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Comparing the effects of three different multilayer dressings for pressure ulcer prevention on sacral skin after prolonged loading: An exploratory crossover trial

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Abstract

Evidence suggests that preventive dressings applied on sacral skin help to prevent pressure ulcers. However, possible performance differences of different dressing types are unclear. An exploratory randomized crossover trial with intra-individual comparisons was conducted to compare the effects of three different multi-layer foam dressings (Mepilex Border Sacrum, ALLEVYN Life Sacrum and Optifoam Gentle Sacrum) compared to no dressing on the sacral skin. Healthy female volunteers (n = 12, mean age 72 years) wore three different dressings on their sacral skin for 3.5 hours while lying supine on a standard hospital mattress. At regular intervals, subjects performed standardized movements to enhance shear loads. Skin surface temperature, stratum corneum hydration, erythema, skin roughness and the interleukin 1 alpha (IL-1α) concentration per total protein were measured at baseline and after the lying periods. After 3.5 hours, the median skin temperature increased in all four groups between 3.0°C and 3.8°C with only minor differences between the no dressing and the dressing groups. Median stratum corneum hydration increased during the lying period in all groups with highest increases in the Optifoam Gentle Sacrum (7.3 arbitrary units) and no dressing group (7.0 arbitrary units). There was a median decrease of the mean roughness (Rz) in the Optifoam Gentle Sacrum group of −6.3 μm but no relevant changes in the other groups. After loading, the erythema index was highest in the ALLEVYN Life Sacrum and no dressing groups. Highest releases of IL-1α were observed in the ALLEVYN Life Sacrum and Optifoam Gentle Sacrum groups, in the Mepilex Border Sacrum group changes were minor. Study results indicate, that the application of preventive dressings on sacral skin during loading do not cause additional occlusion compared to loading without dressings when lying supine. Different dressings cause different cutaneous responses during loading.

1 | INTRODUCTION

Pressure ulcers (PUs), also called pressure injuries, are severe and unwanted cutaneous and/or subcutaneous wounds caused by prolonged skin and underlying soft tissue deformation.[1] They occur predominantly near bony prominences, with the sacral region being most frequently affected in patients lying in a supine position.[2] One cornerstone of PU prevention is to reduce the magnitude and

duration of the mechanical loads pressure and shear. Common interventions are, for example, repositioning, early mobilization and the use of special support surfaces.[1,3] In addition, empirical evidence indicates that the application of preventive dressings on the sacral area helps to prevent the development of PU.[4-8] This intervention is recommended in the latest international Pressure Ulcer Prevention and Treatment Guideline.[1,9] The mode of action of PU preventive dressings includes mechanical cushioning, the reduction of shear loads within soft tissues and a reduced friction coefficient between the dressing and the support surface.[10-12] There are many different dressings on the market and results of in vitro studies indicate that different dressings may have different effects on the skin microclimate, on pressure reduction, and maybe also on clinical outcomes.[10,13-15] However, results of laboratory or computer modeling studies are not automatically transferable to real-life situations and there are only few studies comparing the preventive effects of different prophylactic dressings in vivo directly with each other.[8] A recently published clinical trial of Yoshimura et al described the superiority of soft silicone foam dressings over polyurethane film dressings in spinal surgery patients.[16] Transparent polyurethane film dressings have been reported to be more effective in PU prevention than hydrocolloid dressings in hospital patients.[17] Based on results of a clinical simulation with three healthy subjects, the superiority of a polymeric membrane dressing over a simple foam in terms of skin temperature distribution capability after an 1-hour lying session was proposed.[18] Using the volar forearm skin of healthy volunteers de Wert et al concluded that single-layer foam dressings compared to multi-layered dressings were inferior regarding protection against mechanical loads.[19] These results suggest that performance differences between dressings are likely, but no studies have compared the skin response due to different dressings directly with each other using a variety of physiological parameters.

Next to the "hard" clinical outcome "PU development", a number of alternative biomarkers and parameters that characterize the response of the skin to prolonged loading and deformation have been proposed to evaluate the effectiveness of PU preventive interventions.[20,21] Skin functional parameters such as erythema or stratum corneum hydration (SCH) and structural parameters, like structural stiffness, have been successfully measured in previous PU prevention research.[22,23] These parameters are able to discriminate effects of different loading intensities and skin-support surface interactions to measure PU preventive device performance.[24] Recently, it has been shown that there are associations between structural and functional skin changes at the heel and sacral area during loading.[23] In clinical PU research, it has also been shown that (subclinical) injuries to the skin stimulate the release of inflammatory cytokines such as IL-1α. This molecule is released from keratinocytes in response to deformation[25] and has been proposed as a suitable biomarker for (sub-clinical) skin damages due to mechanical loading.[19,21,26] The aim of this clinical trial was to compare the effects of three different multilayer-layer silicone foam dressings compared to no dressing on the sacral skin area after simulating clinical loading while lying in bed.

