Original Research Article

Which mesh should be used to repair abdominal wall defect in peritonitis? An experimental study

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ABSTRACT

Background: In this study, following the Bogota bag closure of abdominal wall defects created in a rat peritonitis model, the short-term efficacy of polypropylene (PP) mesh (Prolene®, Ethicon), PP Mesh+Seprafilm®, polytetrafluoroethylene (PTFE) mesh [Infinit® Mesh (Gore)] and expanded PTFE (ePTFE) [Dualmesh®plus(Gore)] in the permanent repair of the defects was investigated.
Methods: 64 rats were used. The rats were randomized into four groups, each consisting of 16 subjects: PP mesh (Group 1), PP mesh+Seprafilm (Group 2), PTFE mesh (Group 3), and ePTFE mesh (Group 4). Laparotomy was performed and abdominal wall defects were created. Contamination of the peritoneal cavity was induced, and closure was undertaken using a Bogota bag. After three days, the Bogota bag was removed, and materials were placed. At the end of the follow-up period, the rats were sacrificed. Mortality, grade of adhesion, surgical site infection (SSI), and tensile strength were evaluated.
Results: Mortality was calculated as 6.3%, 50%, 25%, and 0% for Groups 1, 2, 3, and 4, respectively (p=0.002). Adhesion was observed at a rate of 61.1% in Group 1 and 38.9% in Group 2 (p=0.621). There was no adhesion in Groups 3 and 4 (p=0.001). The rate of SSI was 68.8% in Group 1, %75% in Group 2, and 100% in Groups 3 and 4 (p=0.022). Tensile strength was 2196±193.6 g/cm in Group 1 and 1906±142.1 g/cm in Group 2 (p=0.258).
Conclusions: We argue that PP mesh is a suitable prosthesis for the permanent repair of contaminated abdominal wall defects despite the increased adhesion risk.

Keywords: Abdominal wall, Polypropylenes, Polytetrafluoroethylene, Rats, Seprafilm

INTRODUCTION

It is not uncommon for surgeons to encounter cases where it is not possible to perform the primary closure of the abdominal wall after abdominal surgery. This is often seen in general surgery, trauma surgery, and surgical oncology. Examples of cases where the abdominal wall are not primarily closed are massive visceral edema due to resuscitation or loss of abdominal wall, increased intraabdominal pressure due to large retroperitoneal hematoma, excision of the abdominal wall due to neoplasia or necrotizing soft tissue infection, possibility of wound necrosis or infection under high pressure in abdominal compartment syndrome, visceral or peritoneal edema due to intraabdominal sepsis, or potential recurrent surgery.[1-4] These conditions are often accompanied by fecal contamination. The repair of contaminated abdominal wall defects remains a major challenge for surgeons. If possible, autogenous materials should be preferred for repair; however, in cases where the fascia is not sufficient, a prosthetic material can be used. Surgeons use various materials to temporarily close the abdominal

wall, including intravenous solution bags (Bogota bag), latex, Silastic layers, and a wide variety of mesh materials; e.g., nylon, polyglactin, polypropylene (PP), and polytetrafluoroethylene (PTFE).[1,5-13] Researchers have yet to reach a consensus regarding the type of material to be used.[14-16] A Bogota bag is often preferred because it is far more inexpensive and available compared to the other materials; however, PTFE or PP mesh is often used to close the abdominal wall defect after the removal of the Bogota bag.

