FIBRES & TEXTILES in Eastern Europe

sciendo

FIBRES & TEXTILES in Eastern Europe

Research Article • DOI: 10.2478/ftee-2024-0038 FTEE • 32(6) • 2024 • 13–23

Review and evaluation of commercially available wound dressings

Nina Tarzyńska[1], Patryk Śniarowski[1], Anna Bednarowicz[1], Sylwia Jagodzińska[1], Dorota Zielińska[1]*

[1] Łukasiewicz – Lodz Institute of Technology, 19/27 Marii Skłodowskiej–Curie Street, 90-570, Lodz
* Corresponding author. E-mail: dorota.zielinska@lit.lukasiewicz.gov.pl

Abstract
The wound dressing market is now filled with various products designed to treat different types of wounds. Choosing the proper dressing alone is crucial to the wound healing process. However, with so many options available, identifying and selecting the most appropriate dressing can be challenging for healthcare professionals - doctors, nurses, pharmacists and medical staff - as well as non-professional users and pharmacy customers. This study aims to provide an overview of the properties and characteristics of the most commonly used dressings available on the market. Specifically, dressings were tested for their vapour transmission rate, free swelling absorption capacity and mechanical properties.

Keywords
dressing, wound healing, moisture vapour transmission rate, free swell absorptive capacity.

1. Introduction

Wound dressings are materials applied to wounds to promote healing, preventing infection and protecting from further injury. Depending on the application, they are available in many forms and types, each with various functions [1]. The primary purpose of a dressing is to create an environment that promotes wound healing, supports healthy cell growth, and facilitates the healing process (Fig. 1) [2]. The frequency of dressing changes depends on the specific condition of the wound, particularly the amount of exudate relative to the dressing's absorbent capacity, with changes typically occurring between 1 day and 1 week [3].

More than 3,000 different types of wound dressings are currently available on the market. The wound dressing market is a significant and rapidly growing sector within the medical device industry, essential for effectively treating wounds from various sources. The global wound dressing industry is projected to reach a revenue of approximately US$ 18,867.4 million by 2030 [5].

Despite the vast range of dressings available on the market and the many possible applications, researchers are still working on the next generation [6–8]. Efforts are being made to make dressings enhance the wound closure process, responding to stimuli such as pH and temperature. In addition, researchers are working on wound dressings with better mechanical properties that could be applied to moving, bending or stretching areas on the human body - neck, elbows or knees. Another group of smart dressings focuses on monitoring parameters such as pH, temperature or glucose levels and signalling a change in these parameters, which indicates wound infection [9].

One other group of smart wound dressings are those designed to deliver medications. These dressings use different types of medication depending on the patient's needs. These may include antibiotics [10] and metformin [11]. However, the Polish Wound Management Association does not recommend using antibiotics in topical applications to wounds [12]. In order to avoid overuse of antibiotics or antibiotic resistance, nanoparticles can be used. Metal nanoparticles such as silver [13], copper [14], zinc [15] and gold [16] are the most frequently used. In addition to dressings made from conventional biomaterials containing commonly used additives, research is being carried out on dressings containing soft electronic materials that collect data from the wound and transmit them to a smartphone [17,18].

A separate group of smart dressings are those made using 3D printing technology. This technology enables the design of dressings to be customised to the patient's specific needs. In addition, 3D bioprinting allows the incorporation of drugs or other active substances into the dressing material, promoting wound healing [19,20].

A broad group of dressing materials can be classified by considering various criteria such as function, type of raw material, and material form (Tab. 1). The raw materials used for typical dressing materials are cotton, cellulose fibres, alginates, polyamides, polyurethanes or other synthetic polymers [21,22]. Dressings can also take various forms, such as films, non-wovens, foams, hydrogels, hydrocolloids, or meshes [23,24].

The proper choice of dressing can and should have a significant and crucial impact on wound healing. It should be carried out based on a comprehensive wound assessment following the latest guidelines and trends, patient preferences, wound healing history and additional factors (e.g. diseases) affecting the healing process.

Wound healing is a particular biological process that is linked to physiological

Open Access. © 2024 Łukasiewicz Research Network-Łódź Institute of Technology, published by Sciendo. BY-NC-ND This work is licensed under the Creative Commons Attribution alone 3.0 License.

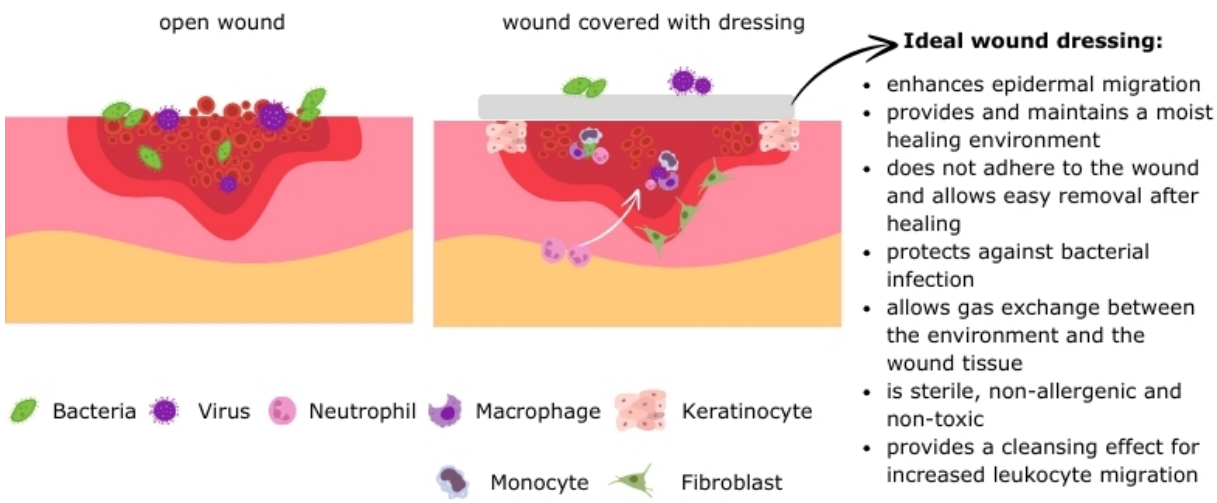

Fig. 1. Wound healing process with an adequately fitted dressing. (figure based on [4])

