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Influence of Accumulation of Humidity under Wound Dressings and Effects on Transepidermal Water Loss (TEWL) and Skin Hydration

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Abstract: The moisture content of the human skin, but also the loss of water through the skin, the transepidermal water loss (TEWL), plays a significant role in the skin's health. Various medical indications require the use of a wound dressing. However, how the skin environment changes under a wound dressing has not yet been sufficiently investigated. Skin moisture and TEWL values were measured in 20 healthy volunteers before and after the application of a total of 23 different wound dressings distributed over the back. Significant changes in the parameters from day 1 to day 2 were tested. Wound dressings change the underlying skin environment. Occlusive dressings significantly increase skin hydration and TEWL. The findings could contribute to quantitative analysis and monitoring of topical-wound therapy in the future.

Keywords: TEWL; water evaporation; skin microclimate; wound dressings; skin hydration; skin moisture

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1. Introduction

In the United States, more than 6 million patients suffer from chronic wounds [1], while acute and chronic wounds affect around 1.5–2 million people in Europe [2]. Not only is the prevalence of wounds very high, their treatment is also costly and accounts for a significant proportion of the healthcare budget [2]. A Welsh study analyzed the cost factor of patients with chronic wounds. With an overall prevalence of chronic wounds of 6% in the population, the cost of wound care, comorbidities and complications amounted to 5.5% of total healthcare expenditure [3]. In the United States, chronic wounds are even listed as one of the main causes of morbidity and mortality [4]. This is one of the reasons why knowledge about the correct care of wounds is so relevant. As the range of wound dressings available is large, and choosing the right dressing is not a trivial matter, clinical staff must be trained accordingly. Ultimately, correct wound care is also a cost factor. The initial correct treatment of a wound saves money for the healthcare system and also accelerates the healing process for the patient [5].

Wound dressings can be divided into interactive, inactive and bioactive dressings [6]. Inactive wound dressings are characterized by their high absorption capacity and rather low cost factor. They are made of cotton or synthetic fibers. Interactive wound dressings fulfill several criteria. They should generate a sufficiently moist wound environment and a constant pH value. They are also supposed to absorb any toxic substances that are released.

And they should prevent wound infections, be practical and enable simple and painless changing of the dressings. Interactive wound dressings include alginates, hydrofiber dressings, wound dressings containing silver, hydrogels, hydrocolloids, hydropolymer wound dressings, foams and gauzes. Bioactive wound dressings are reserved for special medical indications. They are mainly used in the treatment of chronic wounds, and predominantly in hospitals. These are skin substitutes such as autologous- skin, pig-skin or collagen-based wound dressings [6]. Wound dressings also differ in terms of their occlusive properties: dressings with a membrane overlay (such as dressings with an adhesive border), for example, are more occlusive than those without a membrane, such as compresses or plain foam dressings. However, how exactly the skin underneath a wound dressing changes has not yet been sufficiently investigated. Similarly, there is no established method for quantitative assessment, for example in the clinical testing of wound dressings, with regards to their occlusive effects. This study aims to investigate how transepidermal water loss (TEWL) and skin moisture change under different wound dressings as a result of topical therapy with the associated different occlusion.

Different types of wound dressings are used in the medical treatment of wounds. The selection of the correct dressing depends on the cause of the skin damage, on the one hand, and on the determination of the degree of drainage and depth of the wound, on the other [4]. During treatment, attention must also be paid to the likelihood that the tissue is already colonized with pathogenic microorganisms and to the amount of necrotic tissue in the wound [7]. The degree of exudation also plays an important role in wound care. With an area of 1.4 to 2 m^2, the skin is the largest organ in the human body. It makes up about 15% of the human body weight and has a thickness of 1–2 mm [8–10]. It is built up in several layers. A distinction is made between two larger compartments: the dermis, whose functions are diverse and complex [11], and the overlying epidermis, which, among other things, fulfills barrier functions. Four further layers, the stratum corneum, stratum granulosum, stratum spinosum and stratum basale, in turn, form the structure of the epidermis [8–10]. The stratum corneum plays a special role in relation to the significance of the present study. The stratum corneum regulates the water content and loss within this layer. The presence of water in the stratum corneum is physiological and depends on hygroscopic substances within the corneocytes (the histological cell form of this skin layer) and intercellular lipids. Overall, these factors represent a barrier to transepidermal water loss [12].

The maintenance of these skin layers is necessary to maintain health. However, objectively assessing the condition of the skin is not a trivial matter. With the help of certain measuring probes (©Courage & Khazaka electronic GmbH, Cologne, Germany) it is possible to collect the relevant skin parameters. In this study, skin hydration and TEWL were investigated after a topical therapy with different wound dressings and scar plasters.