Permanent prostheses must be flexible and foldable in order not to cause the erosion of the intestinal wall, inert to prevent an inflammatory response, perforated to allow drainage of fluids, non-carcinogenic, and stable in the presence of infections.[3,13] Carrying most of these properties, PP mesh is the most commonly used material. However, despite being a strong and inert material, it is also known to have disadvantages, such as increasing visceral adhesions and causing erosion in the skin and intestines. It also leads to further inflammatory response and fistula development in case of direct contact with the intestines. These complications and the difficulties in removing PP mesh have encouraged the search for new, better materials.[13,17]

PTFE mesh is an inert substance that causes very little tissue reaction and less adhesion. However, due to its structure, it has less resistance to infections in contaminated environments because during the wound healing process, the capillary tissue cannot move through the prosthesis and leukocyte migration is not possible.[13] Therefore, this study used an expanded PTFE (ePTFE) mesh containing silver carbonate and chlorhexidine diacetate, developed to reduce these disadvantages of the original material, and Seprafilm® [hyaluronic acid (HA) and carboxy methyl cellulose (CMC)], developed to eliminate the disadvantages of PP mesh and prevent intestinal contact.

METHODS

This study was conducted at the Experimental Animals Application and Research Center of Akdeniz University after obtaining the approval of the Ethics Committee for Animal Experiments of the university (approval code number 2003 04.0103.006). This study was carried out at the Experimental Animals Application and Research Center of Akdeniz University between 01,06,2004 and 30,06,2004. A total of 64 six- to eight-week-old male Wistar-Albino rats weighing between 180-290 gr were used. During the study, the rats were kept in groups of eight in specifically prepared cages with controlled temperature under light and dark conditions and provided ad libitum access to food and water. Antibiotics were not administered to any of the animals.

In this study, four different groups were randomly formed (Table 1): PP mesh (Group 1), PP mesh+Seprafilm (Group 2), PTFE mesh (Group 3), and ePTFE mesh (Group 4).

Table 1: Study groups.

Groups	Prosthetic material
Group 1	Polypropylene mesh
Group 2	Polypropylene mesh + Seprafilm
Group 3	Polytetrafluoroethylene mesh
Group 4	Expanded polytetrafluoroethylene mesh

After four hours of fasting, the rats were intramuscularly administered 37.5 mg/kg ketamine hydrochloride (Ketalar, Park Devis, Istanbul, Turkey) and 5 mg/kg xylazine (Rompun, Bayer, Istanbul, Turkey) as the anesthetic application. Midline laparotomy of 5 cm and skin and subcutaneous dissection were performed. A 1.5x3 cm muscle-fascia defect was created on the anterior abdominal wall. Fecal contamination was induced by injecting 1 ml of fecal solution prepared in peritoneum (1 g rat feces was suspended by mixing it with 20 ml isotonic). The anterior abdominal wall was closed using a 3.5x2 cm piece cut from an isotonic bag (Bogota bag) and continuous 4.0 polypropylene (Prolene, Ethicon, New Jersey) sutures. The skin was closed with continuous 4.0 prolene suture. After three days, the skin sutures were removed under anesthesia, and the Bogota bag was withdrawn. The peritoneum was washed with 50 cc isotonic. The abdominal wall defect was closed using four separate 3.5x2 cm prostheses through continuous 4.0 prolene suture at a distance of 0.5 cm from the fascia edge. The skin was closed with continuous 4.0 prolene suture (Figure 1).
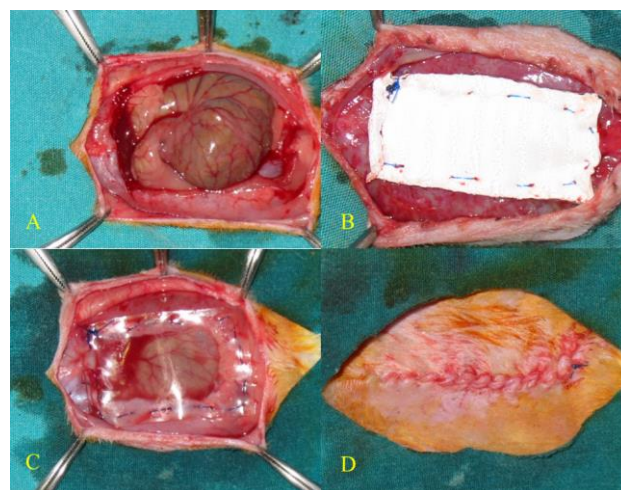
Figure 1: (A) Representative photographs of 1.5×3 cm defect was created on the anterior abdominal wall of rat, (B) representative photographs of rat abdominal wall with PTFE mesh, (C) representative photographs of implanted Bogota Bag, (D) skin suture with prolene 4-0.

