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REFERENCES

Aaboe, M., Pinholt, E.M. and Hjørting-Hansen, E. (1995) Healing of experimentally created defects: a review. *Br J Oral Maxillofac Surg*, 33(5), pp. 312–318.

Abdulkareem, A.A., Al-Taweel, F.B., Al-Sharqi, A.J.B., Gul, S.S., Sha, A. and Chapple, I.L.C. (2023) Current concepts in the pathogenesis of periodontitis: from symbiosis to dysbiosis. *J Oral Microbiol*, 15(1), p. 2197779.

Abou El Fadl, R.K., Abdel Fattah, M.A., Helmi, M.A., Wassel, M.O., Badran, A.S., Elgendi, H.A.A., et al. (2021) Periodontal diseases and potential risk factors in Egyptian adult population-Results from a national cross-sectional study. *PloS one*, 16(11), p. e0258958.

Abu Fanas, S., Brigi, C., Varma, S.R., Desai, V., Senok, A. and D'souza, J. (2021) The prevalence of novel periodontal pathogens and bacterial complexes in Stage II generalized periodontitis based on 16S rRNA next generation sequencing. *J. Appl. Oral Sci*, 29, pp. 1–16.

Abusleme, L., Hoare, A., Hong, B.-Y. and Diaz, P.I. (2021) Microbial signatures of health, gingivitis, and periodontitis. *Periodontol 2000*, 86(1), pp. 57–78.

Abusleme, L., Dupuy, A.K., Dutzan, N., Silva, N., Burleson, J.A., Strausbaugh, L.D., et al. (2013) The subgingival microbiome in health and periodontitis and its relationship with community biomass and inflammation. *ISME J*, 7(5), pp. 1016–1025.

Adamiak, K. and Sionkowska, A. (2020) Current methods of collagen cross-linking: Review. *Int. J. Biol. Macromol*, 161, pp. 550–560.

Ahmad, J., Garg, A., Mustafa, G., Mohammed, A.A. and Ahmad, M.Z. (2023) 3D Printing Technology as a Promising Tool to Design Nanomedicine-Based Solid Dosage Forms: Contemporary Research and Future Scope. *Pharmaceutics*, 15(5), pp. 1–23.

Ahmed, I., Iqbal, H.M.N. and Akram, Z. (2018) Microfluidics Engineering: Recent Trends, Valorization, and Applications. *Arab J Sci Eng*, 43(1), pp. 23–32.

Ahmed, S.K., Hussein, S., Qurbani, K., Ibrahim, R.H., Fareeq, A., Mahmood, K.A., et al. (2024) Antimicrobial resistance: Impacts, challenges, and future prospects. *J Med Surg Public Health*, 2, p. 100081.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Akhtar, A. (2015) The flaws and human harms of animal experimentation. *Camb Q Healthc Ethics*, 24(4), pp. 407–419.

Albers, C.E., Hofstetter, W., Siebenrock, K.A., Landmann, R. and Klenke, F.M. (2013) In vitro cytotoxicity of silver nanoparticles on osteoblasts and osteoclasts at antibacterial concentrations. *Nanotoxicology*, 7(1), pp. 30–36.

Alfonso García, S.L., Mira Uribe, L.M., Castaño López, S., Parada-Sanchez, M.T. and Arboleda-Toro, D. (2022) Ultrastructural Characterization of Human Gingival Fibroblasts in 3D Culture. *Cells*, 11(22), pp. 1–18.

Allen, M.R. and Burr, D.B. (2019) Chapter 5 - Bone Growth, Modeling, and Remodeling. In: BURR, D.B. and ALLEN, M.R. (eds.) *Basic and Applied Bone Biology (Second Edition)*. Academic Press, pp. 85–100.

Almansoori, A.A., Hwang, C., Lee, S.-H., Kim, B., Kim, H.-E. and Lee, J.-H. (2020) Tantalum – Poly (L-lactic acid) nerve conduit for peripheral nerve regeneration. *Neurosci Lett*, 731, p. 135049.

Almansoori, K. and Pervaiz, S. (2023) Effect of layer height, print speed and cell geometry on mechanical properties of marble PLA based 3D printed parts. *Smart Mater. Manuf.*, 1, p. 100023.

Alshammari, A.H. (2024) Structural, Optical, and Thermal Properties of PVA/SrTiO3/CNT Polymer Nanocomposites. *Polymers*, 16(10), pp. 1–13.

American Society for Testing and Materials (2018) *D882-18: Standard Test Method for Tensile Properties of Thin Plastic Sheeting*. ASTM International.

An, S.-H., Matsumoto, T., Sasaki, J., Miyajima, H., Narayanan, R., Imazato, S., et al. (2012) In vitro bioactivity evaluation of nano- and micro-crystalline anodic TiO2: HA formation, cellular affinity and organ culture. *Mater. Sci. Eng. C*, 32, pp. 2516–2522.

An, S.-H., Matsumoto, T., Miyajima, H., Sasaki, J.-I., Narayanan, R. and Kim, K.-H. (2012) Surface characterization of alkali- and heat-treated Ti with or without prior acid etching. *Appl. Surf. Sci*, 258(10), pp. 4377–4382.

Ana, I.D., Matsuya, S., Ohta, M. and Ishikawa, K. (2003) Effects of added bioactive glass on the setting and mechanical properties of resin-modified glass ionomer cement. *Biomaterials*, 24(18), pp. 3061–3067.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Ana, I.D., Lestari, A., Lagarrigue, P., Soulie, J., Anggraeni, R., Maube-Bosc, F., et al. (2022) Safe-by-Design Antibacterial Peroxide-Substituted Biomimetic Apatites: Proof of Concept in Tropical Dentistry. *J. Funct. Biomater*, pp. 1–23.

Ana, I.D. (2022) *Tinjauan Biomedis: Biokeramik dan Rekayasa Jaringan*. HANDAYANI, N. (ed.). Gadjah Mada University Press.

Ana, I.D. and Anggraeni, R. (2021) Development of bioactive resin modified glass ionomer cement for dental biomedical applications. *Heliyon*, 7(1), p. e05944.

Andersen, M.L. and Winter, L.M.F. (2019) Animal models in biological and biomedical research – experimental and ethical concerns. *An Acad Bras Cienc*, 91, pp. 1–14.

Annibali, S., Bignozzi, I., Sammartino, G., La Monaca, G. and Cristalli, M.P. (2012) Horizontal and vertical ridge augmentation in localized alveolar deficient sites: a retrospective case series. *Implant Dent*, 21(3), pp. 175–185.

Ao, Y.J., Yi, Y. and Wu, G.H. (2024) Application of PLLA (Poly-L-Lactic acid) for rejuvenation and reproduction of facial cutaneous tissue in aesthetics: A review. *Medicine*, 103(11), p. E37506.

Aprile, P., Letourneur, D. and Simon-yarza, T. (2020) Membranes for Guided Bone Regeneration: A Road from Bench to Bedside. *Adv. Healthcare Mater*, 2000707, pp. 1–24.

Araújo, M.R.P., Sa-Barreto, L.L., Gratieri, T., Gelfuso, G.M. and Cunha-Filho, M. (2019) The Digital Pharmacies Era: How 3D Printing Technology Using Fused Deposition Modeling Can Become a Reality. *Pharmaceutics*, 11(3), pp. 1–14.

Arroyo-Reyes, B.L., Gómez-Muñoz, C.L., Zaca-Morán, P., Galindo-Ramírez, F. and Morales-Sánchez, M.A. (2024) Fabrication of a PLA/PVA-BIO-HA Polymeric Membrane by the Electrospinning Technique. *Fibers*, 12(4), pp. 1–13.

Ashammakhi, N., Nasiri, R., De, N.R., Tebon, P., Thakor, J., Goudie, M., et al. (2020) Gut-on-a-chip: Current Progress and Future Opportunities. *Biomaterials*, 255(120196), pp. 1–45.

Ashammakhi, N.A. and Elzagheid, A. (2018) Organ-on-a-Chip: New Tool for Personalized Medicine. *J Craniofac Surg*, 29(4), pp. 823–824.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Ashraf, A.A., Zebarjad, S.M. and Hadianfard, M.J. (2019) The cross-linked polyvinyl alcohol/hydroxyapatite nanocomposite foam. *J. Mater. Res. Technol.*, 8(3), pp. 3149–3157.

Aslam, M., Kalyar, M.A. and Raza, Z.A. (2018) Polyvinyl alcohol: A review of research status and use of polyvinyl alcohol based nanocomposites. *Polym. Eng. Sci*, 58(12), pp. 2119–2132.

Athanasiou, V.T., Papachristou, D.J., Panagopoulos, A., Saridis, A., Scopa, C.D. and Megas, P. (2010) Histological comparison of autograft, allograft-DBM, xenograft, and synthetic grafts in a trabecular bone defect: An experimental study in rabbits. *Med Sci Monit*, 16(1), pp. BR24–BR31.

Avila-Campos, M.J., Simionati, M.R.L. and Gaetti-Jardim Jr, E. (2011) Prevotella. In: DONGYOU LIU (ed.) *Molecular Detection of Human Bacterial Pathogens*. Boca Raton: CRC Press, p. 585.

Awad, A., Fina, F., Goyanes, A., Gaisford, S. and Basit, A.W. (2020) 3D printing: Principles and pharmaceutical applications of selective laser sintering. *Int. J. Pharm.*, 586, pp. 1–14.

Azaman, F.A., Zhou, K., Blanes-mart, M., Fournet, M.B. and Devine, D.M. (2022) Bioresorbable Chitosan-Based Bone Regeneration Scaffold Using Various Bioceramics and the Alteration of Photoinitiator Concentration in an Extended UV Photocrosslinking Reaction. *Gels*, 8(696), pp. 1–24.

Aziz, S., Pranowo, H.D., Ana, I.D. and Yusuf, Y. (2024) Energy Efficiency of the Carbonate Hydroxyapatite Nanoparticle Synthesis Using Microwave Heating Treatment and Its Effect on Material Characteristics. *Indones. J. Chem.*, 24(1), pp. 238–249.

Aziz, S., Ana, I.D., Yusuf, Y. and Pranowo, H.D. (2023) Synthesis of Biocompatible Silver-Doped Carbonate Hydroxyapatite Nanoparticles Using Microwave-Assisted Precipitation and In Vitro Studies for the Prevention of Peri-Implantitis. *J. Funct. Biomater*, 14(7), p. 385.

Bachra, Y., Grouli, A., Damiri, F., Zhu, X.X., Talbi, M. and Berrada, M. (2022) Synthesis, Characterization, and Swelling Properties of a New Highly Absorbent Hydrogel Based on Carboxymethyl Guar Gum Reinforced with Bentonite and Silica Particles for Disposable Hygiene Products. *ACS Omega*, 7(43), pp. 39002–39018.

UNIVERSITAS GADJAH MADA
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Baek, D.H. and Lee, S.H. (2021) Characteristics of *Treponema denticola* lipooligosaccharide in presence of hemin and quorum-sensing molecule. *Arch Oral Biol*, 124, pp. 1–9.

Bahadoran, M., Shamloo, A. and Nokoorani, Y.D. (2020) Development of a polyvinyl alcohol/sodium alginate hydrogel-based scaffold incorporating bFGF-encapsulated microspheres for accelerated wound healing. *Sci Rep*, 10(1), pp. 1–18.

Baker, M.I., Walsh, S.P., Schwartz, Z. and Boyan, B.D. (2012) A review of polyvinyl alcohol and its uses in cartilage and orthopedic applications. *J Biomed Mater Res B Appl Biomater*, 100B(5), pp. 1451–1457.

Bartold, P.M., Walsh, L.J. and Narayanan, A.S. (2000) Molecular and cell biology of the gingiva. *Periodontol 2000*, 24, pp. 28–55.

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. *J. Phys. Conf. Ser*, 2071(1), pp. 0–7.

Bauer, S., Schmuki, P., von der Mark, K. and Park, J. (2013) Engineering biocompatible implant surfaces: Part I: Materials and surfaces. *Prog. Mater. Sci*, 58(3), pp. 261–326.

Bee, S.-L., Bustami, Y., Ul-Hamid, A., Lim, K. and Abdul Hamid, Z.A. (2021) Synthesis of silver nanoparticle-decorated hydroxyapatite nanocomposite with combined bioactivity and antibacterial properties. *J. Mater. Sci.: Mater. Med.*, 32(9), p. 106.

Behtaj, S., Ekberg, J.A.K. and St John, J.A. (2022) Advances in Electrospun Nerve Guidance Conduits for Engineering Neural Regeneration. *Pharmaceutics*, 14(2), pp. 1–20.

Belkaid, Y. and Hand, T.W. (2014) Role of the microbiota in immunity and inflammation. *Cell*, 157(1), pp. 121–141.

Bernabe, E., Marcenes, W., Hernandez, C.R., Bailey, J., Abreu, L.G., Alipour, V., et al. (2020) Global, Regional, and National Levels and Trends in Burden of Oral Conditions from 1990 to 2017: A Systematic Analysis for the Global Burden of Disease 2017 Study. *J Dent Res*, 99(4), pp. 362–373.

Bhajantri, R.F., Ravindrachary, V., Harisha, A., Crasta, V., Nayak, S.P. and Poojary, B. (2006) Microstructural studies on BaCl2 doped poly(vinyl alcohol). *Polymer*, 47(10), pp. 3591–3598.

UNIVERSITAS GADJAH MADA
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Bharti, S. (2024) Harnessing the potential of bimetallic nanoparticles: Exploring a novel approach to address antimicrobial resistance. *World J Microbiol Biotechnol*, 40(3), p. 89.

Bhatia, S.N. and Ingber, D.E. (2014) Microfluidic organs-on-chips. *Nat Biotechnol*, 32(8), pp. 760–772.

Bhattacharjee, S. (2021) Understanding the Burst Release Phenomenon: Toward Designing Effective Nanoparticulate Drug-Delivery Systems. *Ther. Deliv.*, 12(1), pp. 21–36.

Billings, M., Holtfreter, B., Papapanou, P.N., Mitnik, G.L., Kocher, T. and Dye, B.A. (2018) Age-dependent distribution of periodontitis in two countries: Findings from NHANES 2009 to 2014 and SHIP-TREND 2008 to 2012. *J. Clin. Periodontol*, 45 Suppl 2, pp. S130–S148.

Bjelica, R., Prpić, V., Drvar, N., Ćatić, A. and Gabrić, D. (2024) Mechanical Characteristics of Individualized Biodegradable Augmentation Scaffold—In Vitro Pilot Study. *Materials*, 17(6), pp. 1–15.

Blanco, J., Alonso, A. and Sanz, M. (2005) Long-term results and survival rate of implants treated with guided bone regeneration: a 5-year case series prospective study. *Clin. Oral Implants Res.*, 16(3), pp. 294–301.

Blessy, M., Patel, R.D., Prajapati, P.N. and Agrawal, Y.K. (2014) Development of forced degradation and stability indicating studies of drugs - A review. *J. Pharm. Anal.*, 4(3), pp. 159–165.

Boonkaew, B., Kempf, M., Kimble, R. and Cuttle, L. (2014) Cytotoxicity testing of silver-containing burn treatments using primary and immortal skin cells. *Burns*, 40(8), pp. 1562–1569.

Botelho, J., Machado, V., Leira, Y., Proença, L., Chambrone, L. and Mendes, J.J. (2022) Economic burden of periodontitis in the United States and Europe: An updated estimation. *J Periodontol*, 93(3), pp. 373–379.

Bottino, M.C., Thomas, V., Schmidt, G., Vohra, Y.K., Chu, T.-M.G., Kowolik, M.J., et al. (2012) Recent advances in the development of GTR/GBR membranes for periodontal regeneration--a materials perspective. *Dent Mater*, 28(7), pp. 703–721.

Bouyer, M., Garot, C., Machillot, P., Vollaire, J., Fitzpatrick, V., Morand, S., et al. (2021) 3D-printed scaffold combined to 2D osteoinductive coatings to repair a critical-size mandibular bone defect. *Mater Today Bio*, 11, p. 100113.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Bovard, D., Sandoz, A., Luettich, K., Frentzel, S., Iskandar, A., Marescotti, D., et al. (2018) A lung/liver-on-a-chip platform for acute and chronic toxicity studies. *Lab Chip*, 18(24), pp. 3814–3829.

Breslin, S. and O'Driscoll, L. (2013) Three-dimensional cell culture: the missing link in drug discovery. *Drug Discov Today*, 18(5–6), pp. 240–249.

Bunyaratavej, P. and Wang, H.L. (2001) Collagen membranes: a review. *J Periodontol*, 72(2), pp. 215–229.

Buser, D., Urban, I., Monje, A., Kunrath, M.F. and Dahlin, C. (2023) Guided bone regeneration in implant dentistry: Basic principle, progress over 35 years, and recent research activities. *Periodontol 2000*, 93(1), pp. 9–25.

Caballé-Serrano, J., Abdeslam-Mohamed, Y., Munar-Frau, A., Fujioka-Kobayashi, M., Hernández-Alfaro, F. and Miron, R. (2019) Adsorption and release kinetics of growth factors on barrier membranes for guided tissue/bone regeneration: A systematic review. *Arch. Oral Biol*, 100, pp. 57–68.

Caballé-Serrano, J., Sawada, K., Miron, R.J., Bosshardt, D.D., Buser, D. and Gruber, R. (2017) Collagen barrier membranes adsorb growth factors liberated from autogenous bone chips. *Clin. Oral Implants Res*, 28(2), pp. 236–241.

Cader, H.K., Rance, G.A., Alexander, M.R., Gonçalves, A.D., Roberts, C.J., Tuck, C.J., et al. (2019) Water-based 3D inkjet printing of an oral pharmaceutical dosage form. *Int. J. Pharm*, 564, pp. 359–368.

Cahaya, C., Sri Lelyati Masulili, dan C., Pendidikan Dokter Gigi Spesialis Periodonsia, P. and Kedokteran Gigi, F. (2015) Perkembangan Terkini Membran Guided Tissue Regeneration/Guided Bone Regeneration sebagai Terapi Regenerasi Jaringan Periodontal. *Maj Ked Gi Ind*, 1(1), p. 1.

