Understanding the Evidence and Improving Outcomes with Implant-Based Prepectoral Breast Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Describe the risks, benefits, and safety profile of prepectoral breast reconstruction. 2. Have knowledge of primary immediate and delayed prepectoral breast reconstruction techniques and secondary procedures required. 3. Describe data on outcomes of prepectoral breast reconstruction.

Summary: Once considered to have an unacceptable complication profile, prepectoral breast reconstruction is increasing in popularity because of decreased surgical invasiveness and postoperative pain and the absence of animation deformity. Short-term outcomes studies comparing prepectoral breast reconstruction to partially submuscular techniques demonstrate similarly acceptable rates of postoperative complications. Aesthetic outcomes demonstrate similar rates of capsular contracture but increased rippling and implant palpability of the upper pole. Postoperative functional data are limited but overall show decreased pain and more rapid return of function but equivalent satisfaction on the BREAST-Q. Long-term aesthetic data and rates of revision are lacking. (*Plast. Reconstr. Surg.* 148: 437e, 2021.)

Subcutaneous implant placement was first described for reconstruction after subcutaneous mastectomy for benign breast conditions before being used for malignant breast disease.[1] With the more tenuous soft-tissue envelope after radical mastectomy, patient series of subcutaneous mastectomy reported an unacceptably high rate of implant loss.[2] This complication profile was attributed to mastectomy skin loss and low-viscosity, thin-shelled breast implants prone to failure.[3,4]

These clinical conditions were ill-suited to subcutaneous implant placement, and ushered in the practice of submuscular implant breast reconstruction, where the highly vascularized pectoralis major muscle provided an additional layer of soft-tissue coverage and also provided upper pole camouflage to hide implant rippling and palpability.[5] Initial reports demonstrated acceptable early surgical outcomes and decreased malposition and capsular contracture compared with subcutaneous implant placement.[6]

The advent of acellular dermal matrix allowed for more effective expansion of the breast lower pole and improved cosmesis,[7] although early reports associated acellular dermal matrix use with increased serous fluid production.[8] In parallel to the use of acellular dermal matrix augmenting the available surface area of soft-tissue support for the lower pole of the breast, mastectomy techniques evolved to increase the surface area of available skin for reconstruction.[9] With the development of skin-sparing and nipple-sparing techniques and the expertise to perform these operations with acceptable rates of skin loss, available skin can be occupied by an implant instead of gradual expansion of the pectoralis major with a limited skin envelope. Larger pieces of acellular dermal matrix with or without fenestrations were subsequently developed for prepectoral breast reconstruction and used in both in vivo anterior support and ex

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vivo wrapping techniques to contain the entire breast implant.[10] The use of indocyanine green fluorescence angiography has allowed real-time intraoperative assessment of mastectomy skin flap viability to further improve postoperative healing after mastectomy.[11] These developments have set the stage to reexplore prepectoral breast reconstruction. This evidence-based report will focus on the safety of prepectoral breast reconstruction and any gaps in knowledge identified with the goal of improving future outcomes.

PERIOPERATIVE SAFETY OUTCOMES OF PREPECTORAL RECONSTRUCTION

The presence of the pectoralis major over the upper pole of the breast implant after mastectomy provides a well-vascularized layer of protection underneath possibly hypoxic mastectomy skin flaps. Considered together with historical concerns of the prepectoral space producing more serous fluid than the submuscular space and larger pieces of acellular dermal matrix causing a greater host serous fluid response, prepectoral breast implant placement could increase infection risk, implant loss, and serous fluid production.

Acute postoperative safety data have been the most reported element in the literature since the resurgence of prepectoral breast reconstruction. Twenty-nine series focusing on prepectoral breast reconstruction from 2014 to 2019 reported perioperative safety outcomes at the completion of this article (Table 1).[12–41]

