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COMPOSITE TEXTILE STRUCTURES FOR PARIETAL DEFECTS

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Abstract: *Composite textile structures designed to repair parietal defects, were obtained from monofilament yarns of polyester, polylactic acid and multifilament of Ag and high-density polyethylene, on Shima Seiki SIG 123 knitting machine of E8 gauge. The mass of composite structures after finishing is placed between 29.6 g/m² and 158.9 g/m². The textile structures from: PES/ Ag and PP/ Ag belong to low elastic modulus meshes (<10.9MPa - specific to the abdominal fascia) and those from: PES/ PE and PES/ PLA belong to high elastic modulus meshes (>10.9MPa). The anisotropy is suitable for all variants of textile structures with values less than 1.00. The best value of cell proliferation indicator - MTT (1,771) was recorded at the PES/PLA composite textile structure which is higher than the control value of 1.22; this structure also shows the lowest value of cell death indicator - LDH (0.405), but which is higher than the control value of 0.370; cell viability has a very high level in this structure (144.83%), higher than that observed in control cells (HT 29 cells in culture) of 100%.*

Key words: *composite, hernia, Young's modulus, anisotropy, biocompatibility*.

1. INTRODUCTION

A composite material is a material obtained of two or more constituent materials having different physical or chemical properties which, when combined, generate a material with better characteristics than the properties of the individual components. Composite textiles are refering to a wide range of textile surfaces that can be obtained by weaving, braiding, knitting, but also to nonwoven materials. These materials are also known as technical textiles used for: transport, geotextiles, civil construction, road construction, aerospace, military, medicine, sports equipment, protective clothing, etc [1].

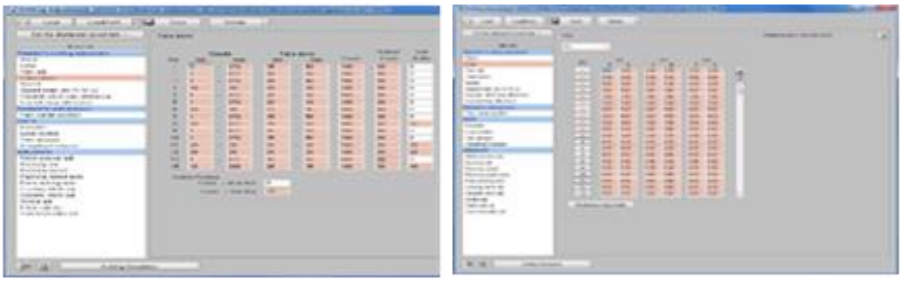
The concept of using meshes to treat hernias was introduced more than 50 years ago. Treating hernias using surgical meshes is now the standard procedure in most countries and is widely accepted as superior to primary suture repair [2, 3]. As a result, there has been a rapid growth in the multitude of meshes available and choosing the most appropriate one can be challenging.

The most important properties of a mesh are the type of filament, tensile strength and porosity. These determine the weight of the mesh and the biocompatibility [4, 5]. The required tensile strength is much lower than initially considered, and low weight meshes are considered to be superior due to the low risk of infection and shrinkage. In case of meshes placed in the peritoneal cavity, special attention should be paid to the risk of adhesion [6]. A wide variety of composite meshes have been developed to overcome this drawback, but so far neither seems to be superior to the other.

2. MATERIALS AND METHODS

Composite textile structures were developed on the Shima Seiki SIG 123 knitting machine of E8 gauge, equipped with the new Rapid Response R2CARRIAGE system from SHIMA SEIKI, which achieves a faster return of the carrier after each stroke. This requires less space to turn, which allows the area to be increased for running at full speed. This allows faster knitting along the way, generating an increase in productivity of over 10%. The variants of composite textiles are identified by the following notations: S1 - from multifilament yarns of PES and Ag, S2 - from multifilament yarns of PES and PE, S3 - from multifilament yarns of PES and monofilaments from PLA; S4 - made of multifilament PP and Ag threads. The design setup of the composite textile structures made on the Shima Seiki SIG 123 knitting machine are presented in fig. 1.

a. Program *b. Section representation* *c. Structure representation*



d. Take-down adjustments *e. Density adjustments*

Fig. 1. *The design setup - single jersey structure*

Biocompatibility is the test for determining the potential toxicity resulting from body contact with a medical material or device. The biocompatibility of the materials was evaluated on HT-29 epithelial cells, cultured in DMEM medium supplemented with 10% fetal bovine serum. To evaluate biocompatibility, HT-29 cells were seeded at a density of 1.5 x 104 cells per well in 500 µl of culture medium and incubated at 37°C (5% CO_2) together with the newly synthesized biomaterials for 24 hours. The evaluation of biocompatibility degree was achieved by MTT - cell proliferation tests, respectively LDH- (Lactate dehydrogenase) - cell death and cell viability (%).

