Surgisis acellular collagen matrix was made commercially available in 1998 soon after Food and Drug Administration (FDA) 510 K clearance for soft tissue reconstruction. Since then, numerous applications have received FDA 510 K clearance of the engineered device. Application of this porcine intestinal mucosa–derived device in plastic surgery applications has been recent. Several IRB–approved studies are currently in progress to assess the long-term performance in aesthetic and reconstructive breast surgery and aesthetic facial rejuvenation. To date, some limited longer-term data are becoming available that support the use of Surgisis in plastic surgery applications.

BASIC SCIENCE AND BACKGROUND

Surgisis is manufactured from a readily available, abundant extracellular matrix (ECM) material derived from the submucosal layer of the pig small intestine, also referred to as small intestinal submucosa, or SIS. The submucosa is the layer of connective tissue that provides strength to the pig small intestine. It is approximately 100 to 200 μm thick, and in the living intestine it supports the growth and differentiation of the mucosal and glandular cells while maintaining a connective tissue structure that gives the intestine its integrity.

Like dermis or fascia, the small intestinal submucosa is composed of fibrillar collagens and adhesive glycoproteins, which serve as a scaffold into which cells can migrate and multiply. Because of its importance in the constant renewal of the multitude of cell types in the intestine, the ECM of the small intestine also contains potent regulatory factors, such as glycosaminoglycans, proteoglycans, and growth factors. These factors help regulate cellular processes that maintain tissue homeostasis and respond to injury and infection.

Unlike allografts or autografts, which are not subject to stringent regulatory oversight to ensure safety, xenograft materials must be purified to ensure safety. Surgisis is manufactured by mechanically separating the submucosa from its outer muscular layers and internal mucosal layers, treating it to remove cells and cellular debris, and subjecting it to robust disinfection methods to eliminate the risk for disease transmission. Unlike acellular cadaveric dermis, it is then terminally sterilized using ethylene oxide gas. When implanted surgically, it stimulates angiogenesis, connective and epithelial tissue growth and

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determination, and deposition, organization, and maturation of ECM components that are functionally and histologically appropriate to the site of implantation.\textsuperscript{1,3,4}

Surgisis is unique among biologic graft materials because the signaling components that make the ECM an interactive structure are retained through the entire manufacturing process. For example, it has been shown to contain potent regulatory factors, such as glycosaminoglycans, proteoglycans, and growth factors, which regulate cellular processes that maintain tissue homeostasis and respond to injury.\textsuperscript{5} It has been shown to recruit marrow-derived stem cells to the area of implant,\textsuperscript{6} protect bioactive factors from a proteolytic wound environment,\textsuperscript{7} and stimulate cultured cells to secrete their own growth factors, which further aids in tissue restoration.\textsuperscript{7,8}

In animal models of angiogenesis, Surgisis has been proven to rapidly stimulate blood vessel growth to allow it early access to the patient’s immune system, providing a possible mechanism by which Surgisis can withstand implantation in contaminated fields.\textsuperscript{9}

Surgisis has been used in various surgical applications. In animals, SIS was first used in the vascular system to experimentally replace superior vena cava and aorta.\textsuperscript{10,11} Since that time, it has been shown to be effective in restoring functional innervation and smooth muscle cell contractility in the injured canine bladder.\textsuperscript{12} It has also been examined in long-term canine studies of experimental body wall replacement. In these studies, it was demonstrated to maintain its strength out to an endpoint of 2 years\textsuperscript{13} and to result in lesser degrees of chronic inflammation and greater amounts of collagen and muscle cell differentiation than other graft materials.\textsuperscript{14}

In humans, products based on the submucosal technology have been used to treat more than 500,000 patients in fields ranging from wound care to colorectal surgery, to hernia and pelvic floor repair, and even to plastic and cosmetic surgery. In randomized clinical wound care trials, the OASIS Wound Matrix was shown to be superior to conventional compression therapy alone in leading to complete healing of venous stasis ulcers within 12 weeks.\textsuperscript{15} It was also shown to be equally as effective as expensive growth factor treatment in leading to complete closure of diabetic foot ulcers.\textsuperscript{16} In European randomized clinical trial against Hyaloskin (a purified hyaluronic acid product), treatment of mixed arteriovenous ulcers with OASIS led to complete closure in 83% of ulcers as compared with 46% of those treated with Hyaloskin. Taken together, these studies indicate that products based on the SIS technology can be effective in healing chronic skin wounds, and suggest that the complex composition of all products based on this technology plays a role in their efficacy.