Cai, H., Xu, X., Lu, X., Zhao, M., Jia, Q., Jiang, H.-B., et al. (2023) Dental Materials Applied to 3D and 4D Printing Technologies: A Review. *Polym.*, 15(2405), pp. 1–27.

Cai, S., Pourdeyhimi, B. and Loboa, E.G. (2019) Industrial-scale fabrication of an osteogenic and antibacterial PLA/silver-loaded calcium phosphate composite with significantly reduced cytotoxicity. *J Biomed Mater Res B Appl Biomate*, 107(4), pp. 900–910.

Cai, W., Huo, Y., Liu, Y., Su, Y., Guo, H., Wang, L., et al. (2025) Biomechanics in bone regeneration and mechanobiology in osteoblasts: Fundamental concepts and recent progress. *EngMedicine*, 2(1), p. 100057.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Calasans-Maia, M.D., Melo, B.R. de, Alves, A.T.N.N., Resende, R.F. de B., Louro, R.S., Sartoretto, S.C., et al. (2015) Cytocompatibility and biocompatibility of nanostructured carbonated hydroxyapatite spheres for bone repair. *J. Appl. Oral Sci.*, 23(6), pp. 599–608.

Calciolari, E., Ravanetti, F., Strange, A., Mardas, N., Bozec, L., Cacchioli, A., et al. (2018) Degradation pattern of a porcine collagen membrane in an in vivo model of guided bone regeneration. *J Periodontal Res*, 53(3), pp. 430–439.

Camelo-Castillo, A.J., Mira, A., Pico, A., Nibali, L., Henderson, B., Donos, N., et al. (2015) Subgingival microbiota in health compared to periodontitis and the influence of smoking. *Front Microbiol*, 6, p. 119.

Campana, V., Milano, G., Pagano, E., Barba, M., Cicione, C., Salonna, G., et al. (2014) Bone substitutes in orthopaedic surgery: from basic science to clinical practice. *J. Mater. Sci.: Mater. Med*, 25(10), pp. 2445–2461.

Cao, U.M.N., Zhang, Y., Chen, J., Sayson, D., Pillai, S. and Tran, S.D. (2023) Microfluidic Organ-on-A-chip: A Guide to Biomaterial Choice and Fabrication. *Int J Mol Sci*, 24(4), pp. 1–22.

Capuana, E., Lopresti, F., Ceraulo, M. and La Carrubba, V. (2022) Poly-L-Lactic Acid (PLLA)-Based Biomaterials for Regenerative Medicine: A Review on Processing and Applications. *Polymers*, 14(6), [Online] Available from: doi.org/10.3390/polym14061153.

Carbonell, J.M., Martín, I.S., Santos, A., Pujol, A., Sanz-Moliner, J.D. and Nart, J. (2014) High-density polytetrafluoroethylene membranes in guided bone and tissue regeneration procedures: a literature review. *Int. J. Oral Maxillofac. Surg*, 43(1), pp. 75–84.

Carrouel, F., Viennot, S., Santamaria, J., Veber, P. and Bourgeois, D. (2016) Quantitative molecular detection of 19 major pathogens in the interdental biofilm of periodontally healthy young adults. *Front Microbiol*, 7, pp. 1–16.

Casalini, T., Rossi, F., Castrovinci, A. and Perale, G. (2019) A Perspective on Polylactic Acid-Based Polymers Use for Nanoparticles Synthesis and Applications. *Front Bioeng Biotechnol*, 7, pp. 1–16.

de Castro Monsores, K.G., da Silva, A.O., de Sant' Ana Oliveira, S., Rodrigues, J.G.P. and Weber, R.P. (2019) Influence of ultraviolet radiation on polymethylmethacrylate (PMMA). *J. Mater. Res. Technol*, 8(5), pp. 3713–3718.

UNIVERSITAS GADJAH MADA
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Caton, J.G., Armitage, G., Berglundh, T., Chapple, I.L.C., Jepsen, S., Kornman, K.S., et al. (2018) A new classification scheme for periodontal and peri-implant diseases and conditions – Introduction and key changes from the 1999 classification. *J Periodontol*, 89(S1), pp. S1–S8.

Chapple, I.L.C., Mealey, B.L., Van Dyke, T.E., Bartold, P.M., Dommisch, H., Eickholz, P., et al. (2018) Periodontal health and gingival diseases and conditions on an intact and a reduced periodontium: Consensus report of workgroup 1 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Periodontol*, 89(December 2017), pp. S74–S84.

Chen, K., Ustriyana, P., Moore, F. and Sahai, N. (2019) Biological Response of and Blood Plasma Protein Adsorption on Silver-Doped Hydroxyapatite. *ACS Biomater Sci Eng*, 5(2), pp. 561–571.

Chen, M.X., Zhong, Y.J., Dong, Q.Q., Wong, H.M. and Wen, Y.F. (2021) Global, regional, and national burden of severe periodontitis, 1990-2019: An analysis of the Global Burden of Disease Study 2019. *J Clin Periodontol*, 48(9), pp. 1165–1188.

Chen, W., Oh, S., Ong, A.P., Oh, N., Liu, Y., Courtney, H.S., et al. (2007) Antibacterial and osteogenic properties of silver-containing hydroxyapatite coatings produced using a sol gel process. *J. Biomed. Mater. Res. A*, 82A(4), pp. 899–906.

Chen, Z. and Taheri, M. (2020) The effect of pre-heating and pre-cold treatment on the formation of liquation and solidification cracks of nickel-based superalloy welded by laser beam. *J. Mater. Res. Technol*, 9(5), pp. 11162–11177.

Chiapasco, M. and Zaniboni, M. (2009) Clinical outcomes of GBR procedures to correct peri-implant dehiscences and fenestrations: a systematic review. *Clin Oral Implants Res*, 20 Suppl 4, pp. 113–123.

Chiellini, E., Corti, A., D'Antone, S. and Solaro, R. (2003) Biodegradation of poly (vinyl alcohol) based materials. *Prog. Polym. Sci.*, 28(6), pp. 963–1014.

Chigasaki, O., Takeuchi, Y., Aoki, A., Sasaki, Y., Mizutani, K., Aoyama, N., et al. (2018) A cross-sectional study on the periodontal status and prevalence of red complex periodontal pathogens in a Japanese population. *J Oral Sci*, 60(2), pp. 293–303.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Chinnasami, H., Dey, M.K. and Devireddy, R. (2023) Three-Dimensional Scaffolds for Bone Tissue Engineering. *Bioeng.*, 10(7), pp. 1-32

Choi, J., Cho, H., Kwak, E., Kwon, T., Ryoo, H., Jeong, Y.-K., et al. (2004) Effect of Ag-Doped Hydroxyapatite as a Bone Filler for Inflamed Bone Defects. *Key Eng. Mater*, 254–256, pp. 47–50.

Chramiec, A., Teles, D., Yeager, K., Marturano-Kruik, A., Pak, J., Chen, T., et al. (2020) Integrated human organ-on-a-chip model for predictive studies of anti-tumor drug efficacy and cardiac safety. *Lab Chip*, 20(23), pp. 4357–4372.

Chua, C.K. and Leong, K.F. (2015) *3D Printing and Additive Manufacturing: Principles and Applications*. YUN, A. (ed.). Singapore: World Scientific Publishing Company.

Ciapetti, G., Granchi, D., Devescovi, V., Baglio, S.R., Leonardi, E., Martini, D., et al. (2012) Enhancing osteoconduction of PLLA-based nanocomposite scaffolds for bone regeneration using different biomimetic signals to MSCs. *Int J Mol Sci*, 13(2), pp. 2439–2458.

Ciobanu, C.S., Iconaru, S.L., Chifiriuc, M.C., Costescu, A., Le Coustumer, P. and Predoi, D. (2013) Synthesis and Antimicrobial Activity of Silver-Doped Hydroxyapatite Nanoparticles. *Biomed Res Int*, 2013(1), p. 916218.

Clarke, B. (2008) Normal Bone Anatomy and Physiology. *Clin. J. Am. Soc. Nephrol*, 3(Supplement_3), pp. S131–S139.

Cohen, R.E. (2003) Position paper: periodontal maintenance. *J Periodontol*, 74(9), pp. 1395–1401.

Cojocaru, V., Frunzaverde, D., Miclosina, C.O. and Marginean, G. (2022) The Influence of the Process Parameters on the Mechanical Properties of PLA Specimens Produced by Fused Filament Fabrication—A Review. *Polymers*, 14(5), pp. 1–23.

Cowan, P.T. and Kahai, P. (2021) Anatomy, Bones. *StatPearls*.

Cugini, C., Ramasubbu, N., Tsiagbe, V.K. and Fine, D.H. (2021) Dysbiosis from a Microbial and Host Perspective Relative to Oral Health and Disease. *Front Microbiol*, 12(March), pp. 1–23.

Culbreath, C., Taylor, M., McCullen, S. and Mefford, O. (2025) A Review of Additive Manufacturing in Tissue Engineering and Regenerative Medicine. *Biomedical Materials & Devices*, 3, pp. 237–258

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Culbreath, C., McCullen, S., McCullen, S.D. and Mefford, O.T. (2024) Controlling Mechanical Properties of Medical-Grade Scaffolds through Electrospinning Parameter Selection. *ACS Omega*, 9(35), pp. 36982–36992.

Culbreath, C.J., Gaerke, B., Taylor, M.S., McCullen, S.D. and Mefford, O.T. (2020) Effect of infill on resulting mechanical properties of additive manufactured bioresorbable polymers for medical devices. *Materialia*, 12, p. 100732.

Cunha, B.L.C., Bahú, J.O., Xavier, L.F., Crivellin, S., de Souza, S.D.A., Lodi, L., et al. (2022) Lactide: Production Routes, Properties, and Applications. *Bioeng*, 9(4), pp. 1–21.

Dahlen, G., Basic, A. and Bylund, J. (2019) Importance of virulence factors for the persistence of oral bacteria in the inflamed gingival crevice and in the pathogenesis of periodontal disease. *J Clin Med*, 8(9), pp. 1–19.

Dahlin, C., Sennerby, L., Lekholm, U., Linde, A. and Nyman, S. (1989) Generation of new bone around titanium implants using a membrane technique: an experimental study in rabbits. *Int J Oral Maxillofac Implants*, 4(1), pp. 19–25.

Dahlin, C., Linde, A., Gottlow, J. and Nyman, S. (1988) Healing of Bone Defects by Guided Tissue Regeneration. *Plast Reconstr Surg*, 81(5), [Online] Available from: doi.org/http://dx.doi.org/10.1097/00006534-198805000-00004 [Accessed 13/06/2025].

Dahlin, C., Gottlow, J., Linde, A. and Nyman, S. (1990) Healing of Maxillary and Mandibular Bone Defects Using a Membrane Technique: An Experimental Study in Monkeys. *Scand J Plast Reconstr Surg Hand Surg*, 24(1), pp. 13–19.

Dalimunthe, N.F., Wirawan, S.K., Michael, M., Tjandra, T.M., Al Fath, M.T. and Sidabutar, R. (2024) Pectin-carbonate hydroxyapatite composite films as a potential drug delivery system for cinnamaldehyde: Characterization and release kinetics modeling. *Case Stud. Chem. Environ. Eng.*, 10, p. 100905.

Dall'Ara, E. and Cheong, V.S. (2022) Bone biomechanics. In: *Human Orthopaedic Biomechanics: Fundamentals, Devices and Applications*. pp. 97–120.

Daly, M., Tarfaoui, M., Bouali, M. and Bendarma, A. (2024) Effects of Infill Density and Pattern on the Tensile Mechanical Behavior of 3D-Printed Glycolyzed Polyethylene Terephthalate Reinforced with Carbon-Fiber Composites by the FDM Process. *J. Compos. Sci*, 8(4), pp. 1–15.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Decco, O., Cura, A., Beltrán, V., Lezcano, M. and Engelke, W. (2015) Bone augmentation in rabbit tibia using microfixed cobalt-chromium membranes with whole blood, tricalcium phosphate and bone marrow cells. *Int J Clin Exp Med*, 8(1), pp. 135–144.

DeMerlis, C.C. and Schoneker, D.R. (2003) Review of the oral toxicity of polyvinyl alcohol (PVA). *Food Chem Toxicol*, 41(3), pp. 319–326.

Deo, P.N. and Deshmukh, R. (2019) Oral microbiome: Unveiling the fundamentals. *J Oral Maxillofac Pathol*, 23(1), pp. 122–128.

Dewi, A.H. and Ana, I.D. (2018) The use of hydroxyapatite bone substitute grafting for alveolar ridge preservation, sinus augmentation, and periodontal bone defect: A systematic review. *Heliyon*, 4(10), p. e00884.

Dinçel, Y.M. (2018) Bone Graft Types. In: KUMMOONA, R. (ed.) *Bone Grafting - Recent Advances with Special References to Cranio-Maxillofacial Surgery*. IntechOpen.

Dojindo Laboratories (2019) *Measuring Cell Viability/Cytotoxicity: Cell Counting Kit-8*. [Online] https://dojindo.com/ASIA/products/CK04/ [Accessed 27/11/24].

Dong, C., Petrovic, M. and Davies, I.J. (2024) Applications of 3D printing in medicine: A review. *Ann. 3D Print. Med.*, 14, pp. 1–17.

Doost, N.F. and Srivastava, S.K. (2024) A Comprehensive Review of Organ-on-a-Chip Technology and Its Applications. *Biosensors*, 14(5), pp. 1–27.

Doshi, M., Mahale, A., Singh, S.K. and Deshmukh, S. (2021) Printing parameters and materials affecting mechanical properties of FDM-3D printed parts: Perspective and prospects. *Mater. Today: Proc.*, 50, pp. 2269–2275.

Durán, N., Nakazato, G. and Seabra, A.B. (2016) Antimicrobial activity of biogenic silver nanoparticles, and silver chloride nanoparticles: an overview and comments. *Appl. Microbiol. Biotechnol*, 100(15), pp. 6555–6570.

Duval, K., Grover, H., Han, L.H., Mou, Y., Pegoraro, A.F., Fredberg, J., et al. (2017) Modeling physiological events in 2D vs. 3D cell culture. *Physiology (Bethesda)*, 32(4), pp. 266–277.

Efremov, L., Kanjevac, T., Ciric, D. and Bosnakovski, D. (2013) Perspectives on regeneration of alveolar bone defects. *Serbian J. Exp. Clin. Res*, 14(4), pp. 145–153.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Elbasuney, S., El-Sayyad, G.S., Radwan, S.M. and Correa-Duarte, M.A. (2022) Antimicrobial, and Antibiofilm Activities of Silver Doped Hydroxyapatite: A Novel Bioceramic Material for Dental Filling. *J. Inorg. Organomet. Polym. Mater.*, 32(12), pp. 4559–4575.

Elgali, I., Omar, O., Dahlin, C. and Thomsen, P. (2017) Guided bone regeneration: materials and biological mechanisms revisited. *Eur. J. Oral Sci*, 125(5), pp. 315–337.

Eliaz, N. (2019) Corrosion of Metallic Biomaterials: A Review. *Mater*, 12(3), pp. 1–91.

Ergün, E., Toraman, E., Barış, Ö., Budak, H. and Demir, T. (2023) Quantitative investigation of the bacterial content of periodontal abscess samples by real-time PCR. *J. Microbiol. Methods*, 213, p. 106826.

European Parliament (2021) *Plans and actions to accelerate a transition to innovation without the use of animals in research, regulatory testing and education*. Available from : https://www.europarl.europa.eu/doceo/document/TA-9-2021-0387_EN.html [Accessed 08/03/23].

Fairag, R., Li, L., Ramirez-GarciaLuna, J.L., Taylor, M.S., Gaerke, B., Weber, M.H., et al. (2021) A Composite Lactide-Mineral 3D-Printed Scaffold for Bone Repair and Regeneration. *Front. Cell Dev. Biol.*, 9, [Online] Available from: doi.org/10.3389/fcell.2021.654518.

Fang, Y. and Eglen, R.M. (2017) Three-Dimensional Cell Cultures in Drug Discovery and Development. *SLAS Discov*, 22(5), pp. 456–472.

Farsi, M., Asefnejad, A. and Baharifar, H. (2022) A hyaluronic acid/PVA electrospun coating on 3D printed PLA scaffold for orthopedic application. *Prog Biomater*, 11(1), pp. 67–77.

Federer, W.T. (1955) *Experimental Design: Theory and Application*. California: Macmillan.

Félix Lanao, R.P., Leeuwenburgh, S.C.G., Wolke, J.G.C. and Jansen, J.A. (2011) In vitro degradation rate of apatitic calcium phosphate cement with incorporated PLGA microspheres. *Acta Biomater.*, 7(9), pp. 3459–3468.

Feng, Q.L., Wu, J., Chen, G.Q., Cui, F.Z., Kim, T.N. and Kim, J.O. (2000) A mechanistic study of the antibacterial effect of silver ions on Escherichia coli and Staphylococcus aureus. *J. Biomed. Mater. Res*, 52(4), pp. 662–668.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Ferdinand, A.S., McEwan, C., Lin, C., Betham, K., Kandan, K., Tamolsaian, G., et al. (2024) Development of a cross-sectoral antimicrobial resistance capability assessment framework. *BMJ Glob Heal*, 9(1), p. e013280.

Fernandez-Vicente, M., Calle, W., Ferrandiz, S. and Conejero, A. (2016) Effect of Infill Parameters on Tensile Mechanical Behavior in Desktop 3D Printing. *3D Print. Addit. Manuf*, 3(3), pp. 183–192.

Ferrari, A.J., Santomauro, D.F., Aali, A., Abate, Y.H., Abbafati, C., Abbastabar, H., et al. (2024) Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *The Lancet*, 403(10440), pp. 2133–2161.

Ferraz, M.P. (2024) Antimicrobial Resistance: The Impact from and on Society According to One Health Approach. *Societies*, 14(9), pp. 1–22.

Ferraz, M.P. (2023) Bone Grafts in Dental Medicine: An Overview of Autografts, Allografts and Synthetic Materials. *Mater.*, 16(11), pp. 1–22.

