INFLUENȚA PLASELOR TEXTILE SINTETICE ASUPRA RECONSTRUCȚIEI CHIRURGICALE A DEFECTELOR PERETELUI ABDOMINAL
THE INFLUENCE OF SYNTHETIC MATERIAL MESHES ON THE SURGICAL REPAIR OF THE ABDOMINAL WALL DEFECTS

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The repair of the abdominal wall defects has always been a challenge. Good long term results (low percentage of recurrences) represent the purpose of different surgical techniques. Modern techniques use various types of alloplastic materials, making it possible for a lower recurrence rate, under a certain assumed and acceptable level. In the case of alloplastic repair, the tolerance of the organism towards the non-biologic material should be taken into consideration. Three types of meshes made of different synthetic materials were characterized by mesh density, pore size, pore shape, material composition by FT-IR microscopy and mechanical properties. The present study retrospectively analyzes the results obtained in our clinic within 3 years (October 2011- October 2014), using alloplastic repair of the abdominal wall defects. The recurrence rate and the occurrence of different complications (seroma, postoperative leakage, mesh rejection, neuromas with postoperative pain) were studied using the three meshes.

Repararea defectelor peretelui abdominal a fost întotdeauna o provocare. Scopul diferitelor tehnici chirurgicale este obținerea de rezultate bune pe termen lung (procent scăzut de recurență). Tehnicile moderne utilizează diverse tipuri de materiale aloplastice, ceea ce face posibil ca rata de recurență să fie mai mică, sub un anumit nivel asumat şi acceptabil. În cazul regenerării aloplastice ar trebui luată în considerare toleranța organismului față de materialul non-biologic. Trei tipuri de plase chirurgicale realizate din diferite materiale sintetice au fost caracterizate prin densitatea ochiurilor, dimensiunea porilor, forma porilor, compoziția materialului prin microscopie FT-IR și proprietățile mecanice. Acest studiu analizează retrospectiv rezultatele obținute clinic, de echipa noastră, pe o durată de 3 ani (octombrie 2011 – octombrie 2014), folosind repararea aloplastică a defectelor peretelui abdominal. Rata de recurență şi apariția diferitelor complicații (serom, scurgeri postoperatorii, respingerea plasei, neurom cu dureri postoperatorii) au fost studiate cu ajutorul celor trei plase.

Keywords: *synthetic meshes, pore size, mechanical strength, hernia repair*

1. Introduction

Over 100 types of synthetic and biologic film have been developed as meshes and are commercially available for hernia repair applications.[1] The use of alloplastic materials in the surgical repair of the abdominal wall defects decreases the recurrence rate. Some complications, such as seroma, chronic pain, infection, abdominal wall stiffness, neuritis, are more frequent when non-biologic material is used, strong related with a pronounced local inflammatory response. [2]

The implantation of surgical biomaterials causes a local inflammatory reaction that can be a sterile, non-systemic response (for example, local necrosis), microbiologic (infection), or both. [3]

Local inflammation determined by the mesh has its origin in the foreign body granuloma, which triggers changes in the composition of the collagen [4].

Long term recurrence is an important factor in abdominal wall repair. [5] Autologous tissue reconstruction techniques are less resource consuming, regarding the availability and the cost of the alloplastic material. Some authors reported low recurrence rate for this method [6,7], but, ultrasonography revealed a higher recurrence rate [8].

Incisional hernia occurs in 5-15% of cases with laparotomy [9, 10], becoming clinically evident within the first 5 years after the surgical intervention [11], but, also, an interval of 15 years being possible. [12] The most incriminated causes are

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inappropriate surgical technique and the postoperative leakage. The median scars are more vulnerable. Other risk factors are: obesity, initial defect dimension, age, increased intraabdominal pressure, malnutrition, uremia, diabetes [10].

The rationale of the alloplastic materials use is represented by the decrease of the recurrence rate. The mesh can cause an intense inflammatory reaction, leading to an invasion of the fibroblasts through the pores of the mesh, followed by collagen synthesis, thus strengthening the abdominal wall.

2. Materials and methods

Three types of commercially alloplastic meshes were used: one based on polytetrafluoroethylene (PTFE) - MotifMESH and two based on polypropylene (PP) - PARIETENE Composite (30/20 cm) and surgical prosthesis from monofilament.