2 | MATERIALS AND METHODS

An exploratory randomized crossover trial with intra-individual comparisons was conducted at the Clinical Research Center for Hair and Skin Science at the Department of Dermatology and Allergy, Charité-Universitätsmedizin Berlin (Germany). This study simulated a clinical situation in which the study participants spent 3.5 hours on a standard hospital mattress lying on their backs. The study was approved by the local ethics committee at the Charité - Universitätsmedizin Berlin (approval number: EA4/166/18) and was registered at ClinicalTrials.gov (NCT03815240).

2.1 | Participants

Healthy female volunteers between 65 and 80 years and with a Body Mass Index (BMI) from 18.5 to 29.9 kg/m^2 were eligible for study participation. The skin phototype had to be I, II, or III according to Fitzpatrick[27] and the participants had to be free of any clinical dermatosis or scars in the investigational area. The regular use of leave-on or other products on the sacral skin area was forbidden.

2.2 | Variables and outcomes

Due to the exploratory nature of this study, no distinction between primary, secondary or other variables was made.

2.2.1 | Demographic characteristics

Age (years), BMI (kg/m^2) and skin phototype according to the classification of Fitzpatrick were recorded at the beginning of the study.

2.2.2 | Skin function parameters

The skin surface temperature (°C), the stratum corneum hydration and the erythema index (EI) were measured at baseline and after the 3.5 hours loading phase. All measurements were performed three times per measurement time point and the mean was calculated. The skin surface temperature was measured with a skin thermometer based on the infrared technique (Courage & Khazaka electronic GmbH, Germany). The Corneometer CM 825 (Courage and Khazaka Electronic GmbH, Germany) was used to measure the SCH in arbitrary units (AU) that ranges from 0 to 120 AU. This measurement is based on the change in the dielectric constant due to differences in the superficial skin surface hydration. Higher readings indicate higher SCH. The measurement depth is not greater than 20 μm in order to avoid the influence of deeper skin layers (eg, of blood vessels). According to the manufacturer, the accuracy is ±3%. Evidence supports high reliability and low absolute measurement errors of SCH

estimates.[28] The EI was measured with the Mexameter MX18 (Courage and Khazaka Electronic GmbH, Germany). This device uses specific wavelengths to measure the absorption capacity of the skin, specifically the content of hemoglobin in the skin, and presents values from 0 to 999 in AU.[29] The measuring accuracy is specified by the manufacturer as ±5%.

2.2.3 | Skin structure parameters

Skin surface roughness was measured with the Visioscan VC 98 camera (Courage & Khazaka Electronic GmbH, Germany). Two duplicate images were taken at baseline and after 3.5 hours loading phase. The special UV light source of this device provides high-resolution images of the skin surface whose grayscale represents different depths. The distribution of the 255 gray levels allows the calculation of different roughness parameters by the corresponding software. The roughness parameters "mean roughness" (Rz) and "average roughness" (Ra) were determined as the mean value of the software output based on both images taken and was reported in μm. The reliability and validity of these two roughness parameters is supported by previous research.[29-31]

2.2.4 | Clinical evaluations

The clinical assessment of erythema was done via visual inspection of the sacral skin at baseline and after 3.5 hours loading phase using a four category scale: 0 = none, 1 = mild, 2 = moderate, 3 = severe. For this assessment the whole sacral area, not only the two measurement areas, were considered. Sacral pain was assessed by the subjects' self-report. The subjects were instructed to report if any pain was sensed at the sacral area during the study visit. The time until pain reported had to be noted by the study staff.

2.2.5 | Cyanoacrylate skin surface stripping

Cyanoacrylate skin surface stripping (CSSS) was used to obtain stratum corneum material for IL-1α and total protein analysis according to a standard operating procedure.[32] CSSS removes approximately 30% of the stratum corneum whereas the remaining stratum corneum is left intact.[33] Two drops of cyanoacrylate glue were applied on the investigational area of 2 cm × 2.5 cm. The glue was spread evenly on the investigational site with the help of a microscope slide and an adhesive tape was placed on it. A rubber roll was used to improve the adherence and to eliminate air bubbles. After 20 minutes of hardening time, the tape (and the adhering glue) were removed quickly from the skin surface, was cut to size based on markings on the tape, and immediately stored in tubes at −80°C until analysis.[34] For protein extraction phosphate bufferered saline with 0.005% Tween 20 was used. IL-1α was measured by a human IL-1α enzyme-linked immunosorbent assay (ELISA) (DuoSet R&D system) and the total protein by a Coomassie Plus protein assay (Thermo Scientific), with subsequent photometric analyses. In order to adjust the amount of sample uptake to be compared, the IL-1α was calculated per 1 μg total protein (pg/μg).

