Analysis and Prediction of Compression Bandages Tension

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Analysis and prediction of compression bandages tension

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Abstract:

Three types of woven compression bandages are evaluated. Uniaxial stresses of the input yarns and the produced bandage will be tested. This work presents a new method to predict optimum applied tension by calculating compression bandage porosity using spectrometer. The obtained results will be compared with theoretical compression forces calculated by a modified Laplace's law equation which predicts graduated compression ranging from 18–61 mmHg at the ankle, tapering to 10–19 mmHg below the knee. Results confirm that theoretical pressure is not exactly consistent with practical compression. New multi weft weaving techniques in combination with antimicrobial treated weft threads will be produced.

Keywords: *Bandage structures, tension, porosity, Laplace's law, PicoPress.*

1 INTRODUCTION

Medical compression bandages are widely used in the treatment of venous leg ulcers. In order to design effective compression bandages, researchers have attempted to describe the interface pressure applied by these bandages using mathematical models [1].

Venous ulceration is the most common type of leg ulceration and a significant health problem, affecting approximately 1% of the population and 3% of people over 80 years of age in westernized countries [2]. Systematic reviews and meta-analyses have identified good quality evidence from randomized controlled trials (RCTs) to support the use of advanced or antimicrobial dressings (such as iodine, honey or silver dressings) for chronic wounds [3].

In clinical practice, bandages are applied in the form of overlapping layers which results in multiple layers of fabric that overlay a particular point of the surface of the limb [4]. For example, Medical Compression Bandages (MCBs) applied with spiral 50% overlap technique will overlay the leg with two layers of bandage, MCBs applied with 33% overlap will result in three layers of bandage and MCBs applied with the figure-of-eight technique with 50% overlap will result in four layers of bandage [4].

Hence it was necessary to evaluate the structure of three basic types of woven compression bandages showing the material, production as well as deformation viewpoint during the uniaxial stress. Then introduce a new method to predict suitable compression bandage tension by measuring the bandage porosity using spectrometer. The obtained results are compared with theoretical compression forces calculated by a modified Laplace's law equation as follows [5-7]:

$$Pressure\ (Pascal) = \frac{Tension\ (N) \times No.of\ \ Layers}{Radius\ (m) \times Bandage\ width\ (m)} \qquad (1)$$

2 EXPERIMENTAL WORK

2.1 Materials

a) Three basic types of woven compression bandages (100% Cotton, Viscose-Lycra, and Viscose-Nylon bandages) will be evaluated.

b) For testing the new bandage, double weft fabric structure with repeat Twill 3 and Twill 4 will be produced.

c) Cotton yarns treated with Silver Nano-Particles as one weft yarns, second weft without treatment, and high twist (1600 – 2200 T/m) plied cotton yarns for the warp can be used.

2.2 Testing Procedure

1) Compression bandages tension is evaluated according to test method ISO 13934-1:1999(E). Testometric M350-5CT was used to measure the tension developed in the bandage while extension at a constant speed of 100 mm/min. A 100 N load cell was used to measure the tension in the bandage. The device gauge length was set to 100 mm.

2) Bandage porosity is calculated by measuring the binary area fraction using spectrometer as shown in "Fig. 3 & 4".

3) Bandages pressure will be measured using Pico Press as shown in "Fig. 1" [8]

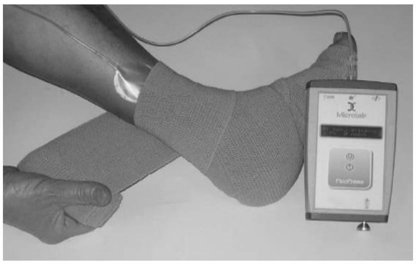


Figure 1 Microlab PicoPress instrument M-700

3 RESULTS AND DISCUSSION

3.1 Load – elongation Curve of the Bandages

Load-elongation curves for both Cotton and Viscose-Lycra bandages were analyzed as shown in "Fig. 2". Bandage samples were subjected to 200% extension of its original length. Both Cotton and Viscose-Lycra bandages required tension of 10 N at 130% extension; these values are achieving the required bandage pressure (4000 Pa or 30 mmHg) according to Laplace's law equation (1) for two layers bandaging at radius 5 cm and bandage width 10 cm. For pressure more than 30 (mmHg): Viscose-Lycra bandages required more extension than Cotton bandages.

