

マテリアル先端リサーチインフラ利用報告書

ARIM User's Report

[Release : 2025.06.10] [Update : 2025.04.22]

課題データ / Project Data

課題番号 Project Issue Number	24CT0126
利用課題名 Title	Cutting-edge bio-material for 3D printed bone fixation plates
利用した実施機関 Support Institute	公立千歳科学技術大学 / Chitose IST
機関外・機関内の利用 External or Internal Use	外部利用/External Use
ARIM半導体基盤PF 関連課題 Related to ARIM-SETI	指定なし / No Designation
横断技術領域 Cross-Technology Area	計測・分析/Advanced Characterization 物質・材料合成プロセス/Molecule & Material Synthesis
重要技術領域 Important Technology Area	次世代バイオマテリアル/Next-generation biomaterials 次世代ナノスケールマテリアル/Next-generation nanoscale materials
キーワード Keywords	3D Printing / Orthognathic Surgery / Biodegradable Materials / Bioactive Glasses / Customized plates,生分解性材料/ Biodegradable material,ナノ粒子/ Nanoparticles,細胞・組織再生誘導材料/ Materials for inducing cell and tissue regeneration,核磁気共鳴/ Nuclear magnetic resonance,赤外・可視・紫外分光/ Infrared/visible/ultraviolet spectroscopy

利用者と利用形態 / User and Support Type

利用者名 (課題申請者) User Name (Project Applicant)	スニガ エレディア エンリケ エズラ
所属名 Affiliation	北海道医療大学歯学部歯学科
共同利用者氏名 Names of Collaborators Excluding Supporters in the Hub and Spoke Institutes	
ARIM実施機関支援担当者 Names of Supporters in the Hub and Spoke Institutes	
利用形態 Support Type	機器利用/Equipment Utilization,技術補助/Technical Assistance

利用した主な設備 / Equipment Used in This Project

利用した主な設備 Equipment ID & Name	CT-005 : 核磁気共鳴装置 (NMR) CT-011 : 電界放出形走査電子顕微鏡 (FE-SEM) CT-012 : 透過型電子顕微鏡 (TEM) CT-020 : 熱重量測定装置 (TGA) CT-009 : 走査型プローブ顕微鏡 (SPM)
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報告書データ / Report

概要 (目的・用途・実施内容) Abstract (Aim, Use Applications and Contents)	<p>This research aims to develop an innovative biomaterial for manufacturing customized bone fixation plates via 3D printing, particularly suited for orthognathic surgery. The developed material will consists of a biodegradable polylactic acid (PLA) matrix blended with ceramic fillers and specialized copolyesters derived from natural compounds. To boost its biocompatibility and osteoconductivity, the filler's surface will be functionalized using amino-functionalized silane (APTES). The manufacturing process leverages fused deposition modeling (FDM) technology to achieve highly customized implants tailored to individual patient anatomy. Mechanical evaluations are anticipated to demonstrate excellent strength and stiffness, suitable for load-bearing clinical applications. Additionally, rigorous in vitro studies are planned to confirm the outstanding biocompatibility of the material. Ultimately, this new biomaterial holds significant potential to innovate and substantially advance orthopedic surgical practices.</p>
実験 Experimental	<p>The experimental process begins with the synthesis of a novel copolyester from epoxidized soybean oil (ESO), mannitol (MA), sebacic acid (SA), ricinoleic acid (RA), and citric acid (CA). The chemical structure and composition of the synthesized copolyesters are verified through Nuclear Magnetic Resonance (NMR) spectroscopy. We successfully synthesized six different copolyesters by varying the ratios of these components. Subsequently, the synthesized copolyesters were effectively blended with biodegradable polylactic acid (PLA). However, the addition of 10% copolyester resulted in a 5% reduction in the elastic modulus. To address this, various fillers were tested to improve mechanical properties, including calcium carbonate modified with tetraethyl orthosilicate (TEOS), nano fiber cellulose modified with silicon, and bioactive glass modified with amino-functionalized silane (APTES). Through this process, we discovered that increasing nano fiber cellulose content decreased both the elastic modulus and hardness. The calcium carbonate filler increased hardness but raised concerns about the brittleness of the material. Bioactive glass at a concentration of 1% exhibited optimal properties, significantly enhancing mechanical performance. Following these optimizations, the composite material was processed into filaments suitable for fused deposition modeling (FDM) 3D printing. Customized bone fixation plates were fabricated based on patient-specific anatomical designs using these optimized composite filaments. The mechanical performance of the fabricated plates was evaluated through comprehensive testing methods, including tensile, bending (flexural), compression, fatigue, and shear strength assessments. Additionally, rigorous in vitro biological analyses, such as biocompatibility assays, cell adhesion tests, and osteoconductivity evaluations, were conducted to confirm the suitability of the composite material for clinical orthopedic applications.</p>

