A NOVEL COMPRESSION BANDAGE WITH ENHANCED FUNCTIONALITIES

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ABSTRACT

Among different ways of delivering compression therapy, compression bandages that fall under the group of medical textiles, is currently a rapidly evolving area of interest. However, most bandages experience pressure drops at longer periods due to the viscoelastic nature of the bandage structure and yarns used. To explore these structures and to obtain the optimal results, while keeping the other properties unaltered, five bandage samples that consists of three woven (plain, 2/1 twill, weft rib) and two knitted structures (plain pique, single lacoste) were engineered, where the same yarn types were used. Three important aspects, namely the structural effect on pressure drop, skin friendly antimicrobial finish and wearing comfort or hand feel were examined. The weft rib woven structure resulted a minimum pressure drop of 23% when tested on a static cylindrical limb model having a limb circumference of 23 cm for 12 hours, which was tested using a fixed load of 20 N. Upon further validation using the Maxwell-Weichert model, numerically it was proven that the maximum pressure drop even when applied on a spherical surface was 30%. Results indicated that chitosan, which is a biodegradable, biocompatible antimicrobial finish has provided 92.9% effectiveness while other essential properties such as moisture management, abrasion and hand feel remain unaltered. Moreover, the average ratings of 9 and 8 were received from human trials on areas of odour sensation and tactile comfort, which suggests that the woven weft rib structure with its finishes contains the optimal expected properties of a compression bandage.

KEYWORDS: *Compression bandage, Anti-microbial, Weft-rib, Pressure, Core-spun yarn*

1. INTRODUCTION

Compression is a medical therapy which is commonly used in the treatment of lymphoedema, venous insufficiency, deep vein thromboses and in boosting athletic performance and recovery (Parkinson et al., 2019). Among the many ways of offering compression therapy, compression bandages play an important role in providing the pressure to the required area or the limb. According to the literature, medical compression bandages are worn by nearly 1% of the population (Franks et al., 2016). The convenient alignment of these bandages around the limbs improves venous flow and lowers venous hypertension, such that the limb recovers its form and shape (Asmiza and Nasir, 2021). According to BS 7505:1995, compression bandages fall in to the category of Type 3 and under this, four classes are available varying as per the level of compression (3A – Light: up to 20 mmHg, 3B – Moderate: 21-30 mmHg, 3C – High : 31-40 mmHg, 3D – Very high : 41-60 mmHg) (Kumar et al., 2014).

A wide variety of compression bandages are available today, each with its own fabric structure, extensibility, yarn type, and advanced properties (Kumar et al., 2014). The most commonly used fabric structures are woven and knitted. Understanding the relationship between the bandage structure and its properties is crucial, as it assists in designing and evaluation of the bandage performance during use (Haririan and Asayesh, 2021).

In a study conducted by Maqsood et al. (2016), stretchable knitted structures exhibited better stretch and recovery, than bi-stretch woven structures. However, it was found that the compression delivered after repeated use had significantly dropped in knitted than woven structures, which implies the better useful life of the latter.

In a review conducted by Milosavljevic and Skundric (2007), the better elasticity and conformability shown by knitted compression bandages have been highlighted over woven cotton crepe bandages. However, they have emphasized that the selection of yarns is of the greatest importance, when reviewing the performance of compression bandages. Moreover, it has been highlighted that the strength of the bandage may be subtly managed by the choice of suitable yarns (Milosavljevic and Skundric, 2007).

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The most common combinations of yarns are elastane and cellulosic fibres, where core spun yarns have been used to impart thermoregulation, air permeability, pressure balance and comfort (Kumar et al., 2014). According to Oğlakcioğlu et al. (2016), though there are disadvantages such as allergenicity to skin and poor moisture management in elastane yarns, the mechanical properties and excellent stretch and recovery properties have encouraged its use in compression bandages. Thus, the researchers propose to cover elastane using cellulosic fibres to impart soft touch, anti-allergic effects, while improving thermal and moisture management properties (Maqsood et al., 2016; Maqsood et al., 2017; Oglakcioglu et al., 2016; Athirah Nabilah Asmiza and Hana Nasir, 2021).