The microclimate of the skin includes the factors of temperature and skin moisture and, depending on the source, the air flow near the skin surface also plays a relevant role [13–16]. Changes in the microclimate can affect the integrity of the skin and lead to skin damage. Prolonged exposure to water and elevated temperatures are associated with increased TEWL values, and can lead to impairment of the skin's barrier function [13]. The term microclimate is used particularly in the context of pressure ulcer studies. In this context, it has been established that increased skin moisture is a significant risk factor for pressure-ulcer formation, so current studies are investigating the influence of external factors on the skin's microclimate [17].

2. Materials and Methods

The study was approved by the Ethics Committee of the University of Regensburg (21-2481-101, 28 July 2021).

A total of 20 subjects (6 women, 14 men) were recruited from the investigator's circle of acquaintances to carry out the study, all of whom had given their written consent. In addition, the following inclusion criteria had to be met: subjects had to be of legal age, capable of giving informed consent, subjects were not allowed to be pregnant, they were not allowed to have any skin diseases or pronounced skin nevi in the study area, and were not allowed to be currently undergoing any topical skin therapy.

For each subject, a randomized order of application of 23 (+1 control site) different wound dressings was determined on the back of the subjects (Figure 1). An online randomization tool was used to generate the randomization of the distribution (between 2021 and 2024). The randomization was intended to ensure that any measurement differences could not be associated with different locations on the skin. A total of 23 different wound dressings were examined. One area of skin was omitted. This served as a control condition.

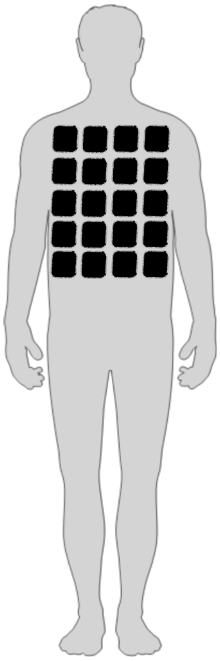

Figure 1. Shows how the different wound dressings were distributed across the subjects' backs. The image was generated with https://smart.servier.com/ (accessed on 26 August 2024).

The wound dressings used belong to different wound-dressing categories (Table 1). Three different types of simple dressings were examined (Gazin® gauze dressings, Solvaline®N, Metalline® dressings, each from Lohmann & Rauscher, Rengsdorf, Germany). A total of 7 wound dressings can be assigned to the foam-dressing category (Allevyn non-adhesive foam dressing, Allevyn adhesive foam dressing, Allevyn thin foam dressing from Smith+Nephew© (London, UK); Mepilex, Mepilex Border Flex from Mölnlycke© (Gothenburg, Sweden); Biatain® non-adhesive, Biatain® Adhesive from Coloplast Professional© (Humlebaek, Denmark). Four Lohmann & Rauscher© brand film dressings were examined (Suprasorb P non-adhesive, Suprasorb P adhesive, Suprasorb P sensitive border light, and Suprasorb P sensitive non-border). A transparent dressing was also examined: Tegaderm from the brand 3M Healthcare Germany GmbH© (Düsseldorf, Germany). As synthetic skin substitutes, Suprathel® (1× in moist, 1× in dry version) from PolyMedics Innovations GmbH© (Kirchheim unter Teck, Germany), EpiGARD from Biovision GmbH© (Ilmenau, Germany), Xenoderm from Medical Biomaterial Products© (Neustadt-Glewe, Germany), and Biobrane from Smith+Nephew© were examined. The last wound-dressing category examined was scar plasters, including Mepiform from the Mölnlycke© brand, Cica care from the Smith+Nephew© brand and Scar FX from the TRICONmed GmbH© brand (Körle, Germany).

Table 1. Wound dressings.

