CIRUGÍA ESPAÑOLA

www.elsevier.es/cirugia

Special article

The labyrinth of composite prostheses in ventral hernias

José Luis Aguayo-Albasini, Alfredo Moreno-Egea, and José Antonio Torralba-Martínez*

Servicio de Cirugía General, Hospital General Universitario Morales Meseguer, Murcia, Spain

ARTICLE INFO

Article history:
Received July 1, 2008
Accepted January 9, 2009
Online June 21, 2009

Keywords:
Abdominal wall
Incisional hernia
Composite prosthesis
Biomaterials

A B S T R A C T

Reinforcement or replacement are increasingly being used in the repair of incisional hernias. In many occasions it is necessary to place the prosthesis in the intraperitoneal plane, for which the so called «composite» or bilaminar prostheses have been designed.

A terminological precision is made in this article, defending the denomination of dual or "composite" prosthesis for these materials, and the different commercial available options at present are related. The numerous suitable alternatives on the market can do that the surgeon is in a labyrinth.

A review of the experimental and clinical studies that support their use, efficiency, safety and complications is included. It concludes by recommending the prostheses for which there is consistent documentary evidence: Bard Composix, Dual Mesh, Parietex Composite, Parietene Composite, and Proceed. However, longer term studies and randomised clinical trials are needed to make stronger recommendations.

El laberinto de las prótesis composite en las eventraciones

Palabras clave:
Pared abdominal
Eventraciones
Prótesis *composite*
Biomateriales

R E S U M E N

Los materiales protésicos de refuerzo o sustitución se emplean cada vez con mayor frecuencia en el tratamiento de las eventraciones. En muchas ocasiones es necesario ubicar la prótesis en plano intraperitoneal, para lo cual se han diseñado las llamadas prótesis composite o bilaminares.

En este artículo se realiza una precisión terminológica, defendiendo la denominación de prótesis dual o *composite* para estos materiales y se relacionan las diferentes opciones comerciales disponibles en la actualidad. Las numerosas alternativas elegibles en el mercado pueden hacer que parezca al cirujano que se encuentra en un laberinto.

Se añade una revisión de los estudios experimentales y clínicos que avalan su utilización, su eficacia, su segurid ad y sus complicaciones. Se concluye recomendando las prótesis sobre las que existe un acervo documental más consistente: Bard Composix, Dual Mesh, Parietex, Parietene Composite y, recientemente, Proceed. No obstante, son necesarios estudios a largo plazo y ensayos clínicos aleatorizados para proporcionar recomendaciones de mayor potencia.

**Corresponding author.*
E-mail address: josel.aguayo@carm.es (J.L. Aguayo-Albasini).

Introduction

The results of traditional surgical treatment for ventral hernia were very unfavourable, with high complication and relapse rates, until prosthetic material began to be used for repairing defects in the abdominal wall. The characteristics of the prosthesis and where it should ideally be located along different planes of the abdominal wall are topics for constant debate.[1] At times, whether due to the extension of the defect or to the use of the laparoscopic approach, it is necessary to place the prosthesis intraperitoneally, and therefore right against the abdominal organs. Furthermore, the laparoscopic method is gaining an increasing number of supporters because it adheres closely to the principles of minimally invasive surgery.[2-4] When the prosthesis will be in contact with the abdominal viscera, which type should be used? Surgeons' fear of peritoneal adhesion, intestinal obstruction, fistulisation, etc, has brought about research and design of materials that may be ideal for the abdominal wall-peritoneal interface. We will now review the concepts including mesh, prosthesis, etc, the meaning of "composite," the different models that exist on the market, and some of the experimental and clinical studies that have taken place with these biomaterials.

Basic concepts

We frequently hear or read the terms "mesh," "prosthesis," "laminar," "hybrid," "dual," "composite," etc. Let us take a moment to clarify these concepts. Mesh: fabric made of thread or wire with an open weave that leaves holes[5]; prosthesis: artificial part that replaces or reinforces part of the body[5]; hybrid: generally refers to items stemming from 2 different sources or having 2 different natures[5]; dual: applying to items that have or contain 2 aspects or which refer to 2 things, etc[5]; laminar: having a leaf-shaped form (a thin, flat section of any material)[5]; composite: signifying a material made up of two or more distinct parts).[6]

When referring to a prosthetic reinforcement or replacement for intraperitoneal use, it is common to use the terms "composite mesh," "bilaminar/dual-layer mesh," or "bilaminar match." However, all of these terms are conceptually incorrect; as we all know, one of the components of these prostheses is a sheet, rather than a mesh, and no prosthesis contains 2 sheets. Therefore, more appropriate terms would be "compound prosthesis," "dual-layer patch," or the more common "composite prosthesis." The term "hybrid" is only used when 2 materials are present within the same structure (a mesh for example), and normally one is absorbable and the other is not.

Composite prostheses

As stated above, these materials are necessary for repairing defects in the abdominal wall when the prosthesis is attached within the peritoneal cavity. These biomaterials are designed to have 2 properties: on their parietal side, excellent integration into the abdominal wall, lending it strength and resistance; and on the visceral side, good interaction with the visceral peritoneum, meaning that it would provoke a minimum amount of adhesion and its sequelae, intestinal obstruction, or fistulisation.

