3D Printed Osteochondral Scaffold With Biomimetic Structure

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Introduction

Articular osteochondral repair and regeneration are a challenging problem worldwide due to the extremely weak inherent regenerative capacity of the tissue. Currently, the gold standard surgical procedures for treating chondral lesions are autologous cartilage transplantation or autologous chondrocyte implantation, etc. However, this approach is still not perfect due to limited resources of cartilage tissue. In addition, TGF-β1 and nano hydroxyapatite (nHA) play a crucial role in chondrogenesis and osteogenesis, respectively. Here, we firstly prepared TGF-β1 loaded PLGA nanoparticles (TPNPs) by a coaxial electrospray method. Next, we fabricated 3D bioprinted gelatin methacrylate–polyethylene glycol diacrylate (GelMA-PEGDA) scaffolds with biphasic TPNPs and nHA distributions, and then investigated the effects of this scaffold on the growth and osteochondral differentiation of human bone marrow mesenchymal stem cells (hMSCs).

Overview and characterization

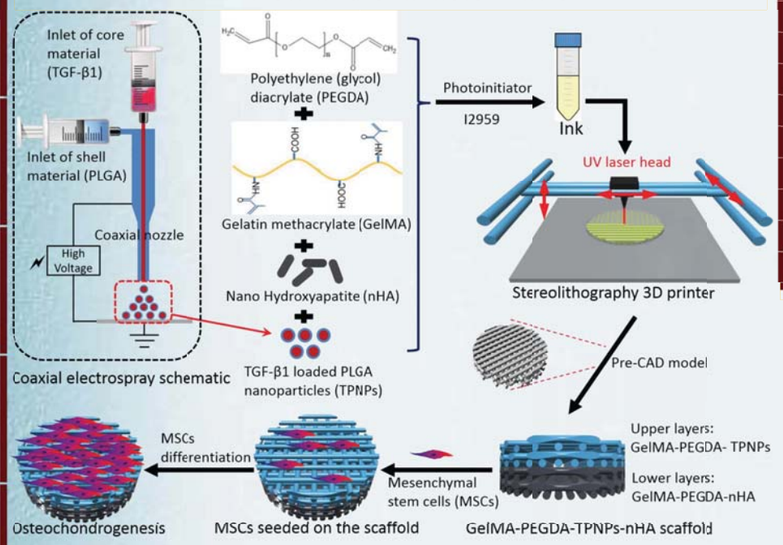


Figure 1. Schematic diagram of the research

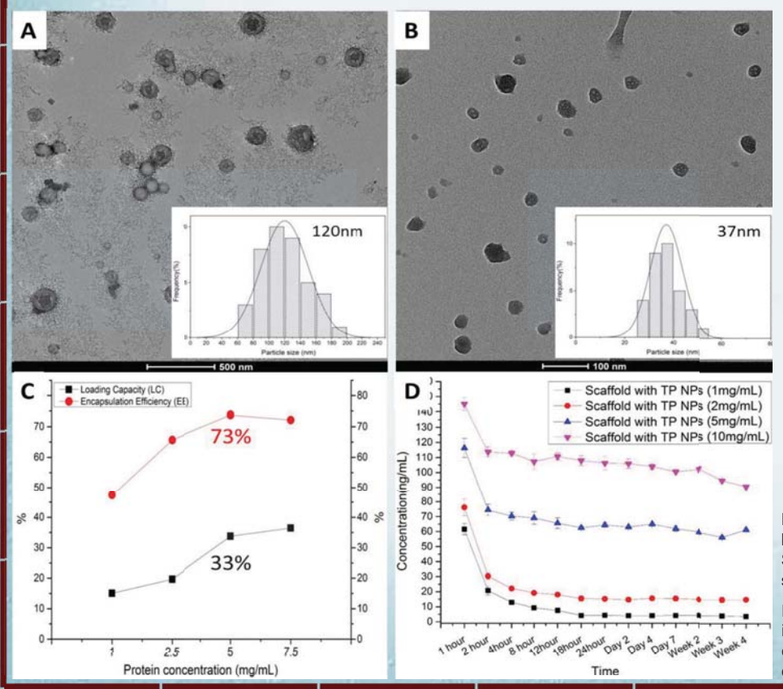


Figure 2. Transmission electron micrographs of (A) TPNPs and (B) blank PLGA nanoparticles. The inset images are particle sizes of the corresponding nanoparticles. (C) The loading capacity and encapsulation efficiency of TPNPs in different mass ratios. (D) Controlled release profile of the scaffold containing different TPNP ratios.

