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# Compression Properties of knitted Supports with silicone elements for scars treatment and New Approach to Compression Evaluation

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**Abstract.** Innovative compression products for scars treatment have to fulfil various functions and contains extra elements for different purposes. It is already known that all rigid elements, inserted into support, can change elasticity of entire product – there is a strong linear dependence between the rigid element relative area and compression generated by the knitted orthopaedic support. The aim of this research was to investigate the mechanical behaviour of different knitted compression apparel products with silicon elements for scars treatment. The unique complex mean of bandages for compression treatment was created in cooperation with JSC „Ortopedijos klinika“ and JSC „Plėtra“. Products were manufactured from knitted material with an elastic structure and layer of biocompatible silicon with medical plants substrate which creates antihypertrophic effect for scars treatment. Knitted compression fabrics were made by knitting two types of elastomeric yarns together (4.4 tex PU core double covered with 2.2 tex PA6.6; 33 tex PU core double covered with 2.2 tex PA6.6). Samples were stretched till the selected tensile force and hold in this position for 120s in case to measure elongation in more accurate way. According to results, recommended elongation for selected products was found.

## 1. Introduction

The use of compression textile products for medical purposes has increased significantly since 1970. Originally, these products were used to exert pressure along the human body for the treatment of scars resulting from burns, and treatment of post-surgical condition. Knitted medical textile garments are widely used because of their greater flexibility, higher porosity, more flexible structure and better forming technology [1]. Nowadays innovative products for scars treatment have to fulfil various functions and contains extra elements for different purposes. Compression apparel for treatment after burns (usually 3th grade burns) has to generate not less than 24 mmHg compression and has to be worn at least 12 months, 23 hours per day [2, 3]. The average pressure level applied to the treated tissues is about 25 mmHg [4].

Compression apparel is often designed from knitted fabric with additional details for different purposes. It is known that there is a high correlation between the mechanical properties of the fabric and generated pressure [5]. Orthopaedic supports often have added silicone elements such as modified biocompatible silicon components or other parts for functional application and may also comprise other components, such as straps, fasteners including disengage able two-part fastener system, such as



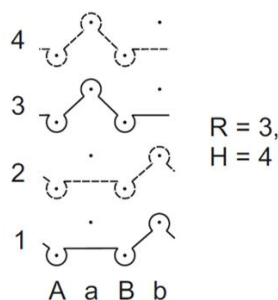
Velcro (the brand name of the first commercially marketed fabric hook-and-loop fastener) for engaging the support with the body [6]. All rigid elements, inserted into support, can change elasticity of entire product. It is already known that in the area of low extensions, there is a strong linear dependence between the rigid element relative area and compression generated by the knitted orthopaedic support – compression linearly increases by increasing the area of the rigid element [7, 8]. Moreover, additional rigid elements can significantly affect generated compression or can even change the compression class of the product. It was established that rigid element, that occupies  $\sim 8\%$  of the total area of a support, enhances the tensile force as well as compression up to 15% even at low elongation (10%). This influence depends on the level of elongations in which orthopaedic support is used. Compression, generated by the support with 25% relative area covered by a rigid element, increases up to  $\sim 17\%$  at 10% fixed elongation and up to  $\sim 24\%$  at 20% fixed elongation. However, if area covered by a rigid element is up to 3% and such support is used in area of low deformations (up to 10%), it is not necessary to assess the influence of relative rigid area on compression of the knitted support [7, 8].

Compression products usually are worn for a medical reasons and are indicated for long lasting term of wearing. After securing product to the body part, relaxation process appears and compression value may differ during the wearing time [9]. It is known that relaxation process of different type and nature of the yarns appears differently [10].

The aim of this study was to investigate the mechanical behavior of different knitted compression products with silicon elements for scars treatment.

## 2. Materials and Methods

The unique complex mean of bandages for compression treatment was created in cooperation with JSC „Ortopedijos klinika“ and JSC „Plėtra“. Experimental samples were manufactured on a flat double needle-bed 14E gauge knitting machine CMS 340TC-L (f. STOLL, Germany). Plain knitted fabric and three different location supports (ankle, knee and wrist) were designed and manufactured. Combined “Bird eye” and rib 1x1 patterns were used for the samples. Products were manufactured from knitted material with an elastic structure and layer of biocompatible silicon with medical plants substrate which creates antihypertrophic effect for scars treatment. Samples of supports for different locations were made by knitting two types of elastomeric yarns together: 4.4 tex PU core double covered with 2.2 tex PA6.6 and 33 tex PU core double covered with 2.2 tex PA6.6. The schematic structure of the knitting pattern is presented in the figure 1.



**Figure1.** Schematic structure of the knitting pattern (H is the height of the pattern repeat, R is the width of the pattern repeat).

The tensile behavior of the knitted fabric tested was evaluated using universal testing machine ZWICK/Z005 according to Standard LST EN ISO 13934–1:2000. According to the shape of the samples of supports special claps were designed and used for this research. The tensile speed was 100 mm/min; pretension – 2N, sensor – 5kN. According to the results of the latest research [9], samples of supports for different locations were stretched till the selected tensile force and held in this position for 120s in case to evaluate relaxation process and to measure elongation in more accurate way. Results of each point are calculated as average of five tensile tests. Compression is calculated by the Laplace

formula and depends on pressure  $P$  (Pa), tensile force in the knitted sample  $F$  (N) and the area of the knitted sample  $S$  (m<sup>2</sup>):

$$P = \frac{2\pi F}{S} \quad (1)$$

All experiments were carried out in a standard atmosphere for testing according to Standard LST EN ISO 139:2005.

Structure parameters of knitted samples were analysed according to British Standard BS 5441:1998.

