Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

REFERENCES

Abdelmoneim, D., Alhamdani, G.M., Paterson, T.E., Santocildes Romero, M.E., Monteiro, B.J.C., Hatton, P. V., Asencio, I.O., 2020. Bioactive and topographically-modified electrospun membranes for the creation of new bone regeneration models. Processes 8, 1–21.

Adjei, I.M., Sharma, B., Labhasetwar, V., 2014. Nanoparticles: Cellular uptake and cytotoxicity. Adv Exp Med Biol 811, 74–91.

Ahmad, A., Banat, F., Alsafar, H., Hasan, S.W., 2024. An overview of biodegradable poly (lactic acid) production from fermentative lactic acid for biomedical and bioplastic applications. Biomass Convers Biorefin.

Ahmad, T., Wani, I.A., Ahmed, J., Al-Hartomy, O.A., 2014. Effect of gold ion concentration on size and properties of gold nanoparticles in TritonX-100 based inverse microemulsions. Appl. Nanosci. 4, 491–498.

Aimanianda, V., Haensler, J., Lacroix-Desmazes, S., Kaveri, S. V., Bayry, J., 2009. Novel cellular and molecular mechanisms of induction of immune responses by aluminum adjuvants. Trends Pharmacol Sci 30, 287–295.

Al-Azzam, N., Alazzam, A., 2022. Micropatterning of cells via adjusting surface wettability using plasma treatment and graphene oxide deposition. PLoS One 17.

Al-Gebory, L., Mengüç, M.P., 2018. The effect of pH on particle agglomeration and optical properties of nanoparticle suspensions. J Quant Spectrosc Radiat Transf 219, 46–60.

Aliyu, M., Zohora, F.T., Anka, A.U., Ali, K., Maleknia, S., Saffarioun, M., Azizi, G., 2022. Interleukin-6 cytokine: An overview of the immune regulation, immune dysregulation, and therapeutic approach. Int Immunopharmacol 111.

Amsar, R.M., Wijaya, C.H., Ana, I.D., Hidajah, A.C., Notobroto, H.B., Kencana Wungu, T.D., Barlian, A., 2022. Extracellular vesicles: a promising cell-free therapy for cartilage repair. Future Sci OA 8, 1–13.

Ana, I.D., Barlian, A., Hidajah, A.C., Wijaya, C.H., Notobroto, H.B., Kencana Wungu, T.D., 2021. Challenges and strategy in treatment with exosomes for cell-free-based tissue engineering in dentistry. Future Sci OA 7, 1–21.

Andiani, D., Tuti, R.W., Satispi, E., 2023. Public Trust Analysis of Vaccination Covid-19 Policy in Indonesia. KnE Social Sciences.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Anggraeni, R., Ana, I.D., Agustina, D., Martien, R., 2022a. Induction of protein specific antibody by carbonated hydroxy apatite as a candidate for mucosal vaccine adjuvant. Dent Mater J 41, 710–723.

Anggraeni, R., Ana, I.D., Wihadmadyatami, H., 2022b. Development of mucosal vaccine delivery: an overview on the mucosal vaccines and their adjuvants. Clin Exp Vaccine Res 11, 235–248.

Anggraeni, R., Martien, R., Agustina, D., Ana, I.D., 2018. Incorporation of ovalbumin into carbonate apatite as a candidate for protein delivery. Key Eng Mater 782, 27–31.

Apostólico, J.D.S., Alves, V., Lunardelli, S., Coirada, F.C., Boscardin, S.B., Rosa, D.S., 2016. Adjuvants: Classification, Modus Operandi, and Licensing Juliana. J Immunol Res 2016, 1–16.

Arcos Rosero, W.A., Bueno Barbezan, A., Daruich de Souza, C., Chuery Martins Rostelato, M.E., 2024. Review of Advances in Coating and Functionalization of Gold Nanoparticles: From Theory to Biomedical Application. Pharmaceutics 16.

Augustine, R., Hasan, A., Primavera, R., Wilson, R.J., Thakor, A.S., Kevadiya, B.D., 2020. Cellular uptake and retention of nanoparticles: Insights on particle properties and interaction with cellular components. Mater Today Commun.

Ayukawa, Y., Suzuki, Y., Tsuru, K., Koyano, K., Ishikawa, K., 2015. Histological Comparison in Rats between Carbonate Apatite Fabricated from Gypsum and Sintered Hydroxyapatite on Bone Remodeling. Biomed Res Int 2015, 1–8.

Azegami, T., Yuki, Y., Kiyono, H., 2014. Challenges in mucosal vaccines for the control of infectious diseases. Int Immunol 26, 517–528.

Bacardí, D., Cosme, K., Aldana, L., Merino, N., Suárez, J., Mosqueda, O., Urquiza, D., Romero, J., Madrigal, R., Amaya, R., Hernández, L., 2013. Preclinical safety testing of the Quimi-Hib® vaccine adjuvanted with aluminum phosphate during product development. Biotecnol Apl 30, 118–124.

Bachman, H., Nicosia, J., Dysart, M., Barker, T.H., 2015. Utilizing Fibronectin Integrin-Binding Specificity to Control Cellular Responses. Adv Wound Care (New Rochelle) 4, 501–511.

Badran, G., Angrand, L., Masson, J.D., Crépeaux, G., David, M.O., 2022. Physico-chemical properties of aluminum adjuvants in vaccines: Implications for toxicological evaluation. Vaccine 40, 4881–4888.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Bain, C.C., Scott, C.L., Uronen-Hansson, H., Gudjonsson, S., Jansson, O., Grip, O., Guilliams, M., Malissen, B., Agace, W.W., Mowat, A.M.I., 2013. Resident and pro-inflammatory macrophages in the colon represent alternative context-dependent fates of the same Ly6C hi monocyte precursors. Mucosal Immunol 6, 498–510.

Banerjee, A., Qi, J., Gogoi, R., Wong, J., Mitragotri, S., 2016. Role of nanoparticle size, shape and surface chemistry in oral drug delivery. Journal of Controlled Release 238, 176–185.

Bannunah, A.M., Vllasaliu, D., Lord, J., Stolnik, S., 2014. Mechanisms of nanoparticle internalization and transport across an intestinal epithelial cell model: Effect of size and surface charge. Mol Pharm 11, 4363–4373.

Barzgar Torghabeh, A., Barzgar Torghabeh, I., Kafaee Razavi, M., 2024. 3D Printed PLA Porous Scaffolds with Engineered Cell Size and Porosity Promote the Effectiveness of the Kelvin Model for Bone Tissue Engineering. Macromol Mater Eng.

Bashyal, S., Seo, J.E., Keum, T., Noh, G., Choi, Y.W., Lee, S., 2018. Facilitated permeation of insulin across TR146 cells by cholic acid derivatives-modified elastic bilosomes. Int J Nanomedicine 13, 5173–5186.

Bastola, R., Noh, G., Keum, T., Bashyal, S., Seo, J.E., Choi, J., Oh, Y., Cho, Y.S., Lee, S., 2017. Vaccine adjuvants: smart components to boost the immune system. Arch Pharm Res 40, 1238–1248.

Behzadi, S., Serpooshan, V., Tao, W., Hamaly, M.A., Alkawareek, M.Y., Dreaden, E.C., Brown, D., Alkilany, A.M., Farokhzad, O.C., Mahmoudi, M., 2017. Cellular uptake of nanoparticles: Journey inside the cell. Chem Soc Rev 46, 4218–4244.

Beit-Yannai, E., Tabak, S., Stamer, W.D., 2018. Physical exosome:exosome interactions. J Cell Mol Med 22, 2001–2006.

Bhati, R., Nagrajan, R.K., 2012. A detailed review on oral mucosal drug delivery system. Int J Pharm Sci Res 3, 659–681.

Bierbaumer, L., Schwarze, U.Y., Gruber, R., Neuhaus, W., 2018. Cell culture models of oral mucosal barriers: A review with a focus on applications, culture conditions and barrier properties. Tissue Barriers 6.

Bobrie, A., Colombo, M., Raposo, G., Théry, C., 2011. Exosome Secretion: Molecular Mechanisms and Roles in Immune Responses. Traffic 12, 1659–1668.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Bolandi, Z., Mokhberian, N., Eftekhary, M., Sharifi, K., Soudi, S., Ghanbarian, H., Hashemi, S.M., 2020. Adipose derived mesenchymal stem cell exosomes loaded with miR-10a promote the differentiation of Th17 and Treg from naive CD4+ T cell. Life Sci 259.

Bonam, S.R., Partidos, C.D., Halmuthur, S.K.M., Muller, S., 2017. An Overview of Novel Adjuvants Designed for Improving Vaccine Efficacy. Trends Pharmacol Sci 38, 771–793.

Bonsergent, E., Grisard, E., Buchrieser, J., Schwartz, O., Théry, C., Lavieu, G., 2021. Quantitative characterization of extracellular vesicle uptake and content delivery within mammalian cells. Nat Commun 12.

Bortolotti, P., Faure, E., Kipnis, E., 2018. Inflammasomes in tissue damages and immune disorders after trauma. Front Immunol 9.

Burgess, M., Wicks, K., Gardasevic, M., Mace, K.A., 2019. Cx3CR1 Expression Identifies Distinct Macrophage Populations That Contribute Differentially to Inflammation and Repair. Immunohorizons 3, 262–273.

Cai, S., Wu, C., Yang, W., Liang, W., Yu, H., Liu, L., 2020. Recent advance in surface modification for regulating cell adhesion and behaviors. Nanotechnol Rev 9, 971–989.

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

Cambronero, M.R., Prado-Cohrs, D., Lopez Sanroma, M., 2017. Basic immunological concepts applied to vaccination. Vaccines 18, 49–58.

Canizales-Rodríguez, D.F., Rodriguez-Felix, F., Tapia-Hernández, J.A., Del-Toro-Sanchez, C.L., Ruiz-Cruz, S., Aubourg, S.P., Castro-Enriquez, D.D., Barreras-Urbina, C.G., Burruel-Ibarra, S.E., Pompa-Ramos, J.L., Armenta-Villegas, L., 2024. Food Grade Nanofiber of Polylactic Acid by Electrospinning: Physicochemical Characterization of Solutions and Parameters of the Technique. J Food Qual 2024.

Cao, X., Coyle, J.P., Xiong, R., Wang, Y., Heflich, R.H., Ren, B., Gwinn, W.M., Hayden, P., Rojanasakul, L., 2021. Invited review: human air-liquid-interface organotypic airway tissue models derived from primary tracheobronchial epithelial cells-overview and perspectives. In Vitro Cell Dev Biol Anim 57, 104–132.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Cao, X., Zhong, W., Guo, S., Zhang, Z., Xie, C., 2022. Low expression of miR-27b in serum exosomes of non-small cell lung cancer facilitates its progression by affecting EGFR. Open Med 17, 816–825.

Castañeda-Rodríguez, S., González-Torres, M., Ribas-Aparicio, R.M., Del Prado-Audelo, M.L., Leyva-Gómez, G., Gürer, E.S., Sharifi-Rad, J., 2023. Recent advances in modified poly (lactic acid) as tissue engineering materials. J Biol Eng 17.

