Cardiac Patch

Course: Drug Delivery Systems

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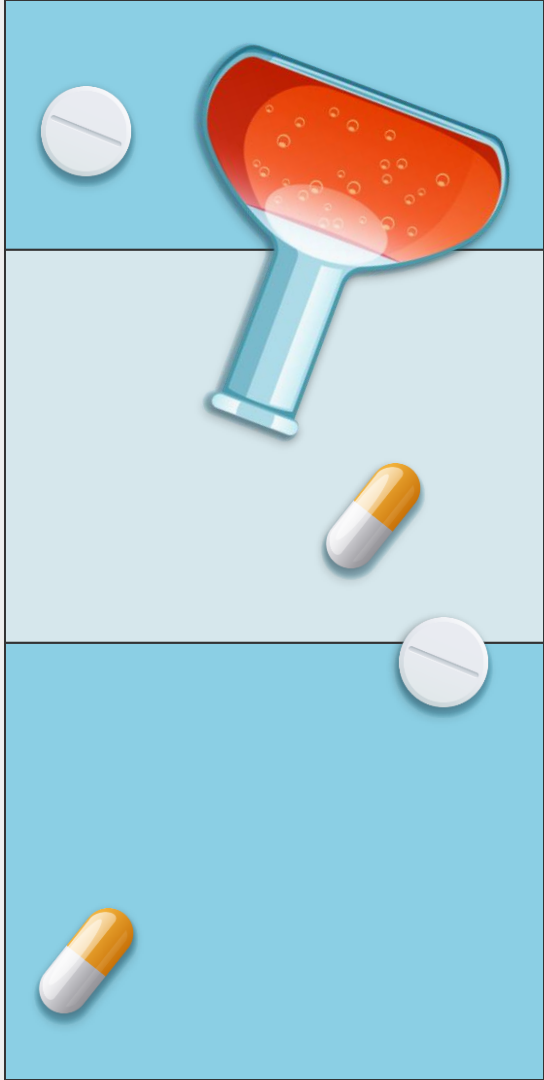
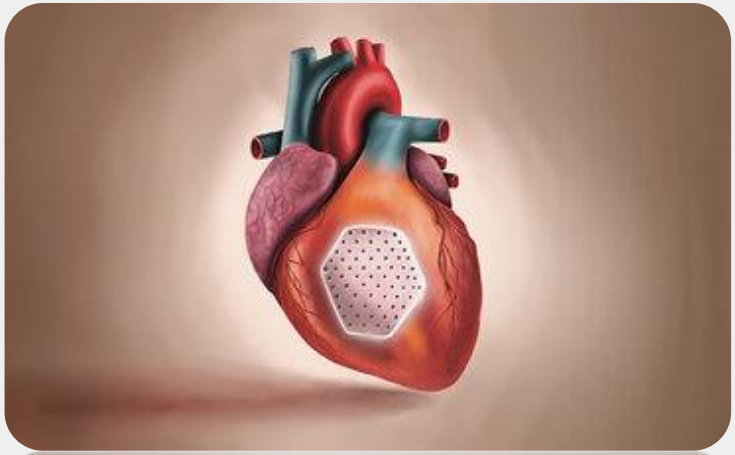


