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Review Paper

Next-Generation Smart Polymers in Wound Healing: Responsive and Self-Healing Systems

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ABSTRACT

The skin is the largest organ of the body, which serves as a protective element of the body against physical, chemical, and microbial danger, as well as indicates general health and wellbeing. Any injury, burn or another disease damages this barrier and influences the quality of life, which is why proper wound care is crucial. Conventional wound dressings like gauze are usually not effective to guarantee the wound heals fully and may lead to scarring hence the use of advanced biomaterials. Biocompatibility, biodegradability, and safe interaction with biological systems makes biomaterials important components in contemporary healthcare. They provide structural support and suitable environment of cell proliferation, migration and differentiation in wound healing. There are four stages in the process of healing; hemostasis, inflammation, proliferation, and remodeling that are regulated by cytokines, growth factors, and other types of cells such as macrophages, fibroblasts, keratinocytes, and endothelial cells. The perfect wound dressing must be able to absorb the excess fluid, allow air passage, prevent infection by the microbes and ensure regeneration of tissues. In this, recent dressings have incorporated the use of natural polymers (including chitosan, collagen and alginate) with synthetic polymers (including polyvinyl alcohol and polylactic acid) so as to provide adequate biological activity and mechanical strength. Moreover, bioactive substances like drugs, growth factors and nanoparticles also promote healing. High-tech wound care equipment, such as hydrogel dressings, foam dressings, and negative pressure equipment is used to maximize the wound environment, especially in the chronic wound. This review has shown that biomaterials based on polymers could help in enhancing wound healing and assist in future tissue regeneration research.

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INTRODUCTION

The skin protects against biological, physical, chemical, and radiation threats, regulates temperature, synthesizes vitamin D, and supports appendages like hair follicles [1]. Its constant exposure makes it prone to injury, requiring effective wound care.

A wound is a disruption of skin or underlying tissue from injury, surgery, or disease [2]. Wound healing restores tissue through phases: hemostasis, inflammation, proliferation, and remodeling [2–4]. Hemostasis stops bleeding; inflammation removes debris; proliferation rebuilds tissue and ECM; remodeling restores strength and function [1,5,6]. Wounds are acute (heal in 8–12 weeks) or chronic (>12 weeks), often linked to diabetes, ischemia, venous insufficiency, or pressure [7,8]. Biomaterials aid healing by supporting cell adhesion, proliferation, migration, and differentiation [9]. Polymeric biomaterials, especially synthetic systems, enable controlled, sustained drug release, improving efficacy [10,11]. Conventional dressings like cotton gauze are passive, lacking moisture balance, infection control, or regenerative stimulation [12]. Polymeric biomaterials act as barriers, moisture regulators, scaffolds, and drug carriers[13]. Natural polymers (alginate, chitosan, collagen, gelatin, hyaluronic acid) provide bioactivity and ECM mimicry; synthetic polymers (PCL, PLGA, PEG, PVA) offer strength and controlled degradation. Combining them creates multifunctional dressings[14].

They can form hydrogels, films, foams, nanofibrous mats, and composites that maintain moisture, absorb exudate, allow oxygen exchange, and deliver therapeutics. Smart dressings with antimicrobial, self-healing, and stimuli-responsive properties enhance healing [15]. Polymeric biomaterials are a key platform in advanced wound care, improving outcomes in acute and chronic wounds.

WOUND HEALING AND ITS TYPES

Wound healing is the process through which the body is known to recover the damaged tissue and restore it back to its normality. Various cells and tissue matter collaborate towards restoration of the balance caused by affliction. Harms can happen because of accidents, surgical operations, burns or illness and one must recover to live. The body decreases the chances of being infected, and it is healthy through the closing of the injury [16] A wound has been defined as any injury that results in damage or disruption in the normal structure and functioning of the body [17].

TYPES OF WOUND HEALING

There are various criteria that can be used to classify wounds;

Acute wound

Acute wounds are injuries that heal in a predictable and orderly manner with proper care. They often result from surgeries, accidents, or burns, and typically heal within a few weeks. The healing process usually takes anywhere from 5 to 10 days, but in some cases, it may take up to 30 days, ultimately restoring the tissue to its normal state [18].

