Living-Bacterial Hydrogels: A Promising Frontier in Accelerated Wound Healing

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TBIOMD 492

BACKGROUND

- **Hydrogels are 3D networks of hydrophilic polymers** that absorb large amounts of water, making them ideal for biomedical uses due to their similarity to biological tissue.
- They can be **made from natural or synthetic polymers** and are used in applications like tissue engineering, drug delivery, wound dressings, and implants.
- Hydrogels **promote wound healing** by maintaining a moist environment, reducing pain, cooling wounds, and accelerating tissue regeneration, especially in burns, ulcers, and surgical wounds.
- **Modern hydrogel dressings outperform traditional methods** by offering better moisture control, infection prevention, and less trauma during removal, though their accessibility is limited in low-resource settings.
- **One-way hydrogels minimize infection risk** by directing would fluid away and preventing backflow, while also supporting healing and reducing scar formation.
- Some hydrogels **deliver bioactive compounds** like growth factors to regulate inflammation and enhance tissue regeneration.
- Bacterial hydrogels **incorporate living probiotics** to fight harmful bacteria, support balanced skin microbiome, and accelerate wound healing through natural secretion of healing compounds.

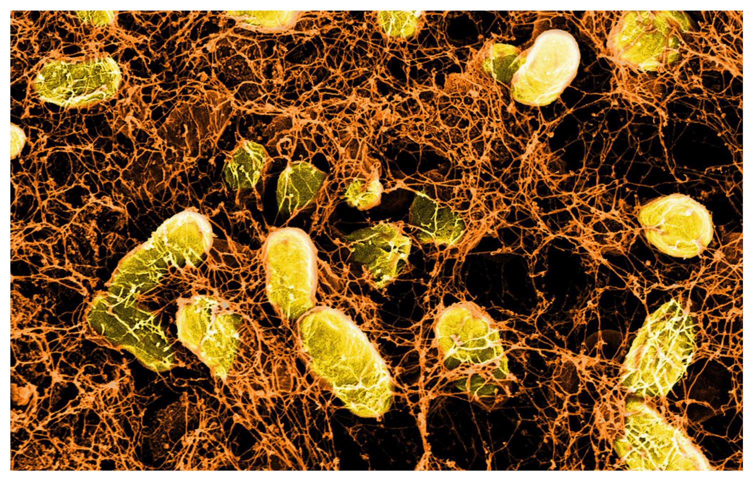

Figure 1. Microscopic image showing a bacterial hydrogel adhering to mucus proteins on the intestinal wall surface (Boettner 2019).

METHODS

- Literary review of primary and peer reviewed articles in relation to LBHs in hydrogels
- Articles were collected from PubMed, Science Direct, NCBI, etc.

