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INTEGRATED STUDY MASTER'S THESIS

Meshes in Implant-Based Breast Reconstruction: Classification, Examples, Indications and Results. Literature Review

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1. Abbreviations

ADM: Acellular dermal matrix

BCS: Breast-conserving surgery

BII: Breast implant illness

BRC1/BRC2: Breast cancer 1 / breast cancer 2

BREAST-Q: Breast Reconstruction and Augmentation Quality of Life Questionnaire

CI: Confidence Interval

DTI: Direct-to-implant

hADM: Human acellular dermal matrix

IBBR: Implant-based breast reconstruction

IBR: Immediate breast reconstruction

IMF: Inframammary fold

NSM: Nipple-sparing mastectomy

OR: Odds ratio (95% CI)

p: p-value (statistically significant: $p < 0.05$; statistically not significant: $p > 0.05$)

PPBR: Prepectoral breast reconstruction

PROs: Patient-reported outcomes

SPBR: Subpectoral breast reconstruction

SSM: Skin-sparing mastectomy

TE: Tissue expander

2. Abstract

Background: Breast cancer is the most common cancer among women. Implant-based breast reconstruction plays an important role after mastectomy due to breast cancer or genetic predisposition and helps to restore feminine body contours. Biological (acellular dermal matrix) and synthetic meshes are commonly used to support the implant or expander. Although outcomes with meshes are promising, studies have reported contradictory findings. The aim of this study is to provide an overview of some of the literature on mesh-assisted implant-based breast reconstruction and to analyze the clinical benefits, complication rates, and differences between biological and synthetic meshes in implant-based breast reconstruction.

Method*:* A literature review was conducted using electronic databases, such as PubMed and Google Scholar. A total of 80 articles were included for analysis.

Results: Biological and synthetic meshes are used globally in subpectoral and prepectoral breast reconstruction. They are applied in both one-stage and two-stage breast procedures involving a tissue expander. Commonly investigated biological meshes include AlloDerm, Braxon, and Strattice; synthetic mesh examples are Vicryl Mesh and TIGR Matrix. Reported complication rates varied depending on the mesh type and study design. Common complications included seroma, infections, necrosis, and implant loss or the need for reoperation. Several studies found no statistically significant differences between biological and synthetic meshes regarding overall complication rates. However, synthetic meshes were often associated with lower infection and seroma rates, and they offer significant cost advantages. Patient-reported outcome measures showed similarly favorable results across mesh types.

Conclusions: Both biological and synthetic meshes provide valuable support in implant-based breast reconstruction and lead to overall satisfactory aesthetic and functional outcomes. No single mesh type appears superior in all aspects. Meshes should not be applied on a routine basis. Instead, mesh selection should be individualized based on patient-related factors, anatomic conditions, implant size, costs, patient preference, and the surgeon's experience. While synthetic meshes offer notable cost benefits and comparable safety, further research with standardized outcome reporting and extended follow-up periods is needed to optimize clinical decision-making and mesh selection.

3. Keywords

Breast cancer, implant-based breast reconstruction, synthetic meshes, biological meshes, acellular dermal matrix, ADM, clinical outcomes.

4. Introduction

Many women are afraid of breast cancer and the possible consequences of losing their breasts (1, 2). In women, breast cancer is the most common type of cancer. It is also the second most prevalent cancer globally. In 2022, approximately 2.3 million women were newly diagnosed with breast cancer, and 670,000 died of the disease globally (3). The countries with the highest incidence of breast cancer were China, the US, and India (4). Over time, there has been significant progress in the field of breast cancer detection and treatment. Surgery, such as mastectomy or a breast-conserving surgery (BCS), is the most important part of breast cancer treatment (5). Additionally, prophylactic mastectomy plays a fundamental role in women who have an increased risk of breast cancer; for example, if they have a genetic mutation of the breast cancer 1/breast cancer 2 (BRCA 1/2) genes or some other, more rare genetic mutations. There is a rising trend toward prophylactic mastectomies (6). Mastectomy can have salient effects on the quality of life of the patients. This surgery may not only result in physical limitations but may also have negative impacts on the psychological well-being. Reshaping the breast with reconstructive surgery following mastectomy has a considerable positive impact on the quality of life for most patients (2). According to the American Society of Plastic Surgeons' 2023 Statistics, breast reconstruction has been in the top five reconstructive procedures for the last two years. Restoring the natural contour of the breast has been proven to enhance self-esteem and aid in a positive body image (7). In general, reconstructive surgery is categorized as either autologous or alloplastic. Autologous reconstruction means tissue-based procedures, like the latissimus dorsi flap or deep inferior epigastric perforator (DIEP) flap. Alloplastic reconstruction includes the use of implants to reshape or reconstruct the breast (8). These two reconstructive surgeries can also be combined (6). In addition to reconstructive breast surgery after a radical mastectomy, it is also performed after nipple-sparing mastectomy (NSM) and skin-sparing mastectomy (SSM) (9). According to the 2023 procedural statistic report by the American Society of Plastic Surgeons (ASPS), implant-based breast reconstruction (IBBR) is the most common breast reconstructive surgery (7). Not only is the recovery time after this procedure faster, but the surgery itself is also shorter compared to autologous reconstruction (6). Besides recreating a natural looking breast with satisfactory aesthetic result, the goals of IBBR are to achieve symmetry, achieve the desired outcome with a low number of surgeries and in the shortest amount of time, and keep the complications to a minimum (10). IBBR can be performed with or without the use of meshes. Meshes are generally classified as biological (acellular dermal matrix; ADM) or synthetic meshes (11). In both prepectoral breast reconstruction (PPBR) and subpectoral breast reconstruction (SPBR), ADMs or synthetic meshes have come to play an important role. The goals of mesh application are to stabilize the implant or expander, have a better lower pole projection, reduce complications such as capsular contracture, provide structural support for the mastectomy skin flap, and to enhance aesthetic results (12).

However, it is important to mention that the application of meshes may be accompanied by complications and additional costs, emphasizing the need for a thorough evaluation of their cost-effectiveness (13).

The purpose of this paper is to provide an overview and a summary of the current literature on implant-based breast reconstruction using meshes following breast surgery due to cancer or prophylactic surgery. The classification of meshes, their market availability, and advantages as well as disadvantages of their application will be discussed.

5. Method

This study is a literature review. Starting in May 2024, a search was conducted using major electronic databases and sources, including PubMed, Google Scholar, Science Direct, Plastic and Reconstructive Surgery, WHO, World Cancer Research Fund, and GLOBOCAN, for the collection of the literature. This review of the literature ended in March 2025.

The following terms were used for the research: breast cancer, breast cancer risk, BRC1 and BRC2, implant-based breast reconstruction or IBBR, prepectoral, subpectoral, meshes in breast reconstruction, synthetic mesh (breast), biological mesh (breast), and acellular dermal matrix (or ADM). The initial focus was on inclusion and exclusion criteria. The studies included patients who had undergone mastectomy or prophylactic surgery due to breast cancer or a genetic predisposition. Articles were restricted to the English language and published within the last 10 years. Moreover, only articles with free full access were used. Articles in languages other than English, a publication time frame of more than 10 years, and literature without free access were excluded. The PubMed database was predominantly used.

After finding a very high number of publications, all the titles and abstracts were initially screened to identify their relevance. After excluding non-matching articles, the literature was carefully and fully analyzed. Through citation auditing, further applicable articles published more than 10 years ago were found and integrated. After reviewing all relevant articles, 80 sources were selected for the literature review. Key elements were identified, and important information about implant-based breast reconstruction was summarized. Table 1 provides a detailed outline of the search strategy for the literature review.

Table 1. Search strategy

Items	Specification
Research period	May 2024 – March 2025
Electronic databases and other sources	PubMed, Google Scholar, Science Direct, Plastic and Reconstructive Surgery, WHO, World Cancer Research Fund, GLOBOCAN
Search terms	breast cancer, breast cancer risk, BRCA1, BRCA 2, implant-based breast reconstruction or IBBR, prepectoral, subpectoral, meshes in breast reconstruction, synthetic mesh breast, biological mesh breast, acellular dermal matrix or ADM
Publication	March 2015 – March 2025
Inclusion and exclusion criteria	Inclusion: - publication date not more than 10 years (besides those articles further found through citation auditing), English language, patients who underwent a mastectomy or prophylactic surgery because of breast cancer or a genetic predisposition, articles with free access Exclusion: - articles in a language other than English, articles with no free access
Literature selection	Reading abstracts and full literature

6. Breast Cancer

Breast cancer is a worldwide known and essential topic with many women affected. It is the predominant type of malignant cancer in women in the world. According to the WHO, in 2022, 670,000 deaths caused by breast cancer were recorded globally. In the female population, approximately 50% of all breast cancer cases have no specific risk factors beyond sex and age (3). While lung cancer remains the leading cause of cancer-related deaths in men and women, breast cancer is the fourth most common cause, according to a report from the according to the Global Cancer Observatory (14). With the developing frequency of breast cancer, there was progress in the field of breast cancer (5).

6.1 Risk Factors

It takes multiple steps and changes in the progression from a normal and healthy epithelium to develop into cancer (15). Despite the knowledge of the diverse risk factors for developing breast cancer, the exact cause has not yet been found. Alongside many modifiable factors, such as an unhealthy lifestyle, there are also some non-modifiable factors, such as genetic predisposition (5).

6.1.1 Non-hereditary

The most substantial risk factor for breast cancer is female sex. With 99% of all cases, women are much more affected than men. One of the common risk factors is age. Despite breast cancer occurring at any age after puberty, the risk increases with developing age. Living in an industrialized environment with smoking, drinking alcohol, and obesity due to an imbalanced diet also contribute to the disease (3). Although the incidence of breast cancer is higher in some developed countries, mortality rates are higher in less developed countries. This imbalance in mortality rates is due to the lack of early detection and screening programs (16). The duration of hormone estrogen intake, such as many years of hormonal contraception or hormonal replacement therapy after menopause, as well as late age of menopause and early age of first menstruation, correlates with the risk of breast cancer. Reproductive habits, including childlessness and first birth after 30 years of age, are well-known risk factors. In addition, ionizing radiation therapy at a younger age is a potential risk factor (17).

6.1.2 Hereditary

Some of the greatest risk factors associated with this malignant disease are a prior history and a family history of breast cancer (17). Concerning hereditary breast cancer, the most important genetic mutations are linked with the BRCA1 and BRCA2 genes (18). Both are accountable for breast cancer inherited in its early stages (15). BRCA1 and BRCA2, located on chromosomes 17 and 13 respectively, produce tumor suppressor genes. Women with any mutations or changes in the BRCA1 or BRCA2 gene have a significantly higher risk of being diagnosed with breast cancer (18). Approximately 3-5% of women affected with breast cancer have mutations in these genes. Patients with BRCA1 or BRCA2 gene mutations should be included in preventive programs (5). Tumor protein 53 (TP 53) and phosphatase and tensin homolog (PTEN) are different suppressor genes with high penetrance. These mutations increase the risk of breast cancer (19). It is assumed that only about 5% of breast cancer cases in women are linked to genetics. In contrast, the majority of breast cancer cases result from acquired mutations (15).

6.2 Treatment

The treatment modality is multidisciplinary and depends on the molecular subtype of the cancer. Breast cancer treatment includes surgery, radiation therapy, systemic therapy, or a combination of those. Examples of systemic treatments are hormone therapy for hormone-positive breast cancer, anti-human epidermal growth factor receptor 2 (anti-HER2) therapy for HER2-positive breast cancer, chemotherapy, and immunotherapy (15).

Types of surgical methods for breast cancer in female individuals are tumor excision, mastectomy, excision of the sentinel lymph node, and excision of the axilla. In early forms of breast cancer, breast-conserving therapy (BCT) or BCS is becoming more and more prominent (5). In BCS, an expanded local excision, including the removal of the tumor together with a circumferential margin of healthy tissue, is performed (20). In mastectomy, the whole breast and skin enveloping the mammary gland (excluding NSM and SSM) are removed. The following different surgeries are available: simple mastectomy, subcutaneous mastectomy, and modified radical mastectomies (Patey method or Madden method). The main goal of surgery in breast cancer treatment is oncological completeness (5). The surgical oncologist and plastic surgeon have to make a decision together about the method of incision and mastectomy to address both reconstructive and oncological requirements. To get the best aesthetic results, it is desirable to keep as much of the native breast skin envelope as achievable. Some patients may be candidates for NSM or SSM (10). As the name implies, the nipple-areolar complex is maintained in NSM (21). In cases in which the tumor involves the nipple or subareolar tissue, as well as malignancy associated with nipple discharge, NSM is contraindicated. (22). In SSM, the native skin envelope is maintained, and all glandular tissue of the breast is excised. The whole breast envelope remains well perfused by viable vascularization (21).

