHOLOGY AND INTERNAL SOFT TISSUE ANATOMY OF GOLD-LIPPED PEARL OYSTER PINCTADA MAXIMA (JAMESON , 1901) IN MYEIK ARCHIPELAGIC WATERS," *J. Myanmar Acad. Arts Sci*, XIX(4).

Ho, W.-F., Lee, M.-H., Thomas, J.L., Li, J.-A., Wu, S.-C., Hsu, H.-C. and Lin, H.-Y. (2021) "Porous Biphasic Calcium Phosphate Granules from Oyster Shell Promote the Differentiation of Induced Pluripotent Stem Cells," *International Journal of Molecular Sciences*, 22(17). Available at: https://doi.org/10.3390/ijms22179444.

Hossain, S., Akter, S. and Ahmed, S. (2023) "Results in Chemistry

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Crystallographic characterization of bio-waste material originated CaCO 3 , green-synthesized CaO and Ca (OH) 2," *Results in Chemistry*, 5(January), p. 100822. Available at: https://doi.org/10.1016/j.rechem.2023.100822.

Hussin, M.S.F., Abdullah, H.Z., Idris, M.I. and Abdul Wahap, M.A. (2022) "Heliyon Extraction of natural hydroxyapatite for biomedical applications — A review," *Heliyon*, 8(8), p. e10356. Available at: https://doi.org/10.1016/j.heliyon.2022.e10356.

International Organization for Standardization, I. (2008) Implan*ts for surgery — Hydroxyapatite — Part 1: Ceramic hydroxyapatite (ISO 13779-1:2008)*. Geneva.

IOF, I.O.F. (2024) *Epidemiology of Osteoporosis and Fragility Fractures*, *International Osteoporosis Foundation*. Available at: https://www.osteoporosis.foundation/facts-statistics/epidemiology-of-osteoporosis-and-fragility-fractures (Accessed: December 1, 2025).

Irfan, M., Suprajaa, P.S., Baraneedharan, P. and Reddy, B.M. (2020) "A Comparative Study of Nanohydroxyapetite Obtained from Natural Shells and Wet Chemical Process," *Journal of Materials Science & Surface Engineering*, 7(1), pp. 938–943. Available at: https://doi.org/10.jmsse/2348-8956/7-1.5.

Ismail, R., Cionita, T., Lai, Y.L., Fitriyana, D.F., Siregar, J.P., Irawan, A.P. and Hadi, A.E. (2022) "Characterization of *PLA* / *PCL* / Green Mussel Shells," *Materials*, 15(8641).

ISO (2014) *ISO 23317:* Implan*ts for Surgery — In Vitro Evaluation for Apatite-Forming Ability of* Implan*t Materials*. Geneva.

Izzati, L. (2023) *SERBUK KALSIUM KARBONAT (CaCO3) DARI SERBUK KALSIUM KARBONAT (CaCO3) DARI CANGKANG KERANG MUTIARA (Pinctada maxima)*. Universitas Mataram.

Jamarun, N., Prasejati, A., Trycahyani, N.., Novesar, M.., Zilfa, Sisca, V., Septiana, I.T. and Isa, I.M. (2026) "SYNTHESIS OF HIGH SURFACE AREA HYDROXYAPATITE FROM EGGSHELL-DERIVED CaO USING ACETIC ACID FOR ENHANCED ADSORPTION AND REGENERATION PERFORMANCE," *RASAYAN Journal of Chemistry*, 19(1), pp. 400–408. Available at: https://doi.org/10.31788/RJC.2026.1919440.

Jang, S., Park, Kyeongmun, Song, S., Lee, H., Park, S., Youn, B. and Park, Kanghyun (2021) "Removal of Various Hazardous Materials Using a Multifunctional Biomass-Derived Hydroxyapatite (HAP) Catalyst and Its Antibacterial Effects," *Water*, 13(22). Available at: https://doi.org/10.3390/w13223302.