Chronic wound

Chronic wounds heal slowly and may remain open for months or years due to factors like infection, poor circulation, repeated injury, or conditions such as diabetes. They do not follow normal healing stages and require specialized care. Common examples include pressure sores, venous ulcers, and diabetic foot wounds [17]

Healing may be delayed or incomplete due to infection, poor oxygen supply, tissue necrosis, excess fluid, and high inflammatory cytokines, which disrupt inflammation and tissue repair [19]. Causes include pressure, arterial and venous insufficiency, burns, vasculitis, and naturopathic conditions [20,21]

WOUND HEALING PROCESS

Wound healing is a complicated biological process through which the body repairs damaged tissue and restores its normal structure and function. This process usually progresses through four key stages: Haemostasis, Inflammation, Proliferation, and Tissue remodeling [22].

Table:1. Stages of Wound Healing [23,24]

Stages	Durations	Processes	Cell involved	Functions
Haemostasis	Few seconds after injury	• Vaso constriction • Platelet aggregation • Fibrin clot formation	Platelets	• Stops bleeding • Temporary framework development • Cell migration
Inflammation	0-3 Days	• Removal of bacteria & debris • Discharge of signal chemicals	Neutrophils, Macrophages	• Cleaning of the wound site • Start of the healing or repair process
Proliferation	3-12 Days	• Collagen formation • Angiogenesis • Re-epithelialization	Fibroblasts, Endothelial cells, Keratinocytes	• Formation of granulation tissue or new tissue
Tissue remodeling	6-24 months	• Collagen reorganization • Type III - Type I collagen • Wound contraction	Myofibroblasts	• Increased tissue strength • Final scar tissue formation

POLYMERIC BIOMATERIALS

Polymeric biomaterials are macromolecular materials created by repeating structural units designed to interact with biological tissues in a deliberate and controlled way. They are used in wound healing as dressings, scaffolds, hydrogels, films, or drug-delivery systems that support the healing process, shield the wound from external infections, and regulate the microenvironment healing. Their physicochemical properties can be tailored to achieve optimal biocompatibility, biodegradability, moisture regulation, and mechanical stability, making them essential in modern wound care approaches [25,26].

CLASSIFICATIONS OF POLYEMRIC BIOMATERIALS

Wound-healing polymeric biomaterials can be further classified into natural and synthetic polymers, each possessing its advantages and disadvantages.

NATURAL POLYMERS

Natural polymers are derived from biological sources such as microorganisms, plants, and animals. Their biodegradability, biocompatibility, and biological activity make them suitable for medical applications. Due to their similarity to the extracellular matrix, they show strong biological recognition and effective interaction with tissues [27,28].

Collagen:

The primary structural protein of the skin, collagen provides mechanical strength and supports cell adhesion, migration, and tissue formation during wound healing [29]. Collagen-based dressings act as ECM-like scaffolds, promoting fibroblast attachment, granulation tissue formation, and faster wound closure [30]. It is biodegradable and biologically active, enabling seamless integration without adverse reactions [31].

Chitosan: A natural polysaccharide derived from chitin (from crustacean shells and fungi) with antimicrobial and hemostatic properties, useful in preventing infection and controlling bleeding [32]. It promotes wound healing by enhancing cell proliferation and clot formation, while its similarity to the extracellular matrix supports cell attachment and tissue regeneration. However, it has limited solubility at neutral pH, restricting its use unless modified or combined with other polymers [33].

Alginate: A naturally derived polysaccharide from brown seaweed with high fluid absorption capacity. It forms a gel in contact with wound exudate, maintaining a moist environment that promotes epithelial migration and reduces infection risk. It is especially suitable for wounds with moderate to heavy exudate [32–36].

Hyaluronic acid: It is a naturally occurring glycosaminoglycan found in the extracellular matrix of skin. It regulates inflammation and supports angiogenesis during wound healing. By promoting cell migration and proliferation, it aids tissue remodeling, particularly in early stages. Its hydrophilic nature helps maintain tissue hydration, enhancing regeneration [27,32,37,38].