Chakraborty, D., Ethiraj, K.R., Mukherjee, A., 2020. Understanding the relevance of protein corona in nanoparticle-based therapeutics and diagnostics. RSC Adv 10, 27161–27172.

Chalut, K.J., Paluch, E.K., 2016. The Actin Cortex: A Bridge between Cell Shape and Function. Dev Cell 38, 571–573.

Chang, T.-H., Wu, C.-S., Chiou, S.-H., Chang, C.-H., Liao, H.-J., 2022. Adipose-Derived Stem Cell Exosomes as a Novel Anti-Inflammatory Agent and the Current Therapeutic Targets for Rheumatoid Arthritis. Biomedicines 10, 1725.

Chasaide, C.N., Mills, K.H.G., 2020. Next-generation pertussis vaccines based on the induction of protective t cells in the respiratory tract. Vaccines 8, 1–28.

Chen, L., Yokel, R.A., Hennig, B., Toborek, M., 2008. Manufactured aluminum oxide nanoparticles decrease expression of tight junction proteins in brain vasculature. J. Neuroimmune Pharmacol 3, 286–295.

Chen, W., Patel, G.B., Yan, H., Zhang, J., 2010. Recent advances in the development of novel mucosal adjuvants and antigen delivery systems. Hum Vaccin 6, 706–714.

Chowdhury, E., 2008. Self-Assembly of DNA and Cell-Adhesive Proteins onto pH-Sensitive Inorganic Crystals for Precise and Efficient Transgene Delivery. Curr Pharm Des 14, 2212–2228.

Chowdhury, E.H., Akaike, T., 2007. High performance DNA nano-carriers of carbonate apatite: Multiple factors in regulation of particle synthesis and transfection effi ciency. Int J Nanomedicine 2, 101–106.

Choy, E., Rose-John, S., 2017. Interleukin-6 as a multifunctional regulator: Inflammation, immune response, and fibrosis. J Scleroderma Relat Disord 2, S1–S5.

Christensen, D., Bøllehuus Hansen, L., Leboux, R., Jiskoot, W., Christensen, J.P., Andersen, P., Dietrich, J., 2019. A Liposome-Based Adjuvant Containing Two

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Delivery Systems with the Ability to Induce Mucosal Immunoglobulin A Following a Parenteral Immunization. ACS Nano 13, 1116–1126.

Coffman, R.L., Sher, A., Seder, R.A., 2010. Vaccine adjuvants: Putting innate immunity to work. Immunity 33, 492–503.

Cope, A.L., Chestnutt, I.G., 2023. The implications of a cost-of-living crisis for oral health and dental care. Br Dent J 234, 501–504.

Correa, V.A., Portilho, A.I., De Gaspari, E., 2022. Vaccines, adjuvants and key factors for mucosal immune response. Immunology 167, 124–138.

Creighton, R.L., Woodrow, K.A., 2019. Microneedle-Mediated Vaccine Delivery to the Oral Mucosa. Adv Healthc Mater 8, 1–17.

Custódio, C.A., Alves, C.M., Reis, R.L., Mano, J.F., 2010. Immobilization of fibronectin in chitosan substrates improves cell adhesion and proliferation. J Tissue Eng Regen Med 4, 316–323.

da Silva, D., Kaduri, M., Poley, M., Adir, O., Krinsky, N., Shainsky-Roitman, J., Schroeder, A., 2018. Biocompatibility, biodegradation and excretion of polylactic acid (PLA) in medical implants and theranostic systems. Chem. Eng. J. 340, 9–14.

Dai, X., Dai, M., Liang, Y., Li, X., Zhao, W., 2025. Global burden and trends of oral disorders among adolescent and young adult (10–24 years old) from 1990 to 2021. BMC Oral Health 25.

Dash, M., Palaniyandi, K., Ramalingam, S., Sahabudeen, S., Raja, N.S., 2021. Exosomes isolated from two different cell lines using three different isolation techniques show variation in physical and molecular characteristics. Biochim Biophys Acta Biomembr 1863.

Davis, M.M., Bajrovic, I., Croyle, M.A., 2025. Assessment of In Vitro Models of the Human Buccal Mucosa for Vaccine and Adjuvant Development. Mol Pharm.

De Chambrun, G.P., Body-Malapel, M., Frey-Wagner, I., Djouina, M., Deknuydt, F., Atrott, K., Esquerre, N., Altare, F., Neut, C., Arrieta, M.C., Kanneganti, T.D., Rogler, G., Colombel, J.F., Cortot, A., Desreumaux, P., Vignal, C., 2014. Aluminum enhances inflammation and decreases mucosal healing in experimental colitis in mice. Mucosal Immunol 7, 589–601.

De Gregorio, E., Caproni, E., Ulmer, J.B., 2013. Vaccine adjuvants: Mode of action. Front Immunol 4, 1–6.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Deng, Z., Kalin, G.T., Shi, D., Kalinichenko, V. V., 2021. Nanoparticle delivery systems with cell-specific targeting for pulmonary diseases. Am J Respir Cell Mol Biol 64, 292–307.

Dinarello, C.A., van der Meer, J.W.M., 2013. Treating inflammation by blocking interleukin-1 in humans. Semin Immunol 25, 469–484.

Ding, Y., Luo, Q., Que, H., Wang, N., Gong, P., Gu, J., 2022. Mesenchymal Stem Cell-Derived Exosomes: A Promising Therapeutic Agent for the Treatment of Liver Diseases. Int J Mol Sci 23.

Djouina, M., Esquerre, N., Desreumaux, P., Vignal, C., Body-Malapel, M., 2016. Toxicological consequences of experimental exposure to aluminum in human intestinal epithelial cells. Food Chem. Toxicol 91, 108–116.

Donahue, N.D., Acar, H., Wilhelm, S., 2019. Concepts of nanoparticle cellular uptake, intracellular trafficking, and kinetics in nanomedicine. Adv Drug Deliv Rev 143, 68–96.

Donate, R., Monzón, M., Alemán-Domínguez, M.E., 2020. Additive manufacturing of PLA-based scaffolds intended for bone regeneration and strategies to improve their biological properties. E-Polymers 20, 571–599.

Doryab, A., Taskin, M.B., Stahlhut, P., Schröppel, A., Orak, S., Voss, C., Ahluwalia, A., Rehberg, M., Hilgendorff, A., Stöger, T., Groll, J., Schmid, O., 2021. A Bioinspired in vitro Lung Model to Study Particokinetics of Nano-/Microparticles Under Cyclic Stretch and Air-Liquid Interface Conditions. Front Bioeng Biotechnol 9.

Dotiwala, F., Upadhyay, A.K., 2023. Next Generation Mucosal Vaccine Strategy for Respiratory Pathogens. Vaccines 11.

Durand, C.P., Pauthe, E., Gand, A., 2021. Fibronectin-enriched biomaterials, biofunctionalization, and proactivity: A review. Appl. Sci. 11.

Dutzan, N., Abusleme, L., Bridgeman, H., Greenwell-Wild, T., Zangerle-Murray, T., Fife, M.E., Bouladoux, N., Linley, H., Brenchley, L., Wemyss, K., Calderon, G., Hong, B.Y., Break, T.J., Bowdish, D.M.E., Lionakis, M.S., Jones, S.A., Trinchieri, G., Diaz, P.I., Belkaid, Y., Konkel, J.E., Moutsopoulos, N.M., 2017. On-going Mechanical Damage from Mastication Drives Homeostatic Th17 Cell Responses at the Oral Barrier. Immunity 46, 133–147.

Essola, J.M., Zhang, M., Yang, H., Li, F., Xia, B., Mavoungou, J.F., Hussain, A., Huang, Y., 2024. Exosome regulation of immune response mechanism: Pros and cons in immunotherapy. Bioact Mater 32, 124–146.

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Fathi-Achachelouei, M., Knopf-Marques, H., Ribeiro da Silva, C.E., Barthès, J., Bat, E., Tezcaner, A., Vrana, N.E., 2019. Use of Nanoparticles in Tissue Engineering and Regenerative Medicine. Front Bioeng Biotechnol 7.

Feller, L., Altini, M., Khammissa, R.A.G., Chandran, R., Bouckaert, M., Lemmer, J., 2013. Oral mucosal immunity. Oral Surg Oral Med Oral Pathol Oral Radiol 116, 576–583.

Feng, P., Jia, J., Liu, M., Peng, S., Zhao, Z., Shuai, C., 2021. Degradation mechanisms and acceleration strategies of poly (lactic acid) scaffold for bone regeneration. Mater Des 210.

Feng, S., Achoute, L., Margolskee, R.F., Jiang, P., Wang, H., 2020. Lipopolysaccharide-Induced Inflammatory Cytokine Expression in Taste Organoids. Chem Senses 45, 187–194.

Feuser, P.E., Jacques, A.V., Arévalo, J.M.C., Rocha, M.E.M., dos Santos-Silva, M.C., Sayer, C., de Araújo, P.H.H., 2016. Superparamagnetic poly(methyl methacrylate) nanoparticles surface modified with folic acid presenting cell uptake mediated by endocytosis. J. Nanopart. Res. 18.

Francis, M.J., 2018. Recent Advances in Vaccine Technologies. Vet. Clin. North Am. Small Anim. Pract 48, 231–241.

Frank-Kamenetskaya, O. v., 2008. Structure, Chemistry and Synthesis of Carbonate Apatites — The Main Components of Dental and Bone Tissues, in: Minerals as Advanced Materials I. pp. 241–252.

Freire Haddad, H., Roe, E.F., Collier, J.H., 2023. Expanding opportunities to engineer mucosal vaccination with biomaterials. Biomater Sci 11, 1625–1647.

Freytag, L.C., Clements, J.D., 2015. Mucosal Adjuvants: New Developments and Challenges, in: Mucosal Immunology: Fourth Edition. Elsevier Inc., pp. 1183–1199.

Galagali, P.M., Kinikar, A.A., Kumar, V.S., 2022. Vaccine Hesitancy: Obstacles and Challenges. Curr Pediatr Rep 10, 241–248.

Gangadaran, P., Rajendran, R.L., Lee, H.W., Kalimuthu, S., Hong, C.M., Jeong, S.Y., Lee, S.W., Lee, J., Ahn, B.C., 2017. Extracellular vesicles from mesenchymal stem cells activates VEGF receptors and accelerates recovery of hindlimb ischemia. J. Contr. Release 264, 112–126.

Gao, Y., Guo, Y., 2023. Research progress in the development of natural-product-based mucosal vaccine adjuvants. Front Immunol 14.

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Gheisari, H., Karamian, E., Abdellahi, M., 2015. A novel hydroxyapatite - Hardystonite nanocomposite ceramic. Ceram Int 41, 5967–5975.

Groeger, S., Meyle, J., 2019. Oral mucosal epithelial cells. Front Immunol 10, 1–22.