The most commonly reported early complications include hematoma/seroma, mastectomy incision dehiscence, skin necrosis, implant infection, and explantation. Skin dehiscence after prepectoral breast reconstruction was commonly reported in 1.3 to 7.7 percent, with one study including obese, high-risk patients, with skin reduction showing a 28.6 percent T-point breakdown treated by wound care alone.[15] Skin flap necrosis rates ranged from 0 to 17 percent, with one study reporting 27.8 percent.[34] Implant-associated infection was reported in 1.2 to 12 percent of patients, with 2.3 to 3.6 percent being most common. Implant loss was reported in 0 to 6.5 percent, with one study reporting 12 percent[41] and another reporting 17.7 percent.[34] In some patient series, hematoma and seroma were a combined category, with rates of 0 to 6.5 percent.[13,26,36] Where seroma rates were calculated separately, the most common range was 0 to 8 percent. Eleven series used an acellular dermal matrix anterior support technique, with the remaining six reporting an acellular dermal matrix wrap technique with no difference between seroma outcomes. Two study outliers included one report with a 15.2 percent seroma rate[34] where an acellular dermal matrix wrap was used and another 23 percent incidence where a Vicryl (Ethicon, Inc., Somerville, N.J.) wrap with or without acellular dermal matrix overlay was used.[32] Nine of these patient series used a partially submuscular acellular dermal matrix–assisted cohort as a comparison group, with no significant differences in any of the outcomes listed above when compared to prepectoral breast reconstruction to demonstrate equivalence to an accepted technique.[13–15,17,20–22,27,35]

Earlier reports were more likely to describe a mesh wrap using either an acellular dermal matrix or synthetic material such as polypropylene or Vicryl, with seven such reports from 2014 to 2016[30,31,33,37–40] and only three patient series with an acellular dermal matrix anterior support technique.[33,35,36] During this time, one patient series did not specify their acellular dermal matrix technique,[37] whereas two series used no acellular dermal matrix support.[29,30] The subsequent years of 2017 to 2019 showed more uniformity in acellular dermal matrix technique, with 12 series reporting anterior support techniques,[14,15,18,19,21–27] with only three patient series where an acellular dermal matrix wrap was used.[16,20,28] Fenestrations were used in one anterior support series with the intention of increasing the surface area of the interface between patient and acellular dermal matrix to support patient tissue ingrowth.[26,42] No differences in early outcomes between acellular dermal matrix techniques can be discerned from the data reported (Table 1).

Different acellular dermal matrix sizes and choice of tissue expander or direct-to-implant reconstruction will vary with surgeon technique [**See Video 1 (online)**, which displays the clinical case of immediate bilateral breast reconstruction with prepectoral tissue expander placement and acellular dermal matrix anterior support. **See Video 2 (online)**, which displays the clinical case of second-stage bilateral prepectoral tissue expander to silicone gel implant exchange with concomitant fat grafting and 3-month follow-up results.]

Meshing and fenestrating the acellular dermal matrix to increase its functional surface area[26] while stabilizing cost have been described, as has orienting mesh differently based on breast base width.[43] Meshing or fenestrating acellular dermal matrices would create potential space for native capsule formation that may increase capsular

