Surg Today (2005) 35:223–227
DOI 10.1007/s00595-004-2907-1

SURGERY TODAY
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Comparison of Prosthetic Materials in Incisional Hernia Repair

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Abstract

Purpose. Incisional hernias are not uncommon after abdominal surgery, but their repair is associated with a high risk of complications, including adhesions and recurrence. Many different types of meshes and adhesion barriers have been developed in an attempt to overcome these problems, some of which we have assessed in a rat model.

Methods. We made a full-thickness 1.5 × 2.5-cm abdominal wall defect in 30 Sprague-Dawley rats, which were divided into three groups according to the materials used for repair: 2 × 3-cm polypropylene mesh (group 1); expanded polytetrafluoroethylene (PTFE) with double-layer polypropylene mesh (group 2); or polypropylene mesh with oxidized cellulose adhesion barriers (group 3). We assessed adhesion formation, tensile strength, and histopathologic findings.

Results. The mean adhesion scores were 3.3, 1.3, and 0.7, in groups 1, 2, and 3, respectively ($P < 0.001$). The area involved by adhesions was significantly greater in group 1 than in groups 2 or 3 ($P < 0.01$, $P < 0.05$), but there was no significant difference between groups 2 and 3 ($P < 0.05$). The tensile strength in group 2 was less than that in groups 1 or 3 ($P < 0.01$, $P < 0.05$), but there was no significant difference between groups 1 and 3 ($P > 0.05$).

Conclusion. Although there was less adhesion formation with PTFE and oxidized cellulose, PTFE not only impaired the tensile strength, but also induced fibrosis and inflammation. An oxidized cellulose adhesion barrier can be safely used in incisional hernia repair to prevent intra-abdominal adhesions.

Key words Prosthetics · Incisional hernia · Rat model

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Received: May 12, 2003 / Accepted: November 4, 2003

Introduction

Incisional hernias are still a frequent complication of abdominal surgery, occurring after 2%–11% of all laparotomies.[1–3] According to the literature,[4–6] large incisional hernias of more than 10 cm in diameter have a recurrence rate of 20%–54% if they are repaired by simple suturing or autoplasty. This recurrence rate increases with the size and diameter of the muscular defect, and with obesity and chronic constipation.[5–7] Tension on the suture line is considered the main cause of recurrence; however, many researchers have found that prosthetic materials such as polypropylene (Marlex, Prolene), polyester (Mersilene, Parietex Composite, Polyester Composite), and expanded polytetrafluoroethylene (PTFE) (Dualmesh, Composix) are well tolerated and associated with a remarkably lower recurrence rate, varying from 0% to 10%.[8–15] Using a rat model of incisional hernia, we compared the adhesion formation, durability, and early complications of repair using polypropylene mesh, polypropylene mesh with an adhesion barrier (oxidized cellulose), and PTFE-coated double-layer polypropylene mesh.

Materials and Methods

Thirty male Sprague-Dawley rats weighing 210–240 g were divided into three groups of ten, for repair of an abdominal wall defect with the following meshes: Group 1, polypropylene mesh (Bard Mesh, monofilament knitted polypropylene; Bard, Crawley, UK); Group 2, PTFE-coated double-layer polypropylene mesh (Bard Composix Mesh, double-layer Bard polypropylene mesh bound on expanded polytetrafluoroethylene; Bard, Crawley, UK); Group 3, polypropylene mesh (Bard Mesh, monofilament knitted polypropylene; Bard, Crawley, UK), with an oxidized cellulose adhesion barrier (Interceed, TC7, oxidized

regenerated cellulose; Ethicon, Cincinnati, OH, USA). The rats were kept at room temperature, fed standard laboratory chow, and allowed tap water ad libitum.

Operative Technique

All operations were done under sterile conditions. The rats were given ether inhalation anesthesia followed by 20 mg/kg intramuscular ketamine (Ketalar, Eczacibasi, Turkey) with further ether inhalation for maintenance. Cephazoline sodium injection (Sefazol; Mustafa Nevzat, Turkey) was given as a prophylactic antibiotic.

We made a 3-cm median transadbominal incision and decollated the subcutaneous tissue from the anterior abdominal wall. A 1.5 × 2.5-cm plastic template was formed, which was placed on the anterior abdominal wall, with the long axis vertically, and a defect involving all the layers of the abdominal wall was made. The defect was then repaired with 2 × 3-cm mesh. Polypropylene mesh, Composix mesh, and polypropylene mesh with Interceed were used in groups 1, 2, and 3 respectively. The mesh was placed intraperitoneally using single 4/0 polypropylene (Prolen; Ethicon) sutures, and the skin incision was closed with continuous 3/0 silk sutures (Dogsan, Turkey).