Biomaterials used in the abdominal wall are continuously being perfected[7] and for now, the ideal dual-layer or composite prosthesis does not exist. As for the behaviour of the prosthesis, the importance of its structure has been evaluated more than the importance of its composition.[8] Consequently, reticular or macroporous materials with a pore size >75 µm (polypropylene or polyester mesh) have shown excellent parietal integration, but on the contrary, they may generate some concern about their effects on the peritoneum (adhesion, obstruction, erosion, fistula, etc). Laminar or microporous materials (ePTFE with pores from <10 to 75 µm) are known for their good coexistence with the peritoneum, but they lead to worse parietal integration with a risk of encapsulation.[9] This is how the idea arose of designing a dual-property prosthesis by modifying the structure or composition of the available materials to make a dual composite prosthesis (DCP). The first, or parietal component of a DCP is the reinforcement, made from ePTFE, polypropylene or polyester; the second, visceral component is an anti-adhesive barrier that may be chemical (absorbable) or physical (non-absorbable).

E-PTFE is a special case, because is a single material that can be used to make a DCP. During the search for solutions to its problems, the prosthesis evolved from the single-sheet of ePTFE (Soft Tissue Patch) to the perforated sheet (Micro Mesh) and subsequently became composed of 2 face-specific layers: a textured parietal side to promote integration, and an anti-adhesive sheet on its visceral side (DualMesh Corduroy).[10]

The rest of the DCPs are made of polypropylene or polyester mesh as a reinforcing component with an added chemical or physical anti-adhesive barrier on the visceral side. The chemical or absorbable products include sheets of collagen-polyethylene glycol-glycerol, hyaluronic acid-carboximethyl cellulose, oxidised regenerated cellulose, and omega-3 acid. The physical or non-absorbable products include silicone, polyurethane, and ePTFE once again. The different DCPs that are on the market are listed in Table 1.

New materials exist based on lightweight concepts and including a smaller proportion of non-absorbable material in the prosthesis, which is thought to decrease the local inflammatory reaction and increase postoperatory well-being.[11] We also find acellular biological prostheses that may be either xenogenic (Surgisis)[12] or allogenic (AlloDerm)[13] which foster integration, vascularisation and infection resistance, and bioactive materials with the ability to liberate growth factors locally. However, giving details about these devices is not within the scope of this article.

Experimental studies in animals

Numerous studies[14-49] have been carried out to evaluate DCP behaviour in the abdominal-peritoneal wall interface

Table 1 – Dual-layer or composite prostheses. Alphabetical order

	Manufacturer	Parietal side	Visceral side
Bard Composix LP	CR Bard	Polypropylene	ePTFE
C-QUR Edge	Atrium	Polypropylene	Omega 3 fatty acids
DualMesh	WL Gore & Associates	Textured ePTFE	Smooth e-PTFE
HI-TEX Endo IA	Bioser	Polyester	Polyurethane
Intramesh T1	Cousin-Biotech	Polypropylene	ePTFE
Microval Intro	Microval	Polypropylene	Silicone
Parietex Composite	Sofradim, Covidien	Polyester	Collagen, polyethylene glycol, glycerol
Parietex Composite	Sofradim, Covidien	Polypropylene	Collagen, polyethylene glycol, glycerol
PL-PU 99	JM Bellón	Polypropylene	Polyurethane
Proceed	Ethicon	Polypropylene and PDS	Oxidised regenerated cellulose
Sepramesh	Genzyme Surgical Corporation	Polypropylene	Hyaluronic acid and carboxymethyl cellulose
Surgimesh WN Non-Stick	Aspide Medical	Polypropylene	Silicone
Ti-Mesh	GfE Medizintechnik GmbH	Polypropylene	Titanium[a]

[a]Although this prosthesis is manufactured for intraperitoneal use, the titanium covers a lightweight polypropylene mesh with no anti-adhesive layer on the visceral side.

with regard to reinforcement and integration, creation of neoperitoneum, induction of the adhesion phenomenon, and resistance to bacterial contamination and infection (Table 2). This research has generally been done on a short-term basis in small animals and with small amounts of biomaterial, and results have been highly variable if not contradictory. Contrasted, acceptable results exist for Dual-Mesh, Parietex, and Parietene Composite, Bard Composix, and most recently, Proceed. The advantage of this last prosthesis is that its reinforcing component is made of low-density polypropylene mixed with absorbable polydioxanone (PDS). All of the above products, which obtain better or worse results depending on the study, are sufficiently strong, foster new peritoneal formation over the prosthesis in 1-2 weeks with very little adhesion, and provide a good defence against bacterial contamination. In general, macroporous prostheses are better at integrating and resisting infection than microporous or laminar prostheses. In practice, there have not been enough studies to evaluate other DCPs.

