Review

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Review

Biologic and Bioabsorbable Meshes: The Use of Mesh in Complex Hernia Repairs

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Abstract: Complex ventral hernia repairs pose unique challenges in high-risk patients with impaired tissue quality or contaminated fields. While traditional synthetic meshes are effective, their use in these scenarios carries an increased risk of chronic inflammation and infection. Biologic and bioabsorbable meshes are alternative options designed to provide a temporary scaffolding that supports tissue healing while minimizing foreign body reactions. This paper explores the strengths and limitations of biologic, bioabsorbable, and hybrid meshes, particularly in contaminated or high-risk settings. Biologic meshes, though costly, offer temporary reinforcement and promote tissue integration, while absorbable meshes present a viable alternative with promising safety data. Hybrid meshes, which combine durability with biocompatibility, represent a promising class of materials, particularly for patients with impaired wound healing. As the field advances, further research and comparative studies will be critical to optimizing mesh selection and improving long-term outcomes in complex ventral hernia repair.

Keywords: complex ventral hernia repair; hernia; biologic; bioabsorbable; hybrid; mesh; MIS

Introduction

Complex hernia repairs present significant challenges, particularly in high-risk patients with compromised tissue quality or an elevated risk of infection. While traditional synthetic meshes are effective in many cases, their use in at-risk patients has raised concerns with complications such as chronic inflammation or infection. Advancements in material science have led to the development of biologic and bioabsorbable meshes, which offer a biocompatible and more temporary alternative to synthetic options. These innovative materials are designed to support tissue healing while minimizing the risk of long-term foreign body reactions. This paper examines biologic, bioabsorbable and hybrid meshes, with a focus on their composition, mechanisms of action, and clinical outcomes, particularly in high-risk patients with contaminated fields or poor tissue quality.

Overview of Mesh Materials

The use of mesh in hernia repair has a history spanning over a century. In the late 1800s, Witzel and Goepel first described the use of a silver-based mesh.[1] Metallic prostheses continued to gain popularity over the next several decades due to their low hernia recurrence rates, durability, and ability to induce scarring by acting as tissue irritants. However, these meshes were prone to complications, including fistula formation and fracturing over time. Various other metallic substitutes, such as tantalum and stainless steel, have entered the market but were eventually supplanted by plastic meshes due to the stiffness, radiopacity, and discomfort associated with metal meshes.

The development of nylon marked a significant milestone in the evolution of synthetic meshes. In 1944, Aquaviva and Bounet were the first to use a nylon-based mesh for inguinal hernia repair. However, nylon eventually fell out of favor because it lost tensile strength over time and was prone

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to infection. Polypropylene meshes emerged as a more durable alternative, with Usher and colleagues first describing their use in 1959.[2] Marlex, the first knitted polypropylene monofilament mesh, was strong, durable, inert, and rapidly incorporated into surrounding tissue. It induced fibrosis, which increased tensile strength during healing. To this day, polypropylene mesh remains one of the most widely used materials in hernia repair.

As permanent meshes became widely adopted, their long-term drawbacks became more apparent. Synthetic meshes were prone to infection and so were avoided in contaminated fields. Mesh infections carried significant morbidity, including wound dehiscence and recurrence, and often required mesh excision. In response to these challenges, absorbable meshes were developed in the mid-1980s. Absorbable prosthetics are designed to dissolve over time, providing temporary support while allowing natural tissue healing. They are flexible, easy to handle, and suitable for use in contaminated fields or situations requiring abdominal fascia bridging to facilitate skin closure and wound healing. Additionally, absorbable meshes generally do not require removal in cases of wound infection. Absorbable meshes can be classified into biologic, bioabsorbable and hybrid types (Table 1).

Table 1. Summary of different mesh types, their compositions and time until degradation separated by category.