3. RESULTS

The textile structures were finished on the laboratory equipment of INCDTP by applying the following technological flow:

- ✓ washing - degreasing with 2 g/l sodium carbonate, 2 g/l sodium hydroxide at 38°C, 2 g/l Kemapon PC/LF, 2 g/l trisodium phosphate, duration 30 min, temperature 60°C ;
- ✓ rinsing with water at 60°C, 40°C, 20°C;

- ✓ rinsing with distilled water;
- ✓ laser or mechanical cutting to the dimension of 10/10 cm or 20/20 cm;
- ✓ packaging in a package consisting of multilayer foil based on polyolefins, lined with special paper for the circulation of sterilizing agent and provided with sterilization indicators. Sterilization with ionizing radiation (table 1).

Table 1. *The physico-mechanical characteristics of the finished composites structures*

No.	Characteristic			UM	Variant			
					S1	**S2**	**S3**	**S4**
1	Composition			%	95% PES 4,8% Ag	68,5% PES 31,5% PE	97,6% PES 2,4% PLA	34,1% PP 65,2% Ag
2	Mass			g/m^2	51,3	29,6	38,1	158,9
3	Density	Horiz		wales/10 cm	70	72	50	90
		Vert	PES	rows/10 cm	120	105	155	72
			Ag		2	2	2	2
4	Breaking resistance	Horiz		N	84,5	62,4	43,7	551,3
		Vert			117,10	74,3	31,6	42,3
5	Elongation at break	Vert		%	33,5	53,5	59,5	62,5
		Horiz			51,9	56,1	26,1	55,4
6	Thickness			mm	0,77	0,27	0,75	0,86
7	Deformation resistance			kPa	139,0	98,4	91,5	471,1
				mm	45,4	37,7	41,7	50,8
8	Young's modulus	warp		MPa	0,31	11,57	0,74	2,4
		weft			1,68	16,3	0,13	16,0
9	Anisotropy			-	0,73	0,15	0,77	0,82

The analysis of the data presented in table 1 shows the following aspects:

- the composite structure with the highest mass (S4 - 2PP + Ag) has the highest values of breaking strength (551.3 N) and resistance to deformation (471 kPa), but also the highest values of elongation (62.5 % and 155.5%) and of the deformation (50.8 mm);

- the composite structure S2 (PES + PE) with the lowest mass (29.6 g/m^2) has good values of the breaking strength (62.4 N and 74.3 N) and of the deformation resistance (98.4 kPa), smaller elongations (53.5% and 56.1%) and the smallest deformation (37.7 mm);

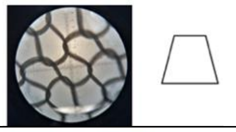
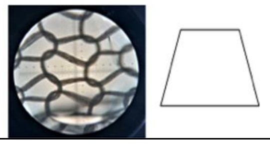
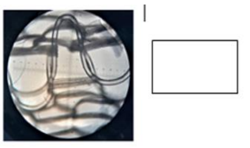
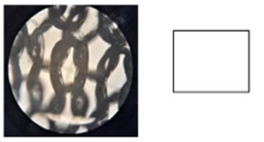
- the textile structures S1 and S4 fall belong to low elastic modulus meshes (<10.9 MPa) which do not generate high shear forces but have a higher degree of deformation. In general, because the abdominal wall behaves almost twice as elastic vertically compared to the horizontal direction, meshes with higher elasticity are required in the cranio-caudal direction for the midline of the defect repair area;

- the textile structures S2 and S4 belong to high elastic modulus meshes (>10.9 MPa) providing a strong mechanical reinforcement of the abdominal wall, but with the disadvantage of increasing shear forces between the mesh and the abdominal wall;

- the anisotropy of the composite textile structures is very good having values <1.0, the best value, 0.15 recording for the variant S2.