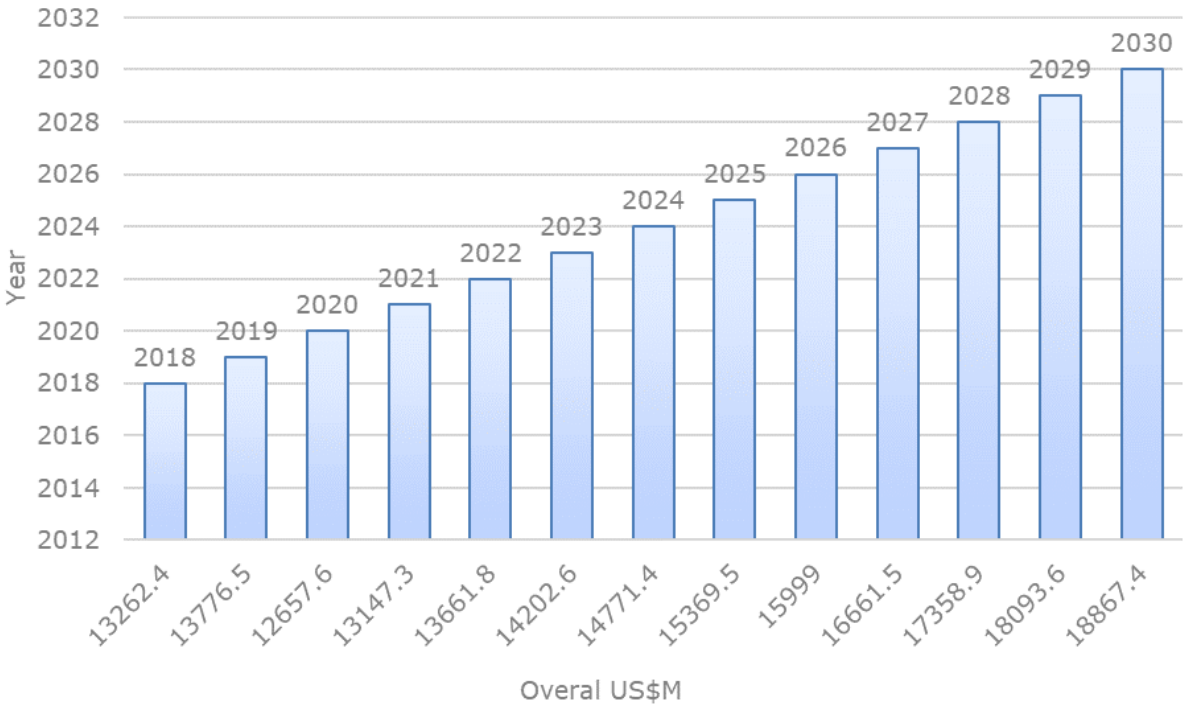

Fig. 2 Prospects for the global dressing market (figure based on [5])

parameters. It consists of the following phases [26]:

– Haemostasis is the first stage of wound healing, during which a temporary fibrin matrix of the wound is produced, and platelets release cytokines and growth factors in the wound.
– Inflammation is the second stage, during which bacteria, pathogens and dead cells are removed from the wound and replaced by macrophages, and the wound bed is prepared for new tissue growth.
– Proliferation is the third stage of wound healing, which is dedicated to filling and covering the wound. Fibroblasts, supported by new capillaries, proliferate and synthesise the affected extracellular matrix (ECM).

Remodelling is the final stage of wound healing; there is a reduction in the density of fibroblasts and capillaries, and the initial scar tissue is removed and replaced by ECM, which more closely resembles healthy skin. The new tissue gradually becomes stronger and more elastic.

In 2004, in Paris, at the Congress of the European Wound Management Associations (EWMA), medical experts (International Advisory Board) published the TIME wound treatment concept for doctors and therapists involved in wound

Table 1. Type and properties of dressings (table based on [25])

Type	Properties
Passive dressing	
– **Foams** – **Films** – **Silicones**	– Protection against dehydration – Protection against infection and injury – For wounds with little exudate and epithelial wounds
Occlusive dressings	
– **Hydrocolloids**	– Occlusive – Completely protects the wound from the external environment
Interactive dressings	
– **Alginates** – **Hydrocolloids** – **Hydrogels**	– For clean granulation wounds – Protection against dehydration – Promoting an optimal environment for wound healing – Actively interacting with the wound surface by filling in tissue defects to stimulate granulation or protecting non-viable tissue to stimulate wound debridement.

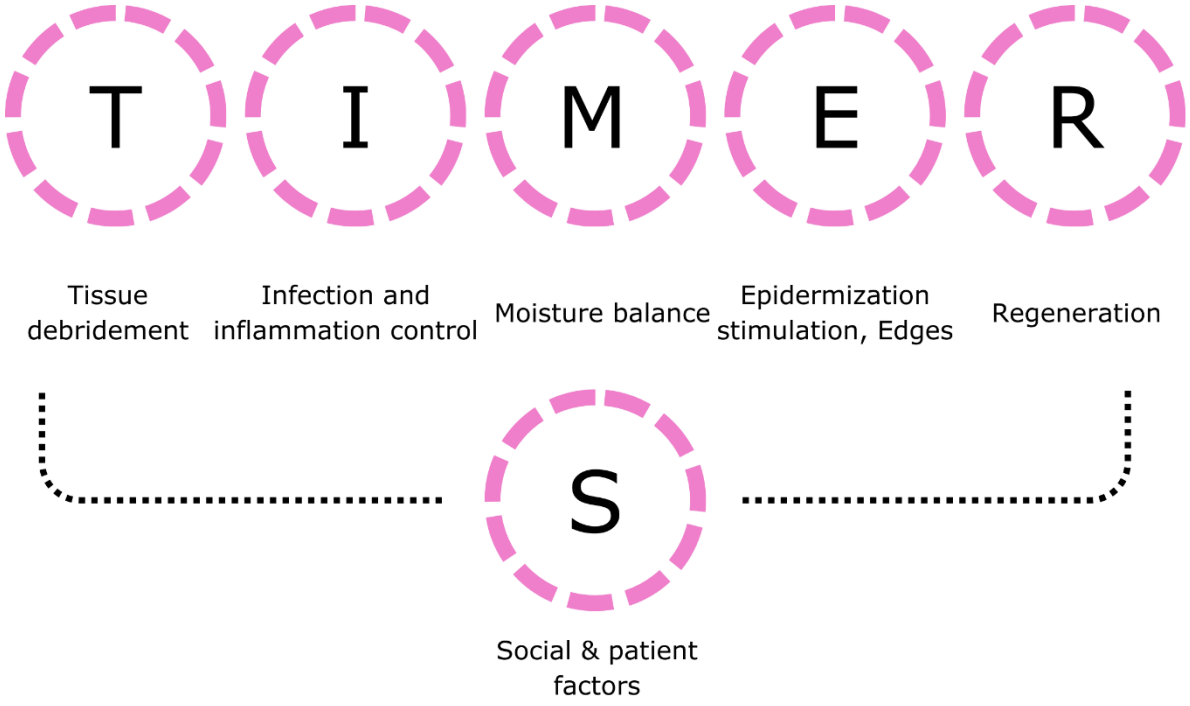

Fig. 3. *TIMERS concept (figure based on [29])*

care [27]. It addresses the different phases of wound healing, describes them practically, and defines goals and actions specific to each stage.

In 2019, the TIME concept was updated by two more factors: repair/regeneration (R) and social (S) [28] (Fig. 3). Factor R focuses on promoting wound closure, among others, by stimulating cell activity. Factor S emphasises the importance of social and patient-related factors. Understanding these overarching factors is crucial for effective wound management.

This study showed the results of free swell absorptive capacity, the moisture vapour transmission rate and mechanical analysis of commercially available dressings from various manufacturers. So far, there has been no collective analysis of dressings from different groups and multiple manufacturers. Dressings were divided into groups and presented as the average results for a given group. The EN 13726 standard describes the test methods recommended for assessing the moisture vapour transmission rate and free swell absorptive capacity. However, it does not specify values for these parameters in a way that would allow the categorisation of dressings.