Gelatin: It is obtained by partial hydrolysis of collagen, retains its beneficial biological properties. It promotes cell adhesion, proliferation, and differentiation, making it suitable for wound healing scaffolds and hydrogels. Its biodegradability and ease of modification enable widespread use in advanced wound dressings and tissue engineering systems [39,40].

SYNTHETIC POLYMERS

Synthetic polymers are widely used in wound healing applications due to their reproducible properties, structural stability, and ease of modification. Unlike natural polymers, synthetic materials can be precisely engineered to achieve desired mechanical strength, degradation rates, and functional performance, making them highly suitable for advanced wound dressings and tissue engineering systems [30].

Polyvinyl alcohol (PVA): A hydrophilic synthetic polymer used in wound dressings and hydrogels that retains water to maintain a moist environment, promoting epithelial regeneration and reducing discomfort. It also offers flexibility and good film-forming properties for protective coverings [41].

Polyvinylpyrrolidone (PVP): It is a water-soluble, biocompatible, and chemically stable polymer, often blended to enhance mechanical properties and drug-loading. In wound healing, it aids moisture retention and controlled drug release [30,42].

Polyurethane (PU): It has excellent elasticity, durability, and gas permeability. PU dressings protect wounds, allow oxygen diffusion, prevent bacterial infiltration, and improve comfort by adapting to irregular surfaces [26,43].

Polylactic acid (PLA) and polyglycolic acid (PGA): They are biodegradable aliphatic polyesters used in tissue engineering scaffolds, degrading into non-toxic by-products and providing temporary support for cell attachment and regeneration. Their copolymer, PLGA, enables controlled degradation and is widely used for drug delivery and sustained release in wound healing [26–30,41].

Polycaprolactone (PCL): It is a slowly degrading synthetic polymer with high mechanical strength. It is often used in electro spun nanofibrous scaffolds that mimic the extracellular matrix, thereby promoting cell adhesion and long-term tissue support [44,45].

Polyethylene glycol (PEG): A highly biocompatible polymer used in hydrogels that enhances hydration, reduces protein adsorption, and improves healing when combined with bioactive agents [30,41–45].

POLYMERIC WOUND HEALINGS

Polymers play a crucial role in wound healing, as they are essential for preparing advanced dressings, drug delivery systems, and tissue scaffolds that provide a humid, protective environment. This environment promotes cell growth and tissue repair, while also preventing infection. Natural (collagen, chitosan) and synthetic (PLGA, PVA) polymers are utilized, which offer advantages such as controlled drug release and the ability to adjust mechanical properties. Hydrogels regulate the exudate, and biopolymers replicate the extracellular matrix of the body [46,47].

TYPES OF POLYMERIC MATRICES IN WOUND HEALINGS

Hydrogels: Hydrogels are cross-linked polymers with high water content that maintain a moist, well-ventilated wound environment, enhancing comfort, tissue repair, and protection against microbes [48]. They provide a cooling effect, reduce pain, and support cell migration, proliferation, and epithelial regeneration. Their porous structure aids oxygen and nutrient diffusion, while low adhesion minimizes tissue damage during removal. However, due to low mechanical strength in the swollen state, they are often reinforced for improved durability [49–51].

Films and Membranes: Polymeric films and membranes are thin, flexible, adhesive coverings that protect wounds. Their semi-permeable nature allows oxygen and water vapour exchange while preventing fluid loss and microbial entry, maintaining an optimal healing environment [52–55]. They are transparent for easy wound monitoring and conform well to irregular surfaces [55,56]. However, due to low absorption capacity, they are best suited for low-exudate wounds or as outer layers in composite dressings [56–58].

Foam dressings: Foam dressings are porous, three-dimensional polymeric matrices with interconnected pores that enable efficient absorption and retention of wound exudate. This helps maintain optimal moisture balance, preventing both dehydration and maceration, thereby supporting a favorable healing environment[59,60]. Their porosity also allows gas exchange, promoting oxygen diffusion essential for tissue regeneration. Additionally, they provide thermal insulation and cushioning, protecting the wound from temperature fluctuations and mechanical stress[60,61]. Foam dressings are soft, flexible, and comfortable for long-term use. They can be modified with bioactive or antimicrobial agents to enhance protection, reduce infection risk, and improve healing outcomes.[61–63]

Nanofibers: Nanofiber-based wound dressings consist of ultrafine polymer fibers produced by techniques like electrospinning [64]. They form highly porous networks resembling the extracellular matrix, promoting cell attachment, migration, and proliferation. Their high surface area supports gas exchange, nutrient diffusion, and acts as a barrier to microbes.