Table 1. Acute Perioperative Safety Outcomes

Reference	No. of Patients (No. of Breasts) TE/DTI	Safety Outcomes	Mean Follow-Up	ADM Technique	Findings
Viezel-Mathieu et al., 2019[13]	39 (60) DTI	Complications, 13%; reoperation, 6.5%; infection, 2.3%; hematoma/seroma, 2.3%; skin necrosis, 1.2%	163.7 days	Anterior support	Fewer visits but with comparable complication profile to partially submuscular cohort
Momeni et al., 2019[14]	80 (138) TE	Outpatient infection, 10%, inpatient infection, 2.5%; seroma, 10%; explantation, 2.5%; minor skin necrosis, 10%; major skin necrosis, 5%	5.7 mo	Anterior support	No difference when compared to partial submuscular cohort (PP group with 24 hr antibiotics only)
Thuman et al., 2019[15]	21 (37) TE	Inpatient infection, 2.7%; outpatient infection, 2.7%; explantation, 2.7%; minor skin dehiscence, 28.6%	6 mo	Anterior support	High-risk obese population; diabetes and increasing BMI; associated with minor nonoperative skin dehiscence
Khalil et al., 2019[16]	8 (16) DTI	Skin necrosis, 0%; explantation, 0%; seroma, 0%; revision, 6.3%	12 mo (range, 2–34 mo)	Wrap	Use with Wise-pattern reduction; safe for large or ptotic breasts
Elswick et al., 2018[17]	54 (93) TE	Infection, 7.7%; seroma, 5.6%; skin necrosis, 2.6%; dehiscence, 7.7%; hematoma, 2.6% (non-XRT cohort)	19 mo TE; 9 mo implant	Varied	Higher second-stage surgical infection after radiation therapy but no significance
Jones and Antony, 2008[18]	234 (357); 305 DTI	Seroma, 2.8%; infection, 3.1%; explantation, 3.6% hematoma, 0.4%	Mean, 15.1 mo (up to 3.8 yr)	Anterior support	Safe and reproducible technique
Sinnott et al., 2018[19]	274 (426); 45 (56) XRT TE	Infection, 2.8%; seroma, 0.2%; hematoma, 0%; dehiscence, 1%; skin necrosis, 1%; explantation, 4% (all prepectoral patients)	19 ± 16.9 mo	Anterior support dermal flap	Irradiated prepectoral reconstructed cohort with similar complication profile to nonirradiated prepectoral patients
Wormer et al., 2018[20]	32 (60) TE	Minor complications, 25%; readmissions, 5%; seromas, 8.3%; reoperation, 3.3%; explantation, 5%	281 ± 119 days	ADM wrap	Complication rates similar to subpectoral cohort
Baker et al., 2017[21]	28 (43) DTI	Implant loss, 4.7%; infection, 2.3%; seroma, 2.3%; skin necrosis, 4.7%	9.2 mo	Anterior support	No statistical difference; implant loss to subpectoral cohort
Bettinger et al., 2017[22]	110 (165) TE	Total complication, 13%; explantation, 8.5%; seroma, 3% hematoma, 1%; infection, 6.7%; skin necrosis, 3.6%	6 mo–6 yr	Anterior support	No difference by technique, ADM-assisted or total submuscular; implant loss associated with radiation therapy
Highton et al., 2017[23]	71 (113) DTI	Skin necrosis, 4.4%; implant loss, 3%; delayed healing, 4.2%; red breast syndrome, 1.2%; seroma, 3%; total complication, 11.4%	485 days (range, 81–1446 days)	Anterior support	Well-tolerated technique, complication profile not affected by radiation therapy/chemotherapy
Nahabedian et al., 2017[24]	39 (62) TE	Infection, 8.1%; seroma, 4.8%; explantation, 6.5%; skin necrosis, 6.5%	8.7 mo	Anterior support	Insignificantly greater SSI and seroma when compared to submuscular cohort, safe with radiation therapy
Jones et al., 2017[25]	50 (73) DTI	Infection, 2.7%; skin dehiscence, 1.3%; explantation, 2.7%; seroma, 1.3%; delayed healing, 8.2%	48 wk (range 13–103 wk)	Anterior support	Safe technique; no association with obesity, smoking, large breasts
Paydar et al., 2017[26]	10 (18) DTI/TE 16/2	Skin necrosis, 17%; infection, 5.5%; explantation, 5.5%; seroma/hematoma, 0%; reoperation, 22%	14.4 mo	Anterior support; fenestrated	Safe technique; more rapid expansion
Sbitany et al., 2017[27]	51 (84) TE	Overall complication, 17.9%; infection, 7.2%; necrosis, 2.4%; seroma; 3.6%; hematoma, 2.4%; explantation, 1.2%	12.5 mo (range, 7–28 mo)	Anterior support and IMF cuff	No difference when compared to partial submuscular cohort
Onesti et al., 2017[28]	52 (64) DTI	Infection, 1.9%; explantation, 3.8%; dehiscence, 5.7%	Up to 2 yr	ADM wrap	Appropriate safety profile
Salibian et al., 2016[29]	155 (250) TE	Skin necrosis, 3.6%; infection, 2.4%; explantation, 3.6%; reoperation, 5.6%; hematoma, 2%	55 mo	No ADM	Well-tolerated technique
Caputo et al., 2016[30]	27 (33) DTI	Skin necrosis, 6%	6–24 mo	Dermal sling; no ADM	Large ptotic breasts
Vidya et al., 2016[31]	72 (100)	Implant loss, 2%; skin necrosis, 1%; seroma, 5%; dehiscence, 3%; hematoma, 2%	9.5–25.7 mo	ADM wrap	>1-cm skin flaps
Kobraei et al., 2016[32]	13 (23) DTI	Seroma, 23%; hematoma, 7%; infection, 7%; implant loss, 7%	10 mo (range, 6–18 mo)	Vicryl wrap with or without ADM overlay	Patient selection considering BMI

(*Continued*)

