pH-Dependent Nanodiamonds Enhance the Mechanical Properties of 3D-Printed Hyaluronic Acid Nanocomposite Hydrogels

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Dae Gon Lim
Dongguk University

Eunah Kang
Chung-Ang University

eakangek@cau.ac.kr *Corresponding Author*

Seong Hoon Jeong
Dongguk University

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Abstract

Background: Nanocomposite hydrogels capable of undergoing manufacturing process have recently attracted attention in biomedical applications due to their desired mechanical properties and high functionality. Mechanically enhanced biomaterials composited with diverse nanophase inorganic particles are challenging because metastatic materials mimicking biological tissues require softness, biocompatibility, strength, and structurally compatible elasticity. Herein, nanodiamonds (NDs) have been chosen due to their hydrophilicity and pH-dependent surface functionality, along with their convenient chemical modality

Results: 3D printing nanocomposite hydrogels of hyaluronic acid (HA)/nanodiamond (ND) revealed that the addition of ND with the low weight ratio of 0.02 wt % resulted in higher compressive force and gel breaking point, compared with HA only nanocomposites. These HA nanocomposite hydrogels loaded with surface functionalized ND allowed for the enforced compressive stress to be tuned in a pH-dependent manner. HA nanocomposite hydrogels with ND-OH at pH 8 showed an increase of 1.40 fold (236.18 kPa) and 1.37 fold (616.72 kPa) the compressive stress at the composition of 0.02 wt % and 0.04 wt %, respectively, compared to those of ND-COOH (168.31, 449.59 kPa) at the same pH. Moreover, the compressive stress of HA/ND-OH (0.04 wt %) at pH 8 was mechanically enhanced 1.29 fold, compared to that of HA/ND-OH (0.04 wt %) at pH 7. These results indicate that the tunable buffering environment and interaction with the long chains of HA at the molecular level have a critical role in the dependency of the mechanical properties on pH.

Conclusion: Due to the pH stability of the ND-OH nanophase, filament-based processing and layer-based deposition at microscale attained enforced mechanical properties of hydrogel. Fine surface tuning of the inorganic ND nanophase and controlled 3D printing leads to improved control over the pH-dependent mechanical properties of the nanocomposite hydrogels reported herein.

Full-text

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