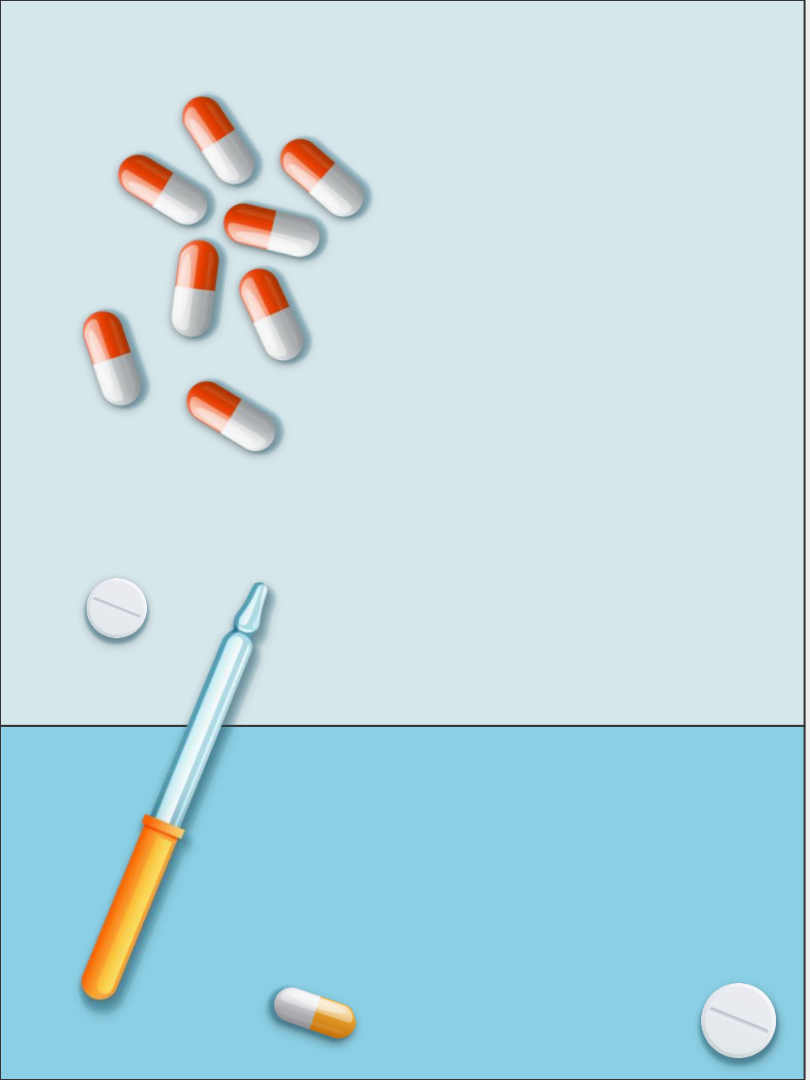
1 Introduction

Cardiac patches

- Cardiovascular diseases (CVDs) are the leading cause of death globally
- Current treatments for myocardial infarction (MI) have limited regeneration potential
- Cardiac patches offer a platform for localized drug delivery and tissue regeneration