Table 1. *Continued*

Reference	No. of Patients (No. of Breasts) TE/DTI	Safety Outcomes	Mean Follow-Up	ADM Technique	Findings
Schnarrs et al[33]	126 (170) TE/DTI	Overall complications, 19.7%, infection, 10.5%; seroma, 2.4%; necrosis, 2.4%; reoperation, 7.1%	>3 mo	Anterior support	Smokers, large breasts, affected outcomes; not age, BMI, technique
Downs et al[34]	45 (79) DTI	Seroma, 15.2%; flap necrosis, 27.8%; infection, 10.1%; implant loss, 17.7%	22 mo	Wrap	Acceptable safety profile, textured anatomical implants
Zhu et al., 2015[35]	29 (50) TE	Infection, 2%; skin necrosis, 4%; seroma, 8%	17.3 mo (range, 2–34 mo)	IMF cuff or no ADM	No differences when compared to partial submuscular cohort
Becker et al., 2015[36]	31(62) DTI	Seroma/hematoma, 6.5%; flap necrosis, 6.5%; implant loss, 6.5%; capsular contracture, 6.5%	2 yr (range, 1–55 mo)	Anterior support	Appropriate safety profile
Woo et al[37]	75 (135) DTI/TE	Explantation, 3.8%; reoperation, 3.8%; for hematoma, 2.6%; seroma, 3.8%	10 mo (range, 2–36 mo)	Not specified	Appropriate safety profile
Bernini et al., 2015[38]	34 (39) DTI	Implant loss, 5.1%	25 mo (range, 16–40 mo)	TCPM wrap	Small to medium sized breasts; no smoking or prior XRT; insignificantly higher implant loss rate prepectoral cohort
Casella et al., 2015[39]	25 (25) TE	Skin/nipple necrosis, 4%; infection, 12%; hematoma, 4%; seroma, 0%; explantation, 0%	14 mo (range, 7–23 mo)	TCPM wrap	Small to medium sized breasts; no smoking or prior XRT
Reitsamer et al., 2014[40]	13 (22) DTI	Skin necrosis, 9%; hematoma, 4.5%; reoperation, 4.5%	6 mo (range, 1–12 mo)	Wrap	Well-tolerated
Berna et al., 2014[41]	19 (25) DTI	Implant loss, 12%; seroma, 8%; infection, 4%	14 mo	Wrap	>1 cm

TE, tissue expander; DTI, direct to implant; ADM, acellular dermal matrix; PP, prepectoral; BMI, body mass index; XRT, radiation therapy; SSI, surgical-site infection; IMF, inframammary fold; TCPM, titanium-coated polypropylene mesh.

contracture rates or may simply provide points of egress for serous fluid and increase the rate of biointegration.[42] Incision location may also have an impact on wound healing outcomes, as mastectomy skin flaps are thinner centrally than they are at the inframammary fold. It has not been demonstrated yet whether differences in technique impact the complication rate of prepectoral breast reconstruction, but they are useful points to consider while designing the operation.

Red breast syndrome, an asymptomatic redness of the mastectomy skin associated with acellular dermal matrix, has been attributed to preservatives, donor DNA, bacterial endotoxins, and biofilm. As prepectoral breast reconstruction increases the surface area of acellular dermal matrix to patient skin interface, it was anticipated that cases of red breast syndrome in this patient population would increase. Currently, there are no studies describing red breast syndrome in prepectoral breast reconstruction, potentially because of its now lower incidence in acellular dermal matrix–assisted breast reconstruction as a whole (1.7 to 14 percent) with improved technique and technology.[44]

ALGORITHMS TO GUIDE PREPECTORAL BREAST RECONSTRUCTION

Current algorithms use preoperative and intraoperative clinical factors to determine whether a patient is a candidate for prepectoral implant-based reconstruction. Algorithms for studies from 2014 to 2016 described the appropriate candidate as a patient with small to moderate breast size; with a body mass index less than 30 kg/m^2; and without a history of diabetes, nicotine use, or radiation therapy.[31,32,38–41] Intraoperative evaluation included mastectomy skin flap thickness greater than 1 cm. More recent studies focus on intraoperative fluorescence angiography and the absence of visualized dermis as a determining factor for immediate prepectoral reconstruction versus delayed reconstruction or a transition to partially submuscular reconstruction.[45,46] Current algorithms maintain that preoperative smoking, body mass index greater than 30 kg/m^2, and preoperative radiation therapy are contraindications to immediate prepectoral breast reconstruction.[46,47]