In no single application does the composition of Surgisis and its ability to quickly interact with patient tissues play a more critical role than when it is placed in potentially contaminated or contaminated fields. Even though success varies based on the degree of infection and the type of microorganism present, in many of these cases traditional synthetic meshes cannot be ethically used because it has been well established that they become infected and need to later be removed; two well-documented uses include anal fistula repair and complex hernia repair.

In anorectal fistulas, the Surgisis material has been documented repeatedly to result in effective fistula closure within approximately 3 months of placement (see Refs.\textsuperscript{17-19}). Multiple published case series report healing rates at 3 months in excess of 70%,\textsuperscript{17-23} whereas others report only a 24% to 46% healing rate.\textsuperscript{23-27} The major difference between these series was that the lower success rates seemed to be related to the presence of overt abscesses in the fistula tracts and application of Surgisis in tracts that had repeatedly failed other procedures. The Surgisis material fared better in cases of contamination as compared with cases of overt infection, and in cases that were more acute as compared with more chronic fistulas that had failed multiple other procedures. It is obvious that in the cases in which Surgisis fails, no other graft materials are likely to succeed either.

Surgisis has an extensive history of use in various hernia repair procedures. In inguinal hernia repair, it has been shown to be effective and durable to more than 3 years when used with tacks or fibrin glue.\textsuperscript{28} It has been effective in returning athletes to the field quickly in cases of “sports hernia,” wherein groin pain is experienced but a hernia is not confirmed.\textsuperscript{29} It has also been shown to result in less chronic pain than synthetics in this location, and has been effective even in immunocompromised patients.\textsuperscript{30} In a prospective, randomized trial of large paraesophageal hernias, it significantly reduced the rate of early recurrence when used as a bolster,\textsuperscript{31} and in ventral hernia repair it has effectively resulted in long-term retention of domain for as long as 5 years.\textsuperscript{9}

The most challenging locations in which to use Surgisis are grossly contaminated hernias, where any surgical repair is likely to result in complications. When using Surgisis in grossly contaminated cases, Helton and colleagues\textsuperscript{32} suggest a staged repair strategy and caution its use in dirty
wounds or in critically ill patients if a staged strategy is not used. They suggest that the avoidance of closed-space infection adjacent to the Surgisis material is important for long-term efficacy and that prevention of colonization at the time of implantation should prevent delayed infections from occurring. They further note that their best results were achieved when they were able to minimize seroma or hematoma formation and prevent infection between the mesh and the peritoneal cavity. It is likely that maintaining contact of the mesh with vascularized tissue is essential to a satisfactory outcome. In their experience, fewer complications were noted with laparoscopic placement of the Surgisis than with open placement, but when open repair was needed in the presence of contamination, they suggested the use of Surgisis as an inlay prosthesis without completely closing the wound, making liberal use of wet-to-dry dressings and vacuum-assisted closure until the contamination was resolved, and then subsequently placing a skin graft if necessary to achieve complete closure.

PLASTIC SURGERY APPLICATIONS

Breast Reconstruction

The use of biologic implants in reconstructive breast surgery is a recent innovation in plastic surgery. Breunig and Warren initially reported the use of human cadaveric allografts in reconstructing the inframammary crease and to allow immediate single-stage breast reconstruction with an alloplastic implant in 2005. Subsequently, multiple authors have reported its use in the same application in immediate breast reconstruction with tissue expanders. This technique allows for a more natural and efficient expander/implant reconstruction than either the complete submuscular or partial submuscular reconstruction technique. The complication rates of this new technique also seem to be comparable to published series of tissue expander breast reconstruction. Its success and popularity have led to rapid adoption of this relatively new technique.

The cost-prohibitive nature of using multiple pieces of cadaveric human dermis remains a significant concern and reason for pause. Additionally, the inconvenience of having to suture pieces of cadaveric human or porcine dermis together to achieve complete expander coverage led the author to seek an engineered biologic implant alternative. Surgisis EXL biologic mesh is an FDA-approved product with indications for soft tissue reconstruction, the indication for which it was intended in this application. This engineered product is cost effective in nature, readily available in large sizes, and easy to use.

After complete informed consent was obtained, patients who were deemed candidates for immediate tissue expander reconstruction were reconstructed using a Surgisis EXL 5 × 30 cm biologic mesh suture to the previously marked inframammary crease position and to the inferior border of the detached pectoralis. Complete coverage of the expander was achieved in all cases (Fig. 1). The procedure was performed similarly to the previously published technique. The patient in Fig. 2 demonstrates the efficacy and applicability of Surgisis biologic implants in this soft tissue reconstruction application. Table 1 documents the outcomes associated with its use in different applications.