The analysis of the pore shape and dimensions (table 2) shows that the pore surface is between: 0.272 mm^2 (S3) and 0.502 mm^2 (S4). The analysis of SEM images of the composite structures (table 3) illustrates the alternation of the rows of meshes between the component threads of the textile structures. The analysis of the elemental composition (figure 2) shows the following aspects:

Table 2. *The pore shape and dimensions*

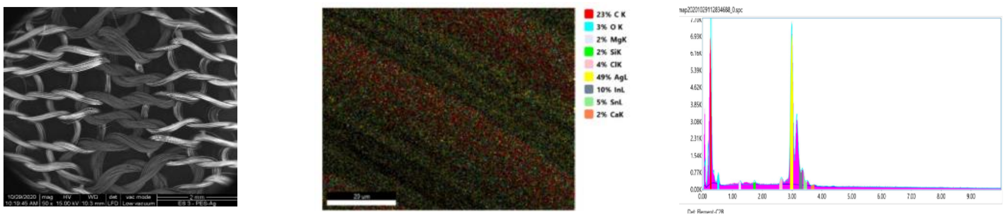
No.	Name	Pore shape	Dimensions
1.	S1-PES+Ag		P=2.5 mm S=0.440 mm^2
2.	S2-PES+PE		S=0.273 mm^2 P=2.26 mm
3.	S3-PES+PLA		PES S=0.272 mm^2 P=2.92 mm PLA Monofilament P=3.89 mm
4.	S4-2PP+Ag		P=2.64 mm S=0.502 mm^2

– for the textile structures S1 and S4 where Ag threads are present, the percentage of this element is 49%, respectively 43%, followed by carbon (23–30%); the presence of Ag threads attracts the presence of the following elements: indium (10–8%) and titanium (5–4%);

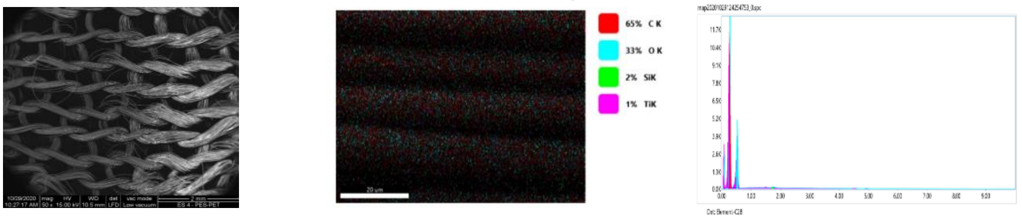
– the textile structures S2 (PES + PE) and S3 (PES + PLA) have the highest percentage of the element carbon (65%), followed by oxygen (33–32%), silicon (2%) and titanium (1%).

-for the textile structures S1 and S4 where Ag threads are present, the percentage of this element is 49%, respectively 43%, followed by carbon (23–30%); the presence of Ag threads attracts the presence of the following elements: indium (10–8%) and titanium (4–5%);

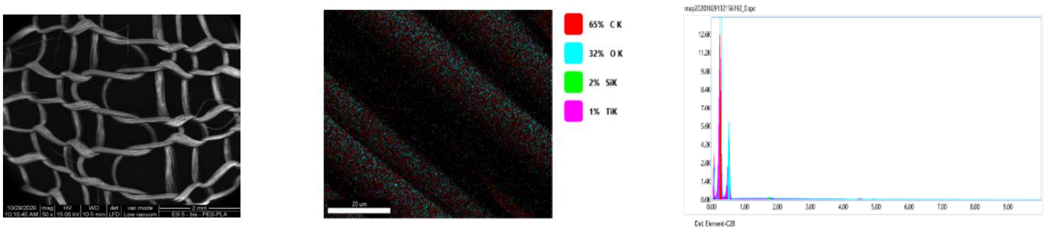
– textile structures S2 (PES + PE) and S3 (PES + PLA) have the highest percentage of the element carbon (65%), followed by oxygen (33–32%), silicon (2%) and titanium (1%).