Wound Dressing Category	Type of Wound Dressing	Area of Application	Product Composition
Simple dressings	Gazin	Simple wound coverage	100% cotton
	Solvaline	Bodily fluid absorption	80% viscose, 20% polyester
	Metalline	Superficial wounds	Viscose coated with aluminum
Foam dressings	Allevyn non-adhesive/ adhesive foam dressing	Superficial wounds, moderately to heavily exuding wounds, Ulcers, postoperative wounds	Polyurethane foam
	Allevyn thin foam dressing		Polyurethane matrix with embedded superabsorbers
	Mepilex		Polyurethane foam dressing with Safetac technology
	Mepilex border flex		Polyurethane foam dressing with Safetac technology
	Biatain non-adhesive/adhesive		Polyurethen foam with semi-permeable, bacteria- and water-repellent top film
Brand film dressings	Suprasorb P non-adhesive/adhesive	Ulcera, decubiti, diabetic foot syndrome, postoperative wounds	Polyurethan foam + polyurethan film
	Suprasorb sensitive border lite/non border	Used for more fragile and damaged skin	additional silicone contact layer
Transparent dressing	Tegaderm	Covering of venous catheter sites, wound observation	Polyurethan film + acrylate adhesive
Synthetic skin substitutes	Suprathel moist/dry	Skin grafting, burn wounds, difficult to heal wounds	Copolymer of polylactic acid (PLA) and polyglycolic acid (PGA) + Poly(ε-caprolactone)
	Epigard		Silicone-based
	Xenoderm		special bioresorbable, synthetic polymer based on Polyurethan
	Biobrane		Synthetic silicone + collagen-based material
Scar plasters	Mepiform	Hypertrophic scars, colloids, traumatic and post-operative scars and scar prevention	Silicone + acrylate adhesive
	Cica care		Silicone based
	Scar FX		Silicone + acrylate adhesive

The data were collected in an air-conditioned and heated room with closed doors and constant air conditions, so as not to interfere with the measurements. Subjects were able to acclimatize to the room conditions prior to the investigations, so as not to impair the measurements.

Skin hydration and TEWL were measured at each of 24 skin sites, starting in an area below the neck and extending to the skin above the coccyx, using the Khazaka probes, before applying the corresponding wound dressing. After the baseline measurements, the respective wound dressings were applied. Some of the wound dressings were self-adhesive (e.g., “Biatain adhesive”), and others were applied to the skin using adhesive strips attached to the edge (e.g., Solvaline), whereas the wound dressings were only fixed at the borders, in order to not compromise the effects on the underlying skin. Measurements were taken in the skin areas with no adhesive, to exclude a potential impact of tape stripping on the measurements. Another measurement was carried out after 24 h. The test subjects were allowed to move freely in the time between the two measurements but were not allowed to take a shower or bath or expose themselves to any physical stress, to avoid measurement errors, for example those due to sweating or wet skin. Here too, the test subjects had to acclimatize to the room conditions before the measurement. The wound dressings were removed in the respective order and all skin parameters were measured again.

The Courage & Khazaka Multi Probe Adapter (Courage & Khazaka, Cologne, Germany) with Corneometer CM825 (Courage & Khazaka, Cologne, Germany) and Tewameter TM Hex (Courage & Khazaka, Cologne, Germany) were used for all measurements. Three measurements were taken using the Corneometer probe, and the average value was used in the analysis to account for fluctuations in the individual measurements. The Tewameter probe measured data over a period of 30 s until the device obtained a stable measurement value.

The collected data were compiled in an Excel 2016 spreadsheet. Statistical analysis was performed using Python (https://www.python.org/). After testing for normal distribution using the Shapiro–Wilk test, two types of statistical tests were applied. *t*-tests for dependent samples were performed to test for day-dependent measurement differences. In order to test for significant differences between the individual wound dressings, *t*-tests for independent samples were carried out.

3. Results

Collective of subjects. We included 20 subjects, 6 females and 14 males (Table 2).

Table 2. Collective of test subjects.

Variables	Females	Males
Number [total]	6	14
Age [years, mean]	34.84	38.14
Height [m, mean]	169.83	182
Weight [kg, mean]	64	80.86
Diagnosis	Arthritis, Hypothyroidism	Glomerulonephritis, Diabetes mellitus, Atrial fibrillation, Arterial hypertension, condition after stent implantation
Current medication	1× Levothyroxin 100 µg	Clopidogrel, Bisoprolol, Ezetimib, Metformin, Atorvastatin, Hydrochlorothiazid, Flutiform
Smokers	1	4

It was tested whether the TEWL and skin-hydration values measured on the first day differed significantly from the values measured on the second day of the study (Figures 2 and 3). In addition, the mean daily difference values of all wound dressings were examined for significant differences in relation to the control condition.

With two exceptions, an increased TEWL value was measured for all wound dressings on the second day of the study. For the wound dressings Tegaderm, Allevyn adhesive, Allevyn thin, Mepilex Border, Suprasorb P, Suprasorb adhesive, Suprasorb Sensitive border lite, Suprasorb P sensitive non border, Biatain, Biatain adhesive, Mepiform, Cica care and Scar FX, the TEWL values were significantly higher on the second day of the examination than on the first day. Slightly lower values were measured for Metalline and Solvaline on the second day. Both belong to the wound-dressing category of compresses. The greatest difference in the measured values between day 1 and day 2 was for the preparation Cica care, with a mean daily difference of 47.23. The measured values for the wound dressings Tegaderm, Allevyn adhesive, Allevyn thin, Mepilex Border, Suprasorb adhesive, Suprasorb sensitive border lite, Suprasorb P sensitive non border, Biatain adhesive, Mepiform, Cica care and Scar FX differed significantly from the control site.