Ferreira, A.M., Gentile, P., Chiono, V. and Ciardelli, G. (2012) Collagen for bone tissue regeneration. *Acta Biomater*, 8(9), pp. 3191–3200.

Fesseha, H. and Fesseha, Y. (2020) Bone Grafting, Its Principle and Application: A Review. *Osteol Rheumatol Open J*, 1(1), pp. 43–50.

Fielding, G.A., Roy, M., Bandyopadhyay, A. and Bose, S. (2012) Antibacterial and biological characteristics of silver containing and strontium doped plasma sprayed hydroxyapatite coatings. *Acta Biomater*, 8(8), pp. 3144–3152.

Figoli, A. (2016) Thermally Induced Phase Separation (TIPS) for Membrane Preparation. In: DRIOLI, E. and GIORNO, L. (eds.) *Encyclopedia of Membranes*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 1–2.

Fijoł, N., Aguilar-Sánchez, A., Ruiz-Caldas, M.-X., Redlinger-Pohn, J., Mautner, A. and Mathew, A.P. (2023) 3D printed polylactic acid (PLA) filters reinforced with polysaccharide nanofibers for metal ions capture and microplastics separation from water. *Chem Eng J*, 457, p. 141153.

Fine, D.H., Patil, A.G. and Loos, B.G. (2018) Classification and diagnosis of aggressive periodontitis. *J. Clin. Periodontol*, 45 Suppl 2, pp. S95–S111.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Fiocchi, J., Biffi, C.A., Gambaro, S., Paternoster, C., Mantovani, D. and Tuissi, A. (2020) Effect of laser welding on the mechanical and degradation behaviour of Fe-20Mn-0.6C bioabsorbable alloy. *J. Mater. Res. Technol*, 9(6), pp. 13474–13482.

Fleischer, S., Shapira, A., Feiner, R. and Dvir, T. (2017) Modular assembly of thick multifunctional cardiac patches. *Proc Natl Acad Sci U S A*, 114(8), pp. 1898–1903.

Florencio-Silva, R., Sasso, G.R.D.S., Sasso-Cerri, E., Simões, M.J. and Cerri, P.S. (2015) Biology of Bone Tissue: Structure, Function, and Factors That Influence Bone Cells. *Biomed. Res. Int.*, 2015(421746), pp. 1–17.

Forysenkova, A.A., Fadeeva, I. V, Deyneko, D. V, Gosteva, A.N., Mamin, G. V, Shurtakova, D. V, et al. (2023) Polyvinylpyrrolidone—Alginate—Carbonate Hydroxyapatite Porous Composites for Dental Applications. *Materials*, 16(12), [Online] Available from: doi.org/10.3390/ma16124478 [Accessed 13/06/2025].

França, C.M., Tahayeri, A., Rodrigues, N.S., Ferdosian, S., Puppin Rontani, R.M., Sereda, G., et al. (2020) The tooth on-a-chip: a microphysiologic model system mimicking the biologic interface of the tooth with biomaterials. *Lab Chip*, 20(2), pp. 405–413.

Frencken, J.E., Sharma, P., Stenhouse, L., Green, D., Laverty, D. and Dietrich, T. (2017) Global epidemiology of dental caries and severe periodontitis – a comprehensive review. *J Clin Periodontol*, 44, pp. S94–S105.

Frunzaverde, D., Cojocaru, V., Bacescu, N., Ciubotariu, C.-R., Miclosina, C.-O., Turiac, R.R., et al. (2023) The Influence of the Layer Height and the Filament Color on the Dimensional Accuracy and the Tensile Strength of FDM-Printed PLA Specimens. *Polymers*, 15(10), pp. 1–15.

Fu, L., Wang, Z., Dong, S., Cai, Y., Ni, Y., Zhang, T., et al. (2017) Bilayer poly(Lactic-co-glycolic acid)/nano-hydroxyapatite membrane with barrier function and osteogenesis promotion for guided bone regeneration. *Mater.*, 10(3), pp. 1–19.

Fuchs, R.K., Thompson, W.R. and Warden, S.J. (2019) Bone biology. In: *Bone Repair Biomaterials: Regeneration and Clinical Applications, Second Edition*. pp. 15–52.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Fukuba, S., Okada, M., Nohara, K. and Iwata, T. (2021) Alloplastic bone substitutes for periodontal and bone regeneration in dentistry: Current status and prospects. *Materials*, 14(5), pp. 1–28.

Gaaz, T.S., Sulong, A.B., Akhtar, M.N., Kadhum, A.A.H., Mohamad, A.B. and Al-Amiery, A.A. (2015) Properties and Applications of Polyvinyl Alcohol, Halloysite Nanotubes and Their Nanocomposites. *Molecules*, 20(12), pp. 22833–22847.

Gallo, P. and Díaz-Báez, D. (2019) Management Of 80 Complications In Vertical and Horizontal Ridge Augmentation with Nonresorbable Membrane (d-PTFE): A Cross-Sectional Study. *J Oral Maxillofac Implants*, 34(4), pp. 927–935.

Gao, L., Kang, M., Zhang, M.J., Reza Sailani, M., Kuraji, R., Martinez, A., et al. (2020) Polymicrobial periodontal disease triggers a wide radius of effect and unique virome. *NPJ Biofilms Microbiomes*, 6(1), p. 10.

Garcia, J., Berghezan, S., Caramês, J.M.M., Dard, M.M. and Marques, D.N.S. (2017) Effect of cross-linked vs non-cross-linked collagen membranes on bone: A systematic review. *J. Periodont. Res*, 52(6), pp. 955–964.

García-martínez, E., Miguel, V., Martínez-martínez, A., Manjabacas, M.C. and Coello, J. (2019) Sustainable Lubrication Methods for the Machining of Titanium Alloys: An Overview. *Materials*, 12(23), pp. 1–22.

Garot, C., Schoffit, S., Monfoulet, C., Machillot, P., Deroy, C., Roques, S., et al. (2022) 3D-printed polymeric scaffolds with optimized architecture to repair a sheep metatarsal critical-size bone defect. *bioRxiv*, [Online] Available from: doi.org/10.1101/2022.12.14.520447 [Accessed 13/06/2025].

Gavini, G., Santos, M. Dos, Caldeira, C.L., Machado, M.E. de L., Freire, L.G., Iglecias, E.F., et al. (2018) Nickel-titanium instruments in endodontics: a concise review of the state of the art. *Braz. Oral Res*, 32(e67), pp. 44–65.

Ge, Y., Xue, J., Liu, L., Wan, H. and Yang, Y. (2024) Advances in multiple assembly acoustic structural design strategies for honeycomb composites: A review. *Mater. Today Commun*, 38, p. 108013.

Ghensi, P., Stablum, W., Bettio, E., Soldini, M.C.T.T.R. and Soldini, C. (2017) Management of the exposure of a dense PTFE (d-PTFE) membrane in guided bone regeneration (GBR): a case report. *Oral Implantol (Rome)*, 10(3), pp. 335–342.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Gibson, I., Rosen, D., Stucker, B. and Khorasani, M. (2020) *Additive Manufacturing Technologies*. 3rd ed. Cham: Springer International Publishing.

Gielkens, P.F.M., Schortinghuis, J., De Jong, J.R., Raghoebar, G.M., Stegenga, B. and Bos, R.R.M. (2008) Vivosorb®, Bio-Gide®, and Gore-Tex® as barrier membranes in rat mandibular defects: an evaluation by microradiography and micro-CT. *Clin Oral Implants Res*, 19(5), pp. 516–521.

Goole, J. and Amighi, K. (2016) 3D printing in pharmaceutics: A new tool for designing customized drug delivery systems. *Int. J. Pharm*, 499(1), pp. 376–394.

Gordon, O., Vig Slenters, T., Brunetto, P.S., Villaruz, A.E., Sturdevant, D.E., Otto, M., et al. (2010) Silver coordination polymers for prevention of implant infection: thiol interaction, impact on respiratory chain enzymes, and hydroxyl radical induction. *Antimicrob Agents Chemother*, 54(10), pp. 4208–4218.

Gottlow, J., Nyman, S., Karring, T. and Lindhe, J. (1984) New attachment formation as the result of controlled tissue regeneration. *J Clin Periodontol*, 11(8), pp. 494–503.

Gottlow, J., Nyman, S., Lindhe, J., Karring, T. and Wennström, J. (1986) New attachment formation in the human periodontium by guided tissue regeneration Case reports. *J Clin Periodontol*, 13(6), pp. 604–616.

Goutam, M., Batra, N., Jyothirmayee, K., Bagrecha, N., Deshmukh, P. and Malik, S. (2022) A Comparison of Xenograft Graft Material and Synthetic Bioactive Glass Allograft in Immediate Dental Implant Patients. *J. Pharm. Bioallied Sci*, 14(Suppl 1), pp. S980–S982.

Goyal, M., Mittal, N., Gupta, G. and Singhal, M. (2015) Ridge augmentation in implant dentistry. *J. Int. Clin. Dent. Res. Organ*, 7(3), p. 94.

Griffen, A.L., Beall, C.J., Campbell, J.H., Firestone, N.D., Kumar, P.S., Yang, Z.K., et al. (2012) Distinct and complex bacterial profiles in human periodontitis and health revealed by 16S pyrosequencing. *ISME J*, 6(6), pp. 1176–1185.

Gross, B.C., Erkal, J.L., Lockwood, S.Y., Chen, C. and Spence, D.M. (2014) Evaluation of 3D printing and its potential impact on biotechnology and the chemical sciences. *Anal Chem*, 86(7), pp. 3240–3253.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Gu, J., Wensing, M., Uhde, E. and Salthammer, T. (2019) Characterization of particulate and gaseous pollutants emitted during operation of a desktop 3D printer. *Environ Int*, 123, pp. 476–485.

Guillen, G.R., Pan, Y., Li, M. and Hoek, E.M. V (2011) Preparation and Characterization of Membranes Formed by Nonsolvent Induced Phase Separation: A Review. *Ind. Eng. Chem. Res.*, 50(7), pp. 3798–3817.

Gultekin, B., Bedeloglu, E., Kose, T.E. and Mijiritsky, E. (2016) Comparison of Bone Resorption Rates after Intraoral Block Bone and Guided Bone Regeneration Augmentation for the Reconstruction of Horizontally Deficient Maxillary Alveolar Ridges. *Biomed Res Int*, 2016(4987437), pp. 1–9.

Gultekin, B.A., Cansiz, E. and Yalcin, S. (2016) Ridge Augmentation Techniques in Preprosthetic Implant Surgery. In: *A Textbook of Advanced Oral and Maxillofacial Surgery*. IntechOpen.

Haddad, A., Menezes, A., Guarnieri, C., Coimbra, D., Ribeiro, E., Sarubi, J., et al. (2019) Recommendations on the use of injectable poly-L-lactic acid for skin laxity in off-face areas. *J Drugs Dermatol*, 18(9), pp. 929–935.

Hadrup, N., Sharma, A.K. and Loeschner, K. (2018) Toxicity of silver ions, metallic silver, and silver nanoparticle materials after in vivo dermal and mucosal surface exposure: A review. *Regul. Toxicol. Pharmacol.*, 98, pp. 257–267.

Hajishengallis, G. (2015) Periodontitis: from microbial immune subversion to systemic inflammation. *Nat Rev Microbiol*, 15(1), pp. 30–44.

Halldorsson, S., Lucumi, E., Gómez-Sjöberg, R. and Fleming, R.M.T. (2015) Advantages and challenges of microfluidic cell culture in polydimethylsiloxane devices. *Biosens Bioelectron*, 63, pp. 218–231.

Han, J., Park, S., Kim, J.E., Park, B., Hong, Y., Lim, J.W., et al. (2023) Development of a Scaffold-on-a-Chip Platform to Evaluate Cell Infiltration and Osteogenesis on the 3D-Printed Scaffold for Bone Regeneration. *ACS Biomater Sci Eng*, 9(2), pp. 968–977.

Hanawa, T. (2019) Titanium-Tissue Interface Reaction and Its Control With Surface Treatment. *Front. Bioeng. Biotechnol*, 7, pp. 1–13.

Hardes, J., Ahrens, H., Gebert, C., Streitbuerger, A., Buerger, H., Erren, M., et al. (2007) Lack of toxicological side-effects in silver-coated megaprostheses in humans. *Biomaterials*, 28(18), pp. 2869–2875.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Harpaz, D., Axelrod, T., Yitian, A.L., Eltzov, E., Marks, R.S. and Tok, A.I.Y. (2019) Dissolvable Polyvinyl-Alcohol Film, a Time-Barrier to Modulate Sample Flow in a 3D-Printed Holder for Capillary Flow Paper Diagnostics. *Materials*, 12(3), pp. 1–11.

Haryńska, A., Gubanska, I., Kucinska-Lipka, J. and Janik, H. (2018) Fabrication and Characterization of Flexible Medical-Grade TPU Filament for Fused Deposition Modeling 3DP Technology. *Polymers*, 10(12), pp. 1–19.

Hasegawa, H., Masui, S. and Ishihata, H. (2018) New microperforated pure titanium membrane created by laser processing for guided regeneration of bone. *Br J Oral Maxillofac Surg*, 56(7), pp. 642–643.

Hashim, N.T., Babiker, R., Priya, S.P., Mohammed, R., Chaitanya, N.C.S.K., Padmanabhan, V., et al. (2024) Microbial Dynamics in Periodontal Regeneration: Understanding Microbiome Shifts and the Role of Antifouling and Bactericidal Materials: A Narrative Review. *Curr. Issues Mol. Biol.*, 46(11), pp. 12196–12213.

Hassanzadeh, P., Atyabi, F. and Dinarvand, R. (2018) Tissue engineering: Still facing a long way ahead. *J Control Release*, 279, pp. 181–197.

Haugen, H.J., Lyngstadaas, S.P., Rossi, F. and Perale, G. (2019) Bone grafts: which is the ideal biomaterial? *J Clin Periodontol*, 46(S21), pp. 92–102.

Hayashi, K., Shimabukuro, M., Zhang, C., Taleb Alashkar, A.N., Kishida, R., Tsuchiya, A., et al. (2024) Silver phosphate-modified carbonate apatite honeycomb scaffolds for anti-infective and pigmentation-free bone tissue engineering. *Mater. Today Bio.*, 27, p. 101161.

Hegde, M.N. (2018) Dysbiosis of Oral Microflora: A Review. *J Health Allied Sci. NU*, 08(04), pp. 034–039.

Hofer, U. (2019) The cost of antimicrobial resistance. *Nat Rev Microbiol*, 17(1), p. 3.

Homan, K.A., Gupta, N., Kroll, K.T., Kolesky, D.B., Skylar-Scott, M., Miyoshi, T., et al. (2019) Flow-enhanced vascularization and maturation of kidney organoids in vitro. *Nat Methods*, 16(3), pp. 255–262.

Hong, H., Seo, Y.B., Kim, D.Y., Lee, J.S., Lee, Y.J., Lee, H., et al. (2020) Digital light processing 3D printed silk fibroin hydrogel for cartilage tissue engineering. *Biomaterials*, 232, p. 119679.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Hooks, K.B. and O'Malley, M.A. (2017) Dysbiosis and its discontents. *mBio*, 8(5), pp. 1–11.

Hoornaert, A., D'Arros, C., Heymann, M.F. and Layrolle, P. (2016) Biocompatibility, resorption and biofunctionality of a new synthetic biodegradable membrane for guided bone regeneration. *Biomed. Mater. (Bristol)*, 11(4), [Online] Available from: doi.org/10.1088/1748-6041/11/4/045012.

Hsu, Y.-T. and Wang, H.-L. (2013) How to Select Replacement Grafts for Various Periodontal and Implant Indications. *Clin Adv Periodontics*, 3(3), pp. 167–179.

Hu, R., Deng, L., Hao, X., Chen, J., Zhou, X. and Sahai, N. (2024) Direct, Broad-Spectrum Antimicrobial Activity of Ag+-Doped Hydroxyapatite against Fastidious Anaerobic Periodontal and Aerobic Dental Bacteria. *Materials*, 17(19), pp. 1–20.

Huang, C., Sanaei, F., Verdurmen, W.P.R., Yang, F., Ji, W. and Walboomers, X.F. (2023) The Application of Organs-on-a-Chip in Dental, Oral, and Craniofacial Research. *J Dent Res*, (220345221145555), pp. 1–12.

Huang, X. and Brazel, C.S. (2001) On the importance and mechanisms of burst release in matrix-controlled drug delivery systems. *J. Control. Release,* 73(2), pp. 121–136.

Hudzicki, J. (2009) *Kirby-Bauer Disk Diffusion Susceptibility Test Protocol*. American Society for Microbiology.

Huh, D., Hamilton, G.A. and Ingber, D.E. (2011) From 3D cell culture to organs-on-chips. *Trends Cell Biol*, 21(12), pp. 745–754.

Humayun, M., Chow, C.-W. and Young, E.W.K. (2018) Microfluidic lung airway-on-a-chip with arrayable suspended gels for studying epithelial and smooth muscle cell interactions. *Lab Chip*, 18(9), pp. 1298–1309.

Hussein, S., Sulaiman, S., Ali, S., Pirot, R., Qurbani, K., Hamzah, H., et al. (2024) Synthesis of Silver Nanoparticles from Aeromonas caviae for Antibacterial Activity and In Vivo Effects in Rats. *Biol Trace Elem Res*, 202(6), pp. 2764–2775.

Iconaru, S.L., Predoi, D., Ciobanu, C.S., Motelica-Heino, M., Guegan, R. and Bleotu, C. (2022) Development of Silver Doped Hydroxyapatite Thin Films for Biomedical Applications. *Coatings*, 12(3), pp. 1–18.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Ilyas, R.A., Sapuan, S.M., Harussani, M.M., Hakimi, M.Y.A.Y., Haziq, M.Z.M., Atikah, M.S.N., et al. (2021) Polylactic Acid (PLA) Biocomposite: Processing, Additive Manufacturing and Advanced Applications. *Polymers*, 13(8), pp. 1–34.

Iniesta, M., Chamorro, C., Ambrosio, N., Marín, M.J., Sanz, M. and Herrera, D. (2023) Subgingival microbiome in periodontal health, gingivitis and different stages of periodontitis. *J Clin Periodontol*, 50(7), pp. 905–920.