2. Methods

The following tests of dressing were performed:

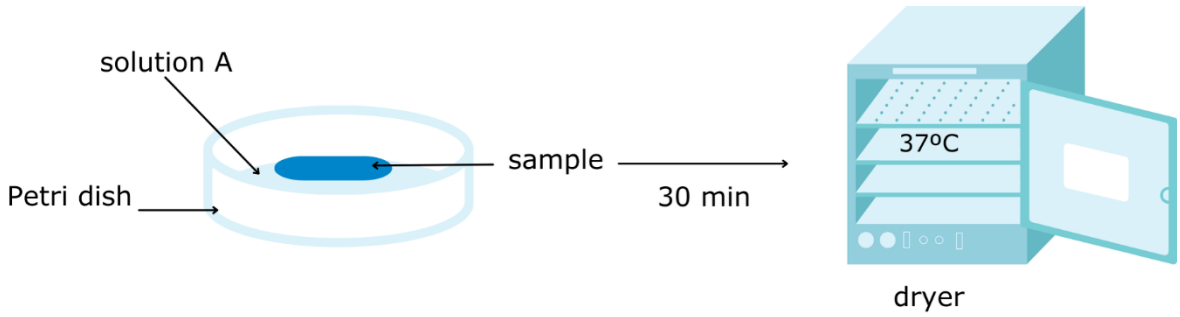

Fig. 4. Scheme of free swell absorptive capacity (figure based on self-analysis)

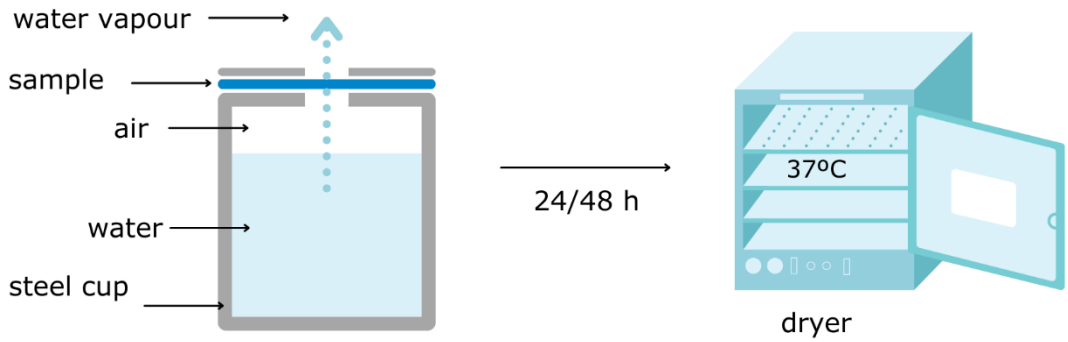

Fig. 5. Scheme of moisture vapour transmission rate (figure based on self-analysis)

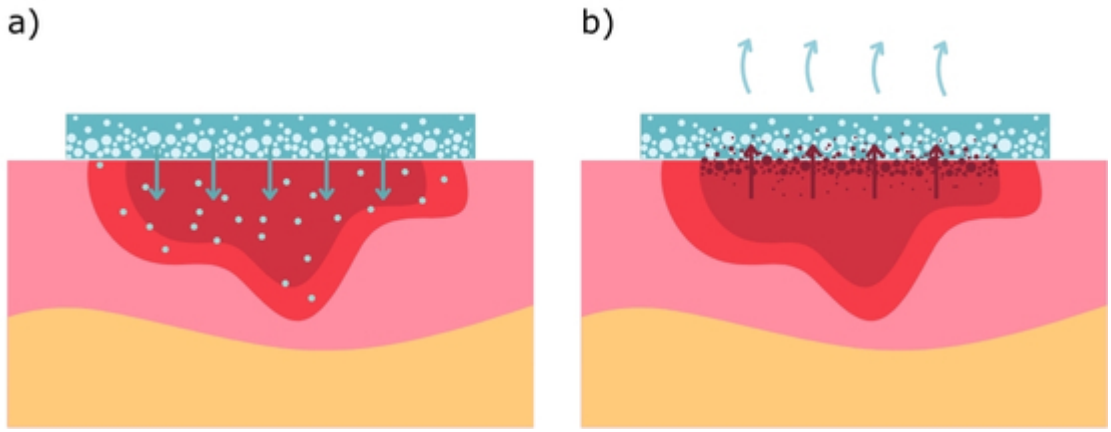

Fig. 6. Mode of action of the hydrogel dressing in the case of- a) dry wounds, b) wounds with exudate (figure based on [34])

– The free swell absorptive capacity was determined according to the guidelines described in EN 13726-1:2002/AC:2003 [30] (Fig. 4).
– The moisture vapour transmission rate (MVTR) in contact with water vapour was determined using the guidelines, as defined in EN 13726-2:2002 [31] (Fig. 5)
– Mechanical analysis was performed on an INSTRON testing machine - model 5544 according to PN-EN ISO 1798:2009 [32], at a 500 mm/min stretching rate and distance of 10 mm between clamps. The samples were conditioned before the measurements (standard conditions: 50% humidity, 23°C, 48 h).

3. Materials

Studies were conducted on the following groups of dressings:
– Hydrogel dressings (Fig. 6) are designed to maintain an optimal moisture balance in the wound [33]. They are typically used for painful, dry wounds, burns, radiation-induced skin injuries, and severe lacerations. These dressings are non-adherent, meaning they do not damage newly formed tissue and help reduce pain. However, they are unsuitable for heavily exudating wounds and may require an additional dressing to secure them.
– Dressings used in this study are Aqua-Gel® (KIKGEL), HydroTac®

Transparent Comfort (Hartmann), Suprasorb G (Lohamann&Rauscher), Medihoney® HCS (Derma Sciences) and Medihoney® HCS with an adhesive border (Derma Sciences).

– Hydrocolloid dressings (Fig. 7) create a moist environment that enhances wound healing, making them suitable for very dry wounds [33]. They support the removal of dead tissue without damaging new tissue and usually absorb a slight to moderate amount of exudate. The dressings used in this study are Granuflex™ Extra Thin (Convatec), Hydrocoll® (Hartmann), Hydrocoll® Thin (Hartmann), Granuflex™ Bordered (Convatec), Granuflex™ (Convatec), Granuflex™ Signal (Convatec), and Medisorb H (TZMO).
– Superabsorbent dressings (Fig. 8) are multilayered with a semi-adhesive or non-adhesive outer layer and a highly absorbent inner layer containing a superabsorbent polymer (SAP). SAP can absorb and retain much fluid relative to weight [35]. These dressings are designed to minimise adhesion to the wound and effectively manage exudate. They are suitable as either a primary or secondary dressing.

The dressings used in this study are Zetuvit® Plus (Hartmann), Mextra Superabsorbent® (Mölnlycke), Vliwasorb® Pro (Lohmann & Rauscher), Eclypse Adherent (Advancis Medica), Vliwasorb® Adhesive (Lohmann & Rauscher), HydroClean® Plus (Hartmann), Sorbact® Superabsorbent (Abigo Medical), and ConvaMax™ Superabsorber (Convatec).

– Absorbent dressings (Fig. 9) can absorb wound exudate and provide a relatively dry wound environment. They are characterised by varying degrees of absorbency, depending on the nature of the wound. They absorb moisture from the wound by encapsulating it within their structure, and the dressing layer directly adhering to the wound remains dry, preventing skin maceration and soaking of the dressing.