Mesh Name	Company	Composition	Degradation Time
Biologic Mesh			
Alloderm®	LifeCell	Acellular human dermis	1-3 months
Allomax™	BD	Acellular human dermis	1-3 months
FlexHD®	MTF Biologics	Acellular human dermis	1-3 months
Permacol™	Medtronic	Cross-linked acellular porcine dermis	1 year
Strattice®	Allergan	Acellular porcine dermis	1-3 months
XenMatrix™	BD	Acellular porcine dermis	1-3 months
Surgisis®	Cook Medical	Porcine small intestinal submucosa	4-6 months
Biodesign®	Cook Medical	Porcine small intestinal submucosa	4-6 months
Surgimend®	Integra LifeSciences	Acellular bovine dermis	1-3 months
Periguard®	Baxter	Bovine pericardium	1-3 months
Bioabsorbable Mesh			
Dexon®	Medtronic	Polyglycolic acid	2-3 months
Vicryl®	Ethicon	Polyglactin 910	1-3 months
Bio-A®/Enform®	Gore	Polyglycolic acid + trimethylene carbonate	6 months
Phasix®	BD	Poly-4-hydroxybutyrate (P4HB)	12–18 months
TIGR Matrix®	Novus Scientific	Fast (glycolic acid + lactic acid + trimethylene carbonate) and slow (lactic acid + trimethylene carbonate) resorbing fibers	4 months (fast), 3 years (slow)

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Synthetic Hybrid Mesh			
Zenapro®	Cook Medical	Porcine small intestinal submucosa + polypropylene	Permanent
Synecor®	Gore	Polytetrafluoroethylene + polyglycolic acid + P4HB	Permanent
Ovitex®	TELA Bio	Ovine extracellular matrix + polypropylene	Permanent

Biologic Mesh

Biologic meshes are commonly derived from human, porcine or bovine sources. They are processed to remove cellular components while preserving the extracellular matrix. This matrix acts as a scaffold to support tissue remodeling, neovascularization and tissue integration following hernia repair. Over time, the mesh integrates with surrounding tissues and eventually degrades, reducing the risk of foreign body reactions. Biologic meshes are particularly favored in contaminated fields, although this is an off-label use. Their ability to revascularize and integrate with surrounding tissue makes them more resistant to infection than synthetic alternatives.

Collagen cross-linking is a natural or artificial process that enhances tissue durability by increasing resistance to collagenases. Cross-linked meshes are designed for longevity, persisting for several years after implantation. In contrast, non-cross-linked mesh prioritizes biocompatibility and tissue integration, typically degrading within 2-3 months.[3]

Human Acellular Dermal Matrices

Human acellular dermal matrices (HADM) are a category of biological mesh derived from cadaveric dermis and are commercially available under brand names such as Alloderm™, AlloMax™, and FlexHD®. Initially introduced in 1992 for treatment of full thickness burn wounds, their first use in abdominal wall closure was described in 2003 after decompressive laparotomy for abdominal compartment syndrome.[4]

HADM is most effective when used after primary fascial closure. A comparative study revealed a ventral hernia recurrence rate of 80% when HADM mesh was used for fascial bridging, compared to 20% for fascial reinforcement after primary repair.[5] Bridging repairs with HADM have been associated with implant stretching and eventration in 88% of cases, likely due to elastin fibers within the graft stretching and causing laxity.[6,7] Conversely, HADM maintains a tensile strength similar to surrounding tissues during repair, providing reinforcement until integration is complete, and forms fewer adhesions compared to synthetic alternatives.[8] In clean hernia repairs, HADM mesh has a recurrence rate of approximately 5% at 15-month follow-up.[9]

In contaminated fields, HADM has become a popular option for single-stage hernia closure. Synthetic mesh has been avoided in these scenarios, which have been classically repaired primarily in anticipation for hernia recurrence and staged months to years later. Closure with biologic mesh is an attractive alternative and can be implanted at the time of the original operation. A multi-institutional retrospective review analyzed 240 patients undergoing complex hernia repair using HADM mesh and reported a hernia recurrence rate with 17.1%, with higher recurrent rates in patients undergoing fistula or stoma takedown after a mean follow up period of 317 days.[10] Another study by Patton *et al*. reported a recurrence rate of 18% and surgical site infection rate of 23% in 67 contaminated ventral hernia repairs, comparable to noncontaminated repairs at a mean follow up of 10.6 months post operatively.[11] HADM performs best when primary wound closure is achieved. A small case study comparing HADM mesh implantation in primary wound closure compared to cases where the skin was left to heal by secondary intention found significantly lower hernia recurrence rates in closed wounds (33% vs. 83%; p=0.03).[12]