INSTRON® (2024) *The Definitive Guide to ASTM D882 - Tensile Testing of Thin Plastic Film*. Available from : https://www.instron.com/en/testing-solutions/astm-standards/astm-d882 [Accessed 16/01/25].

International Organization for Standardization (2009) *10993–5: 2009 Biological evaluation of medical devices—part 5: tests for in vitro cytotoxicity*. Geneva, Switzerland: ISO.

International Organization for Standardization (2016) *ISO 13485:2016 Medical devices — Quality management systems —Requirements for regulatory purposes*. [Online] Online Browsing Platform (OBP) ISO. Available from : https://www.iso.org/standard/59752.html [Accessed 11/06/25].

International Organization for Standardization (2021) *ISO/ASTM 52900:2021 Additive manufacturing — General principles — Fundamentals and vocabulary*. Switzerland: https://www.iso.org.

Ishikawa, K., Miyamoto, Y., Tsuchiya, A., Hayashi, K., Tsuru, K. and Ohe, G. (2018) Physical and histological comparison of hydroxyapatite, carbonate apatite, and β-tricalcium phosphate bone substitutes. *Materials*, 11(10), [Online] Available from: doi.org/10.3390/ma11101993.

Ivankovic, T., Turk, H., Hrenovic, J., Schauperl, Z., Ivankovic, M. and Ressler, A. (2023) Antibacterial activity of silver doped hydroxyapatite toward multidrug-resistant clinical isolates of Acinetobacter baumannii. *J. Hazard. Mater.*, 458, pp. 1–10.

Jabbar, A., Arruda, S. and Sadick, N. (2017) Off face usage of poly-L-lactic acid for body rejuvenation. *J Drugs Dermatol*, 16(5), pp. 489–494.

Jadhav, A. and Jadhav, V.S. (2022) A review on 3D printing: An additive manufacturing technology. *Mater Today*, 62, pp. 2094–2099.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
Muh. Hidayat Syahruddin, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. Rahmi Anggraeni, S.Kep., M.Sc.; Dr. drg. Dyah
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Jahromi, H.K., Farzin, A., Hasanzadeh, E., Barough, S.E., Mahmoodi, N., Najafabadi, M.R.H., et al. (2020) Enhanced sciatic nerve regeneration by poly-L-lactic acid/multi-wall carbon nanotube neural guidance conduit containing Schwann cells and curcumin encapsulated chitosan nanoparticles in rat. *Mater. Sci. Eng. C*, 109, p. 110564.

Jain, N., Dutt, U., Radenkov, I. and Jain, S. (2024) WHO's global oral health status report 2022: Actions, discussion and implementation. *Oral Dis*, 30(2), pp. 73–79.

Jalageri, M.B. and Mohan Kumar, G.C. (2022) Hydroxyapatite Reinforced Polyvinyl Alcohol/Polyvinyl Pyrrolidone Based Hydrogel for Cartilage Replacement. *Gels*, 8(9), pp. 2–13.

Jang, H.J., Kang, M.S., Kim, W.-H., Jo, H.J., Lee, S.-H., Hahm, E.J., et al. (2023) 3D printed membranes of polylactic acid and graphene oxide for guided bone regeneration. *Nanoscale Adv.*, 5(14), pp. 3619–3628.

Januariyasa, I., Ana, I.D. and Yusuf, Y. (2020) Nanofibrous poly(vinyl alcohol)/chitosan contained carbonated hydroxyapatite nanoparticles scaffold for bone tissue engineering. *Mater Sci Eng C Mater Biol Appl*, 107, p. 110347.

Al Jasser, R. and Andreana, S. (2016) An overview of bone augmentation techniques. *Clin Case Rep Rev*, 2(4), [Online] Available from: doi.org/10.15761/ccrr.1000226.

Jaworska, J., Sobota, M., Pastusiak, M., Kawalec, M., Janeczek, H., Rychter, P., et al. (2022) Synthesis of Polyacids by Copolymerization of l-Lactide with MTC-COOH Using Zn[(acac)(L)H2O] Complex as an Initiator. *Polymers*, 14(3), pp. 1–16.

Jazayeri, H.E., Tahriri, M., Razavi, M., Khoshroo, K., Fahimipour, F., Dashtimoghadam, E., et al. (2017) A current overview of materials and strategies for potential use in maxillofacial tissue regeneration. *Mater. Sci. Eng. C*, 70, pp. 913–929.

Jeong, J., Kim, J.H., Shim, J.H., Hwang, N.S. and Heo, C.Y. (2019) Bioactive calcium phosphate materials and applications in bone regeneration. *Biomater. Res.*, 23(1), p. 4.

Jeong, L., Kim, M.H., Jung, J.Y., Min, B.M. and Park, W.H. (2014) Effect of silk fibroin nanofibers containing silver sulfadiazine on wound healing. *Int J Nanomedicine*, 9(1), pp. 5277–5287.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Jin, L., Kou, N., An, F., Gao, Z., Tian, T., Hui, J., et al. (2022) Analyzing Human Periodontal Soft Tissue Inflammation and Drug Responses In Vitro Using Epithelium-Capillary Interface On-a-Chip. *Biosensors*, 12(5), pp. 1–14.

Jovanovic, S.A. and Nevins, M. (1995) Bone formation utilizing titanium-reinforced barrier membranes. *Int J Periodontics Restorative Dent*, 15(1), pp. 56–69.

Juhl, O.J., Latifi, S.M. and Donahue, H.J. (2021) Effect of carbonated hydroxyapatite submicron particles size on osteoblastic differentiation. *J Biomed Mater Res B Appl Biomater*, 109(9), pp. 1369–1379.

Jung, R.E., Herzog, M., Wolleb, K., Ramel, C.F., Thoma, D.S. and Hämmerle, C.H.F. (2017) A randomized controlled clinical trial comparing small buccal dehiscence defects around dental implants treated with guided bone regeneration or left for spontaneous healing. *Clin. Oral Implants Res*, 28(3), pp. 348–354.

Jung, W.K., Koo, H.C., Kim, K.W., Shin, S., Kim, S.H. and Park, Y.H. (2008) Antibacterial activity and mechanism of action of the silver ion in Staphylococcus aureus and Escherichia coli. *Appl. Environ. Microbiol*, 74(7), pp. 2171–2178.

Kaczmarek, H., Nowicki, M., Vuković-Kwiatkowska, I. and Nowakowska, S. (2013) Crosslinked blends of poly(lactic acid) and polyacrylates: AFM, DSC and XRD studies. *J Polym Res*, 20(3), p. 91.

Kalyan, P.Bg. and Kumar, L. (2022) 3D Printing: Applications in Tissue Engineering, Medical Devices, and Drug Delivery. *AAPS PharmSciTech*, 23(4), [Online] Available from: doi.org/10.1208/s12249-022-02242-8.

Kamada, N., Chen, G.Y., Inohara, N. and Núñez, G. (2013) Control of pathogens and pathobionts by the gut microbiota. *Nat Immunol*, 14(7), pp. 685–690.

Kamada, N., Seo, S.U., Chen, G.Y. and Núñez, G. (2013) Role of the gut microbiota in immunity and inflammatory disease. *Nat Rev Immunol*, 13(5), pp. 321–335.

Kamal, A., Elsheikh, A.H. and Showaib, E. (2020) Pre-Cracking techniques of polymeric materials: An overview. *IOP Conf. Ser. Mater. Sci. Eng.*, 973(1), pp. 1–9.

Kanellakopoulou, K. and Giamarellos-Bourboulis, E.J. (2000) Carrier systems for the local delivery of antibiotics in bone infections. *Drugs*, 59(6), pp. 1223–1232.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Kang, H.-W., Lee, S.J., Ko, I.K., Kengla, C., Yoo, J.J. and Atala, A. (2016) A 3D bioprinting system to produce human-scale tissue constructs with structural integrity. *Nat. Biotechnol.*, 34(3), pp. 312–319.

Kapila, Y.L. (2021) Oral health's inextricable connection to systemic health: Special populations bring to bear multimodal relationships and factors connecting periodontal disease to systemic diseases and conditions. *Periodontol 2000*, 87(1), pp. 11–16.

Karched, M., Bhardwaj, R.G., Qudeimat, M., Al-Khabbaz, A. and Ellepola, A. (2022) Proteomic analysis of the periodontal pathogen Prevotella intermedia secretomes in biofilm and planktonic lifestyles. *Sci Rep*, 12(1), pp. 1–11.

Karre, R., Kodli, B.K., Rajendran, A., J, N., Pattanayak, D.K., Ameyama, K., et al. (2019) Comparative study on Ti-Nb binary alloys fabricated through spark plasma sintering and conventional P/M routes for biomedical application. *Mater Sci Eng C Mater Biol Appl*, 94, pp. 619–627.

Kaushal, S., Kumar, A., Khan, M.A. and Lal, N. (2016) Comparative study of nonabsorbable and absorbable barrier membranes in periodontal osseous defects by guided tissue regeneration. *J Oral Biol Craniofac Res*, 6(2), pp. 111–117.

Kawase, T., Kamiya, M., Kobayashi, M., Tanaka, T., Okuda, K., Wolff, L.F., et al. (2015) The heat-compression technique for the conversion of platelet-rich fibrin preparation to a barrier membrane with a reduced rate of biodegradation. *J. Biomed. Mater. Res. Part B Appl. Biomater*, 103(4), pp. 825–831.

Kędziora, A., Speruda, M., Krzyżewska, E., Rybka, J., Łukowiak, A. and Bugla-Płoskońska, G. (2018) Similarities and Differences between Silver Ions and Silver in Nanoforms as Antibacterial Agents. *Int J Mol Sci*, 19(2), pp. 1–17.

Keles, H., Naylor, A., Clegg, F. and Sammon, C. (2015) Investigation of factors influencing the hydrolytic degradation of single PLGA microparticles. *Polym. Degrad. Stab*, 119, pp. 228–241.

Kenkre, J.S. and Bassett, J.H.D. (2018) The bone remodelling cycle. *Ann Clin Biochem*, 55(3), pp. 308–327.

Khodaei, M., Amini, K. and Valanezhad, A. (2020) Fabrication and Characterization of Poly Lactic Acid Scaffolds by Fused Deposition Modeling for Bone Tissue Engineering. *J. Wuhan Univ. Technol.-Mat. Sci. Edit.*, 35(1), pp. 248–251.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Khojasteh, A., Kheiri, L., Motamedian, S.R. and Khoshkam, V. (2017) Guided Bone Regeneration for the Reconstruction of Alveolar Bone Defects. *Ann. Maxillofac. Surg.*, 7(2), pp. 263–277.

Khoshaim, A.B., Elsheikh, A.H., Moustafa, E.B., Basha, M. and Showaib, E.A. (2021) Experimental investigation on laser cutting of PMMA sheets: Effects of process factors on kerf characteristics. *J. Mater. Res. Technol*, 11, pp. 235–246.

Kim, H.R., Kim, M.J., Lee, S.Y., Oh, S.M. and Chung, K.H. (2011) Genotoxic effects of silver nanoparticles stimulated by oxidative stress in human normal bronchial epithelial (BEAS-2B) cells. *Mutat Res Genet Toxicol Environ Mutagen*, 726(2), pp. 129–135.

Kim, J.F., Kim, J.H., Lee, Y.M. and Drioli, E. (2016) Thermally induced phase separation and electrospinning methods for emerging membrane applications: A review. *AIChE J*, 62(2), pp. 461–490.

Kim, J.S., Kuk, E., Yu, K.N., Kim, J.-H., Park, S.J., Lee, H.J., et al. (2007) Antimicrobial effects of silver nanoparticles. *Nanomedicine*, 3(1), pp. 95–101.

Kim, S., Ko, J., Lee, S.-R., Park, D., Park, S. and Jeon, N.L. (2021) Anchor-IMPACT: A standardized microfluidic platform for high-throughput antiangiogenic drug screening. *Biotechnol. Bioeng*, 118(7), pp. 2524–2535.

Kim, S. and Takayama, S. (2015) Organ-on-a-chip and the kidney. *Kidney Res Clin Pract*, 34(3), pp. 165–169.

Kim, Y., Nowzari, H. and Rich, S.K. (2013) Risk of Prion Disease Transmission through Bovine-Derived Bone Substitutes: A Systematic Review. *Clin. Implant Dent. Relat. Res.*, 15(5), pp. 645–653.

Kim, Y.K. and Ku, J.K. (2020) Guided bone regeneration. *J Korean Assoc Oral Maxillofac Surg*, 46(5), pp. 361–366.

Kimura, H., Sakai, Y. and Fujii, T. (2018) Organ/body-on-a-chip based on microfluidic technology for drug discovery. *Drug Metab. Pharmacokinet.*, 33(1), pp. 43–48.

Klemm, E.J., Wong, V.K. and Dougan, G. (2018) Emergence of dominant multidrug-resistant bacterial clades: Lessons from history and whole-genome sequencing. *Proc. Natl. Acad. Sci. U.S.A*, 115(51), pp. 12872–12877.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Koizhaiganova, M., Yaşa, I. and Gülümser, G. (2016) Characterization and Antimicrobial Activity of Silver Doped Hydroxyapatite Obtained by the Microwave Method. *Medziagotyra*, 22(3), pp. 2–7.

Kokubo, T. and Takadama, H. (2006) How useful is SBF in predicting in vivo bone bioactivity? *Biomater.*, 27(15), pp. 2907–2915.

Kolmas, J., Groszyk, E. and Kwiatkowska-Rózycka, D. (2014) Substituted hydroxyapatites with antibacterial properties. *Biomed Res. Int*, 2014(178123), pp. 1–15.

Kono, T., Sakae, T., Nakada, H., Kaneda, T. and Okada, H. (2022) Confusion between Carbonate Apatite and Biological Apatite (Carbonated Hydroxyapatite) in Bone and Teeth. *Minerals*, 12(2), pp. 1–11.

Könönen, E., Gursoy, M. and Gursoy, U.K. (2019) Periodontitis: A Multifaceted Disease of Tooth-Supporting Tissues. *J. Clin. Med.*, 8(8), pp. 1–12.

Kora, A.J. and Arunachalam, J. (2011) Assessment of antibacterial activity of silver nanoparticles on Pseudomonas aeruginosa and its mechanism of action. *World J. Microbiol. Biotechnol*, 27(5), pp. 1209–1216.

Kosorn, W., Sakulsumbat, M., Uppanan, P., Kaewkong, P., Chantaweroad, S., Jitsaard, J., et al. (2017) PCL/PHBV blended three dimensional scaffolds fabricated by fused deposition modeling and responses of chondrocytes to the scaffolds. *J Biomed Mater Res B Appl Biomater*, 105(5), pp. 1141–1150.

Kumar, M., Ghosh, S., Kumar, V., Sharma, V. and Roy, P. (2022) Tribo-mechanical and biological characterization of PEGDA/bioceramics composites fabricated using stereolithography. *J. Manuf. Process*, 77, pp. 301–312.

Kumar, N., Pratibha, Trajkovska Petkoska, A., Khojah, E., Sami, R. and Al-Mushhin, A.A.M. (2021) Chitosan Edible Films Enhanced with Pomegranate Peel Extract: Study on Physical, Biological, Thermal, and Barrier Properties. *Materials*, 14(12), pp. 1–18.

Kumar, V. V, Ebenezer, S. and Thor, A. (2022) Bone Augmentation Procedures in Implantology. In: BONANTHAYA, K. et al. (eds.) *Oral and Maxillofacial Surgery for the Clinician*. Singapore: Springer Nature Singapore, pp. 407–426.

Kwon, T.H., Lamster, I.B. and Levin, L. (2021) Current Concepts in the Management of Periodontitis. *Int. Dent. J.*, 71(6), pp. 462–476.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Lafaurie, G., Neuta, Y., Ríos, R., Pacheco-Montealegre, M., Pianeta, R., Castillo, D., et al. (2022) Differences in the subgingival microbiome according to stage of periodontitis: A comparison of two geographic regions. *PLoS One*, 17(8), pp. 1–19.

Lalia, B.S., Kochkodan, V., Hashaikeh, R. and Hilal, N. (2013) A review on membrane fabrication: Structure, properties and performance relationship. *Desalination*, 326, pp. 77–95.

Lamont, R.J., Koo, H. and Hajishengallis, G. (2018) The oral microbiota: dynamic communities and host interactions. *Nat Rev Microbiol*, 16(12), pp. 745–759.

Lan, W., Zhang, X., Xu, M., Zhao, L., Huang, D., Wei, X., et al. (2019) Carbon nanotube reinforced polyvinyl alcohol/biphasic calcium phosphate scaffold for bone tissue engineering. *RSC Adv.*, 9(67), pp. 38998–39010.

Landi, E., Celotti, G., Logroscino, G. and Tampieri, A. (2003) Carbonated hydroxyapatite as bone substitute. *J. Eur. Ceram. Soc.*, 23(15), pp. 2931–2937.

Lang, N.P. and Bartold, P.M. (2018) Periodontal health. *J Periodontol*, 89(S1), pp. S9–S16.

Lasica, A., Golec, P., Laskus, A., Zalewska, M., Gędaj, M. and Popowska, M. (2024) Periodontitis: etiology, conventional treatments, and emerging bacteriophage and predatory bacteria therapies. *Front Microbiol*, 15, pp. 1-22.

Lee, I.-S., Whang, C.-N., Oh, K.-S., Park, J.-C., Lee, K.-Y., Lee, G.-H., et al. (2006) Formation of silver incorporated calcium phosphate film for medical applications. *Nucl Instrum Methods Phys Res B*, 242(1), pp. 45–47.

Lee, S.-Y., Wu, S.-C., Chen, H., Tsai, L.-L., Tzeng, J.-J., Lin, C.-H., et al. (2018) Synthesis and Characterization of Polycaprolactone-Based Polyurethanes for the Fabrication of Elastic Guided Bone Regeneration Membrane. *BioMed Res. Int*, 2018(1), p. 3240571.

Leung, C.M., de Haan, P., Ronaldson-Bouchard, K., Kim, G.A., Ko, J., Rho, H.S., et al. (2022) A guide to the organ-on-a-chip. *Nat Rev Methods Primers*, 2(1), pp. 1–29.