Groza, Y., Jemelkova, J., Kafkova, L.R., Maly, P., Raska, M., 2022. IL-6 and its role in IgA nephropathy development. Cytokine Growth Factor Rev.

Gruber, S., Nickel, A., 2023. Toxic or not toxic? The specifications of the standard ISO 10993-5 are not explicit enough to yield comparable results in the cytotoxicity assessment of an identical medical device. Front Med Technol 5.

Gruening, M., Dawson, J.E., Voelkner, C., Neuber, S., Fricke, K., van Rienen, U., Speller, S., Helm, C.A., Barbara Nebe, J., 2021. Automatic actin filament quantification and cell shape modeling of osteoblasts on charged ti surfaces. Appl. Sci 11.

Grunenwald, Anne, Keyser, Christine, Sautereau, A.-M., Crubézy, E., Ludes, Bertrand, Drouet, Christophe, Grunenwald, A, Keyser, C, Sautereau, A., Crub ezy, E., Ludes, B, Drouet, C, 2014. Revisiting carbonate quantification in apatite (bio)minerals: a validated FTIR methodology. J Archaeol Sci 49, 134–141.

Gurung, S., Perocheau, D., Touramanidou, L., Baruteau, J., 2021. The exosome journey: from biogenesis to uptake and intracellular signalling. Cell Commun. Signal 19, 1–19.

Hamza Fares, B., Abdul Hussain Al-Tememy, H., Mohammed Baqir Al-Dhalimy, A., 2022. Evaluation of the Toxic Effects of Aluminum Hydroxide Nanoparticles as Adjuvants in Vaccinated Neonatal Mice. Arch Razi Inst 77, 221–228.

Haque, S.T., Karim, M.E., Abidin, S.A.Z., Othman, I., Holl, M.M.B., Chowdhury, E.H., 2020. Fe/Mg-modified carbonate apatite with uniform particle size and unique transport protein-related protein corona efficiently delivers doxorubicin into breast cancer cells. Nanomaterials 10, 1–23.

Hasan, A., Morshed, M., Memic, A., Hassan, S., Webster, T.J., Marei, H.E.S., 2018. Nanoparticles in tissue engineering: Applications, challenges and prospects. Int J Nanomedicine 13, 5637–5655.

Hayashi, K., Kishida, R., Tsuchiya, A., Ishikawa, K., 2019. Carbonate Apatite Micro-Honeycombed Blocks Generate Bone Marrow-Like Tissues as well as Bone. Adv Biosyst 3, 1–12.

Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

He, P., Takeshima, S.-N., Tada, S., Akaike, T., Ito, Y., Aida, Y., 2014. PH-sensitive carbonate apatite nanoparticles as DNA vaccine carriers enhance humoral and cellular immunity. Vaccine 32, 6199–6205.

He, P., Zou, Y., Hu, Z., 2015. Advances in aluminum hydroxide-based adjuvant research and its mechanism. Hum Vaccin Immunother 11, 477–488.

He, Y., Cheng, M., Yang, R., Li, H., Lu, Z., Jin, Y., Feng, J., Tu, L., 2023. Research Progress on the Mechanism of Nanoparticles Crossing the Intestinal Epithelial Cell Membrane. Pharmaceutics 15.

Hebishima, T., Tada, S., Takeshima, S. nosuke, Akaike, T., Ito, Y., Aida, Y., 2011. Induction of antigen-specific immunity by pH-sensitive carbonate apatite as a potent vaccine carrier. Biochem Biophys Res Commun 415, 597–601.

Hendarmin, L.A., Novianita, B., Anggraeni, Y., Febriyanti, K., 2024. Exploring the potential of tomato juice (Solanum lycopersicum L.) patch for tooth bleaching. J Dent Res Dent Clin Dent Prospects 18, 157–164.

Ho, Y.T., Azman, N.A., Loh, F.W.Y., Ong, G.K.T., Engudar, G., Kriz, S.A., Kah, J.C.Y., 2018. Protein Corona Formed from Different Blood Plasma Proteins Affects the Colloidal Stability of Nanoparticles Differently. Bioconjug Chem 29, 3923–3934.

HogenEsch, H., 2012. Mechanism of immunopotentiation and safety of aluminum adjuvants. Front Immunol 3.

Hogenesch, H., 2002. Mechanisms of stimulation of the immune response by aluminum adjuvants, Vaccine.

Hoogesteijn von Reitzenstein, N., Sonmez Baghirzade, B., Pruitt, E., Hristovski, K., Westerhoff, P., Apul, O.G., 2022. Comparing the morphologies and adsorption behavior of electrospun polystyrene composite fibers with 0D fullerenes, 1D multiwalled carbon nanotubes and 2D graphene oxides. Chem. Eng. J. Adv 9.

Hossain, S.M., Chowdhury, E.H., 2018. Citrate- and succinate-modified carbonate apatite nanoparticles with loaded doxorubicin exhibit potent anticancer activity against breast cancer cells. Pharmaceutics 10, 1–26.

Hossain, S.M., Shetty, J., Tha, K.K., Chowdhury, E.H., 2019. α-ketoglutaric acid-modified carbonate apatite enhances cellular uptake and cytotoxicity of a raf-kinase inhibitor in breast cancer cells through inhibition of MAPK and PI-3 kinase pathways. Biomedicines 7, 1–23.

Hovav, A.H., 2014. Dendritic cells of the oral mucosa. Mucosal Immunol 7, 27–37.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Hua, S., 2019. Advances in nanoparticulate drug delivery approaches for sublingual and buccal administration. Front Pharmacol 10, 1–9.

Huang, C.B., Alimova, Y., Ebersole, J.L., 2016. Macrophage polarization in response to oral commensals and pathogens. Pathog Dis 74.

Huang, M., Wang, W., 2014. Factors affecting alum-protein interactions. Int J Pharm 466, 139–146.

Ibrahim, H.M., Mohammed, G.M., Sayed, R.H., Elshoky, H.A., Ahmed, M.M., El Sayed, M.F., Elsaady, S.A., 2024. Polymeric nanocarrier-based adjuvants to enhance a locally produced mucosal coryza vaccine in chicken. Sci Rep 14.

Ibrahim, W.N., Rosli, L.M.B.M., Doolaanea, A.A., 2020. Formulation, cellular uptake and cytotoxicity of thymoquinone-loaded plga nanoparticles in malignant melanoma cancer cells. Int J Nanomedicine 15, 8059–8074.

Idrees, H., Zaidi, S.Z.J., Sabir, A., Khan, R.U., Zhang, X., Hassan, S.-U., 2020. A review of biodegradable natural polymer-based nanoparticles for drug delivery applications. Nanomaterials 10, 1–22.

Isaac, R., Reis, F.C.G., Ying, W., Olefsky, J.M., 2021. Exosomes as mediators of intercellular crosstalk in metabolism. Cell Metab 33, 1744–1762.

Ishikawa, K., 2010. Bone substitute fabrication based on dissolution-precipitation reactions. Materials 3, 1138–1155.

Ishikawa, K., Hayashi, K., 2021. Carbonate apatite artificial bone. Sci Technol Adv Mater 22, 683–694.

Ishikawa, K., Miyamoto, Y., Tsuchiya, A., Hayashi, K., Tsuru, K., Ohe, G., 2018. Physical and histological comparison of hydroxyapatite, carbonate apatite, and β-tricalcium phosphate bone substitutes. Materials 11, 1–12.

Ishikawa, K., Munar, M.L., Tsuru, K., Miyamoto, Y., 2019. Fabrication of carbonate apatite honeycomb and its tissue response. J Biomed Mater Res A 107, 1014–1020.

Islam, R.A., Al-Busaidi, H., Zaman, R., Abidin, S.A.Z., Othman, I., Chowdhury, E.H., 2020. Carbonate apatite and hydroxyapatite formulated with minimal ingredients to deliver SiRNA into breast cancer cells in vitro and in vivo. J Funct Biomater 11, 1–28.

Islam, S.A., Luster, A.D., 2012. T cell homing to epithelial barriers in allergic disease. Nat Med 18, 705–715.

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Iyire, A., Alayedi, M., Mohammed, A.R., 2016. Pre-formulation and systematic evaluation of amino acid assisted permeability of insulin across in vitro buccal cell layers. Sci Rep 6.

Jahangir, A., Rumi, T., Khan, E.I., Jahangir, M.A., Rumi, T.M., Wahab, A., Rahman, M.A., Sayed, Z. Bin, 2017. Poly Lactic Acid (PLA) Fibres: Different Solvent Systems and Their Effect on Fibre Morphology and Diameter. American Journal of Chemistry 2017, 177–186.

Jain, P., Rimal, R., Möller, M., Singh, S., 2023. Topographical influence of electrospun basement membrane mimics on formation of cellular monolayer. Sci Rep 13.

Jana, N.R., 2019. Colloidal Nanoparticles: Functionalization for Biomedical Applications, 1st ed. Taylor & Francis Group, Boca Raton.

Jayasree, R., Madhumathi, K., Rana, D., Ramalingam, M., Nankar, R.P., Doble, M., Kumar, T.S.S., 2017. Development of Egg Shell Derived Carbonated Apatite Nanocarrier System for Drug Delivery. J Nanosci Nanotechnol 18, 2318–2324.

Jazayeri, S.D., Lim, H.X., Shameli, K., Yeap, S.K., Poh, C.L., 2021. Nano and Microparticles as Potential Oral Vaccine Carriers and Adjuvants Against Infectious Diseases. Front Pharmacol 12, 1–15.

Jiménez-Pérez, A., Martínez-Alonso, M., García-Tojal, J., 2024. Hybrid Hydroxyapatite–Metal Complex Materials Derived from Amino Acids and Nucleobases. Molecules 29.

John, D.A., Roy, A., 2019. Nanoparticles for Oral Transmucosal Drug Delivery – A Review. J. Pharm. Sci. Res 11, 3712–3716.

Jully, V., Mathot, F., Moniotte, N., Préat, V., Lemoine, D., 2016. Mechanisms of Antigen Adsorption onto an Aluminum-Hydroxide Adjuvant Evaluated by High-Throughput Screening. J Pharm Sci 105, 1829–1836.

Jung, M.K., Mun, J.Y., 2018. Sample preparation and imaging of exosomes by transmission electron microscopy. J. Vis. Exp 2018.

K. Garg, N., Mangal, S., Khambete, H., K. Sharma, P., K. Tyagi, R., 2010. Mucosal Delivery of Vaccines: Role of Mucoadhesive/Biodegradable Polymers. Recent Pat Drug Deliv Formul 4, 114–128.

Kanchanapally, R., Khan, M.A., Deshmukh, S.K., Srivastava, S.K., Khushman, M., Singh, S., Singh, A.P., 2020. Exosomal formulation escalates cellular uptake

Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

of honokiol leading to the enhancement of its antitumor efficacy. ACS Omega 5, 23299–23307.

Karabulut, H., Unal, S., Ulag, S., Ficai, A., Ficai, D., Gunduz, O., 2024. Mapping the Influence of Solvent Composition over the Characteristics of Polylactic Acid Nanofibers Fabricated by Electrospinning. ChemistrySelect 9.