TABLE 1 Sample characteristics (n = 12)

Age (years)	
Mean (SD)	72.2 (4.2)
Median (IQR)	71 (69–77)
Body mass index (kg/m^2)	
Mean (SD)	24.9 (3.0)
Median (IQR)	24.3 (22.7–27.8)
Skin phototype (n)	
II	4
III	8

2.3 | Intervention

All included subjects came to the study center for four visits. At three visits, a five-layer silicone foam dressing was applied to the subjects' sacrum (each time from a different manufacturer); at one visit no dressing was applied. In between, there were at least 3 weeks to allow the stratum corneum to regenerate after tape stripping and to prevent possible carry over effects. The order of assigned treatments was based on a 1:1:1:1 randomization scheme, created by the data manager, who was not involved in the study conduct. The three dressings were (1) Mepilex Border Sacrum from Mölnlycke Health Care AB, (2) ALLEVYN Life Sacrum from Smith & Nephew Medical Ltd. and (3) Optifoam Gentle Sacrum LQ from Medline Industries Inc. Due to the nature of the interventions, the subjects were aware when no dressing was applied and were only blinded in regard of the type of dressing. At the beginning of each visit, the subjects were asked to lie down in supine position on a standard hospital mattress covered by a cotton sheet for a maximum of 10 minutes. It was ensured that there was direct sacral skin to sheet contact during this period. After the 10 minutes, subjects turned around into prone position. Two fields of equal size (each 2 cm × 2.5 cm) were marked with a skin pen, one for the baseline and one for the follow-up measurements. If erythema occurred at the sacral area during the 10 minutes in supine position, the investigational skin area was marked within the reddened skin area. In case of no erythema, the test area was identified by palpating the most protuberant point at the sacrum. After marking the measurement areas, the subjects acclimatized under standardized room temperature and humidity conditions (22 ± 2°C, 40%-60% rel. humidity) for 30 minutes with the sacral skin uncovered. After that, subjects moved into prone position and baseline measurements of skin surface temperature, SCH and erythema index were conducted and Visioscan images were taken. Lastly, the cyanoacrylate skin surface stripping was performed and possible erythema was evaluated clinically. After the baseline measurements at the first visit, a randomization envelope was opened by the study staff to allocate the subjects to one of four intervention groups. According to the randomization scheme, one of the dressings was

TABLE 2 Comparisons between interventional groups (n = 12)

Skin temperature (°C)	Baseline	After 3.5 hours	Difference	*P*-value[a]
No dressing, Median (IQR)	30.5 (29.0 to 31.6)	33.7 (32.6 to 33.9)	3.1 (1.9 to 4.1)	.002
Mepilex Border Sacrum, Median (IQR)	29.8 (29.5 to 31.0)	33.6 (33.5 to 33.9)	3.8 (2.8 to 4.1)	.002
ALLEVYN Life Sacrum, Median (IQR)	30.8 (29.1 to 31.7)	33.8 (33.4 to 34.2)	3.0 (2.4 to 4.4)	.002
Optifoam Gentle Sacrum, Median (IQR)	30.2 (29.8 to 31.2)	33.7 (33.3 to 34.0)	3.3 (2.3 to 3.9)	.002
P-value[b]	-	-	0.423	-
SC hydration (AU)	**Baseline**	**After 3.5 hours**	**Difference**	***P*-value[a]**
No dressing, Median (IQR)	30.1 (23.0 to 36.8)	37.0 (32.8 to 43.9)	7.0 (0.7 to 13.3)	.006
Mepilex Border Sacrum, Median (IQR)	28.5 (22.4 to 29.1)	30.9 (28.8 to 34.8)	4.4 (1.2 to 11.5)	.005
ALLEVYN Life Sacrum, Median (IQR)	30.0 (23.5 to 33.0)	35.5 (28.7 to 40.1)	5.9 (−0.4 to 9.2)	.033
Optifoam Gentle Sacrum, Median (IQR)	24.8 (21.3 to 28.6)	34.4 (27.4 to 41.3)	7.3 (3.6 to 15.0)	.004
P-value[b]	-	-	0.104	-
Erythema index (AU)	**Baseline**	**After 3.5 hours**	**Difference**	***P*-value[a]**
No dressing, Median (IQR)	194 (168 to 224)	234 (198 to 266)	29 (19 to 49)	.003
Mepilex Border Sacrum, Median (IQR)	175 (154 to 226)	202 (162 to 232)	7 (−9 to 45)	.239
ALLEVYN Life Sacrum, Median (IQR)	166 (148 to 223)	201 (170 to 215)	41 (−2 to 63)	.062
Optifoam Gentle Sacrum, Median (IQR)	180 (169 to 206)	191 (147 to 222)	4 (−24 to 25)	.724
P-value[b]	-	-	0.039	-
Mean roughness (Rz, µm)	**Baseline**	**After 3.5 hours**	**Difference**	***P*-value[a]**
No dressing, Median (IQR)	30.0 (27.4 to 37.5)	31.0 (29.1 to 31.5)	−0.8 (−7.6 to 1.8)	.289
Mepilex Border Sacrum, Median (IQR)	30.3 (27.0 to 37.4)	30.3 (30.0 to 31.4)	−1 (−5.3 to 2.8)	.285
ALLEVYN Life Sacrum, Median (IQR)	30.5 (28.1 to 31.0)	29.3 (26.6 to 31.8)	−0.8 (−2.0 to 0.9)	.306
Optifoam Gentle Sacrum, Median (IQR)	33.0 (32.0 to 36.4)	26.0 (25.1 to 28.5)	−6.3 (−9.4 to −5.0)	.002
P-value[b]	-	-	0.129	-
Average roughness (Ra, µm)	**Baseline**	**After 3.5 hours**	**Difference**	***P*-value[a]**
No dressing, Median (IQR)	24.3 (22.3 to 29.5)	24.8 (22.6 to 27.4)	- 0.8 (−3.9 to 2.4)	.415
Mepilex Border Sacrum, Median (IQR)	24.8 (21.4 to 33.4)	25.0 (24.1 to 27.5)	−0.3 (−5.8 to 3.1)	.415
ALLEVYN Life Sacrum, Median (IQR)	24.3 (22.6 to 24.9)	24.3 (23.0 to 26.9)	0.5 (−0.5 to 2.3)	.245
Optifoam Gentle Sacrum, Median (IQR)	26.5 (24.8 to 29.4)	23.0 (22.1 to 25.0)	−4.5 (−6.9 to −0.6)	.007
P-value[b]	-	-	0.078	-
Interleukin-1alpha (pg/µg)	**Baseline**	**After 3.5 hours**	**Difference**	***P*-value[a]**
No dressing, Median (IQR)	13.0 (5.6 to 18.9)	16.7 (5.3 to 22.5)	1.1 (−0.1 to 4.2)	.071
Mepilex Border Sacrum, Median (IQR)	9.0 (5.6 to 14.9)	11.1 (5.6 to 14.2)	−0.1 (−0.9 to 2.5)	.695
ALLEVYN Life Sacrum, Median (IQR)	9.9 (4.8 to 15.4)	12.6 (4.4 to 15.6)	1.3 (0.1 to 3.7)	.050
Optifoam Gentle Sacrum, Median (IQR)	11.3 (3.5 to 16.8)	12.6 (4.9 to 17.3)	1.3 (−0.8 to 2.8)	.272
P-value[b]	-	-	0.475	-