Cell proliferation

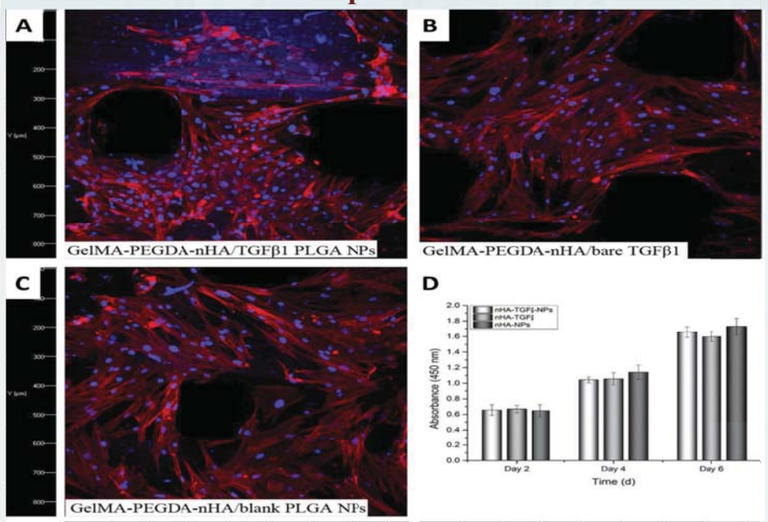
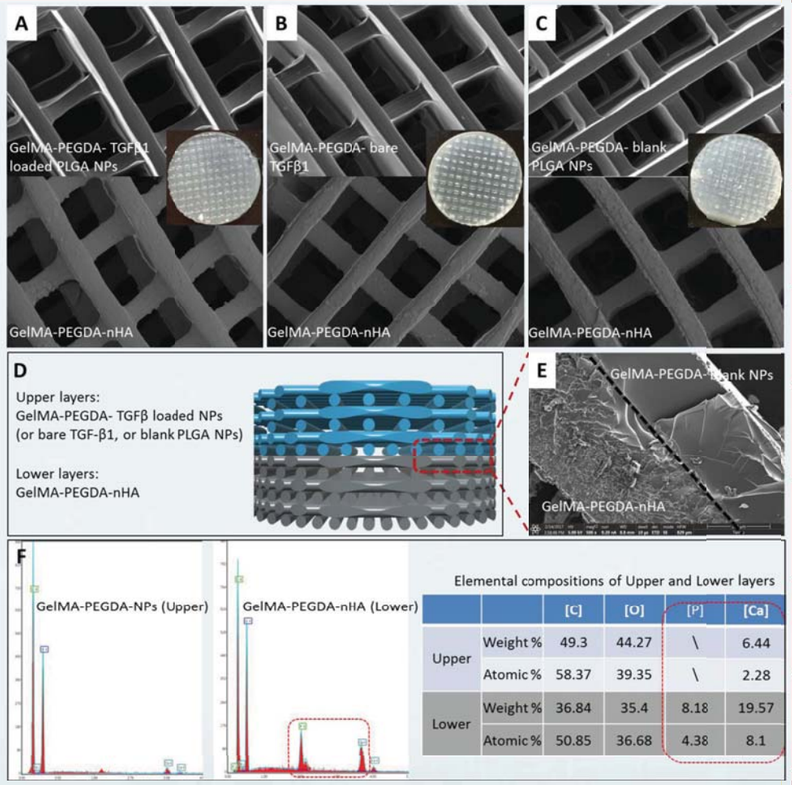


Figure 4. (A-C) Confocal microscopy images (6 days) and (D) proliferation (2, 4 and 6 days) of hMSCs grown on three types of scaffolds. The cytoskeleton and cell nuclei were stained with Texas Red®-X phalloidin (red) and DAPI (blue), respectively.



Elemental compositions of Upper and Lower layers

		[C]	[O]	[P]	[Ca]
Upper	Weight %	49.3	44.27	\	6.44
	Atomic %	58.37	39.35	\	2.28
Lower	Weight %	36.84	35.4	8.18	19.57
	Atomic %	50.85	36.68	4.38	8.1

Figure 3. (A-C) Scanning electron micrographs of upper and lower layer of three types of scaffolds with biphasic structure, respectively. The inset images are photographs of the corresponding scaffolds. (D) Schematic of the scaffold with biphasic structure. (E) Amplification image of biphasic beam in cross section. (F) The elemental analysis of upper and lower layer of scaffold with biphasic structures.