Mastopexy—Internal Suspension

The use of internal suspension sutures and mesh in mastopexy surgery has been well documented in the literature. The recurrence of skin laxity leading to parenchymal descent in the long term is a vexing problem experienced by many plastic surgeons in the United States. Outside the United States, the use of alloplastic permanent and absorbable mesh has been popularized by Sampaio-Goes. His long-term results support the efficacy of internal mesh suspension in prolonging the results of the mastopexy procedure. Concerns about the impact of alloplastic mesh in confounding the results of screening mammography and the potential for litigation has delayed the widespread adoption of its use in this application. Mastopexy is another application for soft tissue reconstruction in which an engineered, cost-effective biologic

Fig. 1. Intraoperative view of Surgisis EXL 5 × 30 cm graft in an immediate tissue expander reconstruction. The graft is sutured in place to the inframammary fold; the lateral axillary fascia and the inferior border of the detached pectoralis major providing complete implant coverage.
implant like Surgisis seems to have a role. Its incorporation and replacement by the host’s tissue should allay the concerns about mammographic alteration. The author is unaware of any evidence in the literature that cadaveric or xenogenic biologic implants have oncogenic potential. The cadaveric and porcine dermal products, while similarly effective, have the disadvantage of being cost prohibitive in cosmetic applications and cumbersome to use because of size limitations. Although the author’s long-term results in this application are limited, the device seems to have usefulness in this application (Figs 3 and 4). Its efficacy in prolonging the therapeutic effect of a mastopexy is deserving of further study in a systematic and objective way. Controlled studies in bilateral procedures are difficult to perform from a practical and an ethical standpoint.

**Nasolabial, Labiomialdibular, Glabellar Folds**

The treatment of nasolabial, labiomandibular, and glabellar folds has long been managed with injectable fillers. The off-the-shelf convenience and relative safety of these devices have made them popular with consumers. Unfortunately, the significant volume of fillers required to achieve a good clinical result and the longevity of the fillers remain economic concerns for most patients. “Filler fatigue” among patients is not an uncommon finding in many aesthetic practices. Although the noninvasive and low-downtime nature of these treatments make them popular early on, the average patient frequently tires of the cost of repeated treatments. This fatigue has led companies to develop fillers of longer duration and even some that purport to be permanent. Although the author feels that the quest for a permanent filler is likely misguided, longer-lasting fillers that are cost effective for patients would certainly be welcome in the market. Surgisis acellular collagen matrix grafts seem to potentially fit this niche. Although a surgical procedure is required to treat these areas, Surgisis strans or cylinders can be deployed in various subcutaneous planes to get good soft tissue augmentation and correction (Fig. 5). The longevity of these treatments still requires thorough documentation, but early results in a small series of patients are promising (Figs. 6-9). Its cost effectiveness also makes it competitive with fillers and more cost effective than cadaveric or other xenogenic grafts. Formal study of the longevity of the device in the treatment of nasolabial folds is currently in progress.

**Neck Suspension Sling**

The use of sutures and devices to perform a minimally invasive neck lift or as an adjunct to open
<table>
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<th>Breast</th>
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<th>Labiomandibular Folds</th>
<th>Glabellar Folds</th>
<th>Premaxillary, Premandibular</th>
<th>Neck</th>
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neck and face lift procedure is a fertile area of investigation and marketing today. Various devices have been used in this application, including Surgisis. The drawback of the current techniques available is the edema and ridge effect that persists after these procedures (Figs. 10 and 11). Although this problem is likely self-limited and is possibly technique related, in the author’s experience all of the devices used in this application seem to suffer from the same drawback. Neck procedures have a significant amount of dependent edema independent of the use of fixation devices. This application is one in which surgical intervention still seems to provide the best solution with the fastest recovery and fewest complications.

**Lip Augmentation**

Pribitkin and colleagues\(^{36}\) reported the use of Surgisis acellular collagen matrix in lip augmentation. Eight patients underwent augmentation with 1 × 6 cm strips and were followed for 6 months. Four of the eight patients were satisfied with the outcome and four patients desired further augmentation. Adverse events included transient erythema and cellulitis in one patient that resolved with oral antibiotics. The author has no personal clinical experience with the device in this application. Given the average aesthetic patient’s desire for a short recovery, this procedure seems applicable in lip augmentation patients who have filler fatigue and tolerance for potential morbidity. Our inability as surgeons to achieve effective long-lasting lip augmentation with existing techniques supports further study of this procedure.

