The Effects of Compression Wrapping Techniques and Primary Wound Dressings on Leg Skin Interface Pressure

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THE EFFECTS OF COMPRESSION WRAPPING TECHNIQUES AND PRIMARY WOUND DRESSINGS ON LEG SKIN INTERFACE PRESSURE

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Bioengineering

by
James Bryson Cox
August 2023

Accepted by:
Dr. John DesJardins, Committee Chair
Dr. Jordan Gilmore
Dr. Jeremy Mercuri
ABSTRACT

Peripheral edema affects approximately 20% of people in the US over the age of 50 and is frequently encountered among individuals with conditions such as heart disease, prolonged immobility, and venous insufficiency.\(^1\) Compression is an established therapeutic tool utilized for the management of several chronic edema presentations including lymphedema and venous leg ulcers.\(^2\)\(^3\) Therapeutic efficacy of compressive applications can be evaluated by defining interface pressure (IP) and IP distributions associated with specific textile combinations.\(^2\) During compressive applications where an open wound is present, primary wound dressings should be used in combination with compressive wraps. Primary wound dressings provide a barrier and maintain a moist environment that promotes healing while compressive textiles applied over the primary wound dressing exert pressure on the wound and surrounding tissues. This pressure helps improve blood circulation and lymphatic drainage, reducing edema and promoting the delivery of oxygen and nutrients to the wounded area.\(^4\)

This clinical study was conducted using 40 participants where each participant had three compressive textile combinations applied to their lower extremity. IP distribution data was collected for each textile combination immediately after application and following a brief exercise period. IP distributions resulting from the presence of primary wound dressings were evaluated in a separate benchtop study. Based on the results, the three compressive textile combinations evaluated in the clinical study and the three wound dressings evaluated in the benchtop study were shown to induce adequate amounts of pressure to improve circulation, promote wound healing, and reduce edema.
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CHAPTER ONE

INTRODUCTION

Chronic edema refers to swelling that occurs in the lower extremities due to fluid accumulation. This condition affects approximately 20% of people in the US ages 50 and older and is frequently encountered among individuals with conditions such as heart failure, kidney and liver disease, prolonged immobility, and venous insufficiency.\textsuperscript{1,5} Compression is an established therapeutic tool utilized for the management of several chronic edema presentations including lymphedema, venous reflux, and venous leg ulcers.\textsuperscript{2,3} Therapeutic efficacy of compressive applications can be evaluated by defining interface pressure (IP), or the pressure between the compressive textile and the skin, and IP distributions associated with specific textile combinations.\textsuperscript{2}

During compressive applications where an open wound is present, primary wound dressings should be used in combination with compressive garments. Primary wound dressings provide a barrier and maintain a moist environment that promotes wound healing while compressive textiles applied over the dressing exert pressure on the wound and surrounding tissues. This pressure helps improve blood circulation and lymphatic drainage, reducing edema and promoting the delivery of oxygen and nutrients to the wounded area.\textsuperscript{4}

This body of work summarizes the findings from this clinical trial including the collection of background information, development of the procedure, recruitment of participants, in-person testing, benchtop testing, and data analysis. The clinical trial was conducted using 40 healthy participants where each participant had three compressive
textile combinations applied to their lower extremity over the course of three days. The textile combinations evaluated in this clinical trial included: a Fuzzy Wale Compression (FWC) stockinette, a traditional two-layer cohesive bandage, and a combination of the two. IP distribution data was collected for each of these textile combinations immediately after application and following a brief exercise period.

This body of work also summarizes the findings from a separate benchtop study that was conducted to evaluate IP distributions in and around a wound with the presence of three different primary wound dressings. The primary wound dressings evaluated in the benchtop portion of this study included: Agile, Tritec Silver, and Ultra Silver. For each primary wound dressing, a customized air bladder was used to apply known amounts of pressure at different simulated wound depths. IP distribution data in and around the simulated wound was collected at four different application pressures. Based on the results, the three compressive textile combinations evaluated in the clinical portion of the study and the three wound dressings evaluated in the benchtop study were shown to induce adequate amounts of pressure to improve circulation, promote wound healing, and reduce edema.
CHAPTER TWO
LITERATURE REVIEW AND BACKGROUND

Clinical Statistics and Presentations of Chronic Edema

Edema is defined as swelling resulting from excessive fluid retention in the body’s tissues. While this can occur in any bodily tissue, edema is most prevalent in the legs and feet.6 Prevalence rates reported in past studies range between 19% and 20% among US adults ages 50 and older.1,5 In addition to advanced age, chronic edema is also associated with female sex, low activity levels, and various underlying conditions such as heart failure, kidney or liver disease, venous insufficiency, pregnancy, diabetes, and hypertension.5

One of the most common clinical presentations of edema is lymphedema. This condition occurs within the lymphatic system, which plays important roles in fluid balance and immune function. Lymphedema results from the accumulation of lymphatic fluid, or protein-rich lymph, in the interstitial spaces, ultimately resulting in edema.7,8,9 There are two major types of lymphedemas. Primary lymphedema is usually congenital and can manifest at any age. Secondary lymphedema, on the other hand, results from damage or obstruction to the lymphatic system due to various factors such as surgery, infection, exposure to radiation, trauma, or cancer.8

Another common clinical presentation of edema is venous insufficiency. This condition can lead to edema due to weakened vein walls and dysfunctional valves. In individuals with venous insufficiency, normal blood flow is disrupted, causing blood to pool in the veins and venous pressure to increase. This increase in venous pressure results
in greater hydrostatic pressure in the capillaries which pushes fluid out of the capillaries and into surrounding tissues. Consequently, this condition causes interstitial fluid accumulation in the affected area, leading to edema.

**Pathology and Physiology of Chronic Edema**

In healthy individuals, the equilibrium of hemodynamic forces along the capillary walls prevents the accumulation of interstitial fluid which may potentially result in edema. In order for edema to occur, these hemodynamic forces must be altered in a way that favors fluid movement from the vascular space into the interstitium. There are several factors which dictate the direction of fluid movement across the capillary walls. These factors are governed according to Starling’s law, which states that fluid movement across the capillaries is proportional to the hydrostatic and oncotic pressure gradients along the capillary walls as well as capillary permeability. Therefore, alterations that may lead to fluid retention and the onset of edema include increased capillary hydrostatic pressure, decreased capillary oncotic pressure, and increased capillary permeability.

\[
Filtration = Kf \times (Pc - Pif - Oc + Oif)
\]

\(Pc = \text{hydrostatic capillary pressure}, Pif = \text{interstitial fluid hydrostatic pressure}\)

\(Oc = \text{capillary osmotic pressure}, Oif = \text{interstitial fluid osmotic pressure}\)

\(Kf = \text{capillary filtration coefficient (permeability x Surface Area)}\)

Equation 1.0: Starling’s Law equation for describing fluid movement across capillaries

Increased capillary hydrostatic pressure occurs when the pressure within the capillaries exceeds normal levels, disrupting the hydrostatic pressure gradient along the capillary walls. This disruption results in fluid retention in the interstitium as fluid is forced out of the capillaries to areas of lower pressure. This may occur due to several
systemic conditions such as congestive heart failure, renal disease, or allergic reactions, or several localized conditions such as lymphedema or venous insufficiency. The interstitial fluid pressure resulting from fluid movement out of the capillaries is dependent on tissue density in the affected area, with more dense connective tissues experiencing greater interstitial hydrostatic pressures.12

Oncotic pressure is a type of osmotic pressure induced by plasma proteins, most notably albumin. Plasma proteins do not pass freely between the interstitium and plasma, and therefore, these proteins produce an osmotic effect along the capillary walls. This osmotic pressure exerted by plasma proteins aids in fluid retention within the blood vessels. If the concentration of plasma proteins in the blood decreases, such as in cases of liver disease and malnutrition, the oncotic pressure also decreases, allowing fluid to escape from the blood vessels into the interstitium.12

Certain conditions can cause inflammation or damage to the capillary walls. Under normal conditions, the capillary walls act as semipermeable barriers, allowing selective passage of water, oxygen, and nutrients. When capillary impermeability increases, the integrity of the capillary walls is compromised, allowing fluid to leak into the surrounding tissues. This increased permeability can be the result of a number of underlying causes including allergic reactions, tissue injury, and infections.12

In addition to the alterations of hemodynamic forces described above, edema can also result from decreased lymphatic drainage or the accumulation of protein-rich lymph in patients with lymphedema. The lymphatic system is a unidirectional drainage route designed to expel excess fluid and filter out bacteria. In most cases, it is believed that the
The root cause of lymph accumulation is lymphatic pump failure. When pump failure results from malformation, which is usually congenital, this condition is described as primary lymphedema. Secondary lymphedema, on the other hand, occurs when damage occurs from factors originating outside of the lymphatic system, such as surgical removal of the lymph nodes.¹³

Under normal conditions, there is a balance between hydrostatic pressure, oncotic pressure, and lymphatic drainage, ensuring that fluid remains within the blood vessels. Fluid filtration and reabsorption occurs at the capillary level. Because capillaries have higher hydrostatic pressure at the arteriolar end, this facilitates fluid filtration out of the vessels. At the venous end, the hydrostatic pressure decreases, and the oncotic pressure resulting from the presence of plasma proteins becomes the dominant force, facilitating reabsorption of fluid back into the vessels. However, when this balance is disrupted, excess filtration or reduced reabsorption of fluid can occur, leading to the onset of edema.¹²

**The Use of Compression for Edema Management**

Because edema is a multifactorial condition resulting in fluid retention in the tissues, many treatment options focus on addressing the underlying causes. For example, reducing sodium intake and prescribing diuretics which act to eliminate excess fluid is often the first course of action. However, treatment of the underlying conditions is not always possible. In these cases, the application of compressive devices may be recommended to increase circulation in the affected extremity.¹⁴
Compression therapy has long been recognized as the cornerstone of edema management. It involves the application of external pressure on the affected area through compressive textiles, facilitating venous and lymphatic flow. This helps reduce elevated venous and capillary hydrostatic pressures, enhancing fluid reabsorption and minimizing leakage into the interstitial spaces. By applying external pressure, compressive devices effectively reduce the space available for fluid accumulation, promoting the drainage of excess fluid. Additionally, this external pressure narrows and compresses the veins, reducing their diameter and enhancing blood flow velocity. This facilitates the return of blood back to the heart, reducing fluid pooling in the extremities and promoting circulation.\textsuperscript{15}

Compression also assists in improving lymphatic function by promoting lymphatic vessel contraction and enhancing lymphatic drainage. The external pressure applied by compressive devices aids in the enhancement of lymphatic vessel contraction, facilitating the movement of lymph fluid through the lymphatic system.\textsuperscript{16} Lymphatic vessels are equipped with one-way valves that prevent the backflow of lymph fluid. Compression therapy enhances the function of these valves by aiding in their closure, effectively preventing reflux of lymph fluid, and promoting unidirectional flow. In cases where the main lymphatic pathways are compromised or damaged, compression therapy can help support collateral lymphatic pathways. These pathways are alternative routes for lymphatic drainage that can compensate for impaired or blocked main lymphatic vessels. In these cases, compression therapy helps direct lymph fluid towards collateral pathways, enabling efficient fluid drainage.\textsuperscript{17}
While compression is an established therapeutic tool for promoting circulation and preventing fluid accumulation in the tissues, the effectiveness of compression therapy in reducing edema depends on the type of compressive device used, the amount of external pressure provided by the selected compressive device, and individual patient characteristics.

**Types of Compressive Textiles Used in Edema Management**

Compressive textiles are specialized fabrics or materials designed to apply pressure to specific areas of the body. They are commonly used in medical applications to provide compression therapy, which involves the controlled external application of pressure to aid in the prevention, management, or treatment of various conditions including edema. Compressive textiles are available in a variety of forms including wraps, stockings or socks, and tubular stockinettes, depending on the targeted area and purpose of use.\(^{18,19,20,22}\)

*Compressive Wraps*

One type of compressive textile is compressive wraps. These elastic or inelastic textiles typically consist of either hook-and-loop fasteners, straps, or are made of flexible, cohesive material that allows for customized compression and easy application. The amount of external pressure provided by compressive wraps depends on the stiffness or elasticity of the material. Generally, inelastic wraps offer higher levels of external pressure during exercise and minimal pressure at rest while elastic wraps provide high pressures at rest but lower pressures as the muscles contract during activity.\(^{19}\)
Compressive wraps are often utilized in cases where higher compression levels (up to 40 mmHg) are desired such as in managing severe edema or venous insufficiency. They are usually applied in multiple layers and produce a pressure gradient along the limb with pressures being greatest at the ankle and lowest at the calf or knee. It is important to note that the selection of the appropriate level of stiffness should be based on individual needs, comfort, and the specific condition being treated. In some cases, a more flexible wrap with lower application pressures may be preferred, especially in cases where long-term use is necessary, as elastic wraps can better conform to irregular body contours and provide a more comfortable fit.

Figure 1.1: Coflex TLC 2-layer compressive wrap

*Compressive Stockings or Socks*

Compression stockings are elastic garments worn on the legs, providing graduated compression from the ankle to the knee or thigh. They are commonly used to improve blood circulation and reduce swelling in the lower extremities. Compared to compressive wraps, compressive stockings provide lower compression levels (less than 20 mmHg) but
can be worn for extended periods of time. For this reason, compressive stockings or socks are often used as a preventative measure for individuals at risk of chronic edema.\textsuperscript{18}

Compared to compressive wraps, compressive stockings are generally easier to apply because they only consist of one layer. Stockings are pre-sized and designed to be pulled up the leg, eliminating the need for complex wrapping techniques or a trained professional for application. Compressive stockings are also designed to be worn for extended periods and are often made with comfortable, breathable materials that allow for proper air circulation and moisture management. Lastly, compressive stockings are specifically designed to conform to the shape of the leg and are typically made with elastic materials that stretch and adapt to different leg contours. This conformity helps prevent wrinkling or bunching up of the fabric, ensuring consistent pressure distribution. While their breathability and comfort levels increase the likelihood of consistent use, compression stockings lose their application pressures after a few months and need to be replaced.\textsuperscript{18,19}

![Figure 1.2: Miracle Socks anti-fatigue compression sock](image_url)
Tubular Elastic Stockinettes and Fuzzy-Whale Compression (FWC)

Tubular elastic stockinettes are stretchable, seamless, and cylindrical garments designed to provide breathability for enhanced comfort and skin health. They are typically made from elastic fabric materials that allow for flexibility, comfort, and ease of application. For individuals with painful leg edema, tubular stockinettes can help reduce pain associated with compression therapy while still providing adequate amounts of pressure to reduce swelling or support primary wound dressings.