They can be made from natural or synthetic polymers and are often used in advanced dressings. Due to low mechanical strength, they are usually combined into composite systems for better handling [65,66].

Composite Dressings: Composite polymeric dressings combine two or more polymer matrices to achieve synergistic effects, integrating properties like moisture retention, and absorption[67].

They offer improved stability, moisture control, and protection, making them effective for complex and chronic wounds by better mimicking the wound environment [68].

Other scaffolds

- Sponges are three-dimensional scaffolds with a highly porous architecture that enables efficient absorption of wound exudate while permitting oxygen transport and cellular infiltration [66].
- Fibrous scaffolds including microfibrous and nonwoven matrices, provide structural reinforcement and function as temporary frameworks that support cell adhesion and migration, making them particularly useful for treating deep or uneven wound surfaces.[67]
- Three-dimensional porous polymeric scaffolds commonly fabricated through methods such as freeze-drying, provide a mechanically stable structure that encourages cell proliferation and extracellular matrix formation.[68]
- Multilayer electrospun scaffolds are engineered to replicate the stratified architecture of skin by integrating barrier protection with extracellular matrix–like fibrous layers[67,69].
- Biopolymer-based scaffolds derived from natural polymers such as collagen, chitosan, and alginate exhibit excellent biocompatibility and biodegradability[68].
- Hybrid or reinforced scaffolds created by combining multiple polymeric systems, are designed to improve mechanical integrity, regulate moisture levels, and enhance overall wound healing efficiency.[66,67]

MECHANISM OF ACTION OF POLYMERIC BIOMATERIALS

Regulated release of therapeutic agents

Polymeric biomaterials are widely used in wound healing as drug delivery systems, enabling controlled and sustained release of therapeutic agents (e.g., antibiotics, anti-inflammatories, growth factors) through tailored polymer networks. This enhances local drug exposure and reduces systemic toxicity. Advanced systems can also respond to wound stimuli (e.g., pH, enzymes) for targeted drug release, especially in chronic and infected wounds [70,71].

Moisture retention at the wound site

A moist wound environment, maintained by polymeric biomaterials like hydrogels, supports healing by preventing drying and promoting cell growth and migration. Hydrophilic polymers absorb exudate and retain moisture, mimicking the extracellular matrix, reducing inflammation and scab formation, and enhancing re-epithelialization and collagen synthesis. Hydrogels (>90% water) also allow gas exchange and nutrient diffusion [72,73].

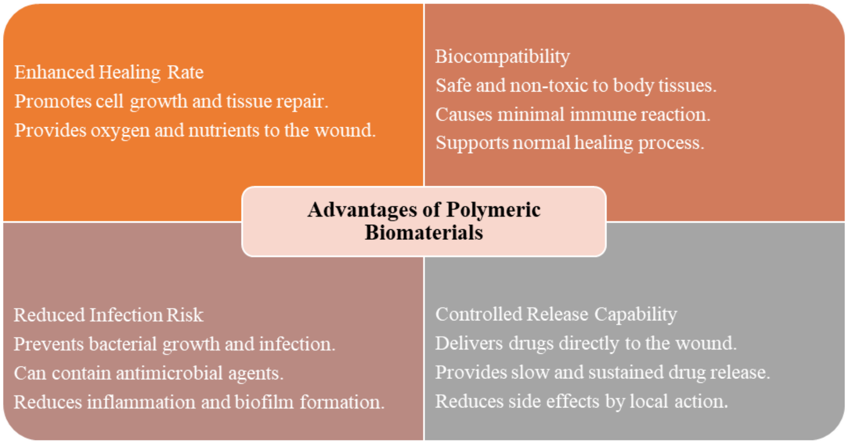
Enhancement of cell movement and tissue repair

Wound healing occurs in a way in which not only is the wound covered, but also new tissue is formed through various cell behaviors in coordination with each other. Polymeric material contributes to this in various ways: ECM-mimicking scaffolds, Biochemical Cues, Porosity degradation 71,74].