Li, B. and Webster, T.J. (2018) Bacteria antibiotic resistance: New challenges and opportunities for implant-associated orthopedic infections. *J Orthop Res*, 36(1), pp. 22–32.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Li, G., Zhao, M., Xu, F., Yang, B., Li, X., Meng, X., et al. (2020) Synthesis and Biological Application of Polylactic Acid. *Molecules*, 25(21), pp. 1–18.

Li, H. and Xu, H. (2024) Mechanisms of bacterial resistance to environmental silver and antimicrobial strategies for silver: A review. *Environ. Res.*, 248, p. 118313.

Li, J., Zuo, Y., Cheng, X., Yang, W., Wang, H. and Li, Y. (2009) Preparation and characterization of nano-hydroxyapatite/polyamide 66 composite GBR membrane with asymmetric porous structure. *J Mater Sci Mater Med*, 20(5), pp. 1031–1038.

Li, S., Yu, W., Zhang, W., Zhang, G., Yu, L. and Lu, E. (2018) Evaluation of highly carbonated hydroxyapatite bioceramic implant coatings with hierarchical micro-/nanorod topography optimized for osseointegration. *Int J Nanomedicine*, 13, pp. 3643–3659.

Li, Y., Liu, Y., Hu, C., Chang, Q., Deng, Q., Yang, X., et al. (2020) Study of the neurotoxicity of indoor airborne nanoparticles based on a 3D human blood-brain barrier chip. *Environ. Int.*, 143, pp. 1–9.

Liao, C., Li, Y. and Tjong, S.C. (2019) Bactericidal and Cytotoxic Properties of Silver Nanoparticles. *Int. J. Mol. Sci.*, 20(2), pp. 1–47.

Liao, J., Mo, A., Wu, H., Zhang, J. and Li, Y. (2007) Antibacterial Activity of Silver-Hydroxyapatite / Titania Nanoparticles on Oral Bacteria. *Key Eng. Mater*, 330–332, pp. 299–302.

Liao, S., Zhang, Y., Pan, X., Zhu, F., Jiang, C., Liu, Q., et al. (2019) Antibacterial activity and mechanism of silver nanoparticles against multidrug-resistant Pseudomonas aeruginosa. *Int J Nanomedicine*, 14, pp. 1469–1487.

Liau, S.Y., Read, D.C., Pugh, W.J., Furr, J.R. and Russell, A.D. (1997) Interaction of silver nitrate with readily identifiable groups: relationship to the antibacterial action of silver ions. *Lett. Appl. Microbiol*, 25(4), pp. 279–283.

Lim, J.-S., Chai, Y.-Y., Ser, W.-X., Van Haeren, A., Lim, Y.-H., Raja, T., et al. (2024) Novel drug candidates against antibiotic-resistant microorganisms: A review. *Iran J. Basic Med. Sci.*, 27(2), pp. 134–150.

Limpan, N., Prodpran, T., Benjakul, S. and Prasarpran, S. (2012) Influences of degree of hydrolysis and molecular weight of poly(vinyl alcohol) (PVA) on properties of fish myofibrillar protein/PVA blend films. *Food Hydrocolloids*, 29(1), pp. 226–233.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Lin, C., Liu, C., Zhang, L., Huang, Z., Zhao, P., Chen, R., et al. (2018) Interaction of iPSC-derived neural stem cells on poly(L-lactic acid) nanofibrous scaffolds for possible use in neural tissue engineering. *Int J Mol Med*, 41(2), pp. 697–708.

Lin, H.-Y., Tsai, W.-C. and Chang, S.-H. (2017) Collagen-PVA aligned nanofiber on collagen sponge as bi-layered scaffold for surface cartilage repair. *J. Biomater. Sci. Polym. Ed*, 28(7), pp. 664–678.

Lin, W.-C., Yao, C., Huang, T.-Y., Cheng, S.-J. and Tang, C.-M. (2019) Long-term in vitro degradation behavior and biocompatibility of polycaprolactone/cobalt-substituted hydroxyapatite composite for bone tissue engineering. *Dent Mater*, 35(5), pp. 751–762.

Lindfors, L.T., Tervonen, E.A.T. and Sándor, G.K.B. (2010) Guided bone regeneration using a titanium-reinforced ePTFE membrane and particulate autogenous bone: the effect of smoking and membrane exposure. *YMOE*, 109(6), pp. 825–830.

Listl, S., Galloway, J., Mossey, P.A. and Marcenes, W. (2015) Global Economic Impact of Dental Diseases. *J. Dent. Res.*, 94(10), pp. 1355–1361.

Liu, B., Wang, S., Ma, H., Deng, Y., Du, J., Zhao, Y., et al. (2025) Heart-on-a-chip: a revolutionary organ-on-chip platform for cardiovascular disease modeling. *J Transl Med*, 23(1), p. 132.

Liu, F., Hashim, N.A., Liu, Y., Abed, M.R.M. and Li, K. (2011) Progress in the production and modification of PVDF membranes. *J Membr Sci*, 375(1), pp. 1–27.

Liu, J. and Kerns, D.G. (2014) Mechanisms of Guided Bone Regeneration: A Review. *Open Dent J*, 8(1), pp. 56–65.

Liu, M., Liu, B., Shen, J., Qian, S., Lai, H., Yuan, C., et al. (2024) Low energy intake and nutritional maladaptation in terminal stage IV periodontitis. *J Clin Periodontol*, 51(9), pp. 1147–1156.

Liu, X., Hua, X. and Cui, D. (2018) Copolymerization of Lactide and Cyclic Carbonate via Highly Stereoselective Catalysts To Modulate Copolymer Sequences. *Macromolecules*, 51(3), pp. 930–937.

Lloyd, D.R., Kinzer, K.E. and Tseng, H.S. (1990) Microporous membrane formation via thermally induced phase separation. I. Solid-liquid phase separation. *J Membr Sci*, 52(3), pp. 239–261.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Lloyd-Price, J., Abu-Ali, G. and Huttenhower, C. (2016) The healthy human microbiome. *Genome Med.*, 8(1), pp. 1–11.

Locci, P., Calvitti, M., Belcastro, S., Pugliese, M., Guerra, M., Marinucci, L., et al. (1997) Phenotype expression of gingival fibroblasts cultured on membranes used in guided tissue regeneration. *J Periodontol*, 68(9), pp. 857–863.

Lopresti, F., Carfì Pavia, F., Vitrano, I., Kersaudy-Kerhoas, M., Brucato, V. and La Carrubba, V. (2020) Effect of hydroxyapatite concentration and size on morpho-mechanical properties of PLA-based randomly oriented and aligned electrospun nanofibrous mats. *J. Mech. Behav. Biomed. Mater.*, 101, p. 103449.

Lunt, J. (1998) Large-scale production, properties and commercial applications of polylactic acid polymers. *Polym Degrad Stab*, 59(1), pp. 145–152.

Ma, C., Du, T., Niu, X. and Fan, Y. (2022) Biomechanics and mechanobiology of the bone matrix. *Bone Res.*, 10(1), p. 59.

Ma, C., Peng, Y., Li, H. and Chen, W. (2021) Organ-on-a-Chip: A New Paradigm for Drug Development. *Trends Pharmacol. Sci.*, 42(2), pp. 119–133.

Ma, C., Gao, X., Yang, Y., Bian, X., Wang, B., Liu, X., et al. (2023) The three-dimensional culture of L929 and C2C12 cells based on SPI-SA interpenetrating network hydrogel scaffold with excellent mechanical properties. *Front. Bioeng. Biotechnol*, 11, [Online] Available from: doi.org/10.3389/fbioe.2023.1329183.

Ma, Q., Ding, Q., Zhang, L., Sun, Y. and Xie, Q. (2023) Surface Characteristics and Flexural Strength of Porous-Surface Designed Zirconia Manufactured via Stereolithography. *J. Prosthodont.*, 32(4), pp. e81–e89.

MacDonald, A.F., Harley-Troxell, M.E., Newby, S.D. and Dhar, M.S. (2022) 3D-Printing Graphene Scaffolds for Bone Tissue Engineering. *Pharmaceutics*, 14(9), pp. 1–17.

Madupalli, H., Pavan, B. and Tecklenburg, M.M.J. (2017) Carbonate substitution in the mineral component of bone: Discriminating the structural changes, simultaneously imposed by carbonate in A and B sites of apatite. *J. Solid State Chem*, 255, pp. 27–35.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Mahardika, M., Asrofi, M., Priyanto, A., Hermawan, Y., Junus, S., Mulyadi, S., et al. (2021) Aplikasi Serat Alam Muntingia calabura sebagai Pengisi dalam Biokomposit Bermatriks Polivinil Alkohol (PVA): Karakteristik Sifat Kuat Tarik dan Permukaan Patahan. *Agroteknika*, 4(1), pp. 43–52.

Mamo, H.B., Adamiak, M. and Kunwar, A. (2023) 3D printed biomedical devices and their applications: A review on state-of-the-art technologies, existing challenges, and future perspectives. *J. Mech. Behav. Biomed. Mater.*, 143, pp. 1–11.

Mancilla-De-la-Cruz, J., Rodriguez-Salvador, M., An, J. and Chua, C.K. (2022) Three-Dimensional Printing Technologies for Drug Delivery Applications: Processes, Materials, and Effects. *Int. J. Bioprinting*, 8(4), pp. 321–346.

Manohar, D., Babu, R.S., Vijaya, B., Nallakumar, S., Gobi, R., Anand, S., et al. (2024) A review on exploring the potential of PVA and chitosan in biomedical applications: A focus on tissue engineering, drug delivery and biomedical sensors. *Int. J. Biol. Macromol*, 283, p. 137318.

Marsh, P.D., Head, D.A. and Devine, D.A. (2015) Ecological approaches to oral biofilms: Control without killing. *Caries Res*, 49(suppl 1), pp. 46–54.

Marsh, P.D., Head, D.A. and Devine, D.A. (2014) Prospects of oral disease control in the future -an opinion. *J. Oral Microbiol*, 6(1), pp. 1–4.

Martinez-Zelaya, V.R., Zarranz, L., Herrera, E.Z., Alves, A.T., Uzeda, M.J., Mavropoulos, E., et al. (2019) In vitro and in vivo evaluations of nanocrystalline zn-doped carbonated hydroxyapatite/alginate microspheres: Zinc and calcium bioavailability and bone regeneration. *Int J Nanomedicine*, 14, pp. 3471–3490.

Matai, I., Kaur, G., Seyedsalehi, A., McClinton, A. and Laurencin, C.T. (2020) Progress in 3D bioprinting technology for tissue/organ regenerative engineering. *Biomater*, 226(June 2019), p. 119536.

Matsumoto, M.A., Caviquioli, G., Biguetti, C.C., de Andrade Holgado, L., Saraiva, P.P., Rennó, A.C.M., et al. (2012) A novel bioactive vitroceramic presents similar biological responses as autogenous bone grafts. *J. Mater. Sci. Mater. Med.*, 23(6), pp. 1447–1456.

Mazlan, M.A., Anas, M.A., Nor Izmin, N.A. and Abdullah, A.H. (2023) Effects of Infill Density, Wall Perimeter and Layer Height in Fabricating 3D Printing Products. *Materials*, 16(2), pp. 1–11.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

McAllister, B.S. and Haghighat, K. (2007) Bone augmentation techniques. *J Periodontol*, 78(3), pp. 377–396.

Mealey, B.L. and Oates, T.W. (2006) Diabetes Mellitus and Periodontal Diseases. *J Periodontol*, 77(8), pp. 1289–1303.

Mehrotra, N. and Singh, S. (2025) *Periodontitis*. Treasure Island (FL): StatPearls Publishing.

Mei, L. and Guan, G. (2023) Profilometry and atomic force microscopy for surface characterization. *Nano TransMed*, 2(1), p. e9130017.

Meng, Z.X., Wang, Y.S., Ma, C., Zheng, W., Li, L. and Zheng, Y.F. (2010) Electrospinning of PLGA/gelatin randomly-oriented and aligned nanofibers as potential scaffold in tissue engineering. *Mater. Sci. Eng. C*, 30(8), pp. 1204–1210.

Meyer, U., Meyer, T., Handschel, J. and Wiesmann, H.P. (2009) *Fundamentals of Tissue Engineering and Regenerative Medicine*. Leipzig: Springer Berlin Heidelberg.

Mijnendonckx, K., Leys, N., Mahillon, J., Silver, S. and Van Houdt, R. (2013) Antimicrobial silver: uses, toxicity and potential for resistance. *Biometals*, 26(4), pp. 609–621.

Ministry of Health Republic of Indonesia (2019) *Laporan Nasional Riset Kesehatan Dasar 2018*. Jakarta: Lembaga Penerbit Badan Penelitian dan Pengembangan Kesehatan.

Ministry of Health Republic of Indonesia (2023) *Survei Kesehatan Indonesia (SKI) 2023 dalam Angka*. Jakarta.

Mirjalili, F., Mahmoodi, M. and Khazali, S. (2024) Characterization and in vitro bioactivity evaluation of polyvinyl alcohol incorporated electro spun chitosan/ fluor apatite nanofibrous scaffold for bone tissue engineering. *J. Mech. Behav. Biomed. Mater.*, 150, p. 106322.

Mohseni, M., Hutmacher, D.W. and Castro, N.J. (2018) Independent Evaluation of Medical-Grade Bioresorbable Filaments for Fused Deposition Modelling/Fused Filament Fabrication of Tissue Engineered Constructs. *Polymers*, 10(1), pp. 1–17.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
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Muh. Hidayat Syahruddin, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. Rahmi Anggraeni, S.Kep., M.Sc.; Dr. drg. Dyah
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

More, P.R., Pandit, S., Filippis, A. De, Franci, G., Mijakovic, I. and Galdiero, M. (2023) Silver Nanoparticles: Bactericidal and Mechanistic Approach against Drug Resistant Pathogens. *Microorganisms*, 11(2), pp. 1–27.

Moses, O., Vitrial, D., Aboodi, G., Sculean, A., Tal, H., Kozlovsky, A., et al. (2008) Biodegradation of Three Different Collagen Membranes in the Rat Calvarium: A Comparative Study. *J Periodontol*, 79(5), pp. 905–911.

Moyle, G.J., Brown, S., Lysakova, L. and Barton, S.E. (2006) Long-term safety and efficacy of poly-L-lactic acid in the treatment of HIV-related facial lipoatrophy. *HIV Med*, 7(3), pp. 181–185.

Murphy, S. V and Atala, A. (2014) 3D bioprinting of tissues and organs. *Nat. Biotechnol.*, 32(8), pp. 773–785.

Musah, S., Dimitrakakis, N., Camacho, D.M., Church, G.M. and Ingber, D.E. (2018) Directed differentiation of human induced pluripotent stem cells into mature kidney podocytes and establishment of a Glomerulus Chip. *Nat Protoc*, 13(7), pp. 1662–1685.

Muthuramalingam, T., Akash, R., Krishnan, S., Phan, N.H., Pi, V.N. and Elsheikh, A.H. (2021) Surface quality measures analysis and optimization on machining titanium alloy using CO2 based laser beam drilling process. *J. Manuf. Process*, 62, pp. 1–6.

Nadernezhad, A., Unal, S., Khani, N. and Koc, B. (2019) Material extrusion-based additive manufacturing of structurally controlled poly(lactic acid)/carbon nanotube nanocomposites. *Int J Adv Manuf Technol*, 102(5), pp. 2119–2132.

Naenni, N., Lim, H., Strauss, F., Jung, R.E., Hämmerle, C.H.F., Thoma, D.S., et al. (2020) Local tissue effects of various barrier membranes in a rat subcutaneous model. *J Periodontal Implant Sci*, 50(5), pp. 327–339.

Nair, L.S. and Laurencin, C.T. (2007) Biodegradable polymers as biomaterials. *Prog. Polym. Sci*, 32(8), pp. 762–798.

Narins, R.S., Baumann, L., Brandt, F.S., Fagien, S., Glazer, S., Lowe, N.J., et al. (2010) A randomized study of the efficacy and safety of injectable poly-L-lactic acid versus human-based collagen implant in the treatment of nasolabial fold wrinkles. *J Am Acad Dermatol*, 62(3), pp. 448–462.

Nascimento, Gustavo G., Alves-Costa, S. and Romandini, M. (2024) Burden of severe periodontitis and edentulism in 2021, with projections up to 2050: The Global Burden of Disease 2021 study. *J. Periodontal Res.*, pp. 823–865.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Nascimento, Gustaavo G, Alves-Costa, S. and Romandini, M. (2024) Burden of severe periodontitis and edentulism in 2021, with projections up to 2050: The Global Burden of Disease 2021 study. *J Periodont Res*, 59(5), pp. 823–867.

National Center for Biotechnology Information (2025a) *PubChem Compound Summary for CID 107689, Lactic Acid, L-*. [Online] National Library of Medicine. Available from: https://pubchem.ncbi.nlm.nih.gov/compound/Lactic-Acid_-L. [Accessed 11/06/25].

National Center for Biotechnology Information (2025b) *PubChem Compound Summary for Polyvinyl Alcohol*. [Online] National Library of Medicine. Available from: https://pubchem.ncbi.nlm.nih.gov/compound/Polyvinyl-Alcohol. [Accessed 11/06/25].

National Standardization Agency of Republic Indonesia (2024) *SNI 9268:2024-Standard test method for tensile properties of plastics (ASTM D638-22, IDT)*.

Nazir, M., Al-Ansari, A., Al-Khalifa, K., Alhareky, M., Gaffar, B. and Almas, K. (2020) Global Prevalence of Periodontal Disease and Lack of Its Surveillance. *Sci. World J.*, 2020(2146160), pp. 1–8.

Ncube, L.K., Ude, A.U., Ogunmuyiwa, E.N., Zulkifli, R. and Beas, I.N. (2020) Environmental Impact of Food Packaging Materials: A Review of Contemporary Development from Conventional Plastics to Polylactic Acid Based Materials. *Materials*, 13(21), pp. 1–24.