These garments are referred to as “tubular” because they are constructed in the form of a continuous tube with no seams or closures. They are open at both ends, allowing for easy application compared to other types of compressive textiles. One of the main advantages of tubular elastic stockinettes is their versatility. They can be easily cut to the desired length, making them customizable and adaptable to individual needs. Once in place, the stockinette conforms to the shape of the body, providing a snug fit and a uniform pressure distribution. While tubular elastic stockinettes typically induce lower application pressures (less than 20 mmHg), unlike other types of compressive devices, these textiles apply longitudinal pressure along the entire length of the limb rather than circumferential pressure around the limb.

The tubular elastic stockinette used in this clinical study utilized a new textile technology referred to as Fuzzy Wale Elastic Compression (FWC). Wales is a fuzzy corduroy-like material that connects to the skin to deliver effective compression of the subcutaneous fat and to move fluid back to the heart. Previous studies have shown that
FWC is advantageous in controlling all types of swelling, enhancing wound healing, and clearing venous stasis pigment in chronic venous insufficiency.\textsuperscript{23}

Tubular elastic stockinette are commonly used in a variety of medical applications, including edema management, post-operative care, limb support, and orthopaedic bracing. They can be utilized as an underlayer for compressive wraps to provide additional support and to keep the primary dressing or wrap in place. These textiles are often used for individuals with conditions such as lymphedema, venous insufficiency, or swelling due to injury or surgery.\textsuperscript{22,23}

![Figure 1.3: Fuzzy Wale Compression (FWC) tubular elastic stockinette](image)

**The Role of Interface Pressure (IP) in Determining Therapeutic Efficacy**

Interface pressure (IP) plays a crucial role in determining the therapeutic efficacy of compressive devices used in the management of edema and other conditions.\textsuperscript{2,24} The pressure exerted at the interface between the compressive textile and the underlying tissues is responsible for promoting fluid movement, improving circulation, and reducing swelling. The application of external pressure helps counteract elevated hydrostatic pressure in the blood vessels and interstitial spaces, facilitating the reabsorption of excess
fluid and reducing edema. By applying appropriate amounts of pressure, compressive wraps and devices create a compression gradient that assists in directing fluid away from the affected area, enhancing tissue drainage.\textsuperscript{15,16,17}

The distribution of IP is also critical to optimizing therapeutic efficacy. For compressive devices that target lower application pressures, such as tubular elastic stockinettes, a uniform pressure distribution along the limb is considered desirable to prevent localized pressure points or uneven compression.\textsuperscript{22,23} For compressive devices that target higher application pressures, such as compressive wraps, IP is expected to be highest around the ankle and to slightly decrease around the calf.\textsuperscript{19}

Lastly, the duration of IP is also a crucial factor. While sustained pressure is generally required to manage edema effectively, it is important to balance compression with regular periods of relief to avoid skin irritation, pain, or other potential complications. Healthcare professionals typically recommend wearing compressive wraps or devices for specific periods of time each day, ensuring an appropriate balance between therapeutic compression and tissue recovery.\textsuperscript{25}

\textit{Resting v. Working Pressure}

When measuring IP to determine the therapeutic efficacy of compressive devices, it is essential to consider both resting and working pressure. Resting pressure refers to the pressure exerted by the device when the patient is in a relaxed or resting state. This measurement provides valuable information about the baseline compression provided by the device and its ability to maintain consistent pressure during periods of inactivity.\textsuperscript{26}
On the other hand, working pressure refers to the pressure exerted by the device during movement or activity. This measurement is crucial as it reflects the device’s ability to provide adequate compression and support during dynamic movements, ensuring optimal fluid movement and tissue drainage. By assessing both resting and working pressure, healthcare professionals can evaluate the overall effectiveness of the compressive device for a patient’s specific needs, considering both static and dynamic compression requirements.26

Determining Static Stiffness Index (SSI) from IP Measurements

In addition to evaluating both resting and working IP to determine therapeutic efficacy of compressive devices under static and dynamic conditions, it is also essential to evaluate both standing and resting pressure measurements in order to characterize the stiffness of the material. The Static Stiffness Index (SSI) is defined as the difference between standing and resting pressures and is a valuable measurement for characterizing the elasticity of a compressive textile.27 A higher SSI (greater than 10 mmHg) indicates an inelastic, short-stretch compressive textile while a lower SSI (less than 10 mmHg) indicates an elastic, long-stretch material.28

Previous Methods for Evaluating IP and IP Distributions

Previous studies have employed various approaches to evaluate IP and IP distributions in the context of compressive wrap or device applications. One commonly used method is the utilization of pressure mapping systems. These systems consist of pressure-sensitive sensors that are either embedded in a flexible garment or are placed
directly between the skin and the compressive device. Pressure sensors capture and record IP data, allowing for a detailed analysis of IP across the area of the sensor.\(^\text{29}\)

One of the drawbacks of previous approaches for evaluating IP in compressive wrap or device applications is the lack of standardized and consistent methodology across studies. There is a wide variation in the devices and techniques used to measure IP, making it difficult to compare results across different studies. This inconsistency limits the ability to draw definitive conclusions or establish universally applicable guidelines for measuring IP in compression therapy.\(^\text{30}\) Pressure mapping systems utilized in previous studies include pneumatic based pressure measurement systems, most notably PicoPress (Microlab Elettronica, Roncaglia di Ponte San Nicolo, Italy), and piezoresistive pressure sensors such as FlexiForce (Tekscan Inc., Norwood, MA). Each type of pressure mapping system has its advantages and considerations. Ultimately, researchers select between these different pressure mapping systems based on intended application, accuracy requirements, spatial resolution needs, and budget constraints.\(^\text{29}\)

*Pneumatic-Based vs. Piezoresistive Pressure Mapping Systems*

Pneumatic-based pressure mapping systems, such as PicoPress (Microlab Elettronica, Roncaglia di Ponte San Nicolo, Italy) use air-filled cells or sensors to measure IP. These systems rely on changes in air pressure to determine the magnitude of pressure at individual points, allowing the system to measure IP directly. The air-filled cells of pneumatic-based systems are typically larger than cells of piezoresistive systems, resulting in fewer measurement points and lower spatial resolutions. However, this direct
measurement system results in quicker response times for individual cells, making these systems the best choice for capturing dynamic pressure changes during activity.

Figure 2.1: PicoPress Pneumatic-Based Pressure Mapping System (Microlab Elettronica)

Unlike pneumatic-based systems, piezoresistive pressure mapping systems measure pressure indirectly through force sensing piezoresistive material with electrical resistance properties. These sensors change their electrical resistance in response to an applied force, thus allowing the system to calculate IP by measuring the applied force per unit area. Piezoresistive mapping systems generally offer better spatial resolution compared to pneumatic systems with fewer measurement points. This higher resolution can provide more detailed information about pressure distribution across the contact area.\(^{29}\)
Wound Care for Edema Patients

Wound care practices for edema patients often involve the combination of primary wound dressings and compressive wraps or stockings. This approach is necessary for promoting wound healing and addressing the unique challenges faced by individuals with edema-related wounds such as leg ulcers. Primary wound dressings play a crucial role in creating a favorable wound environment, while compressive wraps or stockings provide support, promote circulation, and aid in fluid management.  

The primary wound dressings used in conjunction with compressive wraps or stockings serve multiple functions to support wound healing. For example, these dressings act as a barrier, protecting the wound from external contaminants, bacteria, and mechanical trauma. By creating a sterile and controlled environment, these dressings reduce the risk of infection and further tissue damage, facilitating the healing process. Primary wound dressings also help maintain moisture balance in the wound bed. They can absorb excess fluid from the wound while simultaneously providing a moist environment that supports cell migration, granulation tissue formation, and epithelization.
This optimal moisture level accelerates wound healing and minimizes the risk of scarring or wound complications.\textsuperscript{32}

In addition to their roles in maintaining moisture balance and providing a barrier, primary wound dressings aid in the distribution of IP provided by the compressive wrap or stocking around the edges of the wound. The presence of a primary wound dressing minimizes localized pressure points within the wound bed and maintains proper pressure distribution around the wound which is necessary for supplying the wounded area with adequate blood flow.\textsuperscript{33} This distribution of pressure around the wound bed reduces shearing forces between different tissue layers. In other words, an appropriately applied primary dressing can act as a cushioning layer.\textsuperscript{32}

Proper wound care techniques and appropriate selection and application of primary wound dressings are crucial for optimizing pressure distribution and promoting wound healing. The choice of primary dressing and management approach should be tailored to each individual patient’s needs and wound characteristics.
CHAPTER THREE
MATERIALS AND METHODS

Recruitment

To evaluate IP and IP distributions of the three compressive applications chosen for this study, a clinical trial was conducted at Rhodes Engineering Research Center on Clemson University’s campus with 40 healthy student volunteers. Student interest was obtained through fliers distributed around Clemson’s campus and email notifications. A $50 gift card was offered as an incentive once each participant completed his or her third and final testing session. Potential participants were asked to email a member of the research team via contact information provided on the flier for further instructions.

Acceptance Criteria

Inclusion criteria for participants included greater than 18 years of age, able to walk without an assistive device, able to walk for 10 minutes on a treadmill at a self-selected walking speed (2-4 mph), not allergic to any pre-tape adhesives or adhesive sports tapes, and a student, staff, or faculty at Clemson University. Following initial contact with a member of the research team, potential participants were sent an online form in which they entered information relating to the inclusion criteria to ensure that all requirements were satisfied. Inclusion criteria was established to enable the study to fully take place on Clemson’s campus. Participants were required to be able to walk on a treadmill for 10 minutes at a self-selected walking speed (2-4 mph) without the use of an assistive device as all participants were asked to walk at this pace prior to final pressure recordings being obtained for each compressive wrap tested in this study. Participants
must not be allergic to any pre-tape adhesives or adhesive sports tapes as a pre-tape adhesive was used to secure pressure sensors to participants’ legs prior to wrapping.

**Sensor Equilibration and Calibration**

To measure IP distribution underneath the compressive wraps, the Tekscan I-Scan pressure mapping system was used. Sensor model 6300-10 was chosen for the intended applications, containing 2,288 sensels in a 44x52 matrix.

![Figure 4.1: Tekscan I-Scan model 6300-10 pressure sensor](image)

Equilibration and calibration procedures were conducted using an air compressor and an air bladder between two steel plates, as pictured in Figure 4.2. This setup allowed for the application of a uniform pressure distribution across the entire area of the sensor. Each sensor was equilibrated and calibrated individually to account subtle variations in sensel performance. Sensors were first equilibrated using the Tekscan software by applying ~103 mmHg (2 PSI) to the sensors, normalizing the sensor readings to ensure a uniform pressure distribution across all sensels. Next, sensors were calibrated by
incrementally applying known pressures to create a unique calibration curve for each sensor, converting the raw readings into accurate pressure measurements.

Figure 4.2: Equilibration and calibration apparatus

**Clinical Testing**

Clinical testing took place over the course of two weeks. All testing was conducted under controlled ambient conditions and ambient lighting. The test administrator monitored the participant throughout the procedure and documented all events. Before beginning any study-related activities, participants were first asked to provide research personnel with their approximate height. Heights were used to estimate approximate tibial length in order to aid with sensor placement and ensure that sensors were placed in specific areas of interest on the lower extremity. Areas of interest were first marked with a sharpie. Pre-tape adhesive was then sprayed on the limb and the sensor was placed at the markings designating the area of interest. All pressure sensors were placed on the medial side of the calf, approximately 5-10 cm proximal to the malleolus of the ankle, depending on participant height. A thin Nylon layer was placed over the sensor to secure the sensor during compressive application. An initial pressure
measurement was taken with just the Nylon layer applied over the sensor to account for additional pressure resulting from this thin stocking.

Figure 5.1: Sensor placement with nylon stocking securement

Before application of the first compressive wrap, a picture of the participant's limb was captured. Once the participant's limb was imaged, the first compressive wrap was applied to the participant's leg while he or she was in a supine position. After the participant's leg was wrapped, from the foot to just below the knee, he or she was then instructed to remain in a supine position where the first set of pressure measurements was recorded. Then, the participant was instructed to stand, perform 10 toe raises, and continue standing for 30 seconds with his or her body weight bearing evenly on both lower extremities. The second set of pressure measurements was recorded following this 30 second period while the participant was still standing.
Following initial supine and standing IP measurements the participant was instructed to walk on a treadmill for 10 minutes at a self-selected walking speed (2-4 mph). After walking, the participant was instructed to continue standing with his or her body weight bearing evenly on both lower extremities for 30 seconds. The third set of pressure measurements was recorded following this 30 second period. Finally, the participant was instructed to assume a supine position for final pressure measurements. This procedure was repeated for each compressive application chosen in this study. Participants were asked to participate in 3 total sessions, one session for each...
compressive application, with a minimum of 24 hours in between sessions. The selection of the compressive application was randomized for the first and second sessions. Upon the conclusion of the third and final session, each participant was rewarded with a $50 visa gift card.

Figure 5.4: Participant walking on treadmill prior to final IP measurements

**Benchtop Testing: Evaluation of Primary Wound Dressings**

In order to evaluate IP distributions around a wound with the presence of different primary wound dressings, a separate benchtop study was conducted. The three primary wound dressings evaluated in the benchtop study included Agile, Tritec Silver, and Ultra Silver, shown above in Figure 3.1. First, two simulated wounds were prepared by cutting a 20 mm diameter hole out of the center of a 1 mm thick, 100 cm² sheet of Plastazoate. Plastazoate, a closed-cell polyethylene foam, was selected to simulate skin tissue due to its similar mechanical properties. A third 100 cm² sheet of Plastazoate was prepared without the 20 mm diameter hole to serve as a base layer. Three Tekscan model 5051 I-
Scan sensors were equilibrated and calibrated using the same methods and air bladder apparatus used in preparation of the clinical study, shown above in Figure 4.2.

Calibration points were modified to account for the smaller sensing area of the 5051 sensor, which is a square sensor containing 1,936 sensels in a 44 x 44 matrix.

Following preparation of the simulated tissue layers and calibration of the 5051 sensors, a baseline measurement was captured at four selected applications pressures: 3 PSI, 2 PSI, 1 PSI, and 0.5 PSI. These application pressures were chosen to replicate various levels of compression, ranging from mild to high compression levels. Baseline
measurements were conducted by placing the 5051 sensor directly on top of the base tissue layer without the presence of simulated wound layer. The primary wound dressing was then placed above the sensor and a piece of Coflex TLC was placed above the primary wound dressing. Scotch tape was used to adhere the corners of the base layer and top layer of Coflex TLC to keep the 5051 sensor in place during testing. Finally, this combination of base layer, pressure sensor, primary wound dressing, and Coflex TLC was placed underneath the air bladder and the four selected application pressures were applied. At each application pressure, IP and IP distribution data were collected. These measurements were used to verify that expected amounts of pressure were being distributed through the Coflex TLC and primary wound dressing layers to the 5051 sensor at each application pressure.