Cardiac patches



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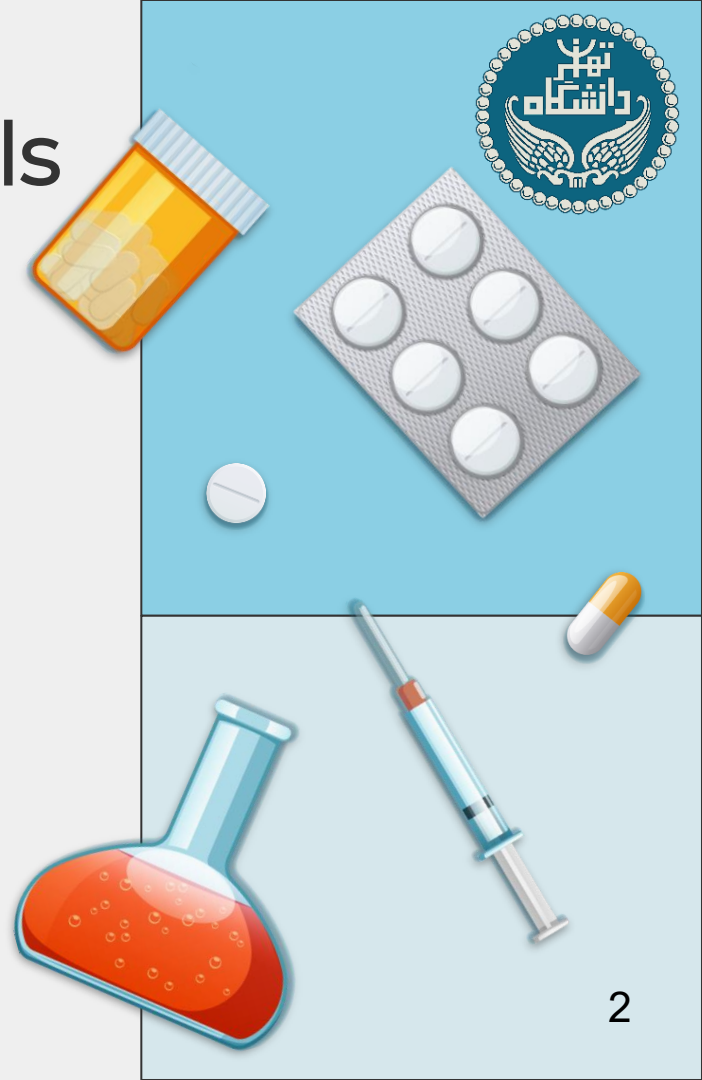
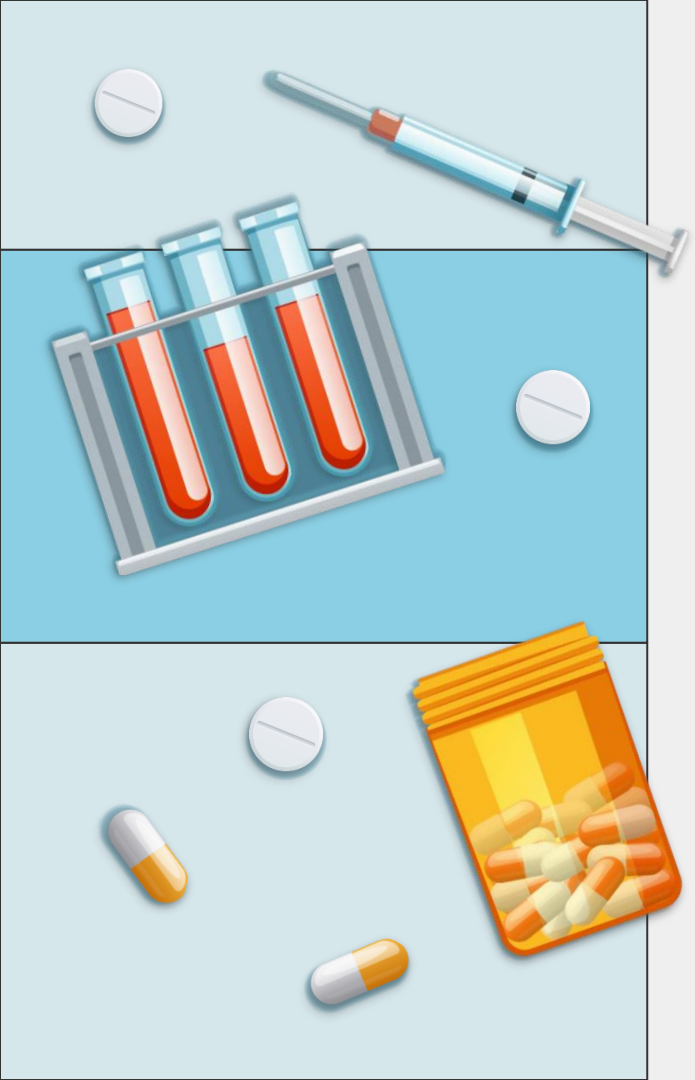
Fundamentals

Drug Delivery Fundamentals

- Controlled release from patches enhances local efficacy
- Mechanisms: Diffusion, degradation, stimuli-responsive release
- Materials: Hydrogels, electrospun nanofibers, biodegradable polymers





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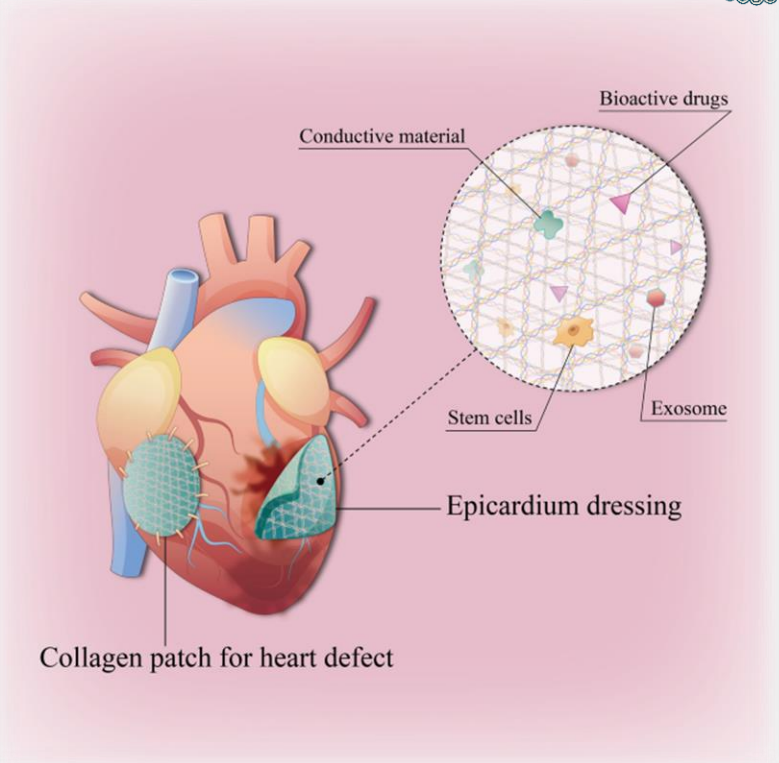
Materials