With the rapid advancements in modern technology, researchers are focusing on developing compression bandages with improved functional properties. Since these bandages often contact with skin and moisture including sweat, the tendency for microbial growth is extremely high. Thus, use of an anti-microbial treatment is of great importance. When comparing different anti-microbial agents used in textiles, Bobbarala and Naiduin (2012) explain Chitosan as the safest, bio-degradable, and most effective anti-microbial agent. Moreover, El-tahlawy et al. (2005) highlight Chitosan as a cost-effective solution, to be effectively used in cotton-based fabrics, which are more prone to microbial growth.

According to Rabe et al. (2020), many patients have experienced itching and skin dryness when using compression bandages. Thus, the requirement of a novel compression bandage with improved properties has become a timely need. Though researchers have developed different bandages with different optimized properties, the enhancement of both the mechanical and comfort properties, remain an area to be investigated further. Hence, this research focuses on investigating different bandage constructions and finishing methods, to produce a novel compression bandage with improved pressure balance, comfort properties and anti-microbial effect.

2. METHODOLOGY

2.1. Compression bandage preparation

In this study, three woven and two knitted compression bandage structures were made using Spandex/Cotton single covered yarn of 84 Tex and ring spun Polyester yarn of 39 Tex. Three woven structures were Plain weave, Twill weave and Weft rib weave, while the two knitted structures were Plain Pique and Single Lacoste. The yarn selection and fabric structure selection were based on an extensive literature review on existing compression bandages, and on feedback from industry experts. As shown in Table 1, the main criterion the authors have focused on is the pressure drop in arriving at suitable yarn types, yarn counts and fabric constructions. Moreover, in the selected covered yarn, cotton ensures comfort through effective moisture management, tactile comfort, and thermal comfort. Spandex provides the necessary stretch and recovery properties, while maintaining the appropriate pressure range along the bandage. Furthermore, Polyester imparts strength and additional comfort properties, owing to its ring-spun nature.

The woven structures were prepared using the Rapier Loom YTB 4/80, and Spandex/Cotton single covered yarns were used as warp and ring spun Polyester yarns as weft. The knitted structures were prepared using Shima-Seiki Flatbed knitting machine N.SSR112 of gauge 12. Two feeders were used to feed the given two yarns (Spandex/Cotton single covered and Ring spun Polyester). Other design parameters are indicated in Table 2. The bandages were characterized by thickness, mass per unit area (areal density), thread density, and extensibility. The thickness of the bandages was measured as per the standard ASTM D1777-96, using Essdiel Thickness Tester at a pressure of 1960 Pa with an accuracy of 0.01 mm. Thread densities of woven and knitted samples were determined using the counting glass according to ASTM D3775-03, and ASTM D8007-15 respectively, while the mass per unit area was obtained as per ASTM D3776. In each of these tests an average of 10 readings were obtained for each sample, and test specimens were taken at randomly distributed places across the length of the bandages (Haririan and Asayesh, 2021).

The elongation of a bandage under a weight of 10 N/cm is defined as its extensibility (Kumar et al., 2014). Thus, extensibility of the bandages was calculated from load-elongation curve obtained from tensile test according to BS 7505 (1995). The tensile test was performed using an Instron® universal tester at a speed of 200 mm/min. The gauge length was maintained at 200 mm while the width of the specimen was 80 mm. Based on the extensibility obtained from load-elongation curve, the developed bandages were classified as short stretch (SS), medium stretch (MS), and long stretch (LS).

2.2. Pressure drop evaluation

The interface pressure was measured up to 12 hours at intervals of 3-hour time periods. The pressure values were recorded using a digital pressure sensor array and Arduino UNO. The mandrel with a load of 20N shown in Figure 1 was used to mimic a fixed limb of circumference 23 cm according to the BS 7505:1995 standard (Kumar et al., 2014).