UNIVERSITAS GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

JEOL (2023) *Scanning Electron Microscope A To Z Basic Knowledge For Using The SEM*. Tokyo: JEOL Serving Advanced Technology.

Jiao, Z., Luo, B., Xiang, S., Ma, H., Yu, Y. and Yang, W. (2019) "Advanced Industrial and 3D 3D 3D printing of HA / *PCL* composite tissue engineering scaffolds," *Advanced Industrial and Engineering Polymer Research*, 2(4), pp. 196–202. Available at: https://doi.org/10.1016/j.aiepr.2019.09.003.

Jubier, N.J., Hassani, R.H., Hathot, S.F. and Salim, A.A. (2023) "A new type of carbonate hydroxyapatite nanoparticles made from PMMA and oyster shells : evaluation of structure , morphology and biocompatible properties," *Polymer Bulletin*, 80(12), pp. 13263–13277. Available at: https://doi.org/10.1007/s00289-023-04712-w.

Kanasan, N., Adzila, S., Rahman, H.A., Bano, N., Panerselvan, G. and Hidayati, N.A. (2018) "FTIR and XRD Evaluation of Magnesium Doped Hydroxyapatite / Sodium Alginate Powder by Precipitation Method," *Key Engineering Materials*, 791, pp. 45–49. Available at: https://doi.org/10.4028/www.scientific.net/KEM.791.45.

Karachalios, T.L. (2014) *Bone*-Implan*t Interface in Orthopedic Surgery*. New York: Springer. Available at: https://doi.org/10.1007/978-1-4471-5409-9.

Kawsar, M., Sahadat Hossain, M., Alam, M.K., Bahadur, N.M., Shaikh, M.A.A. and Ahmed, S. (2024) "Synthesis of pure and doped nano-calcium phosphates using different conventional methods for biomedical applications: a review," *Journal of Materials Chemistry B*, 12(14), pp. 3376–3391. Available at: https://doi.org/10.1039/d3tb02846a.

Keaveny, T.M., Pinilla, T.P., Crawford, R.P., Kopperdahl, D.L. and Lou, A. (1997) "Systematic and random errors in compression testing of trabecular bone," *Journal of Orthopaedic Research*, 15(1), pp. 101–110. Available at: https://doi.org/https://doi.org/10.1002/jor.1100150115.

Kemenkes-RI (2021) *Hindari Tulang Keropos Edisi 136*, *MEDIAKOM*.

Kementerian Kesehatan Republik Indonesia (2018) *Laporan Nasional RISKESDAS 2018*. Jakarta.

Kementrian Kelautan dan Perikanan, K. (2023) *Kelautan dan Perikanan dalam Angka Tahun 2023*. Jakarta.

Khamvongsa, M., Milton, K. and Faisal, T.R. (2025) "Annals of 3D Printed Medicine Mechanical characterization of low-cost 3D FDM printed scaffolds fabricated with synthesized *PLA* / HA bio-composite filament," *Annals of 3D Printed Medicine*, 18, p. 100194. Available at: https://doi.org/10.1016/j.stlm.2025.100194.

Khan, S.A., Khan, S.B., Khan, L.U., Farooq, A., Akhtar, K. and Asiri, A.M. (2018) "Fourier Transform Infrared Spectroscopy : Fundamentals and Application

UNIVERSITAS
GADJAH MADA
**Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada
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in Functional Groups and Nanomaterials Characterization," in *Handbook ofMaterials Characterization*. New York: Springer.

Khan, U.U. and Munir, S. (2026) "CaO Nanoparticles with Calcite Signatures : Antibacterial Function and Biosafety," *Progress in Chemical and Biochemical Research*, 9(2), pp. 130–143.

Kheradmandfard, M., Mahdavi, K. and Zargar, A. (2020) "In vitro study of a novel multi-substituted hydroxyapatite nanopowder synthesized by an ultra-fast , efficient and green microwave-assisted method," *Materials Science & Engineering C*, 117, p. 111310. Available at: https://doi.org/10.1016/j.msec.2020.111310.

