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Review

Application of advanced and smart wound dressings in acute and chronic wound management

Aplicação de curativos avançados e inteligentes no manejo de feridas agudas e crônicas
Aplicación de apósitos avanzados e inteligentes para el tratamiento de heridas agudas y crónicas

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Abstract
Objective: To present modern and smart dressings used in the treatment of different types of wounds by analyzing the types of materials, their structure, mechanisms of action, functional properties, advantages, disadvantages, and the presentation of current research that points to their potential to improve the healing process. **Methods:** A search of Google Scholar and relevant databases, including ScienceDirect, Scopus, and MEDLINE (PubMed), was conducted to identify a large number of peer-reviewed articles. **Results:** Modern and smart wound dressings represent a significant shift in healthcare, offering numerous advantages over conventional methods. The advancement of modern therapeutic options presents a wide range of opportunities for developing a personalized approach to wound healing. **Conclusion:** A multidisciplinary approach and close collaboration between physicians, nurses, and biomedical engineers are the foundation for the future development of personalized therapeutic modalities for different types of acute and chronic wounds.

Descriptors: Wounds; Wound Healing; Wound Dressings.

Whats is already known on this?
Current literature confirms that advanced and smart wound dressings create an optimal microenvironment, reduce the risk of infections, and promote functional wound healing compared to traditional methods.

What this study adds?
This article provides an overview of modern and smart wound dressings, their types, mechanisms of action, advantages, and limitations, highlighting their potential for personalized therapy of acute and chronic wounds.

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Resumo
Objetivo: *Apresentar curativos modernos e inteligentes utilizados no tratamento de diferentes tipos de feridas, analisando os tipos de materiais, sua estrutura, mecanismos de ação, propriedades funcionais, vantagens, desvantagens e a apresentação de pesquisas atuais que apontam para seu potencial de melhorar o processo de cicatrização.* ***Métodos:*** *Foi realizada uma busca no Google Acadêmico e em bases de dados relevantes, incluindo ScienceDirect, Scopus e MEDLINE (PubMed), para identificar um grande número de artigos revisados por pares.* ***Resultados:*** *Os curativos modernos e inteligentes representam uma mudança significativa na área da saúde, oferecendo inúmeras vantagens em relação aos métodos convencionais. O avanço das opções terapêuticas modernas apresenta uma ampla gama de oportunidades para o desenvolvimento de uma abordagem personalizada para a cicatrização de feridas.* ***Conclusão:*** *Uma abordagem multidisciplinar e uma estreita colaboração entre médicos, enfermeiros e engenheiros biomédicos são a base para o futuro desenvolvimento de modalidades terapêuticas personalizadas para diferentes tipos de feridas agudas e crônicas.*

Descritores: *Feridas; Cicatrização de Feridas; Curativos.*

Resumén
Objetivo: *Presentar apósitos modernos e inteligentes utilizados en el tratamiento de diferentes tipos de heridas mediante el análisis de los tipos de materiales, su estructura, mecanismos de acción, propiedades funcionales, ventajas y desventajas, y la presentación de investigaciones actuales que demuestran su potencial para mejorar el proceso de cicatrización.* ***Métodos:*** *Se realizó una búsqueda en Google Académico y bases de datos relevantes, como ScienceDirect, Scopus y MEDLINE (PubMed), para identificar un gran número de artículos revisados por pares.* ***Resultados:*** *Los apósitos modernos e inteligentes representan un cambio significativo en la atención médica, ofreciendo numerosas ventajas sobre los métodos convencionales. El avance de las opciones terapéuticas modernas presenta una amplia gama de oportunidades para desarrollar un enfoque personalizado para la cicatrización de heridas.* ***Conclusión:*** *Un enfoque multidisciplinario y una estrecha colaboración entre médicos, enfermeras e ingenieros biomédicos son la base para el desarrollo futuro de modalidades terapéuticas personalizadas para diferentes tipos de heridas agudas y crónicas.*