Postoperatively, the rats were moved back to their cages and fed with standard food and water. During the follow-up period (either until the development of evisceration and fistulas or for three weeks), the rats were monitored on a daily basis. At the end of the follow-up period, the

rats were sacrificed. Preoperative weight, mortality, presence and degree of adhesion (Table 2), tensile strength (mesh-fascia separation force), and SSI development were evaluated (Table 3). The abdominal wall containing the defect was excised. The abdominal wall and the prosthesis were divided into two sections of 1 cm in the transverse plane using a scalpel. Tensile strength was measured by fixing the prosthesis-fascia junction of 1 cm in width at both ends and applying a constant increased force (1 g/cm).

Table 2: Classification of adhesions.

Grade 0	No adhesion
Grade 1	Adhesion is easy to separate from the prosthesis by blunt dissection
Grade 2	Adhesion is separated from the prosthesis by careful and sharp dissection
Grade 3	Adhesion is not separated from the prosthesis even by sharp dissection

Table 3: Preoperative weight, mortality, number and grade of adhesions, surgical site infection, and tensile strength values of the groups.

Variables		Group 1	Group 2	Group 3	Group 4	P value
Preoperative weight (g)		225.6±16.3	217.8±19.8	212.2±11.7	212.2±21.2	NS
Mortality n (%)		1 (6.3%)	8 (50%)	4 (25%)	-	0.002[1]
Adhesion n (%)		11 (68.8%)	7 (43.8%)	-	-	<0.001
Adhesion grade n (%)	0	4 (26.7%)	1 (12.5%)	-	-	NS
	1	2 (13.3%)	4 (50%)	-	-	NS
	2	9 (60%)	3 (37.5%)	-	-	NS
SSI n (%)		11 (68.8%)	6 (37.5%)	12 (75%)	16 (100%)	0.002[2]
Tensile strength (g/cm)		2280.55±642.04	2038.57±375.92	-	-	NS

NS: Not Significant, [1]The difference between groups 1 and 2 is significant (p=0,015)., [1]The difference between groups 2 and 4 is significant (p=0,002)., [2]The difference between groups 1 and 4 is significant (p=0,043).

Statistical analysis

Statistical analyses were performed using SPSS (version 22.0, SPSS, Chicago, IL, USA). For the categorical parameters, the chi-square or Fisher's exact test was conducted to obtain cross-tabulation, and for numerical parameters, the t-test and the Kruskal-Wallis test were used to evaluate the significance of the difference between the groups. The survival graph was constructed according to the Kaplan-Meier method, and survival analyses were performed using the log-rank test. P<0.05 was considered statistically significant.

RESULTS

The mean preoperative weight of the rats was 220±4.1 g (200-250 g) in Group 1, 217.5±4.9 g (180-250 g) in Group 2, 210±2.9 g (195-230 g) in Group 3, and 210±5.3 g (180-250 g) in Group 4. There was no statistically significant difference between the groups in terms of weight (Figure 2) (p=0.100). Evisceration and bowel fistula were not observed in any of the groups during the follow-up period.

