Breast Reconstruction with Biological and Non-biological Meshes and Matrices

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40.1 Introduction into Meshes and Matrices in Breast Reconstruction

The terms mesh and matrix when applied to breast reconstruction are generally in reference to the composition of the material used in the manufacture of the product. The general consensus is that the term "matrix or matrices" refers to a product derived from biological sources (e.g. dermis), whereas "mesh or meshes" refers to a product wholly manufactured from synthetic materials (e.g. polypropylene). With the exception of SERI™, made from silk-derived bioprotein, the majority of products used in breast reconstruction can be divided into matrices and meshes.

The use of matrices in prosthetic breast reconstruction began with the publication of two papers in 2005 and 2006 by Breuing and Salzberg, respectively [1, 2]. Both authors reported small case series (n = 76; n = 20 breasts) using the human dermal-derived matrix Alloderm, in immediate single-stage implant breast reconstruction. Authors described a novel technique which aimed to shorten the reconstructive process by reducing prosthetic reconstruction from two-stage to one-stage immediate reconstruction. Since then, the use of meshes and matrices in breast reconstruction has gained in popularity and has provided the surgeon with the option for immediate single-stage implant reconstruction with mesh placement as a viable reconstructive option [3]. Single-stage techniques benefit patients by avoiding the need for repeated outpatient appointments for tissue expander fills and a second-stage operation. Meshes and matrices have been successfully employed both in single-stage implant-based breast reconstruction and in the setting of two-stage expander-based prosthetic reconstruction, nipple-sparing mastectomy (NSM) and skin-sparing mastectomy (SSM) [4–8].

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40.2 Mechanics of Meshes and Matrices in Breast Reconstruction

Meshes and matrices in prosthetic breast reconstruction are placed at the inferior border of the reconstruction. Prosthetic devices (implant or expander) are placed submuscularly (pectoralis major ± proximal rectus abdominis, serratus anterior). When partial muscle coverage is performed, pectoralis major is released off the chest wall. The subpectoral plane is developed to the second rib superiorly and to the sternal muscle fibres medially. The pectoralis major is then released and the mesh/matrix can be attached. Meshes/matrices are sutured medially from the inferomedial border of the pectoralis major to the medial border of the inframammary fold (IMF). The mesh/matrix is then sutured from the inferior border of the muscle to the chest wall fascia at the level of the IMF to increase the inferior aspect of the subpectoral pocket; most commonly interrupted sutures are used. A hammock of mesh is created for the prosthesis (Fig. 40.1).

The mesh/matrix is sutured laterally to ensure minimal lateral migration of the device. Some surgeons will perforate the matrix (meshes are already porous) with the aim to minimise fluid pooling around the device [9]. Many surgeons will facilitate fluid evacuation by placing a vacuumed drain between the skin flap and the mesh/matrix to reduce the potential deadspace between the two layers. Drains are left in situ until there is minimal drainage (<30 ml/24 h) to prevent seroma formation. Soft tissue compression dressings can also be employed to help reduce seroma formation in the immediate post-operative period:

1. *Meshes act as an inter-positional graft between the pectoralis major and IMF.*

   In all cases, the mesh allows the surgeon to release the pectoralis major and use the mesh as an extension of this inner tissue plane between the pectoralis lamellae and the outer skin envelope. This is especially useful in patients where the muscle sits high on the chest wall or is too tight which would limit the reconstructive volume [10].

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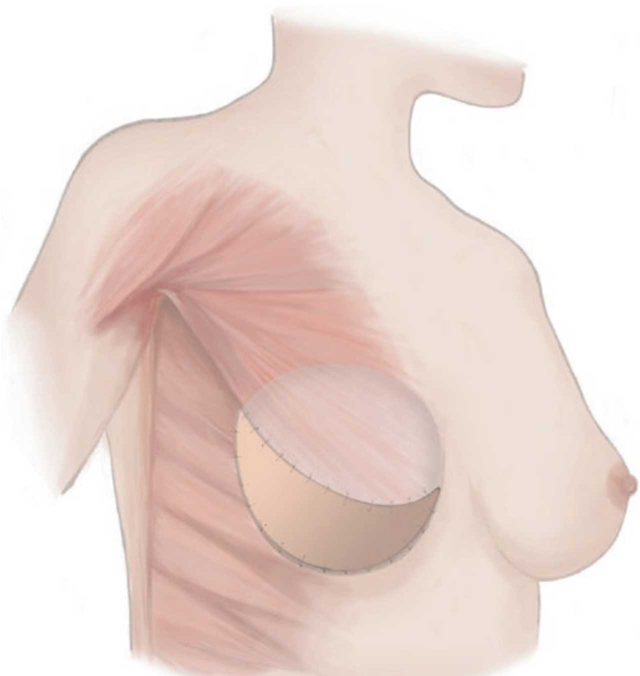