Descriptores*: Heridas; Cicatrización de Heridas; Apósitos.*

INTRODUCTION

A wound is the result of a disruption of the anatomical, functional, and cellular characteristics of the integrity of living tissue.[1]

Wounds are generally classified as acute or chronic. This classification is primarily based on the speed of the healing process. An acute wound refers to skin damage that typically resolves completely within an expected timeframe, which varies according to the wound depth, size, and severity. Common sources of acute wounds include mechanical trauma, as well as exposure to radiation, electrical currents, corrosive chemicals, heat, or blister-forming skin disorders. A chronic wound is one that fails to heal promptly and is often prone to recurrence.[2]

It is estimated that 25–50% of patients have or develop wounds during hospitalization, with a high risk of infection.[3] The healing process can be compromised due to a weakened immune system or the complexity of the wound, indicating the importance of proper wound care.[4]

Wound dressings are used to protect the skin's damaged area and stimulate the healing process by directly interacting with the wound, making the choice of the appropriate material fundamental to effective healing.[5] In modern literature, it is emphasized that the ideal dressing should create a barrier against external influences, provide appropriate conditions (temperature, optimal humidity, slightly acidic pH, and gas exchange), absorb excess exudate, keep the wound clean by removing necrotic tissue and toxins, and prevent adhesion. The dressing must be safe and not cause local irritation and hypersensitivity.[4, 6, 7] In addition, maintaining a humid environment and facilitating gas exchange are crucial abilities of modern dressings, as they enable optimal enzyme activity, epidermal growth factor function, and collagen deposition, all of which contribute to tissue regeneration.[8–10]

Traditional dressings have been used for years, but they stick to the wound and do not create an optimal microenvironment. Modern dressings are characterized by greatly improved biocompatibility, degradability, moisture retention, the ability to relieve pain, and functional wound healing promotion.[11] However, there is still no consensus on the selection of appropriate dressings based on the type of wound and patients' individual characteristics.

It cannot be said whether the care of surgical wounds that heal by primary intention with modern dressings reduces the risk of surgical site infections or whether a particular dressing is more acceptable for patients and superior in terms of scar reduction, pain relief or ease of removal.[12] It is also unclear which dressings or topical agents have the greatest advantage in treating wounds that heal with secondary intention or have a greater amount of exudate.[8, 13] This is particularly evident in pressure injury management.[14, 15]

The clinical application of wound dressings remains limited by the lack of standardized protocols and the heterogeneity of available materials across healthcare systems. [16]

The rapid development of numerous advanced bioengineered solutions underscores the need to review current evidence to systematize existing knowledge and enable the formulation of targeted recommendations for clinical practice.

Therefore, this review aimed to present modern and smart dressings used in the treatment of different types of wounds by analyzing the types of materials, their structure, mechanisms of action, functional properties, advantages, and disadvantages, and the presentation of current research that points to their potential to improve the healing process.

METHODS

This study is a narrative review. A literature search was conducted by two researchers in June 2025 within Google Scholar and relevant databases, including ScienceDirect, Scopus, and MEDLINE (PubMed), to identify a large number of peer-reviewed articles on wound dressings.

The literature search was conducted using the keywords "wounds", "wound healing", and "wound dressings", with additional specific descriptors such as "traditional dressings", "standard dressings", "gauze", "bandage", "advanced dressings", "bioengineered dressings", "hydrogel", "hydrocolloid", "alginate dressing", "foam", "film", "nanofiber", "bioactive electrospun dressing", "3D-printed", and "smart or multifunctional wound dressings", including "sensor-integrated" and "responsive" types.

Inclusion criteria: original research articles; articles published in english; articles published from 2020 to 2025; studies analyzing traditional, advanced, or smart wound dressings; and studies analyzing structure, materials, mechanisms of action, or clinical effectiveness of various types of wound dressings. Exclusion criteria: letters to the editor; conference abstracts; case reports; review articles (systematic or narrative); non-peer-reviewed publications; and studies not directly related to wound dressings or wound healing processes.

The initial search yielded 3,550 abstracts, of which 39 articles were relevant to the scope of the present article. Two references from wound dressings manufacturers' websites were consulted to complement the analysis. Any disagreements between the two researchers during the selection process were resolved through discussion.