Table 1: Design parameters of compression bandages in literature

Yarn type	Yarn count (Tex)	Fabric construction	Pressure drop (%)	Reference
Cotton Spandex single covered yarn	36.9	Plain woven	21.1% after 2h	(Bipin Kumar, Das and Alagirusamy, 2014)
100% Cotton	36.2	Plain woven	32.7% after 2h	(Bipin Kumar, Das and Alagirusamy, 2014)
Elastomeric core spun yarn	19.7	Plain Pique	34.4% after 1h	(Maqsood, Nawab, et al., 2016)
95% Cotton and 5% Lycra:	23	Single Lacoste	37.3% after 3h	(Ovi and Shova, 2022)
Elastomeric core spun yarn	20	2/1 Twill	35% after 2h	(Maqsood, Nawab, et al., 2016)
62% cotton and 38% Nylon	35	3/1 Twill	34% after 2h	(Haririan and Asayesh, 2021)
Elastomeric core spun yarn	20	Weft rib	20.4% after 2h	(Maqsood, Nawab, et al., 2016)
PET/ Spandex single covered yarn	34.4	Warp knitted	28.9% after 2h	(B. Kumar, Das and Alagirusamy, 2014)

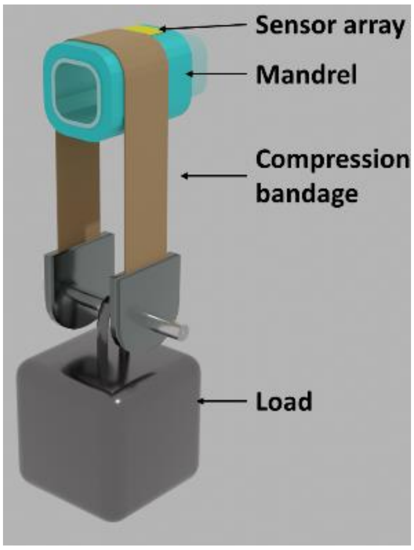


Figure 1: Schematic of pressure drop identification system

The selection of the best compression bandage was proposed based on the minimum pressure drop. Thereafter the correlation between the bandage tension, number of layers, and the radius of curvature was modelled using the Laplace equation as shown in Equation 01.

$$P = Tn / RW \qquad \text{Equation 01}$$

Where, P is the Pressure [Pa], T the Tension [N], n is the number of layers, R is the limb radius [m] and W is the Bandage width [m].

Further validation of the normalized stress relaxation on the selected bandage was determined by a 2x2 factorial experiment, using an Instron bench model tester in compression mode. Square shaped bandage specimens (80 mm X 80 mm) were mounted in circular clamping ring and was extended multi axially by lowering a semi spherical device (diameter of 25 mm and 50 mm) mounted to the machine. The spherical surface was pressed perpendicularly on the sample at a cross section speed of 200 mm per minute to obtain a 20% extension.

The Maxwell-Wiechart mechanical model consisting of springs connected in parallel was used to represent the viscoelastic response to strain over a period of 12 hours, as shown in Equation 02.

$$P(t) = P_0 + P_1 exp\left(-\frac{t}{\tau_1}\right) + P_2 exp\left(-\frac{t}{\tau_2}\right) \qquad \text{Equation 02}$$

where P(t) is the normalized force as a function of time, P_0 is the magnitude of the residual force after t=∞, and P_1 and τ are the constants of the i^{th} term in the function (Ruznan et al., 2021).

2.3. Functional parameter enhancement

To impart an anti-microbial effect to the selected bandage, chitosan-based finish was applied. Chitosan Hydrochloride (Ch-HCl), Butane tetracarboxylic acid (BTCA) and Sodium Hypophosphite (SHP) were purchased from Sigma-Aldrich.

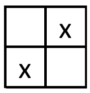
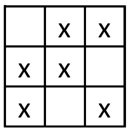
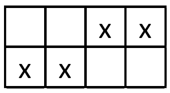
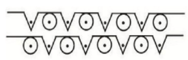
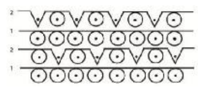
The treatment process which was followed by El-Tahlawy et al. (2005) in a study conducted to impart anti-microbial effect on cotton fabrics, was followed in this study as well. The selected bandage was padded in a solution containing Ch-HCl (0.75% wt), BTCA (10% wt) and SHP (6% wt) such that a wet pick up of 90–95% was achieved. BTCA and SHP acted as the finishing agent and the catalyst respectively. After two dips of treatment, the bandage was dried at 85 ^{0}C for 5 min and cured at 160 ^{0}C for 3 min.

The anti-bacterial effects of the treated and untreated samples were tested with reference to AATCC 100-2019 test method using the micro-organisms *Staphylococcus aureus* and *Klebsiella pneumoniae*. The number of bacteria recovered from the inoculated treated and untreated samples were determined, and the percentage reduction by treated specimen was calculated to arrive at the anti-bacterial efficacy. Details about this test are described by Sathianarayanan et al. (2010).