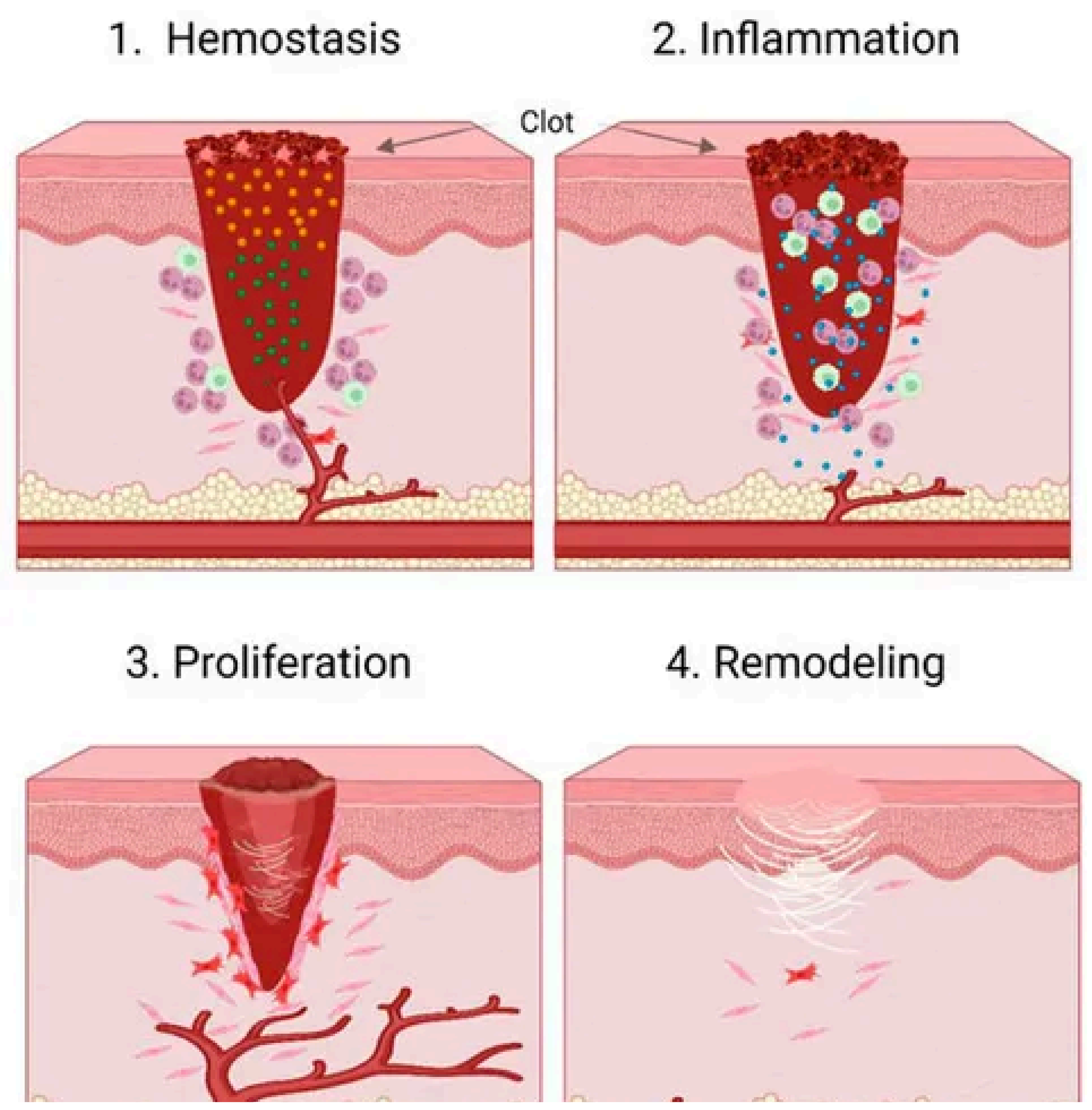

Figure 2. Wound healing occurs in 4 stages – hemostasis, inflammation, proliferation, and tissue repair (Hunt et al. 2023)