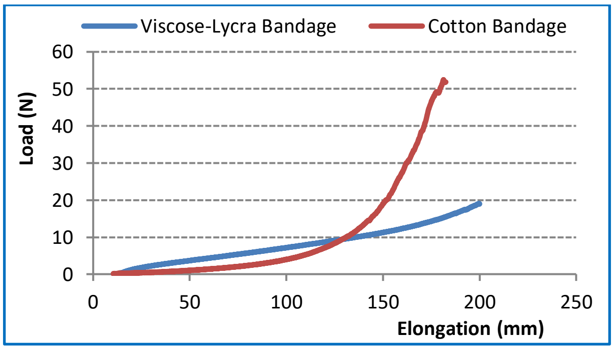
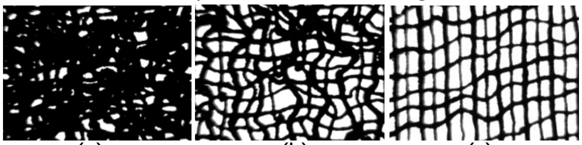


Figure 2 Load–elongation curve of Viscose-Lycra and Cotton bandages

3.2 Effect of Bandage Tension on Binary Area Fraction

While subjecting the bandage samples to constant extension, the resultant images were recorded using Spectrometer as shown in "Fig. 3 & 4". There are 120 frames (images) for each sample; these images were analyzed to measure binary area fraction using Threshold technique as shown in "Fig. 5".



(a) (b) (c)

Figure 3 Binary area of cotton bandage during tension
(a) At 1 sec (b) 60 sec (c) 120 sec

(a) (b) (c)

Figure 4 Binary area of Viscose-Lycra bandage
(a) At 1 sec (b) 60 sec (c) 120 sec

3.3 Relation between Bandage Porosity and Applied Tension.

Binary area fraction represents the bandage porosity (volume of voids among fibers) [9-11].

$$\text{Porosity} = V_P \;/\; V_T \qquad (2)$$

Where: V_P : is the volume of air pores (cm^3),

V_T : is the total volume of the sample (cm^3).

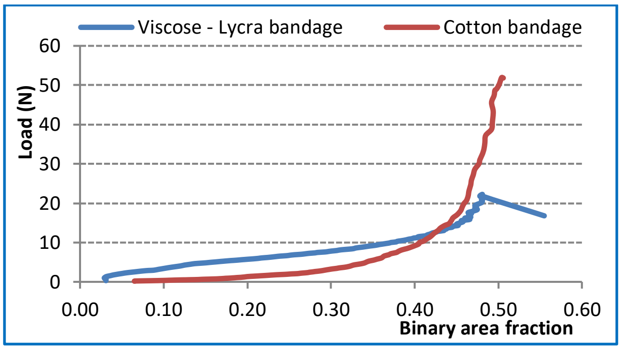


Figure 5 Effect of bandage tension on binary area fraction

3.4 Testing of Bandage Pressure using PicoPress

Experimental pressures of compression bandages (100% Cotton and Viscose-Lycra) are measured using PicoPress on mannequin leg as shown in "Fig.6" and real leg as shown in "Fig. 7 to 9". First type of bandages is 100% cotton using highly twisted plied cotton yarns. There are three levels of bandage tension (low: 50% extension and 50% overlap, medium: 100% extension and 50% overlap, and high: 100% extension and 33% overlap) applied on 1st position (ankle at radius 3.6 cm), 2nd (calf at radius 6.2 cm), and 3rd (below knee at radius 4.9 cm). Average compression at 1st position was about (16, 29, 50 mmHg) decreasing by a percent 11% after 180 s, whereas for 2nd position was (24, 37, 59 mmHg) decreasing by a percent 12%. This decrease may be due to bandage slippage and less fixation.

