Experimental Study of the Impact of the Textile Structure of Mesh Endoprostheses for the Efficiency of Reconstruction of the Anterior Abdominal Wall

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Endoprostheses made from knitted fabric of 3 loop types were used for hernioplasty in rats. Biocompatibility of implanted textile constructions was evaluated after 6 months. The intensity of inflammatory reaction and types of complications in animals depended on the loop type and method of finishing of the mesh endoprosthesis tissue.

Key Words: *surgical mesh; mesh endoprostheses; postoperative hernias; hernioplasty*

Polypropylene endoprostheses with surface density of 70-90 g/m^2 are now most widely used in nonstretching plastic repair of postoperative ventral hernias. The incidence of relapses is the minimum with these endoprostheses. However, the percentage of patients complaining of painful sensations, discomfort, and limited mobility of the anterior abdominal wall during delayed periods after plasty is to more than 30% [6,4]. These complications are caused by disorders in the integration of the endoprosthesis structure and continuing chronic inflammation [8]. Presumably, the intensity and consequences of inflammation are determined not only by tissue reaction to the material, but depend also on the location and connection of the elementary components of knitted fabric.

We studied the biocompatibility of mesh endoprostheses (ME) knitted from polypropylene threads by different loops 6 months after experimental hernioplasty.

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MATERIALS AND METHODS

At the preliminary stage we studied the structural characteristics of 3 ME: Prolene (Ethicon), Esfil (Lintex), and Surgimesh (Resorba) by methods used for analysis of textiles [2,7]. The characteristics of loops were evaluated, thickness of fabric and diameters of threads were measured, and the parameters of surface density, surface and volume porosity were evaluated in 4 specimens of each ME type.

The biocompatibility of ME was studied on the model of hernia in 24 laboratory rats (420-470 g). A 20×25 mm myofascial defect of the anterior abdominal wall was induced under general anesthesia by partial resection of the abdominal rectal muscle and the posterior aponeurosis leaflet without damaging the transverse fascia and peritoneum. Plasty with subaponeurosis position of the studied ME (25×35 mm) was carried out in 18 rats divided into 3 groups. The defect was not repaired in 6 controls; the skin was just sutured. Six months after surgery the animals were sacrificed. Two catheters were inserted into the abdominal cavity and intraabdominal pressure was gradually elevated to 30 mm Hg (hernial test). The anterior abdominal wall was then resected together with ME, transferred onto a

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glass slide of a stereomicroscope, and examined in transmitting cold light at ×7.5-50. The area of the defect, filling of the ME loops with the connective tissue, vascular pattern, and retention of the textile structure were evaluated. Histological study of transverse sections stained with hematoxylin and eosin consisted in evaluation of the inflammatory reaction (by a 5-point scale [5]), cellular composition of infiltrate, and quality of connective tissue.

RESULTS

The structural parameters of the studied ME were close (Table 1). The appearance and structure of the loops differed in principle. The prolene and esfil knitted constructions were created on the basis of incomplete basic knitted woolen cloth tricot and atlas tricot loops with double threads in the loops (Fig. 1, *a*, *b*). The prolene prostheses knitted fabric was subjected to thermoplastic processing at the final stage, rendering them stability and limiting the mobility of the primary elements. The knitted construction of surgimesh net was designed on the basis of the basic atlas loops with closed loops and additional tightening of the second row of loops (Fig. 1, *c*), due to which the density of the fabric filling and rigidity of the material increased. This ME was subjected to thermoplastic processing at the stage of finishing.

Hernial test detected large ventral hernias in all controls. Repair of the myofascial defect with prolene and surgimesh ME prevented the development of postoperative hernias. The prosthesis was partially rejected in one animal in the esfil group; a marginal hernia formed (which was detected during intra-abdominal pressure elevation to 10 mm Hg). In the surgimesh group, central abscess with pronounced growth of cicatricial tissue around it was observed in one case. Formation of peritoneal adhesions between the prosthesis and large omentum were seen in 3 (50%) rats in the prolene group, in 1 (17%) animal in the esfil group, and in 3 (50%) animals with surgimesh.