A negative value was recorded for two wound dressings on the second day of the study. This affected the control condition and Allevyn thin. For all other wound dressings, the skin moisture recorded on the second day of the study was higher than on the first. For Tegaderm, Solvaline, Metalline, Allevyn, Allevyn adhesive, Mepilex Border, Suprasorb P, Suprasorb adhesive, Suprasorb P sensitive non border, Biatain, Biatain adhesive, Suprathel dry, Epigard, Xenoderm, Biobrane, Mepiform, Cica care and Scar FX, the measured skin-moisture values were significantly higher on the second day than on the first day. The greatest difference in the measured values between day 1 and day 2 was for Biatain adhesive, with a mean daily difference of 23.45. A significant difference between the control condition and the respective wound dressing was recorded for the following preparations: Tegaderm, Allevyn thin, Biatain, Biatain adhesive, Suprathel dry, Biobrane, Mepiform, Cica care and Scar FX.

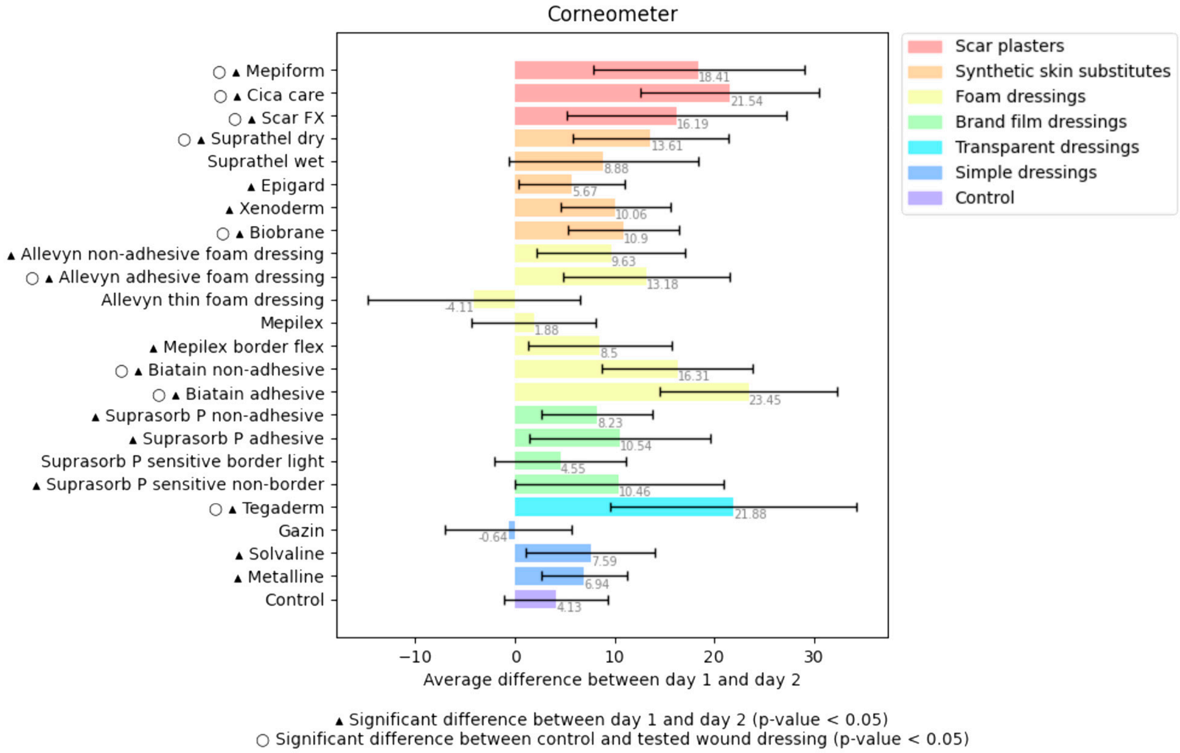

Figure 2. Mean measured skin-hydration values (Day 2–Day 1). Significant differences between day 1 and day 2 are highlighted with a black triangle. White dots mark significant differences between the dependent wound dressing and the control value.