Figure 6.3: Sensor placement for baseline IP measurements

Following baseline IP measurements, a simulated wound layer was added above the base tissue layer to simulate a wound 1 mm in depth. The 5051 sensor was placed directly above the simulated wound layer. The primary wound dressing was then placed above the sensor and a piece of Coflex TLC was placed above the primary wound dressing. Scotch tape was used to adhere the corners of the base layer and top layer of
Coflex TLC to keep the 5051 sensor in place during testing. Finally, this combination of base layer, simulated wound layer, pressure sensor, primary wound dressing, and Coflex TLC was placed underneath the air bladder and the four selected application pressures were applied. At each application pressure, IP and IP distribution data were collected. These measurements were used to evaluate IP distributions in and around the 1 mm deep simulated wound bed at each application pressure.

Figure 6.4: Sensor placement for 1 mm wound depth IP measurements

Following IP measurements for a 1 mm deep simulated wound, an additional simulated wound layer was added above the base tissue layer to simulate a wound 2 mm in depth. The 5051 sensor was placed directly above the simulated wound layers. The primary wound dressing was then placed above the sensor and a piece of Coflex TLC was placed above the primary wound dressing. Scotch tape was used to adhere the corners of the base layer and top layer of Coflex TLC to keep the 5051 sensor in place during testing. Finally, this combination of base layer, two simulated wound layers, pressure sensor, primary wound dressing, and Coflex TLC was placed underneath the air bladder and the four selected application pressures were applied. At each application
pressure, IP and IP distribution data were collected. These measurements were used to evaluate IP distributions in and around the 2 mm deep simulated wound bed at each application pressure. This entire procedure was repeated for each of the three primary wound dressings evaluated in this study.

Figure 6.5: Sensor placement for 2 mm wound depth IP measurements

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

B1 (Ankle) and C (Calf) Average Pressures

Data Analysis

Prior to each compressive application in the clinical study, specific areas of interest were identified by a trained physical therapist and marked with a sharpie to aid in sensor placement. Sensors were placed approximately 5-10 cm proximal to the malleolus of the ankle, depending on the height of the participant. Following final IP measurements and removal of the applied compressive wrap, sensors were marked to identify sensel columns in the B1 (ankle) and C (calf) regions. These regions are common areas of
interest when evaluating IP for compressive applications and are depicted below in Figure 7.1.

A customized MATLAB code was used to evaluate the average IP within the B1 and C regions. To evaluate the average IP within these regions, the individual sensel data for each snapshot was extracted from the Tekscan software into an Excel data sheet. Individual Excel data sheets were analyzed by the MATLAB code using an Excel read function. After extracting numerical data from an Excel sheet, another Excel read function was utilized to extract numerical data from initial pressure measurements corresponding to pressure readings with just the thin Nylon layer applied over the sensor (labeled as “zero measurements”). The MATLAB code then calculated the difference between the individual sensel IP measurements of the given Excel file and the individual sensel IP measurements of the “zero measurements” to account for any additional pressure resulting from the thin Nylon layer. The first and last columns of the B1 and C
regions, as identified by the trained physical therapist, were entered into the MATLAB code through four user input functions.

B1 and C average IP calculations were recorded in an Excel table for each participant, position, and compressive application evaluated in this study. Average IP across all participants was calculated in Excel for each compressive application at each of the four participant positions evaluated during testing sessions. Three Edemawear, five Coflex, and four Coflex + Edemawear (Both) applications were excluded from the average calculations across all participants due to sensor damage obtained while the participant was walking and an inability to reconnect the sensor after extensive damage. Several two-tailed T-tests were conducted using a Bonferroni-corrected alpha of 8.3 x 10^{-3} to evaluate if the differences between IP averages of the three compressive applications evaluated in this study were statistically significant.

Static-stiffness index (SSI) values were calculated in Excel by subtracting the supine IP averages from the standing IP averages for each product, both before and after walking. The percent change between the SSI values before and after walking was also calculated for each product to characterize the change in product stiffness or elasticity during exercise.
Results

Table 7.1: B1 (ankle) and C (calf) average IP measurements

<table>
<thead>
<tr>
<th>Compressive Material</th>
<th>Supine Before Walking</th>
<th>St. Deviation</th>
<th>Standing Before Walking</th>
<th>St. Deviation</th>
<th>Supine After Walking</th>
<th>St. Deviation</th>
<th>Standing After Walking</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edemawear (n = 37)</td>
<td>10.82</td>
<td>4.18</td>
<td>14.04</td>
<td>5.18</td>
<td>12.75</td>
<td>4.49</td>
<td>15.25</td>
<td>5.07</td>
</tr>
<tr>
<td>Coflex (n = 35)</td>
<td>28.48</td>
<td>8.21</td>
<td>32.20</td>
<td>9.44</td>
<td>25.53</td>
<td>9.21</td>
<td>35.93</td>
<td>10.69</td>
</tr>
<tr>
<td>Both (n = 36)</td>
<td>38.34</td>
<td>8.89</td>
<td>43.66</td>
<td>11.21</td>
<td>27.46</td>
<td>8.43</td>
<td>40.68</td>
<td>12.44</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edemawear (n = 37)</td>
<td>10.86</td>
<td>9.16</td>
<td>12.82</td>
<td>4.61</td>
<td>11.73</td>
<td>4.73</td>
<td>14.86</td>
<td>5.40</td>
</tr>
<tr>
<td>Coflex (n = 35)</td>
<td>25.12</td>
<td>9.16</td>
<td>28.49</td>
<td>10.13</td>
<td>18.21</td>
<td>7.88</td>
<td>30.53</td>
<td>10.36</td>
</tr>
<tr>
<td>Both (n = 36)</td>
<td>38.20</td>
<td>10.67</td>
<td>41.76</td>
<td>11.82</td>
<td>23.91</td>
<td>10.17</td>
<td>39.94</td>
<td>13.09</td>
</tr>
</tbody>
</table>

Edemawear had the lowest average IPs at each position, with pressures ranging from 10.82 – 15.25 mmHg in the B1 region and 10.86 – 14.86 mmHg in the C region. Coflex average IPs were significantly greater at each position, with pressures ranging from 25.53 – 35.93 mmHg in the B1 region and 18.21 – 30.53 mmHg in the C region. Applications including both Coflex and Edemawear had the highest average IPs at each position, with pressures ranging from 27.46 – 43.66 mmHg in the B1 region and 23.91 – 41.76 in the C region. For each compressive application evaluated in this study, IP was greatest at the ankle and gradually decreased towards the calf.
Figure 7.2: B1 (ankle) average IP measurements at each position with statistically significant differences(*)

Figure 7.3: C (calf) average IP measurements at each position with statistically significant differences(*)
All three compressive applications evaluated in this study experienced significant decreases in IP when participants assumed a supine position after walking on a treadmill for 10 minutes. In both the B1 and C regions, the differences between IP averages of all three compressive applications were statistically significant for both the supine and standing positions prior to the participant walking on the treadmill ($p < 8.3 \times 10^{-3}$). In the B1 region, the difference between Coflex and Both applications was not statistically significant for both the supine and standing positions after walking ($p > 8.3 \times 10^{-3}$). This was also the case for the C region in the supine position after walking. However, in the C region, the differences between IP averages of all three compressive applications were statistically significant in the standing position after walking ($p < 8.3 \times 10^{-3}$).

<table>
<thead>
<tr>
<th>Area of Interest</th>
<th>Compressive Bandage Set</th>
<th>SSI Pre-Exercise [mmHg]</th>
<th>SSI Post-Exercise [mmHg]</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 (Ankle)</td>
<td>EdemaWear</td>
<td>3.21</td>
<td>2.5</td>
<td>-22%</td>
</tr>
<tr>
<td></td>
<td>Coflex TLC</td>
<td>3.72</td>
<td>10.1</td>
<td>171%</td>
</tr>
<tr>
<td></td>
<td>EdemaWear + Coflex TLC</td>
<td>5.11</td>
<td>13.3</td>
<td>161%</td>
</tr>
<tr>
<td>C (Calf)</td>
<td>EdemaWear</td>
<td>1.96</td>
<td>3.13</td>
<td>59%</td>
</tr>
<tr>
<td></td>
<td>Coflex TLC</td>
<td>1.95</td>
<td>11.61</td>
<td>497%</td>
</tr>
<tr>
<td></td>
<td>EdemaWear + Coflex TLC</td>
<td>3.15</td>
<td>14.88</td>
<td>372%</td>
</tr>
</tbody>
</table>

Table 7.2: B1 (ankle) and C (calf) SSI Summary
Coflex TLC experienced the greatest percent change in SSI in both the B1 and C regions with percent changes of 171% and 497%, respectively. Edemawear experienced the lowest percent change in SSI in both the B1 and C regions. Unlike the other products, the SSI of Edemawear actually decreased by 22% post-exercise in the B1 region. In the C region, the SSI of Edemawear only increased by 59%. Both applications (Edemawear + Coflex TLC) also showed significant increases in SSI in both the B1 and C regions with percent changes of 161% and 372%, respectively.

**Pressure Distribution of Compressive Applications**

*Data Analysis*

The same customized MATLAB code used to evaluate the average IP within the B1 and C regions was also used to evaluate proximal to distal pressure distributions for each compressive application. To evaluate the proximal to distal IP distribution, the individual sensel data for each snapshot was extracted from the Tekscan software into an Excel data sheet. Individual Excel data sheets were analyzed by the MATLAB code using an Excel read function. After extracting numerical data from an Excel sheet, another Excel read function was utilized to extract numerical data from initial pressure measurements corresponding to pressure readings with just the thin Nylon layer applied over the sensor (labeled as “zero measurements”). The MATLAB code then calculated the difference between the individual sensel IP measurements of the given Excel file and the individual sensel IP measurements of the “zero measurements” to account for any additional pressure resulting from the thin Nylon layer.
After subtracting the “zero measurement” pressure readings from the pressure readings of the given Excel file, the MATLAB code evaluated the proximal to distal pressure distribution by taking the average pressure of each column across the sensor. These averages were plotted on the x axis of the distribution graphs with distance across the sensor on the y axis. This was done to allow the pressure distribution graph to match the orientation of sensor placement on the limb and the pressure maps produced by the Tekscan software. If more than 50% of the sensels in a given column produced pressure readings less than or equal to 0 mmHg after the difference between the given Excel file and the “zero measurement” was calculated, the average pressure of the given column was excluded from the distribution graph.

Figure 8.1: Example pressure maps for Edemawear (left), Coflex (center), and both (right) applications
Results

Figure 8.2: Example distribution graphs for Coflex TLC in the supine (left) and standing (right) positions

Figure 8.3: Example distribution graphs for both application in the supine (left) and standing (right) positions
Figure 8.4: Example distribution graphs for Edemawear in the supine (left) and standing (right) positions.

For Coflex and both applications, IP was greatest in the B1 region (between 0 – 2 in and 0 – 4 in distance across the sensor depending on participant height) and gradually decreased moving toward the C region. For Edemawear applications, a uniform pressure distribution was produced along the entire length of the limb. All distribution graphs shown above in Figures 8.2 – 8.4 were produced from pre-exercise pressure recordings. Similar trends were observed for post-exercise pressure distribution graphs, with the occasional spike in pressure in the C region for high pressure both applications (see Appendices for all proximal to distal pressure distribution graphs).
Benchtop Testing: Primary Wound Dressing Performance

Data Analysis

Baseline measurements, or measurements taken without the presence of a simulated wound bed, were used to verify that applied pressure from the air bladder was being distributed through the primary wound dressing and Coflex layers to the 5051 Tekscan pressure sensor. Excel data sheets were extracted from the Tekscan software, and the average pressure across the entire sensor area was calculated in Excel. Individual cells reading 0 mmHg of pressure were omitted from the average calculations. This was done to account for data loss that may arise due to using the same sensor for multiple pressure readings at different application pressures.

A separate customized MATLAB code from the code described above was used to evaluate the average IP in and around simulated wound beds for the benchtop study. Individual Excel data sheets were analyzed by the MATLAB code using an Excel read function. The MATLAB code then determined the size of the Excel file and prompted the user to enter the location of the center of the wound bed via four user input functions.

The center of the wound bed was determined manually in Excel by calculating standard deviations of multiple 6 x 6 arrays of cells, near the center of the sensor. The 6 x 6 group of cells with the lowest standard deviation was used to determine the center. The column and row numbers for the middle two columns and middle two rows of the 6 x 6 group of cells with the lowest standard deviation were entered into the user input functions. Once the center location was entered into the MATLAB code, cartesian coordinates were assigned to each cell and later converted to polar coordinates.
After assigning polar coordinates to each cell, the MATLAB code searched for cells with unique \( r \) values and took the average pressure across all cells with the same \( r \) values. Once the average pressures across all cells with the same \( r \) values were determined, the average pressure from \( r = 0 \) mm to \( r = 10 \) mm was calculated to determine the average pressure inside the 20 mm diameter simulated wound bed.

In addition to summarizing the average pressure within the simulated wound bed, the MATLAB code plotted average pressure [mmHg] v. \( r \) [mm] to characterize the radial distribution of pressure in and around the simulated wound. The linear slope from \( r = 5 \) mm to \( r = 15 \) mm was calculated to characterize the effects of different primary wound dressings on pressure distribution around the edges of the wound bed. A digital caliper was used to measure the thickness of each of the primary wound dressings evaluated in this study: Agile, Tritec Silver, and Ultra Silver.