### 3. Results and discussion

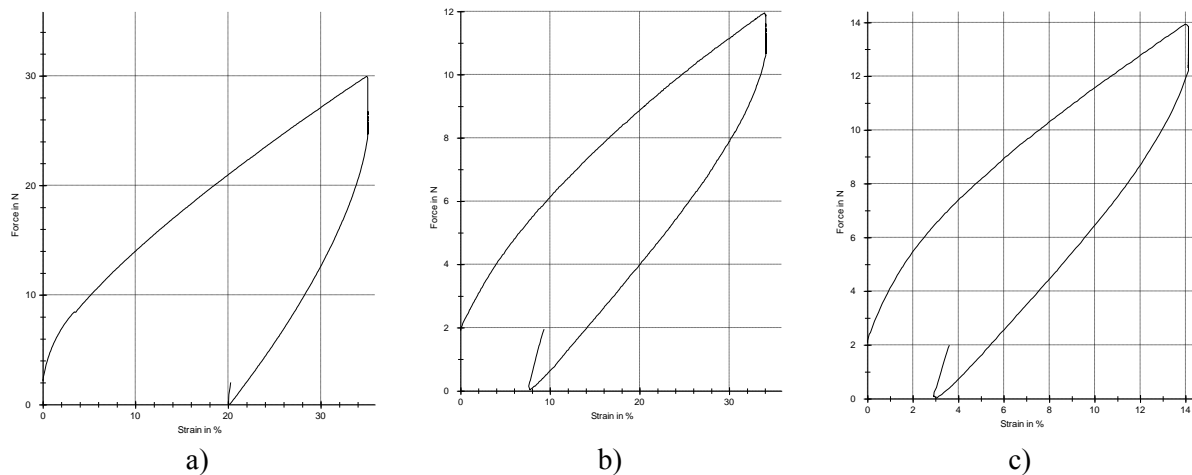
It is well known that mechanical properties of plain knitted fabric has valuable influence to the mechanical properties and behaviour of the complete knitted garment. From the previous research it is also known that additional rigid elements can significantly affect generated compression or can even change the compression class of the product [8]. Nevertheless, same purpose products, produced from the same material but appointed for different locations appears in various forms, dimensions and surface areas occupied by rigid elements. Also, in order to generate compression, perimeter of compression product and perimeter of the limb have to differ. It leads to assumption that tensile force values may be different to fulfil requirements of generated compression for such a products.

In order to investigate influence of different form, measurements and surface area occupied by the silicon element on the compression parameters, three different body locations were chosen. For further analysis supports for knee, ankle and wrist were designed and manufactured. All prepared samples were measured and structure parameters were calculated. It is recommended that compression products for scars treatment have to generate 33.2 ÷ 42.5 kPa compression and to belong to the second compression class (according to the Standard RAL-GZ 387/1:2008). According to the target compression (33.2 ÷ 42.5 kPa) the range of target tensile force was calculated by Laplace formula and average target tensile force was chosen. Obtained results are presented in the table 1.

**Table 1.** Measurements and structure parameters of tested knitted supports.

Location of the support	Knee	Ankle	Wrist
Surface area, m <sup>2</sup>	0.1026	0.0550	0.0378
Surface area of the silicone element, m <sup>2</sup>	0.0027	0.0027	0.0041
Surface area of the silicone element, %	2.6%	4.9%	10.9%
Course density, cm <sup>-1</sup>	7.5	7.5	8
Wale density (right), cm <sup>-1</sup>	9	9.5	9 / 14
Wale density (left), cm <sup>-1</sup>	14	14	14
Calculated target tensile force, N	27-34	10-13	12-15
Chosen average target tensile force, N	30	12	14

Compression products usually are worn for a medical reasons and have to fulfil medical requirements such as appropriate value of generated compression. In order to achieve target tensile force and generate target compression, selected samples were strained till fixed tensile force and hold in this position for 120s. The period of relaxation (120s) was based on the obtained experimental result from the previous research – because the relaxation processes of inner structure the tensile force decreases significantly during this period and after this period the relaxation process is considerably slower [9]. Due to the compression garments for scars treatment are usually indicated and being worn for a long-term (e.g. 12 hours a day), the importance of initial value of generated compression is less substantial.



**Figure 2.** Characteristic force-strain curves of tensile test of supports for different locations: a) knee, b) ankle, c) wrist.

Characteristic force-strain curves of tensile tests are presented in the figure 2. The variation coefficient of elongation ranges from 3.5 to 7.5. It is well known that in order to generate compression perimeter of support and the perimeter of the limb have to differ. According to the results of the tensile tests, the target elongation was estimated. It was found that to achieve target compression, tested samples of knee supports have to be stretched till 20% elongation, ankle supports – till 20% elongation and wrist supports – till 15% elongation. Results confirms the assumption that tensile force values may be different to fulfil requirements of generated compression for compression products for different locations. For this reason the perimeter of compression product and perimeter of the limb has to differ accordingly. Moreover, results of this research shown that in order to predict generated compression values not only the structure parameters of the knitted fabric but also completed product parameters have to be evaluated. More researches in this area may enable possibilities to predict generated compression in the more accurate way.

#### 4. Conclusions

This research was based on investigation of full garment for scars treatment compression properties and recommendation for its formation. According to the results, it was found that prediction of compression properties of the same pattern knitted garment for different body locations should not be evaluated just according to the plain fabric mechanical properties. Results shown that in order to achieve target tensile force and compression values, elongation of the selected samples should be different - knee supports have to be stretched till 20% elongation, ankle supports – till 20% elongation and wrist supports – till 15% elongation. Consequently, the perimeter of compression product and perimeter of the limb has to differ accordingly. Moreover, results of this research shown that in order to predict generated compression values not only the structure parameters of the knitted fabric but also completed product parameters have to be evaluated.

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