Recently, there has been an increasing number of women who receive a prophylactic mastectomy. This trend is due to a change in guidelines in some countries, which now allows genetic testing for BRCA mutations without requiring an oncologist's recommendation. A famous example of this drift is the actress Angelina Jolie, who underwent a bilateral prophylactic mastectomy. This so-called Angelina Jolie effect has also led to a rise in the number of women undergoing testing and subsequently choosing contralateral or bilateral prophylactic mastectomy (6).

7. Implant-Based Breast Reconstruction

Mastectomy has an enormous impact on the quality of life in these patients. Due to the postoperative changes, women may experience physical limitations in ipsilateral upper limb function, which results in problems with their daily activities, like housework, hair brushing, and getting dressed. Additionally, women who have had a mastectomy may also experience adverse psychological side effects, including feelings of unhappiness or even depression. Reconstructing the breast due to reconstructive surgery has, in most patients, a considerable positive impact on their quality of life (2).

The main goal of breast reconstruction is to ensure patient satisfaction while achieving good cosmetic results, preserving physical function, and addressing psychosocial impacts (23). It is also important to consider cases in which women received a prophylactic mastectomy, either due to a history of

previous breast cancer or genetic mutations in BRCA1 or BRCA2. While women who received a risk-reducing mastectomy had less worries about their health condition in the future, they immediately after surgery experienced increased fearfulness, depressive symptoms, and a decline in body image and overall quality of life (1). IBBR is the most common reconstructive surgery (7). Not only is the recovery time after this procedure faster, but the time of surgery itself is shorter (6). Besides recreating a natural and aesthetically pleasing breast, the goals of IBBR are to achieve symmetry, finish the procedure within the smallest number of surgeries and the shortest amount of time, and keep the complications to a minimum (10).

7.1 History

Breast reconstruction has become an essential component of breast cancer treatment. In 1895, after mastectomy, a piece of fatty tissue (lipoma) in the dimension of a fist was grafted from a patient's lower back to the breast wall. This was performed by the German surgeon Czerny (24). Since then, reconstructive breast surgery has made great progress. Implant-based breast reconstruction with the utilization of silicone implants (prosthesis), which was performed after mastectomy, was introduced later in 1963 (25). The fathers of this modern area were Cronin and Gerow, who developed silicone implants. These first implants were characterized by a firm gel filler and solid sheath but had high contracture rates. The next implant generation had thinner shells and softer gel for a more natural feeling, but they allowed silicone particles to escape. Next, third-generation silicone implants were constructed with a thicker shell, including a barrier film. Nowadays, advances in silicone gel technology in fourth- and fifth-generation implants have not only led to more aesthetic pleasing and natural-looking breasts but also to medical security (26). PPBR was introduced around the same time as IBBR in the early 1960s. Deep to the mastectomy skin flap, the first silicone implants were positioned in a pocket in the subcutaneous plane (27). Due to high numbers of complications, PPBR was abandoned during the 1980s. Complications included capsular contractures and aesthetic impoverishment (28). Although the early outcomes were promising and provided great assurance, the high incidence of complications finally gave rise to a shift away from prepectoral implant insertion and toward submuscular implant insertion (26). In submuscular placement, the implant is placed inferiorly to the muscle in a complete sub-muscular pocket, thereby covering the implant. Over time, technical difficulties and barriers were seen in SPBR, such as undesirable side effects on the muscle, pain, and attaining only an insufficient subpectoral pocket for fixed volume implant holding. Because of reoccurring complications, a new dual-plane technique or partial coverage method was introduced. In this method, the implant was partly coated superior with the pectoralis major muscle and inferior with the mastectomy skin flap. A better lower pole expansion was possible, but the breasts' lower stretchy pole showed significant "bottoming out".

With the initiation of the ADM, a fold of the dermis, a modified dual plane method was performed approximately in 2006. By covering the implant inferiorly and laterally with the ADM, the frequency of implant migration was decreased. Unlikely, this modified technique resulted in adverse outcomes, such as animation deformity caused by the detachment of the muscle or rarely limited shoulder function. To avoid these complications, an updated method of PPBR emerged with or without the use of a synthetic mesh or ADM (28).

Evaluation and preservation of a necessary, well-perfused mastectomy skin flap became easier with the introduction of laser-assisted indocyanine green angiography by Harless and Jacobson in 2016. The use of this device diminished the frequency of mastectomy flap necrosis (29). Breast cancer surgical treatment made significant progress over time with a range of available breast reconstructive methods. Figure 1 shows a timeline of the history of IBBR (28).

Figure 1. History of breast reconstruction (28)

7.2 Main Techniques of Implant-Based Breast Reconstruction

As mentioned before, BCS or mastectomy are standard practice for the treatment of breast cancer or in cases of prophylactic mastectomy. IBBR after mastectomy has become a conventional procedure. According to the implant plane, IBBR can be differentiated between SPBR and PPBR. In PPBR, the implant is placed above the muscle; in SPBR, the implant is placed underneath the muscle (10).

IBBR can be done as a one-step surgery with the immediate insertion of permanent implants, or as a two-step surgery, in which a tissue expander (TE) is inserted, and later, after some months, the TE is exchanged with permanent implants (30). In this context, it is additionally essential to differentiate between immediate breast reconstruction (IBR), immediate-delayed reconstruction, and delayed breast reconstruction. Immediate or one-stage reconstruction uses a direct-to-implant (DTI) technique. Immediate-delayed reconstruction uses a two-stage procedure, with an expander implantation first, followed by an exchange with a permanent implant later. Another technique is delayed breast reconstruction, which is usually performed after the end of adjuvant therapy (31). The decision to delay breast reconstruction with the implant can have multiple causes. Reason may be to await completion of additional cancer treatment like radiation therapy, the preference of the patient, or a mastectomy poorly prepared for reconstructive breast surgery (30). Reasons, why a two-stage

technique might be preferred over a DTI breast reconstruction include situations in which mastectomy skin flap vascularization, influenced by surgical or patient factors, is in doubt. In such situations, applying TE is profitable to reduce tension on the flaps (10).

7.2.1 Prepectoral Plane

The plane to place the implant in PPBR, the prepectoral space, is between the pectoralis major muscle and the breast mastectomy skin flap. Crucial is a strong and sufficiently perfused mastectomy flap and an appropriate thickness (32). Although PPBR can be performed either with or without a mesh, the application of ADM is recommended to avoid complications, such as capsular contracture (33). PPBR includes building a novel breast, with the implant covered with ADM or mesh after mastectomy, and connecting it over the chest wall. The pectoralis major muscle and the serratus anterior muscle remain undamaged. With this surgery, the breast is kept in its anatomical place, and complications such as undesired cosmesis are avoided (28).

7.2.2 Subpectoral Plane

During the SPBR, the implant is positioned inferior to the pectoralis major muscle. There are two possible patterns with either complete or partial (ie – dual plane) cover by the muscle. As well as being one of the first and most basic reconstructive techniques, two-stage total submuscular IBBR is still significant, especially in women with an increased potential of healing complications. SPBR may be a good option for women with diabetes or fragile mastectomy flaps because the pressure on those flaps is potentially decreased, and ADM as a foreign body may be avoided. In delayed reconstructions, SPBR is performed in patients with a preoperatively flat chest wall. The first step is to position a TE (Figure 2). Next, the expander is completely covered submuscularly (Figure 3) by the alignment of the serratus anterior and pectoralis major muscle (10). As demonstrated in Figure 4, the expander is gradually expanded over time (23). After the period of expansion, during a second surgery, the expander is replaced by a permanent implant (10).

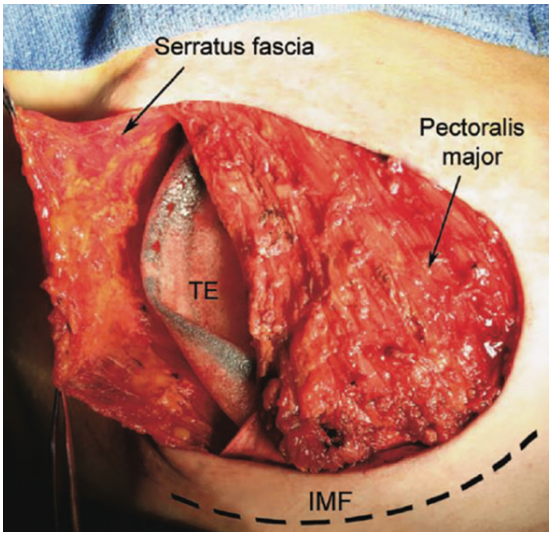

Figure 2. Total submuscular reconstruction: intraoperatively picture showing the positioning of the TE under the serratus anterior fascia and the pectoralis major muscle; IM – inframammary fold, TE – tissue expander (10)

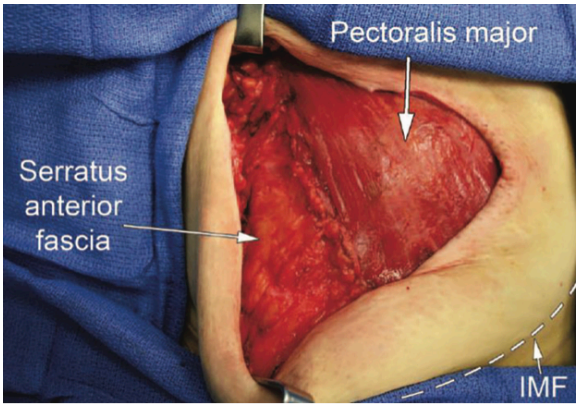

Figure 3. Total submuscular reconstruction: intraoperative picture showing inset of the anterior border to the lateral border of the pectoralis major muscle to have the TE completely covered; IMF – inframammary fold, TE – tissue expander (10)

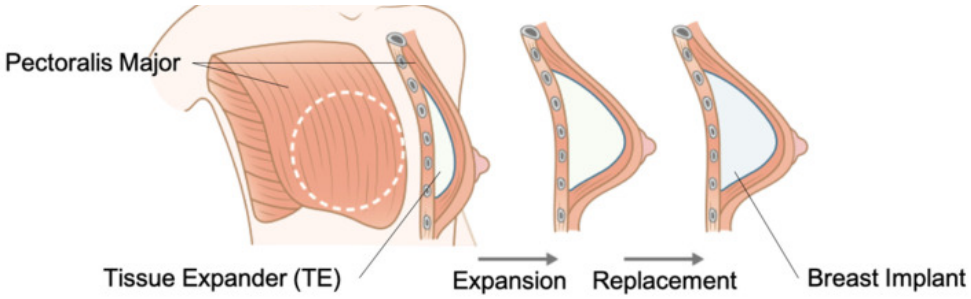

Figure 4. SPBR using a tissue expander: TE is placed in a subpectoral plane; stepwise expansion and saline infusion percutaneously, followed by implant replacement; SPBR – subpectoral breast reconstruction, TE – tissue expander (23)

7.2.3 Dual Plane

A dual-plane position means placing the implant under a combination of pectoralis major and mastectomy flaps with or without an ADM (8). Usually, the implant is positioned under both the pectoralis muscle and skin flap with ADM (sub-ADM pocket). In dual-plane direct-to-implant (DP-DTI) reconstruction, mastectomy flaps with good perfusion are crucial for the insertion of the ADM because the ADM is dependent on revascularization by the overlapping tissues. This is a reason why patients who smoke, have diabetes, or who undergone radiation therapy are not good candidates for this technique. First, the muscle is disinserted inferiorly to begin the lifting in a subpectoral plane. The ADM is brought into shape to connect the lower edge of the pectoralis major muscle to the inframammary fold, and the lateral edge of the muscle to the outer curve of the breast (Figure 5). Subsequently, the lateral and inferior part of the ADM is inserted into the chest wall. This allows an easy approach to the center of the pocket for the following implant positioning. During this step, implant sizers assist in selecting the appropriate implant. Next, the implant is placed, and for the closure of its pocket, the ADM's upper part is approximated to the lateral and inferior edges of the pectoralis muscle. In unilateral breast reconstruction, the contralateral breast is surgically adjusted at this point to be symmetrical with the other breast side (10).