![Pressure maps of 1 mm simulated wound depth at 2 PSI application pressure for Agile (left), Tritec Silver (center), and Ultra Silver (right)](image)

Figure 9.1: Pressure maps of 1 mm simulated wound depth at 2 PSI application pressure for Agile (left), Tritec Silver (center), and Ultra Silver (right)
Results

Table 9.1: Benchtop study summary of results

<table>
<thead>
<tr>
<th>Primary Wound Dressing</th>
<th>Wound Depth [mm]</th>
<th>Applied Pressure [Psi]</th>
<th>Applied Pressure [mmHg]</th>
<th>Average Pressure in Wound Bed [mmHg]</th>
<th>Rate of Pressure Change at Wound Edge [mmHg/mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile (Thickness = 3 mm)</td>
<td>1 mm 0.5</td>
<td>25.85</td>
<td>7.44</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>1</td>
<td>51.7</td>
<td>15.58</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>2</td>
<td>103.4</td>
<td>41.04</td>
<td>13.01</td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>3</td>
<td>155.1</td>
<td>59.65</td>
<td>18.44</td>
</tr>
<tr>
<td></td>
<td>2 mm 0.5</td>
<td>25.85</td>
<td>2.13</td>
<td>4.54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>1</td>
<td>51.7</td>
<td>10.7</td>
<td>6.37</td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>2</td>
<td>103.4</td>
<td>23.49</td>
<td>12.68</td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>3</td>
<td>155.1</td>
<td>39.07</td>
<td>19.68</td>
</tr>
<tr>
<td>Tritec Silver (Thickness = 1 mm)</td>
<td>1 mm 0.5</td>
<td>25.85</td>
<td>4.9</td>
<td>3.93</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>1</td>
<td>51.7</td>
<td>6.69</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>2</td>
<td>103.4</td>
<td>18.41</td>
<td>15.95</td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>3</td>
<td>155.1</td>
<td>41.31</td>
<td>22.55</td>
</tr>
<tr>
<td></td>
<td>2 mm 0.5</td>
<td>25.85</td>
<td>0.69</td>
<td>4.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>1</td>
<td>51.7</td>
<td>5.88</td>
<td>8.56</td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>2</td>
<td>103.4</td>
<td>11.95</td>
<td>17.12</td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
<td>3</td>
<td>155.1</td>
<td>17.17</td>
<td>25.13</td>
</tr>
<tr>
<td>ULTRA Silver (Thickness = 6 mm)</td>
<td>1 mm 0.5</td>
<td>25.85</td>
<td>7.95</td>
<td>3.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mm</td>
<td>1</td>
<td>51.7</td>
<td>20.11</td>
<td>5.88</td>
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<td>1 mm</td>
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<td>47.79</td>
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<td></td>
<td>1 mm</td>
<td>3</td>
<td>155.1</td>
<td>71.2</td>
<td>17.95</td>
</tr>
<tr>
<td></td>
<td>2 mm 0.5</td>
<td>25.85</td>
<td>2.21</td>
<td>4.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
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<td>13.44</td>
<td>6.07</td>
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<td></td>
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<td>37.12</td>
<td>13.11</td>
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<tr>
<td></td>
<td>2 mm</td>
<td>3</td>
<td>155.1</td>
<td>62.31</td>
<td>18.98</td>
</tr>
</tbody>
</table>

Figure 9.2: Average pressures in wound bed
Based on the results, a thicker wound dressing was associated with greater application pressures within the wound bed for each combination of wound depth and application pressure evaluated in this study. Ultra Silver, the thickest and most flexible wound dressing, distributed the greatest amount of pressure to the interior of the wound bed with average pressures ranging from $7.95 - 71.20$ mmHg at a wound depth of 1 mm and $2.21 - 62.31$ mmHg at a wound depth of 2 mm for application pressures ranging from $28.85 - 155.1$ mmHg (0.5 – 3 PSI). Tritec Silver, the least thick and least flexible wound dressing, distributed the least amount of pressure to the interior of the wound bed with average pressures ranging from $4.90 - 41.31$ mmHg at a wound depth of 1 mm and
0.69 – 17.17 mmHg at a wound depth of 2 mm for application pressures ranging from 28.85 – 155.1 mmHg (0.5 – 3 PSI). Agile, a 3 mm thick wound dressing, distributed moderate pressure to the interior of the wound bed, with average pressures ranging from 7.44 – 59.65 mmHg at a wound depth of 1 mm and 2.13 – 39.07 mmHg at a wound depth of 2 mm for application pressures ranging from 28.85 – 155.1 mmHg (0.5 – 3 PSI). Average pressures within the wound bed were greater for 1 mm wound depth application than for 2 mm wound depth applications.

Figure 9.4: Radial IP distribution for Agile at a wound depth of 1 mm and application pressure of 2 PSI
Figure 9.5: Radial IP distribution for Tritec at a wound depth of 1 mm and application pressure of 2 PSI

Figure 9.6: Radial IP distribution for Ultra at a wound depth of 1 mm and application pressure of 2 PSI
A thicker wound dressing was also associated with lower rates of pressure change at the wound edge (from \( r = 5 \) mm to \( r = 15 \) mm) for each combination of wound depth and application pressure evaluated in this study. Ultra Silver, the thickest and most flexible wound dressing, resulted in a 12.15 mmHg / mm rate of pressure change at the wound edge for a wound depth of 1 mm and application pressure of 103.4 mmHg (2 PSI). Tritic Silver, the least thick and least flexible wound dressing, resulted in a 15.95 mmHg / mm rate of pressure change at the wound edge under the same conditions. Agile, a 3 mm thick wound dressing, resulted in a 13.01 mmHg / mm rate of pressure change at the wound edge under the same conditions. Rates of pressure change were greater for a deeper wound for each combination of primary wound dressing and application pressure evaluated in this study (see Appendices for all radial distribution graphs and associated pressure maps).

CHAPTER 5
DISCUSSION AND CONCLUSION

The aim of the clinical study was to evaluate IP and IP distributions underneath three different compressive applications in order to gauge therapeutic efficacy of the different textile combinations. This was done by examining pressures and pressure distribution underneath the compressive textiles under resting and working conditions. The aim of the benchtop study was to evaluate IP distributions in and around simulated wounds with the presence of three different primary wound dressings. This was done by examining pressure and radial pressure distributions in and around simulated wounds of
various wound depths at multiple application pressures, ranging from mild to high compression levels.

Methods – Clinical Study

A clinical trial was conducted where Tekscan sensors were placed between compressive textiles and the leg skin to measure IP and IP distributions of different textile combinations. Similar methods have been utilized in past studies; however, the majority of these studies opted for using pneumatic-based pressure mapping systems over piezoresistive mapping systems such as Tekscan.\textsuperscript{29,36,37,38} Pneumatic-based mapping systems contain air-filled cells that allow for direct measurement of application pressures as air within the cells is compressed. Piezoresistive mapping systems, on the other hand, contain thin strips of resistive ink. Resistance levels change as pressure is applied to the sensor, allowing the software to calculate application pressures based on changes in resistivity. Because pneumatic-based mapping systems measure pressure directly, whereas piezoresistive mapping systems measure pressure indirectly, they may be slightly more accurate at lower pressure levels, according to some studies.\textsuperscript{31,40} However, most pneumatic-based mapping systems are only capable of measuring single-point contact pressures and are unable to characterize IP distributions. Piezoresistive sensors, such as the Tekscan I-scan model 6300-10 sensor, contain multiple sensels arranged in a matrix according to sensor model, allowing for the evaluation of both average pressures and pressure distributions across the sensor area.\textsuperscript{29}

While some studies have shown that pneumatic-based systems may be slightly more accurate in measuring lower levels of IP, other studies have reported that
piezoresistive sensors have shown similar in-vitro performance as pneumatic-based systems.\textsuperscript{39,40} Despite conflicting results from past studies, a Tekscan piezoresistive sensor was selected for use in this study due to its ability to characterize IP distributions under static and dynamic conditions. When evaluating IP of compressive applications, it is necessary to evaluate proximal to distal IP distribution in order to gauge therapeutic efficacy of different textile combinations. Gradient pressure helps facilitate the movement of fluid in chronic edema patients by encouraging fluid flow from areas of high pressure to areas of low pressure. This gradience promotes the drainage of excess fluid, enhances lymphatic flow, and reduces the risk of creating excessive pressure at any specific point, minimizing the potential for pressure-related complications.\textsuperscript{31} In order to measure this gradience along with average IP in specific areas of interest, a piezoresistive sensor was utilized.

\textit{Methods – Benchtop Study}

A benchtop study was conducted to evaluate the effects of three different primary wound dressings on IP and IP distributions in and around a wound. Previous studies have utilized simulated leg models (SLMs) and Tekscan 5051 I-scan sensors, the same sensor used in this benchtop study, to measure IP and IP distributions associated with primary wound dressings under different levels of layered compression. However, these studies did not introduce a simulated wound to the SLM, and therefore, were limited in their ability to measure the effects of primary wound dressings on IP distributions.\textsuperscript{23}

In order to provide a more realistic representation of the wound environment compared to previous studies that relied solely on SLMs, a simulated wound was
introduced to this benchtop study. In addition to providing a more realistic representation of the wound environment, the introduction of a simulated wound provided several advantages. The presence of the simulated wound in this study allowed for factors such as dressing conformity, pressure exerted on the wound bed, and pressure at the edges of the wound to be evaluated, providing valuable insight into how different primary wound dressings affect IP distributions and potentially impact wound healing processes. The use of a simulated wound also provided a controlled, reproducible experimental setting, allowing for more accurate evaluation of the effects of primary wound dressings on IP distributions. In reality, primary wound dressings would not be utilized in a clinical setting unless an open wound was present on the extremity. This approach provided a more realistic assessment of the interaction between primary wound dressings and the wound bed, contributing to evidence-based wound care practices and potentially improving outcomes for individuals with lower extremity open wounds.

**B1 (Ankle) and C (Calf) Local Average Pressures**

Edemawear had the lowest average IPs at each position, with pressures ranging from 10.82 – 15.25 mmHg in the B1 region and 10.86 – 14.86 mmHg in the C region. Coflex average IPs were significantly greater at each position, with pressures ranging from 25.53 – 35.93 mmHg in the B1 region and 18.21 – 30.53 mmHg in the C region. According to the manufacturers, Coflex TLC is rated for compression levels ranging from 35 – 40 mmHg and Edemawear is rated for compression levels ranging from 15 – 20 mmHg.\(^{41,42}\) The slight differences between the findings from this clinical study and the manufacturer rating could be influenced by several mechanisms.
IP pressure readings may have been affected by variability in patient anatomy. IP can vary depending on individual patient factors, such as limb shape, size, and tissue characteristics. These variations can affect the fit and compression provided by the Coflex TLC and Edemawear products, possibly leading to the differences in the measured IP averages compared to the manufacturer ratings. Small variations in sensor positioning or calibration techniques could have also introduced measurement errors, resulting in the observed differences. Lastly, differences in application techniques could have also resulted in differences between measured IP and the manufacturer’s specified range.

Pressure Loss in the Supine Position Post-Exercise

All three compressive applications evaluated in this study experienced significant decreases in IP when participants assumed a supine position after walking on a treadmill for 10 minutes. This observed drop in IP could be attributed by several mechanisms.

One potential factor that could have led to a drop in IP in the supine position after walking is the redistribution of body weight. When participants are in a standing position, body weight is distributed differently compared to when a supine position is assumed. In a standing position, more weight is borne by the lower extremities and the areas in contact with the ground. Previous studies have reported that gravity imposes several challenges to tissue-fluid balance as well. Therefore, in a standing position, fluid accumulation in the lower extremities and interstitial spaces is more likely due to the effects of gravity compared to a supine position. This can contribute to increased tissue swelling, resulting in higher IPs in the standing position compared to the supine position.
The differences between supine and standing IP measurements are more pronounced after exercise likely due to elevated fluid retention levels in the lower extremities.\textsuperscript{44}

In addition to the effects of body weight distribution and the effects of gravity, another mechanism that could have led to the decrease in IP in the supine position after walking is the expansion of the compressive textile during exercise. During walking, the muscles and tissues of the lower extremities are engaged and undergo movement and expansion. This muscle activity can lead to changes in the dimensions and shape of the limb, resulting in the expansion or stretching of the compressive textiles. As the wrap material stretches during activity, the compression applied by the compressive wrap may decrease, subsequently resulting in a drop in IP once participants assume a supine position. Once participants transition to a supine position, the wrap material may relax and conform to the limb more passively, potentially leading to a decrease in IP.\textsuperscript{45}

\textit{Proximal to Distal Pressure Distributions}

For Coflex and both applications, IP was greatest in the B1 region and gradually decreased moving toward the C region. As previously discussed, gradient pressure promotes fluid movement in the extremities by encouraging fluid flow from areas of high pressure to areas of low pressure. This gradience promotes the drainage of excess fluid, enhances lymphatic flow, and reduces the risk of creating excessive pressure at any specific point, minimizing the potential for pressure-related complications or tissue injuries.\textsuperscript{31} Based on the results, Coflex TLC and both applications have the potential to reduce swelling effects in chronic edema and lymphedema patients due to the gradient
pressure distribution and moderate to high compression levels provided by these textile combinations.

For Edemawear applications, a uniform pressure distribution was produced along the entire length of the limb. Unlike the other compressive applications evaluated in this study, which applied circumferential pressure around the limb, Edemawear and other “tubular” stockinettes induce a longitudinal pressure profile along the entire length of the limb.²² Edemawear utilizes a special type of compression known as Fuzzy-wale compression (FWC) which produced a striping pattern and only applies compression to ~20% of the limb surface, making this an ideal product for patients with open wounds or venous leg ulcers. Despite lower compressive levels compared to the other products and a uniform pressure distribution, the longitudinal pressure profile and larger area of non-compressed tissue helps open veins and lymphatics to reduce fluid retention in the limb.⁴² Based on the results, Edemawear also has the potential to reduce swelling effects in chronic edema and lymphedema patients due to the alternative longitudinal pressure profile induced along the limb and high levels of uncompressed tissue.

*Primary Wound Dressing Performance*

Based on the results of the benchtop study, a thicker wound dressing was associated with greater application pressures within the wound bed for each combination of wound depth and application pressure evaluated in this study. Ultra Silver, the thickest and most flexible wound dressing, distributed the greatest amount of pressure to the interior of the wound bed while Tritec Silver, the least thick and least flexible wound dressing, distributed the least amount of pressure to the interior of the wound bed. A
thicker wound dressing was also associated with lower rates of pressure change at the wound edge (from \(r = 5\) mm to \(r = 15\) mm) for each combination of wound depth and application pressure evaluated in this study.

The choice of appropriate wound dressing, therefore, depends on the specific characteristics and needs of the wound. For example, a thicker wound dressing that applies pressure within the wound bed, such as Ultra Silver, may be beneficial for deep wounds or cavity wounds where there is a need for wound bed support and filling. A thicker wound dressing may also be advantageous for wounds with excessive exudate as they can absorb higher levels of exudate while maintaining a moist wound environment. On the other hand, a thinner, stiffer wound dressing may be desired to treat superficial wounds or wounds with fragile or sensitive tissue, such as ulcers, in order to minimize the applied pressure within the wound bed and protect sensitive superficial tissue layers.