Karamanidou, T., Tsouknidas, A., 2022. Plant-derived extracellular vesicles as therapeutic nanocarriers. Int J Mol Sci 23, 1–14.

Khan, Z., Combadière, C., Authier, F.J., Itier, V., Lux, F., Exley, C., Mahrouf-Yorgov, M., Decrouy, X., Moretto, P., Tillement, O., Gherardi, R.K., Cadusseau, J., 2013. Slow CCL2-dependent translocation of biopersistent particles from muscle to brain. BMC Med 11.

Kim, C.G., Lee, J.C., Ju, D. Bin, Kim, S.K., Yun, C.H., Cho, C.S., 2023. Enhancement of Immune Responses Elicited by Nanovaccines through a Cross-Presentation Pathway. Tissue Eng Regen Med.

Kim, D., Kim, Y.G., Seo, S.U., Kim, D.J., Kamada, N., Prescott, D., Philpott, D.J., Rosenstiel, P., Inohara, N., Núñez, G., 2016. Nod2-mediated recognition of the microbiota is critical for mucosal adjuvant activity of cholera toxin. Nat Med 22, 524–530.

Kim, J.Y., Rosenberger, M.G., Chen, S., Ip, C.K., Bahmani, A., Chen, Q., Shen, J., Tang, Y., Wang, A., Kenna, E., Son, M., Tay, S., Ferguson, A.L., Esser-Kahn, A.P., 2023. Discovery of New States of Immunomodulation for Vaccine Adjuvants via High Throughput Screening: Expanding Innate Responses to PRRs. ACS Cent Sci 9, 427–439.

Kim, M.C., Neal, D.M., Kamm, R.D., Asada, H.H., 2013. Dynamic Modeling of Cell Migration and Spreading Behaviors on Fibronectin Coated Planar Substrates and Micropatterned Geometries. PLoS Comput Biol 9.

Kole, G.E., Hasirci, V., Yucel, D., 2024. Development of a Tri-Layered Vascular Construct and In Vitro Evaluation of Endothelization. Macromol Biosci 24.

Komiyama, S., Miyasaka, R., Kikukawa, K., Hayman, R., 2019. Can nano-hydroxyapatite permeate the oral mucosa? A histological study using threedimensional tissue models. PLoS One 14.

Kozawa, K., Sekai, M., Ohba, K., Ito, S., Sako, H., Maruyama, T., Kakeno, M., Shirai, T., Kuromiya, K., Kamasaki, T., Kohashi, K., Tanaka, S., Ishikawa, S., Sato, N., Asano, S., Suzuki, H., Tanimura, N., Mukai, Y., Gotoh, N., Tanino, M., Natsuga, K., Soga, T., Nakamura, T., Yabuta, Y., Saitou, M., Ito, T.,

Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Matsuura, K., Tsunoda, M., Kikumori, T., Iida, T., Mizutani, Y., Miyai, Y., Kaibuchi, K., Enomoto, A., Fujita, Y., 2021. The CD44/COL17A1 pathway promotes the formation of multilayered, transformed epithelia. Curr. Biol. 31, 3086-3097.e7.

Kraan, H., Vrieling, H., Czerkinsky, C., Jiskoot, W., Kersten, G., Amorij, J.P., 2014. Buccal and sublingual vaccine delivery. J. Contr. Release 190, 580–592.

Krauss, S.R., Barbateskovic, M., Klingenberg, S.L., Djurisic, S., Petersen, S.B., Kenfelt, M., Kong, D.Z., Jakobsen, J.C., Gluud, C., 2022. Aluminium adjuvants versus placebo or no intervention in vaccine randomised clinical trials: A systematic review with meta-analysis and Trial Sequential Analysis. BMJ Open 12, 1–19.

Kuhn, D.A., Vanhecke, D., Michen, B., Blank, F., Gehr, P., Petri-Fink, A., Rothen-Rutishauser, B., 2014. Different endocytotic uptake mechanisms for nanoparticles in epithelial cells and macrophages. Beilstein J. Nanotechnol 5, 1625–1636.

Kuroda, E., Coban, C., Ishii, K.J., 2013. Particulate adjuvant and innate immunity: Past achievements, present findings, and future prospects. Int Rev Immunol 32, 209–220.

Lampe, K.J., Namba, R.M., Silverman, T.R., Bjugstad, K.B., Mahoney, M.J., 2009. Impact of lactic acid on cell proliferation and free radical-induced cell death in monolayer cultures of neural precursor cells. Biotechnol Bioeng 103, 1214–1223.

Langen, E.N., Rumampuk, J.F., Leman, M.A., 2017. Pengaruh Saliva Buatan dan Belimbing Wuluh (Averrhoa Bilimbi L.) Terhadap Kekerasan Resin Komposit Nano Hybrid, Pharmacon, Jurnal Ilmiah Farmasi-UNSRAT.

Lavelle, E.C., Ward, R.W., 2021. Mucosal vaccines — fortifying the frontiers. Nat Rev Immunol 0123456789, 1–15.

Lee, C.E., Rezaee, F., 2024. Nanoparticles and Airway Epithelial Cells: Exploring the Impacts and Methodologies in Toxicity Assessment. Int J Mol Sci 25.

Lee, W.H., Loo, C.Y., Rohanizadeh, R., 2014. A review of chemical surface modification of bioceramics: Effects on protein adsorption and cellular response. Colloids Surf B Biointerfaces 122, 823–834.

Leeuwenburgh, S.C.G., Ana, I.D., Jansen, J.A., 2010. Sodium citrate as an effective dispersant for the synthesis of inorganic-organic composites with a nanodispersed mineral phase. Acta Biomater 6, 836–844.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Lesniak, A., Salvati, A., Santos-Martinez, M.J., Radomski, M.W., Dawson, K.A., Åberg, C., 2013. Nanoparticle adhesion to the cell membrane and its effect on nanoparticle uptake efficiency. J Am Chem Soc 135, 1438–1444.

Li, D., Wu, M., 2021. Pattern recognition receptors in health and diseases. Signal Transduct Target Ther 6, 1–24.

Li, M., Wang, Y., Sun, Y., Cui, H., Zhu, S.J., Qiu, H.J., 2020. Mucosal vaccines: Strategies and challenges. Immunol Lett 217, 116–125.

Liam-Or, R., Faruqu, F.N., Walters, A., Han, S., Xu, L., Wang, J.T.W., Oberlaender, J., Sanchez-Fueyo, A., Lombardi, G., Dazzi, F., Mailaender, V., Al-Jamal, K.T., 2024. Cellular uptake and in vivo distribution of mesenchymal-stem-cell-derived extracellular vesicles are protein corona dependent. Nat Nanotechnol 19, 846–855.

Limlawan, P., Thepphanao, N., Insin, N., Vacharaksa, A., 2021. Surface-modified hydroxyapatite nanoparticle for microRNA delivery to regulate gene expression in human mandibular osteoblast cells. J. Nanopart. Res. 23, 1–15.

Lin, G.C., Leitgeb, T., Vladetic, A., Friedl, H.P., Rhodes, N., Rossi, A., Roblegg, E., Neuhaus, W., 2020. Optimization of an oral mucosa in vitro model based on cell line TR146. Tissue Barriers.

Liu, H., Zhang, M., Shi, M., Zhang, T., Lu, W., Yang, S., Cui, Q., Li, Z., 2021. Adipose-derived mesenchymal stromal cell-derived exosomes promote tendon healing by activating both SMAD1/5/9 and SMAD2/3. Stem Cell Res Ther 12.

Liu, Y., Wang, C., Wei, M., Yang, G., Yuan, L., 2021. Multifaceted Roles of Adipose Tissue-Derived Exosomes in Physiological and Pathological Conditions. Front Physiol.

Liverani, L., Killian, M.S., Boccaccini, A.R., 2019. Fibronectin functionalized electrospun fibers by using benign solvents: Best way to achieve effective functionalization. Front Bioeng Biotechnol 7.

Longstreth, J.H., Wang, K., 2024. The role of fibronectin in mediating cell migration. Am J Physiol Cell Physiol 326, C1212–C1225.

Lu, F., Boutselis, I., Borch, R.F., HogenEsch, H., 2013. Control of antigen-binding to aluminum adjuvants and the immune response with a novel phosphonate linker. Vaccine 31, 4362–4367.

Lu, F., HogenEsch, H., 2013. Kinetics of the inflammatory response following intramuscular injection of aluminum adjuvant. Vaccine 31, 3979–3986.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Lundqvist, M., Cedervall, T., 2020. Three Decades of Research about the Corona Around Nanoparticles: Lessons Learned and Where to Go Now. Small 16.

Macartney, R.A., Das, A., Imaniyyah, A.G., Fricker, A.T., Smith, A.M., Fedele, S., Roy, I., Kim, H.-W., Lee, D., Knowles, J.C., 2025. In vitro and ex vivo models of the oral mucosa as platforms for the validation of novel drug delivery systems. J Tissue Eng 16.

Madupalli, H., Pavan, B., 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, 27–35.

Manke, A., Wang, L., Rojanasakul, Y., 2013. Mechanisms of nanoparticle-induced oxidative stress and toxicity. Biomed Res Int 2013.

Martiñón, S., Cisneros, A., Villicaña, S., Hernández-Miramontes, R., Mixcoha, E., Calderón-Vargas, P., 2019. Chemical and immunological characteristics of aluminum-based, oil-water emulsion, and bacterial-origin adjuvants. J Immunol Res 2019, 1–10.

Maruta, M., Arahira, T., Tsuru, K., Matsuya, S., 2019. Characterization and thermal decomposition of synthetic carbonate apatite powders prepared using different alkali metal salts. Dent Mater J 38, 750–755.

Masson, J.D., Badran, G., Domdom, M.A., Gherardi, R.K., Mograbi, B., Authier, F.J., Crépeaux, G., 2023. Advances on the early cellular events occurring upon exposure of human macrophages to aluminum oxyhydroxide adjuvant. Sci Rep 13.

Matsuki, Y., Yanagawa, T., Sumiyoshi, H., Yasuda, J., Nakao, S., Goto, M., Shibata-Seki, T., Akaike, T., Inagaki, Y., 2021. Modification of exosomes with carbonate apatite and a glycan polymer improves transduction efficiency and target cell selectivity. Biochem Biophys Res Commun 583, 93–99.

Mazzinelli, E., Favuzzi, I., Arcovito, A., Castagnola, R., Fratocchi, G., Mordente, A., Nocca, G., 2023. Oral Mucosa Models to Evaluate Drug Permeability. Pharmaceutics 15.

McCulloh, C.J., Olson, J.K., Wang, Y., Zhou, Y., Tengberg, N.H., Deshpande, S., Besner, G.E., 2018. Treatment of experimental necrotizing enterocolitis with stem cell-derived exosomes. J Pediatr Surg 53, 1215–1220.