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Porcine and Bovine Meshes

Biologic meshes can also be derived from porcine and bovine products. Porcine-derived acellular dermis products (e.g., Permacol™, Strattice™, XenMatrix™) are resistant to degradation, provoke limited inflammation, and allow moderate neovascularization. Porcine small intestine submucosa meshes (e.g., Surgisis®, **Biodesign®**) are designed for enhanced tissue ingrowth within six months. Bovine-derived meshes, such as SurgiMend® (fetal dermis) and Periguard® (pericardium) are other, less studied products. Porcine and bovine-derived meshes have been demonstrated to avoid antibody-mediated rejection.[8]

Animal models have compared biologic meshes across species. For example, rabbit models demonstrated superior tensile strength and cellular infiltration in human acellular dermis compared to porcine alternatives while having similar levels of adhesion, inflammation, fibrosis and neovascularization.[13]. Rat models showed porcine-derived acellular dermal matrices to have greater tensile strength, neovascularization, and collagen deposition than small intestine submucosa meshes.[14] A bovine acellular dermal matrix has also been shown to have a significant tensile strength advantage over its porcine counterpart[15], with cross-linked products being stronger than the non-cross-linked variant.[16]

Clinical Studies and Comparative Outcomes

Comparative studies between various biologic meshes often suffer from heterogeneity in hernia repair techniques, small sample sizes, and diverse product types. HADM has shown higher recurrence rates compared to some xenograft products[17], while porcine dermal meshes have demonstrated favorable profiles, with reduced seroma formation and failure rates in contaminated fields compared to Alloderm™ and Surgisis®.[18,19]

A study by Huntington *et al*. involving 223 patients undergoing open ventral hernia repair with biologic mesh revealed recurrence rates varying by mesh type: 35% for Alloderm™, 34.5% for AlloMax™, 37.1% for FlexHD®, 14.7% for Strattice™, and 59.1% for XenMatrix™ at 1.5 years. Strattice™ had the most favorable outcomes, with multivariate analysis showing significantly lower odds of recurrence compared to other products.[20]

Samson *et. al* performed a systemic review of the available literature regarding the use of biologic mesh in complex ventral hernia repair.[21] This analysis encompassed 6079 patients across 51 studies. Meta-analysis found an early complication rate of 50%, including surgical site occurrences (defined as seroma, hematoma, abscess, necrosis, dehiscence and fistula formation, 37%), surgical site infection (18%), reoperation (7%), readmission (20%) and mortality (3%). Long term complications included reoperation (17%), mesh explanation (9%) and hernia recurrence (36%).

Criticism of Biologic Mesh

Recent studies have questioned the superiority of biologic meshes over synthetic alternatives, particularly given their cost. A single-blind randomized clinical trial of 165 patients comparing biologic and synthetic meshes in clean and contaminated hernia repairs reported higher recurrence rates with biologic mesh (39.7% vs. 21.9%; p=0.035) at two years. Subgroup analysis in contaminated wounds showed a recurrence rate of 50% for biologic mesh versus 5.9% for synthetic mesh (p=0.04) with similar postoperative complication rates.[22]

Similarly, Rosen *et. al* conducted a multicenter randomized clinical trial evaluating 253 patients undergoing contaminated ventral hernia repair with either biologic or synthetic mesh[23] They found significantly lower hernia recurrence with synthetic mesh (5.6% vs. 20.5%; p=0.001) and no significant difference in surgical site occurrences at two years. Costs were significantly lower for synthetic mesh ($17,289 vs. $44,936; p<0.001). These findings challenge the paradigm that biologic meshes are superior in contaminated fields, highlighting the potential of synthetic meshes as cost-effective and durable alternatives.

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Bioabsorbable Mesh

Bioabsorbable meshes are synthetic polymers designed to degrade over time. In contrast to biologic mesh, they are not derived from human or animal sources. These meshes degrade through hydrolysis over months to years, providing temporary scaffolding to support wound healing and tissue integration. Eventually, they degrade completely, leaving no residual material, minimizing the risk of chronic infection and eliminating the need for explantation during reoperations. The most common materials used in absorbable mesh are polyglycolic acid (PGA) and poly-4-hydroxybutyrate (P4HB).

