Doctoral Dissertation Evaluation Review

Degree requested: Doctor of Soft Matter Science Applicant's name: Duangkamon VIBOONRATANASRI

Examiner :

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Title of Doctoral Dissertation

Study on Porous and Tough Hydrogels for Biomedical Engineering Applications
(バイオメディカルエンジニアリング応用のための多孔質かつ高靭性ハイドロゲルに関する研究)

Results of Evaluation of the Doctoral Dissertation (Report)

Recently, studies on biomaterials for soft tissue repair, particularly hydrogels and artificial ligaments, have been actively pursued. However, many of these studies focus mainly on mechanical reinforcement or biocompatibility separately. The integration of mechanical toughness, drug delivery potential, and bioactivity into a single hydrogel-based system remains a frontier in biomaterials research, and its advancement has been anticipated for years. In this dissertation, the author conducted a systematic investigation into the fabrication of porous and tough hydrogels using a novel cryo-UV polymerization technique. The study aimed to develop composite materials that mimic the structure and function of natural ligaments and tendons, with the added benefit of controlled drug release and high-water content, thereby enhancing tissue integration.

The author successfully fabricated polyacrylamide/carboxymethyl cellulose (PAAm/CMC) porous gel via a one-pot UV-assisted cryopolymerization method. The resulting porous gels demonstrated improved mechanical strength, particularly the PAAm/CMC porous gel synthesized with 2.5 M AAm (PC2.5), which exhibited an 8.4-fold increase in tensile modulus and a 26-fold increase in toughness compared to the non-cryo gel (prepared at room temperature). Additionally, PC2.5 demonstrated excellent cyclic compression stability in water and phosphate-buffered saline (PBS) after undergoing 100 cycles of testing. These increases in the mechanical properties of PC2.5 are attributed to the formation of macropores with high polymer density and high crosslinking density at the pore walls. Furthermore, this study also demonstrated that the fabricated gels exhibited slow, controlled drug release behavior and biocompatibility, thereby addressing both structural and biological requirements for biomedical use. However, the mechanical properties of the porous gel were not sufficient for artificial ligament and tendon applications. Therefore, the author fabricated a PAAm/CMC porous gel composite material by combining a porous gel with polyethylene terephthalate (PET) fabric, which acts as reinforcement. The result showed that porous gels reinforced with PET fabric (PCC) achieved a 700-fold increase in stiffness compared to a porous gel. In addition, PCC still exhibited a porous and interconnected structure. The findings highlighted their potential for applications in artificial ligaments and tendons.

In conclusion, the author has presented the findings on the fabrication and characterization of porous and tough PAAm/CMC-based hydrogels and their composites, making significant contributions to the fields of soft matter science and biomedical engineering. These findings provide a foundation for the development of advanced biomaterials for ligament/tendon reconstruction, as well as controlled drug delivery. Therefore, we acknowledge that the author is qualified to be granted a Doctorate of Soft Matter Science from Hokkaido University. We believe that the outcomes of this dissertation represent a valuable and original contribution to the field and fully meet the academic standards required for the doctoral degree.