**Conclusion**

Chronic edema affects approximately 20% of people in the US over the age of 50 and is frequently encountered among individuals with conditions such as heart failure, kidney and liver disease, prolonged immobility, and venous insufficiency. Through the course of this clinical trial, the three compressive textile combinations evaluated in this study demonstrated adequate levels of application pressure and appropriate IP distributions to reduce fluid retention in the leg, potentially mitigating the effects of chronic edema. During compressive applications where an open wound is present, primary wound dressings should be used in combination with compressive wraps. Primary wound dressings provide a barrier and maintain a moist environment that
promotes healing while compressive textiles applied over the primary wound dressing exert pressure on the wound and surrounding tissues. The three primary wound dressings evaluated in the benchtop portion of the study demonstrated various levels of application pressures within the wound bed and rates of pressure change at the edge of the wound bed, depending on the thickness of the primary wound dressing. Primary wound dressings should be selected based on the specific needs of the wound and type of wound present. Overall, this clinical trial and benchtop study demonstrated that the evaluated compressive textile combinations, in conjunction with suitable primary wound dressings, have shown promising results in reducing fluid retention and potentially alleviating the effects of chronic edema.
APPENDICES
Appendix A

Figure A1: IP Distribution Graph for Coflex, Supine Before Walking (P1)

Figure A2: IP Distribution Graph for Coflex, Standing Before Walking (P1)

Figure A3: IP Distribution Graph for Coflex, Supine After Walking (P1)

Figure A4: IP Distribution Graph for Coflex, Standing Walking (P1)
Figure A5: IP Distribution Graph for Both, Supine Before Walking (P2)

Figure A6: IP Distribution Graph for Both, Standing Before Walking (P2)

Figure A7: IP Distribution Graph for Both, Supine After Walking (P2)

Figure A8: IP Distribution Graph for Both, Standing After Walking (P2)
Figure A9: IP Distribution Graph for Coflex, Supine Before Walking (P2)

Figure A10: IP Distribution Graph for Coflex, Standing Before Walking (P2)

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Figure A44: IP Distribution Graph for Edemawear, Standing After Walking (P5)
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Figure A96: IP Distribution Graph for Edemawear, Standing After Walking (P10)
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Figure A243: IP Distribution Graph for Coflex, Standing After Walking (P23)
Figure A244: IP Distribution Graph for Edemawear, Supine Before Walking (P23)

Figure A245: IP Distribution Graph for Edemawear, Standing Before Walking (P23)

Figure A246: IP Distribution Graph for Edemawear, Supine After Walking (P23)

Figure A247: IP Distribution Graph for Edemawear, Standing After Walking (P23)
Figure A248: IP Distribution Graph for Both, Supine Before Walking (P24)

Figure A249: IP Distribution Graph for Both, Standing Before Walking (P24)

Figure A250: IP Distribution Graph for Both, Supine After Walking (P24)

Figure A251: IP Distribution Graph for Both, Standing After Walking (P24)
Figure A252: IP Distribution Graph for Coflex, Supine Before Walking (P24)

Figure A253: IP Distribution Graph for Coflex, Standing Before Walking (P24)

Figure A254: IP Distribution Graph for Coflex, Supine After Walking (P24)

Figure A255: IP Distribution Graph for Coflex, Standing After Walking (P24)
Figure A256: IP Distribution Graph for Edemawear, Supine Before Walking (P24)

Figure A257: IP Distribution Graph for Edemawear, Standing Before Walking (P24)

Figure A258: IP Distribution Graph for Edemawear, Supine After Walking (P24)

Figure A259: IP Distribution Graph for Edemawear, Standing After Walking (P24)
Figure A260: IP Distribution Graph for Both, Supine Before Walking (P25)

Figure A261: IP Distribution Graph for Both, Standing Before Walking (P25)

Figure A262: IP Distribution Graph for Both, Supine After Walking (P25)

Figure A263: IP Distribution Graph for Both, Standing After Walking (P25)
Figure A264: IP Distribution Graph for Coflex, Supine Before Walking (P25)

Figure A265: IP Distribution Graph for Coflex, Standing Before Walking (P25)

Figure A266: IP Distribution Graph for Coflex, Supine After Walking (P25)

Figure A267: IP Distribution Graph for Coflex, Standing After Walking (P25)
Figure A268: IP Distribution Graph for Edemawear, Supine Before Walking (P25)

Figure A269: IP Distribution Graph for Edemawear, Standing Before Walking (P25)

Figure A270: IP Distribution Graph for Edemawear, Supine After Walking (P25)

Figure A271: IP Distribution Graph for Edemawear, Standing After Walking (P25)
Figure A272: IP Distribution Graph for Both, Supine Before Walking (P26)

Figure A273: IP Distribution Graph for Both, Standing Before Walking (P26)

Figure A274: IP Distribution Graph for Both, Supine After Walking (P26)

Figure A275: IP Distribution Graph for Both, Standing After Walking (P26)
Figure A276: IP Distribution Graph for Coflex, Supine Before Walking (P26)

Figure A277: IP Distribution Graph for Coflex, Standing Before Walking (P26)

Figure A278: IP Distribution Graph for Coflex, Supine After Walking (P26)

Figure A279: IP Distribution Graph for Coflex, Standing After Walking (P26)
Figure A280: IP Distribution Graph for Edemawear, Supine Before Walking (P26)

Figure A281: IP Distribution Graph for Edemawear, Standing Before Walking (P26)

Figure A282: IP Distribution Graph for Edemawear, Supine After Walking (P26)

Figure A283: IP Distribution Graph for Edemawear, Standing After Walking (P26)
Figure A284: IP Distribution Graph for Both, Supine Before Walking (P27)

Figure A285: IP Distribution Graph for Both, Standing Before Walking (P27)

Figure A286: IP Distribution Graph for Both, Supine After Walking (P27)

Figure A287: IP Distribution Graph for Both, Standing After Walking (P27)
Figure A288: IP Distribution Graph for Coflex, Supine Before Walking (P27)

Figure 289: IP Distribution Graph for Coflex, Standing Before Walking (P27)

Figure A290: IP Distribution Graph for Coflex, Supine After Walking (P27)

Figure A291: IP Distribution Graph for Coflex, Standing After Walking (P27)
Figure A292: IP Distribution Graph for Edemawear, Supine Before Walking (P27)

Figure A293: IP Distribution Graph for Edemawear, Standing Before Walking (P27)

Figure A294: IP Distribution Graph for Edemawear, Supine After Walking (P27)

Figure A295: IP Distribution Graph for Edemawear, Standing After Walking (P27)
Figure A296: IP Distribution Graph for Both, Supine Before Walking (P28)

Figure A297: IP Distribution Graph for Both, Standing Before Walking (P28)

Figure A298: IP Distribution Graph for Both, Supine After Walking (P28)

Figure A299: IP Distribution Graph for Both, Standing After Walking (P28)
Figure A300: IP Distribution Graph for Coflex, Supine Before Walking (P28)

Figure A301: IP Distribution Graph for Coflex, Standing Before Walking (P28)

Figure A302: IP Distribution Graph for Coflex, Supine After Walking (P28)

Figure A303: IP Distribution Graph for Coflex, Standing After Walking (P28)
Figure A304: IP Distribution Graph for Edemawear, Supine Before Walking (P28)

Figure A305: IP Distribution Graph for Edemawear, Standing Before Walking (P28)

Figure A306: IP Distribution Graph for Edemawear, Supine After Walking (P28)

Figure A307: IP Distribution Graph for Edemawear, Standing After Walking (P28)
Figure A308: IP Distribution Graph for Both, Supine Before Walking (P29)

Figure A309: IP Distribution Graph for Both, Standing Before Walking (P29)

Figure A310: IP Distribution Graph for Both, Supine After Walking (P29)

Figure A311: IP Distribution Graph for Both, Standing After Walking (P29)
Figure A312: IP Distribution Graph for Coflex, Supine Before Walking (P29)

Figure A313: IP Distribution Graph for Coflex, Standing Before Walking (P29)

Figure A314: IP Distribution Graph for Coflex, Supine After Walking (P29)

Figure A315: IP Distribution Graph for Coflex, Standing After Walking (P29)
Figure A316: IP Distribution Graph for Edemawear, Supine Before Walking (P29)

Figure A317: IP Distribution Graph for Edemawear, Standing Before Walking (P29)

Figure A318: IP Distribution Graph for Edemawear, Supine After Walking (P29)

Figure A319: IP Distribution Graph for Edemawear, Standing After Walking (P29)
Figure A320: IP Distribution Graph for Both, Supine Before Walking (P30)

Figure A321: IP Distribution Graph for Both, Standing Before Walking (P30)

Figure A322: IP Distribution Graph for Both, Supine After Walking (P30)

Figure A323: IP Distribution Graph for Both, Standing After Walking (P30)
Figure A324: IP Distribution Graph for Coflex, Supine Before Walking (P30)

Figure A325: IP Distribution Graph for Coflex, Standing Before Walking (P30)

Figure A326: IP Distribution Graph for Coflex, Supine After Walking (P30)

Figure A327: IP Distribution Graph for Coflex, Standing After Walking (P30)
Figure A328: IP Distribution Graph for Edemawear, Supine Before Walking (P30)

Figure A329: IP Distribution Graph for Edemawear, Standing Before Walking (P30)

Figure A330: IP Distribution Graph for Edemawear, Supine After Walking (P30)

Figure A331: IP Distribution Graph for Edemawear, Standing After Walking (P30)
Figure A332: IP Distribution Graph for Coflex, Supine Before Walking (P31)

Figure A333: IP Distribution Graph for Coflex, Standing Before Walking (P31)

Figure A334: IP Distribution Graph for Coflex, Supine After Walking (P31)

Figure A335: IP Distribution Graph for Coflex, Standing After Walking (P31)
Figure A336: IP Distribution Graph for Edemawear, Supine Before Walking (P31)

Figure A337: IP Distribution Graph for Edemawear, Standing Before Walking (P31)

Figure A338: IP Distribution Graph for Edemawear, Supine After Walking (P31)

Figure A339: IP Distribution Graph for Edemawear, Standing After Walking (P31)
Figure A340: IP Distribution Graph for Both, Supine Before Walking (P32)

Figure A341: IP Distribution Graph for Both, Standing Before Walking (P32)

Figure A342: IP Distribution Graph for Both, Supine After Walking (P32)

Figure A343: IP Distribution Graph for Both, Standing After Walking (P32)
Figure A344: IP Distribution Graph for Coflex, Supine Before Walking (P32)

Figure A345: IP Distribution Graph for Coflex, Standing Before Walking (P32)

Figure A346: IP Distribution Graph for Coflex, Supine After Walking (P32)

Figure A347: IP Distribution Graph for Coflex, Standing After Walking (P32)
Figure A348: IP Distribution Graph for Edemawear, Supine Before Walking (P32)

Figure A349: IP Distribution Graph for Edemawear, Supine After Walking (P32)

Figure A350: IP Distribution Graph for Edemawear, Standing After Walking (P32)

Figure A351: IP Distribution Graph for Edemawear, Standing Before Walking (P32)
Figure A352: IP Distribution Graph for Both, Supine Before Walking (P33)

Figure A353: IP Distribution Graph for Both, Standing Before Walking (P33)

Figure A354: IP Distribution Graph for Both, Supine After Walking (P33)

Figure A355: IP Distribution Graph for Both, Standing After Walking (P33)
Figure A356: IP Distribution Graph for Coflex, Supine Before Walking (P33)

Figure A357: IP Distribution Graph for Coflex, Standing Before Walking (P33)

Figure A358: IP Distribution Graph for Coflex, Supine After Walking (P33)

Figure A359: IP Distribution Graph for Coflex, Standing After Walking (P33)
Figure A360: IP Distribution Graph for Edemawear, Supine Before Walking (P33)

Figure A361: IP Distribution Graph for Edemawear, Standing Before Walking (P33)

Figure A362: IP Distribution Graph for Edemawear, Standing After Walking (P33)
Figure A363: IP Distribution Graph for Both, Supine Before Walking (P34)

Figure A364: IP Distribution Graph for Both, Standing Before Walking (P34)

Figure A365: IP Distribution Graph for Both, Supine After Walking (P34)

Figure A366: IP Distribution Graph for Both, Standing After Walking (P34)
Figure A367: IP Distribution Graph for Coflex, Supine Before Walking (P34)

Figure A368: IP Distribution Graph for Coflex, Standing Before Walking (P34)

Figure A369: IP Distribution Graph for Coflex, Supine After Walking (P34)

Figure A370: IP Distribution Graph for Coflex, Standing After Walking (P34)
Figure A371: IP Distribution Graph for Edemawear, Supine Before Walking (P34)

Figure A372: IP Distribution Graph for Edemawear, Standing Before Walking (P34)

Figure A373: IP Distribution Graph for Edemawear, Supine After Walking (P34)

Figure A374: IP Distribution Graph for Edemawear, Standing After Walking (P34)
Figure A375: IP Distribution Graph for Edemawear, Supine Before Walking (P35)

Figure A376: IP Distribution Graph for Edemawear, Standing Before Walking (P35)

Figure A377: IP Distribution Graph for Edemawear, Supine After Walking (P35)

Figure A378: IP Distribution Graph for Edemawear, Standing After Walking (P35)
Figure A379: IP Distribution Graph for Both, Supine Before Walking (P36)

Figure A380: IP Distribution Graph for Both, Standing Before Walking (P36)

Figure A381: IP Distribution Graph for Both, Supine After Walking (P36)

Figure A382: IP Distribution Graph for Both, Standing After Walking (P36)
Figure A383: IP Distribution Graph for Coflex, Supine Before Walking (P36)

Figure A384: IP Distribution Graph for Coflex, Standing Before Walking (P36)

Figure A385: IP Distribution Graph for Coflex, Supine After Walking (P36)

Figure A386: IP Distribution Graph for Coflex, Standing After Walking (P36)
Figure A387: IP Distribution Graph for Edemawear, Supine Before Walking (P36)

Figure A388: IP Distribution Graph for Edemawear, Standing Before Walking (P36)

Figure A389: IP Distribution Graph for Edemawear, Supine After Walking (P36)

Figure A390: IP Distribution Graph for Edemawear, Standing After Walking (P36)
Figure A391: IP Distribution Graph for Both, Supine Before Walking (P37)

Figure A392: IP Distribution Graph for Both, Standing Before Walking (P37)

Figure A393: IP Distribution Graph for Both, Supine After Walking (P37)

Figure A394: IP Distribution Graph for Both, Standing After Walking (P37)
Figure A395: IP Distribution Graph for Coflex, Supine Before Walking (P37)

Figure A396: IP Distribution Graph for Coflex, Standing Before Walking (P37)

Figure A397: IP Distribution Graph for Coflex, Supine After Walking (P37)

Figure A398: IP Distribution Graph for Coflex, Standing After Walking (P37)
Figure A399: IP Distribution Graph for Edemawear, Supine Before Walking (P37)

Figure A400: IP Distribution Graph for Edemawear, Standing Before Walking (P37)

Figure A401: IP Distribution Graph for Edemawear, Supine After Walking (P37)