Mortality

All deaths in rats were attributed to intraabdominal sepsis. The difference in the mortality rates between the four groups was statistically significant (p=0.002). The differences in the mortality rates were also statistically significant between Groups 1 and 2 and between Groups 2 and 4 (p=0.015 and p=0.002, respectively). There was no significant difference in the remaining paire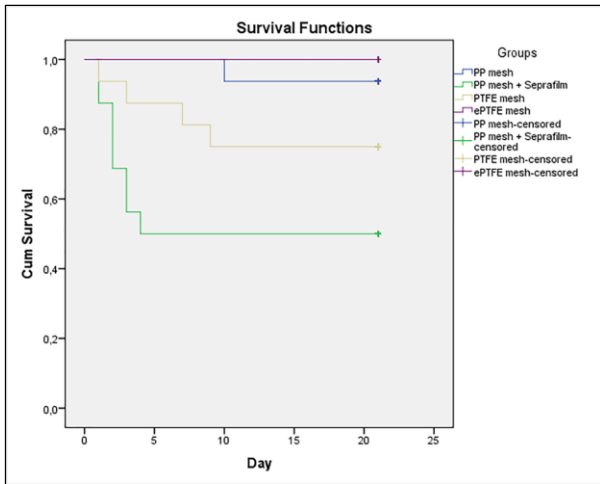d comparisons. When the Kaplan-Meier survival graphs were evaluated using the log-rank test, the results were statistically significant (p=0.001) (Figure 3). The log-rank test revealed statistically significant results for the comparison of Groups 1 and 2, Groups 3 and 4, and Groups 2 and 4 (p=0.0047, p=0.0353, and p=0.0012, respectively).
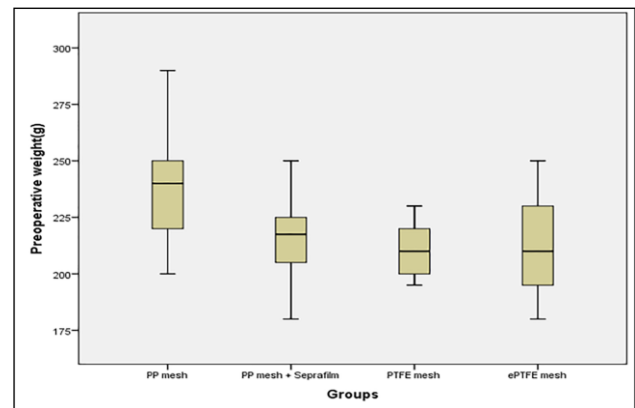
Figure 2: Kaplan-Meier survival graphs (p=0.001). Pre-operative mean weight values of the groups (p=0.100).

Adhesion

All adhesions were omental. Adhesion was not evaluated in Groups 3 and 4 since the patches did not adhere to the anterior abdominal wall. Although the use of Seprafilm seemed to reduce the risk of adhesion two-fold, the difference between Group 1 and Group 2 was not statistically significant (p=0.621).

Figure 3: Kaplan-Meier survival graph of the groups (p=0.001). The log-rank test revealed statistically significant results for the comparison of Groups 1 and 2, Groups 3 and 4, and Groups 2 and 4 (p=0.0047, p=0.0353, and p=0.0012, respectively).

Grade of adhesion

The percentage of grade 0 adhesion was 26.7% in Group 1 and 12.5% in Group 2. While the percentage of grade 1 adhesion was 13.3% in Group 1, it was 50% in Group 2, and that grade 2 adhesion was 60% and 37.5%, respectively. The grade of adhesion was not evaluated in Groups 3 and 4 because the meshes did not adhere to the anterior abdominal wall.

