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- 후 원 : 한국센서연구소(주), 나노종합기술원, 포항공대 나노융합기술원, (주)과학기술분석센터, 티리니티디아이비(주), 미래양자융합포럼, (주)제니컴, (주)오티에스테크놀로지, (주)세미언스, (주)아이브이솔루션, 중원통상, 한국이브이그룹(유), 한국나노기술원, DGIST센소리움연구소, 코리아디지털(주), (주)삼영에스앤씨, 암페놀센싱코리아(유) (주)신성사운드모션, (주)센텍코리아, (주)에스팩솔루션, (주)래트론, (주)한영닉스, (주)파이버프로, 연세대 초임계소재산업기술거점센터, (주)이너센서, 아이쓰리시스템(주), 한화인텔리전스(주), (주)엠에스티코퍼레이션, 여주시청, 전라남도청/전남관광재단, 한국과학기술단체총연합회



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THE KOREAN SENSORS SOCIETY

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<sup>1)</sup>School of Mechanical Engineering, Chonnam National University, <sup>2)</sup>Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University, <sup>3)</sup>School of Polymer Science and Engineering, Chonnam National University, <sup>4)</sup>Korea Institute of Medical Microrobotics, <sup>5)</sup>Center for Next-generation Sensor Research and development, Chonnam National University ..... 383

# 3D-printed stent using biodegradable PCL composite infused with contrast agents for enhanced radiopacity

Yun-Jin Jeong<sup>1),2)</sup>, Byeongjun Choi<sup>3)</sup>, Seokjae Kim<sup>2)</sup>, Juyeong Jo<sup>1),4)</sup>, Arunkumar Shanmugasundaram<sup>1),2)</sup>,  
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<sup>1)</sup>*School of Mechanical Engineering, Chonnam National University*

<sup>2)</sup>*Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University*

<sup>3)</sup>*School of Polymer Science and Engineering, Chonnam National University*

<sup>4)</sup>*Korea Institute of Medical Microrobotics*

<sup>5)</sup>*Center for Next-generation Sensor Research and development, Chonnam National University*

†[mems@jnu.ac.kr](mailto:mems@jnu.ac.kr)

## Abstract

Continuous in vivo observation of polymer-derived biodegradable stents (BDSs) is important for their efficacious interventions in cardiovascular applications. However, the inherent non-radiopacity of BDSs presents substantive impediments in assiduously observing patient trajectories. Herein, we propose a biodegradable contrast medium which is synthesized by conjugating 2,3,5-triodobenzoic acid (TIB) with polycaprolactone diol (PCL-diol). The subsequent PCL-TIB is amalgamated with polycaprolactone (PCL) to prepare a polymer framework apt for stent fabrication via additive manufacturing methodologies. The mechanical resilience of the resultant BDSs is appraised via exhaustive evaluations, evidencing their capacity to counter external perturbations and maintain their architectural coherence. Cell viability tests on human umbilical vein endothelial cells (HUVECs) indicate a viability surpassing 90% relative to a control cohort, highlighting the superior biocompatibility and minimal cytotoxicity of the engineered BDSs. Moreover, in vivo radiographic assessment of the BDSs, inclusive of those laden with iohexol, showcased a decline in radiopacity post 7 days, culminating in an indiscernible radiopacity post 9 days. Conversely, BDSs fortified with the proposed degradable contrast medium sustained their radiographic visibility for an interval extending to 40 days. Owing to the excellent biocompatibility and extended radiopacity, the proposed BDSs can be used to address diverse cardiovascular ailments.

**Keywords:** 3D printing, Biodegradable contrast agent, Radiopacity, Bioresorbable stent

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## References

- [1] I. Akoumianakis, M. Polkinghorne, and C. Antoniadis, "Non-canonical WNT signalling in cardiovascular disease: mechanisms and therapeutic implications", *Nat. Rev. Cardiol.*, Vol. 19, No. 12, pp. 783-797, 2022.
- [2] Y. Li, Y. Shi, Y. Lu, X. Li, J. Zhou, A. A. Zadpoor, and L. Wang, "Additive manufacturing of vascular stents", *Acta Biomaterialia*, Vol. 167, pp. 16-37, 2023.



