Implant-based breast reconstruction with meshes and matrices: biological *vs* synthetic

This article presents an overview of the different acellular dermal matrices and synthetic meshes used in modern-day primary and secondary implant-based breast reconstruction. Case examples are given, along with a description of the senior author's pioneering direct-to-implant reconstruction.

Modern-day breast reconstruction following mastectomy can be either implant-based, autologous, or a hybrid combining both. The most common path to implant reconstruction involves immediate insertion of a tissue expander following mastectomy, subsequent serial expansions as an outpatient, and a secondary operation to exchange the expander for a permanent breast implant. The concept of direct-to-implant breast reconstruction using an acellular dermal matrix, first performed in 2001 and introduced by Salzberg (2006), has gradually gained acceptance. With careful patient selection, this procedure can shorten the reconstructive course and decrease the number of operations needed.

Complete tissue expander and implant coverage is an idea important in the post-mastectomy setting because of the risk of skin flap ischaemia-induced wound breakdown or possible infection causing exposure. Coverage of the superior pole is usually performed using the pectoralis major muscle. Inferior pole coverage has several options, the most common being the use of serratus anterior muscle advancement (complete muscle coverage), acellular dermal matrices and synthetic meshes. While the serratus flap allows completely autologous coverage of the implant, inferior pole expansion can be difficult, leading to a less than ideal final breast shape with loss of lower pole projection and tendency to have a high riding device.

Acellular dermal matrices and synthetic meshes for inferior pole coverage in implant-based breast reconstruction have gained wide acceptance and are now used routinely in both primary and secondary settings with excellent results reported by several groups, including Ngyuen et al (2012) and Forsberg et al (2014). The number of biological and synthetic products available has rapidly increased, and this review of the options currently available will be an important resource for reconstructive breast surgeons to make educated surgical decisions. Selected case examples are also given, including the authors' technique of immediate, direct-to-implant reconstruction.

Biologicals

The major benefits of biological substitutes are regenerative in nature and, as shown by Parvizi et al (2014), they are able to gradually incorporate into the surrounding native tissue through neovascularization. As demonstrated by Debels et al (2015), the acellular dermal matrices are the most widely used biological agents and may be harvested from human, porcine or bovine sources. They provide inferior pole coverage of the breast device in breast reconstruction while allowing adequate expansion because of their elastic properties. Their main drawbacks are the cost, as described by Bank et al (2013), and potential complications, including reported increases in rates of seromas by Israeli Ben-Noon et al (2013) and infections requiring explantation by Weichman et al (2012). Recently, acellular dermal matrix manufacturers have developed perforated versions of their products (*Figure 1*)

Figure 1. Perforated acellular dermal matrix is designed to decrease the rate of seroma formation.

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Table 1. Biological matrices used in breast reconstruction

Name	Country	Manufacturer	Source	Decellularization	Sterilization	Tensile strength (N/cm)	Elasticity (at 16 N/cm)
AlloDerm RTU	USA	Lifecell	Human	Not available	Not available	Not available	Not available
FlexHD	USA	Ethicon, Inc.	Human	Hypertonic bath	Ethanol and peracetic acid decontamination (not terminally sterilized)	929	21.2%
DermACELL	USA	LifeNet Health	Human	N-Lauroyl sarconsinate (Matracell®)	Low-dose gamma radiation	250	Not available
DermaMatrix	USA	Synthes	Human	Sodium chloride and detergent	Acid and antiseptic reagents	146	Not available
Strattice	USA	Lifecell	Porcine	Not available	Electron beam radiation	270	9.6%
AlloMax	USA	Bard, Davol Inc.	Human	Tutoplast process (acetone, hydrogen peroxide, sodium hydroxide)	Gamma radiation	290	26.2%
Epiflex	Germany	DIZG	Human	Not available	Peracetic acid	70	Not available
SurgiMend PRS	USA	TEI Biosciences	Fetal bovine dermal collagen	Not available	Ethylene oxide	432	6.4%
XenMatrix	USA	Bard, Davol Inc.	Porcine	Aquapure process	Electron beam radiation	377	Not available
Permacol	USA	Covidien	Porcine	Not available	Gamma radiation	66	13.1%
Veritas	USA	Synovis	Bovine pericardium	Not available	Not available	128	Not available

to try and decrease seroma formation. A selected list of the many biological products available is detailed below and in *Table 1*.