SSI

When the wound infection rate was evaluated for each group, it was found to be 68.8% in Group 1, 75% in Group 2, and 100% in Groups 3 and 4. There were statistically significant differences in the rate of SSI between the groups (p=0.022). In the paired comparisons of the SSI rates, the p value was calculated as 1.00 between Groups 1 and 2, 0.053 between Groups 1 and 3, 0.043 between Groups 1 and 4, and 0.147 between Groups 2 and 3.
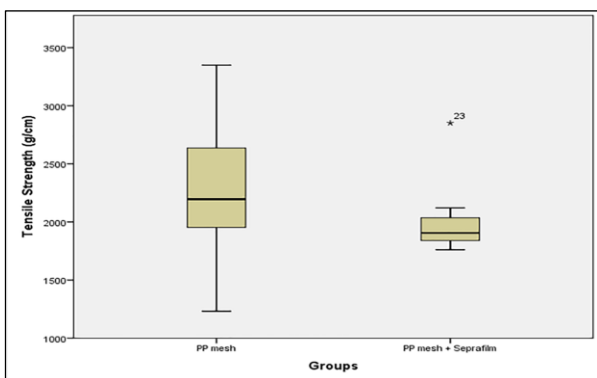
Figure 4: Mean tensile strength of Groups 1 and 2.

Tensile strength was 2196±193.6 g/cm in Group 1 and 1906±142.1 g/cm in Group 2 (Figure 4) (p=0.258). This parameter was not measured in Groups 3 and 4 because the mesh had not adhered to the fascia.

DISCUSSION

Boyd WC used PP mesh in eight patients to repair acute abdominal wall losses due to infection, but did not observe any mortality.[18] In this study, the mortality observed during the follow-up period was attributed to intraabdominal sepsis. The difference in the mortality rates between the four groups was statistically significant (p = 0.002). The mortality rate was 50% in Group 2 and it was much lower in Group 1 at 6.3% (p=0.015). This result suggests that the use of Seprafilm plus PP mesh in contaminated media increases intraabdominal sepsis and leads to mortality. In the evaluation of the remaining groups, the mortality rate was calculated as 25% in Group 3, while no mortality was observed in Group 4. The use of ePTFE mesh, unlike PTFE mesh, can reduce mortality associated with intraabdominal sepsis, although there is insufficient evidence in this regard. Similar to this study, Brawn et al, compared PP mesh and PTFE mesh in the repair of abdominal wall defects in the presence of contamination and found no difference in the mortality rates between the two groups.[19] Bleichrodt et al repaired contaminated abdominal wall defects in rats with PP mesh and PTFE mesh and found no statistically significant difference in the mortality rates between these two groups at the end of the follow-up period.[17] Consistent with the literature, in this study, the mortality rate was 6.3% in Group 1 and 25% in Group 3(p=0.333). No mortality was detected in Group 4(p=1.00). It can be stated that the sepsis-related mortality rate was similarly low in rats that received PP mesh and ePTFE mesh. There was no statistically significant difference between the mortality rate in group 2 and group 3(p=0.273). The absence of a significant difference between these two groups can be attributed to the similarly high sepsis-related mortality rates resulting from the use of Seprafilm plus PP mesh and the use of PTFE mesh. The difference between Group 2 and Group 4 was not statistically significant (p=0.002). It can be argued that the use of PTFE mesh or ePTFE mesh causes less mortality than the combined use of PP mesh+Seprafilm.

In a similar study by Alimoğlu et al adhesion was found to be less in the Seprafilm group.[20] Beck et al also found that adhesion rates decreased by approximately 50% after the use of Seprafilm.[21] Nohuz et al reported that Seprafilin was less adhesive than PP mesh.[22] Dinsmore et al created an abdominal wall defect in rabbits and placed Seprafilm between the mesh and the intestines before closing the defect with PP mesh. At the end of the follow-up period, the authors stated that the number of adhesions in the Seprafilm group was statistically significantly lower compared to the control group.[23] Unlike this study, the authors did not perform this experiment in a contaminated model. In this study, the rate of adhesion