**Premaxillary Augmentation**

Augmentation of the premaxilla has been performed with calcium hydroxyapatite, bone grafts, soft tissue grafts, and alloplastic implants. Today, it is most commonly performed in cosmetic rhinoplasty surgery wherein the patient presents with a hidden columella due to premaxillary bony and

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Fig. 3. Intraoperative view of internal suspension of breast parenchyma in a vertical short scar mastopexy.

Fig. 4. A 35-year-old patient shown 4 months after vertical short scar mastopexy with Surgisis EXL 5 × 30 cm graft internal parenchymal suspension.
soft tissue deficiency. This procedure is often done by constructing either an autogenous or an allo-
pathic graft to fit the application. The availability of a cost-effective, engineered implant certainly is an efficient way of addressing this need. The longevity of the soft tissue correction in this appli-
cation is unknown, but its efficacy is supported by the results shown in Fig. 12.

**Nipple Reconstruction**

Although long-term data are not yet available, nipple reconstruction in post-oncologic breast reconstruction is an application in which Surgisis cylinders may be applicable. Although a plethora of techniques have been described to produce natural, long-term results there is no consensus regarding the best approach to this vexing recon-
structive problem. Early results are favorable with virtually all reconstructive techniques, but the long-term results fail to show persistence in most cases. Attempts at addressing this problem with acellular human dermis and injectable fillers show good short-term success, but marginal long-term results. The unanswered question is whether using an acellular collagen biologically active matrix cylinder to stent the reconstructive flaps will provide for long-term persistence of nipple projection. Off-the-shelf Surgisis nipple reconstruction cylinders are available that show anecdotally good results, but long-term reports are still pending.

**TECHNICAL CONSIDERATIONS**

As with any implant, there are many factors that affect the success of its placement. Host factors, such as whether the surgical site is infected or contaminated, the site has been irradiated, or the patient is undergoing chemotherapy, all are relevant to the success of the procedure. Whether an implant is alloplastic, xenogenic, homologous, or autologous, all of these factors can deleteriously affect the outcome. The use of Surgisis SIS acel-
cular collagen matrix is no exception to these basic tenets. Although Surgisis SIS does show some resistance to infection, optimally the implant should be placed in a noninfected or contaminated site. This placement is especially relevant in aesthetic applications in the face. Placement of a facial implant in patients who have active acne, pustules, or fever blisters should be avoided until these conditions are under control. Although the
Fig. 6. A 38-year-old patient shown 8 months after nasolabial fold correction with Surgisis 1 × 6 cm facial strips under local anesthesia.

Fig. 7. A 69-year-old patient shown 11 months after nasolabial fold correction with Surgisis 2 × 15 cm facial strips under local anesthesia.

Fig. 8. A 40-year-old patient shown 12 months after glabellar fold correction with Surgisis 1 × 6 cm facial strips under local anesthesia and adjunctive treatment with Botox.

Fig. 9. A 31-year-old patient shown 12 months after glabellar fold correction with Surgisis 1 × 6 cm facial strips under local anesthesia and adjunctive treatment with Botox.
handing of the implant and contact with the skin is important in avoiding contamination and colonization with skin flora. Hydration of the implant for the appropriate length of time (neither over- nor underhydration) is also important to timely incorporation. Surgisis can be hydrated in saline containing antibiotics. The manufacturer recommends hydration in cefazolin and bacitracin, but vancomycin, clindamycin, and gentamicin should be avoided. Additionally, using latex-free gloves during placement is recommended by the manufacturer. The implant should be handled with sterile instruments as much as possible.

When placing the implants in the face, care should be taken to place the implant in the subcutaneous tissue and not immediately subdermal to avoid visibility. The ends of the implant should either be trimmed or meticulously buried in a subcutaneous pocket to avoid extrusion of the implant. Another technical matter is placement of the entrance and exit incisions. To treat the nasolabial fold, one incision should be in the nasolabial fold and one incision should be at the border of the mandible in the prejowl area. If the incision is placed at the end of the nasolabial fold, the incision will be visible for a prolonged period of time because of postinflammatory hyperpigmentation and dependent edema. In treating the labiomandibular fold, the oral commissure and the mandibular border should be used as incision locations. In the glabella, the incisions are placed at the end of the fold and the implant ends are buried in a small 0.5-cm pocket that extends beyond the ends of the incisions. Unfortunately, visibility of the incision is unavoidable in the glabella area and patients should be counseled that they will have to conceal it with make-up until it fades. Adjunctive Botox before treatment and limited subcision under
glabellar folds also enhances the outcome in this area. Fortunately, with Surgisis SFI implants there is no risk for embolization associated with injectable fillers or autologous fat in this anatomic area.