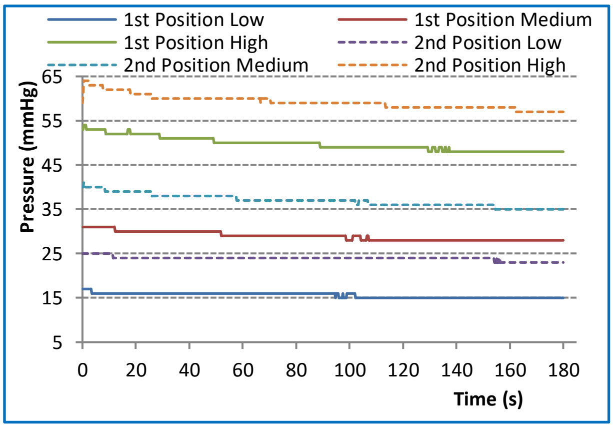


Figure 6 Pressure of Cotton bandage on leg model

As for applying compression bandages on a real leg; "Fig.7" emphasizes the significant change of compression during walking; that is oscillating between (8-16, 18-27, and 35-51) for 1st position, (18-33, 27-43, and 36-61 mmHg) for 2nd position. These oscillations during walking and running should be considered while wearing the compression bandages for long time to achieve effective healing rates. "Fig. 8" shows the pressure of Rosidal (R) compression bandage while walking; that is ranging (17-23, 22-26, and 27-37) for 1st position, (10-19, 20-35, and 34-50 mmHg) for 2nd position, and (12-15, 13-18, and 13-19 mmHg) for 3rd position. Oscillating ranges of (R) bandage are less than for high twist cotton bandage because of more extensibility.

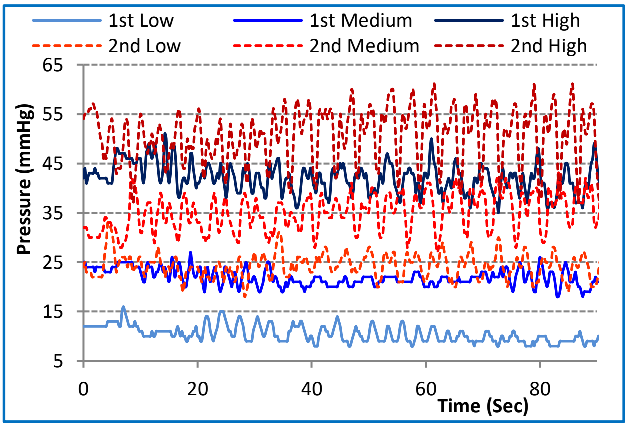


Figure 7 Pressure of Cotton bandage on real leg while walking.

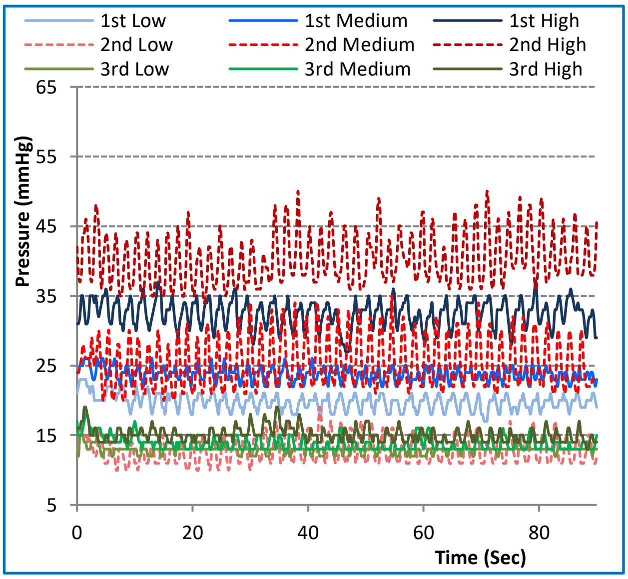


Figure 8 Pressure of (R) Cotton bandage on real leg while walking.