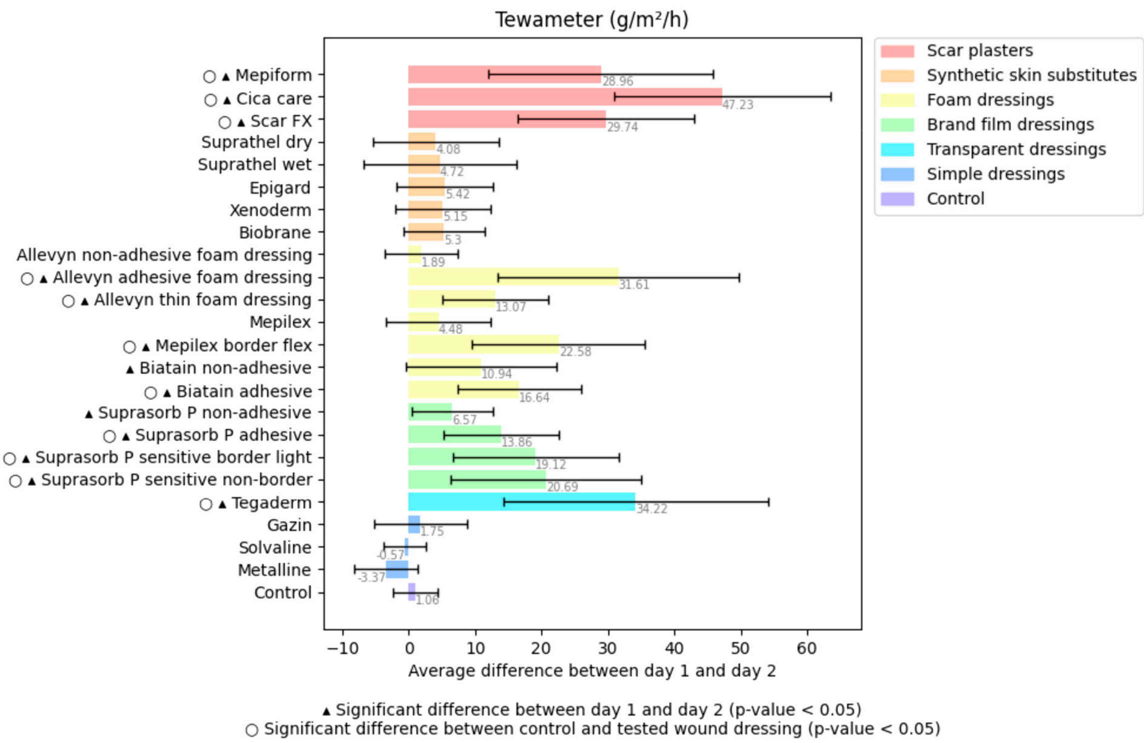

Figure 3. Mean measured-skin TEWL values (Day 2–Day 1). Significant differences between day 1 and day 2 are highlighted with a black triangle. White dots mark significant differences between the dependent wound dressing and the control value.

4. Discussion

Wound dressings fulfill various functions. On the one hand, they form a barrier function. and thus prevent microbial colonization of wounds. On the other hand, they should absorb wound secretions and create a sufficiently moist wound-healing environment, so that the skin is able to re-epithelialize well [18]. Depending on the type of wound dressing, these functions are emphasized to a greater or lesser extent. The range of wound dressings available on the world market is large and confusing [3]. There are different wound dressings for different indications. Even within the respective categories, there are differences of opinion among experts. Some argue that wound dressings should only be selected and used after careful scientific testing. Others believe that experience-based clinical expertise justifies the selection of the correct dressing for the particular wound [19]. In addition, both financial factors and physical availability play a role in the choice of dressing. Individual research areas exist for each wound-dressing category (e.g., dressings, burn plasters, scar plasters, skin substitutes). A very comprehensive paper examined 13 reviews or meta-analyses on the topic of wound dressings. SAWDS (standard advanced wound dressings) were examined: films, foams, gels, hydrocolloid dressings and hydrofibers. Typical areas of application frequently represented in the literature were venous ulcers, pressure ulcers, chronic wounds, surgical wounds and diabetic foot syndromes. It was shown that SAWDS and gauze produced similar results for venous ulcers. Hydrocolloid dressings also showed a better healing process for pressure ulcers and chronic wounds SAWDS. However, it was not possible to make a clear statement about which wound dressing achieves the best results [20]. The data situation is complex and multi-layered. It is not the aim of the present study to assess indications or qualities of individual wound dressings. The aim is to establish a trend in the direction of changes in skin properties under wound dressings. Only intact skin from healthy individuals was examined.

The moisture content of the skin largely determines its physiological condition. Maintaining water homeostasis is crucial for the skin's ability to function [21]. The prerequisite for a healthy moisture balance is an intact stratum corneum, which is maintained by various types of connections (e.g., tight junctions) and the presence of lipids such as ceramides. These elements are influenced by various factors including environment, age, diet, circadian rhythm and ultraviolet radiation, all of which ultimately impact skin hydration [22]. The presence of aquaporins, transmembrane proteins that promote water transport, also plays an important role in the skin's water balance. They influence the regulation of body temperature, skin hydration and skin-healing processes [23]. Assessing the moisture status of a subject's skin is therefore extremely important on the one hand, but on the other hand it is complex and not easy to interpret.