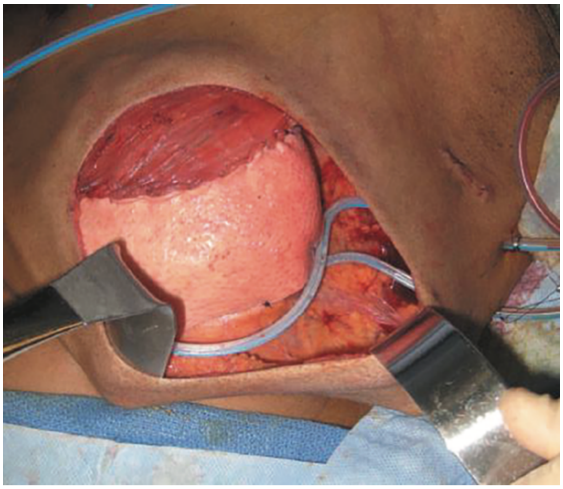

Figure 5. Dual-plane implant placement: intraoperative picture showing dual-plane implant placement under a combination of the pectoralis major muscle and ADM; ADM – acellular dermal matrix (10)

7.3 Implants

As mentioned before, several generations of silicone implants have been developed. Deciding which type of implant to use is multifactorial. Besides patient wishes and the surgeon's preference, the dimensions of a woman's body are important factors. Principally, an implant can be made of a silicone

case with a silicone or saline filling. The surface of the implants can be textured or smooth (21). Furthermore, implants can be either anatomical or round in shape. Anatomical implants are also called shaped or teardrop implants. At the lower pole, they have a higher projection (8). The surface of anatomical implants is textured, whereas round implants have either a textured or smooth surface (34). Due to the improvement of silicone implants over time, they have many advantages and are the favorite material to use compared to saline. As an example, silicone gel implants have a more breast-like, hence natural, feeling (35).

8. Complications in Implant-Based Breast Reconstruction

Complications after IBBR are common and can have a severe impact on both the patient and the surgeon. In IBBR, complications can be implicated by the surgery itself or associated with the implant. Overall, complications can be separated into short- and long-term, as shown in Table 2 (36).

Table 2. Complications of implant-based breast reconstruction (36)

Short-term	**Long-term**
Seroma	Capsular contracture
Hematoma	Malposition
Infection	Contour deformities and rippling
Skin envelope necrosis	Animation deformity
	Implant rupture
	BIA-ALCL
	BII

BIA-ALCL – breast implant associated large cell lymphoma, BII – breast implant illness

Short-term complications can be seen as perioperative complications, which can lead to reconstruction failure (36). In a systematic review and meta-analysis by Ostapenko et al. (2022), including 15 studies and 3,101 patients, there were no significant differences between PPBR and SPBB concerning general complications such as seroma ($p = 0.60$), hematoma ($p = 0.22$), infection ($p = 0.39$), skin flap necrosis ($p = 0.11$), and recurrence ($p = 0.55$). In contrast, patients with PPBR had fewer capsular contractures ($p = 0.02$), prosthesis failures ($p = 0.001$), and animation deformities ($p = 0.002$) than patients with SPBR (37). In PPBR, material influences on the aesthetic results are the quality of the mastectomy skin flap and the size and weight of the implants. Bottoming out with rippling of the upper pole can be a consequence of heavy implants, lack of support, or tension on the skin (Figure 6). It can ultimately result in pressure necrosis of the skin. Thin skin flaps and insufficient

support of the breast lead to visible implant margins and early rippling. Late rippling appears with diminishing support of the soft tissue (38).

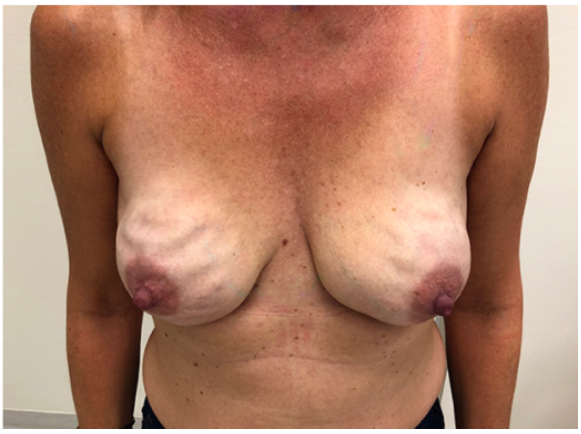

Figure 6. Late-onset rippling and wrinkled/prune appearance of the upper pole during forward bending (38)

Breast implant illness (BII) is associated with a mixture of symptoms encountered by patients who have undergone an IBBR encounter. Symptoms include tiredness, joint aches, symptoms related to the immune system, headaches, and hormonal issues. Patients think that these symptoms are caused directly by their breast implants, but it is not proven that the symptoms and implants are related. Furthermore, BII is not a medical diagnosis (21). Some patients undergoing subpectoral implant placement may experience complications such as long-term deficits in shoulder strength, which can also become a chronic deficit (39).

9. Meshes in Implant-Based Breast Reconstruction

A diversity of meshes is available in modern times (11). They vary in their preparations and are products of different costs (40). Meshes can be used in both PPBR and SPBR (12). Nowadays, they have become a favorite for single-stage and two-stage IBBR (41).

9.1 Types of Meshes

Meshes are generally classified by their material: biological or synthetic. Any mesh capable of providing support or integration can be used. According to Vidya et al. (2019), meshes have five optimal features (Table 3). Compared to biological meshes, which gain integration by neovascularization and collagen remodeling processes, synthetic meshes are incorporated through fibrosis. Nonetheless, all meshes have to be in close contact with the mastectomy flap to ensure integration (11).

Table 3. Optimal features of the mesh (11)

Minimal inflammation
Fast integration
Easy malleability
High strength
Cost effectiveness

9.1.1 Biological Meshes

Biological meshes are also called ADM (28). In 2001, Duncan implemented ADM to correct rippling following breast augmentation (42). In 2005, Breuing and Warren first introduced the technique of the classical inferior sling to address lower pole deficit and the "window-shading" effect caused by the detachment of the inferior part of the pectoralis major muscle (43). ADM, a fold of dermis (28), works like a scaffold and helps with the revascularization of the tissue, the ingrowth of the cells, and subsequently, simple integration into the capsule. Following inflammatory processes and fibrosis decrease simultaneously (44). Before its application, ADM is presterilized (28). Cellular and antigenic components are extracted from ADM by different methods to decrease the immune system's response (45).

Sources for ADMs may be either cadaveric human, porcine, or bovine. Examples of cadaveric human sources are AlloDerm® or DermaMatrix®. At the same time, ADMs with porcine sources are Strattice™, Cellis®, Braxon®, Artia®, Permacol™, and Protexa®. Veritas® and SurgiMend® are biological mashes from bovine sources. Biological meshes are available as fenestrated sheets with slits of various alignments and lengths or perforations that are either formed or round (40). Figure 7 shows an intraoperative picture of PPBR with the use of two fenestrated ADMs (46). Aside from these, ADMs can be true enlargeable meshed products featuring broad open areas. Moreover, they can be used as internal bras or wraps, which are preformed sheet designs. ADM can be stored as ready-to-use, freeze-dried, or pre-wetted (40).

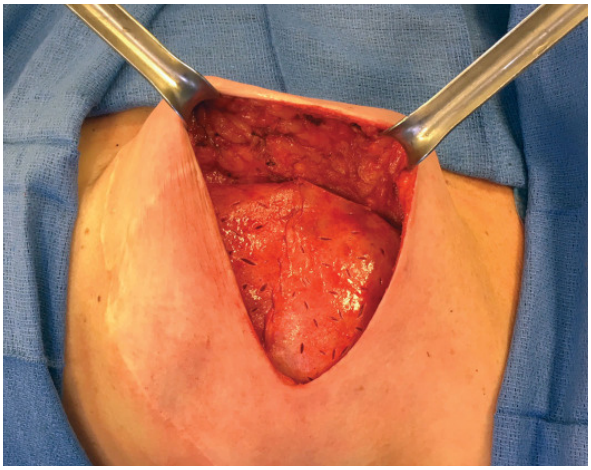

Figure 7. PPBR with two fenestrated ADM pieces, applied to define the pocket and assist the device; PPBR – prepectoral breast reconstruction, ADM – acellular dermal matrix (46)

9.1.2 Synthetic Meshes

In IBBR, an alternative option to biological meshes is the use of synthetic material. Synthetic meshes/matrices are available as long-term absorbable (TIGR® Matrix), absorbable (Vicryl® Mesh), or non-absorbable titanium-coated polypropylene meshes (TiLOOP® Bra) (28). Synthetic meshes like Seragyn® BR are partially absorbable. Other, well-known synthetic meshes are Breform® (non-absorbable), Phasix™ (absorbable) (47), and GalaFLEX® (40).

9.2 Available Meshes on the Market

As previously stated, diverse biological and synthetic meshes are commercially available for the use of IBBR. The selection of mesh depends on patient preference, the surgeon´s choice and know-how, and regional availability. Another critical factor that influences the decision is cost-effectiveness. (11). Table 4 summarizes prices, characteristics, and considerations of some ADMs and two synthetic meshes as alternatives (48).

Table 4. Biological and synthetic meshes and their characteristics (48)

Product	**AlloDerm Ready to Use (RTU)**	**AlloDerm**	**DermaMatrix**	**SurgiMend PRS**	**Strattice**	**Veritas**
Type	Biologic	Biologic	Biologic	Biologic	Biologic	Biologic
Manufacturer	Allergan	Allergan	MTF/Synthes	Integra	Allergan	Baxter
Source	Human	Human	Human	Fetal bovine	Porcine	Fetal bovine pericardium
Preparation	Rinse in NS or LR	2 baths of warm NS or LR	Room temp. NS or LR	Room temp. NS	Room temp. NS or LR	None
Prep. time	2 mins	10–40 mins	<3 mins	60 secs	2 mins	None
Sterility	Yes	No	No	Yes	Yes	Yes
Orientation	Yes	Yes	Yes	No	No	No

Table 4. Biological and synthetic meshes and their characteristics (*continued*) (48)

Shelf life	2 y	2 y	3 y	3 y	18 months	3 y
Approximate price per cm²	–	$28	$28.51–$31.94	$23	$24.65–$30.76	–
Key considerations	Short prep. time	Well studied, recognized by insurance	Short Prep. time, multiple thicknesses	Short prep. time, nonhuman	Short prep. time, nonhuman, short shelf life	Short prep. time, nonhuman
Product	**Permacol**	**AlloMax (Neoform)**	**DermACELL**	**Flex HD**	**Vicryl Mesh**	**Seri Scaffold**
Type	Biologic	Biologic	Biologic	Biologic	Synthetic	Synthetic
Manufacturer	Medtronic	Bard/Davol	Stryker	MTF/Synthes	Ethicon	Allergan
Source	Porcine	Human	Human	Human	Synthetic (polyglactin 910)	Purified silk
Preparation	None	Room temp. NS	None	None	None	Room temp. NS or LR
Prep. time	None	3 mins	None	None	None	
Sterility	Yes	Yes	No	No	Yes	Yes
Orientation	No	No	Yes	Yes	No	No
Shelf life	3 y	5 y	2 y	3 y	–	3 y
Approximate price per cm²	$21.63	–	$34	$27.31–$34.76	–	–
Key considerations	Nonhuman	Short prep. time, only sterile human ADM, long shelf life	Cost	Cost	Short prep. time	Short prep. time, cannot use if silk allergy

Table 5 presents some more important synthetic meshes used in IBBR (49). The synthetic mesh GalaFLEX® Scaffold, which is not mentioned in Table 5, is made from poly-4-hydroxybutyrate (P4HB). It is a microporous monofilament scaffold (Figure 8). GalaFLEX functions as a lattice for tissue ingrowth, integrates well into the tissue over time, and provides strong support. P4HB products have been applied in many surgeries, and GalaFLEX is used in plastic and reconstructive surgery (50), such as IBBR (51).

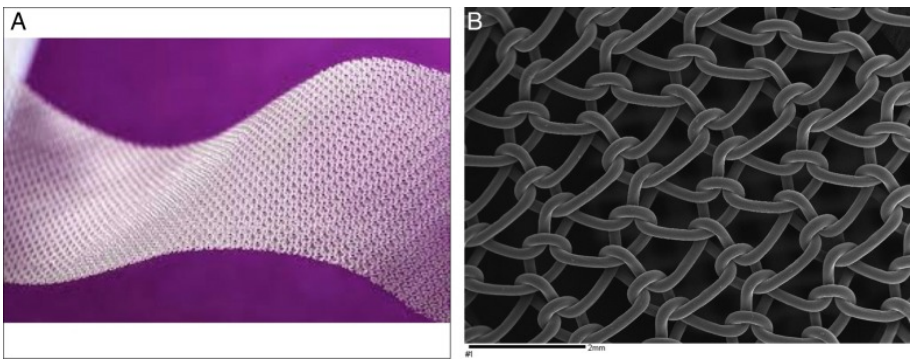

Figure 8. GalaFLEX. A. GalaFLEX Scaffold (10 x 20 cm²), B. GalaFLEX structure: macroporous, monofilament (50)

Seragyn® BR mesh (SERAG WIESSNER, Naila, Germany), a product available in Germany, is a partly absorbable and densely woven mesh (Figure 9 b). The non-absorbable component remains for continued structural support, whereas the absorbable component is absorbed within 90 to 120 days. Figure 9 visualizes some sheets of available biological and synthetic meshes (52).