Dressings used for this research are Vliwaktiv® (Lohmann & Rauscher), Elastopor Steril (Zarys), Sorbact® Absorption Dressing (Abigo Medical), Biatain® Super Adhesive (Coloplast), and Vliwazell® (Lohmann & Rauscher).

– Calcium alginate dressings (Fig. 10) are highly absorbent fibrous structures [37]. Due to the sorptive capacity of alginate, a gel is formed when in contact with the exudate, which promotes autolytic cleansing of the wound while absorbing excess fluid, helping to accelerate the wound healing process. They are suitable for wounds that generate moderate to profuse exudate and require additional support to keep them in place. They can be changed daily, depending on the amount of exudate in the wound.

Dressings used for this research are Sorbalgon® (Hartmann), Medisorb A (TZMO), Kaltostat™ (Convatec), and Suprasorb® A (Lohmann & Rauscher).

– Foam dressings (Fig. 11) aim to create a moist environment that promotes wound healing. They are made of water-resistant polymers,

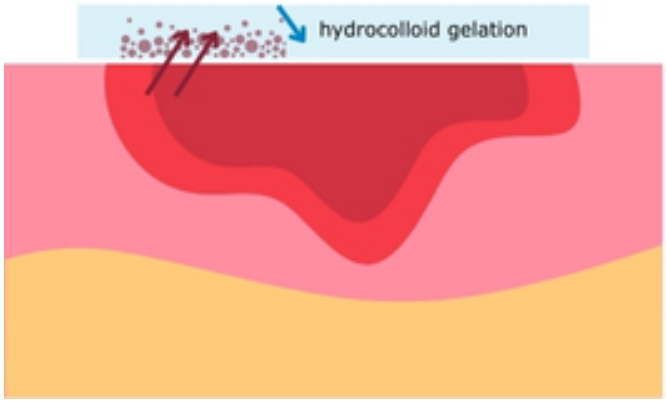

Fig. 7. Mode of action of the hydrocolloid dressing (figure based on self-analysis)

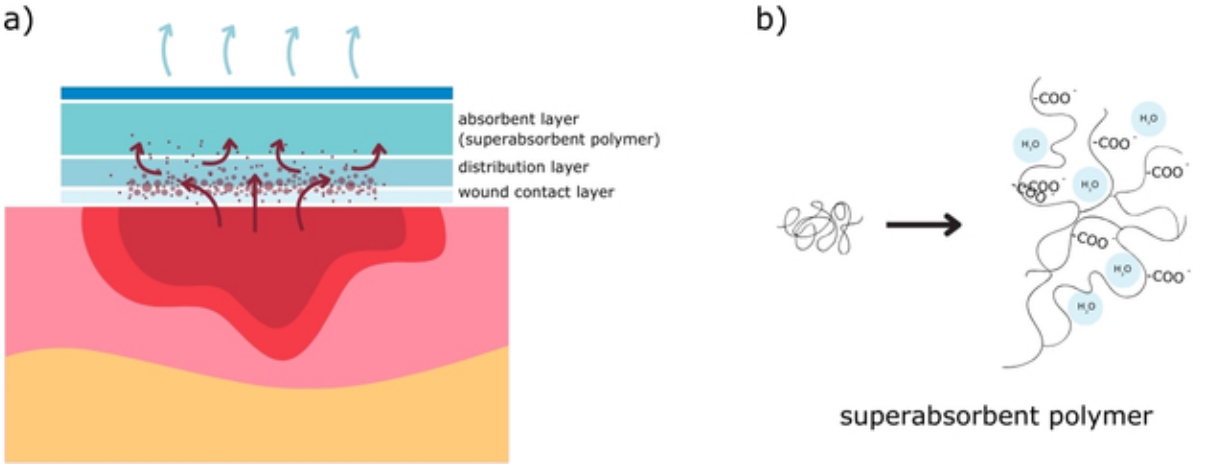

Fig. 8 Mode of action of the a) super absorption dressing and b) superabsorbent polymer (figure based on [36])

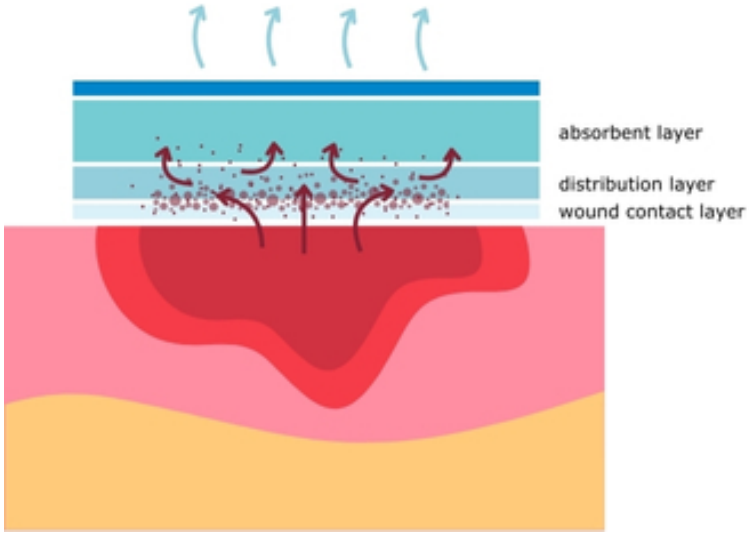

Fig. 9. Mode of action of the absorption dressing (figure based on self-analysis)

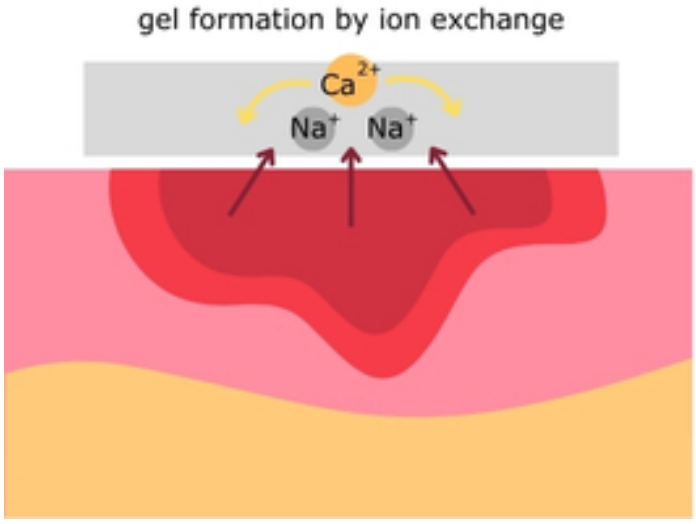

Fig. 10. Mode of action of the alginate dressing (figure based on self-analysis)

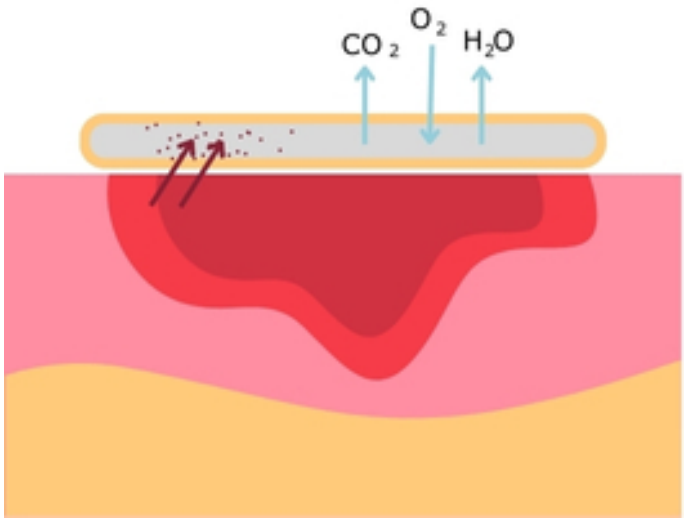

Fig. 11. Mode of action of the foam dressing (figure based on self-analysis)

usually polyurethane, and absorb moderate amounts of exudate. They tend not to adhere tightly and permit vapour transmission, but at the same time, prevent the penetration of bacteria and other contaminants into the wound.