Materials Used in Cardiac Patches

- Natural polymers: Collagen, gelatin, fibrin
- Synthetic polymers: PLGA, PCL, PEG
- Smart materials: Thermo/pH/enzyme-sensitive materials



Collagen cardiac patch schematic

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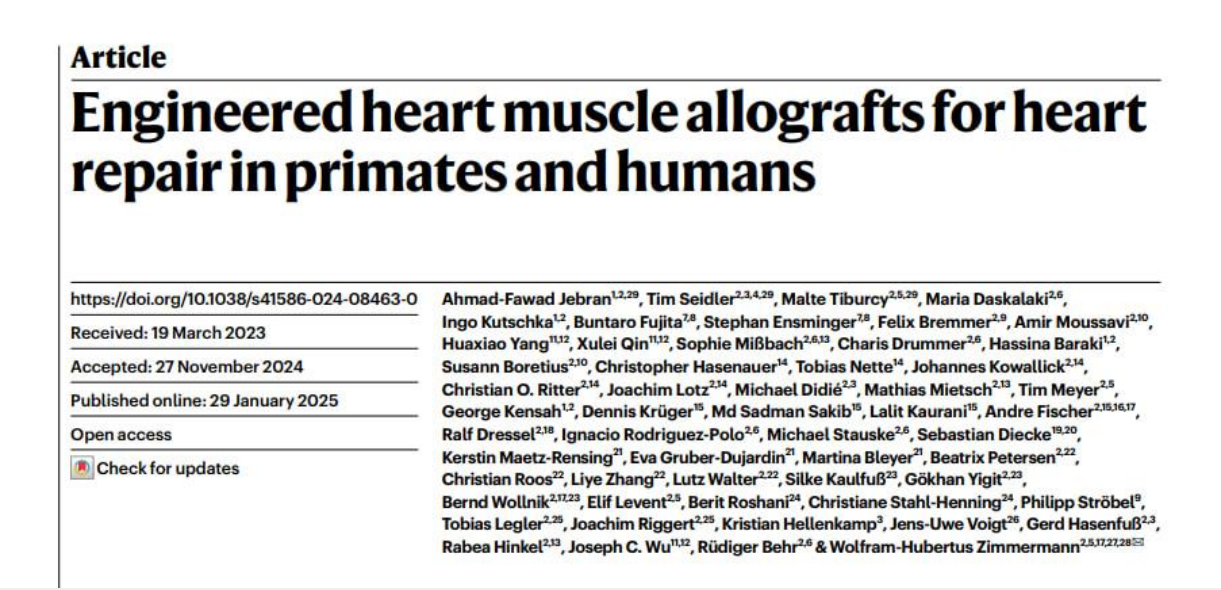
Case studies

Case 1: Engineered heart muscle allografts for heart repair in primates and humans