was 68.8% in Group 1 and 43.8% in Group 2 (p=0.159). Although Seprafilm seems to have halved the risk of adhesion, this was not statistically significant. This may be due to the low number of rats evaluated for adhesion due to high mortality in the Seprafilm group. Similarly, the lower rate of high-grade adhesion in the Seprafilm group with no statistical significance can be attributed to the low number of rats evaluated for adhesion due to septic mortality. In a clinical study by Wietske et al it was reported that the incidence of adhesion did not decrease with the application of Seprafilm, but the severity of adhesion decreased.[24] Thus, their results were similar to the findings we obtained. Bleichrodt et al repaired contaminated abdominal wall defects in rats using PP mesh and PTFE mesh and observed that at the end of the follow-up period, the grade of adhesion in the PTFE mesh group was less compared to the PP mesh group.[25] In this study, we were not able to evaluate the grade of adhesion in the PTFE mesh group because no adhesion occurred in this group. Müller-Stich et al, who compared PP mesh and PTFE mesh in terms of adhesion, found the former to be more adhesive.[26]

In an experimental study by Dinsmore et al it was observed that the use of Seprafilm did not reduce the tensile strength between PP mesh and the fascia.[23] In this study, the tensile strength was 216±193.6 g/cm in Group 1 and 1906±142.1 g/cm in Group 2 (p=0.383). Based on these results, it can be stated that the use of Seprafilm does not reduce the fibrotic reaction between PP mesh and the fascia. In their study by Akçakaya et al it was compared to the tensile strength of PP mesh and PP mesh+seprafilm groups. They found it was much higher than the PP mesh group. A group was much higher than in the PP mesh group.[27] In this study, when the mean values were taken as the basis, the lack of statistical difference in Group 1 despite the high tensile strength may be due to the small sample size. Kayaoglu et al noted that the highest tensile strength was in the PP mesh group.[28]

Bleichrodt et al repaired contaminated abdominal wall defects in rats with using PP mesh and PTFE mesh, and at the end of the follow-up period, they found that 76.2% of the PTFE mesh group and 66.7% of the PP mesh group had SSI, and there was no statistically significant difference between the two groups in terms of the SSI rate.[15] In the current study, no adhesion was seen in any of the rats in the PTFE and ePTFE groups and all were found to develop SSI; therefore, the SSI rates of these two groups differed from that of the PP mesh group. Furthermore, the SSI rates were high in all study groups due to the mesh being applied to a contaminated wound.

The advantage of PP mesh is that it is not separated from the wound even in a contaminated environment and provides strong abdominal wall support. In addition, it does not increase mortality due to sepsis. The disadvantage of this application is that it increases adhesion. As a result of this experiment, it can be concluded that the combined use of PP mesh and Seprafilm tends to reduce adhesion, it may not be preferable for the repair of contaminated abdominal wall defects due to increased sepsis-related mortality.

The advantage of PTFE mesh is that there is no adhesion. In this study, adhesion and tensile strength could not be evaluated because PTFE mesh did not adhere to the wound. The use of PTFE mesh in contaminated wounds is associated with problems, such as high risk of SSI and non-adherence of the mesh to the wound. These two disadvantages are also valid for the application of ePTFE mesh.

In their review, Cevasco et al emphasized the lack of a consensus on where and how biological mesh should be used.[29] In this study, while sepsis-related mortality was 25% in the PTFE mesh group, no mortality was observed in the ePTFE mesh group. According to this result, it can be suggested that the increase in mortality due to intraabdominal sepsis, which is one of the disadvantage of using PTFE mesh in infected wounds, can be eliminated by using ePTFE mesh.

There are some limitations to this study. First, since the experiment was conducted on animals, further animal studies with a larger sample size are needed to confirm the results for in humans. Second, one of the criteria for SSI is occurrence of the infection within the first 30 days postoperatively and one year in wounds for which a prosthesis is used. Although we performed this experiment in a contaminated environment, this longest follow-up period was 21 days.

CONCLUSION

Based on this results, Authors argue that despite its high adhesion risk, PP mesh is a suitable prosthesis for the permanent repair of contaminated abdominal wall defects, whereas ePTFE mesh should be preferred in the temporary repair of such defects because it does not adhere to the abdominal wall or increase sepsis-related mortality.

ACKNOWLEDGEMENTS

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