Early reconstructive algorithms excluded patients with planned radiation therapy from prepectoral implant placement because of concerns for skin dehiscence without muscle support. However, more recent data suggest that placement

of the implant or expander over the pectoralis major muscle avoids implant contracture by the fibrotic irradiated pectoralis major muscle, producing a more appropriate contour without the feared increase in skin dehiscence. Upper pole muscular fibrosis was implicated as a major cause for migration of the inframammary fold in addition to preventing adequate breast pocket release when capsulotomies are indicated.[27] The results are mixed when evaluating the overall safety profile of prepectoral reconstruction and adjuvant radiation therapy. Two patient series, one with 62 breasts reconstructed and another with 113 prepectoral breast reconstructions, showed no increase in acute perioperative complications because of chemotherapy or radiation therapy.[23,24] A separate study with a 56-breast irradiated cohort compared to 370 nonirradiated prepectoral breast reconstructions showed no difference in acute perioperative outcomes.[19] Another smaller series of 93 breast reconstructions showed an insignificantly higher rate of infection after radiation therapy,[17] whereas a series of 165 breast reconstruction showed more skin necrosis and a higher overall complication rate associated with radiation therapy.[22]

Studies on direct-to-implant and staged expander-to-implant breast reconstruction report that both skin-sparing and nipple-sparing mastectomies are options for prepectoral pocket positioning of an implant or expander.[48] Patient series of 113 and 305 patients, respectively,[18,23] and 16 studies with smaller patient subsets demonstrated direct-to-prepectoral placement of gel implants to be a safe and reproducible technique at the time of mastectomy.[13,16,21,23,25,26,28,30,32–34,36–38,40,41] Revision rates were similar to those of staged expander-to-implant surgery, with 2-year rates at 20 percent. Data on immediate device placement in obese patients are mixed, with general recommendations to avoid or delay prepectoral reconstruction in patients with a body mass index greater than 30 kg/m^2. However, there is a growing number of studies using skin-reduction techniques; thus, this mode of reconstruction is offered to obese patients.[15,25,30]

With prepectoral reconstruction after skin-sparing mastectomy and skin reduction techniques for larger skin envelopes, algorithms for selecting candidates for nipple reconstruction will need to be developed. Nipple projection decreases by a varied amount in all patients. However, patients with thin dermis after extensive expansion or irradiated skin will often have significant loss of projection.[49] Studies comparing reconstructed nipple projection between autologous and implant-based breast reconstruction have varying results.[50] No current literature has compared reconstructed nipple projection between subpectoral to prepectoral breast reconstruction. It should be noted that wound dehiscence or partial skin flap loss after nipple reconstruction would potentially have a higher rate of implant exposure or infection without the protection of vascularized pectoralis covering the implant in prepectoral cases.

FUNCTIONAL OUTCOMES, POSTOPERATIVE PAIN, AND RECOVERY

The acute postoperative patient experience and pain control constitute another important aspect of postoperative recovery (Table 2). Prepectoral breast reconstruction is a patient-driven technique where patients want to ensure that this option is available to them when assembling their multiservice care team. With improving access to medical information, patients are availed of firsthand accounts of the patient experience during staged submuscular or partially submuscular reconstruction and hope to avoid the pain and animation deformity associated with breast implants.

Six series describing early outcomes after prepectoral breast reconstruction also include outcomes to describe patient function and/or postoperative pain during recovery with favorable results when compared to partially submuscular patient cohorts.[20,21,35,43–51] The studies were similarly powered, with 24 to 39 patients per study undergoing prepectoral breast reconstruction. Five of the six patient series reported significantly lower patient-reported pain scores in the prepectoral groups than partially submuscular comparison cohorts. The BREAST-Q was used in three studies as a postoperative index of satisfaction, with no differences reported between groups.[21,51,52] Likewise, the Rand 36-Item Health Score and Pain Inventory surveys both scored in favor of the prepectoral approach being less painful.[51,52] Two studies evaluated upper extremity and shoulder function, with more rapid recovery and less upper extremity morbidity than partially submuscular patients.[43,52] One patient series demonstrated fewer morphine equivalents administered after prepectoral reconstruction than in a partially submuscular implant placement cohort.[43] Fewer postoperative visits and more rapid expansion have been demonstrated with prepectoral breast reconstruction when compared with subpectoral techniques, which can improve patient satisfaction with recovery.[13,26] Considered together, these