Kumar, R. and Mohanty, S. (2022) "Hydroxyapatite : A Versatile Bioceramic for Tissue Engineering Application," *Journal of Inorganic and Organometallic Polymers and Materials*, 32, pp. 4461–4477.

Ladd, M. and Palmer, R. (2013) *Structure Determination by X-Ray Crystallography*. Fifth. Springer.

Lan, Y., Chen, S., Lan, G., Li, C. and Wei, J. (2025) "Global , regional , and national burden of fracture of vertebral column , 1990 – 2021 : analysis of data from the global burden of disease study 2021," *Frontiers in Public Health* [Preprint], (April). Available at: https://doi.org/10.3389/fpubh.2025.1573888.

Larkin, P.J. (2011) *IR and Raman Spectroscopy Pricples and Spectral Interpretation*. Oxford: Elsevier.

Lett, J.A., Sagadevan, S., Léonard, E., Fatimah, I., Hossain, M.A.M., Mohammad, F., Al-Lohedan, H.A., Paiman, S., Alshahateet, S.F., Razak, S.I.A. and Johan, M.R. (2021) "Bone tissue engineering potentials of 3D printed magnesium- - hydroxyapatite @ polylactic acid composite scaffolds," *Artificial organs*, (April), pp. 1–12. Available at: https://doi.org/10.1111/aor.14045.

Li, M., Yuan, H., Ding, W., Du, H., Guo, X., Li, D. and Xu, Y. (2023) "Selective laser sintering *PLA* / Mg composite scaffold with promoted degradation and enhanced mechanical," *Journal of Polymers and the Environment*, pp. 1–21. Available at: https://doi.org/10.21203/rs.3.rs-3608380/v1.

Liu, Q., Chen, Z., Pan, H., Drvel, B.W. and Matinlinna, J.P. (2016) "Effect of magnesium on the solubility of hydroxyapatite," *European Journal of Inorganic Chemistry*, pp. 5623–5629. Available at: https://doi.org/10.1002/ejic.201601056.

Luo, Q., Liu, Q., Weng, W. and Zhang, Y. (2026) "Vanillin-modified hydroxyapatite enhanced chitosan film: Preparation, characterization, and application in beef preservation," *International Journal of Biological Macromolecules*, 373, p. 153182. Available at:

UNIVERSITAS
GADJAH MADA
**Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada
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https://doi.org/https://doi.org/10.1016/j.ijbiomac.2026.153182.

MacDonald, C.A. (2017) *An Introduction to X- Ray Physics, Optics, and Applications*. New Jersey: PRINCE TON UNIVERSITY PRESS.

Magvirah, T., Marwati and Ardhani, F. (2019) "UJI DAYA HAMBAT BAKTERI Staphylococcus aureus MENGGUNAKAN EKSTRAK DAUN TAHONGAI (Kleinhovia hospita L.)," *Jurnal Peternakan Lingkungan Tropis*, 2(2), pp. 41–50.

Mahanty, A. and Shikha, D. (2023) "Microstructural , biocompatibility and mechanical investigation of MgHAp and AgHAp : Comparative report," *Journal of Materials Science: Materials in Medicine*, 34(22). Available at: https://doi.org/10.1007/s10856-023-06725-3.

Mahene, W.L., Gervas, C., Hilonga, A.H. and Machunda, R.L. (2020) "Synthesis and FTIR Characterization of Mg-Hydroxylapatite Derived from Dolostone with High Dolomite Mineral Content," *Tanzania Journal of Science*, 46(3), pp. 661–672. Available at: https://doi.org/10.4314/tjs.v46i3.8.

Mall, A.P., Bhandarkar, V. V., Mandaloi, G. and Tandon, P. (2025) "An Overview of Design and Development of Biomimetic Bone Scaffolds Using Heterogeneous TPMS Lattice Structures," *Archives of Computational Methods in Engineering*, 32(4), pp. 2429–2456. Available at: https://doi.org/10.1007/s11831-024-10212-5.