[a]Wilcoxon-test.
[b]Friedman's ANOVA.

applied or the skin was left uncovered, followed by a 3.5 hours loading period. The subjects laid in supine position on a standard hospital mattress. Every 30 minutes the head of the bed was elevated to 45° for 5 minutes. During these 5 minutes, the participants were instructed to bend their knees and to drag the feet repeatedly back and forth 10 times in order to simulate movement and shear forces. The head of the bed was moved back again and the subjects relaxed. The whole exercise was repeated six times, after 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 hours. After 3.5 hours loading time in supine position, the subjects moved into prone position again. In cases where a dressing was applied, it was removed and all skin measurements were conducted immediately, followed by CSSS. An overview of the process of a visit is presented in the Appendix (see Table A2).

2.4 | Statistical methods

Due to the exploratory nature of this trial, a formal sample size calculation was not performed. It was planned to include n = 12 female subjects. Demographic characteristics were described using numbers, means and standard deviations (SD), medians and interquartile ranges (IQR). Metric outcomes were described using median and interquartile

ranges (IQR) per intervention group and per time point. Median differences were calculated and the Wilcoxon-test was used to compare the baseline and after treatment measurements. Friedman's ANOVA was used to compare the median differences between the four interventions. As this study was exploratory, all *P*-values were considered descriptive. Scatter plots were created to show possible associations between the skin parameters in the no dressing group.

3 | RESULTS

3.1 | Participants

The recruitment started after Ethics Committee approval in January 2019 and the study was performed between January and July 2019. The 12 included female volunteers had an average age of 72 years and a mean BMI of 24.9 kg/m^2. Most of the participants (n = 8) had skin phototype III (see Table 1).

3.2 | Outcomes

The comparisons between the four interventional groups (no dressing, Mepilex Border Sacrum, ALLEVYN Life Sacrum, Optifoam Gentle Sacrum) at baseline and after 3.5 hours loading are shown in Table 2.