McKee, A.S., Munks, M.W., MacLeod, M.K.L., Fleenor, C.J., Van Rooijen, N., Kappler, J.W., Marrack, P., 2009. Alum Induces Innate Immune Responses

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

through Macrophage and Mast Cell Sensors, But These Sensors Are Not Required for Alum to Act As an Adjuvant for Specific Immunity J. Immunol. 183, 4403–4414.

McKelvey, K.J., Powell, K.L., Ashton, A.W., Morris, J.M., McCracken, S.A., 2015. Exosomes: Mechanisms of Uptake. J Circ Biomark 4.

Meghil, M.M., Cutler, C.W., 2020. Oral microbes and mucosal dendritic cells, “spark and flame” of local and distant inflammatory diseases. Int J Mol Sci 21, 1–17.

Meister, A., Blume, A., 2017. (Cryo) Transmission electron microscopy of phospholipid model membranes interacting with amphiphilic and polyphilic molecules. Polymers 9.

Mestecky, J., Strober, W., Russell, M.W., Kelsall, B.L., Cheroutre, H., Lambrecht, B.N., 2015. Mucosal immunology, 1st ed, Elsevier. Elsevier, Oxford.

Metcalfe, S., Anselmi, N., Escobar, A., Visser, M.B., Kay, J.G., 2022. Innate Phagocyte Polarization in the Oral Cavity. Front Immunol 12.

Metwally, S., Stachewicz, U., 2019. Surface potential and charges impact on cell responses on biomaterials interfaces for medical applications. Mater. Sci. Eng. C 104.

Midekessa, G., Godakumara, K., Ord, J., Viil, J., Lättekivi, F., Dissanayake, K., Kopanchuk, S., Rinken, A., Andronowska, A., Bhattacharjee, S., Rinken, T., Fazeli, A., 2020. Zeta Potential of Extracellular Vesicles: Toward Understanding the Attributes that Determine Colloidal Stability. ACS Omega 5, 16701–16710.

Mihály, J., Deák, R., Szigyártó, I.C., Bóta, A., Beke-Somfai, T., Varga, Z., 2017. Characterization of extracellular vesicles by IR spectroscopy: Fast and simple classification based on amide and C-H stretching vibrations. Biochim Biophys Acta Biomembr 1859, 459–466.

Mitchell, M.J., Billingsley, M.M., Haley, R.M., Wechsler, M.E., Peppas, N.A., Langer, R., 2021. Engineering precision nanoparticles for drug delivery. Nat Rev Drug Discov 20, 101–124.

Mobergslien, A., Sioud, M., 2014. Exosome-derived miRNAs and cellular miRNAs activate innate immunity. J Innate Immun 6, 105–110.

Mostafazadeh, samira, Emamverdizadeh, P., Abdal, K., sadat Forghani, S., 2020. A comparative study of the frequency of myofibroblasts and macrophages

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

between the oral and cutaneous squamous cell carcinoma. J Dent Res Dent Clin Dent Prospects 13, 253–257.

Moutsopoulos, N.M., Konkel, J.E., 2018. Tissue-Specific Immunity at the Oral Mucosal Barrier. Trends Immunol 39, 276–287.

Mozar, F.S., Chowdhury, E.H., 2017. Surface-modification of carbonate apatite nanoparticles enhances delivery and cytotoxicity of gemcitabine and anastrozole in breast cancer cells. Pharmaceutics 9, 1–18.

Mulder, D.J., Pooni, A., Mak, N., Hurlbut, D.J., Basta, S., Justinich, C.J., 2011. Antigen presentation and MHC class II expression by human esophageal epithelial cells: Role in eosinophilic esophagitis. Am J Pathol 178, 744–753.

Munasur, S.L., Turawa, E.B., Chikte, U.M.E., Musekiwa, A., 2020. Mechanical debridement with antibiotics in the treatment of chronic periodontitis: Effect on systemic biomarkers—A systematic review. Int J Environ Res Public Health 17, 1–19.

Muniyandi, P., Palaninathan, V., Veeranarayanan, S., Ukai, T., Maekawa, T., Hanajiri, T., Mohamed, M.S., 2020. ECM mimetic electrospun porous poly (l-lactic acid) (PLLA) scaffolds as potential substrates for cardiac tissue engineering. Polymers 12.

Muralikumar, M., Manoj Jain, S., Ganesan, H., Duttaroy, A.K., Pathak, S., Banerjee, A., 2021. Current understanding of the mesenchymal stem cell-derived exosomes in cancer and aging. Biotechnol. Rep.

Naafs, M., 2018. Oral Mucosal Immune Suppression, Tolerance and Silencing: A Mini-Review. Modern Approaches in Dentistry and Oral Health Care 1, 25–36.

Nair, V. V., Cabrera, P., Ramírez-Lecaros, C., Jara, M.O., Brayden, D.J., Morales, J.O., 2023. Buccal delivery of small molecules and biologics: Of mucoadhesive polymers, films, and nanoparticles – An update. Int J Pharm 636, 122789.

Németh, Z., Csóka, I., Semnani Jazani, R., Sipos, B., Haspel, H., Kozma, G., Kónya, Z., Dobó, D.G., 2022. Quality by Design-Driven Zeta Potential Optimisation Study of Liposomes with Charge Imparting Membrane Additives. Pharmaceutics 14.

Ness, S., Lin, S., Gordon, J.R., 2021. Regulatory Dendritic Cells, T Cell Tolerance, and Dendritic Cell Therapy for Immunologic Disease. Front Immunol.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Newsted, D., Fallahi, F., Golshani, A., Azizi, A., 2015. Advances and challenges in mucosal adjuvant technology. Vaccine 33, 2399–2405.

Nies, I., Hidalgo, K., Bondy, S.C., Campbell, A., 2020. Distinctive cellular response to aluminum based adjuvants. Environ Toxicol Pharmacol 78.

Nikapitiya, C., Jayathilaka, E.H.T.T., Edirisinghe, S.L., Rajapaksha, D.C., Wasana, W.P., Jayasinghe, J.N.C., De Zoysa, M., 2022. Isolation and Characterization of Plasma-Derived Exosomes from the Marine Fish Rock Bream (Oplegnathus fasciatus) by Two Isolation Techniques. Fishes 7.

Noe, S.M., Green, M.A., HogenEsch, H., Hem, S.L., 2010. Mechanism of immunopotentiation by aluminum-containing adjuvants elucidated by the relationship between antigen retention at the inoculation site and the immune response. Vaccine 28, 3588–3594.

Noi, I., Schlachet, I., Kumarasamy, M., Sosnik, A., 2018. Permeability of novel chitosan-g-Poly(methyl methacrylate) amphiphilic nanoparticles in a model of small intestine in vitro. Polymers 10.

Nowak, B., Wądołek, A., Mazuryk, O., Poznańska, A., Majzner, K., Majka, G., Oszajca, M., Barańska, M., Stochel, G., Marcinkiewicz, J., 2023. Investigation of the Immunogenic Properties of Ovalbumin Modified by Urban Airborne Particulate Matter. Arch Immunol Ther Exp 71.

Oliveto, S., Mancino, M., Manfrini, N., Biffo, S., 2017. Role of microRNAs in translation regulation and cancer. World J Biol Chem 8, 45–56.

Ollington, B., Colley, H.E., Murdoch, C., 2021. Immunoresponsive Tissue-Engineered Oral Mucosal Equivalents Containing Macrophages. Tissue Eng Part C Methods 27, 462–471.

Önal Acet, B., Acet, Ö., Wandrey, M., Stauber, R.H., Gül, D., Odabaşı, M., 2025. Synthesis, characterization, and exosomal corona formation of self-assembled dipeptide nanomaterials. Sci Rep 15.

Otten, K., Dragoo, J., Wang, H.C., Klein, J.R., 2003. Antigen-induced chemokine activation in mouse buccal epithelium. Biochem Biophys Res Commun 304, 36–40.

Ou, B., Yang, Y., Lv, H., Lin, X., Zhang, M., 2023. Current Progress and Challenges in the Study of Adjuvants for Oral Vaccines. BioDrugs 37, 143–180.

Oyston, P., Robinson, K., 2012. The current challenges for vaccine development. J Med Microbiol 61, 889–894.

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Ozdemir, N.S., Belyaev, D., Castro, M.N., Balakin, S., Opitz, J., Wihadmadyatami, H., Anggraeni, R., Yucel, D., Kenar, H., Beshchasna, N., Ana, I.D., Hasirci, V., 2024. Advances in In Vitro Blood-Air Barrier Models and the Use of Nanoparticles in COVID-19 Research. Tissue Eng Part B Rev 30, 82–96.

Öztürk, K., Kaplan, M., Çalış, S., 2024. Effects of nanoparticle size, shape, and zeta potential on drug delivery. Int J Pharm.

Pacheco, P., White, D., Sulchek, T., 2013. Effects of Microparticle Size and Fc Density on Macrophage Phagocytosis. PLoS One 8.

Palomar-Alonso, N., Lee, M., Kim, M., 2024. Exosomes: Membrane-associated proteins, challenges and perspectives. Biochem Biophys Rep.

Parikh, S.J., Mukome, F.N.D., Zhang, X., 2014. ATR-FTIR spectroscopic evidence for biomolecular phosphorus and carboxyl groups facilitating bacterial adhesion to iron oxides. Colloids Surf B Biointerfaces 119, 38–46.

Parisi, L., Toffoli, A., Ghezzi, B., Mozzoni, B., Lumetti, S., Macaluso, G.M., 2020. A glance on the role of fibronectin in controlling cell response at biomaterial interface. Jpn Dent Sci Rev. 56, 50–55.

Park, S.J., 2020. Protein–nanoparticle interaction: Corona formation and conformational changes in proteins on nanoparticles. Int J Nanomedicine 15, 5783–5802.

Pavel, M., Renna, M., Park, S.J., Menzies, F.M., Ricketts, T., Füllgrabe, J., Ashkenazi, A., Frake, R.A., Lombarte, A.C., Bento, C.F., Franze, K., Rubinsztein, D.C., 2018. Contact inhibition controls cell survival and proliferation via YAP/TAZ-autophagy axis. Nat Commun 9.

Pazár, B., Ea, H.-K., Narayan, S., Kolly, L., Bagnoud, N., Chobaz, V., Roger, T., Lioté, F., So, A., Busso, N., 2011. Basic Calcium Phosphate Crystals Induce Monocyte/Macrophage IL-1β Secretion through the NLRP3 Inflammasome In Vitro. J. Immunol 186, 2495–2502.

Peled, Y., Stewart, C.A., Glogauer, M., Finer, Y., 2023. The Role of Bacterial, Dentinal, Salivary, and Neutrophil Degradative Activity in Caries Pathogenesis. Dent J 11.

Petrovsky, N., 2015. Comparative Safety of Vaccine Adjuvants: A Summary of Current Evidence and Future Needs. Drug Saf 38, 1059–1074.

Pieters, I.Y., Van den Vreken, N.M.F., Declercq, H.A., Cornelissen, M.J., Verbeeck, R.M.H., 2010. Carbonated apatites obtained by the hydrolysis of monetite:

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Influence of carbonate content on adhesion and proliferation of MC3T3-E1 osteoblastic cells. Acta Biomater 6, 1561–1568.