Dressings used for this research are Medisorb P Plus Adhesive (TZMO), Mepilex® Border EM (Mölnlycke), Mepilex® EM (Mölnlycke), Mepilex® Border (Mölnlycke), Aquacel™ Foam (Convatec), Aquacel™ Foam Non Adhesive (Convatec), Allevyn Adhesive (Smith & Nephew), Foam Lite™ Convatec (Convatec), Biatain® Non Adhesive (Coloplast), Sorbact® Foam (Abigo Medical), Suprasorb® P (Lohmann & Rauscher), Suprasorb® P Sensitive Border (Lohmann & Rauscher), HydroTac (Hartmann), and HydroTac® Transparent Comfort (Hartmann).

4. Results

The moisture vapour transmission rate (MVTR) is crucial for evaluating dressings. The higher the MVTR value, the greater the dressing's ability to transmit water vapour. For the dressings tested in this study, the MVTR values ranged from 76 to 6,100 g/m²/24h, depending on the group (Fig. 12). The higher the moisture vapour transmission rate (MVTR), the more breathable and permeable the dressing is.

The highest MVTR values were reported for the hydrogel, absorbent and alginate dressings, where values exceeded 3,000 (g/m²/24h). Hydrogel dressings can absorb liquid and then subsequently release it from their structure as vapour. The absorbent dressings can absorb moisture vapour but partially retain it in their structure. Alginate dressings are based on alginate, which has absorbent properties. The lowest value of MVTR was reported for occlusive hydrocolloids [38], which do not allow water, oxygen, or bacteria into the wound. It can be explained by the waterproof barrier on the dressing. Therefore, hydrocolloids should not be placed on heavily exuding wounds due to the risk of maceration. Because

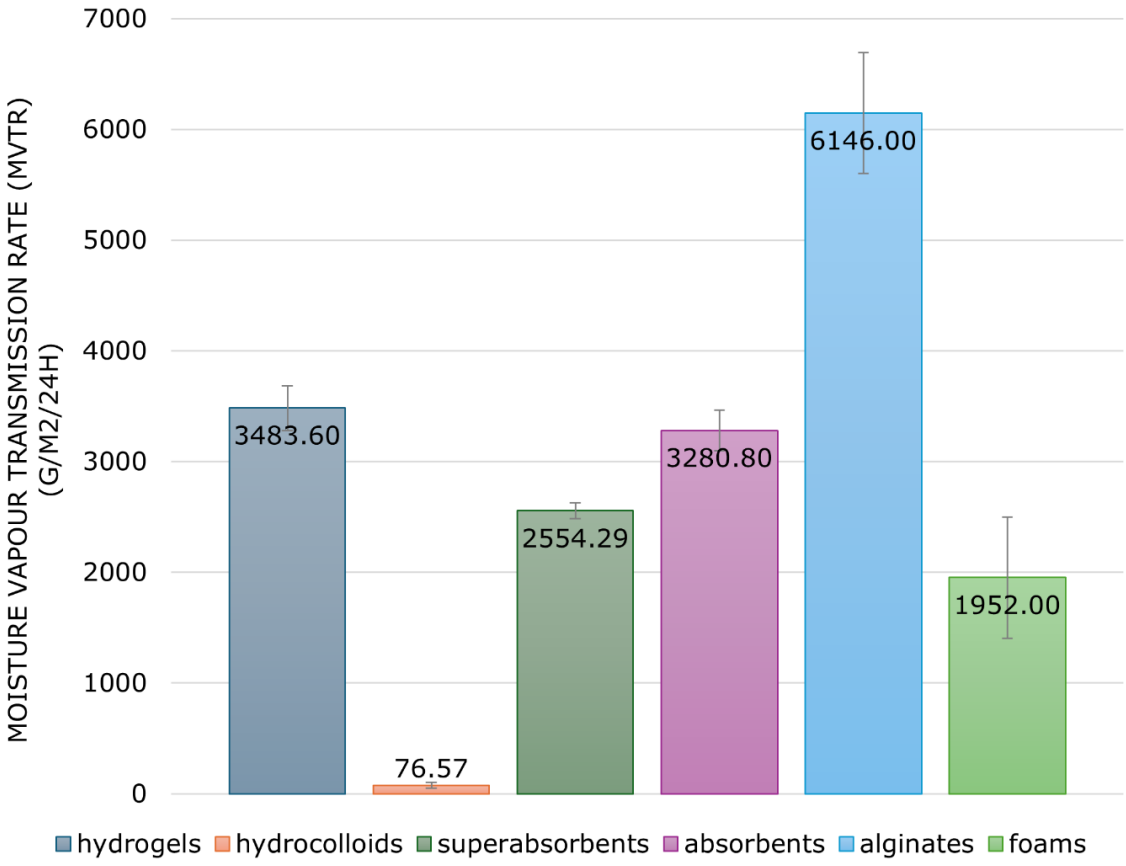

Fig. 12. Moisture vapour transmission rate (MVTR) of wound dressing when in contact with vapour

of their porous structure [39], foam dressings have the capability to retain moisture vapour and consequently create a moist wound healing environment.

The results of free swell absorptive capacity are shown in Figure 13. The highest value was reported for superabsorbent and absorbent dressings, while hydrocolloids had the lowest free swell absorptive capacity value.

The free swell absorptive capacity results are closely related to the structure and material of the individual dressings. Since superabsorbent dressings contain SAP, they can absorb liquids by multiples of their weight [40]. Absorbent dressings are composed of several layers, significantly increasing their absorptive capacity. Foam dressings, which absorb liquid relatively efficiently, are characterised by a highly porous structure, favouring their ability to absorb fluid. Hydrogels are made of hydrophilic polymers, contributing to their relatively good absorption capacity. When exposed to the cations contained in the absorbed fluids, alginate dressings undergo a gelation process, which limits their ability to absorb fluids. Hydrocolloid dressings, however, absorb only a tiny amount of fluid to produce a gel that will provide a sufficiently moist wound environment.

Table 2 shows the mechanical properties of the dressings. The maximum strength and tensile strength were defined, allowing the elasticity of the dressing to be determined. Elasticity is essential in providing patients with freedom of movement [41].