The rats were killed on postoperative day (POD) 14 by an overdose of ether and examined for abdominal adhesions. A bilateral subcostal incision was made and the skin was decollated from the anterior abdominal wall caudally. We evaluated the severity of adhesions using the scale described by Blauer and Collins[16] (Table 1). The abdominal wall was excised, together with the mesh, and different-sized templates comprised of 25%, 50%, or 75% of the mesh were used to measure the percentage of adhesions. The percentage of adhesion formation was recorded for each rat.[17]

After dissecting the adhesions, 2.0 × 0.5-cm tissue bands, consisting of both the anterior abdominal wall and the mesh, were excised without removing the sutures. The tensile strength of the tissue pieces were measured with a mechanism known as the Udupa model.[18] The excised specimen was examined histologically using hematoxylin–eosin staining. We evaluated collagen formation, giant cell and granuloma formation, fibrosis, and the degree of inflammation.

Table 1. Macroscopic evaluation scale of adhesions according to Blauer and Collins[16]

Grade	Findings
0	No significant adhesions
1	Thin, narrow, and easily detachable adhesions
2	Thick adhesions limited to one area
3	Thick and broad adhesions
4	Thick and broad adhesions, involving the anterior or posterior abdominal wall, and the viscera

Statistical Analysis

Statistical analysis was done using the SPSS V.10 program. We used nonparametric tests because of the small number of rats. Qualitative data were evaluated with the χ^2 test. Quantitative data were evaluated with the Kruskall-Wallis test (KW) and subgroups were compared using Dunn's test.

Results

One of the rats from group 2 died on the 5th postoperative day and we found a diffuse intra-abdominal abscess at autopsy. This rat was excluded from the final analysis. Two other rats in group 2 had wound infections and one had an incisional hernia. There was no morbidity or mortality in the other groups.

Five rats in group 1 had severe grade 4 adhesions between the liver and small bowel and abdominal wall. Most of the rats had adhesions involving 50%–75% of the mesh, which could only be excised by sharp dissection. Only two rats in group 1 had limited adhesions involving less than 25% of the mesh area. Two rats with a recurrent incisional hernia in group 2 had grade 4 adhesions involving more than 50% of the mesh, but we were able to divided these adhesions with blunt dissection. There were no adhesions in three of the rats in group 2 and four in group 3. The rats in these groups tended to have limited adhesions involving less than 25% of the mesh area, which could easily be detached.

Figures 1, 2, and 3 show grade 1, 3, and 4 adhesions, respectively. According to the adhesion scoring system

Fig. 1. Thin, narrow, and easily detachable adhesions (grade 1) seen in a group 3 rat after incisional hernia repair with polypropylene mesh and the oxidized cellulose adhesion barrier

Table 2. Comparison of adhesions and tensile strength in the three groups

	Group 1 ($n = 10$)	Group 2 ($n = 9$)	Group 3 ($n = 10$)	Statistical analysis	
Adhesions score (grade)	3.3 ± 0.82	1.3 ± 1.58	0.7 ± 0.67	χ^2: 21.28	$P < 0.001$
Percentage of the adhesions (%)	51 ± 17.60	20 ± 22.22	12 ± 13.78	KW: 11.51	$P < 0.01$
Tensile strength (g)	1428 ± 20.43	1358 ± 73.21	1422 ± 16.86	KW: 14.61	$P < 0.001$

χ^2, chi-square test; KW, Kruskall-Wallis test

Fig. 2. Thick and broad adhesions (grade 3) seen in a group 1 rat after incisional hernia repair with polypropylene mesh

Fig. 3. Thick and broad adhesions, involving the anterior abdominal wall and the viscera (grade 4) seen in a group 2 rat after incisional hernia repair with polytetrafluoroethylene-coated double-layer polypropylene mesh

we used, group 1 had the highest scores whereas groups 2 and 3 both had lower scores (Table 2). The adhesion scores were significantly different among the three groups (χ^2 21.28, $P < 0.001$).

Table 2 shows the grade and ratio of adhesions involving mesh area. The percentages of adhesions were significantly different among the three groups (KW 11.51, $P < 0.01$). The percentages in group 1 were significantly higher than those in groups 2 ($P < 0.01$) and 3 ($P < 0.05$), but there were no significant differences between groups 2 and 3 ($P > 0.05$). The statistical tests were done with Dunn's test. Table 2 also shows the mean tensile strength. There were significant differences among the three groups (KW 14.61, $P < 0.001$). The tensile strength in group 2 was significantly lower than that in group 1 ($P < 0.01$) and that in group 3 ($P < 0.05$), but there was no significant difference between groups 1 and 3 ($P > 0.05$). Dunn's test was used to compare the results.