Ethical approval was not required as the study analyzed previously published articles.

RESULTS

Overview of modern wound dressings

Modern wound dressings consist of natural or synthetic polymers and are classified according to their function as interactive, advanced interactive, and bioactive.[5] Common types of modern dressings are presented below.

Hydrogel wound dressings

Hydrogels are polymeric materials that are widely used in drug release and cell cultures, as well as in the engineering of skin, blood vessels, muscle, and smooth tissue. Hydrogels are moist, non-toxic, and non-sticky, which help keep the wound hydrated, oxygenated, and reduce pain. Recently, they have been developed with self-renewal capacity and antimicrobial properties, due to the poor mechanical resistance and tendency to pressure damage present in earlier designs.[17] For instance, Ghasemi *et al*.[18] have developed biocompatible hydrogel coatings with natural polymers chitosan and sodium alginate, with the addition of silica-stabilized silver nanoparticles to obtain antibacterial properties. The therapeutic effect is facilitated by calendula extract integration.

Foam wound dressings

Foam dressings have an outer layer that stops the penetration of moisture and microorganisms and an inner layer, which absorbs exudate. Polyurethane foams can be used with hydrofibers that form a gel in contact with moisture. Foam dressings reduce pain and the risk of bruising when removed, and can contain silver as an antimicrobial agent.[17] Kim *et al*.[19] created composite polyurethane foams by integrating sodium hydroxide-treated diatomaceous soil. The resulting material showed excellent liquid absorption compared to conventional polyurethane foams. Experiments on animal models have shown faster epidermal regeneration and collagen deposition compared to standard polyurethane foam, emphasizing the potential of this foam dressing for use in tissue engineering and regenerative medicine.

Film wound dressings

Modern film dressings are made of a transparent polyurethane membrane with an adhesive surface, with selective permeability.[17]. One of the many novel approaches in the development of film dressings is reflected in the use of chitosan carbonate (CS-CO_2). Long *et al*.[20] presented a film dressing based on CS-CO_2 that forms at normal pressure, without requiring cytotoxic solvents. In animal models of full-thickness skin, the film allowed the wound to fully heal with the formation of hair follicles within ten days, outperforming the effectiveness of some commercial dressings. Moreover, this film is characterized by pronounced antibacterial properties and non-toxicity, which makes it a multifunctional solution that combines biocompatibility, water resistance, and active healing functions.

Sponge wound dressings

Sponge dressings are flexible and their structure allows them to adhere strongly to the wound and to have hemostatic action, without the need for additional fixation. They can have natural (collagen) or synthetic origin (cellulose derivatives). The disadvantages of sponge dressings include the possibility of the appearance of skin lesions in the wound area, instability, and the development of infection in the absence of antibiotics.[17] Huang *et al*.[21] made pure chitosan sponges using the freeze-thaw method, obviating the necessity for freeze-drying and the use of organic solvents. The chitosan sponge demonstrated excellent mechanical strength, biocompatibility, and accelerated wound healing in Sprague Dawley rat models. This method has great potential for widespread application in the field of tissue engineering due to its scalability, environmental sustainability, and minimal technical requirements.

Nanofibers/nanocomposites

Nanofibers are produced using the electrospinning technique and mimic the structure of the extracellular matrix, making them appropriate for wound healing. They have a large surface area and porosity, allowing the incorporation of drugs, proteins, hormones, and plant extracts. Natural (chitin, collagen, gelatin, silk) and synthetic polymers (polylactic acid, polycaprolactone) are used.[17] Zhao *et al*.[22] developed a triple composite dressing with an asymmetrical moisture structure to accelerate wound healing and reduce the risk of hypertrophic scarring.

