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Comfort and compressional characteristics of padding bandages

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ABSTRACT

Background: Padding bandage is an essential component of the multi-layer compression system used for chronic venous management. Padding plays a critical role in managing pressure over bony prominences and ensuring uniform pressure distribution around the limb circumference. Moreover, it helps in the management of heat, moisture and body fluids or exudates during the course of treatment to provide comfort to the patients.
Objective: To study the effect of structural and constructional parameters on the compressional (pressure absorption or distribution) and comfort (air, moisture and heat transmission) characteristics of the padding.
Methods: This research focuses on the examination of polypropylene based nonwoven padding samples. Critical factors, i.e., fiber linear density, needling density and mass per unit area, have been chosen for this study to find their significance on the performance of padding. Simple laboratory based methods have been proposed to examine pressure reduction and comfort characteristics of the padding.
Results: Pressure absorption by the padding decreases with increase in mass per unit area and needling density of the padding. A padding composed of thicker fiber absorbs more pressure compared to padding made from thinner fiber. On examining comfort, it was found that the air and moisture vapor transmission increase with decrease in mass per unit area and needling density but have opposite effects with fiber linear density ($p < 0.01$). The heat transmission decreases with increase in both mass per unit area and fiber linear density but has opposite effect for needling density.
Conclusion: Padding composed of thick fiber with low mass per unit area and needling density could be more effective in pressure management and ensuring comfort. These results could be very useful for health practitioners, fabric engineers and manufactures to understand the significance of fibrous materials and their role in compression management, and could be further used as design consideration to optimized padding performance.

1. Introduction

Compression therapy is proven to be an effective means for the treatment of venous leg ulceration, venous hypertension, edema and other chronic venous disorders [1,2]. The main objective is to provide external compression to reduce the venous hypertension in the affected area, and also to maintain a uniform pressure gradient in the leg from ankle to knee to improve the venous return to the heart [3]. Pressure can be exerted by several compression modalities including, compression bandage, stockings, pressure garments, etc. The effectiveness of treatment depends primarily on the interface pressure developed between the skin and the compression system [4,5]. It has been found that insufficient or non-sustained levels of compression will be less effective than sufficient and sustained compression. Moreover if the pressure is more than a critical limit then this can lead to tissue damage, even amputation and a reverse gradient compression is likely to impede venous return. The level of pressure exerted on the leg is a function of the tension induced into the compression system and the circumference of the limb as described by Laplace's law [6–8]:

$$P = \frac{T}{R} \tag{1}$$

where P is the interface pressure (N/m^2), T is the longitudinal force per unit length applied (N/m) and R is the radius of the limb. Interface pressure is inversely related to limb circumference and this allows to achieve a pressure gradient by a compression product with high pressure at the ankle and low at the calf provided the force (T) in the fabric structure is constant [9]. However, the cross-section of the leg is not circular due to which the pressure around the circumference could vary significantly. The radius of curvature is small over bony prominences such as tibia or fibula due to which they can experience high pressure (Fig. 1a). This all indicates the need for pressure management where it is aimed to prevent high pressure at critical regions such as the tibia or fibula and to ensure uniform distribution of pressure equally around the circumference at a particular height.

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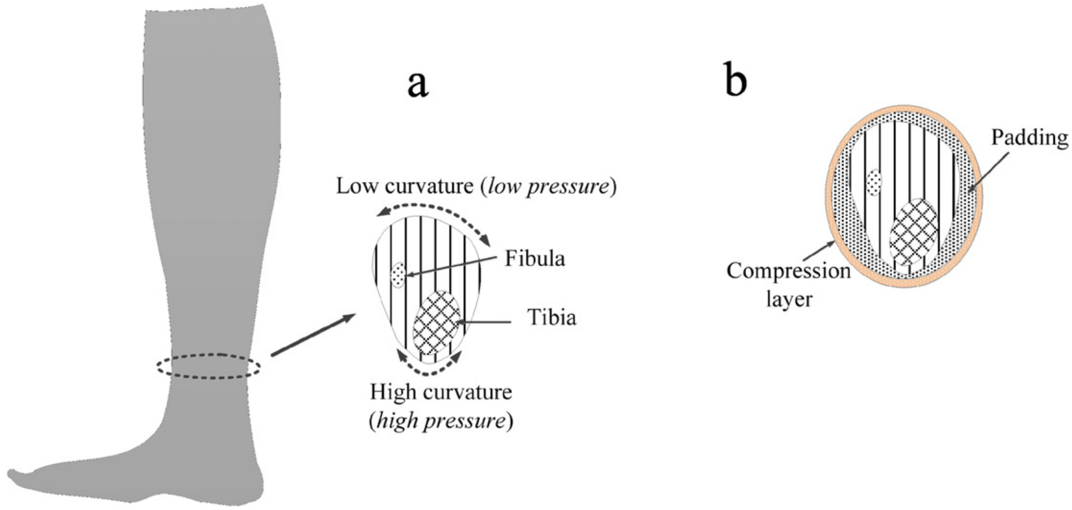

Fig. 1. a) Cross-section of the leg showing high and low curvature around the circumference (this causes *high* and *low* pressure); b) role of padding in reshaping the leg cross-section to obtain same curvature around the circumference to obtain uniform compression.