Article

Engineered heart muscle allografts for heart repair in primates and humans

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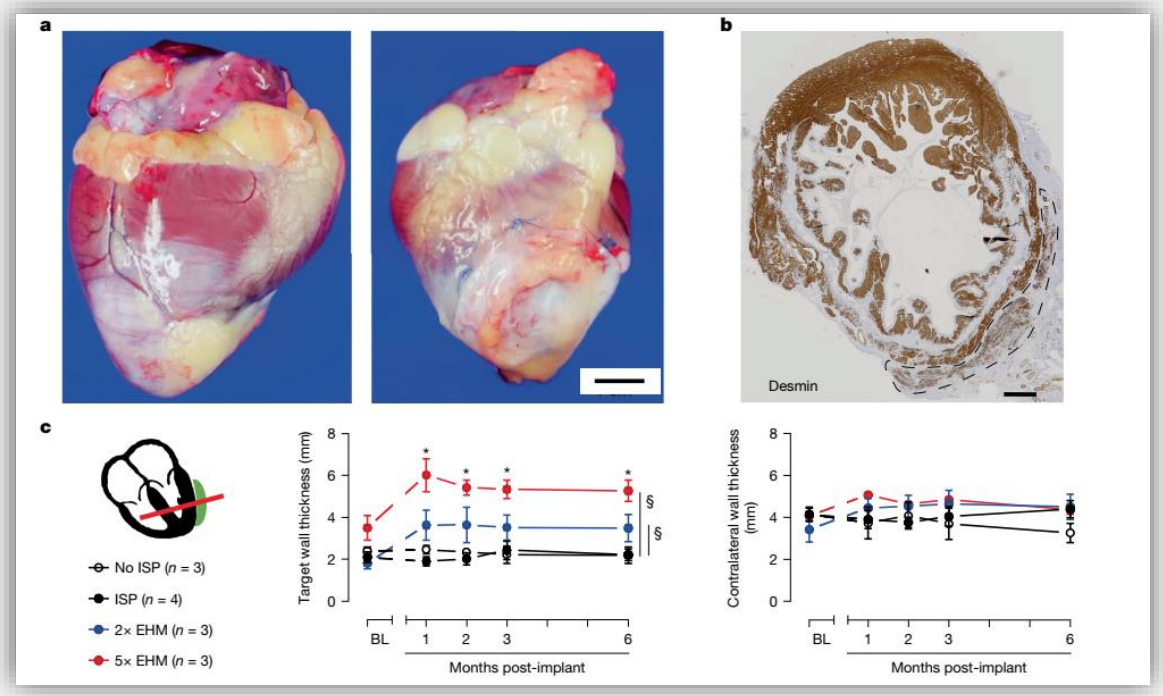
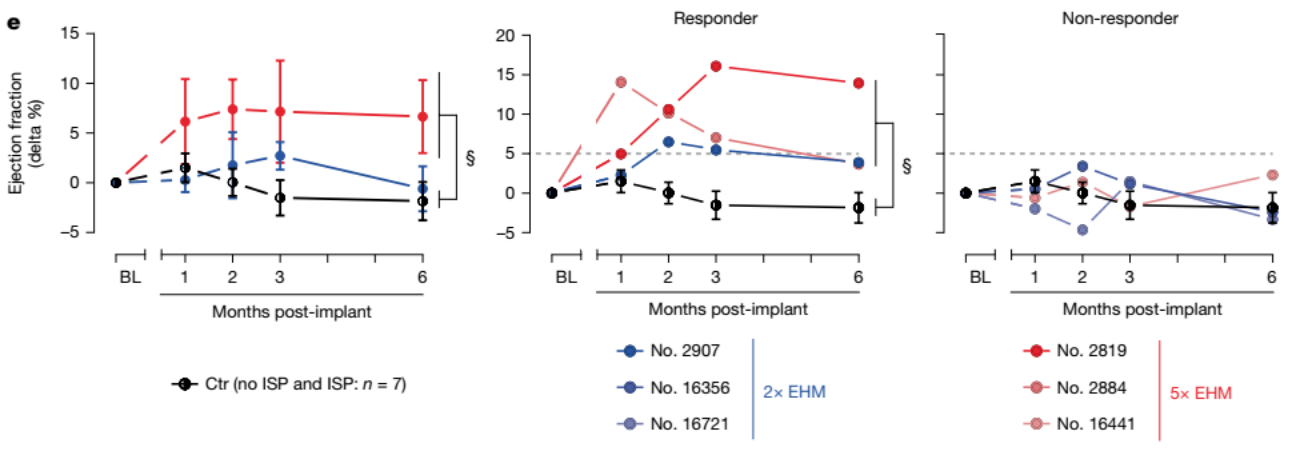
Case 1: Engineered heart muscle allografts for heart repair in primates and humans



Wall thickness after implant

Case 1: Engineered heart muscle allografts for heart repair in primates and humans