Clinical studies

There is already a significant body of work available[50-83] containing studies on the clinical results for strength, integration, adhesion syndrome (and its complications, such as obstruction or fistulisation) and local infection in conjunction with DCP use. Some investigations evaluate a single prosthesis type and others compare different materials. In addition, the approach may vary from open surgery in some to laparoscopic surgery in others (Table 3). The most widely-used material is e-PTFE and the composite prostheses Bard Composix and Parietex Composite; clinical references to Proceed[84,85] are also beginning to appear.

With regard to strength and integration and the relapse rate, studies are not conclusive. Among other reasons, this is because multiple factors—such as the hernia and patient characteristics, the surgical technique that is used, the infection, etc—exert a significant influence on results. With respect to the adhesion syndrome, which is an obvious cause of concern for the surgeon, studies using dynamic ultrasound, and findings from abdominal reinterventions[68,86,87] give significant adhesion rates between 5% and 15%; here, the greatest problem is adhesion of the mesh to the viscera (fundamentally the intestinal loops), resulting in added difficulty for new procedures and the risk of fistulation. In either case, incarcerated ileum or subsequent/recurring intestinal obstruction have not been recorded more frequently than after any other similar type of procedure.

The troublesome enterocutaneous fistulae are absent or have a frequency of less than 2% in most series (when they do arise, it tends to be in cases where open surgery was performed), and it is difficult to determine whether they are caused by the DCP itself, its attachment mechanisms, loss of serous membrane, or by infection. Either way, there is a risk and the patient should be informed.

With regard to infection, the use of composite prostheses is accompanied by a higher risk during healing than if no prosthesis was used, but it is similar to the risk involved when implanting any foreign material. Infection is clearly associated with open surgery techniques and can reach a rate of 5%, particularly when ePTFE is used (for which reason this material now tends to be impregnated with an antimicrobial agent). Infection is very rare if the procedure uses the laparoscopic approach: about 1%. In either case DCPs should not be used to treat hernias in infected or potentially contaminated sites. For cases like these, modern absorbable biological prostheses that leave no permanent material behind may come to play a major role.[12,13]

Other complications and sequelae from DCP use are hernia sac seroma (very frequent following laparoscopic repair), shrinkage or retraction of the prosthesis, and postoperatory pain. It seems that seroma is more persistent following the use of microporous material, but there are no conclusive studies. Shrinkage or retraction of biomaterial may range between 10% and 40%, and therefore a wide overlapping

Table 2 – Experimental studies in animals

	PLP	DM	BCx	PtxC	PtnC	SM	ProC	PU99	TiM
Amid, 1995[14]	X	X (v)							
Malazgirt, 2000[15]						X (v)			
Baptista, 2000[16]	X					X (v)			
Greenawalt, 2000[17]	X		X			X			
Bellón, 2001[18]		X (v)		X					
Ferrando, 2002[19]	X	X(v)	X						
Bellón, 2002[20]			X (v)						
Bellon, 2002[21]	X							X	
Bellón, 2002[22]			X	X				X	
van Riet, 2003[23]	X			X		X			
Matthews, 2003[24]	X	X							
González, 2004[25]	X	X	X	X	X	X			
Jhonson, 2004[26]		X				X			
Young, 2004[27]		X				X			
Borrazo, 2004[28]	X	X				X			
Duffy, 2004[29]			X	X					
Felemovicius, 2004[30]	X					X			
McGinty, 2005[31]	X	X		X					
Matthews, 2005[32]		X	X			X			
Kayaoglu, 2005[33]	X	X(v)		X		X			
Bellón, 2005[34]								X	
Bellón, 2005[35]			X (v)	X		X		X	
Bellón, 2005[36]	X					X			
Demir, 2005[37]	x		x				X (v)		
Harrel, 2006[38]	X	X	X				X		
Schönleben, 2006[39]	X				X (v)				
Burger, 2006[40]	X	X		X		X	X		X
Martín, 2006[41]	X	X							
Schug-Pass, 2006[42]		X							X
Bellón, 2006[43]	X	X				X			
Sikkink, 2006[44]	X		X		X	X			
Novitsky, 2006[45]	X		X				X		
Bellón, 2007[46]	X	X	X	X				X	
Judge, 2007[47]				X		X			
Jacob, 2007[48]	X			X			X		
Olmi, 2007[49]				X					

The boxes corresponding to the materials being used are marked. Some investigations use other materials which are not listed in the table in order to simplify this article.
(v) indicates variants; BC, Bard Composix; DM, Dual Mesh; PL, polypropylene, Pro, Proceed; PtnC, Parietene Composite; PtxC, Parietex Composite; PU-99, PL-PU 99; SM, Sepramesh; TiM: Ti-Mesh.

margin is required at the time of implantation; it also appears that this affects ePTFE even more. Post-op pain has no significant relation with the type of DCP described; rather, it seems to be related to the attachment procedure (transfacial sutures, tackers, nitinol staples, etc) and also to the amount of implanted biomaterial. For this reason, prostheses that incorporate lightweight or hybrid material in the reinforcing component[88,89] appear to have a promising future.