The photos of samples and their codes are presented in Figure 1.

Physical-chemical characterization of synthetic meshes

IR mapping were recorded on a Nicolet iN10 MX FT-IR Microscope with MCT liquid nitrogen cooled detector in the measurement range 4000–715 cm^{-1}. Spectral collection was made in reflection mode at 4 cm^{-1} resolution using an liquid nitrogen cooled imaging detector. For each spectrum, 16 scans were co-added and converted to absorbance using OmincPicta software (Thermo Scientific). The imaging sampling rate was optimized for one spectrum every 25µm while the aperture was set at 150x150μm^2. Pore size and shape were determined from the microscopy images and mesh density were calculated by measuring and weighting and expressed as g/m^2.

Mechanical characterization

The three meshes were characterized by thickness, elongation at 10N/mm, elongation at breaking and tensile strength according with SR EN ISO 3376:2012.

Surgical techniques

A descriptive retrospective study was made on 843 patients, admitted to and operated in the Surgery Clinic of the "Sf. Pantelimon" Emergency Clinical Hospital, within 1.10.2011and 30.09.2014 (three years). All the patients went through a surgical alloplastic repair of the abdominal wall defect. Evaluation of different types of alloplastic materials was made. The patients were not distributed by the type of the abdominal wall defect (for example, inguinal hernia, umbilical hernia or incisional hernia), the distribution of the cases being made by the type of alloplastic material used, studying the tolerance of the organism.

3. Results and discussion

The characteristics of meshes evaluated in this study are presented in Table 1.

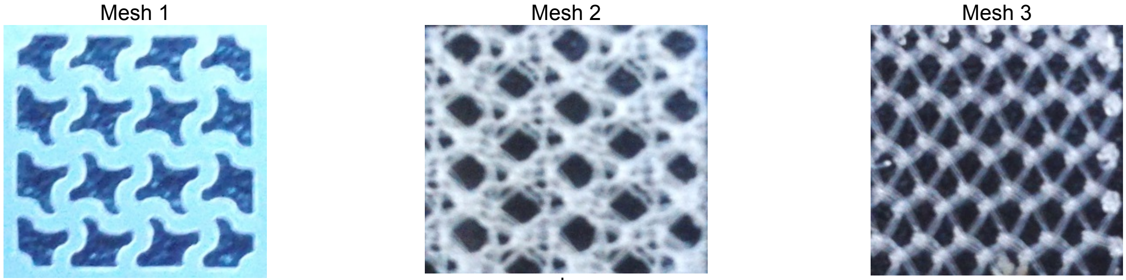
Table 1

Characteristics of meshes
Caracteristicile plaselor

Code of mesh	Mesh density	Pore size	Pore shape
Mesh 1	180 g/m^2	1.5 mm x 1.5 mm	star
Mesh 2	170 g/m^2	1.5 mm x 1.5 mm	hexagonal
Mesh 3	150 g/m^2	1.0 mm x 1.0 mm	square

FTIR (spectroscopic and microscopic) analyses were done in order to identify and confirm the composition and morphology of the three meshes. Based on the FTIR spectra, it can conclude that Mesh 1 is made of high purity (medical grade) PTFE (Figure 2a). The characteristic absorption bands can be assigned to the C-C stretching (1151 and 1205 cm^{-1}) as well as C-F stretching (between 500 and 700cm^{-1}). The band from 2365cm^{-1} can be assigned to the partially oxidized groups of COF [13]. In transmission or reflection mode, due to the saturation of the FTIR bands from 1151 and 1205cm^{-1} and most of the less intense bands can be identified. For instance, in ATR mode, only the