Table 5. Synthetic meshes and their characteristics (49)

Product	**TiLOOP® Bra**	**TIGR Matrix Surgical Mesh**	**Knitted Vicryl Mesh**
Type	Synthetic	Synthetic	Synthetic
Manufacturer	PFM Medical, Cologne, Germany	Novus Scientific Pte Ltd, Singapore	Vicryl, Ethicon, Somerville, New Jersey, USA
Material	Titanium-coated polypropylene mesh	Fast-degrading (copolymer of glycolide and trimethylene carbonate) and slow-degrading (copolymer of lactide and trimethylene carbonate) fibers	Polyglactin 910
Sterility	Terminally sterilized	Terminally sterilized	Terminally sterilized
Use	Inframammary fold-like shape; comes in three sizes; mainly available in Europe	Long-term, absorbable, macroporous knitted mesh; retains mechanics for up to 9 months; totally hydrolyzed by 3 years	Absorbable; ready to use; cheap and widely available; minimum inflammatory response and non-allergenic
Key considerations	Not suitable for revision surgery	Higher complication rates in irradiated patients	Higher complication rates in irradiated patients

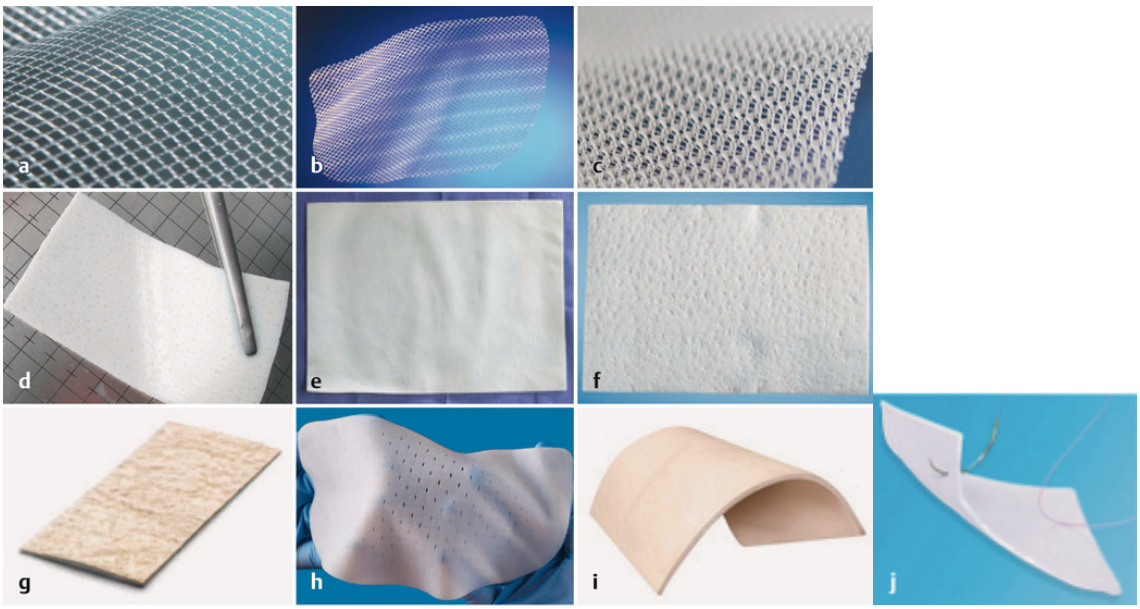

Figure 9. Sheets of biological and synthetic meshes: a. TiLOOP Bra, b. Seragyn BR, c. TIGR Matrix, d. Strattice, e. Permacol, f. AlloMax, g. Epiflex, h. SurgiMend, i. FlexHD, j. DermaMatrix (52)

Costs are a significant consideration, especially regarding cost-effectiveness and resource allocation within national healthcare systems. Despite this, the costs also differ across the USA, UK, and Europe, and biological meshes are more expensive than synthetic meshes (Table 6) (11).

Table 6. Average mesh costs across USA, UK, and Europe (11)

Biological meshes	16 cm × 8 cm piece (128 cm^2)	£1,600 to £1,800
	18 cm × 10 cm piece (180 cm^2)	£2,200 to £2,500
	Preshaped Braxon mesh 30 cm × 20 cm (600 cm^2)	£2,100
	In the US approximate cost	$3,000 to $3,500
Synthetic meshes	6 cm × 20 cm	£400 (€500)

9.3 Implant Coverage with Meshes

At induction, at least one dose of antibiotic must be administered to the patient. Postoperative antibiotics may be given following risk stratification or according to local hospital policy (11). In PPBR with an accessory ADM or synthetic mesh, two techniques of implant cover are performed. Fully preformed ADM (Braxon) sheets or a single (or two) ADM sheet are utilized for the entire wrap technique to cover the implant completely. A minor stripe of ADM is retained on the sides. The ADM, together with the implant, is then placed and sutured to the inframammary fold and the neighboring areas (28). Figure 10 visualizes PPBR with an ADM completely covering the implant (23). In the second method, the ADM is applied to wrap the implant only anteriorly, which is called an anterior wrap technique. The ADM is initially fixed under the skin flap to build a pocket over the pectoralis major muscle, in which the implant is positioned. Following, the ADM is secured to the pectoralis muscle inferiorly and superiorly (28).

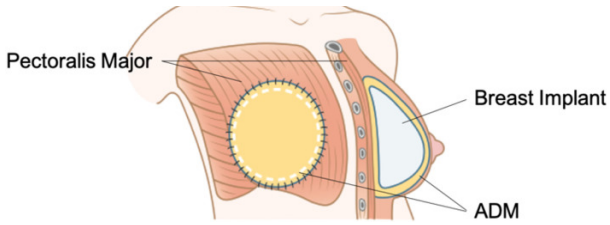

Figure 10. Prepectoral breast reconstruction with the implant completely covered by ADM; ADM – cellular dermal matrix (23)

In SPBR, meshes are used as an inferolateral sling (12), as seen in Figure 11 (23). This procedure, in which a mesh is applied to wrap the new breasts' inferior or lateral pole, is generally called dual-plane reconstruction (53).

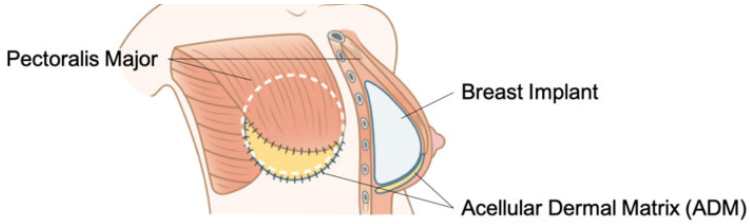

Figure 11. Subpectoral breast reconstruction with the ADM used inferiorly; after detachment of pectoralis major muscle, the ADM is sutured to it; ADM – acellular dermal matrix (23)

Figure 12 shows a scheme of IBBR in different planes with both biological and synthetic meshes. Parts b and c of Figure 12 show prepectoral breast reconstruction with ADM using the anterior wrap technique (41).

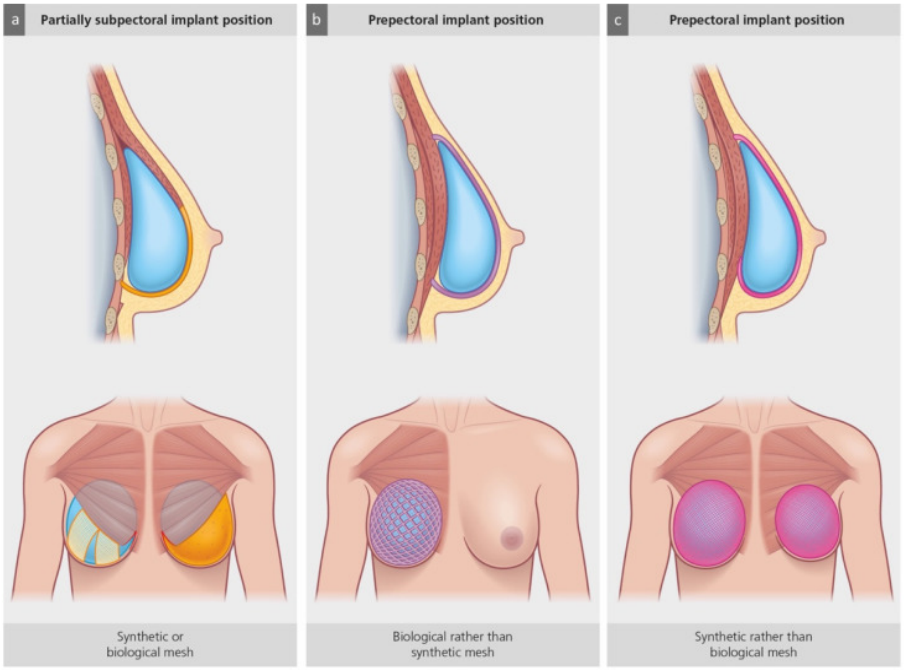

Figure 12. Scheme of implant-based breast reconstructions with the use of meshes;
planes: a. dual-plane, b. prepectoral plane, c. prepectoral plane (41)

10. Discussion

In both PPBR and SPBR, the application of biological and synthetic meshes has become fundamental. As mentioned before, in the prepectoral approach, these meshes cover the implant anteriorly or are used as a wrap to assist the implant (12). An intraoperative picture of PPBR using ADM is shown in Figure 13 (53). ADMs and meshes build a protective plane between the mastectomy flap and the implant. This layer stabilizes the implant and protects the implant from exposure. Furthermore, it prevents lateral implant migration (54). Especially in case of superficial skin necrosis or wound

dehiscence, ADM protects against direct breast implant exposure (44). The goal of meshes is to support the tissue and to decrease the frequency of capsular contracture (12). Secondary to the immense tensile strength and the limited elasticity, ADM is capable of tolerating the strain of tissue expansion, which lowers the transmitted tension on the mastectomy flap. As a result, an early expansion with bigger volumes is possible (44). Additionally, due to the diminished tension on the mastectomy flap by applying either an ADM or synthetic mesh in PPBR, there is a lower risk of ischemic wound complications during the postsurgical period or, later, bottoming out of the implant (41).

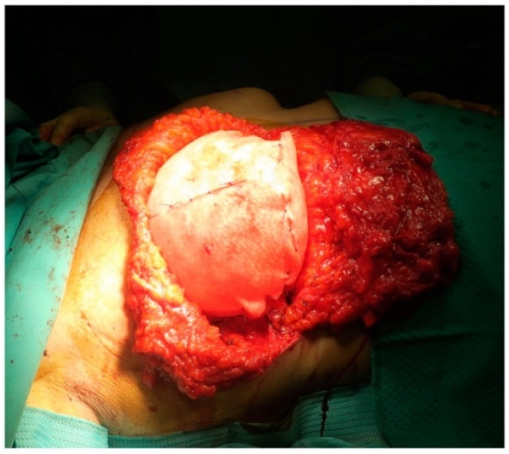

Figure 13. Prepectoral breast reconstruction with ADM; ADM – acellular dermal matrix (53)

In the subpectoral technique, the mesh assists the tissue inferiorly and laterally and builds a pocket for the implant. This also aids the TE before the implant placement and facilitates a more qualitative lower pole projection (12). Figure 14 shows an intraoperative picture of SPBR with ADM (53). Table 7 summarizes the advantages of meshes mentioned above.

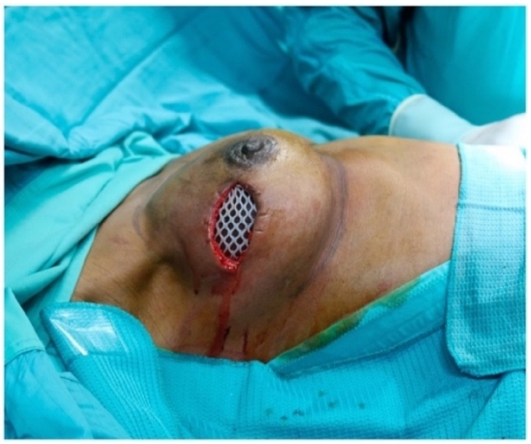

Figure 14. Submuscular breast reconstruction with ADM: To cover the lateral and inferior pole of the implant, a meshed ADM is applied. ADM – acellular dermal matrix (53)

Table 7. Advantages of mesh application

Protective plane (54)
Stabilization of the implant (54)
Prevention of implant exposure (54)
Decreased lateral migration (54)
Supporting the tissue and decreased capsular contractures (12)
Supporting the strain of tissue expansion (44)
Possibility of earlier expansion with bigger volumes (44)
Decreased risk of bottoming out (41)
Building a pocket for the implant and improved lower pole projection (12)

There are many studies on biological and synthetic meshes, comparing both mesh categories as well as different types within each mesh category (biological or synthetic mesh). Research has demonstrated that integrating ADMs or synthetic meshes in IBBR yields favorable outcomes. However, it is crucial to recognize that meshes have drawbacks and should be evaluated with caution (41). Complications can accompany ADM appliances. Infection, seroma, necrosis, and hematoma are common reported issues (55, 56, 57). Early complications, such as hematoma, seroma, infection, skin necrosis, and wound dehiscence, might be mainly related to the surgical procedure. In contrast, late complications, including capsular contracture and rippling, are predominantly linked to implant problems (58).