Finally, we must point out that the complication rates that have been recorded are not what one might expect from a technique that leaves material in the peritoneal cavity. There are even some articles that describe the use of polypropylene mesh with no added protection and without higher complication rates.[90] Other studies, however, warn that its use in this area is not appropriate.[91-93] There are no definitive studies of this topic. From a monetary viewpoint, DCPs are expensive, but no more so than the materials used in other specialties. For example, a reinforcement measuring 20×25 cm is priced at 1000 to 1200 euros, although this sum may vary according to the agent and manner of purchase.

Conclusions

The surgeon who enters the world of DCPs for the first time goes deep into a labyrinth and may feel lost among the many available options. Experimental and clinical studies have shown that these dual-layer patches are effective and safe. However, there are no powerful, evidence-based data to show which is the best, and therefore the choice rests on the surgeon's opinion alone at this moment. As we wait for long-term studies and randomised trials, it seems sensible to recommend the DCPs that are the most widely-used and best known. These are, in alphabetical order: Bard Composix,

Table 3 – Clinical investigations

	Method	Cases	DM	BC	PtxC	PtnC
LeBlanc, 1993[50]	Lap	5	X(v)			
Heniford, 2000[51]	Lap	100	X			
Carbajo, 2000[52]	Lap	100	X			
LeBlanc, 2000[53]	Lap	100	X			
Balique, 2000[54]	Lap/Om	80			X	
Heniford, 2000[55]	Lap	407	X			
Crisos, 2000[56]	Om	52	X			
de María, 2000[57]	Om/Lap	39	X			
Moreno Egea, 2001[58]	Lap	20			X	
Parker, 2002[59]	Lap	50	X	X		
Aura, 2002[60]	Lap	86	X			
Ben-Haim, 2002[61]	Lap	100	X (v)			
Moreno-Egea, 2002[62]	Lap	55			X	
Cobb, 2003[63]	Om	95		X		
Heniford, 2003[64]	Lap	850	X			
Díaz, 2004[65]	Om	55	X			
Ammatur,o 2004[66]	Om	26			X	
Balique, 2004[67]	Lap/Om	80			X	
Lermite, 2004[68]	Om	26			X	
Moreno-Egea, 2004[69]	Lap	86			X	
Denue, 2005[70]	Om	52			X	
Edwards, 2005[71]	Lap	65	X	X		
Yavuz, 2005[72]	Lap	150	X	X		X
Topart, 2005[73]	Lap	146	X			
Morales-Conde, 2005[74]	Lap	146	X			
Olmi, 2006[75]	Lap	178			X	
Johanet, 2006[76]	Lap	222			X	
Hadi, 2006[77]	Om	51		X (v)		
Beldi, 2006[78]	Lap	49				X
Lomanto, 2006[79]	Om/Lap	100			X	
Chelala, 2006[80]	Lap	400			X	
Cobb, 2006[81]	Lap	120	X			
Stickel, 2007[82]	Lap	62	X			
Bernard, 2007[83]	Om	61		X		

(v) indicates variant; BC, Bard Composix; DM, Dual Mesh; Lap, laparoscopic method; Om, open method; PtnC, Parietene Composite; PtxC, Parietex Composite.

DualMesh and Parietex, and Parietene Composite. Proceed may also be heading toward an important role. Lastly, it is very important that all groups using these patches publish the results from their studies, as well as any adverse effects that may arise.

REFERENCES

1. Martínez DA, Vázquez JL, Pellicer E, Aguayo JL, Morales G, Moreno-Egea A. Results of expanded polytetrafluroethylene in moderate and large incisional hernias. Hernia. 1999;3:149–52.
2. Goodney PP, Birkmeyer CM, Birkmeyer JD. Short-term outcomes of laparoscopic and open ventral hernia repair. A metaanalysis. Arch Surg. 2002;137:1161–5.
3. Misra BC, Bansal VK, Kulkarni MP, Pawar DK. Comparison of laparoscopic and open repair of incisional and primary ventral hernia: results of a prospective randomized study. Sur Endosc. 2006;20:1839–45.
4. Barbaros U, Asoglu O, Seven R, Erbil Y, Dinccag A, Deveci U, et al. The comparison of laparoscopic and open ventral hernia repairs: a prospective randomized study. Surg Endosc. 2007;11:51–6.
5. Moliner M, editor. Diccionario del uso del español. Madrid: Gredos; 1998.
6. Kirkpatrick EM, editor. Vox Chambers english learners dictionary. Barcelona: Biblograf; 1990.
7. Morales Conde S, Barreiro Morandeira F. Cirugía de la hernia: nuevos conceptos, nuevas perspectivas. Cir Esp. 2008;83:165–6.
8. Bellón JM. Propuesta de una nueva clasificación de pótesis destinadas a la reparación de defectos herniarios en la pared abdominal. Cir Esp. 2005;78:148–51.
9. Eriksen JR, Gögenur I, Rosenberg J. Choice of mesh for laparoscopic ventral hernia repair. Hernia. 2007;11:481–92.
10. LeBlanc KA. Prosthetic biomaterials in the laparoscopic repair of incisional and ventral hernias. In: Morales-Conde S, editor. Laparoscopic ventral hernia repair. Paris: Springer-Verlag France; 2002. p. 139–59.
11. Veyhe D, Belyaev O, Müller C, Meurer K, Bauer KH, Papapostolou G, et al. Improving outcomes in hernia repair by the use of light meshes—a comparison of different implant constructions based on a critical appraisal of the literatura. World J Surg. 2007;31:234–44.