Platkov, M., Tirosh, R., Kaufman, M., Zurgil, N., Deutsch, M., 2014. Photobleaching of fluorescein as a probe for oxidative stress in single cells. J Photochem Photobiol B 140, 306–314.

Podgórski, R., Wojasiński, M., Ciach, T., 2022. Nanofibrous materials affect the reaction of cytotoxicity assays. Sci Rep 12.

Pokrowiecki, R., Wojnarowicz, J., Zareba, T., Koltsov, I., Lojkowski, W., Tyski, S., Mielczarek, A., Zawadzki, P., 2019. Nanoparticles and human saliva: A step towards drug delivery systems for dental and craniofacial biomaterials. Int J Nanomedicine 14, 9235–9257.

Pondman, K., Le Gac, S., Kishore, U., 2023. Nanoparticle-induced immune response: Health risk versus treatment opportunity? Immunobiology 228.

Ptáček, P., 2016. Synthetic Phase with the Structure of Apatite, in: Ptáček, P. (Ed.), Apatites and Their Synthetic Analogues - Synthesis, Structure, Properties and Applications. IntechOpen, pp. 177–230.

Pu, X., Ma, S., Gao, Y., Xu, T., Chang, P., Dong, L., 2021. Mesenchymal stem cell-derived exosomes: Biological function and their therapeutic potential in radiation damage. Cells 10, 1–20.

Pulendran, B., Ahmed, R., 2011. Immunological mechanisms of vaccination. Nat Immunol 12, 509–517.

Qin, X.F., Zi, H., Zeng, X.J., 2022. Changes in the global burden of untreated dental caries from 1990 to 2019: A systematic analysis for the Global Burden of Disease study. Heliyon 8.

Raboni, S., Fumagalli, F., Ceccone, G., La Spina, R., Ponti, J., Mehn, D., Guerrini, G., Bettati, S., Mozzarelli, A., D'Acunto, M., Presciuttini, G., Cristallini, C., Gabellieri, E., Cioni, P., 2024. Conjugation to gold nanoparticles of methionine gamma-lyase, a cancer-starving enzyme. Physicochemical characterization of the nanocomplex for prospective nanomedicine applications. Int J Pharm 653.

Raïch-Regué, D., Glancy, M., Thomson, A.W., 2014. Regulatory dendritic cell therapy: From rodents to clinical application. Immunol Lett.

Rampersad, S.N., 2012. Multiple applications of alamar blue as an indicator of metabolic function and cellular health in cell viability bioassays. Sensors 12, 12347–12360.

Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Rapaka, R.R., Cross, A.S., McArthur, M.A., 2021. Using adjuvants to drive T cell responses for next-generation infectious disease vaccines. Vaccines 9, 1–19.

Ratnadewi, D., Widjaja, C.H., Barlian, A., Amsar, R.M., Ana, I.D., Hidajah, A.C., Notobroto, H.B., Wungu, T.D.K., 2023. Isolation of Native Plant-Derived Exosome-like Nanoparticles and Their Uptake by Human Cells. Hayati 30, 182–192.

Reed, S.G., Orr, M.T., Fox, C.B., 2013. Key roles of adjuvants in modern vaccines. Nat Med 19, 1597–1608.

Ren, F., Leng, Y., 2012. Carbonated apatite, Type-A or Type-B? Key Eng Mater 493–494, 293–297.

Rhee, J.H., Lee, S.E., Kim, S.Y., 2012. Mucosal vaccine adjuvants update. Clin Exp Vaccine Res 1, 50.

Ricci, C., Azimi, B., Panariello, L., Antognoli, B., Cecchini, B., Rovelli, R., Rustembek, M., Cinelli, P., Milazzo, M., Danti, S., Lazzeri, A., 2023. Assessment of Electrospun Poly(ε-caprolactone) and Poly(lactic acid) Fiber Scaffolds to Generate 3D In Vitro Models of Colorectal Adenocarcinoma: A Preliminary Study †. Int J Mol Sci 24.

Rimaniol, A.C., Gras, G., Verdier, F., Capel, F., Grigoriev, V.B., Porcheray, F., Sauzeat, E., Fournier, J.G., Clayette, P., Siegrist, C.A., Dormont, D., 2004. Aluminum hydroxide adjuvant induces macrophage differentiation towards a specialized antigen-presenting cell type. Vaccine 22, 3127–3135.

Rueckert, C., Guzmán, C.A., 2012. Vaccines: From Empirical Development to Rational Design. PLoS Pathog 8, 1–8.

Ruenraroengsak, P., Novak, P., Berhanu, D., Thorley, A.J., Valsami-Jones, E., Gorelik, J., Korchev, Y.E., Tetley, T.D., 2012. Respiratory epithelial cytotoxicity and membrane damage (holes) caused by amine-modified nanoparticles. Nanotoxicology 6, 94–108.

Sadeghi, M., Dehnavi, S., Khodadadi, A., Ghadiri, A.A., Ganji, A., Sharifat, M., Asadirad, A., 2024. Immunomodulatory features of MSC-derived exosomes decorated with DC-specific aptamer for improving sublingual immunotherapy in allergic mouse model. Stem Cell Res. Ther. 15.

Saitou, M., Gaylord, E.A., Xu, E., May, A.J., Neznanova, L., Nathan, S., Grawe, A., Chang, J., Ryan, W., Ruhl, S., Knox, S.M., Gokcumen, O., 2020. Functional Specialization of Human Salivary Glands and Origins of Proteins Intrinsic to Human Saliva. Cell Rep 33.

Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Sakulpaptong, W., Clairmonte, I.A., Blackstone, B.N., Leblebicioglu, B., Powell, H.M., 2022. 3D engineered human gingiva fabricated with electrospun collagen scaffolds provides a platform for in vitro analysis of gingival seal to abutment materials. PLoS One 17.

Sanchez-Trincado, J.L., Pelaez-Prestel, H.F., Lafuente, E.M., Reche, P.A., 2022. Human Oral Epithelial Cells Suppress T Cell Function via Prostaglandin E2 Secretion. Front Immunol 12.

Sanità, G., Carrese, B., Lamberti, A., 2020. Nanoparticle Surface Functionalization: How to Improve Biocompatibility and Cellular Internalization. Front Mol Biosci 7, 1–20.

Saptarshi, S.R., Duschl, A., Lopata, A.L., 2013. Interaction of nanoparticles with proteins: Relation to bio-reactivity of the nanoparticle. J Nanobiotechnology 11.

Sarasati, A., Jonarta, A.L., 2023. Potential targets of phytochemical immunomodulatory therapy in periodontitis immunopathogenesis: A narrative review. Saudi Dent. J 35, 920–928.

Sarasati, A., Syahruddin, M.H., Nuryanti, A., Ana, I.D., Barlian, A., Wijaya, C.H., Ratnadewi, D., Wungu, T.D.K., Takemori, H., 2023a. Plant-Derived Exosome-like Nanoparticles for Biomedical Applications and Regenerative Therapy. Biomedicines 11.

Sarasati, A., Wihadmadyatami, H., Ana, I.D., 2023b. Carbonate apatite nanoparticles: A novel nano-adjuvant for oral mucosal vaccines and immunomodulator. OpenNano 12, 1–13.

Sari, M., Hening, P., Chotimah, Ana, I.D., Yusuf, Y., 2021a. Porous structure of bioceramics carbonated hydroxyapatite-based honeycomb scaffold for bone tissue engineering. Mater Today Commun 26, 1–12.

Sari, M., Kristianto, N.A., Chotimah, Ana, I.D., Yusuf, Y., 2021b. Carbonated hydroxyapatite-based honeycomb scaffold coatings on a titanium alloy for bone implant application—physicochemical and mechanical properties analysis. Coatings 11, 1–18.

Satyavani, K., Gurudeeban, S., Ramanathan, T., Balasubramanian, T., 2012. Toxicity Study of Silver Nanoparticles Synthesized from Suaeda monoica on Hep-2 Cell Line. Avicenna J Med Biotechnol 4, 35–39.

Schijns, V., Majhen, D., Van Der Ley, P., Thakur, A., Summerfield, A., Berisio, R., Nativi, C., Fernández-Tejada, A., Álverez-Dominguez, C., Gizurarson, S.,

UNIVERSITAS GADJAH MADA
Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal Adjuvant For Trans-Buccal Delivery (In-vitro Study)
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Zamyatina, A., Molinaro, A., Rosano, C., Jakopin, Ž., Gursel, I., McClean, S., 2021. Rational vaccine design in times of emerging diseases: The critical choices of immunological correlates of protection, vaccine antigen and immunomodulation. Pharmaceutics 13, 1–29.

Schönherr, F.A., Sparber, F., Kirchner, F.R., Guiducci, E., Trautwein-Weidner, K., Gladiator, A., Sertour, N., Hetzel, U., Le, G.T.T., Pavelka, N., D'Enfert, C., Bougnoux, M.E., Corti, C.F., LeibundGut-Landmann, S., 2017. The intraspecies diversity of C. albicans triggers qualitatively and temporally distinct host responses that determine the balance between commensalism and pathogenicity. Mucosal Immunol 10, 1335–1350.

Schubert, J., Chanana, M., 2018. Coating Matters: Review on Colloidal Stability of Nanoparticles with Biocompatible Coatings in Biological Media, Living Cells and Organisms. Curr Med Chem 25, 4553–4586.

Seidu, T.A., Kutoka, P.T., Asante, D.O., Farooq, M.A., Alolga, R.N., Bo, W., 2022. Functionalization of Nanoparticulate Drug Delivery Systems and Its Influence in Cancer Therapy. Pharmaceutics 14.

Şenel, S., 2021. An overview of physical, microbiological and immune barriers of oral mucosa. Int J Mol Sci 22, 1–15.

Seo, A., Kitagawa, N., Matsuura, T., Sato, H., Inai, T., 2016. Formation of keratinocyte multilayers on filters under airlifted or submerged culture conditions in medium containing calcium, ascorbic acid, and keratinocyte growth factor. Histochem Cell Biol 146, 585–597.

Shah, T.G., Predescu, D., Predescu, S., 2019. Mesenchymal stem cells-derived extracellular vesicles in acute respiratory distress syndrome: a review of current literature and potential future treatment options. Clin Transl Med 8, 1–6.

Shahir, M., Mahmoud Hashemi, S., Asadirad, A., Varahram, M., Kazempour-Dizaji, M., Folkerts, G., Garssen, J., Adcock, I., Mortaz, E., 2020. Effect of mesenchymal stem cell-derived exosomes on the induction of mouse tolerogenic dendritic cells. J Cell Physiol 235, 7043–7055.

Shakya, A.K., Chowdhury, M.Y.E., Tao, W., Gill, H.S., 2016. Mucosal Vaccine Delivery: Current State and a Pediatric Perspective. J Control Release 240, 394–413.

Shardlow, E., Mold, M., Exley, C., 2018. Unraveling the enigma: Elucidating the relationship between the physicochemical properties of aluminium-based

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

adjuvants and their immunological mechanisms of action. Allergy Asthma Clin Immunol 14.