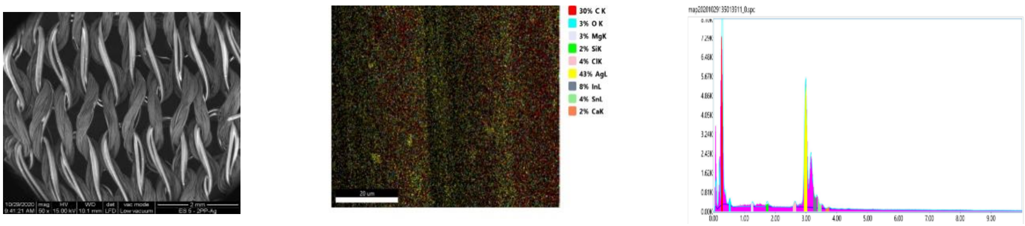
a. S1 – PES + Ag



b. S2 – PES + PE



c. S3 – PES + PLA



d. S4 - PP + Ag

Fig. 2. *The analysis of SEM images of composite structures*

In table 3 and fig. 3 are presented the values of biocompatibility: MTT, LDH and cell viability, for the composite textile structures.

Table 3. *The values obtained for biocompatibility*

Variant	Fiber composition, %	MTT	LDH	Cell viability, %
S1	95% PES 4,8% Ag	1,192	0,421	97,46
S2	68,5% PES 31,5% PE	1,078	0,405	88,15
S3	97,6% PES 2,4% PLA	1,771	0,405	144,83
S4	34,1% PP 65,2% Ag (PA)	1,089	0,437	89,06
Control	-	1,22	0,37	100,0

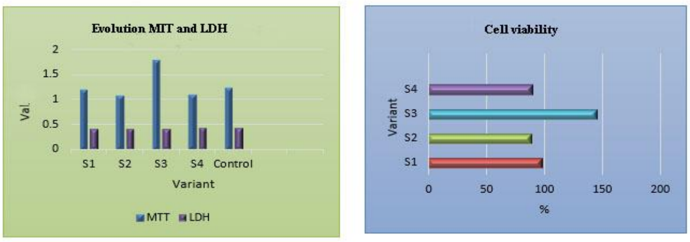


Fig. 3. *MTT, LDH and cell viability*

- the best value of the cell proliferation indicator - MTT (1,771) is measured for the composite textile structure made of PES/ PLA which is superior to the control value of 1.22; this structure also possesses the lowest value of the cell death indicator - LDH (0.405) which is higher than the control value of 0.370; cell viability has a very high level (144.83%) higher than that measured for control cells (HT 29 cells in culture) of 100%.

- composite textile structure of PES/Ag, is next, having a MTT a value of 1,192 (comparable to the control - 1.22) and LDH of 0.421 (higher compared to the control - 0.370) so that cell viability is at 97.46%, comparable to that of control (HT 29 cells in culture) of 100%.

The composite textile structures of PES/ PE and PP/ Ag are at close both in terms of MTT (1.078 and 1.089 respectively), LHD (0.405 and 0.437 respectively) and cell viability (88.15% and respectively 89.06%) but below the value of the control cells of 100%.

5. CONCLUSIONS

- The composite structure with the highest mass (S4 - 2PP + Ag) of 158.9 g/m^2 has the highest values of breaking strength (551.3 N) and deformation resistance (471 kPa), but also the highest values of elongation (62.5% and 155.5%) and deformation (50.8 mm);

-The S2 composite structure (PES + PE) with the lowest mass (29.6 g/m^2) shows good values of breaking strength (62.4 N and 74.3 N) and deformation resistance (98.4 kPa), smaller elongations (53.5% and 56.1%) and the smallest deformation 37.7 mm.

- Textile structures S1 and S4 belong to low Young's modulus meshes (<10.9MPa) and S2 and S4 belong to high Young's modulus meshes (> 10.9MPa).

- The anisotropy is very good for all variants of textile structures, registering values <1.00.

- The best value of the cell proliferation - MTT indicator (1,771) is obseved in case of the composite textile structure of PES/ PLA which is superior to the control value of 1.22; this structure also has the lowest value of cell death indicator - LDH (0.405) ; cell viability shows a very high level (144.83%) higher than that observed in control cells (HT 29 cells in culture) of 100%.

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