AlloDerm
AlloDerm (LifeCell Corporation, Branchburg, NJ) is a non-cross-linked acellular dermal matrix derived from human cadavers and aseptically processed using a proprietary technique to remove the epidermis and cells. The product originally came packaged in an aseptic, freeze-dried form, and required at least 30 minutes of rehydration before use. It is now available as a sterile, ready-to-use product in a variety of contoured shapes and sizes in both perforated and non-perforated forms. When compared to the original aseptic product, this newer form has been shown by Weichman et al (2013) to have a lower rate of complications. It incorporates into the overlying breast skin flap and provides long-term inferior pole support and thickness to help define the inframammary fold and prevent rippling and wrinkling of the thinned tissues from mastectomy (*Figure 2*).

Figure 2. Incorporation of AlloDerm into the overlying skin flap can be seen in secondary procedures.

FlexHD
FlexHD (Ethicon Inc., Somerville, NJ) is a non-cross-linked acellular dermal matrix harvested from human cadavers and decellularized using a hypertonic bath. Its decontamination process involves ethanol and peracetic acid, but it is not terminally sterilized (probability of bioburden surviving the sterilization process $<10^6$). It has a high tensile strength of 929 N/cm, and is used in reconstructive breast surgery as well as abdominal wall reconstruction. A retrospective study by Liu et al (2014) comparing outcomes using FlexHD *vs* AlloDerm in implant-based breast reconstruction showed a similar rate of complications in univariate analysis. However, multivariate analysis showed a greater risk of implant loss in patients who smoked, those who underwent single-stage reconstruction, and those in whom FlexHD was used.

DermACELL
This human-derived acellular dermal material is similar to others, but comes ready to use, preserved in glycerol, and has a proprietary process of preservation. Created by LifeNet Health (Virginia Beach, VA), this large skin and

tissue bank services the entire needs for reconstructive procedures and procurement of transplantable organs.

DermaMatrix

DermaMatrix (Synthes, Westchester, PA) is a non-cross-linked human-derived acellular matrix. It undergoes a decellularization process using sodium chloride and detergent followed by a sterilization process with acid and antiseptic reagents. It comes freeze-dried and requires reconstitution with sterile saline. While its main indications involve dentoalveolar surgeries, it has also been used in breast reconstruction. Becker et al's (2009) comparison of DermaMatrix *vs* AlloDerm in tissue expander reconstruction showed no difference in the incidence of complications. These findings were supported by Brooke et al's (2012) comparison of DermaMatrix, FlexHD and AlloDerm.

Strattice

Strattice (Lifecell Corporation, Branchburg, NJ) is a non-cross-linked porcine-derived acellular dermal matrix that is sterilized using electron beam radiation. It is 1–2 mm in thickness and has less elasticity than the human-derived matrices (*Table 1*). This durability makes it very useful in abdominal wall reconstruction as well as inferior pole support in implant-based breast reconstruction and, according to Pozner et al (2013), in revisionary aesthetic breast surgery. Use of porcine acellular dermal matrix in single-stage implant reconstruction has been successfully reported by Salzberg et al (2013). In addition, according to Kilchenmann et al (2014), use of Strattice requires fewer resources than two-stage breast reconstruction with or without a latissimus dorsi flap. The authors have found that Strattice takes up to a year to completely soften, and patients should therefore be reassured about minor implant malposition in the early postoperative period.