Fig. 40.1 Picture of mesh in breast reconstruction: schematic

The use of meshes enables a greater implant or expander volume to be placed at the original operation to either shorten the second-stage expansion process due to its ability to expand the subpectoral pocket or to remove the second stage entirely [11–13]. In obese patients with large ptotic breasts, there is often a discrepancy between the skin envelope of the patient and the underlying subpectoral pocket. Meshes be can be employed to redress this imbalance and improve the projection vector of the breast [10, 14].

2. *Meshes help to define and control the reconstructive pocket*.

   The use of a mesh along the IMF enables the surgeon to define the inferior aspect of the reconstructive pocket. This control can prevent implant migration and improve aesthetic outcomes by clearly defining the IMF [15–18]. The mesh also acts as a hammock to support the implant/expander and therefore maintain lower pole projection and a natural breast mound shape. Small case series have reported improvements in breast contour, implant placement, lower pole projection and IMF definition using blinded-surgeon assessors [18].

3. *Biological meshes may improve host neovascularisation of the mastectomy skin envelope*.

   Biological meshes may act as a stimulus to surrounding tissue including the skin flap, enhancing neovascularisation via the induction of growth factors in the surrounding host tissue (basic fibroblast growth factor [bFGF], vascular endothelial growth factor [VEGF] and transforming growth factor-beta 1 [TGF-β1]) [19]. Microcirculatory analysis in animal models demonstrated angiogenesis at 4 weeks post implantation on the skin-flap surface with established vasculature on the mesh observed at 8 weeks [20].

4. *Meshes confer additional soft tissue coverage to the prosthesis*.

   The position of the mesh at the infero-lateral pole enables the mesh to provide soft tissue coverage of the prosthesis. This reduces the need for extensive musculofascial dissection. Studies have reported that the increased soft tissue coverage supplied by the mesh can result in reduced capsular contracture around the implant with adjuvant radiotherapy [21, 22]. In addition, by increasing the tissue coverage of the prosthesis, the mesh can act to reduce contour irregularities (rippling, palpable implant) in patients with little subcutaneous fat in the mastectomy flap, thus improving aesthetic outcome [18].

40.3 Types of Meshes for Breast Reconstruction

Various companies have developed a number of meshes for use in breast reconstruction. Types of meshes in breast surgery can be divided into non-biological (synthetic) and biological types (Table 40.1). The majority of surgeons employ the use of biological meshes (also known as acellular dermal matrices/ADMs) in breast reconstruction as they provide a scaffold for host tissue ingrowth [23]. Training provided by manufacturers on the correct use of their product to surgeons and their continued support in its use can influence surgeons' choice of mesh, particularly when there is a learning curve associated with mesh use in breast reconstruction [24, 25].

40.3.1 Non-biological

Non-biological (synthetic) meshes have been used in breast surgery for over 20 years. They are manufactured using a variety of polyglactin, polyglycolic and polypropylene composites. By varying the composition of the mesh, manufacturers can alter its mechanical tensile properties and ability for the body to absorb the mesh. Non-biological meshes can be permanent or absorbable. Although the recent trend in reconstructive breast surgery has been in favour of biologic meshes, non-biological meshes still hold a role in prosthetic breast reconstruction.

Non-biological meshes can be divided into absorbable and non-absorbable meshes. Absorbable meshes in breast surgery include Vicryl (polyglactin 910), Dexon (polyglactin), GalaFLEX (poly-4-hydroxyalkanoate) and TIGR Matrix (copolymer of glycolide- and lactide-degrading fibres