Stereomicroscopy of preparations from the prolene group (Fig. 2, *a*) showed shrinkage of the defect area by 40.4% on average. The position of structural elements (loops, stretching, and loop columns) towards each other did not change. In two animals, the ME structure was evenly filled with the connective tissue. Central spots of excessive photopermeability occupying about 30% prosthesis area were seen in the majority of cases indicating local thinning of the connective tissue layer as a result of continuing chronic inflammation, indirect

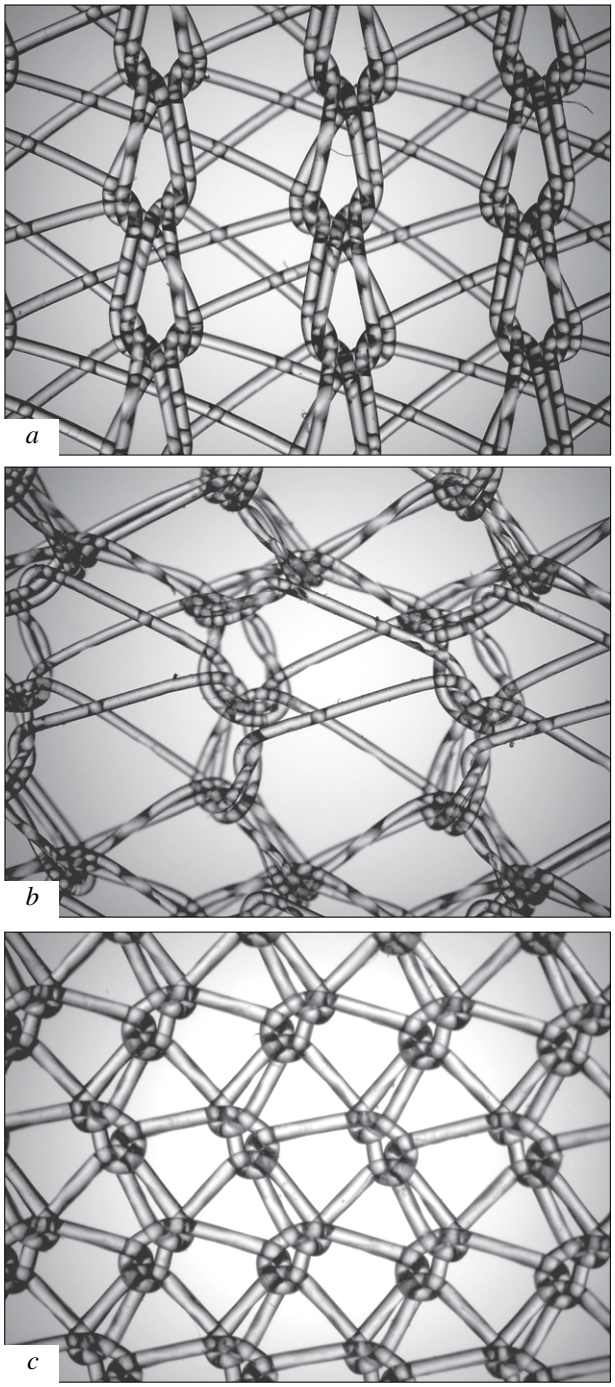

Fig. 1. Mesh endoprosthesis knitted loops, ×25. *a*) prolene (woolen tricot); *b*) esfil (atlas tricot); *c*) surgimesh (closed loop atlas).

evidence of which were numerous small vessels, chaotically filling the mesh structure, and branched large vessels at the site of replaced defect. The structure of the mesh fabric was completely retained in all preparations of the esfil group (except marginal hernia), but there were sites of connective tissue thinning (up to 42% of the area) and excessive vascular reaction around loops (Fig. 2, *b*). The defect area decreased by 29.5%. Uneven filling

TABLE 1. Structural Parameters of Surgical Meshes

ME	Thread diameter, μ	S-density, g/m^2	Thickness, μ	V-Porosity, %	S-Porosity, %
Prolene	132±2	81.2±1.3	523±4	82.8±0.3	50.3±1.6
Esfil	122±4	75.3±1.9	522±7	83.9±0.4	53.8±2.3
Surgimesh	146±7	87.3±1.1	460±2	79.5±0.6	49.9±2.2

Note. S: surface, V: volume.

of ME structure with the connective tissue was observed in the surgimesh group. Vast zones of high density (up to 70% of area) were surrounded by sites of loose connective tissue. Large vessels or their branches approached the dark zones; as a rule, there were also foci of small vessels. Despite pronounced heterogeneity of the connective tissue, the textile structure of the meshes was completely preserved in uneventful course of healing (Fig. 2, *c*). The defect area decreased by 32.2%.