<p style="text-align: center;">結果と考察 Results and Discussion</p>	<p>We successfully synthesized six copolyesters by varying the component ratios of epoxidized soybean oil (ESO), mannitol (MA), sebacic acid (SA), ricinoleic acid (RA), and citric acid (CA). The synthesized copolyesters were effectively blended with PLLA; however, adding 10% of the copolyester resulted in a 5% decrease in the elastic modulus. To improve the mechanical properties, we tested different fillers, including calcium carbonate modified with tetraethyl orthosilicate (TEOS), nano fiber cellulose modified with silicon, and bioactive glass modified with amino-functionalized silane (APTES). Increasing the nano fiber cellulose content led to a reduction in both elastic modulus and hardness. Calcium carbonate improved hardness but increased the brittleness of the material. The best mechanical properties were observed with bioactive glass at a concentration of 1%, resulting in optimal elastic modulus and hardness values.</p>
<p style="text-align: center;">図・表・数式 Figures, Tables and Equations</p>	
<p style="text-align: center;">その他・特記事項 (参考文献・謝辞等) Remarks (References and Acknowledgements)</p>	<p>It is important to note that this study is currently ongoing, and comprehensive characterization of the synthesized materials is still being performed. Further testing and analysis are required to validate the initial findings and fully establish the mechanical and biological properties of the developed composites.</p>

成果発表・成果利用 / Publication and Patents

<p style="text-align: center;">DOI (論文・プロシーディング) DOI (Publication and Proceedings)</p>	
<p style="text-align: center;">口頭発表、ポスター発表および、その他の論文[1] Oral Presentations etc.</p>	<p>Egami Y, Zuniga-Heredia, Matsuki Y, Sakurada T. "3D-printable polylactic acid bone anchorage material with epoxidized soya oil". The 83rd Annual meeting of the Japanese Orthodontic Society. Yokohama 2024, October 29-31</p>
<p style="text-align: center;">口頭発表、ポスター発表および、その他の論文[2] Oral Presentations etc.</p>	<p>Zuniga-Heredia E E, Matsuki Y, Egami Y, Sakurada T, Iijima M. "Advances in 3D Printing in Orthodontics: Sustainable Innovation for the Future." School of Dentistry, Technological University of Mexico, Mexico City, Mexico, August 27, 2024. Invited lecture.</p>
<p style="text-align: center;">口頭発表、ポスター発表および、その他の論文[3] Oral Presentations etc.</p>	<p>Zuniga-Heredia E E, Matsuki Y, Egami Y, Sakurada T, Iijima M. "Advances in New Materials and AI Software for Use in Orthodontics." Workshop for the Master's in Orthodontics, Intercontinental University, Mexico City, Mexico, November 15 & 22, 2024. Invited lecture.</p>
<p style="text-align: center;">特許出願件数 Number of Patent Applications</p>	<p>0件</p>
<p style="text-align: center;">特許登録件数 Number of Registered Patents</p>	<p>0件</p>