Mesh 1 Mesh 2 Mesh 3

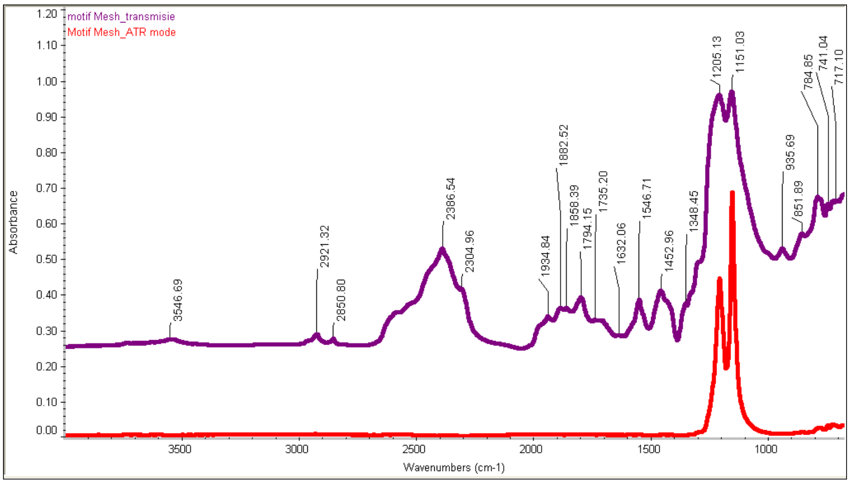


a b c

Fig. 1 - The three meshes evaluated in this study: MotifMESH; b) PARIETENE composite; c) surgical prosthesis from monofilament
Cele trei plase evaluate în acest studiu: a) MotifMESH; b) compozit PARIETENE; c) proteza chirurgicală din monofilament.

strong bands form 1151 and 1205cm^{-1} as well as some weak bands from 717, 741, 772cm^{-1}. In transmission mode, as well as in reflection mode, even some week bands can be identified, including the band of C=O from COF groups; as well as more C=O bands assigned to functional groups containing C=O bond. In the context of these studies the band from 2386cm^{1} is important for monitoring the level of oxidized groups. The black corner in video image (corresponding to red corner in FTIR image) is due to the fastening agent, being not characteristic for the motif mesh. Based on both spectroscopic and microscopic data, the purity of the mesh is very good.

Figures 2 - 6 show the FT-IR spectra and video images of all the studied meshes.



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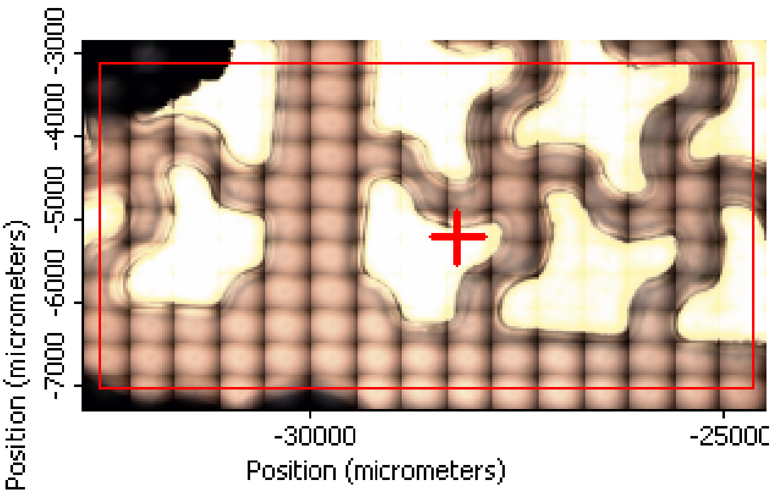


b

Fig. 2 - FTIR spectra of Mesh 1 (a) and video image of Mesh 1 (b) / *Spectrul FT-IR (a) şi imaginea video (b) pentru proba Mesh 1.*

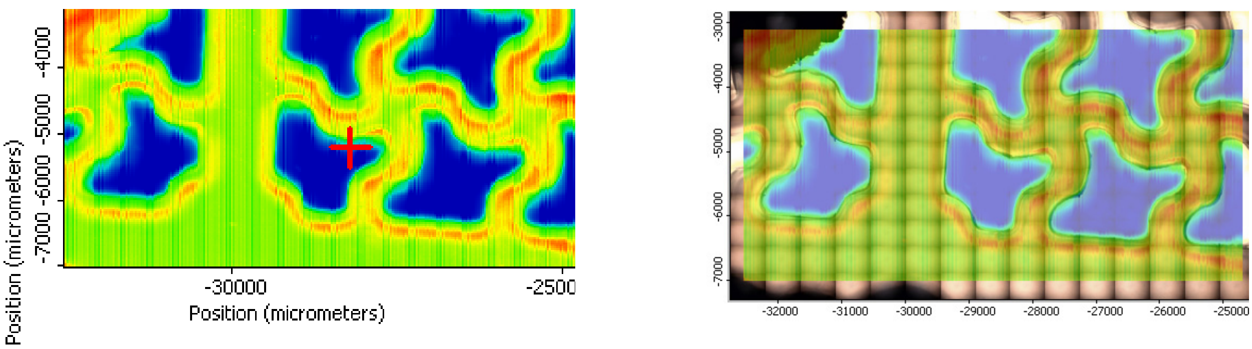


Fig. 3 - Stretching vibration of the C=O from COF (2365 cm^{-1}) / *Vibrații de întindere ale C=O din COF (2365 cm^{-1}).*