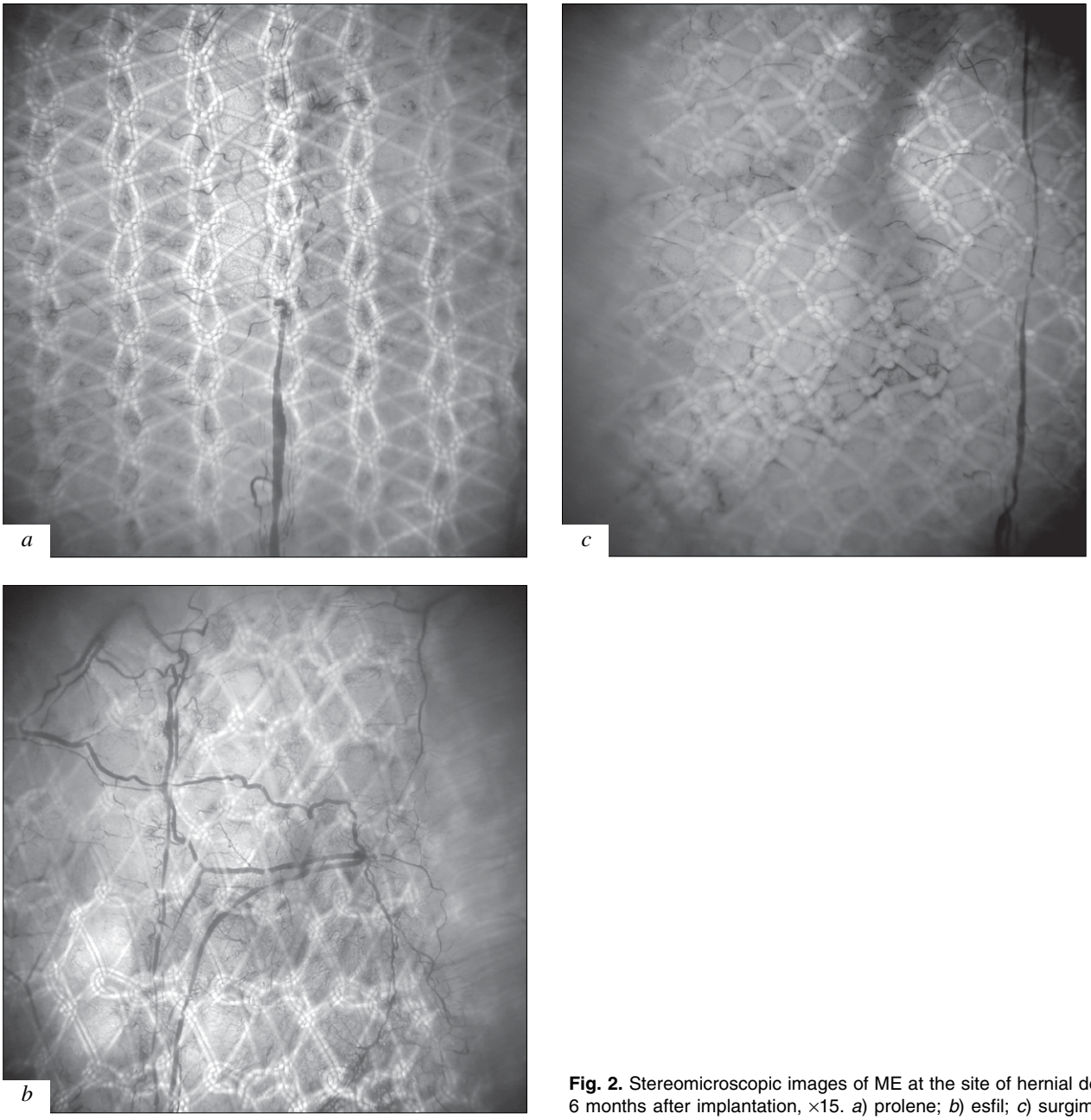

Fig. 2. Stereomicroscopic images of ME at the site of hernial defect 6 months after implantation, ×15. *a*) prolene; *b*) esfil; *c*) surgimesh.