Other functional properties as air permeability, moisture management and pilling resistance, were also tested in standard test methods. Air permeability of the treated and untreated bandages were tested on SDL ATLAS MO21A Air Permeability Tester according to ASTM D737 with a test head of 20 cm^2 and pressure difference of 100 Pa (Maqsood et al., 2017). Moisture management properties of the treated and untreated samples were tested on SDL ATLAS Moisture Management Tester (MMS) as per AATCC 195 (Oglakcioglu et al., 2016). Furthermore, the pilling resistance test was conducted according to ASTM D4970–02.

The end user feedback for the treated bandage was obtained with the help of a skilled practitioner. Five patients with swollen lower limbs (who were seated) were treated with compression therapy delivered from the developed compression bandage. For the bandage application consistency, the same practitioner was facilitated. After 2 hours of compression therapy in static mode, the feedback of the patients was recorded in areas namely, tactile comfort, sensation of pressure, thermal comfort, and odor. The obtained results were analyzed to validate the achievement of intended properties by the developed novel compression bandage.

Table 2: Details of the compression bandages used in the study

Parameters \ Bandage code	A	B	C	D	E
Weave	Woven	Woven	Woven	Knitted	Knitted
Structure	Plain	2/1 twill	Weft rib 1/1	Plain pique	Single Lacoste
Thread notation					

3. RESULTS AND DISCUSSION

3.1. Structural investigation of compression bandage samples

The results obtained upon analyzing the structural properties of the compression bandages are shown in Table 3. In addition, the stitch lengths of the Plain Pique and Single Lacoste structures were measured to be 4.77 mm and 4.80 mm respectively. The thickness values of woven structures are comparatively lower than that of knitted structures, which can be explained through the structural compactness in woven structures. A similar pattern can be observed for GSM values, where the highest is recorded by samples D and E. Even though these samples contain alternate knit and tuck stitches, sample E consists of an additional knitted wale in between, which causes a comparative increment in the stitch length. According to Ovi and Shova (2022), lower stitch lengths cause the GSM to increase. This explains the higher GSM of sample D than E, though both are knitted structures.

Extensibility of the bandage samples studied under application of a constant load showed that knitted samples (wale wise extension) have comparatively a higher value than the woven samples (warp wise extension). As explained by Maqsood et al. (2017), this is due to the less compact structure of knitted structures than woven structures. The sample E showed the highest extensibility owing to the alternative knitted wale that showed prominence in stretch.

Kumar et al. (2014), classified compression bandages as per the extensibility (e) such as SS (e<70%), MS (70%<e<140%), and LS (e>140%). Thus, same classification was used to classify the samples A to E as shown in Table 3.

Table 3: Details of compression bandage samples

Bandage code / Parameters	A	B	C	D	E
Thickness (mm)	0.82	0.92	0.96	1.20	1.14
Mass per unit area (gm^{-2})	278	283	281	302	295
Threads per unit length	18 e/cm 31 p/cm	20 e/cm 31 p/cm	19 e/cm 32 p/cm	24 w/cm 38 c/cm	23 w/cm 37 c/cm
Cover Factor ($\sqrt{Tex}/cm$)	23.9	27.3	26.2	18.6	17.5
Extensibility (%)	82%	85%	87%	136%	143%
Classification	MS	MS	MS	LS	LS

3.2. Comparison of sub bandage pressure for a selected time period

The Laplace equation stated in Equation 01 shows that the sub bandage pressure is directly proportional to the tension applied and the number of layers that it is wrapped. In here, the skill of the practitioner also plays an important role in maintaining appropriate tension while wrapping. Below results are for the optimum tension of 20N and n=2 with a 50% overlapping. The widths of the prepared bandages were 8 cm, and they were modelled onto a limb circumference of 23 cm.