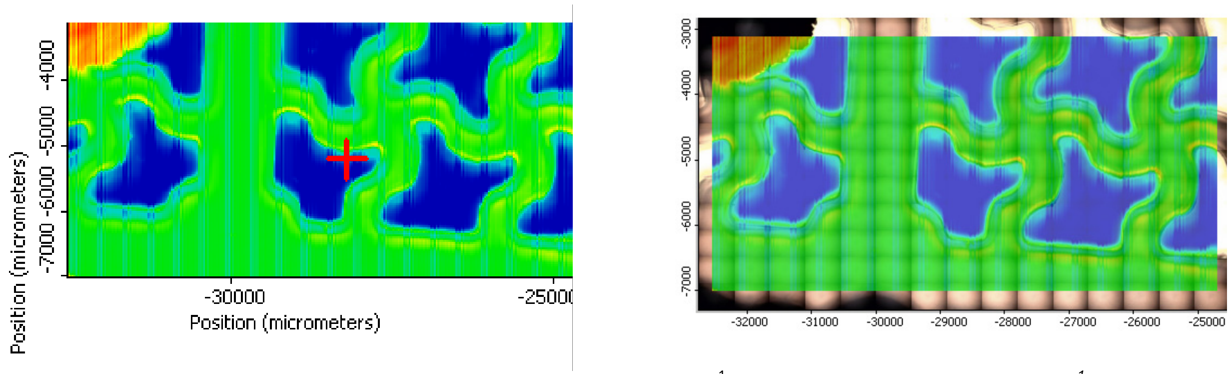
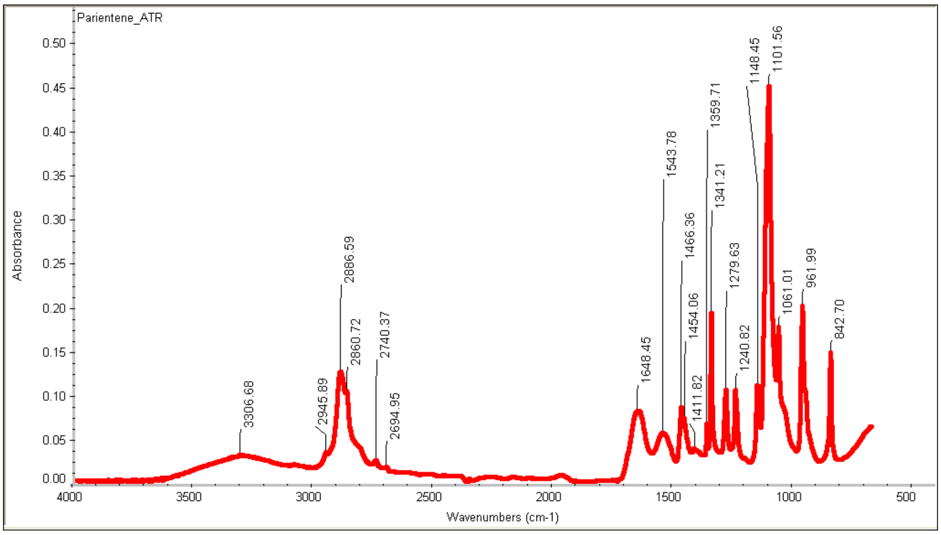


Fig. 4 - Stretching vibration of the C-C backbone (1151 cm^{-1}) / *Vibrații de întindere C-C (1151 cm^{-1}).*