Figure A402: IP Distribution Graph for Edemawear, Standing After Walking (P37)
Figure A403: IP Distribution Graph for Both, Supine Before Walking (P38)

Figure A404: IP Distribution Graph for Both, Standing Before Walking (P38)

Figure A405: IP Distribution Graph for Both, Supine After Walking (P38)

Figure A406: IP Distribution Graph for Both, Standing After Walking (P38)
Figure A407: IP Distribution Graph for Coflex, Supine Before Walking (P38)

Figure A408: IP Distribution Graph for Coflex, Standing Before Walking (P38)

Figure A409: IP Distribution Graph for Coflex, Supine After Walking (P38)

Figure A410: IP Distribution Graph for Coflex, Standing After Walking (P38)
Figure A411: IP Distribution Graph for Edemawear, Supine Before Walking (P38)

Figure A412: IP Distribution Graph for Edemawear, Standing Before Walking (P38)

Figure A413: IP Distribution Graph for Edemawear, Supine After Walking (P38)

Figure A414: IP Distribution Graph for Edemawear, Standing After Walking (P38)
Figure A403: IP Distribution Graph for Both, Supine Before Walking (P38)

Figure A404: IP Distribution Graph for Both, Standing Before Walking (P38)

Figure A405: IP Distribution Graph for Both, Supine After Walking (P38)

Figure A406: IP Distribution Graph for Both, Standing After Walking (P38)
Figure A407: IP Distribution Graph for Coflex, Supine Before Walking (P38)

Figure A408: IP Distribution Graph for Coflex, Standing Before Walking (P38)

Figure A409: IP Distribution Graph for Coflex, Supine After Walking (P38)

Figure A410: IP Distribution Graph for Coflex, Standing After Walking (P38)
Figure A411: IP Distribution Graph for Edemawear, Supine Before Walking (P38)

Figure A412: IP Distribution Graph for Edemawear, Standing Before Walking (P38)

Figure A413: IP Distribution Graph for Edemawear, Supine After Walking (P38)

Figure A414: IP Distribution Graph for Edemawear, Standing After Walking (P38)
Figure A415: IP Distribution Graph for Both, Supine Before Walking (P39)

Figure A416: IP Distribution Graph for Both, Standing Before Walking (P39)

Figure A417: IP Distribution Graph for Both, Supine After Walking (P39)

Figure A418: IP Distribution Graph for Both, Standing After Walking (P39)
Figure A419: IP Distribution Graph for Coflex, Supine Before Walking (P39)

Figure A420: IP Distribution Graph for Coflex, Standing Before Walking (P39)

Figure A421: IP Distribution Graph for Coflex, Supine After Walking (P39)

Figure A422: IP Distribution Graph for Coflex, Standing After Walking (P39)
Figure A423: IP Distribution Graph for Edemawear, Supine Before Walking (P39)

Figure A424: IP Distribution Graph for Edemawear, Standing Before Walking (P39)

Figure A425: IP Distribution Graph for Edemawear, Supine After Walking (P39)

Figure A426: IP Distribution Graph for Edemawear, Standing After Walking (P39)
Figure A427: IP Distribution Graph for Both, Supine Before Walking (P40)

Figure A428: IP Distribution Graph for Both, Standing Before Walking (P40)

Figure A429: IP Distribution Graph for Both, Supine After Walking (P39)

Figure A430: IP Distribution Graph for Both, Standing After Walking (P40)
Figure A431: IP Distribution Graph for Edemawear, Supine Before Walking (P40)

Figure A432: IP Distribution Graph for Edemawear, Standing Before Walking (P40)

Figure A433: IP Distribution Graph for Edemawear, Supine After Walking (P40)

Figure A434: IP Distribution Graph for Edemawear, Standing After Walking (P40)
Appendix B

Figure B1: Agile Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 0.5 PSI)

Figure B2: Agile Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 0.5 PSI)
Figure B3: Agile Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 1.0 PSI)

Figure B4: Agile Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 1.0 PSI)
Figure B5: Agile Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 2.0 PSI)

Figure B6: Agile Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 2.0 PSI)
Figure B7: Agile Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 3.0 PSI)

Figure B8: Agile Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 3.0 PSI)
Figure B9: Agile Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 0.5 PSI)

Figure B10: Agile Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 0.5 PSI)
Figure B11: Agile Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 1.0 PSI)

Figure B12: Agile Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 1.0 PSI)
Figure B13: Agile Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 2.0 PSI)

Figure B14: Agile Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 2.0 PSI)
Figure B15: Agile Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 3.0 PSI)

Figure B16: Agile Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 3.0 PSI)
Figure B17: Tritec Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 0.5 PSI)

Figure B18: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 0.5 PSI)
Figure B19: Tritec Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 1.0 PSI)

Figure B20: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 1.0 PSI)
Figure B21: Tritec Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 2.0 PSI)

Figure B22: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 2.0 PSI)
Figure B23: Tritec Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 3.0 PSI)

Figure B24: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 3.0 PSI)
Figure B25: Tritec Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 0.5 PSI)

Figure B26: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 0.5 PSI)
Figure B27: Tritec Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 1.0 PSI)

Figure B28: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 1.0 PSI)
Figure B29: Tritec Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 2.0 PSI)

Figure B30: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 2.0 PSI)
Figure B31: Tritec Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 3.0 PSI)

Figure B32: Tritec Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 3.0 PSI)
Figure B33: Ultra Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 0.5 PSI)

Figure B34: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 0.5 PSI)
Figure B35: Ultra Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 1.0 PSI)

Figure B36: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 1.0 PSI)
Figure B37: Ultra Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 2.0 PSI)

Figure B38: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 2.0 PSI)
Figure B39: Ultra Benchtop Testing Pressure Map (Depth = 1 mm, Applied P = 3.0 PSI)

Figure B40: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 1 mm, Applied P = 3.0 PSI)
Figure B41: Ultra Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 0.5 PSI)

Figure B42: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 0.5 PSI)
Figure B43: Ultra Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 1.0 PSI)

Figure B44: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 1.0 PSI)
Figure B45: Ultra Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 2.0 PSI)

Figure B46: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 2.0 PSI)
Figure B47: Ultra Benchtop Testing Pressure Map (Depth = 2 mm, Applied P = 3.0 PSI)

Figure B48: Ultra Benchtop Average Pressure v. Radius Graph (Depth = 2 mm, Applied P = 3.0 PSI)
Appendix C

%% Load Excel Files
Zero = xlsread("P17_Both_Z_6300_F.xlsx");
P = xlsread("P17_Both_STBW_6300_F.xlsx");
%% Subtract Zero File from Selected Pressure File. Omit first row in original
%% difference (P_dif1) as this row was blank.
P_dif1 = P-Zero;
P_dif2 = P_dif1(2:end,:);
%% Filter out negative values following subtraction of Zero File. All values <=0
%% have been assigned the abbreviation "Nan" and will be excluded in further
calculations.
posMap = P_dif2 >=0;
m1 = P_dif2.*posMap;
m1(~posMap) = nan;
%% Take mean Pressure Values & St Deviations Proximally to Distally. Lines 19 - 370
%% are responsible for constructing the Proximal -> Distal Pressure Distribution Graphs.
c1 = m1(:,1);
col_avgs(1) = mean(c1,"all","omitnan");
col_std(1) = std (c1,0,"all","omitnan");
c2 = m1(:,2);
col_avgs(2) = mean(c2,"all","omitnan");
col_std(2) = std (c2,0,"all","omitnan");
c3 = m1(:,3);
col_avgs(3) = mean(c3,"all","omitnan");
col_std(3) = std (c3,0,"all","omitnan");
c4 = m1(:,4);
col_avgs(4) = mean(c4, "all","omitnan");
col_std(4) = std (c4,0,"all","omitnan");
c5 = m1(:,5);
col_avgs(5) = mean(c5,"all","omitnan");
col_std(5) = std (c5,0,"all","omitnan");
c6 = m1(:,6);
col_avgs(6) = mean(c6,"all","omitnan");
col_std(6) = std (c6,0,"all","omitnan");
c7 = m1(:,7);
col_avgs(7) = mean(c7,"all","omitnan");
col_std(7) = std (c7,0,"all","omitnan");
c8 = m1(:,8);
col_avgs(8) = mean(c8,"all","omitnan");
col_std(8) = std (c8,0,"all","omitnan");
c9 = m1(:,9);
col_avgs(9) = mean(c9,"all","omitnan");
col_std(9) = std (c9,0,"all","omitnan");
c10 = m1(:,10);
col_avgs(10) = mean(c10,"all","omitnan");
col_std(10) = std (c10,0,"all","omitnan");
c11 = m1(:,11);
col_avgs(11) = mean(c11,"all","omitnan");
col_std(11) = std (c11,0,"all","omitnan");
c12 = m1(:,12);
col_avgs(12) = mean(c12,"all","omitnan");
col_std(12) = std (c12,0,"all","omitnan");
c13 = m1(:,13);
col_avgs(13) = mean(c13,"all","omitnan");
col_std(13) = std (c13,0,"all","omitnan");
c14 = m1(:,14);
col_avgs(14) = mean(c14,"all","omitnan");
col_std(14) = std (c14,0,"all","omitnan");
c15 = m1(:,15);
col_avgs(15) = mean(c15,"all","omitnan");
col_std(15) = std (c15,0,"all","omitnan");
c16 = m1(:,16);
col_avgs(16) = mean(c16,"all","omitnan");
col_std(16) = std (c16,0,"all","omitnan");
c17 = m1(:,17);
col_avgs(17) = mean(c17,"all","omitnan");
col_std(17) = std (c17,0,"all","omitnan");
c18 = m1(:,18);
col_avgs(18) = mean(c18,"all","omitnan");
col_std(18) = std (c18,0,"all","omitnan");
c19 = m1(:,19);
col_avgs(19) = mean(c19,"all","omitnan");
col_std(19) = std (c19,0,"all","omitnan");
c20 = m1(:,20);
col_avgs(20) = mean(c20,"all","omitnan");
col_std(20) = std (c20,0,"all","omitnan");
c21 = m1(:,21);
col_avgs(21) = mean(c21,"all","omitnan");
col_std(21) = std (c21,0,"all","omitnan");
c22 = m1(:,22);
col_avgs(22) = mean(c22,"all","omitnan");
col_std(22) = std (c22,0,"all","omitnan");
c23 = m1(:,23);
col_avgs(23) = mean(c23,"all","omitnan");
col_std(23) = std (c23,0,"all","omitnan");
c24 = m1(:,24);
col_avgs(24) = mean(c24,"all","omitnan");
col_std(24) = std (c24,0,"all","omitnan");
c25 = m1(:,25);
col_avgs(25) = mean(c25,"all","omitnan");
col_std(25) = std (c25,0,"all","omitnan");
c26 = m1(:,26);
col_avgs(26) = mean(c26,"all","omitnan");
col_std(26) = std (c26,0,"all","omitnan");
c27 = m1(:,27);
col_avgs(27) = mean(c27,"all","omitnan");
col_std(27) = std (c27,0,"all","omitnan");
c28 = m1(:,28);
col_avgs(28) = mean(c28,"all","omitnan");
col_std(28) = std (c28,0,"all","omitnan");
c29 = m1(:,29);
col_avgs(29) = mean(c29,"all","omitnan");
col_std(29) = std (c29,0,"all","omitnan");
c30 = m1(:,30);
col_avgs(30) = mean(c30,"all","omitnan");
col_std(30) = std (c30,0,"all","omitnan");
c31 = m1(:,31);
col_avgs(31) = mean(c31,"all","omitnan");
col_std(31) = std (c31,0,"all","omitnan");
c32 = m1(:,32);
col_avgs(32) = mean(c32,"all","omitnan");
col_std(32) = std (c32,0,"all","omitnan");
c33 = m1(:,33);
col_avgs(33) = mean(c33,"all","omitnan");
col_std(33) = std (c33,0,"all","omitnan");
c34 = m1(:,34);
col_avgs(34) = mean(c34,"all","omitnan");
col_std(34) = std (c34,0,"all","omitnan");
c35 = m1(:,35);
col_avgs(35) = mean(c35,"all","omitnan");
col_std(35) = std (c35,0,"all","omitnan");
c36 = m1(:,36);
col_avgs(36) = mean(c36,"all","omitnan");
col_std(36) = std (c36,0,"all","omitnan");
c37 = m1(:,37);
col_avgs(37) = mean(c37,"all","omitnan");
col_std(37) = std (c37,0,"all","omitnan");
c38 = m1(:,38);
col_avgs(38) = mean(c38,"all","omitnan");
col_std(38) = std (c38,0,"all","omitnan");
c39 = m1(:,39);
col_avgs(39) = mean(c39,"all","omitnan");
c40 = m1(:,40);
col_avgs(40) = mean(c40,"all","omitnan");
col_std(40) = std (c40,0,"all","omitnan");
c41 = m1(:,41);
col_avgs(41) = mean(c41,"all","omitnan");
col_std(41) = std (c41,0,"all","omitnan");
c42 = m1(:,42);
col_avgs(42) = mean(c42,"all","omitnan");
col_std(42) = std (c42,0,"all","omitnan");
c43 = m1(:,43);
col_avgs(43) = mean(c43,"all","omitnan");
col_std(43) = std (c43,0,"all","omitnan");
c44 = m1(:,44);
col_avgs(44) = mean(c44,"all","omitnan");
col_std(44) = std (c44,0,"all","omitnan");
c45 = m1(:,45);
col_avgs(45) = mean(c45,"all","omitnan");
col_std(45) = std (c45,0,"all","omitnan");
c46 = m1(:,46);
col_avgs(46) = mean(c46,"all","omitnan");
col_std(46) = std (c46,0,"all","omitnan");
c47 = m1(:,47);
col_avgs(47) = mean(c47,"all","omitnan");
col_std(47) = std (c47,0,"all","omitnan");
c48 = m1(:,48);
col_avgs(48) = mean(c48,"all","omitnan");
col_std(48) = std (c48,0,"all","omitnan");
c49 = m1(:,49);
col_avgs(49) = mean(c49,"all","omitnan");
col_std(49) = std (c49,0,"all","omitnan");
c50 = m1(:,50);
col_avgs(50) = mean(c50,"all","omitnan");
col_std(50) = std (c50,0,"all","omitnan");
c51 = m1(:,51);
col_avgs(51) = mean(c51,"all","omitnan");
col_std(51) = std (c51,0,"all","omitnan");
c52 = m1(:,52);
col_avgs(52) = mean(c52,"all","omitnan");
col_std(52) = std (c52,0,"all","omitnan");

%% Exclude columns with 22 or more cells that meet the below condition
%% Condition: (cell value <= 0 ).