The baseline skin temperatures of approximately 30°C were comparable between the groups. After the lying period, the median temperature increase ranged between 3.0°C in the ALLEVYN Life Sacrum group and 3.8°C in the Mepilex Border Sacrum group. The median SCH at baseline was between 24.8 and 30.1 AU. After lying 3.5 hours in supine position there was an increase in all groups ranging from a median of 4.4 AU (IQR 1.2 to 11.5, Mepilex Border Sacrum) to 7.3 AU (IQR 3.6 to 15.0 AU, Optifoam Gentle Sacrum). The second highest increase in stratum corneum hydration was observed in the group without a dressing. The erythema values at baseline were comparable, but loading differences were subsequently detected between the groups. There were high median increases of erythema in the no dressing (median 29, IQR 19-49) and ALLEVYN Life Sacrum (median 41, IQR −2 to 63) groups. Minor increases were observed in the Mepilex Border Sacrum and Optifoam Gentle Sacrum groups. Results of the roughness parameter Rz and Ra indicate minor changes after loading but there were median decreases of Rz of approximately 6 μm and Ra of approximately 5 μm in the Optifoam Gentle Sacrum group. In three groups, the median IL-1α concentration per 1 μg total protein increased after loading. The highest median increases were observed in the ALLEVYN Life Sacrum (1.3 pg/μg, IQR 0.1-3.7) and Optifoam Gentle Sacrum groups (1.3 pg/μg, IQR −0.8 to 2.8), followed by the no dressing group (1.1 pg/μg, IQR −0.1 to 4.2). In the Mepilex Border Sacrum group, median IL-1α changes were minor −0.1 (IQR −0.9 to 2.5).

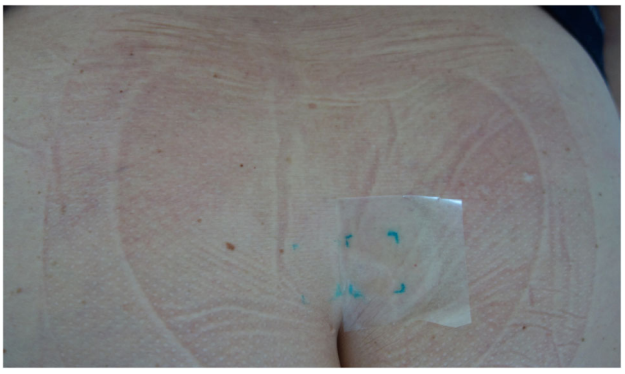

FIGURE 1 Erythema after 3.5 hours loading and removal of one experimental dressing; at right investigational area: adhesive tape for the cyanoacrylate skin surface stripping (during hardening period) [Color figure can be viewed at wileyonlinelibrary.com]

The results of the clinical evaluation of erythema are shown in the Appendix. There was no visible erythema at baseline in any group. In the dressing groups, approximately half of the subjects developed a mild and/or moderate blanchable erythema within the dressing area after the loading period. In the no dressing group this was observed in three subjects. There was no pain reported by the subjects at any time. Figure 1 displays an example of erythema after dressing removal.

Associations between changes of the measured parameters are shown in the scatter plots for the no dressing group (Figure 2).

All subjects showed an increase of skin temperature. Except of one, this was associated with an increase of erythema and in most participants with an increase of SCH. Increases of skin temperature seemed not to be associated with changes of skin surface roughness. Roughness and IL-1α changes seemed to be unrelated as well. Increases in erythema were mostly associated with increased SCH (n = 10), as well as with increased IL-1α release (n = 8). However, three subjects who developed erythema had no inflammatory marker increase and one subject without erythema had a clear rise of IL-1α. Most of the subjects with increased IL-1α had an increase of skin temperature (n = 9) and SCH (n = 8).

4 | DISCUSSION

The overall aim of this study was to compare the effects of three different dressings compared to no dressing and to investigate the physiological response of the sacral skin area while lying in bed for 3.5 hours. The loading condition simulated a clinical situation in a standard hospital bed with pressure and shear due to lying supine and movements in bed. Especially, the repeated backrest elevation induces friction to the sacral skin area and high degrees of mechanical deformation.[35] Compared to similar simulation studies in this area[23,24,26] a loading period of 3.5 hours was very long.The baseline sacral skin temperature of approximately 30°C was within the typical skin temperature range between 29°C and 31°C reported in comparable previous studies.[15,24] The skin temperature increased in all four groups, indicating occlusion and accumulation of heat. The observed temperature increases between 3°C and 4°C were slightly higher compared to 90, 120, and 150 minutes loading[23,24] on a standard hospital mattress. Probably, the main reason for this was the longer duration of occlusion due to the longer lying period. There were only minor differences