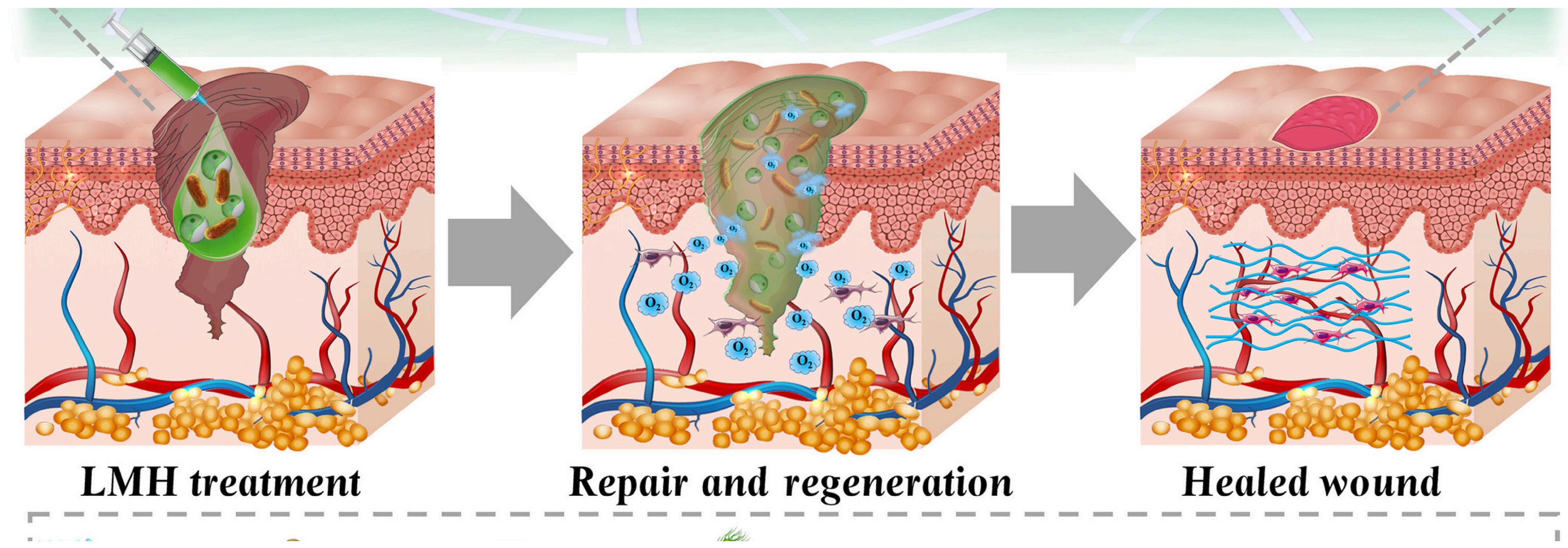

Figure 3. A schematic illustration shows how a living microecological hydrogel (LMH), composed of O2-producing *Chlorella* and antimicrobial B. *subtilis*, promotes healing of hard to heal diabetic wounds by relieving hypoxia and controlling infection (Chen et al. 2023).