Polyglycolic Acid (PGA)

PGA-based meshes include Dexon™ (PGA), Vicryl™ (polyglactin, a copolymer of PGA and lactic acid), and Bio-A® (a combination of PGA and trimethylene carbonate). Dexon™, the first absorbable mesh, was introduced in the 1980s for contaminated ventral hernia repairs.[24] Vicryl™ and Dexon™ degrade rapidly within 1-3 months but have a high hernia recurrence rate of over 50%.[25]

Bio-A® offers a more durable alternative with a degradation period of approximately six months and has shown promising clinical results. The complex open bioabsorbable reconstruction of the abdominal wall (COBRA) study, a prospective multicenter evaluation of Bio-A in single-stage repair of contaminated ventral hernias reported a 17% hernia recurrence rate at two years.[26] Retrorectus mesh placement yielded the best outcomes, with a recurrence rate of 13%, compared to 40% for intraperitoneal placement (HR = 3.41 [95% CI, 1.10–10.60]; p = 0.03). All the patients in this study obtained fascial reapproximation because of the assumption that bridging mesh would lead to a recurrence once the mesh absorbs. The study demonstrated low recurrence and infection rates in high-risk populations, though nearly all patients had retrorectus placement, a potential confounding factor. Additionally, the cohort exhibited heterogeneity, including cases with infected mesh and fistula takedowns as well as routine ventral hernias.

Poly-4-Hydroxybutyrate (P4HB)

Poly-4-hydroxybutyrate is a bacterially derived polymer used in Phasix™ mesh, a bioabsorbable product made from knitted monofilament fibers. It degrades over 12–18 months, providing longer-lasting support than PGA-based meshes. Animal studies have shown that Phasix™ improves abdominal wall strength significantly up to 12 months post-implantation, which may suggest that fully absorbable meshes with longer-term resorption profiles may provide more durable support during hernia repair over faster dissolving alternatives.[27,28]

Clinical trials have also demonstrated favorable outcomes. A multicenter longitudinal study evaluated outcomes of 122 patients undergoing clean ventral hernia repairs with Phasix™ mesh for up to five years. The hernia recurrence rate was 22.0%, with surgical site infections at 10.1%.[29,30] Similarly, a multicenter analysis of 236 patients undergoing contaminated ventral hernia repair with Phasix™ mesh reported a recurrence rate of 14.4% and a surgical site occurrence (SSO) rate of 30%. Notably, onlay mesh placement was identified as an independent risk factor for recurrence.[31]

Composite Bioabsorbable Meshes

Composite absorbable meshes consist of polymers with different degradation profiles. The TIGR® Matrix is a dual-stage absorbable mesh with both fast-resorbing fibers (copolymer of glycolic acid, lactic acid, and trimethylene carbonate) and slow-resorbing fibers (copolymer of lactic acid and trimethylene carbonate). While the fast-resorbing fibers degrade within four months, the slow-resorbing fibers persist for up to three years. Animal studies have shown favorable biocompatibility and thicker collagen matrices compared to synthetic alternatives.[32]

Clinical outcomes of the TIGR® Matrix have been promising. A study by Lewis *et. al* on 91 patients undergoing abdominal wall reconstruction (30% in contaminated settings) reported no

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mesh-related complications or explants at 42 months, with a hernia recurrence rate of 12% and a wound complication rate of 27%.[33] Outcomes were comparable to the Phasix™ trial, with fewer mesh related adverse events.

Comparative Studies

Studies have compared biosynthetic meshes with permanent synthetic meshes. A retrospective review by Sahoo *et al*. evaluated outcomes for 328 patients undergoing ventral hernia repair in clean-contaminated or contaminated settings.[34] No significant differences were found between Bio-A®, Phasix™, and polypropylene meshes in surgical site infections (OR 2.02, 95% CI 0.8–5.06, p = 0.14), SSOs (OR 1.39, 95% CI 0.58–3.34, p = 0.47), or additional procedures (OR 1.85, 95% CI 0.79–4.36, p = 0.16) at 30 days.

A larger multicenter propensity-matched analysis of 2,484 patients undergoing wound class II or III ventral hernia repairs found no differences in surgical site infections between permanent, absorbable, and biologic meshes at 30 days (12% vs 14% vs 12%, p = 0.64). However, permanent mesh had the lowest hernia recurrence rate at one year (23% vs 40% vs 32%, p = 0.029).[35]

Hybrid Mesh

Hybrid meshes are designed to combine the advantages of absorbable and non-absorbable components while mitigating the limitations of single-material products. These products typically feature a synthetic mesh base to provide structural strength, coupled with a biological or absorbable material to encourage tissue ingrowth, reduce inflammation, and minimize foreign body reactions. Additionally, the absorbable component may protect the permanent mesh from infection.[36] Three examples of hybrid mesh products are discussed below.