Measuring skin hydration also has clinical implications. For example, the wound-healing process in diabetic foot syndrome can be positively influenced by sufficiently high skin-moisture levels. Feet with sufficient skin moisture had to be amputated significantly less frequently [24].

Transepidermal water loss (TEWL) can be defined as the "continuous invisible loss of water through the human skin" [25]. This value provides important information about the barrier function of the skin. More than 30 years ago, it was already assumed that the TEWL value changes depending on the skin's state of health, in such a way that it is possible to distinguish physiological from pathological skin conditions [26]. Skin diseases such as psoriasis vulgaris or atopic dermatitis often lead to increased TEWL values. The measurement of the TEWL value, therefore, also plays a role in clinical applications for estimating the course of certain diseases [27]. Covering the skin (e.g., with wound dressings) increases skin moisture on the one hand, and on the other hand, increased TEWL values are also recorded when measured after removal of the occlusion [28–30].

A German study has already shown that TEWL values increased significantly after the application of epicutaneous plasters with sodium lauryl sulphate (SLS) in various concentrations (0.25%, 0.5%). This was demonstrated for incubation times of 12, 24 and 48 h [31]. Similar results were also shown in other studies [28]. However, only one type of skin coverage was examined. Similar results could even be achieved with furred animal skin. In the examination of the stratum corneum of 10 healthy dogs, increased TEWL values were also associated with impaired skin barrier function [32].

The TEWL value is one of the most important measurable parameters for assessing the barrier function of the skin [25,26,28,33,34]. It represents the amount of condensed water that diffuses to the skin surface via the stratum corneum per unit of time [33]. It is a relevant but susceptible parameter. In the present study, increased TEWL values were measured on average across all test subjects for almost all wound dressings on the second day of the study. The only exceptions to this were Solvaline and Metalline. Both wound dressings were compresses. The mean measured daily difference values are only slightly negative, and could also have come about within the framework of acceptable intraindividual measurement variability. However, the nature of the wound dressings could also be responsible for the results. Both dressings can be used for wounds with low-to-moderate exudation.

Most simple wound dressings are made of cotton. This material is characterized by the fact that it is soft, absorbent and hypoallergenic, and is therefore well tolerated by most people [35]. The high absorbency could explain why none of the wound dressings in the simple wound-dressings category showed a significant difference in TEWL between the two measurement days or between the respective preparation and the control group. It could be concluded that the proportion of water lost via the epidermis is absorbed by the preparations and that the accumulation of humidity under the wound dressing is lower and the TEWL is therefore not affected.

Transparent dressings like Tegaderm, on the other hand, are only minimally absorbent. Their advantage is that their transparency allows for the monitoring of wound status. Although these polyurethane films are semi-permeable in nature, fluid collects underneath these dressings [35]. They therefore have a highly occlusive character, which fits the results of our study and explains the high TEWL and skin-hydration values, which were not only significantly higher on the second day, but also in contrast to the control site.

All film dressings examined in the study are made up of different versions of Suprasorb P. The dressings are used for moderately exuding wounds. They are based on polyurethane foam and silicone, are bacteria- and waterproof, and also attempt to create a moist skin environment. Typical areas of application are superficial injuries, minor burns, ulcers and chronic wounds. Film dressings, therefore, share similar areas of application to foam wound dressings. They also consist of polyurethan but, unlike the transparent and film dressings, they have much thicker sheets and can absorb a higher amount of skin moisture [35]. In order to create an optimal healing environment for ulcers, a wound environment that is as moist as possible should be established [36]. Biatain dressings showed the highest mean daily differences in terms of skin hydration, while Allevyn products achieved the highest differences in terms of TEWL. The main component of both types of wound dressing is a hydrophilic polyurethane foam. Both wound-dressing manufacturers use a silicone-based adhesive layer, which contributes significantly to the occlusive character. These similarities with regard to the structure of the products could explain the findings. While the adhesive component of the wound dressings in Allevyn provides a silicone-based seal and Biatain uses non-silicone-based adhesion, both types of wound dressing have an occlusive character and lead to a moist skin environment overall. Mepilex, on the other hand, uses the company's own Safetac® technology. This is a special form of silicone adhesion that is very well tolerated by the underlying skin, but is more suitable for wounds that do not exude as heavily, which might also account for the measured lower-TEWL and moisture values.