Table 40.1 Soft tissue support meshes and matrices available for breast surgery

Type of soft tissue support	Product details	Clinical evidence
Synthetic		Case series
Absorbable		
Vicryl	Polyglactin 910	*n* = 24; 76 (Loustau et al. 2007; Tessler et al. 2014)
Dexon	Polyglactin	
GalaFLEX	Poly-4-hydroxyalkanoate	
		n = 3 (Adams 2014)
TIGR matrix	Copolymer of fast (glycolide) and slow (lactide) degrading fibres with trimethylene carbonate	*n* = 62 (Becker et al. 2013)
Non-absorbable		
Seragyn BR	Bicomponent polyglycolic acid (absorbable) caprolactone/polypropylene (non-absorbable)	*n* = 23 (Paepke et al. 2012)
TiLoop Bra	Titanized polypropylene	*n* = 231 (Dieterich et al. 2013)
Prolene		
PTFE	Polypropylene	*n* = 6 (Amanti et al. 2002)
Mersilene	Polytetrafluoroethylene	*n* = 1 (Coelho et al. 2012)
	Polyester	*n* = 67 (Reitjens et al. 2005)
Biological		
Animal derived		
Strattice	Porcine dermis	*n* = 104 (Salzberg et al. 2013); *n* = 200 (Lardi et al. 2014)
Surgisis	Porcine small intestine mucosa	Centeno 2009
Surgimend PRS	Bovine foetal and neonatal dermis	*n* = 222 (Butterfield 2013)
Veritas	Bovine pericardium	
Cadaveric derived		*n* = 93 (Mofid et al. 2012)
Allomax (Neoform)	Human dermis	*n* = 31 (Losken 2009)
DermaMatrix	Human dermis	*n* = 62 (Brooke et al. 2012)
Alloderm	Human dermis	*n* = 105 (Weichman et al. 2013)
FlexHD	Human dermis	*n* = 97 (Liu et al. 2014)
Silk derived		
Absorbable		
SERI	Silk-derived bioprotein	See results, Table 3
Autologous		
Dermal graft	Abdominal harvest site via mini-abdominoplasty	*n* = 21; 76 (Hudson et al. 2012; Lynch et al. 2013)

with trimethylene carbonate). Non-absorbable meshes include Seragyn BR (bicomponent polyglycolic acid (absorbable) caprolactone/polypropylene (non-absorbable)), TiLoop Bra (titanium-coated polypropylene mesh), PTFE (polypropylene) and Mersilene (polytetrafluoroethylene polyester) [26]. Recently, studies have revisited the use of non-biological meshes in breast reconstruction as they have an established safety profile and cost considerably less than biological meshes [27, 28]. There are no published comparative studies with synthetic versus biological meshes at present. A hybrid biological synthetic mesh, SERI surgical scaffold (Allergan Inc., MA) was recently introduced as a cross-over mesh between synthetic and biological. It is a scaffold made of silk bioprotein, fibroin (Biosilk), which provides strength mechanics similar to synthetic meshes whilst remaining absorbable [29].

40.3.2 Biological

Biological meshes are tissue-derived manufactured meshes. Tissue is processed from a variety of human cadaveric and animal sources to remove the epidermis and cells resulting in an "acellular" matrix (Table 40.1). This is also referred to as ADM (acellular dermal matrix). The majority of biological meshes used in breast reconstruction are derived from processed dermis (cadaveric, porcine, bovine). Other tissue sources include porcine small intestine mucosa (Surgisis) and bovine pericardium (Veritas). Proprietary processing, using a variety of techniques unique to each product, removes the epidermis (in the case of dermal-derived tissue) to leave a non-cross-linked acellular dermal matrix (e.g. Alloderm (LifeCell Corporation, NJ), FlexHD (Ethicon Inc., Somerville NJ), DermACELL (LifeNet Health, VA), DermaMatrix (Synthes, PA), Strattice (LifeCell

Corporation, NJ)) [23]. The resulting mesh is reported to have minimal antigenic properties; however, patients should be counselled in their consent process regarding the mesh composite and carefully screened for previous allergies. A “red breast syndrome” has been reported by Ganske et al. [30]. Patients presented with skin erythema overlying the dermal matrix with punch biopsies of the tissue revealing a delayed-type hypersensitivity reaction suggesting a localised immune host response requiring corticosteroid treatment [30].

Biological meshes have been widely used in immediate and two-stage breast reconstruction in recent years. No head-to-head randomised controlled trials have been completed to date to establish complication rates between the different meshes. Small case series comparing different meshes have been published although these are frequently underpowered and subject to reporting bias; therefore, no clear conclusions can be drawn between the different products on the market. A disadvantage to using biological meshes is that at current market pricings, the direct cost of biological meshes does not appear to offset economic savings related to greater expander fill volumes and a reduction in revision surgery [31, 32]. However, some argue that when the cost-effective incremental cost utility of biological meshes is calculated (due to an increase in quality-adjusted life years with mesh reconstruction), biological meshes can be considered cost-effective [33].