Mamangkey, N.G.F. and Southgate, P.C. (2009) "Fish & Shellfish Immunology Regeneration of excised mantle tissue by the silver-lip pearl oyster , Pinctada maxima (Jameson)," *Fish and Shellfish Immunology*, 27(2), pp. 164–174. Available at: https://doi.org/10.1016/j.fsi.2009.03.009.

Marzuki, A.P., Salleh, F.M., Ismail, M.H., Sulong, A.B., Abdullah, A.M., Tharazi, I. and Murat, B.I.S. (2025) "Fabrication and evaluation of *PLA* / PA - HA filament for 3D printing : towards trabecular bone - compatible biomedical applications," *The International Journal of Advanced Manufacturing Technology*, 141, pp. 891–908. Available at: https://doi.org/10.1007/s00170-025-16623-3.

Middleton, J.C. and Tipton, A.J. (2000) "Synthetic biodegradable polymers as orthopedic devices," *Biomaterials*, 21(23), pp. 2335–2346. Available at: https://doi.org/https://doi.org/10.1016/S0142-9612(00)00101-0.

Nasser, F.T., Elsissy, A.R. and Farouk, W.M. (2025) "and validation for FDM of commercial *PLA* + for bone scaffolds," *The International Journal of Advanced Manufacturing Technology*, 141, pp. 1741–1784. Available at: https://doi.org/10.1007/s00170-025-16369-y.

Nautiyal, P., Boesl, B. and Agarwal, A. (2020) *In-situ Mechanics of Materials Principles,Tools, Techniques and Applications*. Switzerland: Springer.

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
Geby Alawiyah, Prof. Dr.Eng. Yusril Yusuf, M.Si., M.Eng.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

O'Brien, F.J. (2011) "Biomaterials & scaffolds Every day thousands of surgical procedures are performed to re*PLA*ce," *Materials Today*, 14(3), pp. 88–95. Available at: https://doi.org/10.1016/S1369-7021(11)70058-X.

Ooi, C.Y., Hamdi, M. and Ramesh, S. (2007) "Properties of hydroxyapatite produced by annealing of bovine bone," *Ceramics International*, 33, pp. 1171–1177. Available at: https://doi.org/10.1016/j.ceramint.2006.04.001.

Park, J.B. and Bronzino, J.D. (2003) *Biomaterials Principles and Applications*. New York: CRC Press.

Park, S., Kim, J.E., Han, J., Jeong, S., Lim, J.W., Lee, M.C., Son, H., Kim, H.B., Choung, Y., Seonwoo, H., Chung, J.H. and Jang, K. (2021) "3D-Printed Poly(ε-Caprolactone)/Hydroxyapatite Scaffolds Modified with Alkaline Hydrolysis Enhance Osteogenesis In Vitro," *Polymers*, 13, p. 257. Available at: https://doi.org/doi.org/10.3390/polym13020257.

Pathak, J.S. and Saxena, A.K. (2024) "Significance of Using Scanning Electron Microscopy with Energy Dispersive X-ray Spectrometry (SEM-EDX) for Analysis of Evidence Material in Forensic Sciences," *Asian Journal of Research and Reviews in Physics*, 8(2), pp. 1–11. Available at: https://doi.org/10.9734/AJR2P/2024/v8i2159.

Patil, S., Sathish, T., Othman, N.A., Tarawneh, B. and Saidani, T. (2025) "Optimization of Compressive Strength Properties in Fused Deposition Modeling 3D Printed *PLA*/HA Composites for Bone Tissue Engineering Applications," *Engineering Reports*, 7(5), p. e70133. Available at: https://doi.org/https://doi.org/10.1002/eng2.70133.

