Original Investigation

In Vitro Characterization of Pressure Redistribution Among Commercially Available Wound Dressings

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ABSTRACT

OBJECTIVE: Recent clinical evidence has suggested that certain wound dressings may play a significant role in protocols to prevent or reduce pressure injury (PI) in patients at risk by modifying the pressure, friction, and shear forces that can contribute to PI. The aim of this study was to investigate the pressure reduction properties of commercially available wound dressings in vitro.

METHODS: Using a standardized protocol (1.7 kg, 7.5-cm sphere), testing was performed in a controlled environment by the same clinician using a pressure mapping device (XSENSOR LX205; XSENSOR Technology Corporation, Calgary, Alberta, Canada) to measure and compare the pressure mitigation properties in a variety of wound dressings.

RESULTS: A total of 13 different commercially available dressings were tested in triplicate for changes in pressure redistribution as compared with the control. One dressing demonstrated the greatest reduction of pressure forces (OxyBand PR; 50.33 ± 1.45 mm Hg) compared with the control (302.7 ± 0.33 mm Hg) and the greatest surface area of all the study dressings tested. There was a negative correlation (R^2 = 0.73) between the average pressure distribution of a wound dressing and its contact area. Further, the peak pressure for OxyBand PR ($P \leq .05$) was significantly different from all other tested dressings.

CONCLUSIONS: One dressing (OxyBand PR) provided superior pressure redistribution and significantly reduced peak pressure in this study when compared with currently available standard foam and silicone dressings that are marketed for the purpose of PI prevention.

KEYWORDS: friction, mapping, pressure injury, pressure ulcer, redistribution, shear, wound dressing

ADV SKIN WOUND CARE 2021;34:139–42.

DOI: 10.1097/01.ASW.0000723124.76890.6a

INTRODUCTION

Pressure injuries (PIs), defined as "localized damage to the skin and underlying soft tissue usually over a bony prominence or related to a medical or other device,"[1] occur commonly in older populations and individuals with immobility. Pressure injuries significantly affect the quality of life of millions of Americans[2–4] and are a substantial cause of morbidity and societal burden worldwide.[5–7] This condition affects approximately 2.5 million patients and accounts for 60,000 deaths from hospital-acquired PIs, translating into an estimated cost of $25 billion per year to the US healthcare system.[8] The etiology of PI development is multifactorial, involving both extrinsic (lying on hard surface, poor skin hygiene, patient restraints, medical devices, etc) and intrinsic (diabetes, smoking, malnutrition, spinal cord injury, etc) factors. The conceptual framework described by Coleman et al[5] links biomechanical, physiologic, and epidemiologic factors. Mechanical boundary conditions such as magnitude, duration, and type of load; pressure; shear; and friction contribute to epidermal and dermal damage and changes in interstitial fluid flow leading to altered metabolic equilibrium resulting in tissue death.[8] Strategies to prevent PI should consider the microclimate and biomechanics of the soft tissue interacting with direct pressure, shear forces, and friction that can cause tissue distortion and deformation.

Numerous clinical trials have described the use of prophylactic wound dressings in redistributing pressure and have suggested adding these devices to standard pressure prevention protocols to reduce or prevent PI.[9–11] Various new dressing materials (alginate, foam, gauze, honey, hydrocolloid, hydrogel, silver, transparent film, etc) developed in the last decade have been studied for PI management, and clinical and cost-effective comparisons of various wound dressings are documented in the literature.[12] Recently, an algorithm was developed by Boyko et al[2] to help in selecting an appropriate class of dressings for PI management based on the shape, size,

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and anatomic location of the wound; presence or absence of exudate; and presence of tunneling and undermining.

Recent advances in noninvasive pressure mapping technology enable clinicians and researchers to identify and isolate pressure points at risk of ulceration in vulnerable individuals. These technologies are utilized to understand surface interface pressure and pressure distribution during posture shifts in individuals who are not disabled and to develop pressure-relieving cushions and seating interventions that target PI prevention.[13] In the current study, investigators tested the pressure redistribution properties of commercially available wound dressings commonly used in clinical settings that are marketed and promoted as mitigating pressure forces and preventing PI.

METHODS

XSENSOR System

Investigators used a high-resolution pressure mapping system, XSENSOR LX205 (XSENSOR Technology Corporation, Calgary, Alberta, Canada), to measure the reduction in pressure forces achieved by a variety of commercial wound dressings (n = 13) commonly used in clinical settings (Table). The LX205:100.100.10 system includes a thin, flexible mat-like high-resolution sensor with a 2.54-mm pitch (resolution) and 10,000 sensing points with a very fast data acquisition rate.

Standard Mass and Testing

A single clinician used a standardized protocol (1.7 kg, 7.5-cm sphere) to test the products in a controlled environment (Figure 1). The control testing was performed by placing the sphere directly on the sensor map without any material or dressing interface. Each study dressing was sequentially tested three times in the same order. A 2-minute recovery time was used between each test, and no residual visible deformation was observable in any dressings tested within seconds of removal of the sphere. Digital data output including average pressure (mm Hg; average of the measured peak pressures for each dressing for each of the three tests), contact area (cm^2; size of the area under the sphere associated with any measurable pressure reading), peak pressure (mm Hg; the highest pressure measured for each dressing following application of the test sphere), and the corresponding colorized pressure map images (high-pressure areas depicted in red, low-pressure areas in blue) were recorded using X3 Pro Software (XSENSOR Technology Corporation). Mathematical analysis of the averaged pressure readings and surface area was performed.