While Viscose-Lycra compression bandage introduced less oscillating pressure range i.e. (12 - 16, 17 - 22, and 32 - 45) for 1st position and (14 - 19, 26 - 30, and 46 - 56 mmHg) for 2nd position. This lowest range of pressure is due to Lycra extensibility.

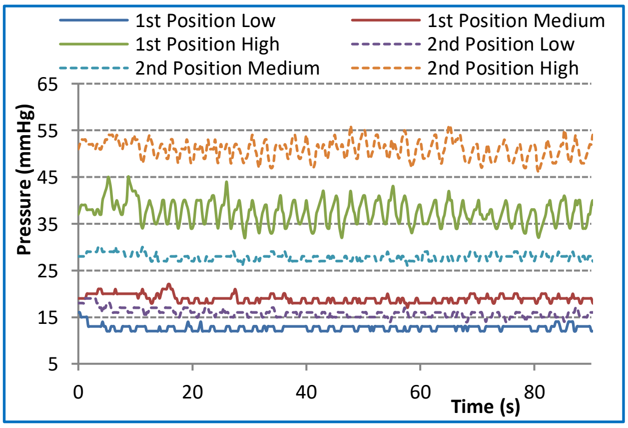


Figure 9 Pressure of Viscose-Lycra bandage on real leg while walking.

3.5 New Proposed Bandage Structure

Double weft fabric structure with repeat Twill 3 and Twill 4 will be produced (by using such repeat, it is possible to obtain a good position of weft from both sides of the woven bandage face and back) as shown in "Fig. 10 & 11".

Cotton yarns treated with Silver Nano-Particles are used as one weft yarns in contact with patient body, second weft without treatment, and high twist (1600 – 2200 T/m) plied cotton yarns for the warp can be used. The proposed structure enables patients to overcome Venus leg ulcers and achieves better healing rates.

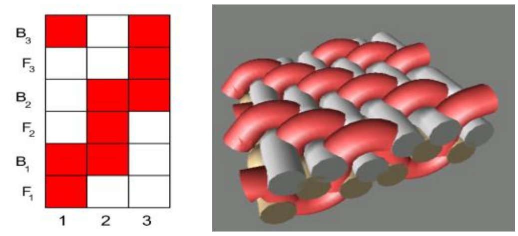


Figure 10 Double weft fabric structure based on Twill weave 1/2

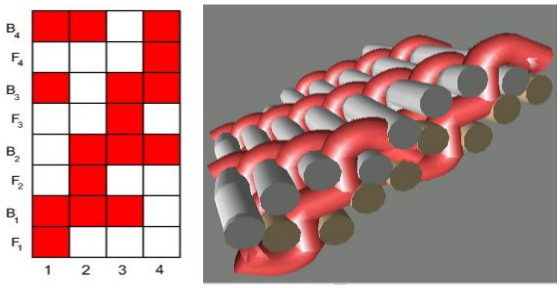


Figure 10 Double weft fabric structure based on Twill weave 1/3

4 CONCLUSION

Candidate work presented a new method to predict bandage tension as a function of bandage porosity; that enables the patient to use the bandage more easily. The experimental compression results were compared with theoretical pressure calculated by Laplace's equation. Statistical analysis confirmed that there are significant differences between theoretical pressure and practical compression results. 100% Cotton bandages achieved highest pressure range i.e. (8-16, 18-27, and 35-51) for 1st position, (18-33, 27-43, and 36-61 mmHg) for 2nd position.

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