This dressing is made using the electrospinning method. It consists of a hydrophobic inner layer containing aligned polylactic acid nanofibers and retinoic acid. There is also a silk fibroin transition layer and an outer hydrophilic layer made of lyophilized cotton wool. The transition layer connects the outer and inner layers, allowing for a gradual gradient of humidity and effective evacuation of fluid from the wound surface. These properties make the dressing suitable for maintaining an optimally moist microenvironment, which promotes tissue regeneration and reduces the risk of infections. *In vitro* studies have shown improved fluid flow and adequate cellular responses, while *in vivo* tests in burn and hypertrophic scar models have shown faster wound healing and significantly reduced scar formation.

Three-dimensional (3D) printed wound dressings

3D printing makes it possible to create custom scaffolds with a precisely defined architecture, aligned with wound characteristics. Shahroudi *et al*.[23] recently introduced functional porous dressings for chronic wound treatment, combining chitosan, alginate, vancomycin, and cerium oxide nanoparticles with the help of 3D printing. The alginate layer with vancomycin breaks down quickly and allows the rapid release of antibiotics, which is useful for rapid antibacterial activity, especially against the bacteria that most often cause skin infections (*Staphylococcus aureus*).

The dressings were biocompatible, promoted cell growth and had an antibacterial effect against gram-positive bacteria. However, Yusakul *et al*.[24] made mixtures of hydrophobic deep eutectic solvents (HDES) and curcuminoids to create photo-cross-linked GelMA hydrogels used as dressings for chronic wounds. They improved the solubility of bioactive compounds and enabled their effective impregnation into a hydrogel by applying HDES solvents. This created a functional material for 3D-printed dressings with controlled drug release and prominent antibacterial properties.

Modern gauzes

Modern gauzes have been modified with the addition of polymers, nanoparticles, and plant extracts to improve their functionality. Sheng *et al*.[25] developed a multi-purpose zinc-based hemostatic dressing by applying metal-organic frameworks to the surface of medical gauze, using the layer-by-layer technique. This modified gauze showed excellent hemostatic properties in animal models, which is explained by the synergistic effects of Zn^{2+} ions, such as activation of coagulation, improved cell binding, and plasma-concentrating porosity of the material. Additionally, this dressing has antimicrobial activity and the ability to stimulate collagen production while maintaining biocompatibility.

Overview of smart wound dressings

In the last ten years, smart dressings have become a new method in the care of different types of wounds. Smart dressings interact with the patients' environment using built-in sensors and provide an adequate response to the wound's needs. They have the ability to monitor changes during all stages of wound healing, thus providing useful information that can influence the course of treatment.[5] Different types of smart dressings and their functional characteristics are described below.

Temperature-sensitive wound dressings

Temperature is an important parameter in the wound healing process, since it depends on various enzymatic and biochemical reactions that take place at the site of injury. Literature data indicate that the temperature of a normally healing wound is around 37.8°C, while an increase or decrease in temperature by 2.2°C can lead to worsening of the condition. A sudden rise in temperature in the area of a chronic wound is a sign of infection, while a local decrease in temperature indicates possible ischemia, which are serious obstacles to successful healing.[3, 26]

pH-reactive wound dressings

pH is one of the factors that has a major impact on the healing process in all four phases. Healthy skin has a pH that ranges between 4.5 and 6.5, while acute and chronic wounds have their own pH range. Due to microbial infection and alkaline byproduct formation, the wound's pH can rise to a value between 7 and 9.[3] Arafa *et al*.[27] developed a smart chitosan-based hydrogel dressing, enriched with red cabbage extract, which is a natural indicator that responds to changes in the wound's pH.

At the same time, this dressing provides protection and visual feedback on the healing process while delivering an appropriate therapeutic effect. It has shown good mechanical properties, high absorbency, and gradual release of active ingredients, thus providing a significant contribution to maintaining an optimal microenvironment for tissue regeneration. Elkenawy *et al*.[28] have introduced smart hydrogel compresses for burns, which reduce the frequency of bandaging and relieve pain.

They were made on the basis of silver-sulfadiazine and alginate and then treated with gamma rays in different doses (2.5, 5, and 10 kGy). The pigment prodigiosin obtained from the bacterium *Serratia marcescens* was responsible for staining silver sulphadiazine-alginate hydrogels with the aim of achieving the properties of pH indicators. Silver sulphadiazine-alginate hydrogel stained with prodigiosin leads to an effective release of the drug and also has great anti-inflammatory, antioxidant, and antibacterial properties.