Table 3. Histopathologic findings in the three groups

Histopathologic findings	Group 1	Group 2	Group 3
Collagen arrangement	×	×××	×/××
Fibrosis	××/×××	×××	××/×××
Giant cell formation	××	×/××	×
Granuloma formation	××	×/××	×
Inflammation	××	××/×××	××

0, None; ×, mild; ××, moderate; ×××, severe

Histologically, there was less collagen formation in group 3 than in the other two groups. Comparing the histiocytic reaction, and the giant cell and granuloma formation, group 3 had the lowest scores, group 2 had low to moderate scores, and group 1 had moderate scores. The degree of the fibrosis and inflammation were similar among the three groups (Table 3).

Discussion

The ideal mesh type for incisional hernia repair is a subject of much debate because each material has advantages and disadvantages.[18–21] Polypropylene and polyester meshes are associated with severe foreign body reaction. They slow down the formation of the mesothelial cell layer in repaired defects, precipitating dense scar tissue surrounding the irregular surface and mesh fibers. Experimental studies show that the incidence of adhesion formation is 80%–90%. A large

peritoneal defect with direct contact between the mesh and intra-abdominal organs might result in adhesion formation, mechanical bowel obstruction, and fistulas.[16,22]

Although surgical technique is known to be a major contributing factor to de novo adhesions, the relative contribution of individual components is more controversial. Scott-Coombes et al.[23] performed a survey of surgeons' perceptions of adhesion formation. A number of preventive measures were generally accepted, such the wearing of starch-free gloves (78% of surgeons), performing peritoneal lavage (68%), and placing the omentum beneath the wound (90%), whereas other measures, such as the routine wetting of swabs (39%) and carrying out nonessential adhesiolysis (49%), were controversial.

Adhesion barriers prevent adhesion formation without activating tissue inflammation and bacterial growth. They can be used either in laparoscopic procedures or at laparotomy, with or without suturing.[24] Hyalunoric acid and carboxymethylcellulose (HA-CMC) and oxidized regenerated cellulose (ORC-Interceed) are the most frequently used adhesion barriers. In an experimental study comparing the tensile strength of polypropylene and PTFE meshes, although polypropylene was found to be stronger in the first 20 days, and PTFE mesh was stronger on the 80th day, there was no significant difference between the two.[25] The Composix mesh prosthesis proved suitable for implantation in abdominal wall defects, showing favorable biocompatibility and integration with minimal side effects. After implantation, adequate tensile strength and a low modulus of elasticity were detected in the restored zone, conferring great adaptability to the abdominal wall.[26] In our study, the mean tensile strength was lower in the PTFE-coated double-layer polypropylene mesh group than in other groups. The tensile strength of the tissues in the two rats with hernia recurrence was also lower than that in the other rats. The recurrence was attributed to the PTFE covering the mesh because PTFE is thought to prevent the mesh holding onto the tissue. A study comparing polypropylene and PTFE, for postoperative infection, adhesions, hernia recurrence, and tissue reactions, revealed no significant difference in the incidence of infection and hernias versus a control group of rats.[27]

Sahin et al.[27] reported that there was no collagen deposition in PTFE and that the mononuclear inflammatory cell reaction and fibroblastic activity outside the graft layer were invariably less severe with PTFE than with polypropylene. We detected more collagen formation in the PTFE-coated double-layer polypropylene mesh group than in the polypropylene mesh group in this study, which we attributed to the double layer of polypropylene. Collagen formation was less intense in the oxidized cellulose adhesion barrier plus polypropylene group. When the histiocytic reaction, giant cell, and granuloma formation were compared, polypropylene mesh and the oxidized cellulose adhesion barrier groups had the lowest scores, the PTFE-coated double-layer polypropylene mesh group had low to moderate scores, and the polypropylene group had moderate scores. The fact that fibrosis and inflammation were similar in all groups indicated that the oxidized cellulose adhesion barrier had no influence in this regard. An intra-abdominal abscess developed in one rat from the PTFE group, which we thought was related to the free space between the polypropylene and PTFE layers in the PTFE-coated double-layer polypropylene mesh, providing a medium for bacterial colonization. On the other hand, no infection occurred in the oxidized cellulose group. An oxidized cellulose adhesion barrier is easier to apply than PTFE-coated double-layer polypropylene mesh, and it does not need to be fixed to the tissue. Moreover, PTFE-coated double-layer polypropylene mesh is not generally used in laparoscopic surgery because it is not bendable or elastic.

In conclusion, the oxidized cellulose adhesion barrier, when combined with polypropylene, inhibits the formation of adhesions, does not adversely affect the tissue's tensile strength, and is less expensive than PTFE-coated double-layer polypropylene mesh. Thus, we recommend the oxidized cellulose adhesion barrier as a safe and effective material to use in incisional hernia-repairing procedures.

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