Synthetic skin substitutes are used for various forms of severe skin damage. These can be traumatic or post-operative in nature, occurring after major burns, and are also used in the treatment of chronic, poorly healing wounds. They are designed to replace the extracellular matrix of the body's own skin, so that the wound healing process in the affected areas of the body is facilitated and better cosmetic and functional results can be achieved [37]. The skin substitutes examined in the present study are of different compositions. While Biobrane and Xenoderm re-synthesize parts of the skin derived from pigs, Epigard and Suprathel are synthetically produced preparations. Suprathel consists of polylactic acid, polycaprolactone and trimethylene carbonate, while Epigard consists of a polymer foam layer coated with a silicone-based, water-repellent layer. Although there are clear differences between the preparations in terms of skin-substitute composition, none of the preparations showed significantly higher TEWL values in the present study, either on the second day of the study or in comparison with the control group, which supports the hypothesis that these dressings could counteract excessive accumulation of humidity in, and evaporation from, the underlying skin, and thus replace some of the protective properties of skin in this respect (skin substitute). Overall, the skin substitutes examined are less occlusive in nature compared to other wound dressings examined. Although one of the objectives is also to create a moist wound environment for skin regeneration [38], it is not as moist as in the case of foam wound dressings, for example.

Scar plasters are characterized by their supportive nature. They exert traction on the underlying skin so that wound healing is supported. They also promote collagen formation and restructuring, control inflammation, and influence the water balance [39]. Most scar plasters are semi-occlusive-to-occlusive in nature, and silicone-based. They increase the hydration of the stratum corneum and thus prevent the formation of hypertrophic scars [40]. In the present study, significantly increased TEWL and skin-hydration values were achieved for all scar patches on the second day of the study. Cica care achieved the highest mean daily differences in the study. Tegaderm, belonging to the wound-dressing category of transparent wound dressings, showed the second-highest mean daily difference values in the study. As previously mentioned, they are semipermeable in nature and are therefore intended to maintain a certain degree of permeability. Nevertheless, they have a primarily occlusive effect and collect fluids underneath the wound dressing, in the form of exudates or sweat, for example [35]. The findings thus match the intended wound-dressing properties.

All dressings that showed significant TEWL differences between the control condition and the measurement condition were self-adherent. With regard to the increase in TEWL, the extent of occlusion of the wound dressing appears to play a significant role. If it is desirable for the clinical setting to create a wound healing environment that is as self-contained as possible, a self-adhesive preparation should be used. Non-self-adhesive dressings did not achieve such high TEWL values. While the findings with regard to skin moisture were not quite as distinct, the comparison of adhesive versus non-adhesive preparations did reveal a noticeable difference. For the foam dressings Allevyn and Biatain, the self-adhesive variants of the preparations showed higher mean daily difference values. The same was evident for the brand Film Suprasorb P, with the sealed version again achieving higher moisture values.

It could be shown that TEWL and skin temperature change, depending on climate and ambient temperature [41]. Whereas it was attempted to keep test conditions as constant as possible for all test subjects, even closer monitoring of conditions could provide additional insights in subsequent studies.

As the scientific field of wound-dressing development is constantly working on new compositions to fill certain gaps of medical usage, in recent years, more complex wound dressings have been developed. Bioactive inorganic particle-based biomaterials are materials that cover more complex functions than just tissue coverage. They have antimicrobial properties, stimulate the regeneration of the body's own cells without damaging the body's own cells, and can also act as a carrier for medical drugs [42]. Tissue engineering is a scientific field in its own right. The aim is the in vitro reconstruction of the extracellular matrix. With the help of these complex methods, scaffolds can be produced that function similarly to the body's own cell structures and have a high degree of cell compatibility, stability and regeneration potential [43–45]. While many of these materials are highly interesting from a scientific standpoint and could also play a greater role in wound care in the future, their main area of application is currently in bone regeneration and, therefore, they are more commonly present in the field of orthopedics and dentistry. Furthermore, their production is complex, and associated with substantial costs. A corresponding preparation could not be included in this paper. Future studies could investigate the extent to which TEWL and skin hydration change under such preparations and whether the results are similar to other wound-dressing categories.

The inclusion criteria for the recruitment of test subjects were only restrictive to a limited extent. The age of the test subjects demonstrably influences the condition of the skin. It could be shown that the age of a person has various effects on the barrier function of the skin. For example, age influences the permeability, hydration of the stratum corneum, the antimicrobial barrier and the chemical composition of the skin [46]. In a potential follow-up study, a more stringent age group could be investigated to control for this confounding variable. While a sample size of 20 subjects can be large enough to draw certain conclusions [47], investigating an even larger cohort could check the replicability of the results and, if necessary, strengthen their validity.