Synthetics

Synthetic meshes have been used in breast surgery for almost 20 years, and consist of both absorbable and non-absorbable products. They offer a less expensive support system with good strength and pliability. The long-term absorbable meshes provide extended lower pole support, but also carry the potential for increased risk of complications. A variety of synthetic meshes are now widely used in both the United States and Europe in reconstructive breast surgery. A selected list of available meshes, as listed in *Table 2*, follows.

Seri Surgical Scaffold

Seri Surgical Scaffold (Allergan Inc., Medford, MA) is a hybrid biological, absorbable mesh derived from silk that has undergone a proprietary processing technique (BIOSILK) to yield the insoluble protein, fibroin. The silk mesh is easy to handle and provides good strength while incorporating into the overlying soft tissue (*Figures 3* and *4*). The manufacturer voluntarily recalled the product in 2013 following potential contamination of the outer pouch of their dual layer packaging. Fine et al's

Figure 3. Inferior pole enforcement with Seri Surgical Scaffold.

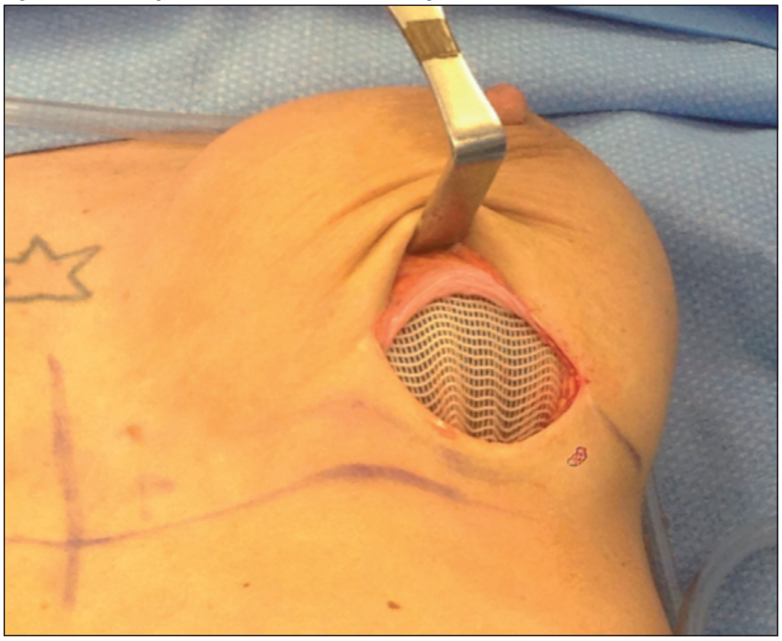


Table 2. Synthetic meshes used in breast reconstruction

Name	Country	Manufacturer	Source	Absorption time	Tensile strength	Elasticity at 16 N/cm
Seri Surgical Scaffold (Hybrid)	USA	Allergan	Silk	24 months	99.7 N	Not available
Phasix Mesh	USA	Bard, Davol Inc.	Poly-4-hydroxybutyrate	12–18 months	210 N	Not available
Vicryl Mesh	USA	Ethicon, Inc.	Copolymer of glycolide and lactide	90 days	Not available	Not available
TiLOOP Bra	Germany	Pfm Medical	Titanium-coated polypropylene	Not applicable	37 N/cm	23%
TIGR Matrix	Singapore	Novus Scientific	Copolymer of lactide, glycolide and trimethylene carbonate	3 years	86.6 N/cm	7%
Seragyn BR	Germany	Serag Wiessner	Polyglycol acid-caprolacton and polypropylene	90–120 days	Before resorption: 67 N/cm, after resorption: 41 N/cm	Before resorption: 14% (length), 50% (crossways); after resorption: 25% (length), 69% (crossways)