c1_zero_count = (sum(c1(:)==0));
c1_nan_count = sum(isnan(c1));
col_count(1) = c1_nan_count + c1_zero_count;
c2_zero_count = (sum(c2(:)==0));
c2_nan_count = sum(isnan(c2));
col_count(2) = c2_nan_count + c2_zero_count;
c3_zero_count = (sum(c3(:)==0));
c3_nan_count = sum(isnan(c3));
col_count(3) = c3_nan_count + c3_zero_count;
c4_zero_count = (sum(c4(:)==0));
c4_nan_count = sum(isnan(c4));
col_count(4) = c4_nan_count + c4_zero_count;
c5_zero_count = (sum(c5(:)==0));
c5_nan_count = sum(isnan(c5));
col_count(5) = c5_nan_count + c5_zero_count;
c6_zero_count = (sum(c6(:)==0));
c6_nan_count = sum(isnan(c6));
col_count(6) = c6_nan_count + c6_zero_count;
c7_zero_count = (sum(c7(:)==0));
c7_nan_count = sum(isnan(c7));
col_count(7) = c7_nan_count + c7_zero_count;
c8_zero_count = (sum(c8(:)==0));
c8_nan_count = sum(isnan(c8));
col_count(8) = c8_nan_count + c8_zero_count;
c9_zero_count = (sum(c9(:)==0));
c9_nan_count = sum(isnan(c9));
col_count(9) = c9_nan_count + c9_zero_count;
c10_zero_count = (sum(c10(:)==0));
c10_nan_count = sum(isnan(c10));
col_count(10) = c10_nan_count + c10_zero_count;
c11_zero_count = (sum(c11(:)==0));
c11_nan_count = sum(isnan(c11));
col_count(11) = c11_nan_count + c11_zero_count;
c12_zero_count = (sum(c12(:)==0));
c12_nan_count = sum(isnan(c12));
col_count(12) = c12_nan_count + c12_zero_count;
c13_zero_count = (sum(c13(:)==0));
c13_nan_count = sum(isnan(c13));
col_count(13) = c13_nan_count + c13_zero_count;
c14_zero_count = (sum(c14(:)==0));
c14_nan_count = sum(isnan(c14));
col_count(14) = c14_zero_count + c14_nan_count;
c15_zero_count = (sum(c15(:)==0));
c15_nan_count = sum (isnan(c15));
col_count(15) = c15_nan_count+c15_zero_count;
c16_zero_count=(sum(c16(:)==0));
c16_nan_count = sum (isnan(c16));
col_count(16) = c16_nan_count+c16_zero_count;
c17_zero_count=(sum(c17(:)==0));
c17_nan_count = sum (isnan(c17));
col_count(17) = c17_nan_count+c17_zero_count;
c18_zero_count=(sum(c18(:)==0));
c18_nan_count = sum (isnan(c18));
col_count(18) = c18_nan_count+c18_zero_count;
c19_zero_count=(sum(c19(:)==0));
c19_nan_count = sum (isnan(c19));
col_count(19) = c19_nan_count+c19_zero_count;
c20_zero_count=(sum(c20(:)==0));
c20_nan_count = sum (isnan(c20));
col_count(20) = c20_nan_count+c20_zero_count;
c21_zero_count=(sum(c21(:)==0));
c21_nan_count = sum (isnan(c21));
col_count(21) = c21_nan_count+c21_zero_count;
c22_zero_count=(sum(c22(:)==0));
c22_nan_count = sum (isnan(c22));
col_count(22) = c22_nan_count+c22_zero_count;
c23_zero_count=(sum(c23(:)==0));
c23_nan_count = sum (isnan(c23));
col_count(23) = c23_nan_count+c23_zero_count;
c24_zero_count=(sum(c24(:)==0));
c24_nan_count = sum (isnan(c24));
col_count(24) = c24_nan_count+c24_zero_count;
c25_zero_count=(sum(c25(:)==0));
c25_nan_count = sum (isnan(c25));
col_count(25) = c25_nan_count+c25_zero_count;
c26_zero_count=(sum(c26(:)==0));
c26_nan_count = sum (isnan(c26));
col_count(26) = c26_nan_count+c26_zero_count;
c27_zero_count=(sum(c27(:)==0));
c27_nan_count = sum (isnan(c27));
col_count(27) = c27_nan_count+c27_zero_count;
c28_zero_count=(sum(c28(:)==0));
c28_nan_count = sum (isnan(c28));
col_count(28) = c28_nan_count+c28_zero_count;
c29_zero_count=(sum(c29(:)==0));
c29_nan_count = sum (isnan(c29));
col_count(29) = c29_nan_count+c29_zero_count;
c30_zero_count=(sum(c30(:)==0));
c30_nan_count = sum (isnan(c30));
col_count(30) = c30_nan_count+c30_zero_count;
c31_zero_count=(sum(c31(:)==0));
c31_nan_count = sum (isnan(c31));
col_count(31) = c31_nan_count+c31_zero_count;
c32_zero_count=(sum(c32(:)==0));
c32_nan_count = sum (isnan(c32));
col_count(32) = c32_nan_count+c32_zero_count;
c33_zero_count=(sum(c33(:)==0));
c33_nan_count = sum (isnan(c33));
col_count(33) = c33_nan_count+c33_zero_count;
c34_zero_count=(sum(c34(:)==0));
c34_nan_count = sum (isnan(c34));
col_count(34) = c34_nan_count+c34_zero_count;
c35_zero_count=(sum(c35(:)==0));
c35_nan_count = sum (isnan(c35));
col_count(35) = c35_nan_count+c35_zero_count;
c36_zero_count=(sum(c36(:)==0));
c36_nan_count = sum (isnan(c36));
col_count(36) = c36_nan_count+c36_zero_count;
c37_zero_count=(sum(c37(:)==0));
c37_nan_count = sum (isnan(c37));
col_count(37) = c37_nan_count+c37_zero_count;
c38_zero_count=(sum(c38(:)==0));
c38_nan_count = sum (isnan(c38));
col_count(38) = c38_nan_count+c38_zero_count;
c39_zero_count=(sum(c39(:)==0));
c39_nan_count = sum (isnan(c39));
col_count(39) = c39_nan_count+c39_zero_count;
c40_zero_count=(sum(c40(:)==0));
c40_nan_count = sum (isnan(c40));
col_count(40) = c40_nan_count+c40_zero_count;
c41_zero_count=(sum(c41(:)==0));
c41_nan_count = sum (isnan(c41));
col_count(41) = c41_nan_count+c41_zero_count;
c42_zero_count=(sum(c42(:)==0));
c42_nan_count = sum (isnan(c42));
col_count(42) = c42_nan_count+c42_zero_count;
c43_zero_count=(sum(c43(:)==0));
c43_nan_count = sum (isnan(c43));
col_count(43) = c43_nan_count+c43_zero_count;
c44_zero_count=(sum(c44(:)==0));
c44_nan_count = sum (isnan(c44));
col_count(44) = c44_nan_count+c44_zero_count;
c45_zero_count=(sum(c45(:)==0));
c45_nan_count = sum (isnan(c45));
col_count(45) = c45_nan_count+c45_zero_count;
c46_zero_count=(sum(c46(:)==0));
c46_nan_count = sum (isnan(c46));
col_count(46) = c46_nan_count+c46_zero_count;
c47_zero_count=(sum(c47(:)==0));
c47_nan_count = sum (isnan(c47));
col_count(47) = c47_nan_count+c47_zero_count;
c48_zero_count=(sum(c48(:)==0));
c48_nan_count = sum (isnan(c48));
col_count(48) = c48_nan_count+c48_zero_count;
c49_zero_count=(sum(c49(:)==0));
c49_nan_count = sum (isnan(c49));
col_count(49) = c49_nan_count+c49_zero_count;
c50_zero_count=(sum(c50(:)==0));
c50_nan_count = sum (isnan(c50));
col_count(50) = c50_nan_count+c50_zero_count;
c51_zero_count=(sum(c51(:)==0));
c51_nan_count = sum (isnan(c51));
col_count(51) = c51_nan_count+c51_zero_count;
c52_zero_count=(sum(c52(:)==0));
c52_nan_count = sum (isnan(c52));
col_count(52) = c52_nan_count+c52_zero_count;

%% Create arrays for Proximal -> Distal P avgs and distance across sensor. Exclude all columns with zero + negative count >=22
for x=1:52
    if col_count(x)<=22
        Horizontal_avgs(x)=col_avgs(x);
        positive_std(x) = Horizontal_avgs(x)+col_std(x);
        negative_std(x) = Horizontal_avgs(x)-col_std(x);
    else
        Horizontal_avgs(x)= nan;
        positive_std(x)= nan;
        negative_std(x) = nan;
    end
end

for y=1:52
    zero_count = sum(isnan(Horizontal_avgs(y)));
    if zero_count==1
        Horizontal_distance(y)=nan;
    end
end
else
    Horizontal_distance(y) = ((10.2)+(10.2/51))-(y*(10.2/51));
end
end

Horizontal_avgs_missingremoved = rmmissing(Horizontal_avgs);
Horizontal_distance_missingremoved = rmmissing(Horizontal_distance);
positive_std_PD_missingremoved = rmmissing(positive_std);
negative_std_PD_missingremoved = rmmissing(negative_std);

%% Plot Proximal to Distal Distribution Graph
figure(1)
hold on
grid on
plot(Horizontal_avgs_missingremoved, Horizontal_distance_missingremoved,"-b","LineWidth",1);
plot(negative_std_PD_missingremoved, Horizontal_distance_missingremoved,"-r","LineWidth",1);
plot(positive_std_PD_missingremoved, Horizontal_distance_missingremoved,"-r","LineWidth",1);
hold off
title(['Proximal-
Distal Pressure Distribution'])
xlabel('Pressure [mmHg]
')
xlim([-10 80])
ylabel ('Distance Across Sensor [in]')
ylim([0 11])
legend ('Mean Pressures', '+ / - St. Deviation','Location','best')
set(gcf,'position',[10,10,225,400])

%% Lines 380 - 705 are responsible for constructing the Medial -> Lateral Pressure Distribution Graphs

%% Find first column where mean Pressures were calculated
for z = 1:44
    if col_count(z)>22
        col_find(z) = 0;
    else
        col_find(z)=1;
    end
end

first_col = find(col_find==1,1,"first");
Calculate medial to lateral pressure avgs and st. deviations

\[
\begin{align*}
   & r1 = m1(1, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(1) = \text{mean}(r1, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(1) = \text{std}(r1, \text{"all"}, \text{"omitnan"}); \\
   & r2 = m1(2, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(2) = \text{mean}(r2, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(2) = \text{std}(r2, \text{"all"}, \text{"omitnan"}); \\
   & r3 = m1(3, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(3) = \text{mean}(r3, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(3) = \text{std}(r3, \text{"all"}, \text{"omitnan"}); \\
   & r4 = m1(4, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(4) = \text{mean}(r4, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(4) = \text{std}(r4, \text{"all"}, \text{"omitnan"}); \\
   & r5 = m1(5, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(5) = \text{mean}(r5, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(5) = \text{std}(r5, \text{"all"}, \text{"omitnan"}); \\
   & r6 = m1(6, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(6) = \text{mean}(r6, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(6) = \text{std}(r6, \text{"all"}, \text{"omitnan"}); \\
   & r7 = m1(7, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(7) = \text{mean}(r7, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(7) = \text{std}(r7, \text{"all"}, \text{"omitnan"}); \\
   & r8 = m1(8, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(8) = \text{mean}(r8, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(8) = \text{std}(r8, \text{"all"}, \text{"omitnan"}); \\
   & r9 = m1(9, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(9) = \text{mean}(r9, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(9) = \text{std}(r9, \text{"all"}, \text{"omitnan"}); \\
   & r10 = m1(10, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(10) = \text{mean}(r10, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(10) = \text{std}(r10, \text{"all"}, \text{"omitnan"}); \\
   & r11 = m1(11, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(11) = \text{mean}(r11, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(11) = \text{std}(r11, \text{"all"}, \text{"omitnan"}); \\
   & r12 = m1(12, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(12) = \text{mean}(r12, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(12) = \text{std}(r12, \text{"all"}, \text{"omitnan"}); \\
   & r13 = m1(13, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(13) = \text{mean}(r13, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(13) = \text{std}(r13, \text{"all"}, \text{"omitnan"}); \\
   & r14 = m1(14, \text{first}_\text{col}: \text{end}); \\
   & \text{row}_\text{avgs}(14) = \text{mean}(r14, \text{"all"}, \text{"omitnan"}); \\
   & \text{row}_\text{std}(14) = \text{std}(r14, \text{"all"}, \text{"omitnan"});
\end{align*}
\]
r15 = m1(15,first_col:end);
row_avgs(15) = mean(r15,"all","omitnan");
row_std(15) = std (r15,0,"all","omitnan");
r16 = m1(16,first_col:end);
row_avgs(16) = mean(r16,"all","omitnan");
row_std(16) = std (r16,0,"all","omitnan");
r17 = m1(17,first_col:end);
row_avgs(17) = mean(r17,"all","omitnan");
row_std(17) = std (r17,0,"all","omitnan");
r18 = m1(18,first_col:end);
row_avgs(18) = mean(r18,"all","omitnan");
row_std(18) = std (r18,0,"all","omitnan");
r19 = m1(19,first_col:end);
row_avgs(19) = mean(r19,"all","omitnan");
row_std(19) = std (r19,0,"all","omitnan");
r20 = m1(20,first_col:end);
row_avgs(20) = mean(r20,"all","omitnan");
row_std(20) = std (r20,0,"all","omitnan");
r21 = m1(21,first_col:end);
row_avgs(21) = mean(r21,"all","omitnan");
row_std(21) = std (r21,0,"all","omitnan");
r22 = m1(22,first_col:end);
row_avgs(22) = mean(r22,"all","omitnan");
row_std(22) = std (r22,0,"all","omitnan");
r23 = m1(23,first_col:end);
row_avgs(23) = mean(r23,"all","omitnan");
row_std(23) = std (r23,0,"all","omitnan");
r24 = m1(24,first_col:end);
row_avgs(24) = mean(r24,"all","omitnan");
row_std(24) = std (r24,0,"all","omitnan");
r25 = m1(25,first_col:end);
row_avgs(25) = mean(r25,"all","omitnan");
row_std(25) = std (r25,0,"all","omitnan");
r26 = m1(26,first_col:end);
row_avgs(26) = mean(r26,"all","omitnan");
row_std(26) = std (r26,0,"all","omitnan");
r27 = m1(27,first_col:end);
row_avgs(27) = mean(r27,"all","omitnan");
row_std(27) = std (r27,0,"all","omitnan");
r28 = m1(28,first_col:end);
row_avgs(28) = mean(r28,"all","omitnan");
row_std(28) = std (r28,0,"all","omitnan");
r29 = m1(29,first_col:end);
row_avgs(29) = mean(r29,"all","omitnan");
row_std(29) = std (r29,0,"all","omitnan");
r30 = m1(30,first_col:end);
row_avgs(30) = mean(r30,"all","omitnan");
row_std(30) = std (r30,0,"all","omitnan");
r31 = m1(31,first_col:end);
row_avgs(31) = mean(r31,"all","omitnan");
row_std(31) = std (r31,0,"all","omitnan");
r32 = m1(32,first_col:end);
row_avgs(32) = mean(r32,"all","omitnan");
row_std(32) = std (r32,0,"all","omitnan");
r33 = m1(33,first_col:end);
row_avgs(33) = mean(r33,"all","omitnan");
row_std(33) = std (r33,0,"all","omitnan");
r34 = m1(34,first_col:end);
row_avgs(34) = mean(r34,"all","omitnan");
row_std(34) = std (r34,0,"all","omitnan");
r35 = m1(35,first_col:end);
row_avgs(35) = mean(r35,"all","omitnan");
row_std(35) = std (r35,0,"all","omitnan");
r36 = m1(36,first_col:end);
row_avgs(36) = mean(r36,"all","omitnan");
row_std(36) = std (r36,0,"all","omitnan");
r37 = m1(37,first_col:end);
row_avgs(37) = mean(r37,"all","omitnan");
row_std(37) = std (r37,0,"all","omitnan");
r38 = m1(38,first_col:end);
row_avgs(38) = mean(r38,"all","omitnan");
row_std(38) = std (r38,0,"all","omitnan");
r39 = m1(39,first_col:end);
row_avgs(39) = mean(r39,"all","omitnan");
row_std(39) = std (r39,0,"all","omitnan");
r40 = m1(40,first_col:end);
row_avgs(40) = mean(r40,"all","omitnan");
row_std(40) = std (r40,0,"all","omitnan");
r41 = m1(41,first_col:end);
row_avgs(41) = mean(r41,"all","omitnan");
row_std(41) = std (r41,0,"all","omitnan");
r42 = m1(42,first_col:end);
row_avgs(42) = mean(r42,"all","omitnan");
row_std(42) = std (r42,0,"all","omitnan");
r43 = m1(43,first_col:end);
row_avgs(43) = mean(r43,"all","omitnan");
row_std(43) = std (r43,0,"all","omitnan");
r44 = m1(44,first_col:end);
row_avgs(44) = mean(r44,"all","omitnan");
row_std(44) = std (r44,0,"all","omitnan");