Needleman, I., Garcia, R., Gkranias, N., Kirkwood, K.L., Kocher, T., Iorio, A. Di, et al. (2018) Mean annual attachment, bone level, and tooth loss: A systematic review. *J Clin Periodontol*, 45 Suppl 2, pp. 112–129.

Nelder, J.A. (1956) Experimental Design, Theory and Application. *J R Stat Soc Ser A Stat Soc*, 119(3), pp. 340–341.

Nenen, A., Maureira, M., Neira, M., Orellana, S.L., Covarrubias, C. and Moreno-Villoslada, I. (2022) Synthesis of antibacterial silver and zinc doped nano-hydroxyapatite with potential in bone tissue engineering applications. *Ceram Inter*, 48(23, Part A), pp. 34750–34759.

Nesic, D., Schaefer, B.M., Sun, Y., Saulacic, N. and Sailer, I. (2020) 3D printing approach in dentistry: The future for personalized oral soft tissue regeneration. *J Clin Med*, 9(7), pp. 1–21.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Newman, M.G., Takei, H.H., Klokkevold, P.R. and Carranza, F.A. (2019) *Newman and Carranza's Clinical Periodontology*. 13th ed. Philadelphia: Elsevier Inc.

Ni, Z., Gu, X., He, Y., Wang, Z., Zou, X., Zhao, Y., et al. (2018) Synthesis of silver nanoparticle-decorated hydroxyapatite (HA@Ag) poriferous nanocomposites and the study of their antibacterial activities. *RSC Adv*, 8(73), pp. 41722–41730.

Nyman, S., Lindhe, J., Karring, T. and Rylander, H. (1982) New attachment following surgical treatment of human periodontal disease. *J Clin Periodontol*, 9(4), pp. 290–296.

Nyman, S., Gottlow, J., Karring, T. and Lindhe, J. (1982) The regenerative potential of the periodontal ligament. *J Clin Periodontol*, 9(3), pp. 257–265.

Oktawati, S., Djais, A.I., Achmad, H. and Jubhari, E.H. (2020) Bone Augmentation Procedure Before Placing the Dental Implant: A Literature Review. *Int. J. Pharm. Sci. Res*, 12(04), pp. 4040–4044.

Oryan, A., Alidadi, S., Moshiri, A. and Maffulli, N. (2014) Bone regenerative medicine: classic options, novel strategies, and future directions. *J Orthop Surg Res*, 9(1), p. 18.

Osório, L.A., Silva, E. and Mackay, R.E. (2021) A review of biomaterials and scaffold fabrication for organ-on-a-chip (OOAC) systems. *Bioengineering*, 8(8), pp. 1–31.

Ottenbacher, N., Alkildani, S., Korzinskas, T., Pissarek, J., Ulm, C., Jung, O., et al. (2021) Novel Histomorphometrical Approach to Evaluate the Integration Pattern and Functionality of Barrier Membranes. *Dent J (Basel)*, 9(11), pp. 1–15.

Ottria, L., Lauritano, D., Andreasi Bassi, M., Palmieri, A., Candotto, V., Tagliabue, A., et al. (2018) Mechanical, chemical and biological aspects of titanium and titanium alloys in implant dentistry. *J. Biol. Regul. Homeost. Agents*, 32(2 Suppl. 1), pp. 81–90.

Owens, K.W. and Yukna, R.A. (2001) Collagen membrane resorption in dogs: a comparative study. *Implant Dent*, 10(1), pp. 49–58.

Ozdemir, N.S., Belyaev, D., Castro, M.N., Balakin, S., Opitz, J., Wihadmadyatami, H., et al. (2024) Advances in In Vitro Blood-Air Barrier Models and the Use of Nanoparticles in COVID-19 Research. *Tissue Eng. Part B Rev.*, 30(1), pp. 82–96.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
Muh. Hidayat Syahruddin, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. Rahmi Anggraeni, S.Kep., M.Sc.; Dr. drg. Dyah
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Padiyara, P., Inoue, H. and Sprenger, M. (2018) Global Governance Mechanisms to Address Antimicrobial Resistance. *Infectious Diseases: Research and Treatment*, 11, p. 1178633718767887.

Pandele, A.M., Oprea, M., Dutu, A.A., Miculescu, F. and Voicu, S.I. (2022) A Novel Generation of Polysulfone/Crown Ether-Functionalized Reduced Graphene Oxide Membranes with Potential Applications in Hemodialysis. *Polymers*, 14(1), pp. 1–18.

Pandzic, A., Hodzic, D. and Milovanovic, A. (2019) Effect of infill type and density on tensile properties of pla material for fdm process. In: *Annals of DAAAM and Proceedings of the International DAAAM Symposium*. Danube Adria Association for Automation and Manufacturing, DAAAM, pp. 545–554.

Papapanou, P.N., Sanz, M., Buduneli, N., Dietrich, T., Feres, M., Fine, D.H., et al. (2018) Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Periodontol*, 89 Suppl 1, pp. S173–S182.

Pattamatta, M., Chapple, I. and Listl, S. (2024) The value-for money of preventing and managing periodontitis: Opportunities and challenges. *Periodontol 2000*, 2024, pp. 1–9.

Patty, D.J., 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. *J. Biomater. Sci. Polym. Ed.*, 33(8), pp. 1043–1062.

Pauksch, L., Hartmann, S., Rohnke, M., Szalay, G., Alt, V., Schnettler, R., et al. (2014) Biocompatibility of silver nanoparticles and silver ions in primary human mesenchymal stem cells and osteoblasts. *Acta Biomater*, 10(1), pp. 439–449.

Pedde, R.D., Mirani, B., Navaei, A., Styan, T., Wong, S., Mehrali, M., et al. (2017) Emerging Biofabrication Strategies for Engineering Complex Tissue Constructs. *Adv Mater.*, 29(19), pp. 1–27.

Pediaditakis, I., Kodella, K.R., Manatakis, D. V, Le, C.Y., Barthakur, S., Sorets, A., et al. (2022) A microengineered Brain-Chip to model neuroinflammation in humans. *iScience*, 25(8), pp. 1–26.

Pertuiset, J.H., Saglie, F.R., Lofthus, J., Rezende, M. and Sanz, M. (1987) Recurrent Periodontal Disease and Bacterial Presence in the Gingiva. *J Periodontol*, 58(8), pp. 553–558.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Petersen, C. and Round, J.L. (2014) Defining dysbiosis and its influence on host immunity and disease. *Cell. Microbiol*, 16(7), pp. 1024–1033.

Petersen, P.E. and Baehni, P.C. (2012) Periodontal health and global public health. *Periodontol 2000*, 60(1), pp. 7–14.

Pinnau, I. and Freeman, B.D. (1999) Formation and Modification of Polymeric Membranes: Overview. In: *Membrane Formation and Modification*. ACS Symposium Series. American Chemical Society, pp. 1–22.

Pîrjan, A. and Petroşanu, D.-M. (2013) The impact of 3D printing technology on the society and economy. *J. Inf. Syst. Oper. Manag*, 7(2), pp. 360–370.

Plamadiala, I., Croitoru, C., Pop, M.A. and Roata, I.C. (2025) Enhancing Polylactic Acid (PLA) Performance: A Review of Additives in Fused Deposition Modelling (FDM) Filaments. *Polymers*, 17(2), pp. 1–34.

Plotkin, L.I. and Bruzzaniti, A. (2019) Molecular signaling in bone cells: Regulation of cell differentiation and survival. In: DONEV, R. (ed.) *Adv Protein Chem Struct Biol*. Advances in Protein Chemistry and Structural Biology. Elsevier, pp. 237–281.

Poly-Med Inc. (2022a) *Lactoflex® 7415- 3DP Filament Datasheet*. [Online] Poly-Med, Inc. Available from: https://poly-med.com/ [Accessed 11/06/25].

Poly-Med Inc. (2022b) *Lactoprene® 100M- 3DP Filament Datasheet*. [Online] Poly-Med, Inc. Available from: https://poly-med.com/ [Accessed 10/06/25].

Pontoriero, R., Nyman, S., Lindhe, J., Rosenberg, E. and Sanavi, F. (1987) Guided tissue regeneration in the treatment of furcation defects in man. *J Clin Periodontol*, 14(10), pp. 618–620.

Pontoriero, R., Lindhe, J., Nyman, S., Karring, T., Rosenberg, E. and Sanavi, F. (1989) Guided tissue regeneration in the treatment of furcation defects in mandibular molars. *J Clin Periodontol*, 16(3), pp. 170–174.

Postlethwaite, A.E., Seyer, J.M. and Kang, A.H. (1978) Chemotactic attraction of human fibroblasts to type I, II, and III collagens and collagen-derived peptides. *Proc. Natl. Acad. Sci. U.S.A*, 75(2), pp. 871–875.

Pouroutzidou, G.K., Lazaridou, M., Papoulia, C., Tsamesidis, I., Chrissafis, K., Vourlias, G., et al. (2022) Electrospun PLGA Membranes with Incorporated Moxifloxacin-Loaded Silica-Based Mesoporous Nanocarriers for Periodontal Regeneration. *Nanomaterials*, 12(5), pp. 1–27.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Poussin, C., Kramer, B., Lanz, H.L., van den Heuvel, A., Laurent, A., Olivier, T., et al. (2020) 3D human microvessel-on-a-chip model for studying monocyte-to-endothelium adhesion under flow – application in systems toxicology. *ALTEX*, 37(1), pp. 47–63.

Prakash, B.B. (2016) 3D Printing and Its Applications. *Int. J. Sci. Res*, 5(3), pp. 1532–1535.

Purkait, M.K., Sinha, M.K., Mondal, P. and Singh, R. (2018) Introduction to Membranes. In: PURKAIT, M.K. et al. (eds.) *Stimuli Responsive Polymeric Membranes*. Interface Science and Technology. Elsevier, pp. 1–37.

Qamar Tanveer, Md., Mishra, G., Mishra, S. and Sharma, R. (2022) Effect of infill pattern and infill density on mechanical behaviour of FDM 3D printed Parts-a current review. *Mater. Today: Proc.*, 62, pp. 100–108.

Quarterman, J.C., Phruttiwanichakun, P., Fredericks, D.C. and Salem, A.K. (2022) Zoledronic Acid Implant Coating Results in Local Medullary Bone Growth. *Mol Pharm*, 19(12), pp. 4654–4664.

Qurbani, K., Khdir, K., Sidiq, A., Hamzah, H., Hussein, S., Hamad, Z., et al. (2022) Aeromonas sobria as a potential candidate for bioremediation of heavy metal from contaminated environments. *Sci Rep*, 12(1), p. 21235.

Qurbani, K., Hussein, S., Hamzah, H., Sulaiman, S., Pirot, R., Motevaseli, E., et al. (2022) Synthesis of Silver Nanoparticles by Raoultella Planticola and Their Potential Antibacterial Activity Against Multidrug-Resistant Isolates. *Iran. J. Biotechnol*, 20(4), pp. 75–83.

Raggatt, L.J. and Partridge, N.C. (2010) Cellular and Molecular Mechanisms of Bone Remodeling. *J. Biol Chem*, 285(33), pp. 25103–25108.

Rahim, T.N.A.T., Abdullah, A.M. and Akil, H.M. (2019) Recent Developments in Fused Deposition Modeling-Based 3D Printing of Polymers and Their Composites. *Polym Rev*, 59(4), pp. 589–624.

Rahyussalim, A.J., Supriadi, S., Marsetio, A.F., Pribadi, P.M. and Suharno, B. (2019) The potential of carbonate apatite as an alternative bone substitute material. *MJI*, 28(1), pp. 92–97.

Rajan, V.P. and Curtin, W.A. (2016) Micromechanical design of hierarchical composites using global load sharing theory. *J. Mech. Phys. Solids*, 90, pp. 1–17.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Rajeshkumar, S. and Bharath, L. V (2017) Mechanism of plant-mediated synthesis of silver nanoparticles – A review on biomolecules involved, characterisation and antibacterial activity. *Chem Biol Interact*, 273, pp. 219–227.

Rajpurohit, S.R. and Dave, H.K. (2021) Impact strength of 3D printed PLA using open source FFF-based 3D printer. *Prog Addit Manuf*, 6(1), pp. 119–131.

Rakhmatia, Y.D., Ayukawa, Y., Furuhashi, A. and Koyano, K. (2013) Current barrier membranes: titanium mesh and other membranes for guided bone regeneration in dental applications. *J. Prosthodont. Res*, 57(1), pp. 3–14.

Rameshbabu, N., Sampath Kumar, T.S., Prabhakar, T.G., Sastry, V.S., Murty, K.V.G.K. and Prasad Rao, K. (2007) Antibacterial nanosized silver substituted hydroxyapatite: synthesis and characterization. *J. Biomed. Mater. Res. A*, 80(3), pp. 581–591.

Ramkumar, V.S., Pugazhendhi, A., Gopalakrishnan, K., Sivagurunathan, P., Saratale, G.D., Dung, T.N.B., et al. (2017) Biofabrication and characterization of silver nanoparticles using aqueous extract of seaweed Enteromorpha compressa and its biomedical properties. *Biotechnol. Rep*, 14, pp. 1–7.

Raveau, S. and Jordana, F. (2020) Tissue engineering and three-dimensional printing in periodontal regeneration: A literature review. *J. Clin. Med*, 9(12), pp. 1–21.

dos Reis, M.Q., Carbas, R.J.C., Marques, E.A.S. and da Silva, L.F.M. (2024) Effect of the Infill Density on 3D-Printed Geometrically Graded Impact Attenuators. *Polymers*, 16(22), pp. 1–16.

Ren, Y., Fan, L., Alkildani, S., Liu, L., Emmert, S., Najman, S., et al. (2022) Barrier Membranes for Guided Bone Regeneration (GBR): A Focus on Recent Advances in Collagen Membranes. *Int J Mol Sci*, 23(23), pp. 1–33.

Resende, R.F.B., Sartoretto, S.C., Uzeda, M.J., Alves, A.T.N.N., Calasans-Maia, J.A., Rossi, A.M., et al. (2019) Randomized controlled clinical trial of nanostructured carbonated hydroxyapatite for alveolar bone repair. *Mater*, 12(22), pp. 1–13.

Retzepi, M. and Donos, N. (2010) Guided Bone Regeneration: biological principle and therapeutic applications. *Clin. Oral Implants Res*, 21(6), pp. 567–576.

Reynolds, I. and Duane, B. (2018) Periodontal disease has an impact on patients' quality of life. *EBD*, 19(1), pp. 14–15.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Riaz, M., Zia, R., Ijaz, A., Hussain, T., Mohsin, M. and Malik, A. (2018) Synthesis of monophasic Ag doped hydroxyapatite and evaluation of antibacterial activity. *Mater Sci Eng C Mater Biol Appl*, 90, pp. 308–313.

Ricard-Blum, S. (2011) The Collagen Family. *Cold Spring Harb. Perspect. Biol*, 3(1), pp. 1–19.

Richardson, L., Kim, S., Menon, R. and Han, A. (2020) Organ-On-Chip Technology: The Future of Feto-Maternal Interface Research?. *Front Physiol*, 11(715), pp. 1–18.

Robles-Águila, M.J., Reyes-Avendaño, J.A. and Mendoza, M.E. (2017) Structural analysis of metal-doped (Mn, Fe, Co, Ni, Cu, Zn) calcium hydroxyapatite synthetized by a sol-gel microwave-assisted method. *Ceram. Int*, 43(15), pp. 12705–12709.

Rodrigues, N.S., França, C.M., Tahayeri, A., Ren, Z., Saboia, V.P.A., Smith, A.J., et al. (2021) Biomaterial and Biofilm Interactions with the Pulp-Dentin Complex-on-a-Chip. *J. Dent. Res.*, 100(10), pp. 1136–1143.

Rodrigues, R.O., Shin, S.-R. and Bañobre-López, M. (2024) Brain-on-a-chip: an emerging platform for studying the nanotechnology-biology interface for neurodegenerative disorders. *J Nanobiotechnol*, 22(1), p. 573.

Romero-Araya, P., Pino, V., Nenen, A., Cárdenas, V., Pavicic, F., Ehrenfeld, P., et al. (2021) Combining Materials Obtained by 3D-Printing and Electrospinning from Commercial Polylactide Filament to Produce Biocompatible Composites. *Polymers*, 13(21), pp. 1–19.

Ronda, M., Rebaudi, A., Torelli, L. and Stacchi, C. (2014) Expanded vs. dense polytetrafluoroethylene membranes in vertical ridge augmentation around dental implants: a prospective randomized controlled clinical trial. *Clin. Oral Implants Res*, 25(7), pp. 859–866.

Rosalem, G.S., Torres, L.A.G., de Las Casas, E.B., Mathias, F.A.S., Ruiz, J.C. and Carvalho, M.G.R. (2020) Microfluidics and organ-on-a-chip technologies: A systematic review of the methods used to mimic bone marrow. *PLoS ONE*, 15(12), pp. 1–31.

Rosier, B.T., Marsh, P.D. and Mira, A. (2018) Resilience of the Oral Microbiota in Health: Mechanisms That Prevent Dysbiosis. *J Dent Res*, 97(4), pp. 371–380.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Rothamel, D., Schwarz, F., Sculean, A., Herten, M., Scherbaum, W. and Becker, J. (2004) Biocompatibility of various collagen membranes in cultures of human PDL fibroblasts and human osteoblast-like cells. *Clin. Oral Implants Res*, 15(4), pp. 443–449.

Roy, M., Fielding, G.A., Beyenal, H., Bandyopadhyay, A. and Bose, S. (2012) Mechanical, in vitro antimicrobial, and biological properties of plasma-sprayed silver-doped hydroxyapatite coating. *ACS Appl. Mater. Interfaces*, 4(3), pp. 1341–1349.

Ruckert, A., Lake, S. and Van Katwyk, S.R. (2024) Developing a protocol on antimicrobial resistance through WHO's pandemic treaty will protect lives in future pandemics. *Glob Health*, 20(1), [Online] Available from: doi.org/10.1186/s12992-024-01015-1.

Ryder, M.I., Couch, E.T. and Chaffee, B.W. (2018) Personalized periodontal treatment for the tobacco- and alcohol-using patient. *Periodontol 2000*, 78(1), pp. 30–46.