Pressure values were directly captured through a calibrated digital sensor array and the mean pressure was considered. Values which showed an unusual deviation (more than 75%) were removed. Figure 2 depicts the percentage pressure drop across the time interval of 12 hours which has been mapped using the Equation 03.

$$Pressure\ drop\ \% = \frac{P_0 - P_t}{P_t} * 100\% \qquad \text{Equation 03}$$

for t = 3, 6, 9, 12

It was observed that in the initial 3-hour time period, there is a significant pressure drop for all structure types. However, it is clearly visible that the pressure drop for the knitted structures are comparatively higher than the woven structures (Maqsood et al., 2016). Furthermore, the knitted samples show that there can be further reduction in pressure values with time. Upon comparing the three woven structures, the weft rib structure showed a minimum pressure drop percentage of 23% after 12 hours. The three woven structures have higher cover factors than that of the selected knitted structures (Refer Table 3), which has resulted in lower pressure drops as visible in Figure 2. However, as explained by Ovi and Shova (2022), a significant pressure drop can be observed in both instances of tighter (higher cover factor) and looser (lower cover factor) structures. In tighter structures, there is a tendency of contraction in load bearing yarns, resulting pressure drops when used for longer durations. Similarly, in loose structures structural deformations can cause an imbalanced stress localization which results in pressure drops. This explains the higher pressure drops in the Plain weave, Twill weave, Plain Pique, and Single Lacoste in contrast with the Weft rib structure.

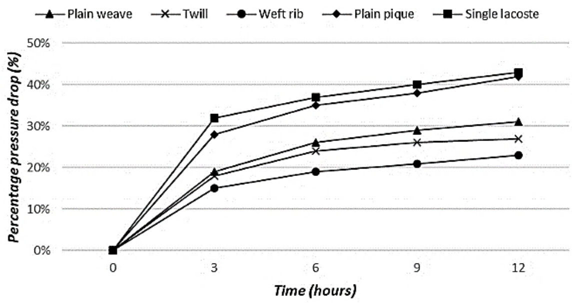


Figure 2: Pressure reduction percentage for different bandage structures

As explained by Parkinson et al. (2019), the correct application of the compression bandage is of greater importance as it could make the condition much worse than the former state. High pressures applied in application of compression bandages could cause inhibition of blood flow, while localized pressure hotspots could impart discomfort to the patient. Thus, the consistency of pressure exerted on the affected area is a crucial requirement. Hence, the fabric structure with the least pressure drop can be selected as the most suitable compression bandage, as they can provide optimum pressure on the affected body area with the time.

In this study, among the five structures analyzed the weft rib structure (Sample C) complies with the above requirement. Figure 3 shows the schematic and the microscopic view of the selected weft rib structure. Henceforth, further analysis was carried out on the selected 'Sample C' structure.

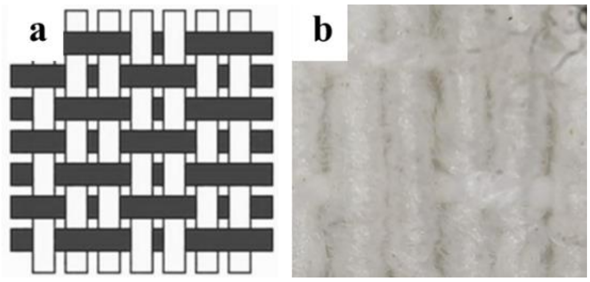


Figure 3: (a) Schematic, (b) Microscopic view of the selected weft rib structure

As provided in Equation 01, the pressure is directly proportional to the tension applied to the bandage. Thus, analyzing the stress relaxation using the Maxwell-Weichert model, an exponential decay can be observed, which confirms the actual percentage pressure drop. Table 4 indicates the estimated values used in the stress-relaxation study using the associated functions with $R^2 > 0.99$ under the two cases provided.

Table 4: Estimates of Maxwell-Weichert Parameters and R^2 for weft rib structure

Sphere Type	P_0	P_1	τ_1	P_2	τ_1	R^2
25 mm probe	0.47	0.43	0.04	0.09	4.45	0.997
50 mm probe	0.44	0.45	0.07	0.06	4.41	0.994

As shown in Figure 4, it is evident that initially within a few hours there is a rapid reduction of internal stress and that the rate gradually reduces with time. Furthermore, it could also be observed that the graph followed the same pattern under both the spherical probes of different diameters. Moreover, the normalized force reduction was found to be 30%-35% due to the stress relaxation. In contrast, the percentage pressure reduction of the weft rib structure was 23% in the analysis conducted under section 3.2, using the mandrel. This deviation can be explained using the difference in the area of application in the tested models. The mandrel focused on a uniform cylindrical limb, whereas the Maxwell model considers spherical locations. Thus, it can be elucidated from the two models, that the maximum percentage drop even on non-uniform areas of application, will be 30%.