Prevention of microbial infection

Infection delays wound healing by prolonging inflammation and causing tissue damage [75–77]Polymeric biomaterials help control infection through:

- Intrinsic antimicrobial activity
- Drug delivery (e.g., antibiotics, silver nanoparticles)
- Barrier action



Enhanced Healing Rate
Promotes cell growth and tissue repair.
Provides oxygen and nutrients to the wound.

Biocompatibility
Safe and non-toxic to body tissues.
Causes minimal immune reaction.
Supports normal healing process.

Advantages of Polymeric Biomaterials

Reduced Infection Risk
Prevents bacterial growth and infection.
Can contain antimicrobial agents.
Reduces inflammation and biofilm formation.

Controlled Release Capability
Delivers drugs directly to the wound.
Provides slow and sustained drug release.
Reduces side effects by local action.

Fig. 1: ADVANTAGES OF POLYMERIC BIOMATERIALS

LIMITATIONS

Drug delivery systems and implantation devices have been around since polymeric biomaterials, both natural and synthetic, have become key elements in the biomedical sphere. Nonetheless, these materials face several practical and scientific constraints that limit their performance and large-scale application despite their versatility and growing clinical adoption.

Stability Issues

Chemical and physical stability—including thermal, hydrolytic, and mechanical—is crucial for long-term in vivo use. Biodegradable polymers like PGA, PLA, and PLGA can degrade prematurely, losing mechanical support before tissue regeneration [78–80]. Natural polymers such as collagen or fibrin may denature under physiological or sterilization conditions, causing unpredictable performance [81].

High Cost

The high cost of producing high-performance polymeric biomaterials, due to complex purification, functionalization, sterile processing, and regulatory requirements, remains a major barrier to clinical adoption, especially in resource-limited settings (82,83].

Limited Mechanical Strength

A major limitation of natural and some biodegradable polymers is low mechanical strength. Natural polymers like gelatin, alginate, and hyaluronic acid have low tensile and compressive strength, making them unsuitable for load-bearing applications without reinforcement [84,85]. Certain synthetic biodegradable polymers, such as PLA, are brittle and have low elongation, limiting their use where elasticity is required.[86,87] These issues are addressed by composites, combining natural polymers with ceramics or fillers to enhance mechanical properties.

Risk of Allergic

Natural polymers are generally biocompatible and mimic the extracellular matrix. However, allo- or Xeno-derived polymers, such as animal collagen or fibrin, may trigger immune or inflammatory responses.[87] Trace impurities or microbial contaminants can also stimulate immunity, making careful purification and quality control essential[88,89]. Individual variations in immune response further complicate biocompatibility prediction, regulatory approval, and clinical use.

RECENT ADVANCES IN POLYMERIC WOUND HEALINGS TECHNOLOGIES

Polymeric biomaterials have revolutionized wound management. Unlike traditional dressings that only protect tissue, modern polymer-based systems actively modulate biological responses. Advances in polymer chemistry and fabrication have enabled smart, bioactive, and stimuli-responsive dressings that monitor wound status, deliver therapeutics in a controlled manner, and stimulate tissue regeneration, particularly benefiting chronic and complex wounds with infection, inflammation, and delayed healing.[90,91]

Nanotechnology-Based Polymeric Dressings

Nanotechnology improves polymeric wound dressings by enhancing precision and functionality. Electro spun nanofibrous mats mimic the ECM, offering high surface area, porosity, and promoting cell attachment and tissue regeneration[92]. Incorporating metallic nanoparticles provides broad-spectrum antibacterial activity with sustained effect and reduced cytotoxicity [93]. Polymeric nanogels and nano capsules enable targeted, stimuli-responsive drug delivery with deeper tissue penetration [94].

Drug-Loaded Polymeric Systems

Topical drug delivery remains vital in wound care, with polymeric systems enabling prolonged, targeted delivery and reduced systemic side effects. Hydrogels, due to their 3D hydrophilic networks, maintain a moist healing environment, with tunable mechanical strength and drug release via cross-linking and degradation control.[95] Polymeric films, membranes, microcarriers, and nanoparticles also provide controlled drug diffusion.[96] Sustained antimicrobial release limits infection and biofilms, while controlled anti-inflammatory delivery reduces tissue damage. Growth factors like PDGF and VEGF enhance angiogenesis and re-epithelialization, accelerating healing[97].