12. Franklin ME, González JJ, Glass JL. Use of porcine small intestinal submucosa as a prosthetic device for laparoscopic repair of hernias in contaminated fields: 2-years follow-up. Hernia. 2004;8:166–9.
13. Butler CE, Langstein HN, Kronowitz SJ. Pelvis, abdominal, and chest wall reconstruction with Alloderm in patients with a increased risk for meshrelated complications. Plast Reconstr Surg. 2005;116:1263–75.
14. Amid K, Shulman G, Lichtenstein L, Sostrin S, Young J, Hakakha M. Évaluation préliminaire de matériels composites pour la réparation des éventrations. Ann Chir. 1995;49:539–43.
15. Malazgirt Z, Ulusoy AN, Karagoz F, Tac K. Bioabsorbable membrana prevents adhesions to polypropylene mesh in rats. Hernia. 2000;4:129–33.
16. Baptista M, Bonsack M, Felemovicius I, Delaney J. Abdominal adhesions to prosthetic mesh evaluated by laparoscopic and electron microscopy. J Am Coll Surg. 2000;190:271–80.
17. Greenawalt KE, Butler TJ, Rowe EA, Finneral AC, Garlick DS, Burns JW. Evaluation of Sepramesh biosurgical composite in a rabbit hernia repair model. J Surg Res. 2000;94:92–8.
18. Bellón JM, García-Carranza A, Jurado F, García-Honduvilla N, Carrera-San Martín A, Bujan J. Peritoneal regeneration after implant of a composite prosthesis in the abdominal wall. World J Surg. 2001;25:147–52.
19. Ferrando JM, Vidal J, Armengol M, Gil J, Manero JM, Huguet P, et al. Experimental evaluation of a new layered prótesis exibiting a low tensile modulus of elasticity: long-term integration response within the rat abdominal wall. World J Surg. 2002;26:409–15.
20. Bellón JM, Jurado F, López R, García-Honduvilla N, Carrera-San Martín A, Buján J. Mejora del comportamiento biomecánico y peritoneal tras el implante de una prótesis composite de PTFEe en la pared abdominal. Cir Esp. 2002;72:210–5.
21. Bellón JM, García-Carranza A, Jurado F, García-Honduvilla N, Carrera-San Martín A, Buján J. Evaluation of a new composite prosthesis (PL-PU99) for the repair of abdominal wall defects in terms of behavior at the peritoneal interface. World J Surg. 2002;26:661–6.
22. Bellón JM, Jurado F, García-Moreno F, Corrales C, Carrera-San Martín A, Bujan J. Healing process induced by three composite prostheses in the repair of abdominal wall defects. J Biomed Mater Res Part B (Appl Biomater). 2002;63:182–90.
23. van' Riet M, de Vos van Steenwijk PJ, Bonthuis F, Marquet RL, Steyeberg EW, Jeekel J, et al. Prevention of adhesions to prosthetic mesh: comparison of different barriers using and incisional hernia model. Ann Surg. 2003;237:123–8.
24. Matthews BD, Pratt BL, Pollinger HS, Backus CL, Kercher KW, Sing RF, et al. Assessment of adhesion formation to intraabdominal polypropylene mesh and polytetrafluoroethylene mesh. J Surg Res. 2003;114:126–32.
25. González R, Rodeheaver GT, Moody DL, Foresman PA, Ramshaw BJ. Resistance to adhesion formation: a comparative study of treated an untreated mesh products placed in the abdominal cavity. Hernia. 2004;8:213–9.
26. Johnson EK, Hoyt CH, Dinsmore RC. Abdominal wall hernia repair: a long term comparison of Sepramesh and Dualmesh in a rabbit hernia model. Am Surg. 2004;70:657–61.
27. Young RM, Gustafson R, Dinsmore RC. Spramesh vs. Dual-mesh for abdominal wall hernia repairs in a rabbit model. Curr Surg. 2004;61:77–9.
28. Borrazo EC, Belmont MF, Boffa D, Fowler DL. Effect of prosthetic materials on adhesions formation after laparoscopic ventral hernia repair in a porcine model. Hernia. 2004;8:108–12.
29. Duffy AJ, Hogle NJ, Lamerle KM, Fowler DL. Comparison of two composite meshes using two fixation devices in a porcine laparoscopic ventral hernia repair. Hernia. 2004;8:358–64.
30. Felemovicius I, Bonsack M, Hagerman G, Delaney JP. Prevention of adhesions to polypropylene mesh. J Am Coll Surg. 2004;198:543–8.
31. McGinty JJ, Hogle NJ, McCarthy H, Fowler DL. A comparative study of adhesion formation and abdominal wall ingrowth after laparoscopic ventral hernia repair in a porcine model using multiple types of mesh. Surg Endosc. 2005;19:786–90.
32. Matthews BD, Mostafa G, Carbonell AM, Joels CS, Kercher KW, Austin C, et al. Evaluation of adhesions formation and host tissue response to intra-abdominal polytetrafluoroethylene mesh and composite prosthetic mesh. J Surg Res. 2005;123:227–34.
33. Kayaoglu HA, Ozkan N, Hazinedaroglu SM, Ersoy OF, Erkek AB, Koseoglu RD. Comparison of adhesive properties of five different prosthetic materials used in hernioplasty. J Invest Surg. 2005;18:89–95.
34. Bellón JM, Carnicer-Escusol E, Rodríguez-Mancheño M, García-Honduvilla N, Serrano-Amarilla N, Buján-Varela J. Estudio experimental comparativo entre una prótesis compuesta (PL-PU 99) y una prótesis biológica (Surgisis) en el cierre temporal abdominal. Cir Esp. 2005;78:103–8.
35. Bellón JM, Serrano N, Rodríguez M, García-Honduvilla N, Pascual G, Buján J. Composite prostheses used to repair abdominal wall defects. Physical or chemical adhesion barriers?. J Biomed Mater Res Part B (Appl Biomater). 2005;74B:718–24.
36. Bellón JM, García-Honduvilla N, Serrano N, Rodríguez M, Pascual G, Buján J. Composite prostheses for the repair of abdominal wall defects: effect of the structure of the adhesión barrier component. Hernia. 2005;9:338–43.
37. Demir U, Mihmanli M, Coskun H, Dilege E, Kalyoncu A, Altinli E. Comparison of prosthetic materials in incisional hernia repair. Surg Today. 2005;35:223–7.
38. Harrel AG, Novitsky YW, Peindl RD, Cobb WS, Austin CA, Cristiano JA, et al. Prospective evaluation of adhesion formation and shrinkage of intraabdominal prosthetics in a rabbit model. Am Surg. 2006;72:808–14.
39. Schönleben F, Reck T, Tannapfel A, Hohenberger W, Schneider I. Collagen foil (TissuFoil E) reduces the formation of adhesions when using polypropylene mesh for the repair of experimental abdominal wall defects. Int J Colorrectal Dis. 2006;21:840–6.
40. Burger JW, Halm JA, Wijsmuller AR, Raa ST, Jeekel J. Evaluation of new prosthetic meshes for ventral hernia repair. Surg Endosc. 2006;20:1320–5.
41. Martín-Cartes JA, Morales-Conde S, Suárez-Grau JM, Bustos-Jiménez M, Cadet-Dussort H, Socas-Maciás M, et al. Prevención de adherencias peritoneales a las prótesis intraperitoneales. Estudio experimental en cerdos. Cir Esp. 2006;80:214–9.
42. Schug-Pass C, Tamme C, Tannapfel A, Kockerling F. A light- weight polypropylene mesh (TiMesh) for laparoscopic intraperitoneal repair of abdominal wall hernias: comparison of biocompatibility with the Dualmesh in an experimental study using the porcine model. Surg Endosc. 2006;20: 402–9.
43. Bellón JM, García-Honduvilla N, Rodríguez M, Pascual G, Gómez-Gil V, Buján J. Influence of the structure of new generation prostheses on shrinkage after implant in the abdominal wall. J Biomed Mater Res Part B (Appl Biomater). 2006;78B:340–6.