Zenapro® (Cook Medical, Inc., Bloomington, IN) was the first synthetic/biologic hybrid mesh approved for abdominal wall reinforcement. It consists of a lightweight microporous polypropylene backbone encased in 8-ply porcine small intestinal submucosa. The biologic layer features perforations to facilitate fluid passage, neovascularization, and tissue integration.[37] Over time, the microporous polypropylene layer integrates fully into the tissue, providing long-term strength after the biologic component degrades.

Bittner *et al*. conducted the first study evaluating Zenapro® hybrid mesh in ventral hernia repair.[38] Their prospective, multicenter post-market trial followed 63 patients undergoing clean or clean-contaminated ventral hernia repair, reporting a 12-month recurrence rate of 6.8% and a surgical site occurrence (SSO) rate of 39%, predominantly seromas. Notably, most patients underwent preperitoneal mesh placement instead of retrorectus mesh placement, differing from other outcomes studies.

GORE® Synecor (W.L. Gore & Associates, inc.) is a three-layered mesh comprised of nonabsorbable macroporous polytetrafluoroethylene (PTFE) fibers sandwiched between two layers of bioabsorbable composite of polyglycolide and trimethylene carbonate (Bio-A®). The bioabsorbable layer degrades through hydrolytic and enzymatic pathways over six to seven months, leaving a permanent structure to support tissue ingrowth.[39,40]

A retrospective, multicenter study evaluated Synecor outcomes in 148 patients undergoing elective ventral hernia repair with retrorectus mesh placement.[41] Procedure-related adverse events occurred in 8.8% of patients within 30 days, with surgical site infections accounting for 4.8%. At 12 months, the infection rate remained at 4.8%, with no recurrences reported after a median follow-up of 36 months. Comparisons of ventral hernia repairs using Synecor mesh (8% recurrence at 22 months) and PTFE mesh (7% recurrence at 11 months) suggest Synecor offers durable, long-term outcomes with lower complication and recurrence rates compared to meshes comprised of its individual components.[42,43]

Ovitex® (TELA Bio, Malvern, PA) features an ovine (sheep)-derived extracellular matrix scaffold layered with a polypropylene weave in a lock-stitch pattern for added strength. Available in various

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thicknesses, Ovitex's biologic component supports host cell migration and adhesion, promoting collagen deposition.

Ovitex® has shown promise in ventral hernia repair. DeNoto *et al*. reported two-year results from the BRAVO study, a prospective, single-arm, multicenter trial, which followed 65 patients for two years post operatively and demonstrated a 2.6% hernia recurrence rate and a 38% SSO rate.[44] Another study assessing Ovitex® in 55 contaminated ventral hernia repairs or abdominal closures after open abdomen procedures reported an 8.7% recurrence rate and a 29% surgical site infection rate over 13 months.[45] Retrospective studies also showed comparable recurrence rates to synthetic mesh (4.0% vs. 6.78%, p=0.68) and lower SSO rates (16.0% vs. 30.5%, p=0.12) at 30 months.[46]

Conclusions

In summary, the options for mesh in complex ventral hernia repair are diverse, each designed to address the persistent challenges of infection and recurrence in contaminated or high-risk settings. Biologic and bioabsorbable mesh are attractive options to place in contaminated fields, as they provide temporary support and promote tissue healing prior to being degraded, minimizing the chances of chronic foreign body reactions or mesh infection. Biologic meshes are typically the most expensive but lack consistent evidence to justify their cost. Bioabsorbable meshes offer an alternative to biologics with encouraging data on their safety in contaminated fields or for patients who do not want a permanent implant. Hybrid meshes represent a promising innovation, offering a balance between durability and biocompatibility. Their design makes them particularly advantageous in high-risk patients with poor tissue and wound healing properties due to diabetes, smoking, obesity, or immunosuppression. Additional research is needed to optimize their use and evaluate their long-term efficacy. As new products are developed, robust and longitudinal head-to-head studies will be essential to guide clinical decision-making during complex ventral hernia repair.

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