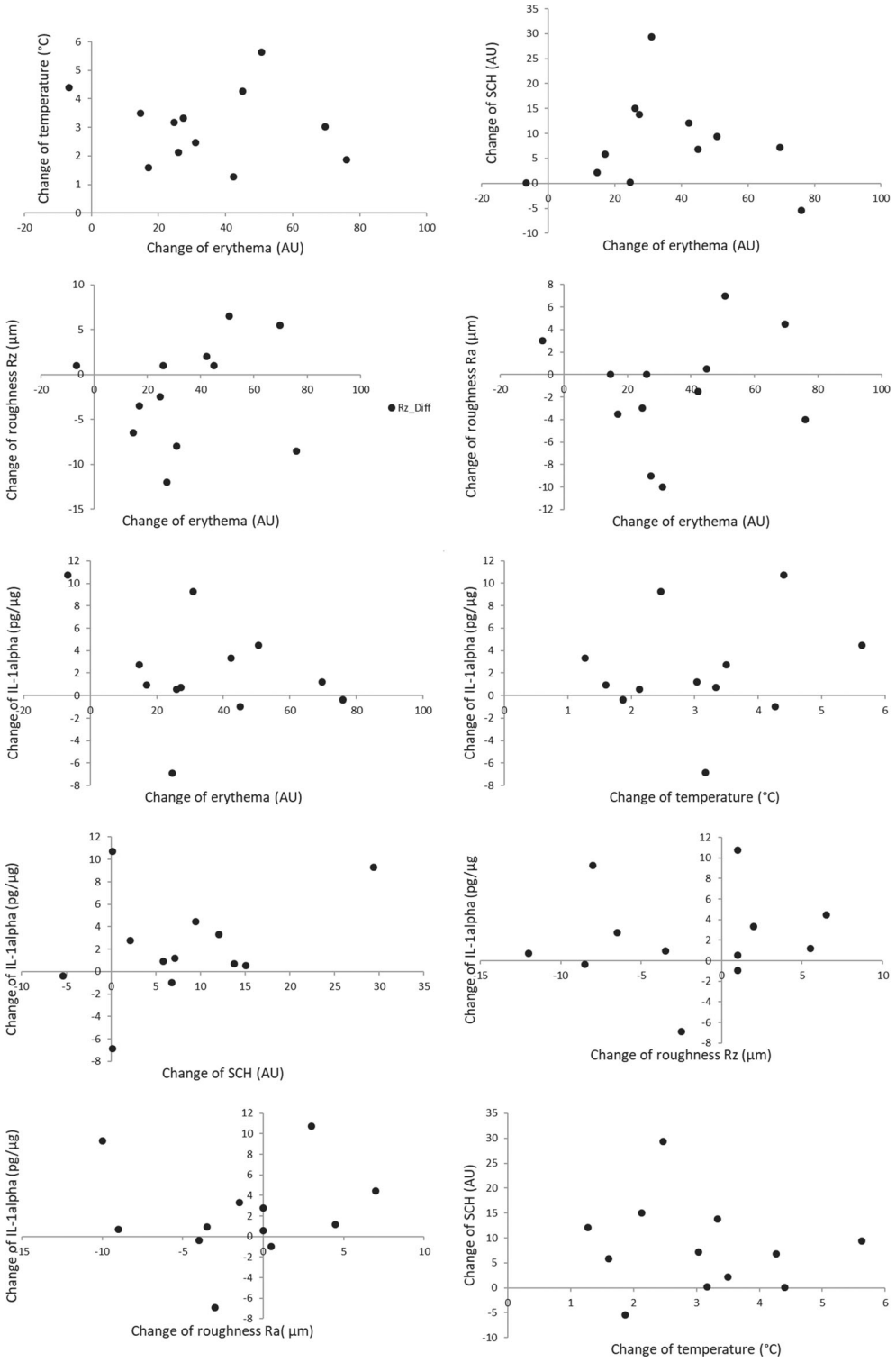

FIGURE 2 Scatter plots between variables of the no dressing group (n = 12)

of temperature increases between no dressing and the dressing groups. This indicates that the dressings do not add "extra" heat to the occlusion caused by lying supine on the mattress alone. This interpretation is supported by results from a similar comparison after lying for 1 hour on a standard foam mattress with and without different dressings.[18] The baseline median sacral SCH ranging from 24.8 to 30.1 AU was similar to previous baseline estimates in a comparable setting.[23,24] After 3.5 hours loading there was an increase in all four groups indicating the accumulation of water molecules in the stratum corneum caused by occlusion. The highest increase of approximately 7 AU was measured in the no dressing and Optifoam Gentle Sacrum groups followed by the ALLEYN Life Sacrum group. These increases were slightly higher compared to previous study results, probably due to the longer loading and occlusion. The Optifoam Gentle Sacrum