40.4 Why Choose Biological Matrices Over Synthetic Non-biological Meshes?

A recent survey of plastic surgeons within the USA demonstrated that the majority of respondents (84.2%, n = 361) used ADM in breast reconstruction in preference to synthetic meshes [34]. The reasons for this are multifactorial.

There is a paucity of clinical data on the use of synthetic meshes in breast reconstruction in the literature. The majority of data exists for the following meshes: TiLoop and TIGR meshes. The largest case series for TiLoop mesh was reported by Dieterich et al. [35]. Two hundred thirty-one breasts were operated on in primary and delayed implant-based reconstruction. The overall complication rate was 29%. Similarly the TIGR mesh case series by Becker and Lind [36] reported on 112 breasts with a complication rate of 19% in primary breast reconstruction. TiLoop Bra has been associated with a host granulomatous reaction in the skin flap (estimated at 4%) which in the context of recurrent DCIS can create an oncological challenge for cancer surveillance [37]. In addition, in patients with thin skin flaps, there have been reports of TiLoop mesh rippling and palpability [38]. The lack of clinical data on synthetic meshes limits the surgeons’ ability to evaluate the product, and therefore it is less in use.

By contrast there are a much greater number of papers reporting on biological matrices in breast reconstruction with longer-term follow-up and larger numbers (n = 6199 cases) [58]. Pharmaceutical industry sponsored research on new biological meshes which influences the surgeons’ choice of product. Marketing strategies and keynote speeches from industry-funded surgeons may influence the surgeons’ choice of product although it is difficult to quantify. The overriding influence on product choice remains based on the reported lower complication rates with matrices compared with meshes.

Current estimates from meta-analysis of reconstructions with ADM give a pooled complication rate of 18%; however, more recent case series have reported lower rates in experienced surgeons of 5.3–8% [39, 40]. Moreover, the risks of total complications in a recent meta-analysis on ADM use in breast reconstruction concluded that the risks of implant loss and total complications were not significantly different from submuscular implant reconstruction without ADM [40].

40.5 Complications associated with Meshes in Breast Reconstruction

Amongst published literature there is conflict surrounding the overall complication rates associated with meshes in primary breast reconstruction. A number of meta-analyses have been performed by various groups in order to establish if the presence of mesh in the reconstruction confers an increased complication rate to the patient [12, 21, 41–44]. Unfortunately, there is a lack of level I evidence to evaluate this topic, with the majority of studies being small numbered comparative or case series [44] and limited by heterogeneity in study design, outcome measurement, selection and reporting bias [44]. As such, any pooled data from non-randomised studies for meta-analyses on complication rates with meshes has limited validity. In addition, a number of the studies published are funded by companies manufacturing the meshes which leads to considerable publication bias [44]. Only one randomised controlled study has been conducted to date which was stopped early due to poor recruitment [45]. The median complication rate following ADM-assisted immediate breast reconstruction was calculated by Potter et al. as 18% (6–64%), compared with 14% (5–45%) in a standard two-stage expander reconstruction without mesh [44]. There is a general consensus between the systematic reviews on this topic that the use of meshes in breast reconstruction does confer increased overall complication rates; however, the magnitude of this effect remains ill-defined. Comprehensive prospective randomised controlled trials are needed to investigate the true effect of meshes on complication rates. It has been suggested that the differing complication rates may reflect not only a surgical learning curve for the technique [24, 25] but also variations in patient selection [11].

40.6 Complications Within the Post-operative Period Following Breast Reconstruction Using Matrices and Meshes and How to Manage Them Clinically

1. *Infection*

   Despite the aseptic techniques used intraoperatively to prevent infection of the mesh (irrigation in antibiotic solution, changing of surgical gloves intraoperatively, minimal mesh and tissue handling, post-operative intravenous antibiotics) as a foreign body, the mesh can act as a nidus for bacterial ingrowth. Observational data suggests there is an association with infection rate and high intraoperative expander/implant volumes greater than 50%of the total volume; however, this needs to be corroborated [46].