Patty, D.J., Nugraheni, A.D., Ana, I.D., Yusuf, Y., Julaidy, D., Nugraheni, A.D., Ana, I.D. and Yusuf, Y. (2022) "Dual functional carbonate-hydroxyapatite nanocomposite from Pinctada maxima and egg- white for bone tissue engineering," *Journal of Biomaterials Science, Polymer Edition*, 33(8), pp. 1043–1062. Available at: https://doi.org/10.1080/09205063.2022.2036934.

Pawelec, K.M. and Planell, J.A. (2019) *Bone Repair Biomaterials Regeneration and Clinical Applications*. Second. Duxford: Woodhead Publishing Elsevier.

Pignatello, R. (2011) *BIOMATERIALS - PHYSICS AND CHEMISTRY*. Croatia: In Tech.

Prakoso, A.T., Syahrom, A., Sulong, M.A., Saad, A.P.M., Yani, I., Nasution, J.D. and Basri, H. (2017) "A Comparison of Degradation Rate Bone Scaffold Morphology Between Computer Simulation and Experimental Approach," *International Medical Device and Technology Conference*, pp. 90–93.

Predoi, D., Iconaru, S.L., Predoi, M.V., Stan, G.E. and Buton, N. (2019) "Synthesis , Characterization , and Antimicrobial Activity of Magnesium-Doped

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
Geby Alawiyah, Prof. Dr.Eng. Yusril Yusuf, M.Si., M.Eng.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Hydroxyapatite Suspensions," *Nanomaterials*, 9(1295), pp. 1–20.

Qulub, F., Widiyanti, P. and Ady, J. (2016) "(1 . 8 OCTANEDIOL CO-CITRATE) (POC) / NANO-HYDROXYAPATITE AS CANDIDATE BIODEGRADABLE BONE SCREW," *Journal of Biomimetics, Biomaterials and Biomedical Engineering*, 27, pp. 36–43. Available at: https://doi.org/10.4028/www.scientific.net/JBBBE.27.36.

Ran, Q., Yang, W., Hu, Y., Shen, X., Yu, Y., Xiang, Y. and Cai, K. (2018) "Osteogenesis of 3D printed porous Ti6Al4V implants with different pore sizes," *Journal of the Mechanical Behavior of Biomedical Materials*, 84, pp. 1–11. Available at: https://doi.org/https://doi.org/10.1016/j.jmbbm.2018.04.010.

Risnasari, I., Karolina, R., Fathurrahman, Pulungan, I.H. and Handinata, O. (2022) *ALAT UNIVERSAL TESTING MACHINE (UTM) DAN PENGOPERASIANNYA*. Banyumas: Pena Persada.

Rosenberg, N. (2023) *Biophysical Osteoblast Stimulation for Bone Grafting and Regeneration From Basic Science to Clinical Applications*. Gewerbestrasse: Springer. Available at: https://doi.org/10.1007/978-3-031-06920-8.

Santoro, M., Shah, S.R., Walker, J.L. and Mikos, A.G. (2016) "Poly(lactic acid) nanofibrous scaffolds for tissue engineering," *Advanced Drug Delivery Reviews*, 107, pp. 206–212. Available at: https://doi.org/10.1016/j.addr.2016.04.019.

Santos, G.G., Nunes, V.L.C., Marinho, S.M.O.C., Santos, S.R.A., Rossi, A.M. and Miguel, F.B. (2020) "Biological behavior of magnesium-substituted hydroxyapatite during bone repair," *Brazilian Journal of Biology*, 6984, pp. 1–9. Available at: https://doi.org/10.1590/1519-6984.217769.

Shanmugavadivu, A. and Selvamurugan, N. (2025) "Surface engineering of 3D-printed polylactic acid scaffolds with polydopamine and 4-methoxycinnamic acid–chitosan nanoparticles for bone regeneration," *Royal Society of Chemistry*, 7, pp. 1636–1649. Available at: https://doi.org/10.1039/d4na00768a.