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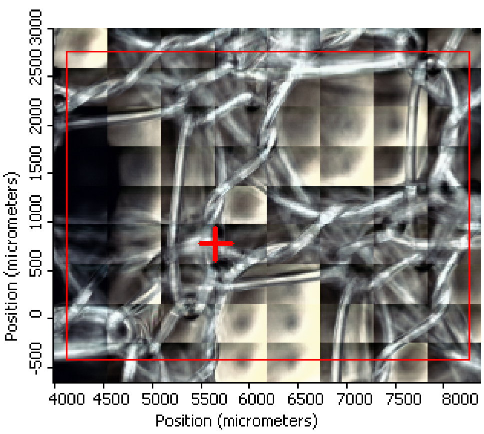
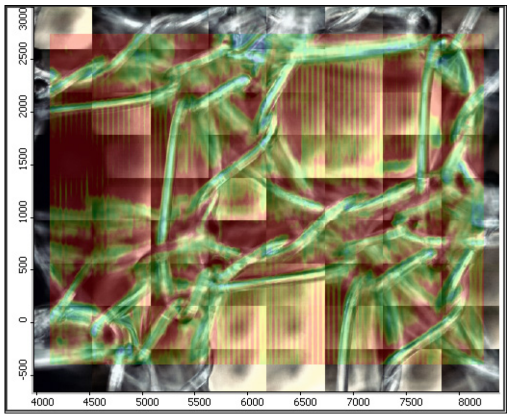


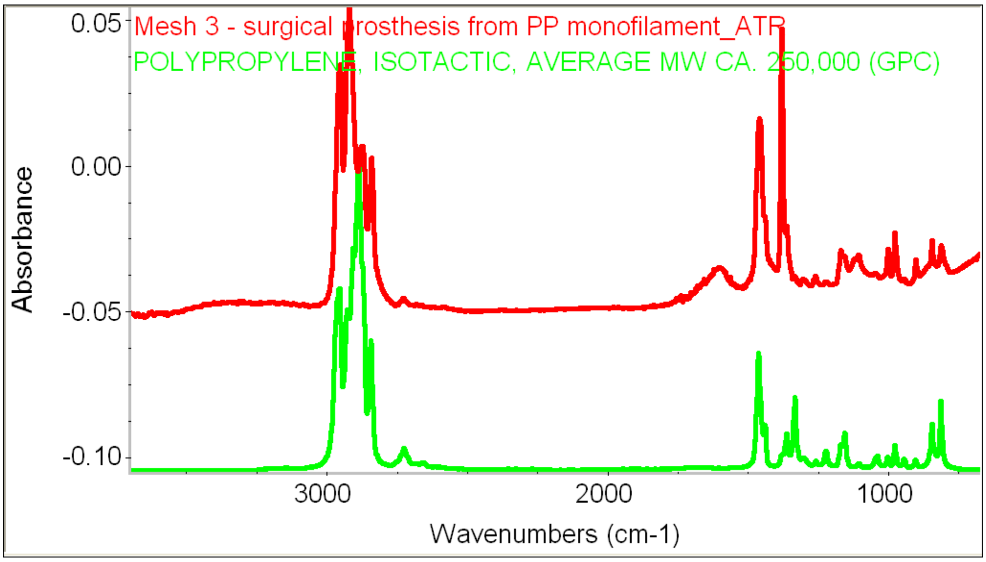


b c

Fig. 5 - FTIR spectra of Mesh 2 (a) and video image of Mesh 2 (b and c) / *Spectrul FT-IR (a) şi imaginile video (bsi c) pentru proba Mesh 2.*

FTIR microscopy is useful because it can be used for monitoring the presence and distribution of functional groups. Based on above mentioned assignments, the FTIR images will be recorded at 2365cm^{-1} (C=O band from COF) (Figure 3) and 1151cm^{-1} (C-C stretching from the PTFE backbone) (Figure 4). Comparing the two IR maps it can be clearly concluded that the surface is partially oxidized. This can be important because it changes the hydrophobic character of the surface and makes it hydrophilic, the integration of these meshes being improved.