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<sup>1)</sup>School of Mechanical Engineering, Chonnam National University, <sup>2)</sup>Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University,

<sup>3)</sup>School of Polymer Science and Engineering, Chonnam National University, <sup>4)</sup>Korea Institute of Medical Microrobotics,

<sup>5)</sup>Center for Next-generation Sensor Research and development, Chonnam National University

## Abstract

Continuous in vivo observation of polymer-derived biodegradable stents (BDSs) is important for their efficacious interventions in cardiovascular applications. However, the inherent non-radiopacity of BDSs presents substantive impediments in assiduously observing patient trajectories. Herein, we propose a biodegradable contrast medium which is synthesized by conjugating 2,3,5-triodobenzoic acid (TIB) with polycaprolactone diol (PCL-diol). The subsequent PCL-TIB is amalgamated with polycaprolactone (PCL) to prepare a polymer framework apt for stent fabrication via additive manufacturing methodologies. The mechanical resilience of the resultant BDSs is appraised via exhaustive evaluations, evidencing their capacity to counter external perturbations and maintain their architectural coherence. Cell viability tests on human umbilical vein endothelial cells (HUVECs) indicate a viability surpassing 90% relative to a control cohort, highlighting the superior biocompatibility and minimal cytotoxicity of the engineered BDSs. Moreover, in vivo radiographic assessment of the BDSs, inclusive of those laden with iohexol, showcased a decline in radiopacity post 7 days, culminating in an indiscernible radiopacity post 9 days. Conversely, BDSs fortified with the proposed degradable contrast medium sustained their radiographic visibility for an interval extending to 40 days. Owing to the excellent biocompatibility and extended radiopacity, the proposed BDSs can be used to address diverse cardiovascular ailments

## Material characterization and 3D printer fabrication

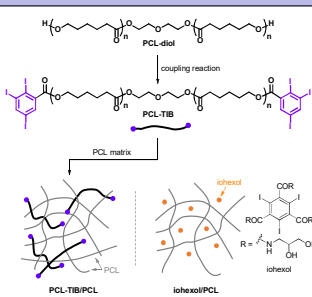


Fig. 1. Schematic illustrates the preparation process flow of the PCL-TIB/PCL hybrid composite and a control iohexol/PCL composite.

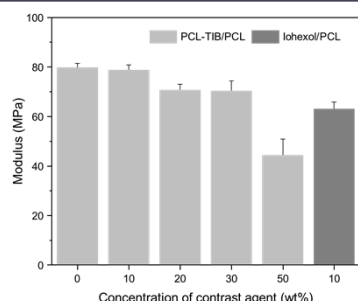


Fig. 2. Change in elastic modulus of the PCL-TIB/PCL hybrid composite according to the weight percentages of the PCL-TIB contrast agent.

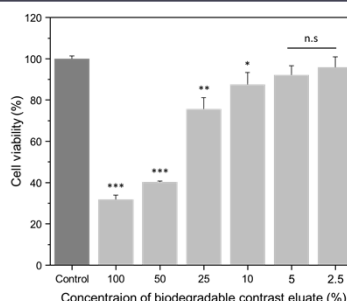


Fig. 3. Cell viability measurements of HUVECs cultured with PCL-TIB contrast agent eluate with different concentration.

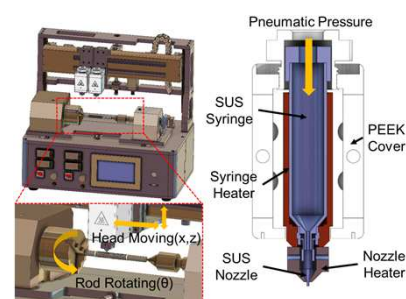


Fig. 4. Schematic diagram of an FDM-type 3D printer for manufacturing biodegradable stents

## Characterization of biodegradable stent with contrast medium

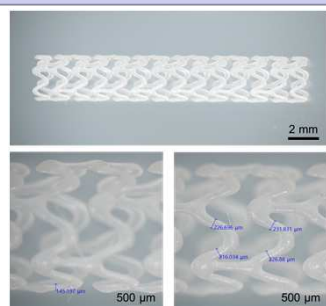


Fig. 5. Optical image of PCL stent with integrated biodegradable contrast agent

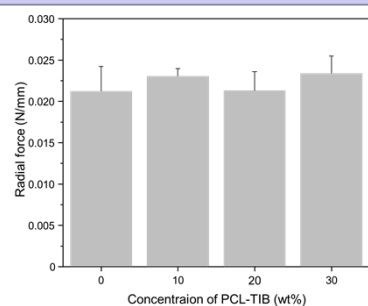


Fig. 6. Bar plots illustrating the radial force exerted by the fabricated BDSs at different concentrations of functional additives.