A variety of bandages are used as padding layer in order to evenly distribute pressure and give protection [10]. Padding bandage is an essential component of the multi-layer compression bandaging system [9–11]. Padding is wrapped underneath the compression bandage and left over the wounded area for a long period of time. In order to distribute pressure evenly around the limb it is essential that high pressures created at the tibia and fibula regions are absorbed by the padding material. Padding can also be used to reshape legs (Fig. 1b) which are not narrower at the ankle than the calf. It helps to reshape the limb more like a cone-shape so that the pressure gradient can be achieved with more pressure at the ankle and less at the calf.

In addition to pressure management by padding, the other concern is to maintain good heat and moisture management to ensure better comfort and compliance for the patient during the course of compression treatment. The compression is continuously provided for an extended period with minimum dressing change. Body fluids and exudates are continuously released from the affected limb, and this may cause irritation and discomfort to the patients if not taken care properly. Moreover, the excessive moisture build-up may lead to over-hydration and even maceration of the underlying tissues [12]. At this moment, the role of fibrous structure is very important as it helps in distributing these fluids to wider areas for faster evaporation. The surplus heat produced due to muscular activity should be discharged into the surrounding to facilitate wound healing. Padding is in direct contact with the underneath skin and therefore, its role is critical in moisture and heat management. Several properties of padding including air permeability, moisture and thermal transmission, wicking, etc., are important to finally ensure better comfort of the compression product.

Fauland et al. assessed moisture management performance of many commercially available multilayer compression systems [13]. They studied the performance of overall textile assemblies and did not examine the role of each layer. The performance properties of each layer differ from other layers. It is therefore important to fully understand the structure–property relationship of each individual layer separately to gain more insight into the development of ideal product. Rajendran and Anand have studied the absorption and pressure distribution properties of several commercial paddings [14]. They also tested several paddings produced using various fibers (PET, Polyolefin, Viscose, Lyocell, cotton, etc.) and fiber blends. The main focus was on examining different fiber performances. Limited attention was given on the structural details such as needling density, gram per square meter, and fiber denier. The effect of fabric construction is equally critical and should be examined in detail.

The material and construction significantly affect the positive outcomes of any fibrous structure used in compression treatment [4]. In general, padding bandage is a nonwoven structure (a fabric-like material made from long fibers, bonded together by chemical, mechanical, heat or solvent treatment) usually made from needle-punching or thermal bonding process [10,15]. It may consist of single component fibers (polyester, polypropylene, viscose or cotton) or blend of fibers (polyester/viscose, polyolefin/viscose or polyester/cotton) in the structure. Most of the available commercial padding bandages are developed using needle punched technology. Needle punching is a part of the nonwoven making process by which the fibers are reoriented and entangled by the action of barbed needles [16]. Testing of commercial bandages can help in evaluating their end performances. However, it is difficult to understand the role of an individual factor by examining different commercial padding bandages as they significantly vary in their material and structure, and therefore several factors can interfere in deciding the overall performance which would make it difficult to analyze the importance of critical factors.

The other concern is the evaluating techniques of the padding. Measurement of pressure variation by padding on the leg is a difficult task due to unavoidable variation in application techniques and varying limb movement. Moreover, the location of pressure sensor at the critical sites especially over bony prominence is highly unstable that may cause unnecessary noise or experimental error. The above facts indicate the need for a simple or easy method to obtain pressure absorption ability of padding. Padding is applied beneath the compression bandage. The normal pressure applied by the compression bandage is absorbed and distributed within the structure of the padding bandage. Some amount of pressure is dissipated in the structure, and the rest is transmitted through the thickness of the padding bandage to exert final absolute pressure on the patient's leg. This pressure loss is attributed to significant changes in the structure of the padding during compression that results in its permanent thickness reduction, and significant energy absorbed. This absorbed energy by the padding during compressive load could be a good indicator of the pressure loss or absorption during the use of padding beneath compression bandage. Recently, Chemani and Halfaoui have also proposed a similar test method of load transference through the thickness of fibrous material to obtain pressure distribution characteristics [17]. In general, compression-recovery tests under transverse loading have been used by researchers over decades to obtain the energy absorbed by textile structures [18]. This can be useful in assessing pressure loss by the padding without doing in-vivo measurement. For comfort evaluation, several measurement techniques