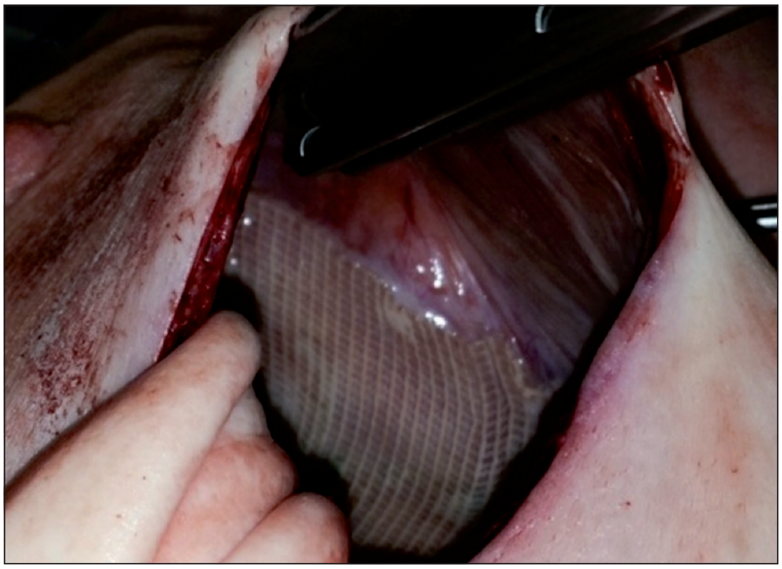


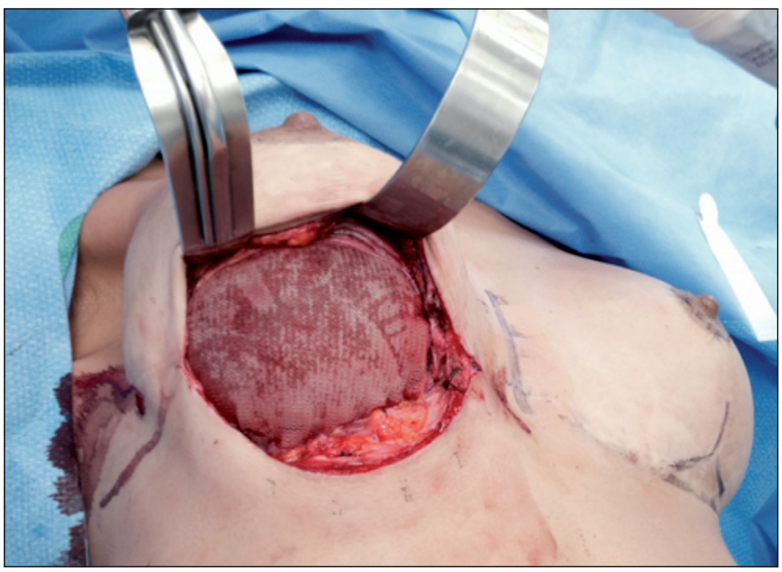
Figure 4. Secondary reconstruction shows incorporation of Seri Surgical Scaffold into the mastectomy skin flap.

(2015) 1-year follow-up data as part of a prospective clinical trial show high levels of investigator and patient satisfaction, and complication rates similar to breast reconstruction using acellular dermal matrices.

Phasix Mesh

Phasix (Bard, Davol Inc., Warwick, RI) is a resorbable monofilament mesh made from poly-4-hydroxybutyrate. It provides inferior pole support with strength comparable to traditional polypropylene mesh (*Figure 5*). Owing to limited early absorption, maximum strength is maintained during the first 12–26-weeks. It then gradually degrades over a 12–18-month period. Long-term studies evaluating breast shape and inframammary fold position are pending.

Figure 5. Phasix Mesh is an absorbable mesh that provides inferior pole support. The mesh is sutured to the pectoralis muscle above and the inframammary fold below.