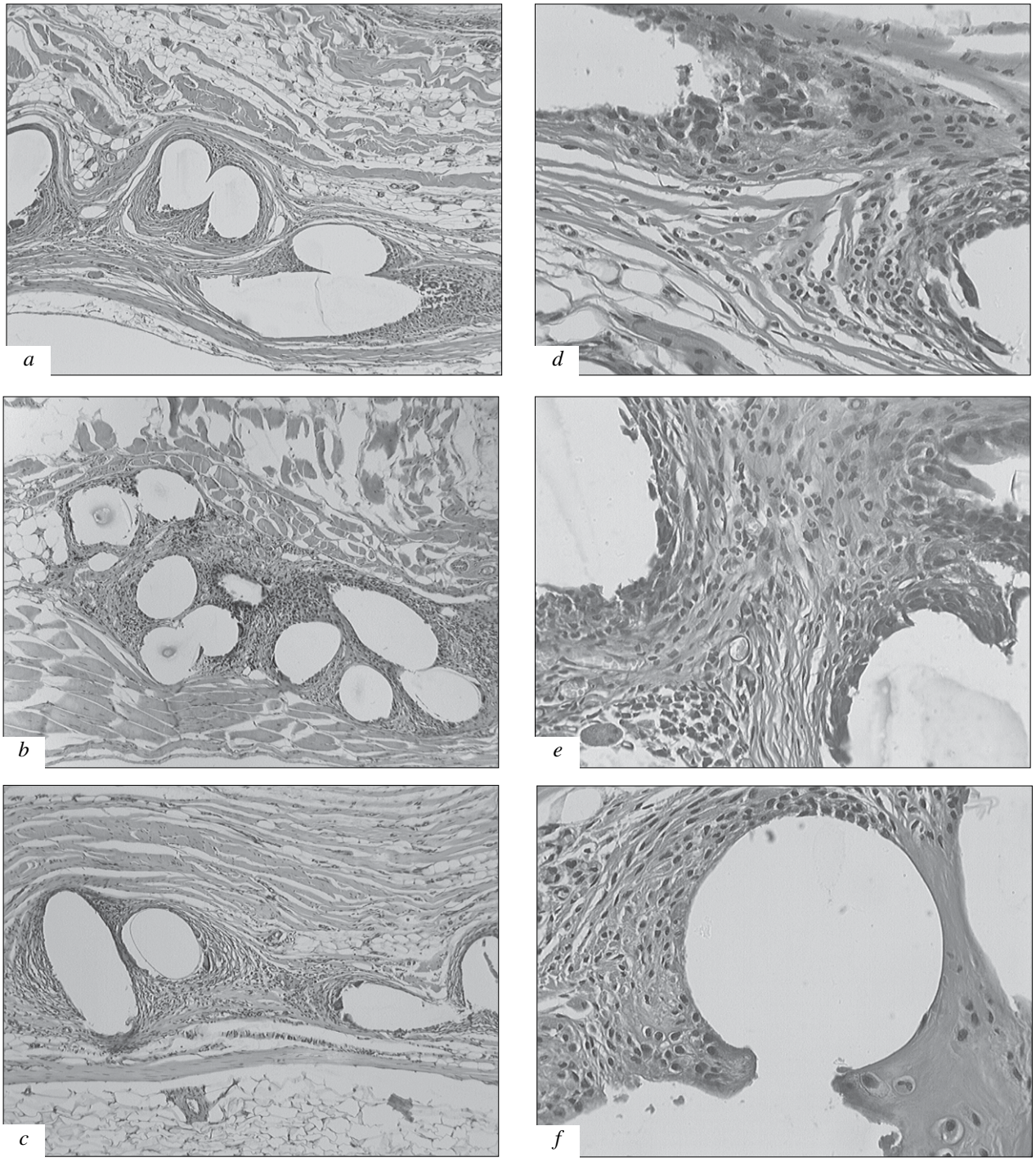

Fig. 3. Morphological picture 6 months after ME implantation. *a*, *d*) prolene; *b*, *e*) esfil; *c*, *f*) surgimesh. Hematoxylin and eosin staining, ×100 (*a-c*), ×400 (*d-f*).