Table 2. Functional Recovery and Pain Outcomes

Reference	No. of Patients (No. of Breasts)	Recovery Outcomes	Mean Follow-Up	ADM Technique	Findings
Schaeffer et al., 2019[43]	24 (45) TE	Lower pain scores; lower morphine equivalents; earlier return of function	6 mo	Anterior support	Decreased pain and earlier functional recovery compared to case-matched partially submuscular cohort
Wormer et al., 2018[20]	32 (60) TE	Fewer days to expansion; fewer expansion visits	281 ± 119 days	ADM wrap	Fewer postoperative resources to achieve expansion
Cattelani et al., 2018[52]	39 (46)	LOS analgesia, pain inventory, upper limb function, BREAST-Q	12 mo (range, 4–22 mo)	ADM wrap	All pain and function assessments favored prepectoral group
Walia et al., 2017[51]	26 Patients	Pain scores, Rand 36 Physical Health Scores, BREAST-Q	30 days	ADM wrap	Pain scores, Rand 36 lower, BREAST-Q no difference
Baker et al., 2017[21]	28 patients	Pain scores, BREAST-Q; LOS	9.2 mo	Anterior support	No difference in pain scores or satisfaction on BREAST-Q
Zhu et al., 2015[35]	29 (50) TE	More rapid expansion; fewer expansion visits; lower pain rating	6 mo	IMF cuff or no ADM	Decreased pain when compared to partial submuscular cohort

TE, tissue expander; ADM, acellular dermal matrix; IMF, inframammary fold; LOS, length of stay.

studies suggest that the immediate postoperative period following prepectoral breast reconstruction can be characterized as having less pain and earlier functional recovery but with equivalent satisfaction ratings to partially submuscular breast reconstruction.

AESTHETIC OUTCOMES

As patient follow-up from prepectoral breast reconstruction grows, more meaningful aesthetic data are being captured (Table 3).[13,17–19,21,23,25–29,32,34,36,38,45,53] Aesthetic dissatisfaction leads to revision surgery and increased anesthetic exposure; therefore, appropriate patient selection and successful achievement of acceptable aesthetics are a secondary safety and quality measure for prepectoral breast reconstruction.

Another barrier to adopting the technique of prepectoral breast reconstruction includes concerns over capsular contracture. Submuscular implants have less capsular contracture,[54] whereas results have varied for textured implants in lowering rates of capsular contracture.[55,56] With smooth implants being preferred to textured implants to avoid concerns over anaplastic large cell lymphoma,[57] the placement of smooth implants above the muscle could result in greater capsular contracture rates with prepectoral breast reconstruction.

The use of larger sheets of acellular dermal matrix in prepectoral breast reconstruction may help mitigate the inflammatory forces contributing to capsular contracture. As such, acellular dermal matrix serves as a relatively inert spacer believed to result in less capsular contracture.[58,59] In prepectoral breast reconstruction, larger sheets of acellular dermal matrix are used to resurface the entire skin envelope, providing protection to the inflammatory process that would lead to capsular contracture in a subset of patients. Pooled analysis of 16 studies showed a 0.6 percent incidence, which is significantly lower than the 3 to 25 percent range previously reported after reconstruction.[60]

Fourteen series were reviewed that measure capsular contracture rates after prepectoral breast reconstruction.[13,17–19,21,23,25–29,32,34,36,38,45,53] Capsular contracture was specified as Baker grades III and IV in all studies but one, where grade II capsular contracture rates were reported.[28] Of the studies with less than 2 years of patient follow-up, grade III and IV capsular contracture rates varied from 0 to 5 percent,[13,17–19,21,23,25–27,45] with one series reporting 46 percent grade II capsular contracture rates.[28] In studies with 2 to 5 years of follow-up, grade III and IV capsular contracture rates were higher, varying from 6.5 to 14.5 percent.[28,34,36,38,53]

Two studies described the impact of radiation therapy exclusively on capsular contracture rates for prepectoral patients. A series of 107 patients undergoing prepectoral reconstructions exhibited a 14.5 percent capsular contracture rate at 5 years overall, but the subset of these patients requiring radiation therapy exhibited a 41.7 percent capsular contracture rate.[53] A second series of 84 prepectoral reconstructions demonstrated a 1.2 percent capsular contracture rate at an average of 1-year follow-up but a 14.2 percent capsular contracture rate among the irradiated breasts.[27]