Mesh 2 - Parientene Mesh was characterized by FTIR and revealed the characteristics bands of poly(ethylene oxide) - PEO (the correlation coefficient with the PEO being ~93%)(Figure 5). The characteristic absorption bands of PEO are: C-H stretching mode at 2876 cm^{-1}, CH_2 scissoring mode at 1466 cm^{-1}, CH_2 wagging mode at 1360 and 1341 cm^{-1}, CH_2 twisting mode at 1279 cm^{-1}, C-O-C stretching at 1104 cm^{-1}, CH_2 rocking and C-O-C vibration mode at 960 cm^{-1}, CH_2 rocking at 841 cm^{-1} and C-O-C bending at 528cm^{-1}. The semi-crystalline



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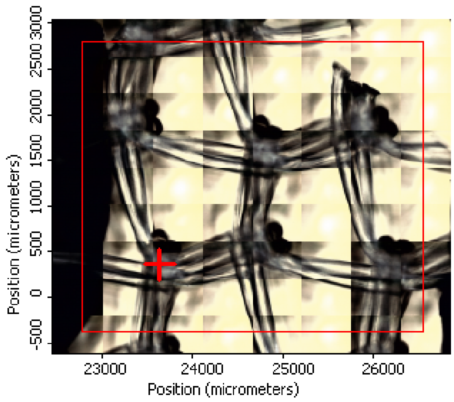

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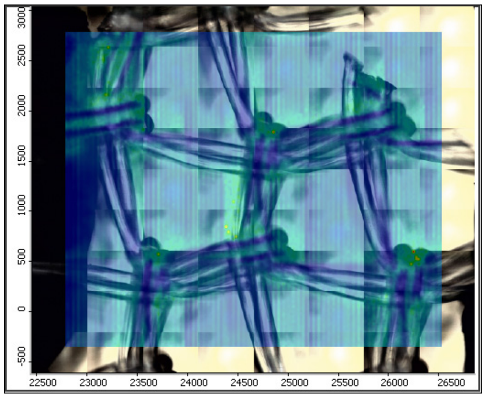


c

Fig. 6 - FTIR spectra of Mesh 3 (a) and video image of Mesh 3 (b and c) / *Spectrul FT-IR (a) şi imaginile video (b şi c) pentru proba Mesh 3.*

phase of PEO is confirmed by the presence of triplet peak of C-O-C stretching at 1145, 1095 and 1059 cm^{-1} with maximum intensity at 1095 cm^{-1} [14-17].

The FTIR microscopy was used but, due to the thin fibers which are placed on different heights the FTIR images are noisy.

Mesh 3 – surgical prosthesis from monofilament reveals that this material is obtained from high purity polypropylene. The flexibility is assured by the used plasticizer (most probably glycol type plasticizer) which can be identified based on the absorption band from 1600, 1104, cm^{-1}(Figure 6).

The FTIR microscopy reveals the morphology of the mesh as well as, based on the distribution of the characteristic bands, the high purity and homogeneity of this medical device.

Mechanical properties are presented in Table 2.

Comparing the 3 meshes we can noticed that their properties vary due to the composition and structure. Mesh 1 has an elongation at 10N/mm and tensile strength comparative with Mesh 3. Mesh 2 has an almost 3 times higher elongation and 3 times lower tensile strength comparative with Mesh 1 and 3. The best elongation was registered for Mesh 3.

Table 2

Mechanical properties of meshes / *Proprietățile mecanice ale plaselor*

Characteristics	Mesh 1	Mesh 2	Mesh 3
Thickness, mm	0.21	0.65	0.59
Elongation at 10N/mm, %	10.00	40.00	12.00
Elongation at break, %	90.00	100.00	120.00
Tensile strength, N/mm^2	11.90	3.07	11.86

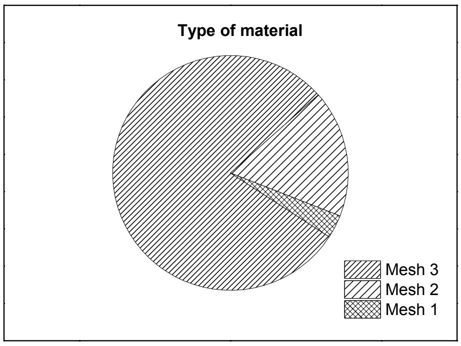
During in vivo implantation, the synthetic meshes are exposed to the foreign body reaction of the organism, with the possibility of altering theirbiochemical properties.

Starting with the second half of the 90's, the most frequently used methodfor the abdominal wall reconstruction is the "tension-free" procedure with various types of meshes , such as polyethylene, high molecular weight polypropylene, expanded polytetrafluoroethylene, polyethyleneterephthalate, low molecular weight polypropylene and even resorbable materials [18].