Histological study showed that the hernial defect in control animals was replaced with a thin layer of connective tissue; no inflammatory reaction was noted (0 points). In ME groups, inflammatory infiltration by neutrophilic and eosinophilic leukocytes, plasma cells, lymphocytes, macrophages, and multinuclear giant cells of foreign bodies of different intensity was seen around the loops. The reaction was most pronounced in the esfil group: 3.00±0.81 points ($p<0.05$ *vs.* control), 2.25±0.96 points in the prolene group ($p<0.05$), and 1.50±0.58 points in the surgimesh group ($p<0.05$ *vs.* control and esfil group). Some threads, despite the difference in diameters (Table 1), were surrounded by

connective tissue fibrils. The pores seen as free gaps between threads and groups of threads in the sections were filled with the granulation, adipose, and connective tissues in different proportions. A specific feature of the esfil group was uneven inflammatory reaction. Inflammatory infiltration was slight around separate threads and pronounced (with numerous neutrophils and abundant giant cells) around groups of threads. Zones of maturing granulation tissue with numerous plethoric capillaries and small focal hemorrhages, which had occurred at different time (Fig. 3, *b*, *e*), were seen. Neuroma contacting the prosthesis threads was detected in one animal. The least pronounced inflammatory reaction was observed in the surgimesh group. The composition of the inflammatory infiltrate was characterized by small number of neutrophils and giant cells and by groups of foamy macrophages. The pores were filled with mature granulation tissue with differentiated vessels. Partial encapsulation of the prostheses was noted with sites of hyalinosis at the site of hernial defect; a hyaline cartilage formed in one animal (Fig. 3, *c*, *f*). Neuromas at the edge of the mesh were detected in two cases. A pronounced inflammatory reaction with neutrophilic infiltration around the thread groups was observed in the majority of animals in the prolene group. Foci of maturing granulation tissue with numerous capillaries were detected in the pores. In some animals of this group, the inflammatory reaction was moderate or slightly pronounced, with few neutrophils, eosinophils, giant cells, and foamy macrophages. In addition, there were zones of extensive growth of the connective tissue with sites of hyalinosis and fibrosis (Fig. 3, *a*, *d*).

Biomechanical factors play an important role in the development of postoperative and relapsing ventral hernias [1,3], and therefore, comparative trials of ME were carried out on a model of postoperative hernia reproducing the conditions maximally similar to the clinical ones, when surgical meshes implanted into the interfascial space were exposed for a long time to repeating mechanical loading. Six months after ME transplantation surgimesh ME characterized by high density of the fabric filling and limited mobility of structural elements were surrounded with heterogeneous connective tissue and exhibited a trend to encapsulation. Esfil ME with loose uneven structure and high mobility of the components supported the inflammatory reaction, presumably at the expense of mechanical trauma of the adjacent tissues. Prolene ME with stabilized structure, but with uneven filling of the fabric because of alternation of double loop columns and solitary stretches caused the greatest variety of tissue reactions: from pronounced inflammation to fibrosis and hyalinosis.

Hence, the loop type and finishing of the knitted fabric used for ME are essential for the intensity of inflammatory reactions and type of complications.

REFERENCES

1. V. I. Belokonev, T. A. Fedorina, Z. V. Kovalyova, *et al.*, *Pathogenesis and Surgical Treatment of Postoperative Ventral Hernias* [in Russian], Samara (2005), pp. 69-97.
2. A. P. Zhikharev, D. G. Petropavlovskii, S. K. Kuzin, and V. Yu. Mishakov, *Material Technologies in the Manufacture of Articles of Light Industry* [in Russian], Moscow (2004), pp. 53-90.
3. W. S. Cobb, J. M. Burns, K. W. Kercher, *et al.*, *J. Surg. Res.*, **129**, No. 2, 231-235 (2005).
4. J. Conze, A. N. Kingsnorth, J. B. Flament, *et al.*, *Brit. J. Surg.*, **92**, No. 12, 1488-1493 (2005).
5. U. Klinge, B. Klosterhalfen, J. Conze, *et al.*, *Eur. J. Surg.*, **164**, No. 12, 951-960 (1998).
6. B. Klosterhalfen, K. Junge, and U. Klinge, *Expert. Rev. Med. Devices*, **2**, No. 1, 1-15 (2005).
7. M. K. McDermott, I. S. Isaeva, and T. M. Thomas, *Hernia*, **10**, No. 2, 131-142 (2006).
8. F. A. Offner, *Meshes: Benefits and Risks*, Eds. V. Schumpelich *et al.*, Berlin (2004), pp. 161-169.