Shen, Y.Q., Sun, L., Wang, S.M., Zheng, X.Y., Xu, R., 2024. Exosomal integrins in tumor progression, treatment and clinical prediction (Review). Int J Oncol.

Shenoda, B.B., Ajit, S.K., 2016. Modulation of immune responses by exosomes derived from antigen-presenting cells. Clin Med Insights Pathol 2016, 1–8.

Shi, S., Zhu, H., Xia, X., Liang, Z., Ma, X., Sun, B., 2019. Vaccine adjuvants: Understanding the structure and mechanism of adjuvanticity. Vaccine 37, 3167–3178.

Shilov, S.Y., Rozhkova, Y.A., Markova, L.N., Tashkinov, M.A., Vindokurov, I. V., Silberschmidt, V. V., 2022. Biocompatibility of 3D-Printed PLA, PEEK and PETG: Adhesion of Bone Marrow and Peritoneal Lavage Cells. Polymers 14.

Shrwani, K.J., Mahallawi, W.H., Mohana, A.I., Algaissi, A., Dhayhi, N., Sharwani, N.J., Gadour, E., Aldossari, S.M., Asiri, H., Kameli, N., Asiri, A.Y., Asiri, A.M., Sherwani, A.J., Cunliffe, N., Zhang, Q., 2024. Mucosal immunity in upper and lower respiratory tract to MERS-CoV. Front Immunol 15.

Sichangi, M.W., 2020. Understanding Mechanisms of Actions for Vaccine Adjuvants Critical for Designing Effective Vaccines : A narrative review. Afr J Health Sci 33, 18–29.

Silva, G.A., Ducheyne, P., Reis, R.L., 2007. Materials in particulate form for tissue engineering. 1. Basic concepts. J Tissue Eng Regen Med 1, 4–24.

Singh, R.P., Ramarao, P., 2012. Cellular uptake, intracellular trafficking and cytotoxicity of silver nanoparticles. Toxicol Lett 213, 249–259.

Skwarczynski, M., Toth, I., 2020. Non-invasive mucosal vaccine delivery: advantages, challenges and the future. Expert Opin Drug Deliv 17, 435–437.

Song, J.-H., Kim, J.-I., Kwon, H.-J., Shim, D.-H., Parajuli, N., Cuburu, N., Czerkinsky, C., Kweon, M.-N., 2009. CCR7-CCL19/CCL21-Regulated Dendritic Cells Are Responsible for Effectiveness of Sublingual Vaccination. J. Immunol. 182, 6851–6860.

Song, P., Liu, C., Sun, M., Liu, J., Lin, P., Wang, A., Jin, Y., 2022. Oxidative Stress Induces Bovine Endometrial Epithelial Cell Damage through Mitochondria-Dependent Pathways. Animals 12.

Song, Y., Mehl, F., Zeichner, S.L., 2024. Vaccine Strategies to Elicit Mucosal Immunity. Vaccines 12.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Soni, S., O'Dea, K.P., Abe, E., Khamdan, M., Shah, S. V., Sarathchandra, P., Wilson, M.R., Takata, M., 2022. Microvesicle-Mediated Communication Within the Alveolar Space: Mechanisms of Uptake by Epithelial Cells and Alveolar Macrophages. Front Immunol 13.

Sonnaert, M., Papantoniou, I., Luyten, F.P., Schrooten, J., 2015. Quantitative Validation of the Presto Blue™ Metabolic Assay for Online Monitoring of Cell Proliferation in a 3D Perfusion Bioreactor System. Tissue Eng Part C Methods 21, 519–529.

Spreafico, R., Ricciardi-Castagnoli, P., Mortellaro, A., 2010. The controversial relationship between NLRP3, alum, danger signals and the next-generation adjuvants. Eur J Immunol.

Srinivasan, B., Kolli, A.R., Esch, M.B., Abaci, H.E., Shuler, M.L., Hickman, J.J., 2015. TEER Measurement Techniques for In Vitro Barrier Model Systems. J Lab Autom 20, 107–126.

Su, N., Hao, Y., Wang, F., Hou, W., Chen, H., Luo, Y., 2021. Mesenchymal stromal exosome-functionalized scaffolds induce innate and adaptive immunomodulatory responses toward tissue repair, Sci. Adv.

Sugiura, Y., Tsuru, K., Ishikawa, K., 2016. Fabrication of carbonate apatite pseudomorph from highly soluble acidic calcium phosphate salts through carbonation. J. Ceram. Soc. Jpn 124, 827–832.

Suharta, S., Barlian, A., Hidajah, A.C., Notobroto, H.B., Ana, I.D., Indariani, S., Wungu, T.D.K., Wijaya, C.H., 2021. Plant-derived exosome-like nanoparticles: A concise review on its extraction methods, content, bioactivities, and potential as functional food ingredient. J Food Sci 86, 2838–2850.

Summer, M., Ashraf, R., Ali, S., Bach, H., Noor, S., Noor, Q., Riaz, S., Khan, R.R.M., 2024. Inflammatory response of nanoparticles: Mechanisms, consequences, and strategies for mitigation. Chemosphere 363.

Supjaroen, P., Niamsi, W., Thirabowonkitphithan, P., Thummarati, P., Laiwattanapaisal, W., 2024. A customizable and low-cost 3D-printed transwell device coupled with 3D cell culture for permeability assay. HardwareX 20.

Swain, S.K., Sarkar, D., 2013. Study of BSA protein adsorption/release on hydroxyapatite nanoparticles. Appl Surf Sci 286, 99–103.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Tabatabaei, F., Moharamzadeh, K., Tayebi, L., 2020. Three-dimensional in vitro oral mucosa models of fungal and bacterial infections. Tissue Eng Part B Rev 26, 443–460.

Tada, R., Hidaka, A., Tanazawa, Y., Ohmi, A., Muto, S., Ogasawara, M., Saito, M., Ohshima, A., Iwase, N., Honjo, E., Kiyono, H., Kunisawa, J., Negishi, Y., 2021. Role of interleukin-6 in antigen-specific mucosal immunoglobulin A induction by cationic liposomes. Int Immunopharmacol 101.

Tada, R., Honjo, E., Muto, S., Takayama, N., Kiyono, H., Kunisawa, J., Negishi, Y., 2022. Role of Interleukin-6 in the Antigen-Specific Mucosal Immunoglobulin A Responses Induced by CpG Oligodeoxynucleotide-Loaded Cationic Liposomes. Membranes 12.

Tada, S., Chowdhury, E.H., Cho, C.S., Akaike, T., 2010. pH-sensitive carbonate apatite as an intracellular protein transporter. Biomaterials 31, 1453–1459.

Takahashi, H., Misato, K., Aoshi, T., Yamamoto, Y., Kubota, Y., Wu, X., Kuroda, E., Ishii, K.J., Yamamoto, H., Yoshioka, Y., 2018. Carbonate apatite nanoparticles act as potent vaccine adjuvant delivery vehicles by enhancing cytokine production induced by encapsulated cytosine-phosphate-guanine oligodeoxynucleotides. Front Immunol 9, 1–17.

Teubl, B.J., Stojkovic, B., Docter, D., Pritz, E., Leitinger, G., Poberaj, I., Prassl, R., Stauber, R.H., Fröhlich, E., Khinast, J.G., Roblegg, E., 2018. The effect of saliva on the fate of nanoparticles. Clin Oral Investig 22, 929–940.

Thakur, A., Foged, C., 2020. Nanoparticles for mucosal vaccine delivery, in: Nanoengineered Biomaterials for Advanced Drug Delivery. Elsevier, pp. 603–646.

Tiberio, L., Del Prete, A., Schioppa, T., Sozio, F., Bosisio, D., Sozzani, S., 2018. Chemokine and chemotactic signals in dendritic cell migration review-article. Cell Mol Immunol 15, 346–352.

Toda, T., Yoshino, S., 2016. Enhancement of ovalbumin-specific Th1, Th2, and Th17 immune responses by amorphous silica nanoparticles. Int J Immunopathol Pharmacol 29, 408–420.

Toscano, F., Torres-Arias, M., 2023. Nanoparticles cellular uptake, trafficking, activation, toxicity and in vitro evaluation. Curr. Immunol. Rev. 4.

Trincado, V., Gala, R.P., Morales, J.O., 2021. Buccal and Sublingual Vaccines: A Review on Oral Mucosal Immunization and Delivery Systems. Vaccines 9, 1–20.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Tsai, C.J.Y., Loh, J.M.S., Fujihashi, K., Kiyono, H., 2023. Mucosal vaccination: onward and upward. Expert Rev Vaccines 22, 885–899.

Uddin, M.B., Pillai, B.B., Tha, K.K., Ashaie, M., Karim, M.E., Chowdhury, E.H., 2018. Carbonate apatite nanoparticles-facilitated intracellular delivery of siRNA(s) targeting calcium ion channels efficiently kills breast cancer cells. Toxics 6, 1–18.

Upadhyay, J., Upadhyay, R.B., Agrawal, P., Jaitley, S., Shekhar, R., 2013. Langerhans cells and their role in oral mucosal diseases. N Am J Med Sci 5, 505–514.

Uribe-Querol, E., Rosales, C., 2020. Phagocytosis: Our Current Understanding of a Universal Biological Process. Front Immunol 11.

Vaernewyck, V., Arzi, B., Sanders, N.N., Cox, E., Devriendt, B., 2021. Mucosal Vaccination Against Periodontal Disease: Current Status and Opportunities. Front Immunol 12.

Vallet-Regí, M., Arcos, D., 2013. Bioceramics for drug delivery. Acta Mater 61, 890–911.

van der Koog, L., Gandek, T.B., Nagelkerke, A., 2022. Liposomes and Extracellular Vesicles as Drug Delivery Systems: A Comparison of Composition, Pharmacokinetics, and Functionalization. Adv Healthc Mater.

Vela Ramirez, J.E., Sharpe, L.A., Peppas, N.A., 2017. Current state and challenges in developing oral vaccines. Adv Drug Deliv Rev 114, 116–131.

Vrieling, H., Kooijman, S., de Ridder, J.W., Thies-Weesie, D.M.E., Soema, P.C., Jiskoot, W., van Riet, E., Heck, A.J.R., Philipse, A.P., Kersten, G.F.A., Meiring, H.D., Pennings, J.L., Metz, B., 2020. Activation of Human Monocytes by Colloidal Aluminum Salts. J Pharm Sci 109, 750–760.

Wahlund, C.J.E., Güclüler, G., Hiltbrunner, S., Veerman, R.E., Näslund, T.I., Gabrielsson, S., 2017. Exosomes from antigen-pulsed dendritic cells induce stronger antigen-specific immune responses than microvesicles in vivo. Sci Rep 7, 1–9.