Pressure-sensitive wound dressings

People with diabetic ulcers and pressure injuries need therapy to relieve pressure. Pressure is caused by friction, sudden movements, shear, and external load, which leads to disruption of circulation and tissue death and slows down the wound healing process. Patients with limited mobility or who are immobile are particularly prone to these complications. Dressings with pressure sensors make it much easier to monitor wound status.[3] Wang *et al*.[29] demonstrated a smart, multifunctional, textile-like gel dressing that can simultaneously treat infected wounds and monitor wound pressure changes.

It is effective in monitoring patients' position during treatment, thanks to its highly sensitive pressure detection, which avoids long-term compression injury. Polydopamine-silver-coated calcium phosphate nanoparticles and vascular endothelial growth factor were added to the gel. *In vitro* tests of antibacterial activity, cytocompatibility, capillary tube formation, and cell migration, as well as in vivo studies, have confirmed the antibacterial and therapeutic effect of the gel.

Moisture-sensitive wound dressings

The moisture level in the wound area is crucial at all stages of healing. Excessive moisture can lead to tissue maceration, and insufficient moisture can slow down the healing process by drying out the wound surface. A high degree of humidity most often occurs due to exudate, excessive sweating, urinary incontinence, or transepidermal water loss, which leads to frequent changes of dressings and possible skin damage. This is why dressings with sensors for real-time humidity monitoring have an advantage over conventional types.(3)

A dressing based on carbon nanotubes, graphene, and methacrylate gelatin was created by Li *et al*.(30) It is stretchy, conductive, breathable, and sensitive to moisture and has shown exceptional resistance to fluctuations in body temperature and humidity. The detection of strain and the presence of moisture on the wound was enabled by the integration of an electronic skin with a portable touch oscilloscope and a mobile phone, thus confirming the possibility of monitoring the degree of damage during healing process in animal models.

Drug-eluting wound dressings

Wound dressings that respond to environmental stimuli allow monitoring and controlled release of drugs at the wound site. Prolonged release can be achieved by incorporating drugs into dressing layers, with hydrogels being the most researched and used for this purpose.(3) Hosseini *et al*.(31) have designed smart dressings suitable for burns and diabetic wounds by combining polyvinyl alcohol nanofibers with chitosan nanoparticles and a graphene oxide-magnetite nanocomposite enriched with tetracycline hydrochloride. These dressings have several qualities: rapid drug release, high absorbency, low degradability, antimicrobial activity, and biocompatibility.

Currently, available wound dressings can be divided into traditional/passive, interactive, bioactive, and skin substituents based on their function.(32)

Chart 1 shows the most commonly used commercial dressings in practice, experimental and clinical research.

Chart 1. Most commonly used modern commercial wound dressings. Novi Sad, Serbia, 2025.

Name	Type/composition	Mechanism of action	Advantages	Disadvantages	Indications	Note	References
Passive wound dressings							
Mepore®	Self-adhesive non-woven adhesive wound dressing	Provides physical protection of the wound	High nurse satisfaction with its application has been reported, reducing the amount of wet exudate	May lead to maceration of the wound or surrounding skin	Wounds with mild to moderate exudate	Non-occlusive, inflexible. May traumatize tissue when removing in the presence of dry wound bed, intended to use exclusively in medical institutions	(33, 34)
DRESSILK®	Silk wrap - protein fibroin from silkworm	Biocompatible material that promotes epithelialization and reduces inflammation	Biocompatibility, favorable mechanical properties, easy applicability, economic availability	Insufficient data on the long-term impact on scar quality	Superficial wounds, burns and skin graft donor sites (face and hands)	No literature data are available on the efficacy in deep wounds with more abundant exudate. Possible changes in skin pigmentation and transepidermal water loss may persist for up to six months after application	(35–38)
Interactive wound dressings							
Vacutex®	Two outer layers of 100% polyester filament and an inner layer of 65% polyester and 35% cotton	Utilizes vacuum textile capillary action to eliminate exudate	Stimulates granulation, reduces maceration, and keeps the wound dry thanks to its rapid absorption and high capillary pressure	Does not promote epithelialization independently	Wet wounds with fibrin and exudate present	Avoid use in arterial bleeding, dry necrotic wounds, or in combination with paraffin-based dressings	(39–42)
Mepilex® Border	Multilayer polyurethane foam, silicone (Safetac® technology)	Hydrophilic properties maintain a moist wound environment	Comfortable for patients, and can remain in place for up to seven days	Potentially low exudate retention	Wet wounds (pressure injuries), traumatic wounds, surgical wounds, dry/necrotic wounds in combination with gels	Available in adhesive and non-adhesive variants, and can be used in combination with other dressings	(42–45)