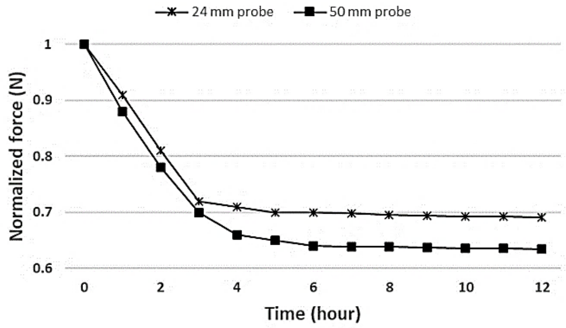


Figure 4: Force-time curve of fabric stress relaxation

3.3. Effect of antimicrobial treatment to the selected compression bandage

Another intended property of the novel bandage was to achieve the anti-microbial effect, to ensure the prolonged use of the compression bandage. The results obtained from AATCC 100 test method for the treated and untreated bandages in 0 and 24 hours of contact period, are shown in Table 5. Excellent reductions of 92.9% and 90.3% could be observed in each of the tested microorganism type. Since the developed bandage contains Spandex covered yarns with Cotton, BTCA acts as the cross-linking agent with the Cotton and Ch-HCl in the presence of SHP as a catalyst (El-Tahlawy et al., 2005). The cross-linked Chitosan then acts as the anti-microbial agent which interacts at the microbial cell surface, leading to the destruction of microbial cell inhibiting its growth. This explains the higher percentage of anti-microbial effect achieved after the treatment.

Table 5: Anti-microbial test results for the treated and untreated samples

Microorganism	*Staphylococcus aureus*	*Klebsiella pneumoniae*
Untreated at 0 hrs (cfu/sample)	3.7×10^4	5.4×10^3
Untreated at 24 hrs (cfu/sample)	1.6×10^8	3.5×10^8
Treated at 0 hrs (cfu/sample)	2.0×10^4	1.1×10^4
Treated at 24 hrs (cfu/sample)	1.4×10^3	1.1×10^3
Percent reduction of Bacteria	92.9%	90.3%

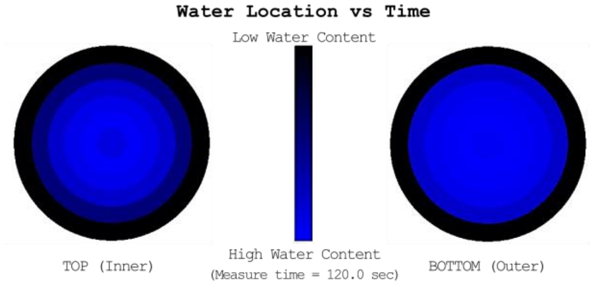
Furthermore, it is clearly visible that there is a significant growth (99.9%) of the microorganisms in the untreated bandage. The presence of a natural fibre such as Cotton makes a favourable space for the microorganisms to grow. Thus, a clear microbial growth in the untreated bandage could be expected, and the results confirm the explanation. Furthermore, in practical use, the microbial growth would be much higher than the tested results, due to the presence of moisture from skin such as sweat, when wearing the untreated compression bandage. Hence, the requirement of the anti-microbial treatment for the novel bandage could be considered as crucial.

3.4. Analysis of other functional parameters

The moisture management and air permeability are closely associated when analyzing the comfort properties of the compression bandage. The air permeability test results for the untreated and treated bandages were obtained as 108.7 $cm^3cm^{-2}s^{-1}$ and 103.5 $cm^3cm^{-2}s^{-1}$ respectively. Since Kumar et al. (2014) suggest the suitable air permeability range as 100-110 $cm^3cm^{-2}s^{-1}$, the obtained results can be concluded as satisfactory and within the acceptable region. It is important to note that the drop in air permeability due to the finishing treatment is insignificant (nearly 4%).