Capsular contracture is a significant adverse event in IBBR. A small study by Chopra et al. (2017), including 19 breasts, evaluated the effect of human ADM (hADM), AlloDerm, used as an inferior sling in immediate two-stage PPBR. During the second stage, two biopsies were taken from each breast capsule, one from the superior part of the pocket directly overlying the muscle and one from the inferior portion lining the AlloDerm. The biopsy of the superior part showed signs of active inflammation, while no signs of inflammation were identified in the inferior biopsy. The capsular thickness was also markedly thinner in the inferior capsular biopsy lining the hADM compared with the superior capsular biopsy (superior biopsy: 782 ± 194 vs. inferior biopsy: 47·91 ± 110 μm). There was enough evidence that using hADM decreases inflammation and subsequent capsular contractures. Despite the small study population and a relatively short follow-up time of five months, the study supports the use of hADM in IBBR (58).

Indeed, numerous studies have reported decreasing capsular contracture rates using meshes. In a prospective long-term observational single-center study, Khan et al. (2024) assessed early and late complications with the application of bovine ADM (SurgiMend) in immediate SPBR. Complications were evaluated during the first year. For the following four years, complications were assessed

retrospectively based on postoperative medical chart reviews. The study included 34 women (56 breasts), with a mean clinical follow-up time of 12.4 months. During the first three months postoperatively, 7.1% lost the implant, 7.1% had hematomas, and 8.9% had seroma formations. 10.7% had necrosis of the skin flap and an exposed ADM and/or implant. During the next nine months, 5.4% of implants had a malposition and one (1.8%) was replaced. After one year, the incidence of capsular contractures was at 71.4%, categorized as Baker grade I, 8.9% as Baker grade II, and only 1.8% as Baker grade III/IV, demonstrating low capsular contracture rates. The total implant exchange rate after a mean follow-up of 6.9 years was 33.9%, and 21.5% of women required a revision surgery. Besides the low incidence of capsular contractures, the study reports high rates of revision surgery (59).

Via a meta-analysis, Liu et al. (2020) concluded that the frequency of capsular contractures may decrease with ADM usage in PPBR. Approved by experiments, ADM helps suppress the formation of a capsule by lowering local inflammatory reactions (60).

In a long-term study by Salzberg et al. (2016), they accurately assessed the effect of ADM application on capsular contractures. They collected their experience with ADM-assisted DTI breast reconstruction over 13 years and published a summary in a report. The mean follow-up time was 4.7 years. A capsular contracture rate of 0.8% was observed. All cases of capsular contractures were seen within the first two years after ADM-assisted IBBR. These findings propose that capsular contracture might appear mainly as an early complication and does not appear beyond about two years after surgery. The authors concluding that ADM might effectively stop the development (61).

Other studies present low capsular contracture rates with the application of ADMs or meshes in IBBR. In a study by Masià et al. (2020), over six years, 1,450 prepectoral procedures were performed with a low capsular contracture rate of 2.1%. This study evaluated patients undergoing PPBR with Braxon porcine ADM completely wrapped around the implant. The mean follow-up time was 22.7 months. One aim of the study was to assess early and post-surgical complication rates. Early complications occurred in 200 breasts, and late complications in 61 breasts. No information about the onset was recorded in almost half (46.7%) of the total complications. In total, low rates of seroma (7.7%), infection (4.8%), necrosis (3.2%), dehiscence (4.6%), and hematomas (2.1%) were reported. The formation of seroma occurred in 3.6% within the first three months and only 0.2% after three months, classifying the latter as a late complication. Similarly, necrosis (within three months: 1.4%; after three months: 0.1%) and infection (within three months: 1.7%; after three months: 0.3%) were mainly related to early postoperative complications. Of those recorded, hematomas (1.4% vs. 0%) and wound

dehiscence (1.9% vs. 0%) were exclusively seen as early complications. These results indicate that early complications were primarily related to surgical adverse events. Moreover, the rate of implant loss at 6.7% was low, and most of them occurred as an early complication within the first three months (2.8% vs. 1.9%). In contrast, capsular contracture or rippling occurred mainly as late complications after three months. Late complications are predominantly related to problems with the implant. Of the total low capsular contracture rate (2.1%), 1.2% occurred after three months, and only 0.3% within three months. Also, of 2.8% implant rippling, 1.7% were observed after three months and only 0.5% earlier. The study emphasized long-term results with low complication rates (33).

A study by Mangialardi (2020) et al. aimed to evaluate and offers an update on the complication rates associated with immediate-delayed and delayed PPBR using AlloDerm, AlloDerm RTU, FlexHD, Dermacell, and Cryoderm. These ADMs are all of human origin. A total of 1,425 patients with 2,270 reconstructed breasts were included in this meta-analysis. Among the patients, 410 received a delayed IBBR, and 1015 received an IBR. The mean follow-up time was 17.6 months. The most commonly used ADM was Alloderm (1062 patients). The pooled data demonstrate an overall complication rate of 19%, affecting 193 patients, with a 95% confidence interval (CI) of 8.9–29.1%. Infection was the most prevalent complication at 7.9% (107 patients, CI 95% 2.74–11.9%), followed by seroma at 4.8% (59 patients, CI 95% 2.25–7.49%), mastectomy flap necrosis at 3.4% (51 patients, CI 95% 0.24–7.03%), and implant loss at 2.8% (40 patients, CI 95% 0.34–5.26%). The lowest complication rate was capsular contractures, at 1.2% (8 patients, CI 95% 0–2.4%). Although low complication results were observed, there might be high variability across the studies, shown by wide confidence intervals (62).

Cortiva is another human-derived ADM. Keane et al. (2024) compared Cortiva with AlloDerm RTU. They conducted a single-blinded randomized controlled trial including 302 patients and 557 breasts receiving IBR with either an implant (DTI 38%) or a temporary TE (62%). Of all breasts, 277 received AlloDerm and 280 Cortiva. According to the plane, PPBR or SPBR were performed. The follow-up time of patients was a minimum of three months after reconstructive surgery or until failure of the reconstructed breast. The incidence of reconstructive failure was comparable between the two ADM groups, with 9.4% in the AlloDerm RTU group and 8.3% in the Cortiva group. The formation of seromas was higher with AlloDerm (12%) compared to Cortiva (7.6%). Regarding the different planes, the incidence of reconstructive failure was similar between the ADM groups. However, when comparing only the patients who underwent single-stage reconstruction, AlloDerm (5.6%) was associated with higher rates of surgical exploration than Cortiva (0%). In addition, complications like infection (9.3% AlloDerm RTU vs. 8.7% Cortiva), hematoma (3.6% AlloDerm RTU vs. 1.4%

Cortiva), necrosis (7.9% AlloDerm RTU vs. 6.1% Cortiva), and implant exposure (1.4 AlloDerm RTU vs. 2.2% Cortiva) did not differ significantly. Postoperative Breast Reconstruction and Augmentation Quality of Life Questionnaire (BREAST-Q) scores, including satisfaction with breasts, psychosocial well-being, and sexual well-being, were similar pre- and postoperatively and did not differ significantly between the ADM groups. Conversely, the score for physical well-being was lower postoperatively in both ADM groups. When there is no significant difference in complication rates or patient-reported outcomes (PROs) between ADMs, costs may become a substantial factor. At the authors' institution, the price for Cortiva ranged from \$23 to \$26/cm^2, and the price for AlloDerm RTU ranged from \$28 to \$31/cm^2. This shows that AlloDerm RTU was 10% to 15% more expensive than Cortiva in this study. Cortiva does not appear inferior to AlloDerm RTU and could be an effective alternative (63).

Silverstein et al. (2024) support that Cortiva is non-inferior to AlloDerm in two-stage PBBR. The study included 104 patients (178 breasts) with a follow-up time of at least 103 days after TE placement. After propensity matching, the follow-up period was longer in the AlloDerm group than in the Cortiva group. Strength, durability, flexibility for surgical manipulation, minimal inflammatory response, efficient integration, and cost-effectiveness are key characteristics of an ideal ADM. Cortiva Silhouette (a new Cortiva product) fulfills many of these characteristics, with fewer complication rates than AlloDerm. Cortiva (11.3%) was related to a significantly lower rate of any complication compared to AlloDerm (33.9%). Significant differences in the rate of seroma (AlloDerm 6.5% vs. Cortiva 0.0%, p-value (p) = 0.003) and mastectomy skin necrosis (AlloDerm 17.7% vs. Cortiva 0.0%, $p < 0.001$) were observed. Infection (12.9% vs. 11.3%), wound healing delay (8.1% vs. 1.6%), and capsular contracture (3.2% vs. 0.0%) were also more present in the AlloDerm group, but this was not statistically significant ($p > 0.05$). Cortiva mesh may improve implant support and facilitates due to its greater pliability than other ADMs, simpler surgical handling, and larger TE fill volumes. Cortiva was related to both larger interoperative TE fill (195.2 vs. 243.5 ml) and final TE fill (355.6 vs. 304.7 ml) (64).

Chu et al. (2023) compared and assessed early outcomes following the application of AlloDerm (human origin), SurgiMend (fetal bovine origin), and FlexHD (human origin) in an immediate-delayed PPBR using an expander. The 726 patients (1,054 breasts) included in the study did not differ significantly according to patient-related factors. Patients were followed up 90 days after TE placement. AlloDerm (11.9%) was associated with a higher incidence of seroma formation compared to FlexHD (4.3%) and SurgiMend (8.3%). The highest rates of infections were seen in SurgiMend at 8.6%, followed by 5.7% in AlloDerm and 3.2% in FlexHD. However, these variable results in

infection and seroma rates across all ADMs did not reach statistical significance ($p < 0.05$). All three meshes had similar rates of TE exposure (SurgiMend: 2.0%; AlloDerm: 1.5%; FlexHD: 1.1%). Additionally, similar rates of TE loss were observed in all three ADM types (AlloDerm: 4.1%; SurgiMend: 3.7%; FlexHD: 3.2%). The study suggested that the type of ADM has no significant effect on the rates of complications or risk of TE loss (65).

Human ADMs are associated with high costs, and their availability on the market is restricted. Due to these barriers, research is increasingly focusing on exploring alternative materials. Gabriel et al. (2024) investigated the histological integration and clinical performance of ADMs of porcine origin (Artia) and compared them to hADM (AlloDerm). The follow-up period was for a minimum of five years. A total of 59 patients receiving two-stage PPBR were included in this study. Each TE was covered with both a hADM on the superior half and a porcine-derived ADM on the lower half (Figure 15). Two biopsies of each ADM type were extracted during the expander exchange with the implant three to four months after the initial reconstruction. The overall postsurgical complication rate was 8.6%, including low incidences of necrosis (6.9%), reoperation (2.6%), implant exposure (1.7%), and seroma (1.7%). In the histological analysis, greater capillary and fibroblast ingrowth was seen in hADM samples (fibroblastic ingrowth: AlloDerm 95.5% vs. Artria 81.9%). However, an increased inflammatory reaction was visible in porcine ADM samples (inflammatory cells: AlloDerm 28.5% vs. Cortiva 44.4%). No occurrence of capsular contracture, graft rejection, or loss of implant was observed in either ADM. These findings support the ability of porcine-derived ADMs to successfully integrate into host tissue and demonstrate a comparable clinical efficacy to hADM (AlloDerm). Overall, the similar clinical outcomes, possible reduction in costs, and structural advantages suggest that porcine ADM may be a safe and variable alternative to hADM for long-term support of implants in prepectoral breast reconstruction (66).

Figure 15. TE partly covered with ADMs (upper half: human ADM; lower half: porcine ADM); TE – tissue expander, ADM – acellular dermal matrix (66)

In a systematic review, Tellarini et al. (2023) reported that various ADMs made from animal sources did not differ much regarding to their complications in immediate PPBR. Three distinct groups with animal-derived ADMs were taken into account for comparison: porcine Braxon, porcine non-Braxon (Artia, Strattice, Native, and Permacol), and bovine (Surgimend, Veritas, Exaflex). In total, 5,089 patients (6598 breasts) were included. Braxon (porcine) was the most commonly applied mesh. The average follow-up was 9-24 months. This review demonstrates higher risks of capsular contracture with the application of bovine ADM (5.0%-8.5%) compared to other animal derived ADMs (Braxon: 0%-4.5%, porcine non-Braxon: 0%-1.1%) when excluding patients with adjuvant radiotherapy. Nevertheless, the authors stated that no mesh type is superior to another. Additionally, they pointed out that the results were difficult to interpret because of an inconsistent reporting of complications and follow-up periods being too short (67).