Hydrocolloid dressings have the highest elongation value in both directions. The reason for this is their structure - the inner layer is made of hydrocolloids, while the outer layer is made of polyurethane foam or film – which allows them to be used in hard-to-treat areas such as elbows, heels or knees. Hydrogel dressings are known for their poor mechanical properties, while their relatively high elongation at maximum strength is worth mentioning. They are designed to be applied and removed delicately to minimise further skin trauma [42]. They should equally exhibit mechanical and physical properties similar to the extracellular matrix of human skin [43]. Foam dressings are similarly flexible, as confirmed by the study results. However, by having to provide a cushioning effect on the wound, they are thicker than hydrogel and hydrocolloid dressings [44]. Absorbent and superabsorbent dressings have mechanical properties based on their layered structure - a layer that adheres to the wound, a distribution layer, an absorbent layer and an outer layer that limits their elasticity. In contrast, the dressings with the lowest elongation values are alginate dressings, which are most commonly non-woven. In addition to their good sorptive properties, calcium alginate fibres have relatively low strength properties (14-18 cN/tex) and low elongation values (2-6%) [45].

Type of dressings	Max. strength, direction 1 (N)	Elongation at max. strength, direction 1 (%)	Max. strength, direction 2 (N)	Elongation at max. strength, direction 2 (%)
Hydrogels	12.2 ± 2.6	629 ± 412	15.0 ± 5.5	498 ± 285
Hydrocolloids	19.4 ± 6.4	1653 ± 616	18.4 ± 6.2	1659 ± 593
Superabsorbents	61.8 ± 26.6	51 ± 37	43.1 ± 13.5	102 ± 48
Absorbents	62.2 ± 42.5	48 ± 26	60.7 ± 47.8	69 ± 26
Alginates	16.7 ± 6.9	22 ± 9	7.4 ± 3.5	35 ± 12
Foams	17.9 ± 7.3	769 ± 249	18.5 ± 7.5	762 ± 229

Table 2. Mechanical properties of dressings

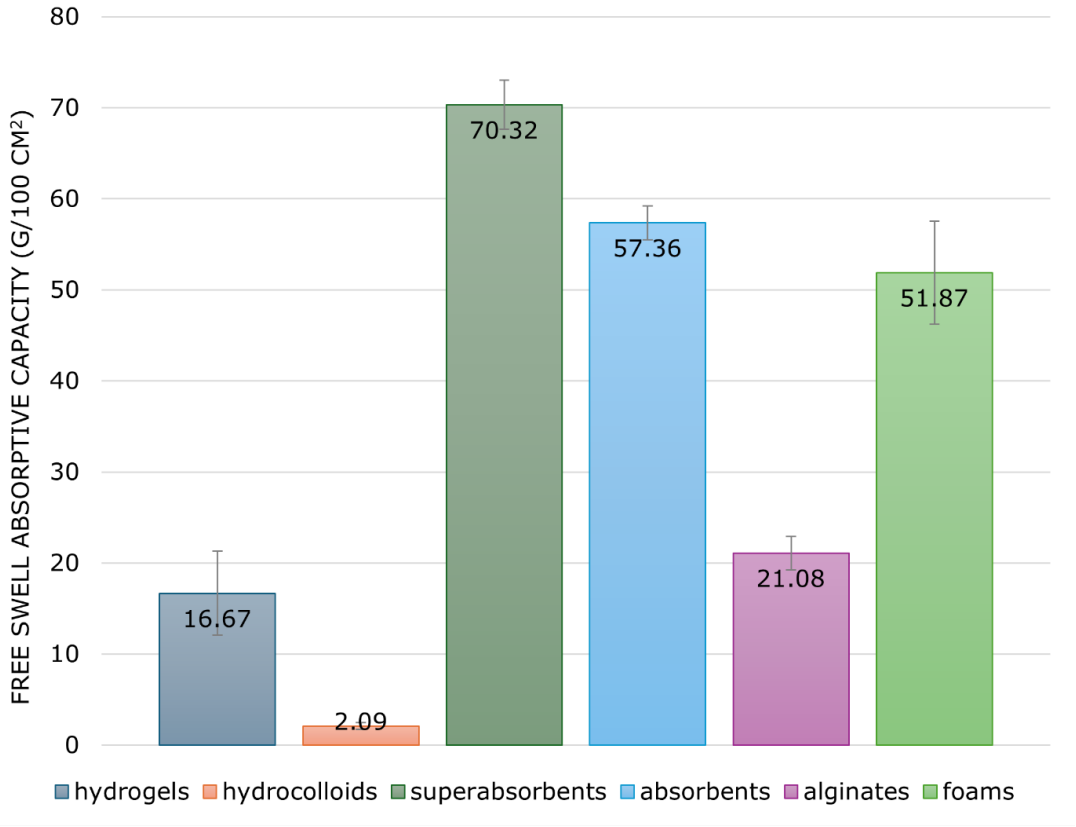

Fig. 13. Free swell absorptive capacity of dressings

5. Discussion

This study characterises the critical properties of various commercially available wound dressings. The EN 13726 standard outlines the recommended test methods for assessing the moisture vapour transmission rate and free swell absorptive capacity. However, it does not provide specific values for these parameters that would allow for the categorisation of dressings. The commercially available dressings vary significantly, and their different structures (e.g., gels, foams, absorbents) can substantially impact the healing process of different types of wounds. Our research confirms the influence of dressing structure on absorption capacity, elasticity, and moisture vapour transmission. Moreover, the current study provides a comprehensive overview, characterisation, and comparison of the critical properties of various wound dressings, which may assist researchers in developing innovative wound dressings.

A summary of all tested dressings is presented in Table 3.

Acknowledgements

Scientific work/publication co-financed from the state budget as part of The Ministry of Education and Science (Poland) within the program "Science for the Society" project no.: NdS/547745/2022/2022, grant amount: PLN 1 315 370.00 total project value: PLN 1 315 370.00. Paulina Król was the project initiator and manager from 1.09.2022 to 21.03.2024