The moisture management test result of the treated bandage is shown in Figure 5, which depicts the entire dynamic behaviour of sweat in the compression bandage. The wetting time is indicated as less than 2 seconds in both the bandages, where the absorption rate is 38.98% and 42.09% per second, for top and bottom surfaces respectively. Since Oğlakcioğlu et al. (2016) states that the acceptable absorption rate to yield a comfortable feeling as above 30%/sec, it can be concluded that the treated bandage is giving the required comfort sensation to the wearer. Furthermore, proper moisture/ sweat handling by the bandage would significantly reduce the frequency of dressings, hence, the cost of patient treatment. Moreover, it is important to note that the percentage difference of absorption rate between the treated and untreated bandages are nearly 3.21% which is acceptable.

Compression bandages are subjected to frequent dressings. Furthermore, bandage-skin and bandage-bandage contact points are the most prominent during repeated use of these compression bandages. Thus, the analysis of pilling resistance is of utmost importance. The pilling results for the treated and untreated bandages were observed as 4. These results are interesting, because it has shown almost no change in pilling resistance of the bandage after the application of the anti-microbial treatment.



	Top Surface	Bottom Surface
Wetting time (sec)	1.593	1.968
Absorption rate(%/sec)	38.9843	42.0934
Max wetted radius (mm)	20.0	25.0
Spreading Speed (mm/sec)	4.5465	5.8446
One way transport capability	321.114	
Description	MMT-	

Figure 5: Moisture management test results of the treated bandage

In order to further assess the comfort properties of the selected treated compression bandage, the feedback from 5 patients (P_1-P_5) were assessed and the ratings (from 10-point Likert scale) were obtained after 2 hours of wear, as given in Table 6.

It can be observed that all the properties have significantly enhanced and, expected results have been achieved. The thermal and tactile comfort are mainly given by the cotton sheath of the Spandex/Cotton covered yarn. The required pressure has been given by the spandex core and the ring spun Polyester yarn. The rating from the patients regarding the odour was nearly 9 on average, which implies the effectiveness of the anti-microbial treatment applied. This is because the gases which emit odour are by-products of microbial activity in moist environments containing sweat. Since the microbial growth is nearly inhibited by the anti-microbial treatment, the odour emission has been minimal. Furthermore, the feedback from the skilled practitioner was satisfactory in terms of hand feel and the ease in application.

Table 6: Feedback of the respondents on wearing comfort

Property	P_1	P_2	P_3	P_4	P_5
Tactile comfort	8	7	9	8	8
Pressure sensation	8	8	8	7	8
Thermal comfort	7	8	7	7	8
Odour	8	9	9	8	9

4. CONCLUSION

The main objective of the study was to produce a compression bandage with lower pressure drop and improved comfort properties for pro-longed use. Thus, a covered yarn was selected where the sheath was Cotton, and the core was Spandex. Cotton was selected with the intention of providing the required comfort properties via proper moisture management, tactile comfort, and thermal comfort. Spandex was selected to yield the required stretch and recovery properties while maintaining the proper pressure range of 2.8 kPa - 4 kPa, along the bandage. Polyester was selected to impart strength, while the ring-spun nature of Polyester provided added comfort properties. Out of the developed knitted and woven structures, the weft rib woven structure (Sample C) showed the lowest pressure drop of 23%, after 12 hours of constant application. Though this drop was comparatively lower than the value obtained from Maxwell-Weichert model, it can be expected to have a maximum of 30% pressure drop even in the application in non-uniform surfaces. An anti-microbial effect of 90.3%-92.9% was achieved after treating the selected bandage with Chitosan. Furthermore, it is interesting to conclude that the anti-microbial finish has not hindered the properties of the bandage in terms of moisture management, air permeability and abrasion resistance. The trials concluded on five patients yielded satisfactory results and the feedback gained on tactile comfort, pressure sensation, thermal comfort and odour were commendable. Thus, the developed compression bandage was able to achieve required improved properties of comfort, anti-bacterial effect, while maintaining the pressure level in pro-longed use. However, further investigations are needed to be conducted to study the impact of the bandage structure with non-uniform treatment surfaces such as cellulitis.

LIST OF ABBREVIATIONS

AATCC – The American Association of Textile Chemists and Colourists

ASTM – American Society for Testing and Materials

BS – British Standard

BTCA – Butane tetracarboxylic acid

c/cm – courses per cm

Ch-HCl – Chitosan Hydrochloride

e/cm – ends per cm

LS – Long Stretch

MS – Medium Stretch

p/cm – picks per cm

SHP – Sodium Hypophosphite

SS – Short Stretch

w/cm – wales per cm.

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