EuroCell Hydro®	Carboxymethyl cellulose	Forms a transparent gel upon contact with exudate due to carboxymethylcellulose, maintains moist environment, and aids in removal of devitalized tissue	High degree of absorption and adaptability	Low mechanical strength and lack of bioactivity	Traumatic wounds, leg ulcers, diabetic ulcers, burns, deep wounds with pockets	Due to their hydrophilic nature, carboxymethylcellulose dressings can be mixed with other biomaterials	(34, 46, 47)
Bioactive wound dressings							
Aquacel® Ag	Hydrofiber® made of sodium carboxymethylcellulose with 1.2% silver	Forms a gel on contact with exudate, absorbs fluid vertically, prevents microbial penetration, and releases bactericidal silver	Reduction of ulcer area, necrotic masses, maceration of the surrounding skin, unpleasant odor, and more effective exudate management	Possible increased need for dressing replacement, potential cytotoxicity of silver	Chronic wounds (ulcers, pressure injuries), traumatic wounds, surgical wounds, and burns	No significant side effects, safe option for application at burns	(45, 48–50)
FIBRACOL®	Hydrogel dressing (90% bovine collagen + 10% calcium alginate)	Combines collagen support with the gel-forming and hemostatic properties of alginates. Moisture acts chemotactically on inflammatory cells, and supports cellular repair	There is evidence of a reduction in wound surface area in the later stages of healing. No significant systemic side effects (animal models)	High cost and mechanical instability	Ulcers of various vascular etiologies, diabetic ulcers, second-degree burns, skin graft donor sites, and other bleeding superficial wounds	Do not use on wounds showing signs of infection	(11, 51, 52)
Acticoat®	Polyethylene mesh with metal Ag^0 nanoparticles	Silver oxidizes ($Ag^0 \rightarrow Ag^+$), binding to protein thiol groups, disrupting electron transport, generating reactive oxygen species, and damaging bacterial membranes	Broad-spectrum antimicrobial activity, highly effective against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. May be combined with antiseptics to improve antimicrobial properties	Potential cytotoxicity to keratinocytes	Burns, wounds with an increased risk of infection, and infected wounds	Some *Staphylococcus aureus* and *Pseudomonas aeruginosa* strains may have innate resistance to preparations with silver nanoparticles	(45, 53)

MEDIHONEY®	Alginate dressing with Manuka honey	Combines alginate's absorptive/hemostatic action with manuka honey's antibacterial, anti-inflammatory, osmotic, and biofilm-disrupting effects. Lowers pH and promotes granulation	Antibacterial action, including methicillin-resistant *Staphylococcus aureus*, optimal absorption of exudate, autolytic wound cleaning, suitable for slow-healing wounds, reduces the number of dressing changes	Burning sensation may occur upon initial application of dressing, potentially excessive drying in wounds with a small amount of exudate	Chronic wounds on the lower extremities, pressure injuries, 1st and 2nd degree burns, wounds, skin graft donation sites, and surgical wounds	Do not use for deep wounds with pockets without secondary dressing, high temperature may affect the antibacterial properties of honey	(42, 54–56)

Source: authors (2025).