Vicryl Mesh

Vicryl Mesh (Ethicon Inc., Somerville, NJ) is a woven absorbable mesh made from a copolymer or glycolide and lactide. The fibre used is identical in composition to Vicryl absorbable suture, which elicits a mild tissue reaction during absorption. It has been shown by Tessler et al (2014) and Haynes and Kreithen (2014) to be an effective, low-cost alternative to acellular dermal matrices in non-irradiated patients in breast reconstruction. For patients with a history of radiation therapy, acellular dermal matrices have been shown by Hunsicker and Salzberg (2014) to have a low rate of capsular contracture, and therefore may be a better choice.

TiLoop Bra

TiLoop (pfm Medical, Cologne, Germany) is a titanium-coated, porous polypropylene mesh mainly used in Europe. It is lightweight, has good strength, and has been shown by Scheidbach et al (2004) to have better biocompatibility than other polypropylene meshes. In patients with healthy skin flaps, as discussed by Dieterich et al (2012), it provides good implant support as a promising, less expensive alternative to acellular dermal matrices.

Basic surgical technique

Use of an acellular dermal matrix or synthetic mesh in implant-based breast reconstruction begins with proper patient and implant selection. Standardized two-dimensional and three-dimensional photographs provide important measurements, including the sternal notch to nipple distances, the breast base widths, the nipple to inframammary fold distances, and the breast volumes. The authors routinely have a range of implant sizes available, as well as appropriate sizers.

Basic landmarks are drawn preoperatively with the patient in the standing position. The midline, inframammary fold levels (as well as any planned raising or lowering of the folds) and breast borders are outlined.

In either the immediate or delayed breast reconstruction setting, the pectoralis major muscle is identified. A subpectoral plane is developed up to the second rib superiorly and to the sternal fibres medially. The origins are released from the ribs up to the 4 o'clock position on the right and the 8 o'clock position on the left. The acellular dermal matrix or synthetic mesh is then secured to the inferior released edge of the muscle. A 3-0 Vicryl suture is typically used, beginning by securing the superomedial edge of the acellular dermal matrix or mesh to the released inferomedial edge of the muscle. This suture is then run laterally to the lateral breast border. When placing an immediate implant, both the muscle and acellular dermal matrix or mesh are advanced medially to accommodate the volume. Continuing this suture, the acellular dermal matrix or mesh is then secured to the chest wall even with anterior axillary line. The suture is temporarily stopped once the inframammary fold level is reached.

A second 3-0 Vicryl suture is started again at the superomedial edge of the acellular dermal matrix or mesh and is used to secure it down to the medial chest wall and re-establish the breast border. This is continued down to the level of the inframammary fold and again temporarily stopped. At this point, the authors typically irrigate the pocket with triple antibiotic solution and change gloves. The implant is placed into the pocket and proper orientation and position ensured. The acellular dermal matrix or mesh is then draped over the implant and the 3-0 Vicryl sutures are continued both medially and laterally to secure it down to the chest wall at the desired level of the inframammary fold. Once the breast capsule reconstruction is complete, the mastectomy flaps are redraped and closed primarily as long as there is sufficient viable skin (nipple-sparing or skin-sparing mastectomy). In cases of previous radiation or insufficient viable skin, the authors have often mobilized a thoracodorsal artery perforator flap to cover the implant or acellular dermal matrix capsule.

The authors usually use two drains underneath the mastectomy skin flaps, one starting laterally and coursing along the superior and medial implant borders, and the other placed along the inframammary fold. These drains are kept in place until their output is <30 cc per 24 hours, typically 2–3 weeks. Proper use of drains and postoperative soft compression, as described by Ganske et al (2103), can significantly decrease the rate of seroma formation and infection.

Use of biological matrix or synthetic mesh in revisionary breast reconstruction surgery

Capsular contracture

Capsular contracture involves a progressive tightening of the implant capsule. The contracture causes a stiffer feeling breast in its early stages, followed by changes in the breast shape and pain in more advanced stages. The standard treatment for cases of advanced capsular contracture (Baker grade III and IV; Baker, 1978) involves removal of the implant as well as an anterior capsulectomy. When placing a new implant, use of an acellular dermal matrix has been shown by Maxwell and Gabriel (2009) and Namnoun and Moyer (2012) to decrease the incidence of recurrence. Both inferior pole coverage as well as complete implant coverage have been described.