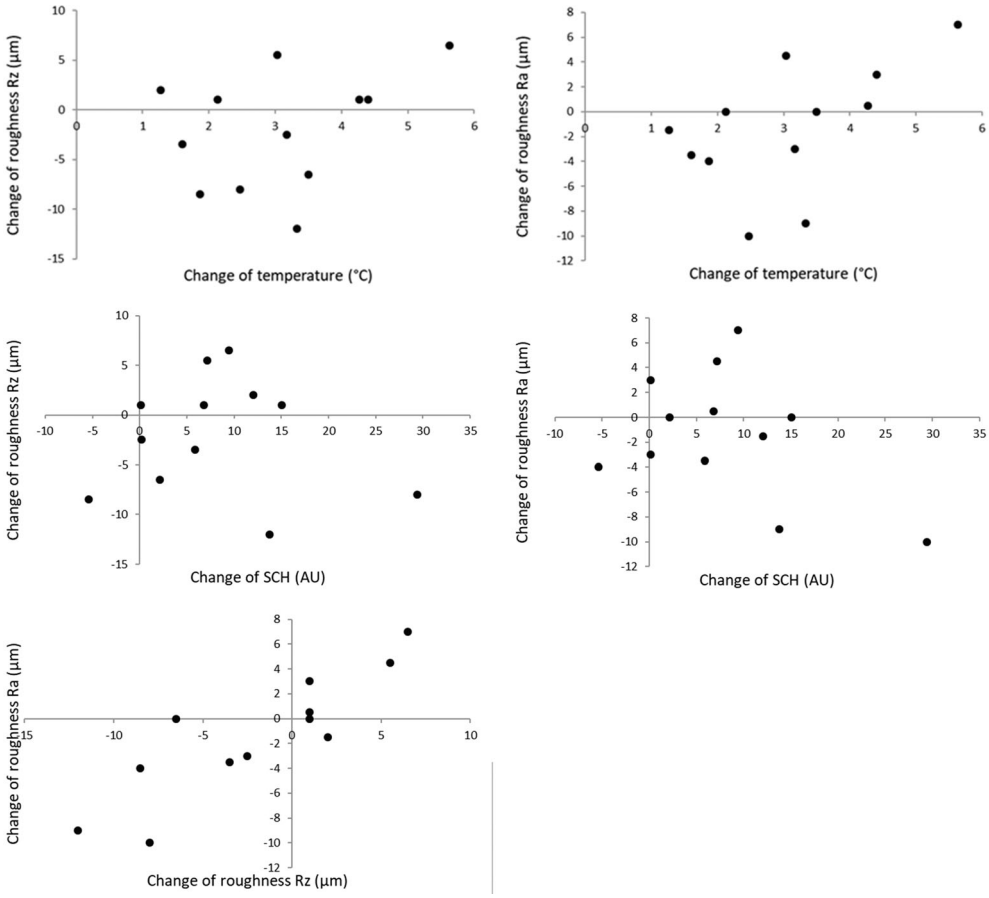

FIGURE 2 (Continued)

dressing was most occlusive in terms of water accumulation. But similar to the temperature increase, the dressings do not seem to contribute to "additional" hydration due to occlusion compared to lying supine without a dressing. Differences between groups might be explained by different water transport properties of dressings[10] and skin-dressing-support surface interactions.[24,36] Measured baseline sacral erythema indices between 166 and 194 AU were nearly identical to previous study results of Tomova-Simitchieva et al.[24] After loading, there were high erythema index increases in the ALLEVYN Life Sacrum and no dressing groups. Erythema increases in the Mepilex Border Sacrum and Optifoam Gentle Border groups were negligible. Tomova-Simitchieva et al reported that the reactive hyperemia of sacral skin after 2 hours loading on a stiff standard foam mattress was three times higher compared to gel and alternating air support surfaces, supporting the interpretation that erythema increases are directly associated with the previous intensity of loading and soft tissue deformation.[24] The relationship between tissue-interface pressure, tissue deformation and erythema has also been established by others[19,26] and a reduction of the reactive hyperemia indicates increased protection.[37] Therefore, our study results on pressure induced reactive hyperemia may suggest that Mepilex Border Sacrum and Optifoam Gentle Sacrum reduced skin and soft tissue deformation better during 3.5 hours loading compared to no dressing and ALLEVYN Life Sacrum. The clinical evaluation of erythema (Table A1) indicates that the application of all dressings in combination with pressure can cause mild irritation in some subjects.The median sacral skin roughness (Rz) of approximately 30 µm was slightly lower but comparable to previous study results.[23,24] In the no dressing, Mepilex Border Sacrum, and ALLEVYN Life Sacrum groups 3.5 hours loading caused no substantial changes to the sacral skin roughness, which is in accordance with other studies.[22-24] However, there was a clear decrease of mean roughness in the Optifoam Gentle Sacrum group indicating a flattening of the skin surface. Because the loading period was the same in all four groups, the high increase in SCH is most likely the reason for this observation. It is known that increasing SCH reduces skin roughness.[15] However, because the increase in SCH was similar to the no dressing group, a specific skin-dressing interaction might explain this phenomenon.

Results showed an increased inflammatory cytokine IL-1α release in the no dressing, the ALLEVYN Life Sacrum and the Optifoam Gentle Sacrum groups after loading. In all three groups, a comparable median increase was observed, ranging from 1.1 to 1.3 pg/µg. While Worsley et al and Soetens et al compared the IL-1α levels via ratios by using a baseline normalization approach, we decided to compare the median differences of baseline and after treatment measurements, as it is not known at present time whether the comparison of relative changes is more appropriate than the comparison of absolute changes to reflect protective effects of dressings.[38,39] Furthermore, there is still uncertainty on how exactly an increase of IL-1α is associated with mechanical loading. While Hemmes et al suggests that IL-1α has a

TABLE 3 Descriptive comparisons of median changes between groups (n = 12)

