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# Use of an experimental model to evaluate infection resistance of meshes in abdominal wall surgery

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ABSTRACT

*Background:* Staphylococcal species are the most common organisms causing prosthetic mesh infections, however, infections due to rapidly growing mycobacteria are increasing. This study evaluates the resistance of biomaterial for abdominal wall prostheses against the development of postoperative infection in a rat model.

*Material and methods:* In 75 rats, we intramuscularly implanted three different types of prostheses: (1) low-density polypropylene monofilament mesh (PMM), (2) high-density PMM, and (3) a composite prosthesis composed of low-density PMM and a nonporous hydrophilic film. Meshes were inoculated with a suspension containing $10^8$ colony-forming units of *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Mycobacterium fortuitum*, or *Mycobacterium abscessus* before wound closure. Animals were sacrificed on the eighth day postoperatively for clinical evaluation, and the implants were removed for bacteriologic analyses.

*Results:* Prostheses infected with *S aureus* showed a higher bacterial viability, worse integration, and clinical outcome compared with infection by other bacteria. Composite prostheses showed a higher number of viable colonies of both *M fortuitum* and *Staphylococcus* spp., with poorer integration in host tissue. However, when the composite prosthesis was infected with *M abscessus*, a lower number of viable bacteria were isolated and a better integration was observed compared with infection by other bacteria.

*Conclusions:* Considering *M abscessus*, a smaller collagen-free contact surface shows better resistance to infection, however, depending on the type of bacteria, prostheses with a large surface, and covered with collagen shows reduced resistance to infection, worse integration, and worse clinical outcome.

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## Introduction

An increasing number of hernia repairs are performed each year in Spain. The use of prostheses has become the preferred method for abdominal wall reconstruction in primary and incisional hernia repair.[1] Repairs of incisional hernias are considered as contaminated surgery, due to the significantly higher infection rates described with these repairs.[2] According to the Spanish Society of Epidemiology, the rate of postoperative surgical infections in Spain is 4.6%.[3] The presence of a foreign body reaction caused by the implanted device predisposes to postoperative clinical infections[4] by smaller numbers of bacteria of a given species. Acute superficial and late deep infection is well known after mesh abdominal wall reconstruction causing patient disability, hospital costs, and the chance of recurrence,[5] frequently making the surgical removal the only solution to an infected prosthesis.[6]

The overall clinical outcome of such persistent infections depends on the virulence of the contaminating pathogen, the microenvironmental factors of the wound site, and the type of surgical mesh material.[7] The well-known key steps in the pathogenesis of infection are bacterial adhesion to implanted biomaterial surfaces, followed by proliferation of bacteria and biofilm development.[5,8] The adsorption or binding of serum proteins and formation of biofilms can be promoted by means of factors including chemical composition of biomaterial, electrostatic interaction with potential pathogens, hydrophobicity, and surface roughness or physical configuration of the prosthesis.[9]

Surgical site and implant contamination could occur during surgery and in the early postoperative period.[10] *Staphylococcus aureus* and *Staphylococcus epidermidis* are prevalent microorganisms of skin flora, ones responsible for over 90% of surgical site infections.[11] Infections due to rapidly growing mycobacteria (RGM) such as the *Mycobacterium fortuitum* and *Mycobacterium abscessus* complexes[12] are growing interest as an example of chronic infection associated with biomaterial-related surgical procedures, such as orthopedic prostheses, peritoneal dialysis catheters, vascular catheters, prosthetic heart valves,[12] and also abdominal wall prostheses.[13] It may be due to RGM are difficult to eradicate with common decontamination practices when forming biofilms adhered to the biomaterial and are also relatively resistant to standard disinfectants.[14]

Surgeons commonly apply polypropylene monofilament mesh (PPM) and dual-facing mesh made of PPM and a nonadherent film (composite prostheses [CP]) in repair of abdominal wall hernias.[11] The influence of biomaterial of abdominal wall prostheses on the development of postoperative infection by *S aureus* and *S epidermidis* has been widely investigated, indicating that meshes with large pores, low-density meshes have a reduced contact area and may be therefore less prone to bacterial colonization than high-density meshes.[8,15] Moreover, there is evidence to suggest that CP can provide an adequate environment for bacterial adherence, niche formation, and biofilm development due essentially to the large surface area provided by the nonadherent film, thus precluding their use in contaminated surgical fields.[11] However, prosthetic mesh infections due to RGM as a paradigm of chronic infection resistant to common antimicrobial treatments have not received enough attention, a point of concern which is the inspiration for our work. In a previous *in vitro* study, we evaluated the bacterial adherence on these meshes. Subsequently, an *in vivo* experimental study was conducted as described in the following section to examine the infection resistance of a contaminated mesh after an abdominal wall reconstruction at the site where the prosthesis was implanted. To our knowledge, this is the first model *in vivo* of foreign body infection by mycobacteria.

## Materials and methods

### Animals

Seventy-five Wistar white rats weighing 350-500g were used in this study. Animal testing will be performed according to current Spanish legislation regarding the use, protection, and care of experimental animals (Royal Decree 1201/2005) and in accordance with those recommended procedures by the Ethics Committee of our institution. The study was conducted with the approval of the local ethics committee for experimental studies.

### Ethical approval details

Animal testing will be performed according to current Spanish legislation regarding the use, protection, and care of experimental animals (Royal Decree 1201/2005) and in accordance with those recommended procedures by the Ethics Committee of our institution. The study was conducted with the approval of the local ethics committee for experimental studies.

### Mesh materials and study design

An established rat infection model by Bellows *et al.*[1] with some modifications considering our previous research *in vitro*[8] was used to evaluate three different types of abdominal wall prostheses: (1) low-density PMM (LD-PMM) (Parietene; Sofradim Production, Trévoux, France), (2) high-density PMM (HD-PMM) (SurgiproUnited States Surgical, Norwalk, CT), and (3) dual-facing prostheses made of PMM and a resorbable hydrophilic film (CP) (Parietene composite; Sofradim Production). Rats ($n = 5$ per mesh type) were assigned randomly to undergo intramuscularly implantation of patches of size 1 × 1 cm of each abdominal wall prostheses. Meshes were prepared as instructed by the manufacturers and were cut into uniform strips at the time of surgery using a precut plastic sterile template. Each patch was implanted in a different rat and was inoculated with 1 mL bacterial suspension of $10^8$ colony-forming units (CFU) of each strain in phosphate-buffered saline (PBS), into the surgical wound after mesh implantation but before to closure the internal edges of superficial incised muscles and skin closure to mimic contaminated conditions. Control (noncolonized) animals received 1 mL of PBS instead of the bacterial suspension ($n = 5$ rats per mesh type). At eighth day after surgery, the animals

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