Smart Wound Dressings

Smart wound dressings are advanced systems that respond to the wound environment and monitor changes. They detect infection-related factors like increased pH and temperature using sensors or responsive polymers.[98] These dressings enable controlled drug release, delivering antimicrobial or anti-inflammatory agents in response to specific biochemical signals, minimizing damage to healthy tissue. [99] Some incorporate wearable sensors or flexible electronics for real-time monitoring of chronic wounds such as diabetic foot ulcers.[100] Overall, they enhance infection control, accelerate healing, and reduce dressing frequency.

Bioactive Polymeric Scaffolds

Bioactive polymeric scaffolds are promising in regenerative wound therapy as they act as 3D matrices that guide tissue formation, unlike conventional dressings. Natural polymers (e.g., collagen, chitosan, alginate) offer biocompatibility and ECM similarity, while synthetic biodegradable polymers provide tunable properties and controlled degradation [101].

Advanced techniques like electrospinning and additive manufacturing ensure optimal architecture, porosity, and strength for proper oxygen, nutrient flow, and cell infiltration[102]. Functionalization with peptides or growth factors enhances cell activity, and controlled degradation supports organized healing with minimal scarring[103].

APPLICATIONS OF POLYMERIC BIOMATERIALS

Acute Wound Management

Polymeric biomaterials are used in acute wounds (surgical incisions, abrasions, trauma) to maintain moisture, improve oxygen permeability, and reduce microbial load. Nanofibrous scaffolds made from polymers like PCL, PU, and PLGA enhance epithelialization and collagen production [104,105]. Hydrogel dressings promote rapid hemostasis and tissue coverage. Their high-water content helps absorb exudate and maintain hydration, improving healing compared to traditional gauze dressings [106].

Chronic Wounds and Diabetic Ulcers

Chronic wounds such as diabetic foot and pressure ulcers are difficult to treat due to persistent inflammation and poor angiogenesis. Composite scaffolds and polymeric hydrogels enable sustained local delivery of antibiotics, anti-inflammatory agents, and growth factors.[107,108] Injectable biodegradable hydrogels promote fibroblast growth, angiogenesis, and collagen formation in diabetic wounds.[108] Additionally, multifunctional polymer systems regulate oxidative stress and enhance vascularization to improve healing.[106,109]

Burn Wound Treatment

Burn patients require dressings that provide thermal insulation, prevent dehydration, and reduce infection. Composite scaffolds combining natural[collagen, chitosan] and synthetic polymers offer improved mechanical strength and biocompatibility.[104] Nanocomposite polymeric materials show enhanced antimicrobial activity and re-epithelialization, promoting dermal regeneration and reducing scarring. [109]

Drug and Growth Factor Delivery

Polymeric dressings act as active therapeutic systems, enabling controlled and sustained release of bioactive molecules such as VEGF, EGF, and PDGF.[110] Stimuli-responsive hydrogels deliver drugs in response to pH, temperature, or bacterial enzymes, improving targeted treatment efficacy and reducing side effects.[110,111]

Tissue Engineering and Skin Substitutes

Polymeric biomaterials play a key role in tissue engineering and skin substitutes. Electro spun 3D porous scaffolds mimic the ECM and support cell adhesion, proliferation, and differentiation[105]. Advances in 3D bioprinting enable the fabrication of multilayered skin constructs using polymer-based bio-inks. [112] These engineered meshes promote skin and dermal regeneration and are promising for full-thickness wounds and large burns.

FUTURE PROSPECTS OF POLYMERIC BIOMATERIALS

Personalized and Precision Wound Care

Wound management is evolving toward personalized treatments using tailored polymeric scaffolds for specific conditions like diabetic and geriatric wounds. Smart bandages with biosensors enable real-time monitoring and adjustment of therapy[113].

Smart and Stimuli-Responsive Dressings

New-generation polymeric dressings can detect changes in pH, enzymes, or temperature to indicate infection and trigger controlled release of antimicrobial or anti-inflammatory agents[110,111]. This reduces treatment time and complications.