Even though these surgical interventions are frequently made, there is a high percentage of primary recurrences for the "tension-free" procedure, the recurrence rate in case of relapses being 10% for laparoscopic approach and 14.1% for open repair [19].

The fact that the implanted mesh, in vivo, does not remain inactive has a great impact on the recurrence rate. These materials determine a strong foreign body reaction of the organism, which, at the beginning, was believed as being necessary for the repair of the defect [18]. Lately, there have been clear proofs that the foreign body reaction can alter the properties of the alloplastic material, leading to unfavorable evolution and recurrence [20-22].

In our study, the majority of the alloplastic repair, within the aforementioned period, used polypropylene mesh, mainly for product availability and cost reasons, but also because of some of the surgeons' ordinariness in using this type of mesh or because of the misconception that the stiffness of the material may assure strong resistance or easier manipulation. For 668 cases of the 843 total patients included in the present study (79.2%) Mesh 3 was used, 148 patients (17.5%) receiving Mesh 2 prosthesis, 27 patients (3.2%) being treated with a Mesh 1 (Figure 7).



	Tipuri de plasă
Mesh 3	668
Mesh 2	148
Mesh 1	27

Fig. 7- Alloplastic materials type used in the last 3 years / *Tipuri de materiale aloplastice utilizate în ultimii 3 ani.*

The mean age of the patients was 62.5 years old. Men: women ratio was 1.1:1 (443 men versus 400 women).

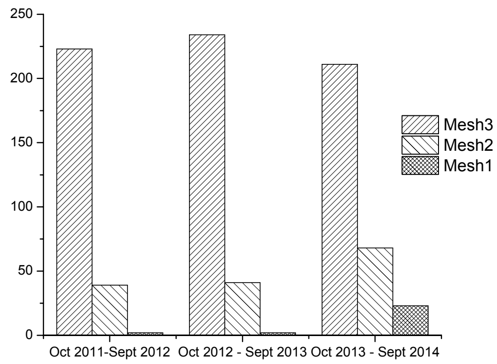
The general trend, within the 3 years of the study, was represented by a higher use of Mesh 2 and Mesh 1, unlike PP, a trend that is similar to the universal trend, these two materials being better tolerated, in comparison with PE prosthesis.

A mesh with visceral protection (Mesh 2) is recommended for open surgery with a high risk of fascial dehiscence and visceral exposure to the mesh, and, also, for open or laparoscopic "underlay" surgical method. In these cases, a material which separates the tissues is preferred, not allowing the development of the abdominal content through the pores of the mesh.

During the first year (October 2011-September 2014), among the 264 alloplasties, 223 (84.5%) were made using Mesh 3, 39 (14.7%) Mesh 2 and only 2 (0.75%) with Mesh 1.

In comparison, within the late year of the study (October 2013- September 2014), from the total of 302 alloplasties, 211 (69.8%) were made using Mesh 3, 68 (22.5%) Mesh 2 and 23 (7.6%) with Mesh 1.

In Figure 8, the evolution through years, of the synthetic materials use can be seen.



	Mesh 3	Mesh 2	Mesh 1
Oct 2011 - Sept 2012	223	39	2
Oct 2012 - Sept 2013	234	41	2
Oct 2013 - Sept 2014	211	68	23

Fig. 8 - Evolution of different types of materials used within the study interval / *Evoluția diferitelor tipuri de material utilizate în intervalul de studiu.*

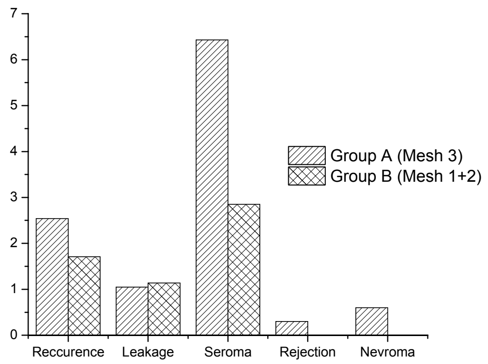
Polypropylene is a thermoplastic polymer, with the possibility of being remelted and remodeled. Usually, polypropylene fibers form a monofilament structure, which is then intertwined in a particular mono- or multifilament design. It is a hydrophobic molecule, resistant to the majority of chemicalsolvents (acid or basis), due to the lateral methyl groups attached to the main carbonic chain.