44. Sikkink CJ, Vries de Reilingh TS, Malyar AW, Jansen JA, Bleichrodt RP, van Goor H. Adhesion formation and reherniation differ between meshes used for abdominal wall reconstruction. Hernia. 2006;10:218–22.
45. Novitsky YW, Harrel AG, Cristiano JA, Paton L, Norton HJ, Peindl RD, et al. Comparative evaluation of adhesión formation, strenght of ingrowth, and textile properties of prosthetic meshes after long-term intra-abdominal implantation in a rabbit. J Surg Res. 2007;140:6–11.
46. Bellón JM, Rodríguez M, García-Honduvilla N, Pascual G, Gómez V, Buján J. Peritoneal effects of prosthetic meshes used to repair abdominal wall defects: monitoring adhesions by sequential laparoscopy. J Laparoendosc Adv Surg Tech. 2007;17:160–6.
47. Judge TW, Parker DM, Dinsmore RC. Abdominal wall hernia repair: a comparison of Sepramesh and Parietex Composite mesh in a rabbit hernia model. J Am Coll Surg. 2007;204: 276–81.
48. Jacob BP, Hogle NJ, Durak E, Kim T, Fowler DL. Tissue ingrowth and bowel adhesion in an animal comparative study: polyprolylene versus Proceed versus Parietex Composite. Surg Endosc. 2007;21:629–33.
49. Olmi S, Addis A, Domeneghini C, Scaini A, Croce E. Experimental comparison of type Tissucol dilution and composite mesh (Parietex) for laparoscopic repair of groin and abdom- inal hernia: observational study conducted in a universitary laboratory. Hernia. 2007;11:211–5.
50. LeBlanc KA, Booth WV. Laparoscopic repair of incisional abdominal hernias using expanded polytetraethylene: preliminary findings. Surg Laparosc Endosc. 1993;3:39–41.
51. Heniford BT, Ramshaw BJ. Laparoscopic ventral hernia repair. A report of 100 consecutives cases. Surg Endosc. 2000;14: 419–23.
52. Carbajo MA, Martín del Olmo JC, Blanco JI, Cuesta C, Martín F, Toledano M, et al. Laparoscopic treatment of ventral abdominal wall hernias: preliminary results in 100 patients. JSLS. 2000;4:141–5.
53. LeBlanc KA, Brooth WV, Whitaker JM, Bellanger DE. Laparoscopic incisional and ventral herniorraphy in 100 patients. Am J Surg. 2000;180:193–7.
54. Balique JG, Alexandre JH, Arnaud JP, Benchetrit S, Bouillot JL, Fagniez PL, et al. Intraperitoneal treatment of incisional and umbilical hernias: intermediate results of a multicenter prospective clinical trial using an innovative composite mesh. Hernia. 2000;4 Suppl :S10–6.
55. Heniford BT, Park A, Ramshaw BJ, Voeller G. Laparoscopic ventral and incisional hernia repair in 407 patient. J Am Coll Surg. 2000;190:645–50.
56. Chrysos E, Athanasakis E, Saridaki Z, Kafetakis A, Dimitriadou D, Koutsoumpas V, et al. Surgical repair of incisional ventral hernias: tension-free technique using prosthetic materials (expanded polytetraethylene Gore-Tex Dual Mesh). Am Surg. 2000;66:679–82.
57. de María EJ, Moss JM, Sugerman HJ. Laparoscopic intraperitoneal polytetrafluoroethylene (PTFE) prosthetic patch repair of ventral hernia. Surg Endosc. 2000;14:326–9.
58. Moreno Egea A, Lirón R, Girela E, Aguayo JL. Laparoscopic repair of ventral and incisional hernias using a new composite mesh (Parietex). Surg Laparosc Endosc Percutan Tech. 2001;11:103–6.
59. Parker HH, Nottingham NN, Bynoe RP, Yost MJ. Laparoscopic repair of large incisional hernias. Am Surg. 2002;68:530–5.
60. Aura T, Habib E, Mekkaoui M, Brassier D, Elhadad A. Laparoscopic tension-free repair of anterior abdominal wall incisional and ventral hernias with an intraperitoneal Gore-Tex mesh: prospective study and review of the literature. J Laparoendosc Adv Surg Tech. 2002;12:263–7.