Singh, J., Singh, H. and Batra, U. (2015) "Magnesium Doped Hydroxyapatite : Synthesis , Characterization and Bioactivity Evaluation," *Biomaterials Science: Processing, Properties, and Applications V* [Preprint]. Available at: https://doi.org/10.1002/9781119190134.ch15.

Siswanto, Hikmawati, D. and Falentina, W.D. (2025) "The Role of Calcination Temperature Variation in The Sol – Gel Synthesis of Hydroxyapatite," *Indonesian Applied Physics Letters The*, 6(1), pp. 8–13. Available at: https://doi.org/10.20473/iapl.v6i1.84056.

Soleymani, S. and Naghib, S.M. (2023) "Heliyon 3D and 4D printing

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

hydroxyapatite-based scaffolds for bone tissue engineering and regeneration," *Heliyon*, 9(9), p. e19363. Available at: https://doi.org/10.1016/j.heliyon.2023.e19363.

Song, Y., Cong, Y., Wang, B. and Zhang, N. (2020) "Applications of Fourier transform infrared spectroscopy to pharmaceutical preparations," *Expert Opinion on Drug Delivery* [Preprint]. Available at: https://doi.org/10.1080/17425247.2020.1737671.

Southgate, P.C. and Lucas, J.S. (2008) *The Pearl Oyster*. Kidlington: Elsevier.

Stipniece, L., Salma-ancane, K., Borodajenko, N., Sokolova, M., Jakovlevs, D. and Berzina-Cimdina, L. (2014) "Characterization of Mg-substituted hydroxyapatite synthesized by wet chemical method," *Ceramics International*, 40, pp. 3261–3267. Available at: https://doi.org/10.1016/j.ceramint.2013.09.110.

Sumarsih (2021) "Uji Daya Hambat Bakteri Escherichia Coli pada Produk Hand Sanitizer," *INDONESIAN JOURNAL OF LABORATORY*, 4(2), pp. 62–66.

Sun, W., Xie, W., Hu, K., Yang, Z., Han, L., Li, L., Qi, Y. and Wei, Y. (2024) "Controlled Assembly of Collagen Polylactic Acid Composite Scaffold for Bone Repair," *Polymers*, 16(498). Available at: https://doi.org/10.3390/polym16040498.

Sunardi, S., Aulia, N., Qurrata, A., Dari, Q.W., Bilalodin, B., Praktino, B., Yulianti, E. and Setio, A.B. (2024) "The Synthesized-Hydroxyapatite Powder from Anadara Granosa Shells using Deposition Time Method for Biomedical Applications," *Jurnal Ilmu Fisika*, 16(1), pp. 88–96. Available at: https://doi.org/10.25077/jif.16.1.88-96.2024.

Tasumi, M. (2015) *Introduction to Experimental Infrared Spectroscopy Fundamentals and Practical Methods*. West Sussex: Wiley.

Tazibt, N., Kaci, M., Dehouche, N., Ragoubi, M. and Atanase, L.I. (2023) "Effect of Filler Content on the Morphology and Physical Properties of Poly(Lactic Acid)-Hydroxyapatite Composites," *Materials*, 16(2). Available at: https://doi.org/10.3390/ma16020809.

Thermo Fisher, S. (2024) *Advance FTIR Spectroscopy Principles, Experiments, and Applications*. Thermo Scientific Fisher.

Thirugnanasambandam, A., Packkirisamy, V., Narayanaswamy, N., Rangappa, S.M., Siengchin, S. and Kechagian, J. (2025) "Influence of infill patterns on the mechanical and antibacterial properties of 3D-printed polylactic acid reinforced with hydroxyapatite / magnesium oxide bone repair scaffolds," *Emergent Materials* [Preprint]. Available at: https://doi.org/https://doi.org/10.1007/s42247-025-01141-5.