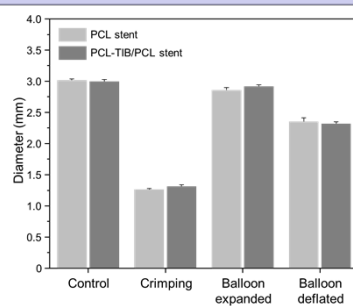


Fig. 7. Bar plots demonstrating the diameter of the fabricated BDSs comparing bare stents with BDSs incorporating 30 wt% of the PCL-TIB.

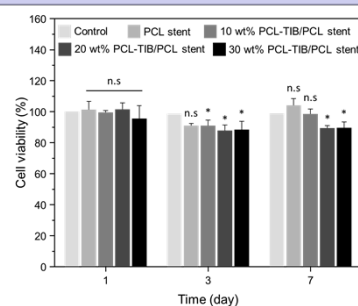


Fig. 8. Cytotoxicity analysis of the fabricated biodegradable stents at different concentration of contrast medium.

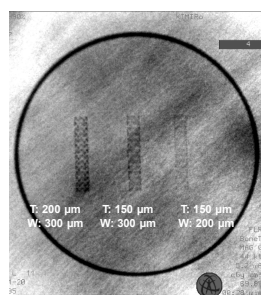


Fig. 9. Visibility of the PCL-TIB/PCL stent under real-time x-ray for in vitro.

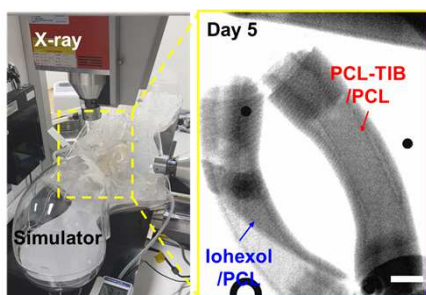


Fig. 10. Prolonged x-ray visibility of stents based on 30 wt% PCL-TIB/PCL and 10 wt% iohexol/PCL in the endovascular evaluator.

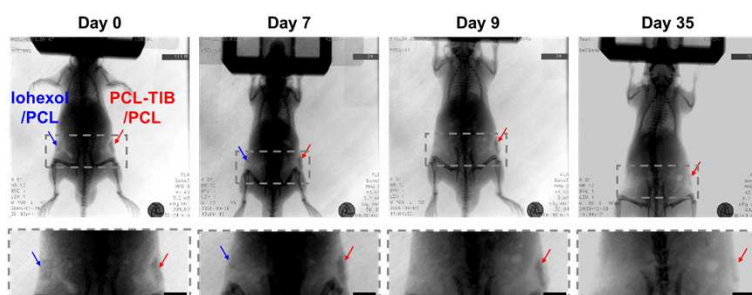


Fig. 11. In vivo prolonged x-ray visibility of stents based on 30 wt% PCL-TIB/PCL and 10 wt% iohexol/PCL

## Conclusion

The aim of this study was to enhance the X-ray visibility and duration of biodegradable polymer stents. To achieve this, a biodegradable contrast medium incorporated PCL composites were synthesized. Subsequently, a stent structure was fabricated 3D printing technology. The PCL composite-based biodegradable stent exhibited no alterations in mechanical stiffness owing to the incorporation of the contrast agent. Furthermore, cell viability analysis using human umbilical vein endothelial cells (HUVECs) demonstrated that over 90% of cells survived, thus confirming biocompatibility. Notably, X-ray visibility persisted for more than 50 days, enabling monitoring post endovascular stent implantation and surgery. Consequently, the PCL composite-based biodegradable stent, featuring the proposed contrast medium, is anticipated to possess significant medical applicability.

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