Unfortunately, polypropylene can be degraded in an oxidative environment, such as a foreign body reaction, thus it oxidizes in vivo, leading to surface changes, mechanical resistance lowering and frailty increasing. [23]

PTFE represents one of the most stable prosthesis. The central carbon chain and the lateral fluoric chains, makes it a strong hydrophobic material. Being inactive, is difficult for the surface to be modified, making it very resistant to the enzymatic attack of the foreign body reaction. Despite its characteristics, PTFE does not represent the ideal material for the abdominal wall reconstruction, being prone, in time, to shortenings and distortions, thus facilitating the recurrences. [24].

The concept of the Dual Mesh consists of stimulating adhesion formation towards the abdominal wall and inhibiting adhesion formation to the cavitaryviscera. The PP/PTFE surface stimulates the invasion of the surrounding tissue, producing local fibrosis and a uniform tissue-mesh complex. The protecting hydrophilic surface was designed to have a benign behavior towards the cavitary organs, having the benefits of a synthetic material, avoiding major complications.

The recurrence rate and the 4 major complications (seromas, postoperative leakage, mesh rejection and neuromas with postoperative pain) were analyzed on the three categories of study population.



	Group A (Mesh 3)	Group B (Mesh 1+2)
Reccurence	2.54	1.71
Leakage	1.05	1.14
Seroma	6.43	2.85
Rejection	0.30	0.00
Nevroma	0.60	0.00

Fig. 9 - Rates of complication in groups A and B / *Raportul complicațiilor în grupele A şi B.*

Between the two patients categories where new generation meshes were used (Mesh 1 and Mesh 2) no statistically significant differences regarding recurrence rate or complication rate were noticed.

For an accurate statistical interpretation, the patients were reorganized into two groups: group A, with 668 cases where polypropylene was used in the repair of the abdominal defect, and group B, with 175 patients for whom Mesh 1 or Mesh 2 was implanted (Figure 9).

Regarding the recurrence rate, the patients were monitored for about 12.3 months, in group A, and 11.7 months, in group B. Within this interval of systematic follow up, relapse was noticed in 17 cases of the group A (2.54%) and in 3 cases of the group B (1.71%). The interpretation of the results cannot be accurately done because of the difficulty in the follow up of all the patients and because of the different period of monitoring. Even though, a detriment in the case of polypropylene meshes was noticed. The recurrence rates are consistent to the ones revealed by the medical literature [25, 26].

The rates of complications were established during the same time period. The patients with alloplastic repair of the inguinal, umbilical or epigastric hernias were not drained. For the patients with incisional hernia, a supraaponevrotic drainage was made in 53.4 % of cases.

It is known that synthetic materials cannot be implanted in a septic environment; in our study, the use of meshes in hernias complicated by strangulation, with a great risk of associated infection, was avoided. Even though data regarding the long term evolution of the biologic materials of alloplastic repair (non-cellular collagen) are not available for the moment, these can have good results when used in contamined or infected, but well drained anatomical spaces [27].

In our study, there were no differences in relation to the supurative complications, with 7 cases of postoperative leakage in group A (1.05%) and 2 in group B (1.14%).

Postoperative seromas were more frequent in group A (43 cases, 6.43%) than in group B (5 cases, 2.85%).

In the follow-up interval, 2 cases of mesh rejection were identified, both of the cases being previously treated by using polypropylene material, for one of them the mesh extraction being mandatory.

Also, all 4 cases of severe and persistent postoperative pain (chronic) were part of the study group with polypropylene mesh repair. One patient with nevroma after inguinal hernia repair needed reintervention for mesh extraction.

Figure 9 shows a comparative analysis of the complications that occurred in the study population.

4. Conclusions

In the last years, a trend of replacing polypropylene mesh with new and better tolerated materials in the surgical treatment of the abdominal wall defects was noticed. The benefits observed were: decreasing the rate of recurrence and decreasing the rate of some of the complications.

Analyzing the 4 major complications: seromas, postoperative leakage, material rejection and neuromas, a lower risk for seromas, rejection and neuromas was noticed in the cases of Mesh 1 and Mesh 2 repair, in comparison to Mesh 3 repair. Regarding postoperative leakage, there were no differences between different types of materials.

In our study population, no differences between Mesh 1 and Mesh 2 were noticed, regarding recurrence or complication rate.

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