Table. COMMERCIALLY AVAILABLE WOUND DRESSINGS FOR PRESSURE REDISTRIBUTION COMPARED IN THIS STUDY

Dressing Name	Size, cm	Manufacturer/Distributor
Cutimed Siltec B	15 × 15	BSN Medical
Eclypse Adherent	10 × 10	Advancis Medical
Optifoam	15.2 × 15.2	Medline
Aquacel Foam	12.5 × 12.5	Convatec
Tielle Plus Sacrum	15 × 15	Systagenix
Tielle Essential	12.5 × 12.5	Systagenix
Drawtex Surgical	9 × 15	SteadMed
Drawtex	10 × 10	SteadMed
Mepilex Border	10 × 10	Mölnlycke
Mepilex Border Heel	22 × 23	Mölnlycke
Allevyn Life	12.9 × 12.9	Smith & Nephew
Allevyn Life Sacrum	17.2 × 17.5	Smith & Nephew
OxyBand PR	11 × 14	OxyBand Technologies

Figure 1. The XSENSOR LX205:100.100.10 system

The device is a capacitive pressure imaging sensor system that can measure pressure ranges from 0.2 to 15 psi. The total sensing area is 10" × 10" with a 2.54-mm pitch (resolution) and 10,000 sensing points.

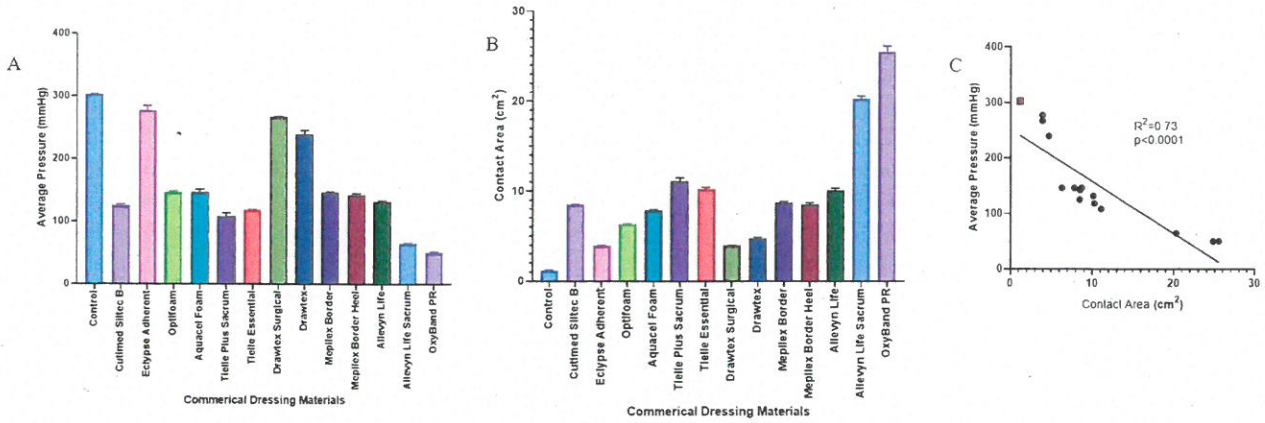
Statistical Analysis

Data are presented as mean ± SEM. Two-way analysis of variance and Dunnett multiple comparisons were performed with the significant criteria, $P < .05$. For correlations between measurements, a Pearson correlation coefficient was determined. Statistical analysis was performed using GraphPad Prism 8.0 (GraphPad, La Jolla, California).

RESULTS

Average pressures (Figure 2A) and contact areas (Figure 2B) generated by the pressure mapping device for all the wound dressings (n = 13) were significantly different

Figure 2. A, AVERAGE PRESSURE; B, CONTACT AREA; AND C, CORRELATION BETWEEN AVERAGE PRESSURE AND CONTACT AREA FOR ALL WOUND DRESSINGS



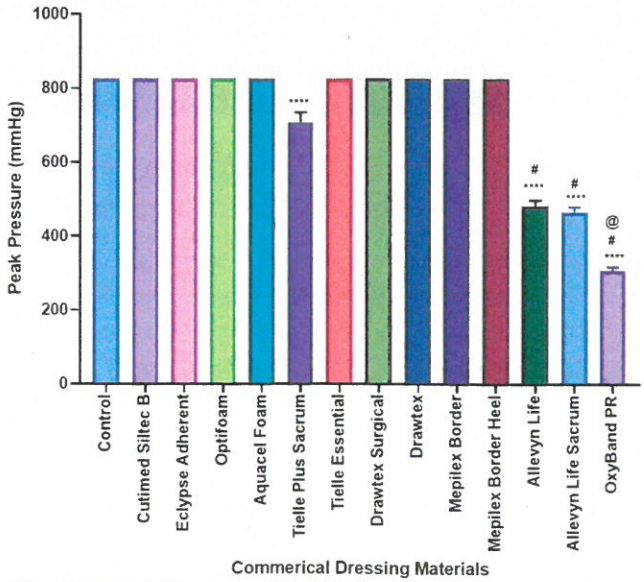
from the control. Pearson *R* data analysis (Figure 2C) revealed a negative correlation ($r = -0.86$) between the average pressure and the contact area of wound dressings used in this study. The OxyBand PR wound dressing demonstrated the lowest average pressure (50.3 ± 1.4 vs 302.7 ± 0.3 mm Hg) and the largest contact area (25.5 ± 0.6 vs 1.2 ± .05 cm^2) compared with the standard mass.