The tests were carried out on materials/ products from randomly selected

Type of dressing	Company (name of dressing)	Type of wound	Properties
Hydrogel	KIKGEL (Aqua-Gel®)	bedsores, diabetic foot, burns	• provide adequate moisture to the wound • high volume of MVTR • a moderate volume of free swell absorptive capacity
	Hartmann (HydroTac® Transparent Comfort)	burns	
	Lohamann & Rauscher (Suprasorb G)	bedsores, ulcers, burns	
	Derma Sciences (Medihoney® HCS, Medihoney® HCS with adhesive border)	bedsores, ulcers	
Hydrocolloid	Convatec (Granuflex™ Extra Thin, Granuflex™, Granuflex™ Signal, Granuflex™ Bordered)	bedsores, ulcers, burns	• create a moist environment that enhances wound healing • low volume of MVTR, low volume of free swell absorptive capacity
	Hartmann (Hydrocoll®, Hydrocoll® Thin)	bedsores, ulcers, burns	
	TZMO (Medisorb H)	bedsores, ulcers, burns	
Superabsorbent	Hartmann (Zetuvit® Plus)	bedsores, ulcers	• minimise adhesion to the wound and effectively manage exudate • a moderate volume of MVTR • high volume of free swell absorptive capacity
	Mölnlycke (Mextra Superabsorbent®)	bedsores, ulcers	
	Lohmann & Rauscher (Vliwasorb® Pro, Vliwasorb® Adhesive)	bedsores, ulcers, burns, postoperative	
	Advancis Medica (Eclypse Adherent)	bedsores, ulcers	
	Abigo Medical (Sorbact® Superabsorbent)	bedsores, ulcers	
	Convatec (ConvaMax™ Superabsorber)	bedsores, ulcers	
Absorbent	Lohmann & Rauscher (Vliwaktiv®)	bedsores, ulcers, burns	• absorb wound exudate and provide a relatively dry wound environment high volume of MVTR • high volume of free swell absorptive capacity
	Zarys (Elastopor Steril)	postoperative, little to no exudate	
	Abigo Medical (Sorbact® Absorbtion Dressing)	ulcers, postoperative, infected	
	Coloplast (Biatain® Super Adhesive)	burns, ulcers, postoperative	
	Lohmann & Rauscher (Vliwazell®)	heavy exudate	
Calcium alginate	Hartmann (Sorbalgon®)	bedsores, ulcers, burns	• generate moderate to profuse exudate and require additional support to keep them in place • high volume of MVTR • a moderate volume of free swell absorptive capacity
	TZMO (Medisorb A)	bedsores, diabetic foot, ulcers	
	Convatec **(**Kaltostat™**)**	ulcers, bleeding heavily	
	Lohmann & Rauscher (Suprasorb® A)	bedsores	
Foam	TZMO (Medisorb P Plus Adhesive)	bedsores, burns	• create a moist environment that promotes wound healing • high volume of MVTR • high volume of free swell absorptive capacity
	Mölnlycke (Mepilex® Border EM, Mepilex® EM, Mepilex® Border)	bedsores, diabetic foot, burns, ulcers	
	Convatec (Aquacel™ Foam, Aquacel™ Foam Non Adhesive, Foam Lite™)	bedsores, diabetic foot, burns, ulcers	
	Smith & Nephew (Allevyn Adhesive)	bedsores, diabetic foot, burns, ulcers	
	Coloplast (Biatain® Non Adhesive)	bedsores, diabetic foot, burns, ulcers	
	Abigo Medical (Sorbact® Foam)	infected	
	Lohmann & Rauscher (Suprasorb® P, Suprasorb® P Sensitive Border)	bedsores, ulcers, burns	
	Hartmann (HydroTac, HydroTac® Transparent Comfort)	bedsores	

Table 3. Types of dressing and their properties

manufacturers available on the market. The research work/publication was not directly or indirectly financed by the manufacturers of these products, and neither Łukasiewicz - ŁIT nor the members of the Research Team received any benefits from these manufacturers in this respect.

This research has been completed while the second author was the Doctoral Candidate in the Interdisciplinary Doctoral School at the Lodz University of Technology, Poland.

Declaration of Conflicting Interests

The Author(s) declare(s) there is no conflict of interest.

References

1. J. Boateng, O. Catanzano, Advanced Therapeutic Dressings for Effective Wound Healing - A Review, J Pharm Sci 104 (2015) 3653–3680. https://doi.org/10.1002/jps.24610.
2. S. Holloway, K.G. Harding, Wound dressings, Surgery (Oxford) 40 (2022) 25–32. https://doi.org/10.1016/J.MPSUR.2021.11.002.
3. G. Dabiri, E. Damstetter, T. Phillips, Choosing a Wound Dressing Based on Common Wound Characteristics, Adv Wound Care (New Rochelle) 5 (2016) 32–41. https://doi.org/10.1089/wound.2014.0586.
4. A. Bal-Öztürk, B. Özkahraman, Z. Özbaş, G. Yaşayan, E. Tamahkar, E. Alarçin, Advancements and future directions in the antibacterial wound dressings – A review, J Biomed Mater Res B Appl Biomater 109 (2021) 703–716. https://doi.org/10.1002/jbm.b.34736.
5. Global Wound Dressing Market Size & Outlook, 2023-2030, (n.d.). https://www.grandviewresearch.com/horizon/outlook/wound-dressing-market-size/global (accessed August 30, 2024).
6. S. O'Callaghan, P. Galvin, C. O'Mahony, Z. Moore, R. Derwin, 'Smart' wound dressings for advanced wound care: A review, J Wound Care 29 (2020) 394–406. https://doi.org/10.12968/jowc.2020.29.7.394.
7. E.E. Tudoroiu, M.G. Albu Kaya, I. Titorencu, C.E. Dinu-Pîrvu, M.M. Marin, A.M. Roșca, L. Popa, V. Anuța, A. Antoniac, C. Chelaru, D.A. Kaya, R.M. Prisada, M.V. Ghica, Design and evaluation of new wound dressings based on collagen-cellulose derivatives, Mater Des 236 (2023) 112469. https://doi.org/10.1016/J.MATDES.2023.112469.
8. D. Zielińska, M.H. Struszczyk, L. Madej-Kielbik, E. Chmal-Fudali, M. Kucharska, M. Wisniewska-Wrona, K. Brzoza-Malczewska, Design of new-generation usable forms of topical haemostatic agents containing chitosan, Molecules 22 (2017) 1–17. https://doi.org/10.3390/molecules22122240.
9. M. Farahani, A. Shafiee, Wound Healing: From Passive to Smart Dressings, Adv Healthc Mater 10 (2021) 1–32. https://doi.org/10.1002/adhm.202100477.
10. P. Mostafalu, G. Kiaee, G. Giatsidis, A. Khalilpour, M. Nabavinia, M.R. Dokmeci, S. Sonkusale, D.P. Orgill, A. Tamayol, A. Khademhosseini, A Textile Dressing for Temporal and Dosage Controlled Drug Delivery, Adv Funct Mater 27 (2017) 1702399. https://doi.org/10.1002/ADFM.201702399.
11. Y. Liang, M. Li, Y. Yang, L. Qiao, H. Xu, B. Guo, pH/Glucose Dual Responsive Metformin Release Hydrogel Dressings with Adhesion and Self-Healing via Dual-Dynamic Bonding for Athletic Diabetic Foot Wound Healing, ACS Nano 16 (2022) 3194–3207. https://doi.org/10.1021/ACSNANO.1C11040/SUPPL_FILE/NN1C11040_SI_001.PDF.
12. B. Mrozikiewicz-Rakowska, M. Tusiński, P. Lipiński, D. Bazaliński, J. Dynarska, L. Czwakiel, A. Zymon, B. Mospan, K. Malinowska, M. Sopata, A. Jawień, Statement of the Polish Wound Management Association on larval therapy in wound management, Leczenie Ran 20 (2023) 89–95. https://doi.org/10.60075/lr.v20i3.43.
13. L.J. Wilkinson, R.J. White, J.K. Chipman, Silver and nanoparticles of silver in wound dressings: a review of efficacy and safety, Https://Doi.Org/10.12968/Jowc.2011.20.11.543 20 (2013) 543–549. https://doi.org/10.12968/JOWC.2011.20.11.543.
14. E. Melamed, P. Kiambi, D. Okoth, I. Honigber, E. Tamir, G. Borkow, Healing of Chronic Wounds by Copper Oxide-Impregnated Wound Dressings—Case Series, Medicina 2021, Vol. 57, Page 296 57 (2021) 296. https://doi.org/10.3390/MEDICINA57030296.
15. A.B.G. Lansdown, U. Mirastschijski, N. Stubbs, E. Scanlon, M.S. Ågren, Zinc in wound healing: Theoretical, experimental, and clinical aspects, Wound Repair and Regeneration 15 (2007) 2–16. https://doi.org/10.1111/J.1524-475X.2006.00179.X.
16. J. Toczek, M. Sadłocha, K. Major, R. Stojko, Benefit of Silver and Gold Nanoparticles in Wound Healing Process after Endometrial Cancer Protocol, Biomedicines 2022, Vol. 10, Page 679 10 (2022) 679. https://doi.org/10.3390/BIOMEDICINES10030679.
17. N. Shamloul, M.H. Ghias, A. Khachemoune, The Utility of Smartphone Applications and Technology in Wound Healing, Https://Doi.Org/10.1177/1534734619853916 18 (2019) 228–235. https://doi.org/10.1177/1534734619853916.
18. H. Chopra, M.A. Islam, K. Dhama, Revolutionizing wound care: The latest advancements in smart-phone based