61. Ben-Haim M, Kuriansky J, Tal R, Zmora O, Mintz Y, Rosin D, et al. Pitfalls and complications with laparoscopic intraperitoneal expanded polytetrafluoroethylene match repair of postoperative ventral hernia. Surg Endosc. 2002;16:785–8.
62. Moreno-Egea A, Castillo JA, Girela E, Canteras M, Aguayo JL. Outpatient laparoscopic incisional/ventral hernioplasty: our experience in 55 cases. Surg Laparosc Endosc Percutan Tech. 2002;12:171–4.
63. Cobb WS, Harris JB, Lokey JS, McGill ES. Incisional herniorrhaphy with intraperitoneal composite mesh: a report of 95 cases. Am Surg. 2003;69:784–7.
64. Heniford BT, Park A, Ramshaw BJ, Voeller G. Laparoscopic repair of ventral hernias. Nine year's experience with 850 consecutive hernias. Ann Surg. 2003;238:391–400.
65. Díaz JJ, Gray BW, Dobson JM, Grogan EL, May AK, Miller R, et al. Repair of giant abdominal hernias: does the type of prosthesis matter?. Am Surg. 2004;70:396–401.
66. Ammaturo C, Bassi G. Surgical treatment of large incisional hernias with an intraperitoneal Parietex Composite mesh: our preliminary experience on 26 cases. Hernia. 2004;8:242–6.
67. Balique JG, Lepere M, Benchetrit S, Bouillot JL, Flament JB, Gouillat C, et al. Traitement des éventrations avec le renfort Parietex Composite: résultats à long terme d'une étude prospective multicentrique. Ann Chir. 2004;129:1–4.
68. Lermite E, Pessaux P, Tuech JJ, Aubé C, Arnaud JP. Adherences viscérales après cure d'eventration par plaque intrapéritoneale: étude monocentrique comparant un refort conventionnel (Mersilene) à un renfort composite (Parietex). Ann Chir. 2004;129:513–7.
69. Moreno-Egea A, Torralba JA, Girela E, Corral M, Bento M, Cartagena J, et al. Inmediate, early, and late morbidity with laparoscopic ventral hernia repair and tolerance to composite mesh. Surg Laparosc Endosc Percutan Tech. 2004;14:130–5.
70. Denue PO, Destrumelle N, Guinier D, Lacroix V, Destrumelle AS, Mathieu P, et al. Étude comparative rétrospective de l'impact médicoéconomique d'un renfort innovant dans la cure des éventrations de la paroi abdominale antérieure. Ann Chir. 2005;130:466–9.
71. Edwards C, Angstadt J, Whipple O, Grau R. Laparoscopic ventral hernia repair: postoperative antibiotics decrease incidente of seroma-related cellulitis. Am Surg. 2005;71:931–6.
72. Yavuz N, Turgut I, As A, Kapan M, Eyuboglu E, Erguney S. Laparoscopic repair of ventral and incisional hernias: our experience in 150 patients. J Laparoendosc Adv Surg Tech. 2005;15:601–5.
73. Topart P, Ferrand L, van den Broucke F, Lozac'h P. Laparoscopic ventral hernia repair with the Goretex Dualmesh: long term results and review of the literature. Hernia. 2005;9:348–52.
74. Morales-Conde S, Cadet H, Cano A, Bustos M, Martín J, Morales-Méndez S. Laparoscopic ventral hernia repair without sutures-double crown technique: our experience after 140 cases with a mean follow-up of 40 months. Int Surg. 2005;90:S56–62.
75. Olmi S, Erba L, Magnone S, Bertolini A, Croce E. Prospective clinical study of laparoscopic treatment of incisional and ventral hernia using a composite mesh: indications, complications and results. Hernia. 2006;10:243–7.
76. Johanet H, Dabrowski A, Hauters P. Laparoscopic cure of small ventral hernias with composite mesh. Hernia. 2006;10:414–8.