Use of Surgisis SIS mesh either in the breast or abdomen requires several strategies to minimize the risk for seroma formation. Reducing dead space in the surgical field with compression and closed suction drainage are important strategies. In the breast, drains are used when Surgisis is applied as in internal sling during mastectomy. In breast reconstruction with expanders and inferior Surgisis sling, the expander is typically filled to approximately 50% of the projected final fill volume based on the weight of the mastectomy specimen. Any redundant skin-sparing mastectomy skin is resected in patients who have pendulous breasts. One to two hubless Blake drains are place to further reduce dead space. Finally, gentle external compression with a fluff dressing and support bra is applied. The drains are left in place until the output is less than 30 mL in 24 hours. Expansion of the expander before drain removal is also helpful in reducing dead space and avoiding seromas. Given the high complication rates associated with tissue expander reconstructions, there is no substitute for sound clinical judgment in this application. In the abdomen, use of closed suction drainage and external compression also helps to reduce the risk for a seroma.

**OUTCOMES**

Surgisis SIS has many potential applications in plastic and reconstructive surgery. To date, this series of 29 patients is the largest series on the use of Surgisis SIS published in the plastic surgery literature (Table 1). This series documents the success of the device in facial rejuvenation surgery, reconstructive and aesthetic breast surgery, and body contouring surgery.

Of the 29 patients, all but 2 are very satisfied with the treatments. The 2 patients who were not completely satisfied were 1 neck lift patient who had prolonged erythema, induration, and visibility of the implant, and 1 nasolabial fold augmentation patient who had a unilateral infection. Both patients had the implants removed without further incident and with complete resolution of their problems.

There were a total of four presumptive infections in the series. One patient had a culture-positive wound infection after abdominoplasty with hernia repair and abdominal wall reinforcement with a 35 x 35 cm Surgisis EXL implant. This patient responded well to oral antibiotics and the implant was left in place. She recovered uneventfully. One glabella fold patient had a culture-positive infection and was treated with oral antibiotics and had the implant removed. One nasolabial fold patient had unilateral erythema that responded to oral antibiotics. She recovered uneventfully and the implant was left in place. The infection rate is thus 4/29 patients (13%) or 4/168 devices or (2%). This finding may reflect the small number of patients in the series. The implants were only removed for infection in two of the four cases, supporting the contention that the biomaterial is resistant to infection. All four patients ultimately had good cosmetic outcomes despite the complications.
Seromas have been reported to be a concern with the use of Surgisis SIS in the general surgery literature. This concern seems to be relevant in plastic surgery procedures in which the implant is placed in a surgical field with dead space. Use of the biomaterial in these cases makes the use of closed suction drainage imperative. Furthermore, compression after drain removal is also helpful in mitigating this problem. In abdominal and breast cases, closed suction drainage and external compression make this issue manageable, but it remains a concern. The use of the Surgisis SIS strip as reinforcement and suspension in a neck lift either through a minimally invasive approach or by way of an open procedure has been problematic in the author’s hands. The paucity of tissue to conceal the implant, the dependency of the surgical field, and the dead space present technical challenges for application of this novel biomaterial. The advantages of using an internal suspension sling seem to be outweighed by the increased morbidity in this application.

The area that seems to hold great promise for the application of Surgisis is in facial soft tissue augmentation, namely glabella, labiomandibular, and nasolabial folds. Soft tissue augmentation to the premaxilla is also promising. The devices can be deployed in multiple subcutaneous planes with good success and soft tissue augmentation. The lack of dead space makes seromas virtually nonexistent. The persistence of the soft tissue correction is also promising. Patients continue to show persistence of the correction up to 1 year later. Prospective trials are currently underway to measure this persistence in a more standardized fashion. The implants are rarely visible if deployed meticulously, but prolonged palpability is an issue. Before incorporation occurs, the implant can be palpated through the skin. If patients are adequately counseled regarding this issue, they rarely find it objectionable. They are uniformly satisfied with the outcome if expectations are appropriately managed.

**SUMMARY**

Tissue engineering in aesthetic and reconstructive plastic surgery remains an elusive goal. The advent of Surgisis extracellular collagen matrix and its performance characteristics suggest that the use of a bioengineered tissue substitute can meet some of our reconstructive requirements. Incorporation and replacement by host tissue with minimal allergic or immune response seems to be achievable today. The ability to engineer the device, the ready availability of substrate, and its cost effectiveness support the use of Surgisis in aesthetic and reconstructive plastic surgery applications. Future product innovations and engineering seem promising. The permanent role of Surgisis in aesthetic and reconstructive plastic surgery will be determined by its documented long-term performance.

**REFERENCES**