In a study by Marco Bernini et al. (2024) on two-stage PPBR with TEs entirely covered by ADM, it was observed that ADMs covering a TE integrated successfully into the surrounding tissue and became a well-perfused new self-tissue. The type of ADM used was Braxon Fast, a pure collagen matrix free from cross-linking elements or preservatives. 64 breasts were included in the study, with an average follow-up period of 10 months. The incidence of complications was minimal (early complications 9.4% and late complications 3.1%). Radiation therapy is an established risk factor for capsular contractures. 20% of the studied patients received post-surgical radiotherapy. Notably, no cases of capsular contracture were evident either in irradiated patients or in patients who did not receive radiation therapy. The study shows that ADM-assisted two-stage PPBR (Figure 16) is a feasible and safe reconstructive technique with good results (68).

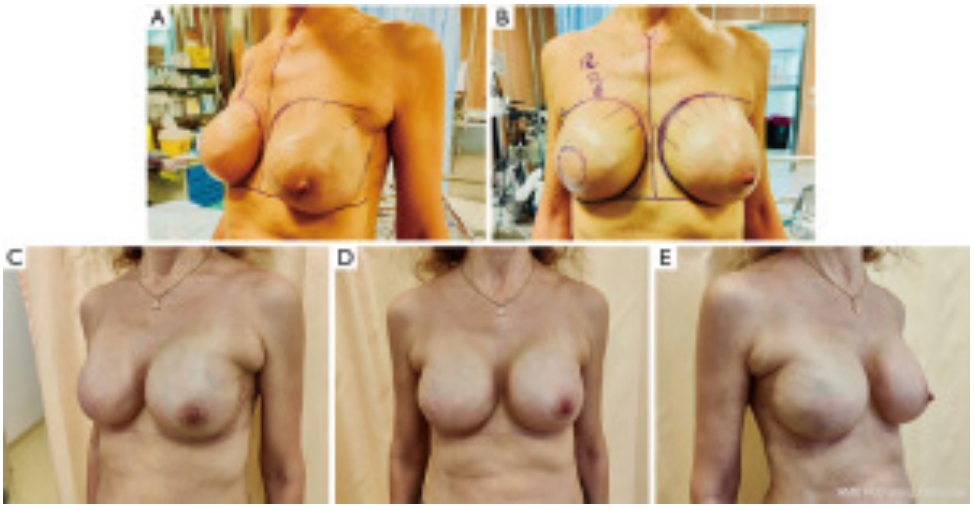

Figure 16. A-B. presurgical image of women with bilateral Braxon Fast covered TE; C-E. postsurgical images two months after bilateral TE removal and permanent implant placement; TE – tissue expander (68)

The effect of ADM on patient satisfaction was investigated by Powell et al. (2018) in a prospective cohort study that included 77 breasts. The mean follow-up time of the patients was 17 months. The studied patients underwent IBR with the implant covered in a porcine ADM, namely Strattice. Measured by the BREAST-Q questionnaire, overall patient satisfaction was markedly high. At six months postoperative, satisfaction with the outcome (82.5 ± 18.9), psychosocial well-being (71.3 ± 20.5), and physical well-being (77.9 ± 19.2) are represented with excellent results. Besides assessing patient satisfaction, the study also aimed to evaluate surgical complications. Eight cases of skin flap necrosis (10.4%) and four hematomas (5.2%) were observed. Only one case each (1.3%) of seroma and infection were identified in only. Four lost their implant either to necrosis or due to an infection. Although the relatively high rate of skin flap necrosis might be concerning, low rates of the majority of complications, good aesthetic results, and high patient satisfaction support the usage of ADM in IBBR. The study underlines the need for a more detailed patient selection and improvement of surgical methods to avoid complications (57).

Other studies assessing PROs in women receiving IBBR with the assistance of ADM report overall high satisfaction rates. Some patients have lower satisfaction rates, possibly due to their experience with complications. In the study by Negenborn et al. (2018), the mean follow-up period was five years. Patients underwent one-stage IBBR after mastectomy (50% prophylactic), with the majority receiving an implant covered with ADM (Alloderm 86.4%). The total complication rate was 7.7%, including 1.5% severe complications, such as nipple necrosis (0.5%) and cellulitis (0.5%). Severe complications led to return to the hospital (5%), removal of the implant (0.5%) and removal of the nipple (0.5%). Of the 541 invited patients, 208 women (38.4%) filled out the BREAST-Q. All respondents had ADM-assisted IBBR. The survey showed a mean satisfaction with the breast of 70.6 ± 20.2 and satisfaction with the outcome of 78.0 ± 20.5. Physical well-being (80.5 ± 16.7) and psychosocial well-being (79.5 ± 22.7) had the highest scores. Conversely, sexual well-being recorded the lowest score, at 60.8 ± 23.7 (69).

As mentioned previously, synthetic meshes are an alternative to biological meshes in IBBR. A clinical, randomized, and prospective trial by Paganini et al. (2022) compared a biological and a synthetic mesh within the same patient in two-stage IBBR. The aim of this study was to identify differences in PROs, including physical well-being, satisfaction, and psychosocial aspects with the synthetic mesh compared to the biological mesh in the same patient. The patients did not know which breast side received the synthetic and the biological mesh. The synthetic mesh used was the TIGR Matrix Surgical Mesh, and the biological mesh used was the Veritas Collagen Matrix. To assess patient satisfaction, the study used the BREAST-Q. The data were collected preoperatively and four

to six years postoperatively. The result showed no general superiority of one mesh type regarding patient-reported outcomes. Regarding questionnaire items such as softness, size of bra, palpable wrinkles, natural part of body, and appearance compared with their presurgical state, most patients were similarly satisfied/dissatisfied with the biological and synthetic mesh. Of those patients who felt a difference, more patients liked the breast side with the biological mesh in terms of natural appearance (64%) and appearance compared with presurgical (89%), and more patients liked the breast side with the synthetic mesh regarding bra size (67%) and natural part of the body (63%). It may be relevant to mention that the biological mesh produced a more natural-feeling breast, while the synthetic mesh seemed to feel more rigid. However, the biological mesh was associated with higher rates of implant loss after the first (biological 14% vs. synthetic 4.8%) and second stages (biological 4.8% vs. synthetic 0%). Notably, no cases of capsular contracture were reported in either the biological or synthetic mesh. Synthetic and biological meshes may lead to variable outcomes of reconstructed breast types (70).

A study by Mookerjee et al. (2023) compared IBBR with ADM (AlloDerm Select RTU or FlexHD) and IBBR with Vicryl Mesh. In their study, 55 breasts (44 patients) underwent PPBR with the application of ADM, and 23 breasts (12 patients) had a PPBR with Vicryl Mesh. The breast reconstructions were performed by different surgeons. The average follow-up time was around three months in both groups. The Vicryl Mesh was applied via a mesh wrap method with one individual stitch (Figure 17). The price for the IBBR with Vicryl Mesh was $760 for each breast compared to $9,033 for breast reconstruction with an ADM, thereby saving $8,273 (91.6%) per breast with the use of Vicryl Mesh ($p < 0.05$). Regarding the duration of reconstructive surgery, the IBBR in the Vicryl Mesh group lasted around 35.7 minutes per breast, almost half as long as the IBBR in the ADM group, which was 68.0 minutes ($p < 0.05$). The rates of complications were low with the Vicryl Mesh (infection 8.7%, hematoma 4.3%, seroma 0%, skin flap necrosis with implant exposure 4.3%) and comparable to the ADM group (infection 3.6%, hematoma 5.5%, seroma 12.7%, skin flap necrosis with implant exposure 3.6%). Finally, the study demonstrates that the single-stitch Vicryl Mesh wrap method may be a quicker and less expensive option than the traditional ADM method (71).

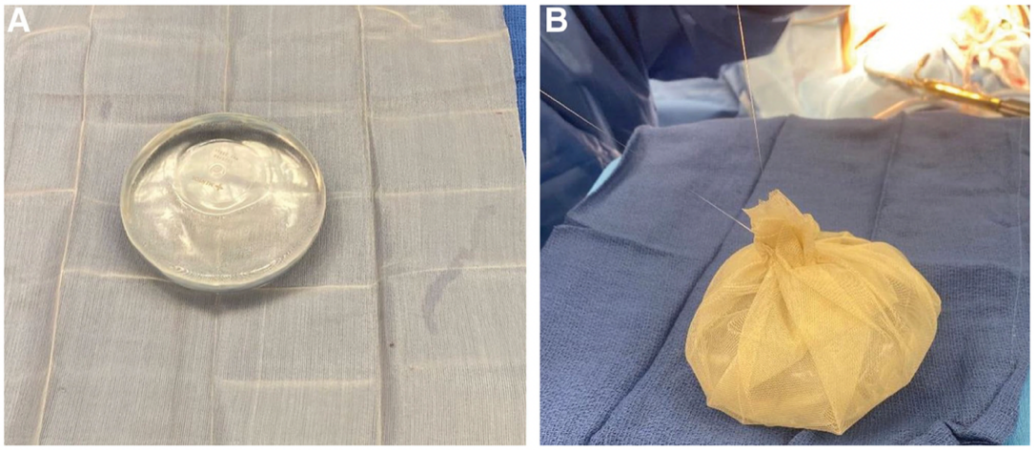

Figure 17. A: Vicryl Mesh on sterile table. B: On the posterior aspect of the implant, the knot is secured (71)

The first-year incidences of complications after two-stage IBBR with a synthetic and a biological mesh were compared by Hansson et al. (2020) in a randomized controlled study. In this study, patients (48 breasts) underwent a bilateral mastectomy followed by IBBR using a synthetic mesh (TIGR Matrix Surgical Mesh) in one breast and a biological mesh (Veritas Collagen Matrix) in the contralateral breast. The use of two different meshes in the same patient eliminates interpatient variability and ensures that there are no discrepancies regarding patient-related or systemic factors between the two mesh groups. The results show that the breasts with a biological mesh were associated with higher rates of implant loss than the breasts with a synthetic mesh (8.5% vs. 2%), although not statistically significant ($p = 0.83$). Additionally, the rate of infection, which may lead to implant loss, is higher with ADMs (12.5% vs. 0%). Seroma was the most common complication, with 38% in the biological mesh group and 3.8% in reconstructed breasts with a synthetic mesh, which was statistically significant ($p = 0.011$). Differences in aesthetic outcomes between mesh groups were noted, which meant asymmetrically reconstructed breasts. The study hypothesized that the formation of seromas may be a factor leading to the higher incidence of infections in biological meshes. Overall, the results of this study demonstrate that biological meshes carry a higher risk of complications than synthetic meshes, such as implant loss, infection, and seroma (56).

In a systematic review and meta-analysis, Choi et al. (2023) compared the adverse effects of synthetic and biological meshes at six months or more after single-stage IBBR. Four groups were compared based on the mesh type used: ADM, absorbable synthetic mesh (Vicryl Mesh, TIGR Matrix, Phasix), non-absorbable synthetic mesh, and no mesh formed. This study classified partially absorbable meshes (Seragyn BR) as non-absorbable (Breform, TiLOOP Bra, Seragyn BR). During the evaluation of complications, the main focus was on seroma, infection, contracture, and major complications. In

this study, major complications referred to all situations where patients had to undergo a reoperation or when the implant had to be explanted. In the ADM group the incidence of infection was significantly higher, with an odds ratio (OR) of 2.965 (95% CI: 1.620-5.488), almost three times, compared to the no mesh group (OR: 1.000). The infection rate was slightly lower among absorbable synthetic meshes (OR 0.798; 95% CI: 0.127-5.016) and slightly higher among non-absorbable meshes (OR 1.369; 95% CI: 0.677-2.769), although neither were statistically significant. This means that the infection rate between the two synthetic mesh groups and the non-mesh group did not significantly differ. The incidence of seroma formation was significantly lower in the two groups with a synthetic mesh (non-absorbable mesh group: OR 0.208; 95% CI: 0.092-0.467 and absorbable mesh group: OR 0.194; 95% CI: 0.052-0.723) than in the group with an ADM (OR 1.000). In addition, no significant differences between the ADM (OR 1.000) and the non-mesh group (OR 0.501; 95% CI: 0.244-1.027) regarding seroma formation existed. The rate of capsular contracture and major complication was similar across all four groups. Concluding, this study reports lower seroma and infection incidences in synthetic meshes, especially absorbable synthetic meshes, compared to ADMs. This suggests the application of synthetic meshes as a possible and good alternative in IBBR (47).