77. Hadi HI, Maw A, Sarma S, Kumar P. Intraperitoneal tension free repair of small midline ventral abdominal wall hernias with a Ventralex hernia patch: inicial experience in 51 patients. Hernia. 2006;10:409–13.
78. Beldi G, Ipaktchi R, Wagner M, Gloor B, Candinas D. Laparoscopic ventral hernia is safe and cost effective. Surg Endosc. 2006;20:92–5.
79. Lomanto D, Iyer SG, Shabbir A, Cheah WK. Laparoscopic versus open mesh hernia repair: a prospective study. Surg Endosc. 2006;20:1030–5.
80. Chelala E, Thoma M, Tatete B, Lemye AC, Dessily M, Alle JL. The suturing concept for laparoscopic mesh fixation in ventral and incisional hernia repair: mid-term analysis of 400 cases. Surg Endosc. 2007;21:391–5.
81. Cobb WS, Paton L, Novitsky YW, Rosen MJ, Kercher KW, Kuwada TS, et al. Intra-abdominal placement of antimicrobial-impregnated mesh is associated with noninfectious fever. Am Surg. 2006;72:1205–9.
82. Stickel M, Rentsch M, Clevert DA, Hernández-Richter T, Jauch KW, Löhe F, et al. Laparoscopic mesh repair of incisional hernia: an alternative to the convencional open repair?. Hernia. 2007;11:217–22.
83. Bernard C, Polliand C, Mutelica L, Champault G. Repair of giant incisional abdominal hernias using open intraperitoneal mesh. Hernia. 2007;11:315–20.
84. Datta T, Eid G, Nahmias N, Dallal RM. Management of ventral hernias during laparoscopic gastric bypass. Surg Obes Relat Dis. 2008 [Epub ahead of print].
85. Rosenberg J, Bucharth J. Feasibility and outcome after laparoscopic ventral hernia repair using Proceed mesh. Hernia. 2008 [Epub ahead of print].
86. Arnaud JP, Hennekinne-Mucci S, Pessaux P, TPECH JJ, Aube C. Ultrasound detection of visceral adhesion after intraperitoneal ventral hernia treatment: a comparative study of protected versus unprotected meshes. Hernia. 2003;7:85–7.
87. Bingener J, Kazantsev GB, Chopra S, Schwesinger WH. Adhesion formation after laparoscopic ventral incisional hernia repair with polypropylene mesh: a study using abdominal ultrasound. JSLS. 2004;8:127–31.
88. Olmi S, Scaini A, Erba L, Croce E. Use of fibrin glue (Tissucol) in laparoscopic repair of abdominal wall defects: preliminary experience. Surg Endosc. 2007;21: 409–13.
89. Memisoglu K, Saribeyoglu K, Pekmezci S, Karahasanoglu T, Sen B, Bayrak I, et al. Mesh fixation devices and formation of intraperitoneal adhesions. J Laparoendosc Adv Surg Tech. 2006;5:439–44.
90. Franklin ME, González JJ, Glass JL, Manjares A. Laparoscopic ventral and incisional hernia repair: an 11-year experience. Hernia. 2004;8:23–7.
91. Losanoff JE, Richman BW, Jones JW. Entero-colocutaneous fistula: a late consequence of polypropylene mesh abdominal wall repair: case report and review of literature. Hernia. 2002;6:144–7.
92. Halm JA, de Wall LL, Steyerberg EW, Jeekel J, Lange JF. Intraperitoneal polypropylene mesh hernia repair complicates subsequent abdominal surgery. World J Surg. 2007;31:423–9.
93. Robinson TN, Clarke JH, Schoen J, Walsh MD. Major meshrelated complications following hernia repair. Surg Endosc. 2005;19:1556–60.