Salam, Md.A., Al-Amin, Md.Y., Salam, M.T., Pawar, J.S., Akhter, N., Rabaan, A.A., et al. (2023) Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. *Healthcare*, 11(13), pp. 1–20.

Salgado, J., Coutinho, O.P. and Reis, R.L. (2004) Bone Tissue Engineering : State of the Art and Future Trends. *Macromol. Biosci.*, 4, pp. 743–765.

Salim, S.A., Loutfy, S.A., El-Fakharany, E.M., Taha, T.H., Hussien, Y. and Kamoun, E.A. (2021) Influence of chitosan and hydroxyapatite incorporation on properties of electrospun PVA/HA nanofibrous mats for bone tissue regeneration: Nanofibers optimization and in-vitro assessment. *J. Drug Deliv. Sci. Technol*, 62, p. 102417.

Sam, G. and Pillai, B.R.M. (2014) Evolution of Barrier Membranes in Periodontal Regeneration-"Are the third Generation Membranes really here?". *J. Clin. Diagn Res*, 8(12), pp. 14–17.

Samani, S., Hossainalipour, S.M., Tamizifar, M. and Rezaie, H.R. (2013) In vitro antibacterial evaluation of sol-gel-derived Zn-, Ag-, and (Zn + Ag)-doped hydroxyapatite coatings against methicillin-resistant Staphylococcus aureus. *J Biomed Mater Res A*, 101(1), pp. 222–230.

Samiei, N. (2020) Recent trends on applications of 3D printing technology on the design and manufacture of pharmaceutical oral formulation: a mini review. *Beni-Suef Univ J Basic Appl Sci*, 9(1), pp. 1–12.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Samykano, M., Selvamani, S.K., Kadirgama, K., Ngui, W.K., Kanagaraj, G. and Sudhakar, K. (2019) Mechanical property of FDM printed ABS: influence of printing parameters. *Int J Adv Manuf Technol*, 102(9), pp. 2779–2796.

Santoso, J., Purbiati, M. and Krisnawati (2019) Antibacterial activity of silver nanoparticles on fixed retainer adhesive toward treponema denticola. *Int J Appl Pharm*, 11, pp. 198–200.

Sanz, M., Herrera, D., Kebschull, M., Chapple, I., Jepsen, S., Beglundh, T., et al. (2020) Treatment of stage I–III periodontitis—The EFP S3 level clinical practice guideline. *J Clin Periodontol*, 48(1), pp. 4–60.

Sanz, M. and Tonetti, M. (2019) Periodontitis: clinical decision tree for staging and grading -Guidance for clinicians. In: *New Classification of periodontal and peri-implant diseases and conditions*. Madrid: European Federation of Periodontology, pp. 1–9.

Sari, M., Ramadhanti, D.M., Amalina, R., Chotimah, Ana, I.D. and Yusuf, Y. (2022) Development of a hydroxyapatite nanoparticle-based gel for enamel remineralization —A physicochemical properties and cell viability assay analysis. *Dent Mater J*, 41(1), pp. 68–77.

Sartorius, B., Gray, A.P., Davis Weaver, N., Robles Aguilar, G., Swetschinski, L.R., Ikuta, K.S., et al. (2024) The burden of bacterial antimicrobial resistance in the WHO African region in 2019: a cross-country systematic analysis. *Lancet Glob. Heal*, 12(2), pp. e201–e216.

Sasaki, J., Abe, G.L., Li, A., Thongthai, P., Tsuboi, R. and Kohno, T. (2021) Barrier membranes for tissue regeneration in dentistry. *Biomater. Investig. Dent*, 8(1), pp. 54–63.

Sato, N., Handa, K., Venkataiah, V.S., Hasegawa, T., Njuguna, M.M., Yahata, Y., et al. (2020) Comparison of the vertical bone defect healing abilities of carbonate apatite, β-tricalcium phosphate, hydroxyapatite and bovine-derived heterogeneous bone. *Dent Mater J*, 39(2), pp. 309–318.

Saud, A.N., Koç, E. and Özdemir, O. (2023) Characterization and in vitro bioactivity analysis of apatite growth on modified calcium borate silicate ceramic. *Ceram Inter*, 49(16), pp. 27373–27381.

Sbricoli, L., Guazzo, R., Annunziata, M., Gobbato, L., Bressan, E. and Nastri, L. (2020) Selection of collagen membranes for bone regeneration: A literature review. *Mater*, 13(3), pp. 1–16.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Schlegel, A.K., Möhler, H., Busch, F. and Mehl, A. (1997) Preclinical and clinical studies of a collagen membrane (Bio-Gide). *Biomaterials*, 18(7), pp. 535–538.

Schneider Werner Vianna, T., Sartoretto, S.C., Neves Novellino Alves, A.T., de Brito Resende, R., de Almeida Barros Mourão, C.F., de Albuquerque Calasans-Maia, J., et al. (2020) Nanostructured Carbonated Hydroxyapatite Associated to rhBMP-2 Improves Bone Repair in Rat Calvaria. *J Funct Biomater*, 11(4), pp. 1–14.

Schroeder, J.E. and Mosheiff, R. (2011) Tissue engineering approaches for bone repair: concepts and evidence. *Injury*, 42(6), pp. 609–613.

Sebastiammal, S., Lesly Fathima, A.S., Alarifi, S., Mahboob, S., Henry, J., Kavipriya, M.R., et al. (2022) Synthesis and physicochemical characteristics of Ag-doped hydroxyapatite nanoparticles, and their potential biomedical applications. *Environ Res*, 210, p. 112979.

Sela, M.N., Babitski, E., Steinberg, D., Kohavi, D. and Rosen, G. (2009) Degradation of collagen-guided tissue regeneration membranes by proteolytic enzymes of Porphyromonas gingivalis and its inhibition by antibacterial agents. *Clin Oral Implants Res*, 20(5), pp. 496–502.

Sela, M.N. (2001) Role of Treponema Denticola in Periodontal Diseases. *Crit Rev Oral Biol Med*, 12(5), pp. 399–413.

Sheikh, Z., Najeeb, S., Khurshid, Z., Verma, V., Rashid, H. and Glogauer, M. (2015) Biodegradable materials for bone repair and tissue engineering applications. *Materials*, 8(9), pp. 5744–5794.

Sheikh, Z., Qureshi, J., Alshahrani, A.M., Nassar, H., Ikeda, Y., Glogauer, M., et al. (2017) Collagen based barrier membranes for periodontal guided bone regeneration applications. *Odontology*, 105(1), pp. 1–12.

Sheikh, Z., Hamdan, N., Ikeda, Y., Grynpas, M., Ganss, B. and Glogauer, M. (2017) Natural graft tissues and synthetic biomaterials for periodontal and alveolar bone reconstructive applications: A review. *Biomater Res*, 21(1), pp. 1–20.

Sheikh, Z., Nayak, V.V., Daood, U., Kaur, A., Moussa, H., Canteenwala, A., et al. (2024) Three-Dimensional Printing Methods for Bioceramic-Based Scaffold Fabrication for Craniomaxillofacial Bone Tissue Engineering. *J. Funct. Biomater*, 15(3), pp. 1–28.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Sheyn, D., Cohn-Yakubovich, D., Ben-David, S., De Mel, S., Chan, V., Hinojosa, C., et al. (2019) Bone-chip system to monitor osteogenic differentiation using optical imaging. *Microfluid Nanofluid*, 23(8), p. 99.

Shi, Z., Huang, X., Cai, Y., Tang, R. and Yang, D. (2009) Size effect of hydroxyapatite nanoparticles on proliferation and apoptosis of osteoblast-like cells. *Acta Biomaterialia*, 5(1), pp. 338–345.

Shibuya, N. and Jupiter, D.C. (2015) Bone Graft Substitute: Allograft and Xenograft. *Clin. Podiatr. Med. Surg*, 32(1), pp. 21–34.

Shirazi, S.F.S., Gharehkhani, S., Mehrali, M., Yarmand, H., Metselaar, H.S.C., Kadri, N.A., et al. (2015) A review on powder-based additive manufacturing for tissue engineering: selective laser sintering and inkjet 3D printing. *STAM*, 16(3), p. 33502.

Signori, R., Barbosa, A. de P., Cezar-dos-Santos, F., Carbone, A.C., Ventura, S., Nobre, B.B. de S., et al. (2024) Efficacy and Safety of Poly-l-Lactic Acid in Facial Aesthetics: A Systematic Review. *Polym.*, 16(18), pp. 1–14.

Silva, M.J. (2013) *Skeletal Aging and Osteoporosis, Biomechanics and Mechanobiology*. St. Louis: Springer Berlin Heidelberg.

Silva, R. de C., Castro, G.M. de, Oliveira, A.B. de S. and Brasil, A.C. de M. (2024) Effect of 3D-Printed Honeycomb Core on Compressive Property of Hybrid Energy Absorbers: Experimental Testing and Optimization Analysis. *Materials*, 17(2), pp. 1–31.

Simchi, A., Tamjid, E., Pishbin, F. and Boccaccini, A.R. (2011) Recent progress in inorganic and composite coatings with bactericidal capability for orthopaedic applications. *Nanomedicine*, 7(1), pp. 22–39.

Simion, M., Baldoni, M., Rossi, P. and Zaffe, D. (1994) A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. *Int J Periodontics Restorative Dent*, 14(2), pp. 166–180.

Singh, B., Dubey, A.K., Kumar, S., Saha, N., Basu, B. and Gupta, R. (2011) In vitro biocompatibility and antimicrobial activity of wet chemically prepared Ca10−xAgx(PO4)6(OH)2 (0.0≤x≤0.5) hydroxyapatites. *Mater. Sci. Eng. C*, 31(7), pp. 1320–1329.

Singh, D., Mathur, A., Arora, S., Roy, S. and Mahindroo, N. (2022) Journey of organ on a chip technology and its role in future healthcare scenario. *Appl. Surf. Sci. Adv*, 9(100246), pp. 1–9.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Siriwardane, M.L., Derosa, K., Collins, G. and Pfister, B.J. (2021) Engineering Fiber-Based Nervous Tissue Constructs for Axon Regeneration. *Cells Tissues Organs*, 210(2), pp. 105–117.

Skoog, S.A., Goering, P.L. and Narayan, R.J. (2014) Stereolithography in tissue engineering. *J Mater Sci: Mater Med*, 25(3), pp. 845–856.

Slavin, Y.N., Asnis, J., Häfeli, U.O. and Bach, H. (2017) Metal nanoparticles: understanding the mechanisms behind antibacterial activity. *J. Nanobiotechnology*, 15(1), p. 65.

Slots, J. (2017) Periodontitis: facts, fallacies and the future. *Periodontol 2000*, 75(1), pp. 7–23.

Sohn, H.-S. and Oh, J.-K. (2019) Review of bone graft and bone substitutes with an emphasis on fracture surgeries. *Biomater Res*, 23(1), p. 9.

Soldatos, N.K., Stylianou, P., Koidou, V.P., Angelov, N., Yukna, R. and Romanos, G.E. (2017) Limitations and options using resorbable versus nonresorbable membranes for successful guided bone regeneration. *Quintessence Int.*, 48(2), pp. 131–147.

Sondi, I. and Salopek-Sondi, B. (2004) Silver nanoparticles as antimicrobial agent: a case study on E. coli as a model for Gram-negative bacteria. *J Colloid Interface Sci*, 275(1), pp. 177–182.

Song, J.-C., Suwanprateeb, J., Sae-Lee, D., Sosakul, T., Pitiphat, W., Prajaneh, S., et al. (2019) 2D and 3D pore structure characterization of bi-layered porous polyethylene barrier membrane using SEM and micro-CT. *ScienceAsia*, 45(2), pp. 159 – 171.

Sosa-Hernández, J.E., Villalba-Rodríguez, A.M., Romero-Castillo, K.D., Aguilar-Aguila-Isaías, M.A., García-Reyes, I.E., Hernández-Antonio, A., et al. (2018) Organs-on-a-chip module: A review from the development and applications perspective. *Micromachines*, 9(10), pp. 1–20.

Spinell, T., Saliter, J., Hackl, B., Unger, K., Hickel, R. and Folwaczny, M. (2019) In-vitro cytocompatibility and growth factor content of GBR / GTR membranes. *Dent Mater*, 35(7), pp. 963–969.

Sprio, S., Dapporto, M., Preti, L., Mazzoni, E., Iaquinta, M.R., Martini, F., et al. (2020) Enhancement of the Biological and Mechanical Performances of Sintered Hydroxyapatite by Multiple Ions Doping. *Front. Mater.*, 7(224), pp. 1–18.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Srivastava, S.K., Foo, G.W., Aggarwal, N. and Chang, M.W. (2024) Organ-on-chip technology: Opportunities and challenges. *Biotechnology Notes*, 5, pp. 8–12.

Šromová, V., Sobola, D. and Kaspar, P. (2023) A Brief Review of Bone Cell Function and Importance. *Cells*, 12(21), pp. 1–31.

Su, X., Wang, T. and Guo, S. (2021) Applications of 3D printed bone tissue engineering scaffolds in the stem cell field. *Regen. Ther*, 16, pp. 63–72.

Sun, M., Lu, S., Zhao, P., Feng, Z., Yu, M. and Han, K. (2022) Scalable Preparation of Complete Stereo-Complexation Polylactic Acid Fiber and Its Hydrolysis Resistance. *Molecules*, 27(21), pp. 1–16.

Sun, W., Starly, B., Daly, A.C., Burdick, J.A., Groll, J., Skeldon, G., et al. (2020) The bioprinting roadmap. *Biofabrication*, 12(2), pp. 1–33.

Suresh, A.K., Pelletier, D.A., Wang, W., Morrell-Falvey, J.L., Gu, B. and Doktycz, M.J. (2012) Cytotoxicity Induced by Engineered Silver Nanocrystallites Is Dependent on Surface Coatings and Cell Types. *Langmuir*, 28(5), pp. 2727–2735.

Syahruddin, M.H., Ana, I.D., Belyaev, D., Irnawati, D., Wihadmadyatami, H., Beshchasna, N., et al. (2025) The Potential of Organ-on-a-Chip in Advancing Synthetic Extracellular Matrix Technology for Bone Tissue Engineering in Dentistry. *Biomed Rep*.

Syahruddin, M.H., Anggraeni, R. and Ana, I.D. (2023) A microfluidic organ-on-a-chip: into the next decade of bone tissue engineering applied in dentistry. *Future Sci. OA*, 9(10), pp. 1–27.

Sygnatowicz, M., Keyshar, K. and Tiwari, A. (2010) Antimicrobial properties of silver-doped hydroxyapatite nano-powders and thin films. *JOM*, 62(7), pp. 65–70.

Tajeddin, A. and Mustafaoglu, N. (2021) Design and Fabrication of Organ-on-Chips: Promises and Challenges. *Micromachines*, 12(12), pp. 1–33.

Takayanagi, H. (2018) Osteoclast Biology and Bone Resorption. In: *Primer on the Metabolic Bone Diseases and Disorders of Mineral Metabolism*. Hoboken: Wiley, pp. 46–53.

Tang, Y., Lin, Y., Ford, D.M., Qian, X., Cervellere, M.R., Millett, P.C., et al. (2021) A review on models and simulations of membrane formation via phase inversion processes. *J. Membr. Sci.*, 640, p. 119810.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Taniguchi, Y., Koyanagi, T., Takagi, T., Kitanaka, Y., Aoki, A. and Iwata, T. (2024) Ridge Preservation and Augmentation Using a Carbonated Apatite Bone Graft Substitute: A Case Series. *Dent J.*, 12(3), pp. 1–13.

Tayebi, L., Rasoulianboroujeni, M., Moharamzadeh, K., Almela, T.K.D., Cui, Z. and Ye, H. (2018) 3D-printed membrane for guided tissue regeneration. *Materials Science and Engineering C*, 84, pp. 148–158.

Teughels, W., Van Assche, N., Sliepen, I. and Quirynen, M. (2006) Effect of material characteristics and/or surface topography on biofilm development. *Clin. Oral Implants Res*, 17(S2), pp. 68–81.

The Human Microbiome Project Consortium (2012) Structure, function and diversity of the healthy human microbiome. *Nature*, 486(7402), pp. 207–214.

The Lancet (2019) *Global Burden of Disease 2019: Periodontal diseases — Level 4 cause*. [Online] Global Health Metrics. Available from : https://www.healthdata.org/results/gbd_summaries/2019/periodontal-diseases-level-4-cause [Accessed 07/11/22].

Thiam, B.G., El Magri, A., Vanaei, H.R. and Vaudreuil, S. (2022) 3D Printed and Conventional Membranes—A Review. *Polymers*, 14(5), pp. 1–16.

Thiam, B.G. and Vaudreuil, S. (2021) Review—Recent Membranes for Vanadium Redox Flow Batteries. *Journal of The Electrochemical Society*, 168(7), p. 070553.

Thian, E., Lim, P.N., Shi, Z., Tay, B.Y. and Neoh, K.G. (2011) Silver-Doped Apatite as a Bioactive and an Antimicrobial Bone Material. *Key Eng. Mater.*, 493–494, pp. 27–30.

Tijing, L.D., Dizon, J.R.C., Ibrahim, I., Nisay, A.R.N., Shon, H.K. and Advincula, R.C. (2020) 3D printing for membrane separation, desalination and water treatment. *Appl. Mater. Today*, 18, p. 100486.

Titsinides, S., Agrogiannis, G. and Karatzas, T. (2019) Bone grafting materials in dentoalveolar reconstruction: A comprehensive review. *Jpn Dent Sci Rev*, 55(1), pp. 26–32.

Toledano, M., Asady, S., Toledano-Osorio, M., García-Godoy, F., Serrera-Figallo, M.-A., Benítez-García, J.A., et al. (2020) Differential Biodegradation Kinetics of Collagen Membranes for Bone Regeneration. *Polymers*, 12(6), pp. 1–17.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Tolstunov, L., Hamrick, J.F.E., Broumand, V., Shilo, D. and Rachmiel, A. (2019) Bone Augmentation Techniques for Horizontal and Vertical Alveolar Ridge Deficiency in Oral Implantology. *Oral Maxillofac Surg Clin North Am*, 31(2), pp. 163–191.