DISCUSSION

With the increasing incidence of diabetes and chronic vascular disease, wound care has attracted significant attention from healthcare professionals. Inadequate wound healing causes pain in patients and is a heavy burden on the entire healthcare system.(57)

The basis for the effectiveness of treatment is adequate wound assessment and the selection of an appropriate dressing.(58) However, the large number of available products and the economic burden make choosing the optimal dressing challenging for healthcare professionals. It is estimated that the product's price is 93% higher for chronic wounds, emphasizing the importance of healthcare planning, which requires wound assessment and identification of the care goal.(59) In addition to the above circumstances, there is still a significant lack of knowledge in the field of wound care among healthcare professionals.(58)

Despite improved wound healing results, conventional wound dressings are far from ideal, due to the complexity of the healing process.(61) Advancements in science and technology in the fields of medicine and tissue engineering have led to the design of wound dressings made from natural or synthetic biomaterials, with the aim to speed up healing time and prevent infections.(62)

It is recommended that modern dressing should be developed according to the need for necrotic tissue removal, epithelialization, maintenance of moisture balance, and infection control.(63) One dressing cannot meet all of these needs because of the complexity of wound healing process.(64)

The limited effectiveness of available therapeutic modalities is due to the fact that each wound heals uniquely, so there is no ideal, universal dressing. Healthcare professionals often lack a sufficiently clear understanding of the benefits and limitations of commercially available therapeutic options, and a significant gap remains between the results of research on advanced materials and the technological level of available products. Therefore, additional efforts are required to make research results more accessible and implemented in practice.(65)

One of the main challenges in selecting the right wound dressing is the discrepancy between success in laboratory conditions and clinical application. Despite the large number of innovative materials available, further research is needed in order to optimize existing solutions.(66) Smart systems face several limitations in their application. For instance, they can track only one biomarker in a wound, which limits diagnosis accuracy and may contribute to therapeutical errors. Considering this, systems that integrate multiple wound-related biomarker signal sensors are necessary.(67)

Numerous experimental studies have demonstrated improved moisture regulation, high biocompatibility, and accelerated wound epithelialization of advanced biomaterials and dressings, such as hydrogels and nanofibers, under controlled laboratory conditions(68-71), which supports the theoretical advantages identified in this narrative review. There is always space for more randomized controlled trials comparing advanced dressings with standard care, as despite laboratory successes, clinical evidence remains heterogeneous.

Smart dressings with integrated sensors show significant potential for real-time *in vitro* wound monitoring, but their application in clinical practice remains limited by financial, technical, and evidence-based barriers. (72-75)

There are also significant shortcomings in the assessment of smart dressings with integrated sensors that monitor various physiological indicators at the wound site, which limits their wider application in clinical settings.(74) The integration of artificial intelligence, machine learning, and the use of stimulus-sensitive materials represents a revolutionary start towards adapted technologies in wound care, taking into account production costs, to establish the availability of affordable and representative products.(66)

Study limitations

This review is limited by its narrative approach, the heterogeneity of the included studies, and the lack of data on long-term clinical outcomes.

CONCLUSION

Modern and smart wound dressings represent a significant shift in healthcare, offering many advantages compared to conventional methods. Advances in modern therapeutic options provide a wide range of opportunities for the development of a personalized approach to wound healing. The choice of an adequate wound dressing must be precisely tailored to each patient, given the complexity of the wound healing process, which depends on many factors.

It is necessary to continue with more extensive research, primarily randomized controlled trials, with the aim of determining the biocompatibility and biofunctionality of modern dressings, while adapting to complex technical and economic requirements. A multidisciplinary approach and close collaboration between physicians, nurses, and biomedical engineers are the foundation for the future development of personalized therapeutic modalities for different types of acute and chronic wounds.

CONTRIBUITIONS

Study conception or design: Ćorić A & Gvozdenović N. Data collection: Ćorić A & Gvozdenović N. Data analysis and interpretation: Ćorić A & Gvozdenović N. Article writing or critical review: Ćorić A & Gvozdenović N. Final approval of the version to be published: Ćorić A & Gvozdenović N.

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