Osteochondral differentiation

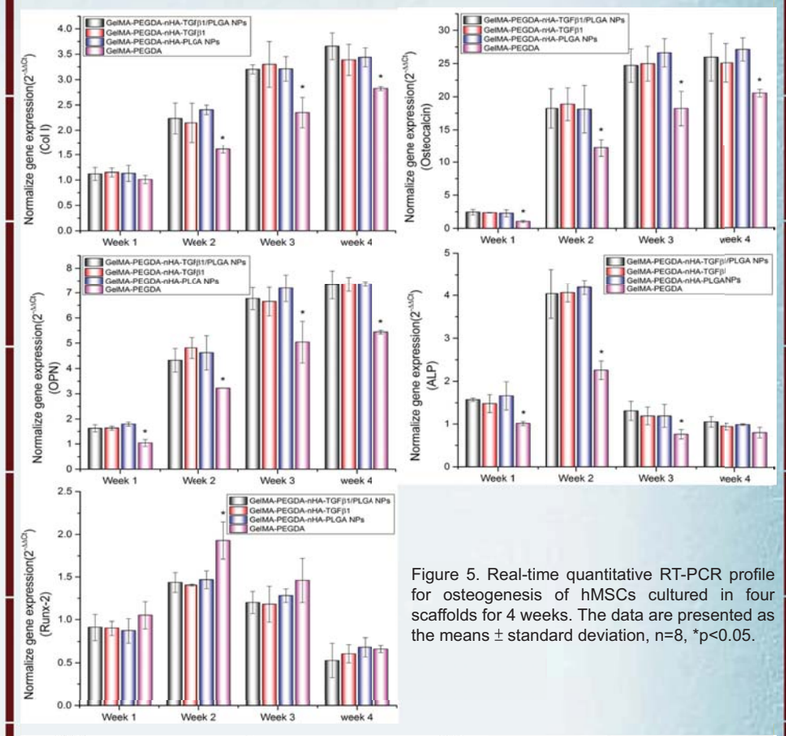


Figure 5. Real-time quantitative RT-PCR profile for osteogenesis of hMSCs cultured in four scaffolds for 4 weeks. The data are presented as the means ± standard deviation, n=8, *p<0.05.

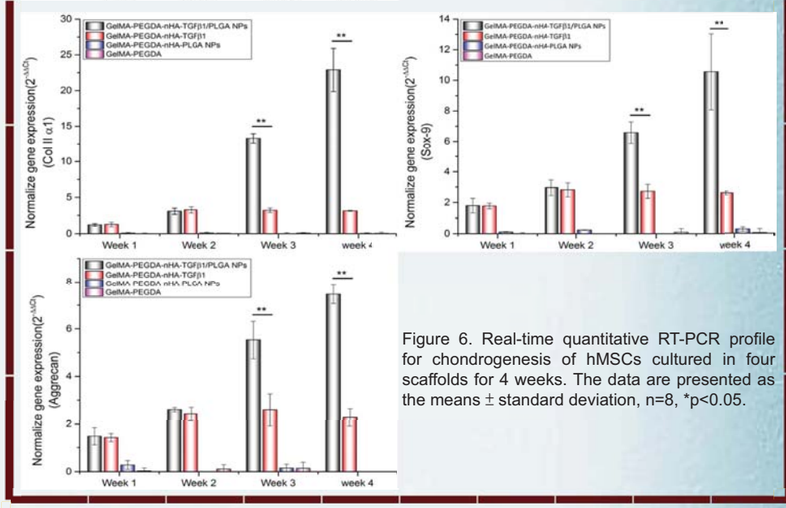


Figure 6. Real-time quantitative RT-PCR profile for chondrogenesis of hMSCs cultured in four scaffolds for 4 weeks. The data are presented as the means ± standard deviation, n=8, *p<0.05.

Conclusion

Customizable 3D printed GelMA-PEGDA scaffolds with biphasic TPNPs and nHA distributions structure were prepared successfully. The scaffolds provided an excellent platform for hMSC proliferation and osteochondral differentiation. The most significant improvement in chondrogenic gene (Col II α1, Sox-9, Aggrecan) and osteogenesis gene (Col I, Osteocalcin, OPN, Runx-2, ALP) expressions were observed on the 3D scaffolds. This study demonstrated that customizable 3D printed scaffolds are excellent candidates for promoting osteochondral differentiation of hMSCs, thus promising for future osteochondral regenerative medicine applications.

Acknowledgments

The authors would like to thank the financial support from NSF BME program grant # 1510561 and the George Washington University Center for Microscopy and Image Analysis for imaging support.