Ejection Fraction after implant

Case 2: Living Nanofiber-Enabled Cardiac Patches for Myocardial Injury

Living Nanofiber-Enabled Cardiac Patches for Myocardial Injury

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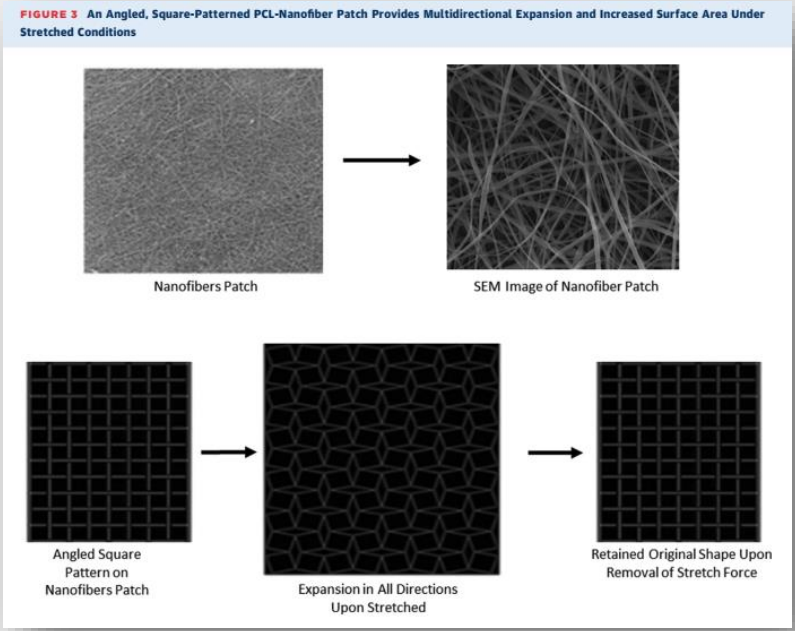
HIGHLIGHTS

- **Adverse cardiac remodeling following myocardial infarction is a leading cause of morbidity and mortality worldwide.**
- **Several impediments exist with current cell therapy approaches to repair damaged myocardium following injury, highlighting the need for alternative approaches.**
- **This review highlights a promising new approach of using biomaterial electrospun nanofiber patches for promoting tissue regeneration.**

Case 2: Living Nanofiber-Enabled Cardiac Patches for Myocardial Injury

- Tailored nanofiber geometry allows multidirectional expansion under cardiac stress
- Square-patterned PCL patch mimics myocardial mechanical dynamics



An Angled, Square-Patterned PCL-Nanofiber Patch

Case 2: Living Nanofiber-Enabled Cardiac Patches for Myocardial Injury

- Diverse biomaterials combined with stem cells or growth factors
- Demonstrated success in improving EF and angiogenesis in MI models

TABLE 1 Nanofibers Cardiac Patches for Myocardial Regeneration

Biomaterials	Cellular Nanofiber Cardiac Patch	First Author
PCL-gelatin	hiPSC-CMs	Kumar et al[26]
PCL/GelMA-Ppy nanoparticles	Cardiomyocytes/fibroblasts	He et al[31]
PCL/gelatin	hiPSC-CMs	Sridharan et al[36]
Alginate/PCL	Cardiac progenitor cells	Karimi et al[44]
PCL-FN-immobilized nanofibers	UCB-MSC	Kang et al[62]
PLA, PEG, and PCL/collagen	HGF and IGF	Kerignard et al[83]
PCL	Sacrificial particles (PEO)	Wanjare et al[84]
Xylan (polysaccharides)/PVA	Acellular patch	Venugopal et al[85]
PLGA	Endothelial cells, VEGF	Fleischer et al[86]
β-PVDF	TiO_2	Arumugam et al[87]
PEO	ECM	Shah et al[76]
PLA/PCL	Cardiomyocytes	Wei et al[77]
Alginate	Cardiomyocytes	Lee et al[78]
CNT/silk	Cardiomyocytes	Zhao et al[79]
PLA/PANI	Cardiomyoblast (H9c2)	Wang et al[80]
PCL/NO	NO_2	Zhu et al[81]
PCL	hiPSC-CMs	Liu et al[82]

Nanofiber Cardiac Patches for Myocardial Regeneration

Case 3:Injectable Hydrogels for Cardiac Tissue Engineering

REVIEW

Hydrogels

Macromolecular Bioscience
www.mbs-journal.de

Injectable Hydrogels for Cardiac Tissue Engineering

*Brisa Peña, Melissa Laughter, Susan Jett, Teisha J. Rowland, Matthew R. G. Taylor, Luisa Mestroni, and Daewon Park**