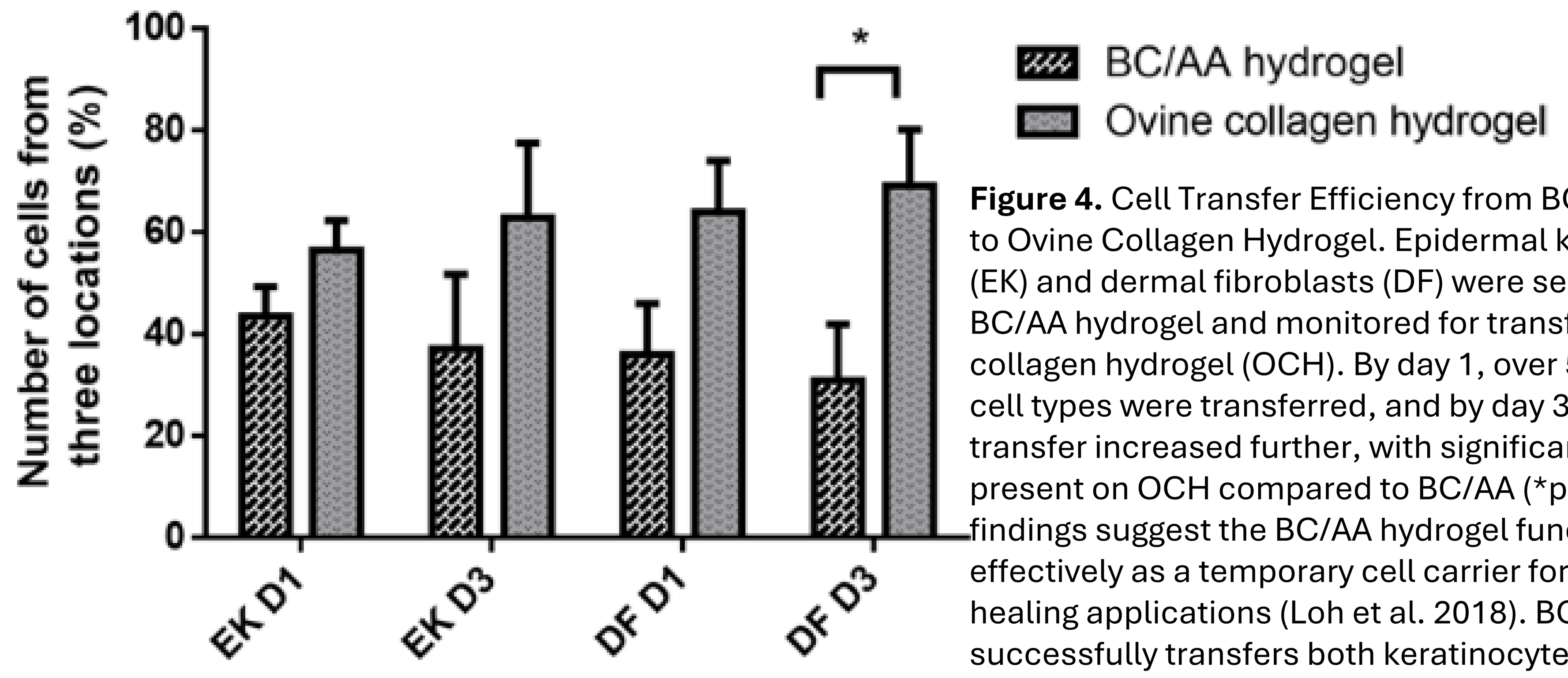

Figure 4. Cell Transfer Efficiency from BC/AA Hydrogel to Ovine Collagen Hydrogel. Epidermal keratinocytes (EK) and dermal fibroblasts (DF) were seeded onto BC/AA hydrogel and monitored for transfer to ovine collagen hydrogel (OCH). By day 1, over 50% of both cell types were transferred, and by day 3, cumulative transfer increased further, with significantly more DF present on OCH compared to BC/AA (*p < 0.05). These findings suggest the BC/AA hydrogel functions effectively as a temporary cell carrier for wound healing applications (Loh et al. 2018). BC/AA hydrogel successfully transfers both keratinocytes and fibroblasts to a collagen-based wound matrix, supporting its use as a temporary, cell-delivering scaffold for wound healing.