Nanotechnology and Multifunctional Systems

Nanotechnology enhances surface area, mechanical strength, and antimicrobial activity of polymeric scaffolds. Nanofiber dressings and nanoparticle-loaded hydrogels show superior performance in treating infected and chronic wounds.[109–111] Future multifunctional scaffolds aim to combine antimicrobial, antioxidant, angiogenic, and anti-inflammatory properties in a single system.

Stem Cell and Regenerative Approaches

Stem cell-loaded polymeric scaffolds are an emerging area in the field of regenerative medicine. These scaffolds induce angiogenesis and tissue remodelling by paracrine signalling pathways [113]. Further studies may help in faster and scarless healing in complicated cases of wounds.

Clinical Translation and Commercialisation

Although laboratory results are promising, challenges such as large-scale production, regulatory approval, cost-effectiveness, and long-term safety remain. The success of polymeric wound healing systems depends on translational research addressing regulatory and commercial viability (112].

CONCLUSION

Polymeric biomaterials in wound management have proved to be a significant component of complex wound management, as they can actively participate in the biological and architectural processes involved in tissue repair. Contemporary wound dressings, which are polymer-based can be programmed to react to the wound microenvironment, as opposed to conventional dressings, which merely provide barriers to healing and retard wound complications.

Natural polymers, such as chitosan, alginate, collagen, hyaluronic acid and gelatin are the most similar polymers to the extracellular matrix (ECM), and are linked to cellular adhesion, cellular migration and cellular proliferation, which are all essential in re-epithelialization and remodelling of tissues. They are compatible with biological systems and degradable; therefore, they can be used in both acute and chronic wounds. However, natural polymers may not be as strong in mechanical properties and have controlled degradation properties. To correct these defects, synthetic polymers such as polycaprolactone (PCL), polyethylene glycol (PEG) and polylactic acid (PLA) are usually incorporated into the composite scaffolds, which enhance the structural stability and the tunable drug release behaviour.

Hydrogel system-based polymeric systems have been well reported in maintaining a wet wound, sucking up exudates as well as carrying antimicrobial agents or growth factors during a sustained treatment. Hydrogel dressings have an excellent impact on angiogenesis, inflammation and scar development compared to the traditional gauze treatment. Moreover, electrospinning-built nano-fibrous polymer scaffolds mimic the natural arrangement of the skin ECM, hence allowing the settling of fibroblasts and accelerating the development of a granulation tissue.

Chronic wounds such as diabetic ulcers and pressure sores pose a significant clinical problem because of continued inflammation and infection. Polymeric biomaterials deal with them by providing controlled delivery systems of drugs, anti-inflammatories, and bioactive molecules, which can be delivered directly to the wound site. Stimuli-responsive and smart polymer systems responding to pH, temperature, or changes in enzymes are also capable of increasing the therapeutic precision and minimizing systemic side effects, as well as enhancing patient outcomes.

To conclude, polymeric biomaterials have a revolutionary role in wound healing since they offer a combination of structural and biological functionality. Modulation of inflammation, improvement of angiogenesis, stimulation of cell proliferation, and local delivery of drugs make them very useful in increasing the healing rates and general tissue regeneration. Further optimization of these systems through continued interdisciplinary studies involving materials science, nanotechnology and regenerative medicine is predicted to further streamline these systems, as a step toward more personalized and effective wound care approaches.

List Of Abbreviations:

Abbreviation	Full Form
ECM	Extracellular Matrix
ADME	Absorption, Distribution, Metabolism, and Excretion
PVA	Polyvinyl Alcohol
PVP	Polyvinylpyrrolidone
PU	Polyurethane
PLA	Polylactic Acid
PGA	Polyglycolic Acid
PLGA	Poly (lactic-co-glycolic acid)
PCL	Polycaprolactone
PEG	Polyethylene Glycol
PDGF	Platelet-Derived Growth Factor
VEGF	Vascular Endothelial Growth Factor
EGF	Epidermal Growth Factor
ROS	Reactive Oxygen Species
ECM-like	Extracellular Matrix-like
3D	Three-Dimensional

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