Case 3:Injectable Hydrogels for Cardiac Tissue Engineering

- Natural hydrogels often exhibit long gelation times (15 min – 3 hrs)
- Slow gelation risks cell loss and inefficient drug delivery

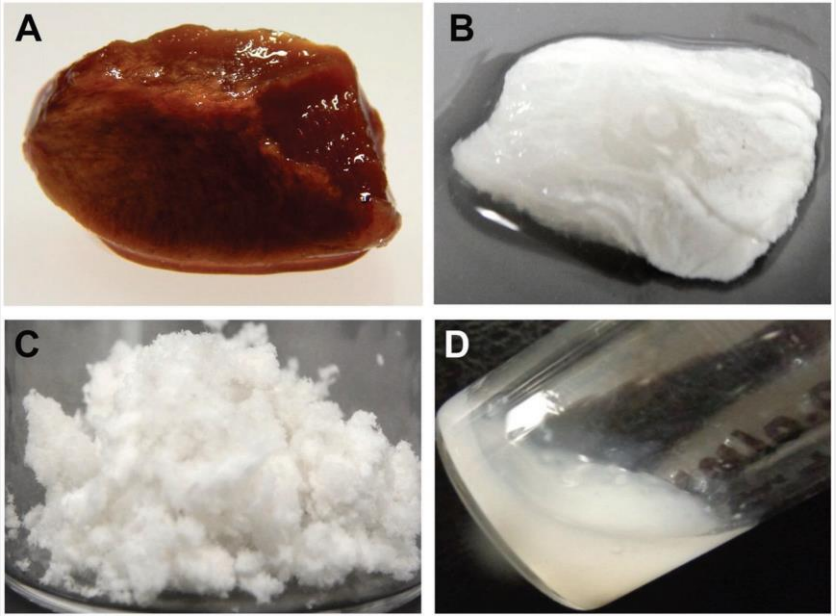
Table 2. Overview of the material properties of the natural injectable hydrogels used for cardiac tissue engineering.

Refs.	Material	Mechanical properties >6 kPa	Conductive	Gel time	Gel stimuli	Degradable
[48]	CNT mixed in collagen type I hydrogel	Yes	Yes	≈15 min	Temp	Yes
[49]	Porcine ECM cross-linked with genipin	No	No	≈15 min	Temp	Yes
[50]	Fullerenol/alginate	No	No	5–10 min	Ca gluconate solution	Yes
[53]	Porcine ECM	N/A	No	N/D	Temp	Yes
[52]	Porcine ECM with mixed or conjugated doxycycline	No	No	N/D	Temp	Yes
[53]	Porcine ECM cross-linked with genipin or chitosan	Yes	No	3 h	Genipin/temp	Yes
[54]	Type I collagen	N/A	No	N/D	Temp	Yes
[55]	Decellularized cardiac and skeletal muscle ECM	No	No	1 h	Temp	Yes
[56]	Chitosan chloride-RoY	N/A	No	8–12 min	Temp	Yes
[57]	Fibrin gel with embedded GF and TIMP-3	N/A	No	N/D	Thrombin	Yes
[58]	Chitosan gel with mixed GN	Yes	Yes	Up to 50 min	BGP-Na salt solution	Yes
[59]	Chitosan hydrogel	Yes	No	s	pH	Yes

Gelation Time of Natural Injectable Hydrogels

Case 3:Injectable Hydrogels for Cardiac Tissue Engineering

Decellularization and digestion of porcine cardiac ECM tissue. The porcine cardiac tissue was sliced into A) sections and then B) decellularized. The decellularized tissue was further lyophilized and ground into C) powder, and then enzymatically digested into a liquid at D) room temperature.



ECM-Derived Hydrogel Injection and Effects on LV

Conclusion

Case	Material	Type	Mechanism	Result
1	Collagen + cells	Bio-patch	Cell therapy	↑ thickness, ↓ risk
2	Nanofibers + GF	Scaffold	Sustained release	↑ angiogenesis
3	Injectable hydrogel	In situ gel	pH/enzymatic	↓ inflammation

- Cardiac patches integrate drug delivery and regenerative functions
- Material design, responsiveness, biocompatibility, mechanics


Thanks for your attention