	Skin temperature	Stratum corneum hydration	Erythema index	IL-1alpha	Mean roughness (Rz)
No dressing	↑	↑↑	↑↑	↑	
Mepilex Border Sacrum	↑↑↑		↑		↓
ALLEVYN Life Sacrum		↑	↑↑↑	↑↑	
Optifoam Gentle Sacrum	↑↑	↑↑↑		↑↑	↓↓

strong relationship with the loading time but not with pressure magnitude, there are studies supporting a positive association with the level of pressure load and direct deformation damage.[19,38] Either way, the release of IL-1α indicates the initiation of an inflammatory response as a consequence of mechanical deformation of the epidermis that may be observed at a lower pressure threshold compared to visible redness.[26] The finding that there was no median change of IL-1α in the Mepilex Border Sacrum group indicates that this dressing may have a better capacity to prevent inflammatory tissue responses.[19,26]

A descriptive summary of median changes of all measured parameters is shown in Table 3. The highest increases or decreases of medians are indicated by three arrows, the second highest by two arrows, and so forth.

The scatter plots (Figure 2) of the no dressing group indicate a positive association between erythema and IL-1α increases in n = 8 subjects. The reason for the deviating results of the other four subjects may be biological variability of cytokine release, which was previously proposed by Worsley et al[38] and is also described by Soetens et al.[38,39] This biological variability is also demonstrated by the different baseline concentrations, which were measured within the same study group at different times (eg, baseline value of 13.0 (pg/μg) in the no dressing group and 9.0 (pg/μg) in the Mepilex Border Sacrum group). Overall, the scatter plots show positive associations between the single variables erythema, SCH, temperature and IL-1α. But here as well, the biological variability seems to be high. During loading, there is a complex interaction between all of these variables and it is difficult to separate the individual contribution to skin changes.

Previous research showed that occlusion, rise in skin temperature and the associated increase in SCH lead to a reduced mechanical stiffness, a softening of the stratum corneum, an increase in cellular permeability and an increase in the coefficient of friction. All these skin alterations can, in addition to the mechanical load, cause and promote erythema and skin irritation, which may induce IL-1α release.[15,22-24,38] However, Mepilex Border Sacrum prevented the increase in IL-1α despite the changes in the microclimate, and therefore supports the assumption of mechanical load as the main trigger for the release of IL-1α.

4.1 | Limitations

Because of the exploratory study design and the rather controlled conditions the clinical relevance is limited and this study is considered hypothesis generating. Allocation was not concealed for visits 2, 3, and 4 and due to the differently shaped imprints on the skin caused by the dressings after the lying phase, all study personal, including the investigator, were unblinded. To reduce biological variability in this exploratory study only females were included. Participants had to be between 65 and 80 years old because aging is indirectly associated with PU risk and they might be considered as more representative for the target population. However, included subjects were healthy and not truly at PU risk. Although the applied 3.5 hours loading regimen was very long for a clinical simulation, it is not representative for patients lying in bed for 24 hours for several days.

5 | CONCLUSION

Lying supine on a standard hospital mattress for several hours leads to deformation and occlusion of the sacral skin area. The application of preventive dressings do not seem to cause substantial occlusion compared to having no dressing when lying on a standard mattress. Different dressings cause different skin responses. While Optifoam Gentle seems to be more occlusive, ALLEVYN Life seems to cause higher mechanical deformation. Mepilex Border Sacrum showed minor changes in IL-1 α and erythema. Reactive hyperemia and IL-1α seem to be suitable biomarkers for pressure-induced skin changes but there is substantial biological variability. The relevance of the observed physiological changes on PU development in clinical settings is unclear.

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DISCLOSURE

Jan Kottner received honoraria as member of an advisory board from Mölnlycke Health Care. The other authors report no conflicts of interest.

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APPENDIX

See Tables A1 and A2.

TABLE A1 Erythema according to clinical score (n = 12)

	Baseline	After 3.5 hours
No dressing		
None	12	9
Mild	0	3
Mepilex Border Sacrum		
None	12	6
Mild	0	6
ALLEVYN Life Sacrum		
None	12	5
Mild	0	6
Moderate	0	1
Optifoam Gentle Sacrum		
None	12	5
Mild	0	5
Moderate	0	2

TABLE A2 Participant timeline per visit

Hours of loading period	Time before	0.0 hour	0.5 hour	1.0 hour	1.5 hours	2 hours	2.5 hours	3.0 hours	3.5 hours	Time after
Supine position for 10 minutes	x									
Marking of investigational areas	x									
Acclimatization for 30 minutes with sacrum uncovered	x									
Pain	←	—	—	—	—	—	—	—	—	→
Skin surface temperature	x									x
SCH	x									x
Erythema index	x									x
Visioscan Rz, Ra	x									x
CSSS (after all other measurements)	x									x
Erythema (clinical assessment)	x									x
Dressing groups: application/ removal of dressing	x									x
Supine position		←	—	—	—	—	—	—	→	
Elevation of head of bed, moving heels on the mattress back and forth 10x			x	x	x	x	x	x		
Adverse events monitoring and documentation	←	—	—	—	—	—	—	—	—	→