   Infection will present as classical signs of inflammation at the site of surgery with purulent discharge, wound swab or blood-positive cultures for bacterial infection and elevated white blood cells and C-reactive protein. This is in contrast to the observed and reported “red breast syndrome” [30] which may present with signs of inflammation without pain and infection markers and cultures will be negative. This condition will settle without antibacterial treatment and can be managed with close observation and simple anti-inflammatory agents.

   If diagnosed early, infection may be treated conservatively with intravenous or oral antibiotics; however, if established the patient will require removal of the infected mesh as a secondary operation with removal of the prosthesis. Common organisms associated with implant infections include *S. epidermidis*, *S. aureus*, *S. marcescens* and *P. aeruginosa* [47]. There is no consensus in the use of prophylactic intraoperative and post-operative antibiotics; however, a 5-day course of oral antibiotics post-operatively is a common regimen. Removal of the matrix is surgeon dependent; however, it can be based on its intraoperative appearance. If the matrix appears partially hydrolysed, non-viable or inflamed, then the authors recommend its removal. A recent systematic review found infection rates with mesh reconstructions to vary from 0% to 31% with a combined average of 11.6%. Of note, in skin-sparing mastectomy the natural barrier to infection is compromised, and infection in the post-operative period must be considered [48]. There is a shift in practice to the use of sterile ADM (versus aseptic ADM), which involves terminal sterilisation in an attempt to reduce infection rates further [49].

2. *Haematoma and Seroma*

   Although biological matrices are processed to prevent a host antigenic reaction to their implantation in the tissue, they do however cause a tissue reaction which predisposes this type of breast reconstruction to increase seroma formation. In addition, the increased reconstructive pocket volume created by the mesh at the lower pole can create an increased deadspace in the reconstruction which may predispose patients to haematoma and seroma formation. Interestingly, there is a correlation between increasing surface area of the matrix used and the odds of seroma formation [46]. A minimised surgical technique has been described (patching only the lateral area of the reconstruction with a small surface area of ADM; $n = 225$) which reports a reduction in seroma from 3% to 0%, although these results need further validation [50]. Extensive use of electrocautery has also been reported as a risk factor for seroma formation [51].

   Judicious use of vacuumed drains post-operatively, soft compression dressings and surgical bras have been effective to reduce the incidence of seroma in these patients, although the drain site must be kept as clean as possible and ideally tunnelled in a long subcutaneous tunnel to minimise exposure of the implant and matrix to outside bacteria [52].

   One study reported with these measures that a reduction of 18.6–4.7% ($p = 0.0022$) in seroma was achieved [53]. Seroma formation may also be due to insufficient intraoperative expansion when using a tissue expander as this will also allow fluid to collect in the reconstructive pocket. However, increased intraoperative fill volumes must be carefully considered as the risk of explantation increases with volumes over 300 cc due to increased skin-flap tension which can compromise vascularity especially if the patient has additional risk factors for complications [46].

   Drains are often placed to prevent fluid accumulation and removed once drainage is less than 20–30 ml in 24 h. Low-grade seromas can be managed with percutaneous ultrasound-guided drainage; larger seromas and haematomas may require surgical evacuation.

3. *Mastectomy Flap Necrosis and Reconstructive Failure (Explantation)*

   Skin-flap necrosis with mesh-assisted prosthetic breast reconstruction has been attributed to mastectomy flap thickness and disruption of the subdermal plexus during surgery. Prior to ADM use, mastectomy flap necrosis was as high as 15%. The additional burden of the mesh on tissue oxygenation demands has been postulated as a reason for the increased flap necrosis rates. Meta-analyses have reported an approximate twofold increased risk in reconstructive failure with mesh-assisted reconstructions [54, 55] although their conclusions are based on limited evidence.

Minor wound dehiscence and matrix exposure can be managed in the outpatient setting with dressings and close monitoring, but may necessitate wound closure in theatres. Larger areas of skin-flap necrosis will require a return to theatres for debridement plus/minus removal of the matrix and implant in some cases. Placement of an expander will be required to facilitate wound closure.

Increased explantation rates observed with ADM-assisted breast reconstructions may also be in part due to prosthesis removal if mesh removal is required with severe infection. This may not be fully represented in the data reported. Although the mesh or matrix provides additional cover to the implant should skin necrosis occur and in smaller areas of necrosis, the implant can be salvaged. An alternative to explantation and delayed reconstruction in cases of matrix infection has been described. In this technique the implant and matrix are removed, and a negative pressure sponge is placed into the cavity. This maintains the reconstructive pocket until the infection is cleared and the patient can have replacement of the implant on the same hospital admission [52].