%% Exclude rows in which more than 1/2 the cells in the row meet the below conditions
%% Condition: (cell value =< 0)

r1_zero_count=(sum(r1(:)==0));
r1_nan_count = sum (isnan(r1));
row_count(1) = r1_nan_count+r1_zero_count;
r2_zero_count=(sum(r2(:)==0));
r2_nan_count = sum (isnan(r2));
row_count(2) = r2_nan_count+r2_zero_count;
r3_zero_count=(sum(r3(:)==0));
r3_nan_count = sum (isnan(r3));
row_count(3) = r3_nan_count+r3_zero_count;
r4_zero_count=(sum(r4(:)==0));
r4_nan_count = sum (isnan(r4));
row_count(4) = r4_nan_count+r4_zero_count;
r5_zero_count=(sum(r5(:)==0));
r5_nan_count = sum (isnan(r5));
row_count(5) = r5_nan_count+r5_zero_count;
r6_zero_count=(sum(r6(:)==0));
r6_nan_count = sum (isnan(r6));
row_count(6) = r6_nan_count+r6_zero_count;
r7_zero_count=(sum(r7(:)==0));
r7_nan_count = sum (isnan(r7));
row_count(7) = r7_nan_count+r7_zero_count;
r8_zero_count=(sum(r8(:)==0));
r8_nan_count = sum (isnan(r8));
row_count(8) = r8_nan_count+r8_zero_count;
r9_zero_count=(sum(r9(:)==0));
r9_nan_count = sum (isnan(r9));
row_count(9) = r9_nan_count+r9_zero_count;
r10_zero_count=(sum(r10(:)==0));
r10_nan_count = sum (isnan(r10));
row_count(10) = r10_nan_count+r10_zero_count;
r11_zero_count=(sum(r11(:)==0));
r11_nan_count = sum (isnan(r11));
row_count(11) = r11_nan_count+r11_zero_count;
r12_zero_count=(sum(r12(:)==0));
r12_nan_count = sum (isnan(r12));
row_count(12) = r12_nan_count+r12_zero_count;
r13_zero_count=(sum(r13(:)==0));
r13_nan_count = sum (isnan(r13));
row_count(13) = r13_nan_count + r13_zero_count;
row_count(14) = r14_zero_count + r14_nan_count;
row_count(15) = r15_zero_count + r15_nan_count;
row_count(16) = r16_zero_count + r16_nan_count;
row_count(17) = r17_zero_count + r17_nan_count;
row_count(18) = r18_zero_count + r18_nan_count;
row_count(19) = r19_zero_count + r19_nan_count;
row_count(20) = r20_zero_count + r20_nan_count;
row_count(21) = r21_zero_count + r21_nan_count;
row_count(22) = r22_zero_count + r22_nan_count;
row_count(23) = r23_zero_count + r23_nan_count;
row_count(24) = r24_zero_count + r24_nan_count;
row_count(25) = r25_zero_count + r25_nan_count;
row_count(26) = r26_zero_count + r26_nan_count;
row_count(27) = r27_zero_count + r27_nan_count;
row_count(28) = r28_zero_count + r28_nan_count;
r28_nan_count = sum (isnan(r28));
row_count(28) = r28_nan_count+r28_zero_count;

r29_zero_count = sum (r29(:)==0);

r29_nan_count = sum (isnan(r29));
row_count(29) = r29_nan_count+r29_zero_count;

r30_zero_count = sum (r30(:)==0);

r30_nan_count = sum (isnan(r30));
row_count(30) = r30_nan_count+r30_zero_count;

r31_zero_count = sum (r31(:)==0);

r31_nan_count = sum (isnan(r31));
row_count(31) = r31_nan_count+r31_zero_count;

r32_zero_count = sum (r32(:)==0);

r32_nan_count = sum (isnan(r32));
row_count(32) = r32_nan_count+r32_zero_count;

r33_zero_count = sum (r33(:)==0);

r33_nan_count = sum (isnan(r33));
row_count(33) = r33_nan_count+r33_zero_count;

r34_zero_count = sum (r34(:)==0);

r34_nan_count = sum (isnan(r34));
row_count(34) = r34_nan_count+r34_zero_count;

r35_zero_count = sum (r35(:)==0);

r35_nan_count = sum (isnan(r35));
row_count(35) = r35_nan_count+r35_zero_count;

r36_zero_count = sum (r36(:)==0);

r36_nan_count = sum (isnan(r36));
row_count(36) = r36_nan_count+r36_zero_count;

r37_zero_count = sum (r37(:)==0);

r37_nan_count = sum (isnan(r37));
row_count(37) = r37_nan_count+r37_zero_count;

r38_zero_count = sum (r38(:)==0);

r38_nan_count = sum (isnan(r38));
row_count(38) = r38_nan_count+r38_zero_count;

r39_zero_count = sum (r39(:)==0);

r39_nan_count = sum (isnan(r39));
row_count(39) = r39_nan_count+r39_zero_count;

r40_zero_count = sum (r40(:)==0);

r40_nan_count = sum (isnan(r40));
row_count(40) = r40_nan_count+r40_zero_count;

r41_zero_count = sum (r41(:)==0);

r41_nan_count = sum (isnan(r41));
row_count(41) = r41_nan_count+r41_zero_count;

r42_zero_count = sum (r42(:)==0);

r42_nan_count = sum (isnan(r42));
row_count(42) = r42_nan_count+r42_zero_count;
r43_zero_count=(sum(r43(:)==0));
r43_nan_count = sum (isnan(r43));
row_count(43) = r43_nan_count+r43_zero_count;
r44_zero_count=(sum(r44(:)==0));
r44_nan_count = sum (isnan(r44));
row_count(44) = r44_nan_count+r44_zero_count;

%%% Create arrays for Medial -> Lateral P avgs, STDs, and
%%% vertical distance across sensor.

for a=1:44
    omit_num=((52-first_col)/2);
    if row_count(a)< omit_num
        Vertical_avgs(a)=row_avgs(a);
        positive_std_ML(a) = Vertical_avgs(a)+row_std(a);
        negative_std_ML(a) = Vertical_avgs(a)-row_std(a);
    else
        Vertical_avgs(a)= nan;
        positive_std_ML(a)= nan;
        negative_std_ML(a) = nan;
    end
end

for b=1:44
    zero_count_ML = sum(isnan(Vertical_avgs(b))); 
    if zero_count_ML==1 
        Vertical_distance(b)=nan; 
    else 
        Vertical_distance(b) = (b*(1.32/43))-(1.32/43); 
    end
end

Vertical_avgs_missingremoved = rmmissing(Vertical_avgs);
Vertical_distance_missingremoved = rmmissing(Vertical_distance);
positive_std_ML_missingremoved = rmmissing(positive_std_ML);
negative_std_ML_missingremoved = rmmissing(negative Std_ML);

%%% Plot Medial to Lateral Distribution graph

figure (2)
hold on
grid on
plot(Vertical_distance_missingremoved, Vertical_avgs_missingremoved, '-b', 'LineWidth', 1);
plot(Vertical_distance_missingremoved, negative_std_ML_missingremoved, '-r', 'LineWidth', 1);
plot(Vertical_distance_missingremoved, positive_std_ML_missingremoved, '-r', 'LineWidth', 1);
title(['Medial -> Lateral Pressure Distribution'])
xlabel('Distance Across Sensor [in]')
xlim([0 1.5])
ylabel('Pressure [mmHg]')
ylim([-10 100])
legend ('Mean Pressures', '+/- St. Deviation', 'Location', 'best')
hold off
set(gcf, 'position', [10, 10, 225, 400])

%% Calculate B1 & C Local Pressure Averages and STDs

B1_start = input('Enter first column of B1:');
B1_end = input('Enter last column of B1:');
C_start = input('Enter first column of C:');
C_end = input('Enter last column of C:');
end_valB1 = (B1_end) - (B1_start) + 1;
end_valC = (C_end) - (C_start) + 1;

B1_firstcol = 53 - B1_end;
B1_lastcol = 53 - B1_start;
C_firstcol = 53 - C_end;
C_lastcol = 53 - C_start;

B1_region = m1(:, B1_firstcol:B1_lastcol);
C_region = m1(:, C_firstcol:C_lastcol);

for e = 1:end_valB1
  for d = 1:44
    if col_count((B1_firstcol - 1) + e) > 22
      B1_avgtable(d, e) = nan;
    elseif row_count(d) > omit_num
      B1_avgtable(d, e) = nan;
    else
      B1_avgtable(d, e) = B1_region(d, e);
    end
  end
end
for f = 1:end_valC
    for g = 1:44
        if col_count((C_firstcol - 1) + f) > 22
            C_avgtable(g,f) = nan;
        elseif row_count(g) > omit_num
            C_avgtable(g,f) = nan;
        else
            C_avgtable(g,f) = C_region(g,f);
        end
    end
end

B1_Avg_P = mean(B1_avgtable,"all","omitnan")
B1_Std = std(B1_avgtable,0,"all","omitnan")
C_Avg_P = mean(C_avgtable,"all","omitnan")
C_Std = std(C_avgtable,0,"all","omitnan")
%% Read excel file
[numData, textData, rawData] = xlsread("ultra_2mm_0.5psi_F.xlsx");

%% Determine the size of the excel file
numRows = size(numData, 1);
numCols = size(numData, 2);

%% Prompt the user for center coordinates
%% Center position determined manually in Excel

centerRowStart = input('Enter the starting row for the center: ');
centerRowEnd = input('Enter the ending row for the center: ');
centerColStart = input('Enter the starting column for the center: ');
centerColEnd = input('Enter the ending column for the center: ');

%% Initialize variables for storing polar coordinates
rCoordinates = zeros(numRows, numCols);
thetaCoordinates = zeros(numRows, numCols);

%% Assign Polar Coordinates to Each Cell
for i = 1:numRows
    for j = 1:numCols
        if i >= centerRowStart && i <= centerRowEnd && j >= centerColStart && j <= centerColEnd
            rCoordinates(i, j) = 0;
            thetaCoordinates(i, j) = 0;
        else
            %% Convert cartesian -> polar
            [theta, r] = cart2pol(((j - centerColStart) * 1.3), ((centerRowEnd - i + 1) * 1.3));
            %% Assign r coordinates
            rCoordinates(i, j) = r;
            %% Assign theta coordinates
            thetaCoordinates(i, j) = theta;
        end
    end
end

%% Calculate the average Pressure for cells with the same R value
uniqueR = rCoordinates(:); % Find unique R values
averageValues = zeros(size(uniqueR));

for k = 1:numel(uniqueR)
    indices = rCoordinates == uniqueR(k);
    averageValues(k) = mean(numData(indices));
end

%%% Calculate the average pressure within the simulated wound bed (r = 0 mm -> r = 10 mm)

averagePressure_0to10 = mean(averageValues(uniqueR >= 0 & uniqueR <= 10));

%%% Calculate the rate of change of pressure at the edge of the wound (from r = 5 mm to r = 15 mm)

slope_start = 5;
slope_end = 15;

slope_indices = uniqueR >= slope_start & uniqueR <= slope_end;
slope_r = uniqueR(slope_indices);
slope_avgValues = averageValues(slope_indices);

%%% Plot P v. R with rate of change at edge of wound shown

p = polyfit(slope_r, slope_avgValues, 1);
slope = p(1);

scatter(uniqueR, averageValues, 'filled');
xlabel('Radius (r) [mm]');
xlim([0, 45]);
ylim([0, 300]);
ylabel('Average Pressure [mmHg]');
title('Radial Pressure Distribution Around a Wound');
grid on;
hold on;
plot(slope_r, polyval(p, slope_r), 'r', 'LineWidth', 2);
slopeText = sprintf('Slope: %.2f mmHg/mm', slope);
text(slope_start + 0.5, polyval(p, slope_start) + 10, slopeText, 'Color', 'r', 'FontSize', 8,'Position',[1,60]); % Display slope value, adjust positioning as needed
%% Print average pressure in wound bed and rate of change at edge of wound in the command window

fprintf('Average Pressure from r = 0 to r = 10 mm: %.2f mmHg\n',
averagePressure_0to10);
fprintf('Linear Slope from r = 5 to r = 15 mm: %.2f mmHg/mm\n', slope);
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