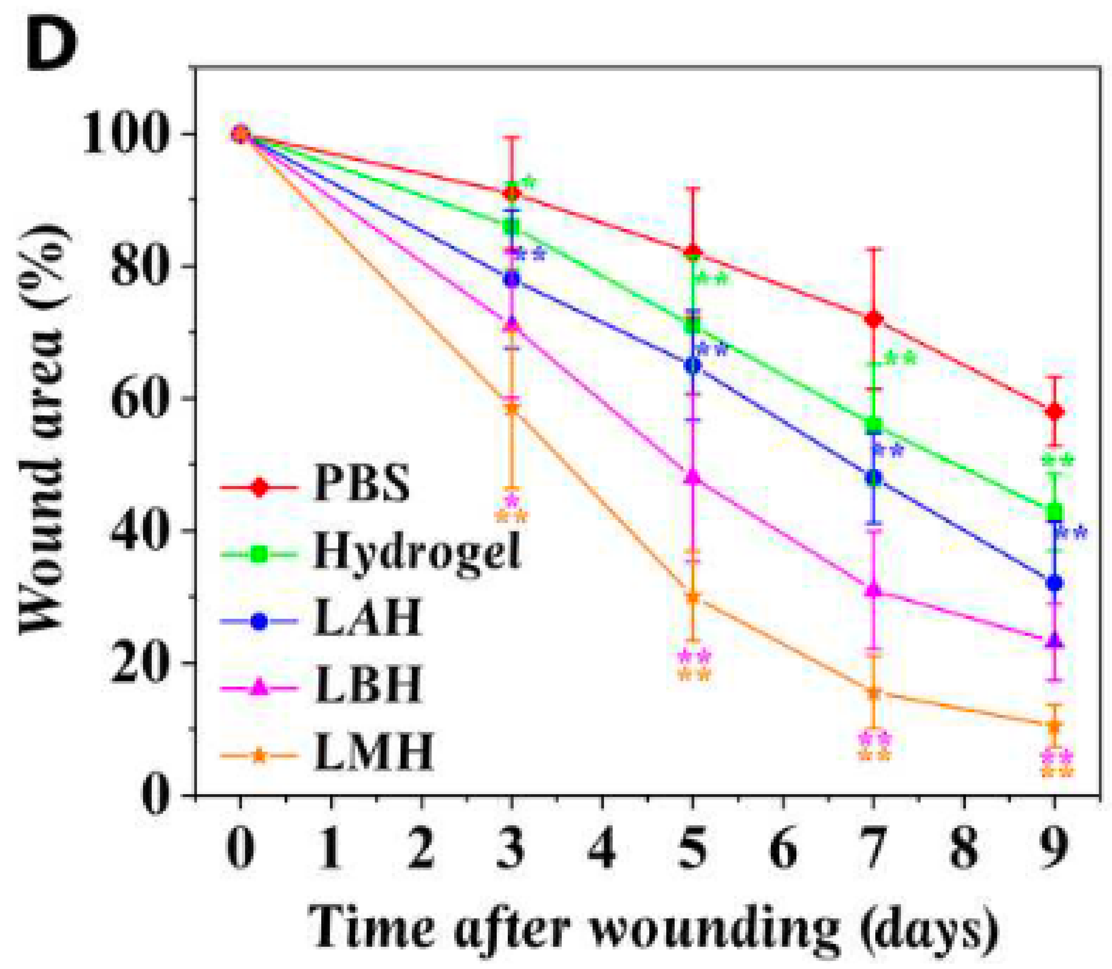

Figure 5. In a diabetic rat model with infected chronic wounds, treatment with the LMH hydrogel, combining O2-producing *Chlorella* and antibacterial *B. subtilis*, significantly accelerated healing, reduced infection and inflammation, and improved wound closure compared to controls and other hydrogels (Chen et al. 2023). The LMH hydrogel effectively accelerates healing in chronic, infected diabetic wounds by combining oxygenated and antibacterial activity, highlighting its therapeutic potential for complex wound care.

RESULTS

- **Mechanism of action**: Living-bacterial hydrogels interact with the wound environment by releasing growth factors that stimulate angiogenesis and tissue regeneration, while also modulating immune responses to support healing.
- **Types of bacteria used**: Non-pathogenic/attenuated strains, carefully selected to avoid introducing infections while maintaining therapeutic effects.
- **Applications**: These hydrogels are especially beneficial for hard-to-heal wounds such as chronic wounds, diabetic ulcers, and surgical wounds, offering targeted healing support.
- **Clinical benefits**: Studies show faster wound closure, lower infection rates, and enhanced tissue repair compared to conventional treatments.
- **Protective and Regenerative Role**: They act as as a physical barrier to pathogens, promote balanced immune responses, and support tissue regeneration at the wound site.
- **Reduced antibiotic use**: By delivering therapeutic agents locally, they may lower the need for systemic antibiotics, decreasing the risk of resistance and preserving the skin's natural microbiota.
- **Potential impact**: With proper monitoring, LBHs offer a cost-effective and innovating alternative to traditional wound care, with improved patient outcomes and reduced healthcare burden.

FUTURE DIRECTIONS

- Focus on optimizing bacterial strains and hydrogel formulations
- Advancements in delivery systems (micro- and nanoencapsulation)
- Integrating smart materials and sensors
- Long-term safety, efficacy, and cost-effectiveness

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REFERENCES