Tonetti, M.S., Jepsen, S., Jin, L. and Otomo-Corgel, J. (2017) Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: A call for global action. *J Clin Periodontol*, 44(5), pp. 456–462.

Tonetti, M.S., Greenwell, H. and Kornman, K.S. (2018) Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. *J Periodontol*, 89 Suppl 1, pp. S159–S172.

Tonetti, M.S. and Sanz, M. (2019) Implementation of the new classification of periodontal diseases: Decision-making algorithms for clinical practice and education. *J Clin Periodontol*, 46(4), pp. 398–405.

Tosoratti, E., Fisch, P., Taylor, S., Laurent-Applegate, L.A. and Zenobi-Wong, M. (2021) 3D-Printed Reinforcement Scaffolds with Targeted Biodegradation Properties for the Tissue Engineering of Articular Cartilage. *Adv. Healthcare Mater*, 10(23), p. 2101094.

Trenfield, S.J., Madla, C.M., Basit, A.W. and Gaisford, S. (2018) The Shape of Things to Come: Emerging Applications of 3D Printing in Healthcare. In: BASIT, A.W. and GAISFORD, S. (eds.) *3D Printing of Pharmaceuticals*. Cham: Springer International Publishing, pp. 1–19.

Trobos, M., Juhlin, A., Shah, F.A., Hoffman, M., Sahlin, H. and Dahlin, C. (2018a) In vitro evaluation of barrier function against oral bacteria of dense and expanded polytetrafluoroethylene (PTFE) membranes for guided bone regeneration. *Clin Implant Dent Relat Res.*, 20(5), pp. 738–748.

Trobos, M., Juhlin, A., Shah, F.A., Hoffman, M., Sahlin, H. and Dahlin, C. (2018b) In vitro evaluation of barrier function against oral bacteria of dense and expanded polytetrafluoroethylene (PTFE) membranes for guided bone regeneration. *Clin Implant Dent Relat Res.*, 20(5), pp. 738–748.

Urban, I.A. and Monje, A. (2019) Guided Bone Regeneration in Alveolar Bone Reconstruction. *Oral Maxillofac Surg Clin North Am*, 31(2), pp. 331–338.

Uskoković, V. (2020) Ion-doped hydroxyapatite: An impasse or the road to follow? *Ceram. Int*, 46(8), pp. 11443–11465.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Uy, S.N.M.R., Deng, K., Fok, C.T.C., Fok, M.R., Pelekos, G. and Tonetti, M.S. (2022) Food intake, masticatory function, tooth mobility, loss of posterior support, and diminished quality of life are associated with more advanced periodontitis stage diagnosis. *J Clin Periodontol*, 49(3), pp. 240–250.

Vakili-Tahami, F., Adibeig, M.R. and Hassanifard, S. (2019) Optimizing creep lifetime of friction stir welded PMMA pipes subjected to combined loadings using rheological model. *Polym Test*, 79, p. 106049.

Valantin, M.-A., Aubron-Olivier, C., Ghosn, J., Laglenne, E., Pauchard, M., Schoen, H., et al. (2003) Polylactic acid implants (New-Fill)® to correct facial lipoatrophy in HIV-infected patients: results of the open-label study VEGA. *AIDS*, 17(17), pp. 2471–2477.

Vanka, S., Abul Kasem, F., Kailani, T., Wali, O. and Vanka, A. (2025) Bone graft substitutes and dental implant stability in immediate implant surgery: a systematic review and meta-analysis. *Evid Based Dent*, 26(1), pp. 1–13.

Vaz, V.M. and Kumar, L. (2021) 3D Printing as a Promising Tool in Personalized Medicine. *AAPS PharmSciTech*, 22(1), [Online] Available from: doi.org/10.1208/s12249-020-01905-8.

Venault, A., Chang, Y., Wang, D.-M. and Bouyer, D. (2013) A Review on Polymeric Membranes and Hydrogels Prepared by Vapor-Induced Phase Separation Process. *Polym Rev*, 53(4), pp. 568–626.

Ventola, C.L. (2014) Medical Applications for 3D Printing: Current and Projected Uses. *P T*, 39(10), pp. 704–711.

Ventura, R.D. (2021) An Overview of Laser-assisted Bioprinting (LAB) in Tissue Engineering Applications. *Med Lasers*, 10(2), pp. 76–81.

Vidakis, N., Petousis, M., Velidakis, E., Mountakis, N., Tzounis, L., Liebscher, M., et al. (2021) Enhanced mechanical, thermal and antimicrobial properties of additively manufactured polylactic acid with optimized nano silica content. *Nanomaterials*, 11(4), pp. 1–17.

Visentin, D., Gobin, I. and Maglica, Ž. (2023) Periodontal Pathogens and Their Links to Neuroinflammation and Neurodegeneration. *Microorganisms*, 11(7), pp. 1–26.

Vleggaar, D. (2006) Soft-Tissue Augmentation and the Role of Poly-L-Lactic Acid. *Plast. Reconst. Surg.*, 118(3S), pp. 46S-56S.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Vleggaar, D., Fitzgerald, R. and Lorenc, Z.P. (2014) The history behind the use of injectable poly-L-lactic acid for facial and nonfacial volumization: the positive impact of evolving methodology. *J Drugs Dermatol*, 13(4 Suppl), pp. s32-4.

Van Vugt, T.A.G., Geurts, J. and Arts, J.J. (2016) Clinical Application of Antimicrobial Bone Graft Substitute in Osteomyelitis Treatment: A Systematic Review of Different Bone Graft Substitutes Available in Clinical Treatment of Osteomyelitis. *Biomed Res Int.*, 2016, pp. 1–9.

Vurat, M.T., Şeker, Ş., Lalegül-Ülker, Ö., Parmaksiz, M., Elçin, A.E. and Elçin, Y.M. (2022) Development of a multicellular 3D-bioprinted microtissue model of human periodontal ligament-alveolar bone biointerface: Towards a pre-clinical model of periodontal diseases and personalized periodontal tissue engineering. *Genes Dis*, 9(4), pp. 1008–1023.

Wang, C., Huang, W., Zhou, Y., He, L., He, Z., Chen, Z., et al. (2020) 3D printing of bone tissue engineering scaffolds. *Bioact Mater*, 5(1), pp. 82–91.

Wang, D., Zhou, X., Cao, H., Zhang, H., Wang, Daping, Guo, J., et al. (2023) Barrier membranes for periodontal guided bone regeneration: a potential therapeutic strategy. *Front. Mater*, 10, pp. 1–21.

Wang, H.L. and Carroll, M.J. (2001) Guided bone regeneration using bone grafts and collagen membranes. *Quintessence Int*, 32(7), pp. 504–515.

Wang, J., Qiao, P., Dong, L., Li, F., Xu, T. and Xie, Q. (2014) Microencapsulated rBMMSCs/calcium phosphate cement for bone formation in vivo. *Biomed Mater Eng*, 24(1), pp. 835–843.

Wang, M., Zhang, X., Li, Y. and Mo, A. (2021) Lateral ridge augmentation with guided bone regeneration using particulate bone substitutes and injectable platelet-rich fibrin in a digital workflow: 6 month results of a prospective cohort study based on cone-beam computed tomography data. *Materials*, 14(21), pp. 1–11.

Wang, R.R. and Fenton, A. (1996) Titanium for prosthodontic applications: a review of the literature. *Quintessence Int*, 27(6), pp. 401–408.

Wang, S., Chen, X., Han, X., Hong, X., Li, X., Zhang, H., et al. (2023) A Review of 3D Printing Technology in Pharmaceutics: Technology and Applications, Now and Future. *Pharmaceutics*, 15(2), pp. 1–29.

Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane
for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
Muh. Hidayat Syahruddin, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. Rahmi Anggraeni, S.Kep., M.Sc.; Dr. drg. Dyah
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Wang, X., Huang, L., Li, Y., Wang, Y., Lu, X., Wei, Z., et al. (2024) Research progress in polylactic acid processing for 3D printing. *J. Manuf. Process.*, 112, pp. 161–178.

Wang, Yuyang, Wang, Yinbao, Fan, L. and Yu, Y. (2025) The Burden of Severe Periodontitis in China From 1990 to 2021, With Projections to 2050: A Comprehensive Analysis From The Global Burden of Disease Study 2021. *Int. Dent. J.*, 75(1), pp. 32–44.

Weir, N., Stevens, B., Wagner, S., Miles, A., Ball, G., Howard, C., et al. (2022) Aligned Poly-l-lactic Acid Nanofibers Induce Self-Assembly of Primary Cortical Neurons into 3D Cell Clusters. *ACS Biomater Sci Eng*, 8(2), pp. 765–776.

White, P.C., Hirschfeld, J., Milward, M.R., Cooper, P.R., Wright, H.J., Matthews, J.B., et al. (2018) Cigarette smoke modifies neutrophil chemotaxis, neutrophil extracellular trap formation and inflammatory response-related gene expression. *J Periodont Res*, 53(4), pp. 525–535.

Wilcock, C.J., Stafford, G.P., Miller, C.A., Ryabenkova, Y., Fatima, M., Gentile, P., et al. (2017) Preparation and Antibacterial Properties of Silver-Doped Nanoscale Hydroxyapatite Pastes for Bone Repair and Augmentation. *J Biomed Nanotechnol*, 13(9), pp. 1168–1176.

Wiria, F.E., Chua, C.K., Leong, K.F., Quah, Z.Y., Chandrasekaran, M. and Lee, M.W. (2008) Improved biocomposite development of poly(vinyl alcohol) and hydroxyapatite for tissue engineering scaffold fabrication using selective laser sintering. *J Mater Sci: Mater Med*, 19(3), pp. 989–996.

World Economic Forum (2016) *Top 10 Emerging Technologies of 2016*. [Online] Global Agenda. Available from : https://www.weforum.org/reports/top-10-emerging-technologies-of-2016 [Accessed 01/08/23].

World Health Organization (2022) *Global oral health status report: towards universal health coverage for oral health by 2030*. Geneva.

World Health Organization (2023) *Global Oral Health Status Report : Towards Universal Health Coverage for Oral Health by 2030. Regional Summary of the South-East Asia Region*. Geneva: World Health Organization.

Wu, J., Peters, B.A., Dominianni, C., Zhang, Y., Pei, Z., Yang, L., et al. (2016) Cigarette smoking and the oral microbiome in a large study of American adults. *ISME J*, 10(10), pp. 2435–2446.

UNIVERSITAS GADJAH MADA
Development of Silver Ion-doped Carbonated Hydroxyapatite-Based Three-Dimensional Printing Membrane for Periodontal Tissue Regeneration (In Vitro Study and Preliminary Study using Organ-on-a-chip Prototype)
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Wu, Q., Liu, J., Wang, X., Feng, L., Wu, J., Zhu, X., et al. (2020) Organ-on-a-chip: Recent breakthroughs and future prospects. *Biomed. Eng. Online*, 19(1), pp. 1–19.

Wu, Y., Lyu, D., Chen, L., Ren, H. and Yan, Y. (2023) High-strength/high-modulus polyvinyl alcohol fiber reinforced poly(amino acid)/hydroxyapatite composite for load-bearing orthopedics applications. *Polym Compos*, 44(4), pp. 2379–2395.

Xu, H., Qian, Y., Jia, S., Shi, Z. and Zhong, Q. (2023) Comparative analysis of subgingival microbiota in patients with mild, moderate, and severe chronic periodontitis. *Oral Dis*, 29(7), pp. 2865–2877.

Xu, X.Y., Li, X., Wang, J., He, X.T., Sun, H.H. and Chen, F.M. (2019) Concise Review: Periodontal Tissue Regeneration Using Stem Cells: Strategies and Translational Considerations. *Stem Cells Transl. Med.*, 8(4), pp. 392–403.

Yadav, P., Sahai, A. and Sharma, R.S. (2021) Strength and Surface Characteristics of FDM-Based 3D Printed PLA Parts for Multiple Infill Design Patterns. *J. Inst. Eng. India Ser. C*, 102(1), pp. 197–207.

Yang, D., Guo, L. and Fan, C. (2024) Mechanical Behavior of 3D-Printed Thickness Gradient Honeycomb Structures. *Materials*, 17(12), pp. 1-22.

Yang, Y., Yang, S., Wang, Y., Yu, Z., Ao, H., Zhang, H., et al. (2016) Anti-infective efficacy, cytocompatibility and biocompatibility of a 3D-printed osteoconductive composite scaffold functionalized with quaternized chitosan. *Acta Biomaterialia*, 46, pp. 112–128.

Yang, Z., Wu, C., Shi, H., Luo, X., Sun, H., Wang, Q., et al. (2022) Advances in Barrier Membranes for Guided Bone Regeneration Techniques. *Front. Bioeng. Biotechnol.*, 10(June), pp. 1–19.

Yin, I.X., Zhang, J., Zhao, I.S., Mei, M.L., Li, Q. and Chu, C.H. (2020) The antibacterial mechanism of silver nanoparticles and its application in dentistry. *Int J Nanomedicine*, 15, pp. 2555–2562.

Yin, N., Liu, Q., Liu, J., He, B., Cui, L., Li, Z., et al. (2013) Silver Nanoparticle Exposure Attenuates the Viability of Rat Cerebellum Granule Cells through Apoptosis Coupled to Oxidative Stress. *Small*, 9(9–10), pp. 1831–1841.

Yoong, W.S. and Ismail, W.N.W. (2020) Synthesis and characterization of water-soluble polyvinyl alcohol/pomegranate peel powder films. *Biointerface Res. Appl. Chem*, 10(3), pp. 5484–5489.

UNIVERSITAS GADJAH MADA
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Yotsova, R. and Peev, S. (2024) Biological Properties and Medical Applications of Carbonate Apatite: A Systematic Review. *Pharmaceutics*, 16(2), pp. 2–19.

Yuan, Q., Zhou, C., Xie, J., Zhang, D., Zheng, L., Li, Y., et al. (2021) Subgingival Microbes - From Healthy Microflora to Disease. In: ZHOU, X. and LI, Y. (eds.) *Atlas of Oral Microbiology*. Singapore: Springer Singapore, p. 144.

Yulianto, H.D.K., Rinastiti, M., Cune, M.S., de Haan-Visser, W., Atema-Smit, J., Busscher, H.J., et al. (2019) Biofilm composition and composite degradation during intra-oral wear. *Dent. Mater.*, 35(5), pp. 740–750.

Yulianto, H.D.K. and Rinastiti, M. (2014) Contact Angle Measurement of Dental Restorative Materials By Drop Profile Image Analysis. *Jurnal Teknosains*, 3(2), pp. 112–119.

Zaura, E. and Ten Cate, J.M. (2015) Towards understanding oral health. *Caries Res*, 49(suppl 1), pp. 55–61.

Zeng, H., Chan, Y., Gao, W., Leung, W.K. and Watt, R.M. (2021) Diversity of Treponema denticola and Other Oral Treponeme Lineages in Subjects with Periodontitis and Gingivitis. *Microbiol Spectr*, 9(2), pp. 1–16.

Zhang, B., Wang, L., Song, P., Pei, X., Sun, H., Wu, L., et al. (2021) 3D printed bone tissue regenerative PLA/HA scaffolds with comprehensive performance optimizations. *Mater Des*, 201, p. 109490.

Zhang, F., Zhang, W. Bin, Shi, Z., Wang, D., Jin, J. and Jiang, L. (2013) Nanowire-haired inorganic membranes with superhydrophilicity and underwater ultralow adhesive superoleophobicity for high-efficiency oil/water separation. *Adv Mater*, 25(30), pp. 4192–4198.

Zhang, K.-R., Gao, H.-L., Pan, X.-F., Zhou, P., Xing, X., Xu, R., et al. (2019) Multifunctional Bilayer Nanocomposite Guided Bone Regeneration Membrane. *Matter*, 1(3), pp. 770–781.

Zhang, S., Zhao, Y., Lalsiamthara, J., Peng, Y., Qi, L., Deng, S., et al. (2024). Current research progress on Prevotella intermedia and associated diseases. *Crit Rev Microbiol*, pp. 1-18.

Zhang, S., Xue, S., Wang, Y., Zhang, G., Arif, N., Li, P., et al. (2023) Three-Dimensional Printing, an Emerging Advanced Technique in Electrochemical Energy Storage and Conversion. *Batteries*, 9(11), pp. 1–17.

UNIVERSITAS GADJAH MADA
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Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Zhang, X.-F., Shen, W. and Gurunathan, S. (2016) Silver Nanoparticle-Mediated Cellular Responses in Various Cell Lines: An in Vitro Model. *Int J Mol Sci*, 17(10), pp. 1–26.

Zhang, Yi, Zhang, Yan, Chen, M., Yan, J., Ye, Z., Zhou, Y., et al. (2012) Surface properties of amino-functionalized poly(ε-caprolactone) membranes and the improvement of human mesenchymal stem cell behavior. *J. Colloid Interface Sci.*, 368(1), pp. 64–69.

Zhao, R., Yang, R., Cooper, P.R., Khurshid, Z., Shavandi, A. and Ratnayake, J. (2021) Bone grafts and substitutes in dentistry: A review of current trends and developments. *Molecules*, 26(10), pp. 1–27.

Zhao, Y., Wang, E.Y., Lai, F.B.L., Cheung, K. and Radisic, M. (2023) Organs-on-a-chip: a union of tissue engineering and microfabrication. *Trends Biotechnol*, 41(3), pp. 410–424.

Zheng, W., Jiang, B., Wang, D., Zhang, W., Wang, Z. and Jiang, X. (2012) A microfluidic flow-stretch chip for investigating blood vessel biomechanics. *Lab Chip*, 12(18), pp. 3441–3450.

Zhou, L., Su, Y., Wang, Jiaqi, Wang, X., Liu, Q. and Wang, Jing (2022) Effect of Exposure Rates with Customized Versus Conventional Titanium Mesh on Guided Bone Regeneration: Systematic Review and Meta-Analysis. *J Oral Implantol*, 48(4), pp. 339–346.

Zhu, W., Ma, X., Gou, M., Mei, D., Zhang, K. and Chen, S. (2016) 3D printing of functional biomaterials for tissue engineering. *Curr Opin Biotechnol*, 40, pp. 103–112.