Walkey, C.D., Olsen, J.B., Song, F., Liu, R., Guo, H., Olsen, D.W.H., Cohen, Y., Emili, A., Chan, W.C.W., 2014. Protein corona fingerprinting predicts the cellular interaction of gold and silver nanoparticles. ACS Nano 8, 2439–2455.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Wang, J., Zhao, Z., Wang, Q., Shi, J., Wong, D.W.C., Cheung, J.C.W., 2024. Advancements in Nanoparticle-Based Adjuvants for Enhanced Tuberculosis Vaccination: A Review. Vaccines 12.

Wang, K., Wang, M.H., Wang, Q.G., Lu, X., Zhang, X.D., 2017. Computer simulation of proteins adsorption on hydroxyapatite surfaces with calcium phosphate ions. J Eur Ceram Soc 37, 2509–2520.

Wang, K., Zhou, C., Hong, Y., Zhang, X., 2012. A review of protein adsorption on bioceramics. Interface Focus 2, 259–277.

Wang, Shaohe, Matsumoto, K., Lish, S.R., Cartagena-Rivera, A.X., Yamada, K.M., 2021. Budding epithelial morphogenesis driven by cell-matrix versus cell-cell adhesion. Cell 184, 3702-3716.e30.

Wang, Shuangqing, Zuo, A., Guo, J., 2021. Types and evaluation of in vitro penetration models for buccal mucosal delivery. J Drug Deliv Sci Technol.

Wang, X., Ding, B., Li, B., 2013. Biomimetic electrospun nanofibrous structures for tissue engineering. Materials Today 16, 229–241.

Wang, Y., Cui, Y., Zhao, Y., Zhao, Q., He, B., Zhang, Q., Wang, S., 2018. Effects of surface modification and size on oral drug delivery of mesoporous silica formulation. J Colloid Interface Sci 513, 736–747.

Wang, Y., Zhang, Y., Li, T., Shen, K., Wang, K.J., Tian, C., Hu, D., 2023. Adipose Mesenchymal Stem Cell Derived Exosomes Promote Keratinocytes and Fibroblasts Embedded in Collagen/Platelet-Rich Plasma Scaffold and Accelerate Wound Healing. Advanced Materials 35.

Wang, Z., Popowski, K.D., Zhu, D., de Juan Abad, B.L., Wang, X., Liu, M., Lutz, H., de Naeyer, N., DeMarco, C.T., Denny, T.N., Dinh, P.U.C., Li, Z., Cheng, K., 2022. Exosomes decorated with a recombinant SARS-CoV-2 receptor-binding domain as an inhalable COVID-19 vaccine. Nat Biomed Eng 6, 791–805.

Wong, L.W., Mak, S.H., Goh, B.H., Lee, W.L., 2023. The Convergence of FTIR and EVs: Emergence Strategy for Non-Invasive Cancer Markers Discovery. Diagnostics 13.

Wu, J., Ma, G., 2020. Biomimic strategies for modulating the interaction between particle adjuvants and antigen-presenting cells. Biomater Sci 8, 2366–2375.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Wu, R.Q., Zhang, D.F., Tu, E., Chen, Q.M., Chen, W., 2014. The mucosal immune system in the oral cavity-an orchestra of T cell diversity. Int J Oral Sci 6, 125–132.

Xia, Y., Li, B., Zhang, F., Wu, Q., Wen, S., Jiang, N., Liu, D., Huang, C., Liu, S., 2022. Hydroxyapatite Nanoparticles Promote Mitochondrial-Based Pyroptosis via Activating Calcium Homeostasis and Redox Imbalance in Vascular Smooth Muscle Cells. Nanotechnology 33.

Xing, Z., Afkhami, S., Bavananthasivam, J., Fritz, D.K., D'Agostino, M.R., Vaseghi-Shanjani, M., Yao, Y., Jeyanathan, M., 2020. Innate immune memory of tissue-resident macrophages and trained innate immunity: Re-vamping vaccine concept and strategies. J Leukoc Biol 108, 825–834.

Xu, T., Qingru, Z., Fu, Q., Wang, Z., Liu, X., Xiao, S., Jiang, X., Lu, Y., Gong, Z., Wu, Y., Fang, M., 2023. Fluorescence determination of 3-MCPD by combining amino silica nanoparticles with fluorescein isothiocyanate. J Anal Sci Technol 14.

Xue, S., Liu, X., Chen, S.L., Gan, W., Yuan, Q., 2019. Surface curvature-dependent adsorption and aggregation of fluorescein isothiocyanate on gold nanoparticles. Physical Chemistry Chemical Physics 21, 26598–26605.

Xue, Y., Tran, M., Diep, Y.N., Shin, S., Lee, J., Cho, H., Kang, Y.J., 2024. Environmental aluminum oxide inducing neurodegeneration in human neurovascular unit with immunity. Sci Rep 14.

Yaghoobi, N., Majidi, R.F., Faramarzi, M.A., Baharifar, H., Amani, A., 2017. Preparation, optimization and activity evaluation of PLGA/streptokinase nanoparticles using electrospray. Adv Pharm Bull 7, 131–139.

Yahata, S., Hirose, M., Ueno, T., Nagumo, H., Sakai-Kato, K., 2021. Effect of Sample Concentration on Nanoparticle Tracking Analysis of Small Extracellular Vesicles and Liposomes Mimicking the Physicochemical Properties of Exosomes. Chem. Pharm. Bull 69, 1045–1053.

Yang, K., Fu, W., Ma, Y., Wu, M., Li, X., Wang, Y., 2025. A simple capillary isoelectric focusing method as the novel strategy for the isoelectric point measurement of exosomes and its application in disease diagnosis. Microchimica Acta 192.

Yang, W., Wang, L., Fang, M., Sheth, V., Zhang, Y., Holden, A.M., Donahue, N.D., Green, D.E., Frickenstein, A.N., Mettenbrink, E.M., Schwemley, T.A., Francek, E.R., Haddad, M., Hossen, M.N., Mukherjee, S., Wu, S., DeAngelis,

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

P.L., Wilhelm, S., 2022. Nanoparticle Surface Engineering with Heparosan Polysaccharide Reduces Serum Protein Adsorption and Enhances Cellular Uptake. Nano Lett 22, 2103–2111.

Yoder, C.H., Landes, N.T., Tran, L.K., Smith, A.K., Pasteris, J.D., 2016. The relative stabilities of A- and B-type carbonate substitution in apatites synthesized in aqueous solution. Mineral Mag 80, 977–983.

Yotsova, R., Peev, S., 2024. Biological Properties and Medical Applications of Carbonate Apatite: A Systematic Review. Pharmaceutics 16.

You, J., Fu, Z., Zou, L., 2021. Mechanism and Potential of Extracellular Vesicles Derived From Mesenchymal Stem Cells for the Treatment of Infectious Diseases. Front Microbiol.

Yuan, T., Meijia, L., Xinyao, C., Xinyue, C., Lijun, H., 2023. Exosome derived from human adipose-derived stem cell improve wound healing quality: A systematic review and meta-analysis of preclinical animal studies. Int Wound J 20, 2424–2439.

Zeng, L., 2016. Mucosal adjuvants: Opportunities and challenges. Hum Vaccin Immunother 12, 2456–2458.

Zeng, Q., Wang, R., Hua, Y., Wu, H., Chen, X., Xiao, Y. cai, Ao, Q., Zhu, X., Zhang, X., 2022. Hydroxyapatite nanoparticles drive the potency of Toll-like receptor 9 agonist for amplified innate and adaptive immune response. Nano Res 15, 9286–9297.

Zhang, J., Jiao, Y., Zhang, Y., Wang, K., Sui, X., Song, D., Drioli, E., Cheng, X., 2022. Development of Hydrophilic Polylactic Acid Hollow-Fiber Membranes for Water Remediation. Ind Eng Chem Res 61, 17479–17487.

Zhang, S., Gao, H., Bao, G., 2015. Physical Principles of Nanoparticle Cellular Endocytosis. ACS Nano 9, 8655–8671.

Zhang, T., He, P., Guo, D., Chen, K., Hu, Z., Zou, Y., 2023. Research Progress of Aluminum Phosphate Adjuvants and Their Action Mechanisms. Pharmaceutics 15, 1756.

Zhang, W., Liu, R., Chen, Y., Wang, M., Du, J., 2022. Crosstalk between Oxidative Stress and Exosomes. Oxid Med Cell Longev.

Zhang, Y., Liu, Y., Liu, H., Tang, W.H., 2019. Exosomes: Biogenesis, biologic function and clinical potential. Cell Biosci 9, 1–18.

UNIVERSITAS
GADJAH MADA
**Development Of Exosome-Functionalized Carbonate Apatite Nanoparticles As An Immunomodulatory Mucosal
Adjuvant For Trans-Buccal Delivery (In-vitro Study)**
Andari Sarasati, Prof. drg. Ika Dewi Ana, M.Kes., Ph.D.; Dr. med. vet. drh. Hevi Wihadmadyatami, M.Sc.; Prof. Dr. Va
Universitas Gadjah Mada, 2025 | Diunduh dari http://etd.repository.ugm.ac.id/

Zhang, Y., Yu, M., Tian, W., 2016. Physiological and pathological impact of exosomes of adipose tissue. Cell Prolif 49, 3–13.

Zhao, H., Shang, Q., Pan, Z., Bai, Y., Li, Z., Zhang, H., Zhang, Q., Guo, C., Zhang, L., Wang, Q., 2018. Exosomes from adipose-derived stem cells attenuate adipose inflammation and obesity through polarizing M2 macrophages and beiging in white adipose tissue. Diabetes 67, 235–247.

Zhao, K., Xie, Y., Lin, X., Xu, W., 2022. The Mucoadhesive Nanoparticle-Based Delivery System in the Development of Mucosal Vaccines. Int J Nanomedicine 17, 4579–4598.

Zheng, Y., Luo, S., Xu, M., He, Q., Xie, J., Wu, J., Huang, Y., 2024. Transepithelial transport of nanoparticles in oral drug delivery: From the perspective of surface and holistic property modulation. Acta Pharm Sin B.

Zhou, C., Zhang, B., Yang, Y., Jiang, Q., Li, T., Gong, J., Tang, H., Zhang, Q., 2023. Stem cell-derived exosomes: emerging therapeutic opportunities for wound healing. Stem Cell Res Ther.

Zhou, H., Wu, T., Dong, X., Wang, Q., Shen, J., 2007. Adsorption mechanism of BMP-7 on hydroxyapatite (001) surfaces. Biochem Biophys Res Commun 361, 91–96.

Zhou, Y., Yokel, R.A., 2005. The chemical species of aluminum influences its paracellular flux across and uptake into Caco-2 cells, a model of gastrointestinal absorption. Toxicol Sci. 87, 15–26.

Zhu, S., Huang, H., Liu, D., Wen, S., Shen, L., Lin, Q., 2022. Augmented cellular uptake and homologous targeting of exosome-based drug loaded IOL for posterior capsular opacification prevention and biosafety improvement. Bioact Mater 15, 469–481.

Zulkifli, M.Z.A., Nordin, D., Shaari, N., Kamarudin, S.K., 2023. Overview of Electrospinning for Tissue Engineering Applications. Polymers 15.