Faulkner et al. (2020) reinforced that synthetic meshes could indeed be a valuable and safe alternative to biological meshes. In a seven-year review, they observed low rates of infection (2.1%), implant exposure (2.9%), capsular contracture (4.8%), and implant loss (4.5%) in patients undergoing single-stage SPBR with a synthetic absorbable mesh (Vicryl Mesh, size 30 x 30 cm). The study included 227 patients (376 breasts), the majority of whom had NSM. Only 1.3% had a hematoma, and only 1.1% had seroma formation. In addition, this study suggests that applying synthetic mesh instead of biological mesh could save over $1.2 million in costs. As an example, during this study the price of one 12 x 12-inch sheet of Vicryl Mesh was $710, and one 8 x 16 cm AlloDerm was $3,415 (72).

Schüler et al. (2021) observed similar postoperative complication results when comparing two synthetic meshes and one biological mesh in SPBR. Overall, 188 breasts from 157 patients who received either the biological mesh Strattice or one of the two synthetic meshes, Seragyn BR (partially absorbable mesh) or TiLOOP Bra (titanium-coated mesh), were included in this study. The average follow-up period was 11.7 months. In total, 27 minor (14.4%) and 31 major (16.5%) complications were recorded. Among the 19 breasts (10.1%) experiencing implant loss due to reconstructive failure, more than half occurred in the Strattice cohort (27.5%), and only 2 (3.7%) and 6 (6.4%) in the Seragyn BR and TiLOOP Bra cohorts, respectively. Strattice had the highest complication incidence, with 27.5% minor and 27.5% major complications. TiLOOP Bra (9.6% minor and 14.9% major) and

Seragyn BR (13% minor and 11.1% major) showed lower complication rates. Seroma (11.7%), revision surgery (8.0%), hematoma (7.6%), and wound infection (5.9%) were some of the most common reported complications. The rate of seroma formation was 27.5% in the Strattice group, 13% in the Seragyn BR group, and 4.3% in the TiLOOP Bra group. The biological porcine mesh Strattice was related to higher complication rates than the two synthetic meshes in SPBR. This study supports the assumption that synthetic meshes may be a variable alternative to biological meshes (73).

As stated in the previous studies, capsular contracture rates tend to be low in both synthetic and biological meshes. Ferenz et al. (2024) compared the capsular contracture rates in patients undergoing IBR with different meshes. The biological meshes included AlloDerm, FlexHD, AlloMax (rebranded as Cortiva), and the synthetic meshes used were GalaFlex, SeriScaffold, and DuraSorb. Overall, 772 breasts received IBR. The biological mesh was applied in 689 breasts (AlloDerm in 185, AlloMax/Cortiva in 13, and FlexHD in 491) and the synthetic mesh in 83 breasts (DuraSorb in 76, GalaFlex in 2, and SeriScaffold in 2). The follow-up period in the biological group, an average of 54.7 months, was significantly longer than the follow-up period in the synthetic mesh group, an average of 18.8 months. Overall, 5.1% experienced dehiscence, 5.1% seroma, 1.0% hematoma, 3.5% infection, or 4.4% necrosis. Capsular contracture was observed in 18 breasts, of which 15 (2.2%) belonged to the biological and three (3.6%) to the synthetic mesh group, which demonstrated no significant difference ($p = 0.430$). From the biological mesh group experiencing capsular contracture, nine had AlloDerm inserted and six FlexHD. All three capsular contracture cases in the synthetic group were associated with DuraSorb. In comparison, no significant difference was observed between the two mesh cohorts (51).

Surgeons should use the smallest possible quantity of the foreign substance but still enough to have sufficient material for the desired effects. [41] In light of this, Rose et al. (2016) observed in a retrospective study that the risk of complications such as skin necrosis, seroma, or infection is higher with the use of a thicker ADM, although not statistically significant. Patients who underwent IBBR with AlloDerm mesh were followed up over four years. The thickness of the ADM was 0.86-2.18 mm, and the study defined a thick ADM as ≥1.2 mm and more. Of the 77 breasts, 41 received a thick ADM and 36 breasts a thin ADM. In the thin ADM group, 11.1% had seroma, 11.1% skin necrosis, 8.3% infection, and 8.3% required an intervention. Conversely, in the thick ADM group, 14.6% developed seroma, 14.6% skin necrosis, 17.1% infection, and 17.1% required intervention. Regarding the drainage period, the average drain weeks of thin ADMs was 2.43 compared to 2.45 in the thick ADM group. Patients with thick ADMs were more likely to have a longer drain time but without statistical significance (74).

Referring to a study on ADM usage in subpectoral DTI breast reconstruction, Kong et al. (2022) assessed the effect of ADM size and thickness on complication rates, drainage volume, and drainage time. Three different types of ADMs were used: AlloDerm, MegaDerm, and CGCryoDerm. Four different groups were formed regarding the surface area and thickness of ADMs: group 1, which included thin and small; group II, thin and large; group III, thick and small; and group IV, thick and large. ADMs below 2.5 mm were categorized as thin, and ADMs 2.5 mm or above as thick. ADMs measuring 64 cm^2 or more were classified as large, and ADMs below 64 cm^2 as small. Two drains were placed, one in the submuscular plane and one in the supramuscular plane. The patients were followed up for more than six months. In the supramuscular drain, there were no significant differences related to drainage volume and the timing of drain removal between the four groups. Though, the volume of drainage was significantly increased in group II (614.38 ± 287.40 ml) and group IV (574.38 ± 346.74 ml) compared with group I (430.82 ± 186.46 ml) and group III (360.86 ± 176.2 ml). No significant difference between groups I and III and between groups II and IV was reported. Furthermore, the submuscular drain was removed significantly later in groups II (17.79 ± 7.18 days) and IV (16.92 ± 6.87 days) than in groups I (13.26 ± 4.42 days) and III (10.52 ± 3.81 days). The results show that using larger-sized ADMs with similar thicknesses led to higher drainage volumes, but using similar-sized ADMs with variable thicknesses did not result in higher drainage volumes. In total, there were 17 cases of infection (7.8%) and 19 cases of seroma (8.7%), with significantly higher rates observed in group II (11 seroma cases and 10 infection cases) and group IV (seven seroma cases and five infection cases) than in groups I (one seroma case and two infection cases) and III (zero seroma and infection cases). Using a larger ADM led to higher volumes of drainage and longer drainage duration, which in turn increased the likelihood of seroma or infection. Neither the thickness of the ADM nor its manufacture revealed differences in the drainage duration, drainage volume, or complications (75).

Other studies, such as the one by Hong and Kim report (2021), support the finding that the thickness of ADM has no impact on postoperative outcomes, including complications and time of drainage removal. The study evaluated patients undergoing dual-plane SPBR with ADM (MegaDerm) used as an inferior sling. One group received a thin ADM measuring 0.6-1.5 mm, and one group received a thick ADM of 1.5-3.0 mm. Overall, 51 patients were included in the study, of whom 21 (41.2%) received a thin ADM and 30 (58.8%) a thick ADM. The mean follow-up time of the patients was 13.5 months (6-42 months). The time of drain removal was 14.67 ± 1 in the thin ADM group and 15.17 ± 1.02 in the thick ADM group ($p = 0.731$). The two groups together showed an overall complication rate of 21.6%. The total complication rate was 19% for the thin ADM group and 23.3% for the thick ADM group. The incidence of seroma was slightly higher with thick ADMs (13.3%)

than with thin ADMs (9.5%), although not statistically significant (p = 0.679). Similarly, slightly higher rates of skin necrosis (6.7% vs. 4.8%) and revision surgery (10.0% vs. 9.5%) were observed in the thick ADM group, neither of which was statistically significant (p > 0.5). Interestingly, the thin ADM group (4.8%) had a minimal higher infection rate than the thick ADM group (3.3%). The group with thick ADM had slightly increased complication rates, but overall differences were insignificant between the thin and thick mesh groups (76).

Rippling and wrinkling remains a complication of ADM-assisted PBBR (Figure 18). Patients with thin upper pole skin in particular may be affected (77).

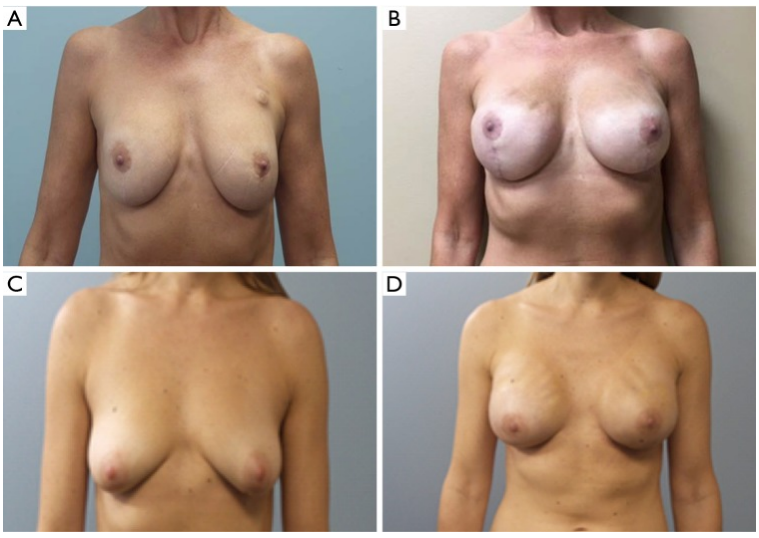

Figure 18. A and C showing preoperative view, B and C showing postoperative view of two patients who received immediate PPBR with the use of ADM; PPBR - prepectoral breast reconstruction, ADM - acellular dermal matrix (77)

This undesired aesthetic result occurs over time and is categorized into four grades (Figure 19). This grading is essential for therapeutic management (78).

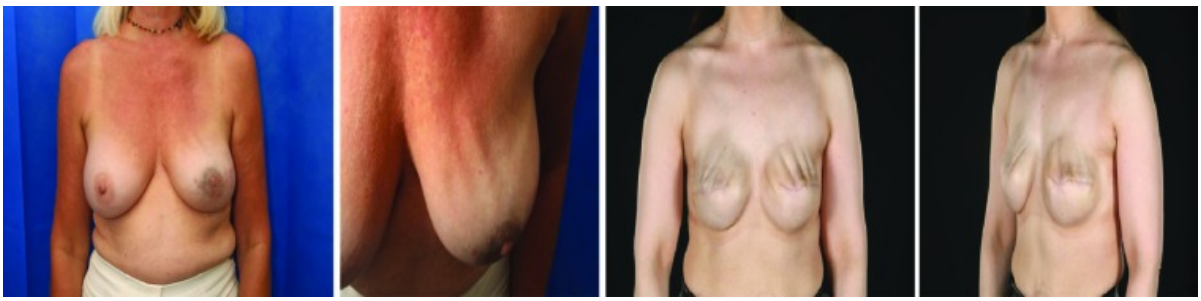

Figure 19. Different grades of rippling: Grade 3 (left two pictures) = moderate grade of rippling present during rest and exercise; Grade 4 (right two pictures) = extensive malformation caused by long-term rippling; Bra left indentations (78).

In a randomized controlled trial, Lohmander et al. (2019) assessed the results of IBBR with and without the use of ADM (Strattice). Patients received either an immediate or an immediate-delayed SPBR. In total, 129 patients were evaluated and followed up for six months. In the comparison of the complications, the frequency of skin blisters was greater in the group with an ADM than in the non-ADM group (9% vs. 0%). Additionally, the ADM group had a higher rate of seroma (22% vs. 12%). Overall, 41% of ADM patients experienced at least one adverse event, contrasted with 28% of the non-ADM group. More patients in the group with an ADM had to undergo a reoperation of any kind (17% vs. 11%). However, no significant difference in the risk of implant loss was observed between the two groups (6% in both). Nipple necrosis was a little lower in patients with an ADM (3% vs. 5%). In the ADM group, 45% had at least one complication or reoperation compared to 29% in the non-ADM group. Table 8 shows the comparison between the ADM and non-ADM groups. IBR with ADM and without ADM had similar risks of implant loss within a six-month follow-up period. Although not statistically significant, ADM application was associated with higher rates of surgical complications necessitating reoperation at 24 months (55).