dressings for healing and monitoring, International Journal of Surgery Open 55 (2023). https://doi.org/10.1016/J.IJSO.2023.100627.
19. M.H. Nadhif, H. Assyarify, M. Irsyad, A.R. Pramesti, M. Suhaeri, Recent advances in 3D printed wound dressings, AIP Conf Proc 2344 (2021). https://doi.org/10.1063/5.0047183/748857.
20. M. Alizadehgiashi, C.R. Nemr, M. Chekini, D. Pinto Ramos, N. Mittal, S.U. Ahmed, N. Khuu, S.O. Kelley, E. Kumacheva, Multifunctional 3D-Printed Wound Dressings, ACS Nano 15 (2021) 12375–12387. https://doi.org/10.1021/ACSNANO.1C04499/SUPPL_FILE/NN1C04499_SI_001.PDF.
21. L.J. Borda, F.E. Macquhae, R.S. Kirsner, Wound Dressings: A Comprehensive Review, Curr Dermatol Rep 5 (2016) 287–297. https://doi.org/10.1007/s13671-016-0162-5.
22. K.J.B. Kus, E.S. Ruiz, Wound Dressings – A Practical Review, Curr Dermatol Rep 9 (2020) 298–308. https://doi.org/10.1007/s13671-020-00319-w.
23. S.-K. Han, Interactive Wound Dressings, Innovations and Advances in Wound Healing (2023) 43–76. https://doi.org/10.1007/978-981-19-9805-8_2.
24. C. Weller, C. Weller, V. Team, Interactive dressings and their role in moist wound management, Advanced Textiles for Wound Care (2019) 105–134. https://doi.org/10.1016/B978-0-08-102192-7.00004-7.
25. E.T. Chamanga, Clinical management of non-healing wounds, 32 (2018) 48–63.
26. R. Fitridge, M. Thompson, eds., Mechanisms of Vascular Disease: A Reference Book for Vascular Specialists, Barr Smith Press, 2011.
27. R.L. Harries, D.C. Bosanquet, K.G. Harding, Wound bed preparation: TIME for an update, Int Wound J 13 (2016) 8–14. https://doi.org/10.1111/iwj.12662.
28. L. Atkin, Z. Bućko, E. Conde Montero, K. Cutting, C. Moffatt, A. Probst, M. Romanelli, G. Schultz, W. Tettelbach, Implementing TIMERS: the race against hard-to-heal wounds, J Wound Care 28 (2019).
29. S.L. Becker, S. Kody, N.M. Fett, A. Hines, A. Alavi, A.G. Ortega-Loayza, Approach to the Atypical Wound, Am J Clin Dermatol 25 (2024) 559–584. https://doi.org/10.1007/s40257-024-00865-0.
30. EN 13726-1:2002/AC:2003 Test methods for primary wound dressings - Part 1: Aspects of absorbency, (n.d.).
31. EN 13726-2:2002 Test methods for primary wound dressings - Part 2: Moisture vapour transmission rate of permeable film dressings, (n.d.).
32. PN EN ISO 1798 : 2009 FLEXIBLE CELLULAR POLYMERIC MATERIALS - DETERMINATION OF TENSILE STRENGTH AND ELONGATION AT BREAK, (n.d.).
33. V. Brumberg, T. Astrelina, T. Malivanova, A. Samoilov, Modern Wound Dressings: Hydrogel Dressings, Biomedicines 9 (2021). https://doi.org/10.3390/BIOMEDICINES9091235.
34. Aqua-Gel®. Sterylne opatrunki hydrożelowe, (n.d.). https://kikgel.com.pl/produkty/aqua-gel/#zalety-gojenia-ran-w-wilgotnym--rodowisku (accessed November 17, 2024).
35. V. M. Veličković, T. Macmillan, E. Lones, Y. Arlouskaya, P.A. Prieto, N. Webb, A. Crompton, I. Munro, V.F. Carvalho, S. Attila, D. Bárdos, Y.N. Lin, H.Y. Chiao, S. Probst, Systematic review and quality assessment of clinical and economic evidence for superabsorbent wound dressings in a population with chronic ulcers, Int Wound J 21 (2024). https://doi.org/10.1111/IWJ.14750.
36. Mextra Superabsorbent, (n.d.). https://www.molnlycke.pl/produkty-i-rozwiazania/mextra-superabsorbent/ (accessed November 17, 2024).
37. K. Vowden, P. Vowden, Wound dressings: principles and practice, Surgery (United Kingdom) 35 (2017) 489–494. https://doi.org/10.1016/j.mpsur.2017.06.005.
38. P.S. Murphy, G.R.D. Evans, Advances in Wound Healing: A Review of Current Wound Healing Products, Plast Surg Int 2012 (2012) 1–8. https://doi.org/10.1155/2012/190436.
39. K. Fogh, J. Nielsen, Clinical utility of foam dressings in wound management: a review, Chronic Wound Care Management and Research (2015) 31. https://doi.org/10.2147/cwcmr.s50832.
40. S. Barrett, R. Callaghan, P. Chadwick, S. Haycocks, M. Rippon, J. Stephen-Haynes, S. Simm, An observational study of a superabsorbent polymer dressing evaluated by clinicians and patients, Https://Doi.Org/10.12968/Jowc.2018.27.2.91 27 (2018) 91–100. https://doi.org/10.12968/JOWC.2018.27.2.91.
41. S. Kaya, S. Derman, Properties of Ideal Wound Dressing, J. Fac. Pharm. Ankara 47 (2023) 1119–1131. https://doi.org/10.33483/jfpau.1253376.
42. N.A. Peppas, J.Z. Hilt, A. Khademhosseini, R. Langer, Hydrogels in Biology and Medicine: From Molecular Principles to Bionanotechnology, Advanced Materials 18 (2006) 1345–1360. https://doi.org/10.1002/ADMA.200501612.
43. G.D. Mogoşanu, A.M. Grumezescu, Natural and synthetic polymers for wounds and burns dressing, Int J Pharm 463 (2014) 127–136. https://doi.org/10.1016/J.IJPHARM.2013.12.015.
44. H. Kirwan, R. Pignataro, Chapter 2 - The Skin and Wound Healing, in: D.J. Magee, J.E. Zachazewski, W.S. Quillen, R.C.B.T.-P. and I. in M.R. (Second E. Manske (Eds.), Pathology and Intervention in Musculoskeletal Rehabilitation, W.B. Saunders, 2016: pp. 25–62. https://doi.org/https://doi.org/10.1016/B978-0-323-31072-7.00002-6.
45. V.J. Chapman, D.J. Chapman, Algin and Alginates, in: Seaweeds and Their Uses, 1980: pp. 194–225. https://doi.org/10.1007/978-94-009-5806-7_6.