Despite the widespread use of the TEWL probe from Courage & Khazaka, there are sometimes significant deviations in the data collected. Possible causes for this were investigated in a study. Many factors, such as age, the measuring position on the body, and temperature, influence TEWL values. Exact cause-and-effect relationships could not be found. The most likely assumption is that the TEWL value is dependent on many variables, and that it is important to ensure that the measurement is as accurate as possible when collecting data [48]. One factor that significantly affects measured TEWL values is sweating. When sweat glands are highly active, higher TEWL values can be recorded [4,5,25]. In the context of occupational medicine, a meta-analysis attempted to compare and analyze studies on the collection of TEWL, skin hydration (stratum corneum hydration: SCH) and pH value (skin surface pH: SSpH). The aim was to gain insights into prevention strategies for possible skin diseases. It was also shown here that the measurement conditions and measurement positions have an important influence on the parameters recorded, which ultimately made it difficult to draw conclusions from the study [34]. TEWL values are not only influenced by environmental conditions, but even by environmental pollution. It is assumed that damage caused by free radicals in the context of environmental pollution leads to an increase in measured TEWL values [49]. Another comprehensive study analyzed 33 studies for possible confounding variables, factors that could influence TEWL measurement. Twelve variables could be summarized, including factors such as wearing a mask and vascular diseases, but also age and weight. Since many of these factors cannot be controlled in clinical studies, the authors even go so far as to say that the definition of a "normal" TEWL value is not trivial or even impossible [27]. Overall, there is already a lot of literature on supposedly impure TEWL measurements. However, a comparison of 22 different measuring devices in a total of 38 studies showed that different devices achieve similar TEWL results. The results obtained are therefore far from random [50]. Nonetheless, there is a non-negligible susceptibility to error and confounding variables. A comprehensive study compared a total of 19 studies that provided data on the hydration of the stratum corneum. It was clearly shown that the hydration values of the skin depend on the respective localization. In the study, the lowest hydration values were found for the back of the test subjects and the highest for the face [51]. In the present study, TEWL and skin hydration were measured exclusively on the back of the test subjects, with randomization. A further investigation that also includes other parts of the body could provide additional groundbreaking findings. On the other hand, the area to be examined could also be limited even further. This is because the localization-dependent measurement differences are prevalent, even within the "back" area. For example, an almost linear increase in the skin moisture of the back could be determined from back areas at the level of the hip region up to the skin of the neck [52]. As the area of the back where the crossbar of the bra underwire runs was omitted in the present study, in order to avoid premature detachment of the dressings, no measurements could be carried out in the corresponding skin area. A follow-up study with an equal sample size of male and female participants could investigate whether this circumstance has a significant influence on the data collected.

The Corneometer CM 820 (©Courage & Khazaka) was used in the present study. In a study by Alanen et al., it was shown that the measuring probe provides reliable results that are comparable with other manufacturers' devices [53]. Nevertheless, even more accurate measurements could be obtained for the MoistureMeter SC-2 (Delfin Technologies Ltd., Kuopio, Finland) [53]. Future comparative studies with other manufacturers' devices could confirm the results obtained.

In summary, it can be said that the imitations of the study concern the following aspects: inter-individual differences in measurement could contribute to biased effects. The TEWL value is very susceptible to interference, and depends on many factors. Not all of these factors can be adequately controlled. For financial and economic reasons, not all categories of wound dressings available on the market could be investigated (e.g., newer bioengineering approaches). In addition, the number of test subjects had to be limited. Based on our experience with the measuring device, a total of 20 test subjects had been estimated as adequate for the experiments. Further studies could build on these findings and expand our knowledge on the complex field of wound dressings.

5. Conclusions

To our knowledge, this study is the first to examine such a wide range of different wound dressings in healthy volunteers under controlled conditions, with regard to changing skin parameters. Wound dressings with adhesive borders demonstrated a stronger occlusion effect, resulting in higher transepidermal water loss (TEWL) and increased skin moisture levels. The use of various wound dressings creates different moist skin environments, suggesting that the composition of each dressing plays a critical role in influencing both skin hydration and TEWL. The underlying reasons for these differences are likely related to the specific details of the dressings' formulations, as several categories even share common ingredients such as polyurethane, which is present in foam dressings, film dressings, transparent dressings, and synthetic skin substitutes. Given that TEWL and skin moisture content are associated with skin health, selecting the appropriate wound dressing could potentially enhance wound healing. This connection underscores the clinical relevance of choosing the correct dressing to optimize patient outcomes.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are part of a potentially ongoing research project and are not publicly available in order to protect the intellectual property and the novelty of the findings. Additionally, to safeguard the privacy of individuals involved and to prevent any potential identification of private persons, the data will be shared selectively upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

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