4. *Management of the Aesthetic Profile*

Clinical follow-up in the post-operative period includes clinical assessment of the reconstruction at 2 weeks, 3 months, 6 months and 12 months in general. During this time the reconstructed breast will begin to soften and develop into its long-term shape. Repeated aesthetic assessment is required to monitor for the need of further procedures to optimise the end aesthetic result. Autologous fat grafting (lipofilling) of the ADM-assisted implant reconstruction is often required to the upper pole to aid with implant coverage and volume especially in patients with a low BMI. Symmetrisation procedures on the contralateral native breast are often performed in unilateral reconstructions.

40.7 Risk Factors for Complications associated with Meshes in Breast Reconstruction

Since the advent of meshes in prosthetic breast reconstruction, a number of relative contraindications for the technique have been developed with increasing surgical experience [56].

Patients with a high body mass index (BMI) of over 30 and long ptotic breasts are at increased risk of poor wound healing as long skin flaps are prone to ischaemia and infection [11, 24, 46, 57, 58]. In addition, the thickness of the subcutaneous layer (>3 cm in some cases) can prevent significant projection from the prosthesis, impairing aesthetic results and adherence of the mesh to the subcutaneous layer [7]. Patients who have undergone pre-reconstruction radiotherapy to the chest wall are at increased risk of impaired skin-flap perfusion and post-radiotherapy fibrotic changes [7, 46]. The addition of mesh within a prosthetic reconstruction in these patients should be assessed on an individual basis intraoperatively based on skin-flap perfusion to prevent skin-flap necrosis (clinical assessment ± laser Doppler or laser-assisted indocyanine green imaging) [59]. Similarly, heavy smokers are at higher risk of necrosis due to impaired microvasculature and wound healing and therefore reconstructive failure with or without mesh [58]. This increased risk for reconstructive failure has been estimated at up to five times that of non-smokers in prosthetic reconstruction [60]. In addition, patients with non-nipple-sparing mastectomy, implant volumes of 600 ml or greater and age over 50 years are also at increased risk of post-operative complications ($p < 0.001$) [39]. Positive sentinel lymph node sampling and post-operative radiotherapy are not prohibitive to mesh use. Careful assessment of skin-flap perfusion intraoperatively is key to help minimise post-operative complications.

In all patients being considered for mesh-/matrix-assisted prosthetic breast reconstruction, an assessment of skin-flap perfusion should be made intraoperatively. If there is any concern regarding perfusion, the use of biological or synthetic meshes would be contraindicated. In patients with multiple risk factors for complications, an alternative reconstructive option must be considered.

40.8 Patient Selection for Mesh-/Matrix-Assisted Breast Reconstruction: Achieving Good Results

Patient selection is paramount in ensuring a good reconstructive result from ADM-assisted implant reconstruction. The technique is not without its pitfalls, and a considered approach should be used when deciding if the patient is suitable for this technique. The procedure is only 10 years from its conception, and as such, we have limited long-term data for this operation. Similarly, biological matrices in particular have unpredictable long-term characteristics, and as such, in young patients where the reconstruction will require longevity and consistency, autologous reconstructive options must be considered first. Although, as stated previously, the complication rates for ADM-assisted implant reconstructions have reduced with time and surgical experience, they are still considerable with a total rate ranging from 6 to 64%. With the experienced surgeon who is used to this form of reconstruction, the complication rate will be low; however, there is a considerable learning curve to this procedure [24]. This may explain the unacceptably high complication rates reported. Complications may delay adjuvant therapy and cause the patient considerable psychological stress with repeated procedures especially if faced with reconstructive failure. Although the benefits and good outcomes with this technique are well documented and surgical practice has shifted to ADM-assisted implant reconstruction, it must be remembered that there is little level I evidence to support this technique.

A number of papers have been published presenting surgeons with treatment algorithms to aid the decision in placing mesh when performing prosthetic breast reconstructions [11, 25, 61]. Good aesthetic results with mesh-assisted tissue expander/implant reconstruction have been achieved in the following patients:

- Low BMI (<30)
- Non-smokers
- Small pre-operative cup size
- Patients <50 years old
- Patient unsuitable or refusing autologous reconstruction

In summary, careful patient selection is the most important step prior to ADM-assisted breast reconstruction and will determine in part, along with surgical technique and skill, the overall reconstructive outcome.

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