Table 8. Complications and reoperations after IBBR with ADM and without ADM (55)

	IBBR with ADM	**IBBR without ADM**
Adverse events:		
1. Skin blisters /wound dehiscence/ exposure of ADM or implant	6 (9%)	0 (0%)
2. Redness without infection	1 (2%)	0 (0%)
3. Nipple necrosis	2 (3%)	3 (5%)
4. Infection in-hospital treatment	4 (6%)	4 (6%)
5. Seroma	14 (22%)	8 (12%)
6. Infection out-patient treatment	9 (14%)	4 (6%)
Patients with any (1-6):	26 (41%)	18 (28%)
Reoperations:		
7. Open evacuation of hematoma	2 (3%)	1 (2%)
8. Re-excision after mastectomy	1 (2%)	2 (3%)
9. Re-entry of implant cavity	4 (6%)	0 (0%)
10. Implant removal	4 (6%)	4 (6%)
Patients with any reoperation (7-10):	11 (17%)	7 (11%)
Any complication (1-10):	29 (45%)	19 (29%)

AE – adverse event, IBBR – implant-based breast reconstruction, ADM – acellular dermal matrix

Later, in 2021, another randomized clinical trial by Lohmander et al. presented the results of SPBR with and without the use of an ADM in women with breast cancer. All women had either NSM or SSM and received an immediate or immediate-delayed IBBR. In this study, the focus was on the rate of reoperations. The primary objective was to evaluate whether applying an ADM together with partial muscle coverage decreases the need for reoperations compared to a breast reconstruction

without a mesh and full muscle coverage. Reoperations were specified as any breast intervention under general anesthesia. A total of 129 patients, of whom 64 belonged to the ADM group and 65 belonged to the non-ADM group, were followed up for 24 months after the surgery. Additionally, PROs were measured as a secondary outcome, where no significant mean differences were reported (satisfaction with cosmetic outcome: $p = 0.11$; perception of body image: $p = 0.57$). In the ADM group, 69% experienced at least one surgical event compared to 66% in the group without ADM. At least one reoperation on the ipsilateral breast was required in 35 (54%) women belonging to the non-ADM group and in 31 (48%) women from the ADM group. In the ADM group, 9 (14%) women had the implant removed vs. 7 (11%) in the non-ADM group. In conclusion, the rate of reoperations was not lower in IBBR with ADM than in IBBR without ADM, and neither was there a significant difference in Health-Related Quality of Life (HRQoL) and patient-reported aesthetic results ($p > 0.05$) (9).

In a retrospective, single-institution comparative study, Salibian et al. (2021) demonstrated that two-stage PPBR has similar results with or without the use of biological meshes. The study included 76 breasts (51 patients), of which 35 patients received a PPBR with ADM and 41 a conventional PPBR. There were no significant differences in patient-related factors between the two groups. The follow-up period for the non-ADM group was 12.3 months, and for the ADM group, 20.3 months, which was significantly longer ($p < 0.001$). The ADM used was either FlexHD (11.4%) or AlloDerm (88.6%). More patients needed two sheets of ADM (71.4%) instead of one sheet (28.6%). Both groups received similar implant sizes (ADM group 460.3 ± 31.5 vs. non-ADM group 456.6 ± 20.0, $p = 0.584$). Interestingly, initial intraoperative filling volumes were significantly higher in the non-ADM group (296.8 ± 19.1 cm^3 vs. 151.4 ± 17.4 cm^3, $p < 0.001$). The rate of any complication did not differ significantly between the two cohorts (ADM group 25.7% vs. non-ADM group 17.1%, $p = 0.375$). Both groups had low rates of major mastectomy flap necrosis (ADM 2.9% vs. non-ADM 2.4%, $p = 1.000$). The incidence of capsular contracture grade III/IV was low in the non-ADM cohort (4%), and there were no cases in the ADM cohort (0%) ($p = 1.000$). Similar rates were reported of major and minor infection (minor: ADM 2.9% vs. non-ADM 4.9% ($p = 1.000$); major: ADM 8.6% vs. non-ADM 2.4% ($p = 0.329$)) and seroma (ADM 2.9% vs. non-ADM 7.3%, $p = 0.620$). Four patients (16.0%) from the non-ADM group and one (5.0%) from the ADM group had notable rippling ($p = 0.362$). In each group, four TEs had to be explanted (ADM 11.4% vs. non-ADM 9.8%, $p = 1.000$). The findings of this study demonstrate that the rates of complications are low and comparable between two-stage PPBR with ADM and two-stage PPBR without ADM. Immediate-delayed PPBR without ADM is a safe technique, and routine ADM use may not be necessary (46).

In an observational, single-surgeon, retrospective cohort analysis, Hajiesmaeli et al. (2024) compared one-stage PPBR with and without ADM use. Patients were followed up over a period of 18 months. The study shows that PPBR without ADM has similar early results and is cost-effective compared to PPBR with ADM. All 101 patients had SSM or NSM. The ADM and the non-ADM group included 60 breasts each. The ADM mesh type used was Braxon. Most complications were not significantly different between the two cohorts. Two patients in the ADM group and two patients in the non-ADM group lost their implants. Similarly, no differences in the incidence of seroma (ADM three patients vs. non-ADM three patients) and dehiscence (ADM one vs. non-ADM one) were reported. More patients from the ADM group had hematoma (ADM two vs non-ADM one) and superficial skin necrosis (ADM two vs. non-ADM one). Only one patient in the ADM group experienced red breast syndrome, and none in the non-ADM group. None of these complication-related findings were statistically significant ($p > 0.05$). A significant difference between the two cohorts was the larger implant size used in patients with mesh-assisted PPBR (430 cc) compared to PPBR without mesh (340 cc). In this study, significantly more patients from the mesh group needed postoperative radiation therapy (ADM 24 vs. non-ADM 12, $p = 0.049$). Furthermore, a significant difference between the two groups was the extra costs for the Braxon mesh, which is available as a preshaped 30 x 20 cm (600 cm^2) mesh and costs around £2,100. The study findings suggest that meshes may be favored for bigger implants and may be used in women undergoing postoperative radiation therapy due to the additional support a mesh possibly offers (79).

ADMs are expensive, and the balance between cost and clinical effectiveness is essential in IBBR. In a multicenter randomized clinical trial, Negenborn et al. (2019) evaluated the short-term cost-effectiveness of single-stage ADM-assisted IBBR compared to a conventional two-stage IBBR without ADM. In total, 121 women (183 breasts) underwent NSM, followed by 59 women (91 breasts) receiving an IBR with ADM (Strattice) and 62 (92 breasts) an immediate-delayed IBBR without ADM. After the first surgery, the mean follow-up time was 37 months for the group that received one-stage ADM-assisted IBBR and 35 months for the two-stage group. The analysis was conducted from the perspective of a hospital. The duration of surgery for the primary procedure was significantly longer for the IBR with ADM compared to the immediate-delayed IBBR for both bilateral (243 mins vs. 205 mins, $p < 0.001$) and unilateral (172 mins vs. 122 mins, $p < 0.017$) procedures. When both stages in the two-stage group were combined, the total surgery time for bilateral IBBR (289 mins) was longer than one-stage IBBR with ADM (243 mins). Additionally, the median time of hospitalization was significantly longer in the two-stage group (unilateral 5 and bilateral 5 days) than in the one-stage group (unilateral 3 and bilateral 4 days).

For unilateral breast reconstruction, in the one-stage group (ADM group 44%), significantly higher rates of complications were recorded than in the two-stage group (non-mesh group 3%). Similar results were seen in bilateral reconstructions (one-stage 26% vs. two-stage 15%). The higher incidence of complications in the one-stage group led to higher rates of implant removal (26% vs. 4%) and reoperation (32% vs. 13%). More patients experienced complications in the one-stage group. No differences in patient-reported health outcomes were seen between both groups ($p > 0.05$). Costs were evaluated separately for bilateral and unilateral IBBR.

For bilateral procedures, the costs of single-stage reconstruction (€14,364) were significantly higher ($p = 0.004$) compared to two-stage reconstruction (€12,566). Including the total costs for complications, the mean expanses per woman were significantly higher single-stage IBBR (€16,741 vs. €13,061, $p = 0.001$). Including the amount for cosmetic surgical interventions, the sum of direct costs was also higher in women with single-stage IBBR (€16,939€ vs. €13,383, $p = 0.002$). In unilateral IBBR, the mean total direct cost was similar between single-stage (€9,052) and two-stage IBBR (€8,940) ($p = 0.815$). Similar to bilateral procedures, including the costs for complications, the mean cost per patient was higher in single-stage unilateral IBBR (€11,752€ vs. €9,000, $p = 0.008$), and including the amount for cosmetic surgical interventions, the overall direct cost was higher in one-stage IBBR (€12,448 vs. €9,871, $p = 0.025$), too. The additional use of ADM (Strattice in this case) played a significant role concerning the costs with a price of €2,370. Other cost factors included the implant or expander at €530 each, €1,240 per hour for the surgery, €150 per hour for the surgeon, and €550 per inpatient day. This study demonstrated that immediate ADM-assisted IBBR, which had higher costs and comparable health outcomes, was not cost-effective relative to immediate-delayed IBBR. Although one-stage procedures saved costs due to a shorter operating duration, the extra costs associated with the ADM itself and higher costs caused by increased complication rates outweighed the cost savings (13).

Patient-related risk factors associated with complications are a critical part of mesh-assisted IBBR, and it is important to inform patients about them. As mentioned above, the study by Masià et al. (2020) also identified risk factors contributing to postoperative complications in IBBR with mesh support. For example, patients on immunosuppression ($p = 0.017$) have an increased risk of seroma formation, and patients with diabetes ($p = 0.003$), as well as an active or previous smoking history ($p = 0.016$), have an increased risk of infection. Active smokers have a high risk of wound dehiscence ($p = 0.001$). Risk factors for postoperative skin flap necrosis were smoking, implant volume, and immunosuppressive therapy ($p < 0.05$) (33).

Hong and Kim (2021) found in their study that an increased BMI ($p < 0.036$), higher implant volumes ($p < 0.001$), and hypertension ($p < 0.038$) significantly prolonged the drainage time. The rates of surgical revision were also significantly higher in patients with overweight ($p = 0.039$) and hypertension ($p < 0.005$). Regarding the analysis of total complications, the obese patients were associated with a significantly higher incidence ($p = 0.047$) (76).

When especially evaluating patients with and without risk factors, Schnarrs et al. (2016) observed that breast weight and smoking history had a significant impact on the rate of adverse outcomes in IBBR with hADM usage. The follow-up period was at least three months after the surgery. While the overall complication rate for the whole study population was 19.4%, those surgeries conducted on women who smoked showed a markedly higher complication rate of 37.8%. Similarly, surgeries performed on patients with larger breasts (≥500 g) demonstrated a complication rate of 32.7%. The same study also compared the outcomes between four different hADM manufacturers: AlloDerm, AlloDerm RTU, FlexHD, and hMatrix. No statistically significant differences were detected among the four hADM types in complication rates, neither when analyzing complication categories (seroma, tissue necrosis, minor and major infection, and others) nor when comparing implant placement (PPBR or SPBR). However, in women without major risk factors (breast weight <500 g and nonsmokers), remarkable variations in the rate of complications were noted between the hADM types. With 57%, patients with AlloDerm showed the highest complication rate, followed by FlexHD (40%), hMatrix (25%), and AlloDerm RTU (0%). While these differences did not reach statistical significance due to the limited sample size, the considerably low complication rates associated with AlloDerm RTU and hMatrix in low-risk patients are worth highlighting (80).

11. Conclusions

This literature review illustrates the increasing use of biological and synthetic meshes in implant-based breast reconstruction. A key issue is the selection of the appropriate mesh type. Numerous studies report favorable results for both biological and synthetic meshes, including high patient satisfaction, good aesthetic outcomes, and low complication rates, especially low rates of capsular contractures. However, biological meshes more often show higher complication rates, such as seroma and infection, and synthetic meshes are also less expensive. Moreover, biological and synthetic meshes may lead to variable outcomes of reconstructed breasts in terms of feeling, texture, and form. No single mesh type is clearly superior over another. Notably, some studies focus only on a specific type of mesh, and differences in results may be influenced more by the specific quality and design of the individual mesh type. In addition, studies vary in their design: some have short follow-up periods, differ in surgical techniques, or are affected by patient-related factors. Ultimately, meshes should not

be used routinely. Rather, the decision should be individualized based on patient-related factors, the mastectomy flap quality, implant size, costs, patient preference, and surgeons' experience. Such an approach may help improve both clinical and aesthetic outcomes, reduce costs, and keep complication rates to a minimum. Further research is necessary, and studies should focus on standardized outcome reporting and longer follow-up periods for better clinical decision-making and appropriate mesh selection.

12. Recommendations for Mesh Appliance and Future Research

1. Tailored decision-making on mesh usage based on patient-related factors to optimize results.
2. Application of risk stratification models.
3. Modifications of surgical techniques to mitigate adverse events.
4. Balance between cost and effectiveness of meshes.
5. More randomized controlled trials (RCTs) to improve accuracy.
6. Larger study population to enhance statistical significance.
7. Extended follow-up periods (years) to assess outcomes and longevity of meshes over a long time.
8. Inclusion in studies of all reconstructive techniques across different surgical planes and timings.
9. Evaluation of a broader range of biological and synthetic meshes in one study.
10. Standardized matching of study groups.

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