Implant malposition

Superior and inferior implant malposition occurring in the first month postoperatively (acute) typically results from inaccurate placement by the surgeon. Superior displacement of the implant in the subacute setting (1–6 months) usually results from contraction of the pectoralis major muscle. Cases of inferior displacement in this time period may be the result of disruption of the inferior pole support. The typical implant malposition seen in the delayed setting (>6 months) involves inferior migration as a result of bottoming out of the inferior pole. Use of acellular dermal matrix and mesh provides long-term inferior pole support aimed at establishing and maintaining the level of the inframammary fold.

Implant rippling or wrinkling

Implant rippling is commonly seen in the breast reconstruction patient, especially when saline implants are used. Owing to a more natural feel and appearance, silicone breast implants are now preferred in the majority of women undergoing implant-based reconstruction. Despite the development of highly cohesive silicone gel implants, patients with very little subcutaneous fat on their mastectomy flaps are at risk of implant rippling or wrinkling.

Successful treatment of these deformities involves placement of volume between the skin flap–implant tissue plane. The authors have found acellular dermal matrix to be very effective in these scenarios. The superior mastectomy flap (with the underlying pectoralis major) is dissected off the implant capsule up the superior breast border. A sheet of acellular dermal matrix is then ‘parachuted’ up the superior implant border (using non-absorbable marionette sutures), draped over the implant, and secured either to the implant capsule (for superior coverage only) or to the inframammary fold (for complete coverage).

Synmastia

Synmastia occurs when either one or both of the medial breast capsules cross the midline and invade the normally densely adherent skin over the sternum. Initially, an attempt to perform a medial capsulorrhaphy is made. Many times, however, this is unsuccessful, and recurrence of synmastia is common. Both acellular dermal matrices and synthetic mesh are very useful for this difficult deformity. The acellular dermal matrix or mesh may be used to either reinforce the subpectoral medial capsulorrhaphy or provide implant coverage in the subcutaneous plane or, as described by Spear et al (2009), the ‘neosubpectoral’ plane.

Animation deformity

An animation deformity results from superior or lateral implant displacement during pectoralis contraction. Women with larger muscle bellies and thinner breast skin flaps are more commonly affected. The authors have found that the most successful secondary treatment of this deformity is transfer of the implant to a subcutaneous plane. Maximum skin flap thickness is maintained by careful dissection on top of the muscle. The implant capsule is excised and the muscle is sutured back down to the chest wall. The authors perform complete implant coverage with an acellular dermal matrix to not only ensure precise, long-lasting positioning, but also to reduce the chance of implant rippling.

Conclusions

Biological and synthetic materials have been used in breast reconstruction since the 1980s. The concept of direct-to-implant breast reconstruction has changed the paradigm and drastically improved the aesthetics of implant-based reconstruction. The indications for their use in both primary and secondary reconstruction have greatly increased and there has been a consequent increase in the number of products available. Both acellular dermal matrices and synthetic meshes provide complete implant coverage and inferior pole support. A clear understanding of the benefits and risks of these products will allow the reconstructive breast surgeon to tailor his/her plan to each patient. **BJHM**

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KEY POINTS

- With careful patient selection, direct-to-implant breast reconstruction using an acellular dermal matrix can shorten the reconstructive course and decrease the number of operations.
- Biological substitutes are regenerative and gradually incorporate into the surrounding tissue through neovascularization.
- Synthetic meshes in breast reconstruction provide lower cost alternatives to acellular dermal matrices and may be absorbable or non-absorbable.
- Secondary breast reconstruction with acellular dermal matrix and mesh allows correction of many difficult deformities, including synmastia, capsular contracture, malposition and implant rippling.