Peak pressure was significantly different ($P < .0001$) for four wound dressings (Tielle Plus Sacrum, Allevyn Life, Allevyn Life Sacrum, and OxyBand PR) compared with the control (Figure 3). OxyBand PR demonstrated the greatest reduction of peak pressure (310.3 ± 8.4 mm Hg), which was significantly ($P < .05$) different from Tielle Plus Sacrum (709.0 ± 26.1 mm Hg), Allevyn Life (483.0 ± 14.1 mm Hg), and Allevyn Life Sacrum (467.3 ± 12.9 mm Hg).

DISCUSSION

Pressure injuries (also known as pressure ulcers, decubitus ulcers, and bed sores) develop as a result of a combination of physiologic events and external conditions. The concept that the prophylactic application of materials, primarily foam-based wound dressings, over certain anatomic locations at increased risk of PI may help mitigate forces that can contribute to their formation has recently been suggested and is gaining clinical interest.[9,10] The data suggest that using certain types of wound dressings in this fashion reduces pressure and thus may decrease onset of PI in certain at-risk patients.[9,10] Many wound dressings are available to clinicians to treat PIs, but these may vary significantly in their degree of effectiveness.[12] Dressing manufacturers who historically reported only the properties of their dressing design as an adjunct to promote wound healing are now beginning to jump onboard the PI risk reduction bandwagon. Few data exist to help practitioners contrast and compare the various dressings and validate these pressure-relief claims. Accordingly, these investigators performed a controlled in vitro trial to compare many of the commonly known and available wound dressings that are used in the management of patients with PI. The goal was to measure and then compare the pressure redistribution characteristics of a variety of dressings. Pressure is the force per unit area exerted perpendicular to the plane of interest. Pressure redistribution is defined as the ability of a support surface to distribute load over the contact areas of the human body. The National Pressure Injury Advisory Panel has recommended that "pressure redistribution" should replace prior terminology (ie, "pressure reduction").[14]

Figure 3. PEAK PRESSURE GENERATED FOR ALL THE WOUND DRESSINGS



***$P < .0001$, significantly different from control. #$P < .05$, significantly different from Tielle Plus Sacrum. @$P < .05$, significantly different from Allevyn Life and Allevyn Life Sacrum.

The authors studied a total of 13 different dressings, all touted as providing wound healing benefit to patients with PI. Many of these dressings are also marketed as providing pressure reduction and as being viable options for prophylactic PI prevention. Interestingly, 9 of the 13 dressings showed an identical peak pressure to that of control, suggesting that these dressings would offer little if any benefit for pressure reduction and PI mitigation. Four of the dressings (Tielle Plus Sacrum, Allevyn Life, Allevyn Life Sacrum, and OxyBand PR) produced significant reductions in peak pressure ($P < .0001$) compared with control. The oxygenated composite foam dressing OxyBand PR demonstrated the greatest reduction of peak pressure compared with control. However, the reduction in pressure force with OxyBand PR was significantly less compared with the other best performers (Tielle Plus Sacrum, Allevyn Life, and Allevyn Life Sacrum; $P < .05$).

A basic tenet of PI prevention and treatment is placing patients on surfaces that achieve pressure redistribution and disbursing PI forces over a greater contact area. This study suggests that the same theory can be extrapolated to the benefit conferred by certain wound dressings. The dressings tested in the study showed that those that provided the greatest contact area also provided the greatest reduction in peak pressure forces.

To the authors' knowledge, this is the first study to report a comparison of pressure redistribution properties of dressings in current use for clinical management of PIs. Although this study demonstrated that pressure forces can be mitigated by certain commercially available wound dressings and that those dressings that provide the greatest contact area correlate with the greatest reduction in peak pressure forces, this study was accomplished in vitro. The results of the study therefore are not intended to promote one dressing over another; the clinical benefit achieved by the use of any wound dressing to reduce PI risk and formation must be validated clinically. Further clinical study is certainly warranted in this area.

CONCLUSIONS

This study confirms that foam and silicone dressings may provide some protection for patients at risk of PI by decreasing and dispersing pressure over a greater surface area. OxyBand PR provided significantly greater pressure reduction in this study. These results may be attributable to the unique composite oxygenated reservoir contained in this composite dressing, which could improve the clinical benefit achieved when using wound dressings to provide pressure redistribution in at-risk patients. ●

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