Trzaskowska, M., Vivcharenko, V., Benko, A., Franus, W., Goryczka, T., Barylski, A., Palka, K. and Przekora, A. (2024) "Biocompatible

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

nanocomposite hydroxyapatite-based granules with increased specific surface area and bioresorbability for bone regenerative medicine applications," *Scientific Reports*, 14(28137 |), pp. 1–19.

Tseng, T.B., Chilukuri, A., Park, S.C. and Kwon, Y.J. (2014) "Automated quality characterization of 3D printed bone scaffolds," *Journal of Computational Design and Engineering*, 1(3), pp. 194–201. Available at: https://doi.org/10.7315/JCDE.2014.019.

Wagner, W.R. and Elbert, S.E.S. (2020) *Biomaterials Science An Introduction to Materials in Medicine*. Fourth Edi. Edited by G. Zhang and M.J. Yaszemski. London: Elsevier.

Wang, F., Liu, S., Gao, M., Yu, Y., Zhang, W., Li, H. and Peng, X. (2025) "3D-Printed Polycaprolactone / Hydroxyapatite Bionic Scaffold for Bone Regeneration," *Polymers*, 17, p. 858. Available at: https://doi.org/10.3390/polym17070858.

Wang, W., Zhang, B., Li, M., Li, J., Zhang, C., Han, Y., Wang, L., Wang, K., Zhou, C., Liu, L., Fan, Y. and Zhang, X. (2021a) "3D printing of *PLA*/n-HA composite scaffolds with customized mechanical properties and biological functions for bone tissue engineering," *Composites Part B: Engineering*, 224, p. 109192. Available at: https://doi.org/https://doi.org/10.1016/j.compositesb.2021.109192.

Wang, W., Zhang, B., Li, M., Li, J., Zhang, C., Han, Y., Wang, L., Wang, K., Zhou, C., Liu, L., Fan, Y. and Zhang, X. (2021b) "3D printing of *PLA* / n-HA composite scaffolds with customized mechanical properties and biological functions for bone tissue engineering," *Composites Part B*, 224, p. 109192. Available at: https://doi.org/10.1016/j.compositesb.2021.109192.

Waseda, Y., Matsubara, E. and Shinoda, K. (2011) *X-Ray Diffraction Crystallography Introduction, Examples and Solved Problems*. New York: Springer.

WHO, W.H.O. (2024) *Fragility Fractures*, *World Health Organization*. Available at: https://www.who.int/news-room/fact-sheets/detail/fragility-fractures (Accessed: December 1, 2025).

Yang, Y., Qiu, B., Zhou, Z., Hu, C., Li, J. and Zhou, C. (2023) "Three-Dimensional Printing of Polycaprolactone / Nano-Hydroxyapatite Composite Scaffolds with a Pore Size of 300 / 500 μm is Histocompatible and Promotes Osteogenesis Using Rabbit Cortical Bone Marrow Stem Cells," *Annals of TransPLAntation*, 28, pp. 1–14. Available at: https://doi.org/10.12659/AOT.940365.

Yarnpakdee, S., Senphan, T., Karnjanapratum, S., Jaisan, C. and Wangtueai, S. (2025) "Structural characterization and antibacterial activity of pearl oyster (Pinctada maxima) shell as affected by calcination temperature," *Journal*

UNIVERSITAS
GADJAH MADA
Optimasi Fabrikasi Perancah 3D Komposit Mg-HAp/PLA/PCL Berbasis Cangkang Kerang Mutiara (Pinctada maxima) dengan Metode Fused Deposition Modeling
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of Agriculture and Food Research journal, 19(101551). Available at: https://doi.org/10.1016/j.jafr.2024.101551.

Zhang, K., Liu, Y., Zhao, Z., Shi, X., Zhang, R., He, Y., Zhang, H., Sun, Y. and Wang, W. (2023) "Synthesis Technology of Magnesium-Doped Nanometer Hydroxyapatite : A Review," *ACS OMEGA*, 8, pp. 44458–44471. Available at: https://doi.org/10.1021/acsomega.3c06091.