Table 3. Aesthetic Outcomes

Reference	No. of Patients (No. of Breasts)	Aesthetic Outcomes	Mean Follow-Up	ADM Technique	Findings
Viezel-Mathieu et al., 2019[13]	39 (60)	Capsular contracture; rippling, 12%	163.7 days	Anterior support	$5500 decrease in cost for prepectoral DTI compared to staged subpectoral
Jones and Antony, 2018[18]	234 (357)	Capsular contracture, 0.4%; non-XRT, contour differences requiring FG, 30%; mild rippling, 7%	15.1 mo (up to 3.8 yr)	Anterior support	Upper pole contour differences responsive to fat grafting
Sinnott et al., 2018[19]	274 (426); 45 (56) XRT	Capsular contracture, 5.2%; rippling, 0.5%	19 ± 16.9 mo	Superior pole with dermal flap	16% contracture with XRT, 52% subpectoral contracture with radiation therapy
Elswick et al., 2018[17]	54 (93) TE	Contour difference requiring fat grafting, 83%; additional ADM, 15%; capsular contracture, 1.9%	19 mo	Varied	Similar revision rates to partially subpectoral after radiation therapy
Sigalove et al., 2017[45]	207 (353)	No capsular contracture	6–26 mo	Anterior support	No capsular contracture; excluded diabetes, >BMI; radiation therapy
Sbitany et al., 2017[27]	51 (84) TE	Capsular contracture; overall, 1.2%; after radiation therapy, 14.2%	12.5 mo (range, 7–28 mo)	Anterior support and IMF cuff	No difference when compared to ADM-assisted cohort
Jones et al., 2017[25]	50 (73) DTI	No capsular contracture; upper pole contour difference, 48%; rippling, 12.3%,	48 wk (range, 13–103 wk)	Anterior support	No animation deformity
Paydar et al., 2017[26]	10 (18) DTI/ TE 16 (2)	No capsular contracture; upper pole contour/ rippling, 17%	14.4 mo	Anterior support; fenestrated	No contracture but significant rippling/ contour differences
Baker et al., 2017[21]	28 patients	Rippling, 54%	9.2 mo	Anterior support	Significantly more rippling than submuscular cohort, 11% ($p = 0.02$)
Highton et al., 2017[23]	106 (166)	4% fat grafted for rippling; no grade III/IV capsular contracture	485 days (range, 81–1446 days)	Anterior support	Acceptable capsular contracture rates and rippling
Onesti et al., 2017[28]	52 (64)	Grade II capsular contracture, 46%	Up to 2 yr	ADM wrap	Significant rate of grade II capsular contracture
Salibian et al., 2016[29]	155 (250); no ADM	Grade III capsular contracture, 4%; grade IV capsular contracture, 3.6%; mild rippling, 3%; aesthetic assessment, 54% very good, 31% good, 9% fair, 6% fair	55 mo	No ADM	85% favorable aesthetic rating; minimal capsular contracture; minimal rippling
Kobraei et al., 2016[32]	13 (23) DTI	Rippling, 7%	6–18 mo	Vicryl mesh	Expected rates of rippling
Downs et al., 2016[34]	45 (79) DTI	Rippling, 35.1%; contracture, 10.1%	12.7–33.5 mo	ADM wrap	Significant rates of rippling
Becker et al., 2015[36]	31 (62) DTI	Capsular contracture, 6.5%	Mean, 2 yr	Anterior support	Acceptable capsular contracture rates
Bernini et al., 2015[38]	34 (39) DTI	Visible implant, 6%; palpable implant, 9%; rippling, 9%	Median, 25 mo	Polypropylene mesh	Small to medium sized breasts; no prior smoking or XRT
Benediktsson and Perbeck, 2006[53]	107	Capsular contracture, 14.5% (non-XRT)	5 yr	None	Irradiated, 41.7%; capsular contracture

ADM, acellular dermal matrix; DTI, direct to implant; XRT, radiation therapy; FG, fat grafting; BMI, body mass index; TE, tissue expander.

In an evaluation of 426 prepectoral breast reconstructions, a comparison of capsular contracture rates following prepectoral and subpectoral reconstruction was performed controlling for radiation exposure.[19] There was an overall 5.2 percent grade III and IV capsular contracture rate for the study cohort. An irradiated subset of 56 prepectoral breast reconstructions demonstrated a 16 percent capsular contracture rate, with a mean 19 months of follow-up, demonstrating a modest yet clinically relevant increase in capsular contracture with radiation exposure (Fig. 1). However, in the subpectoral comparison cohort, 52 percent of breasts that were irradiated

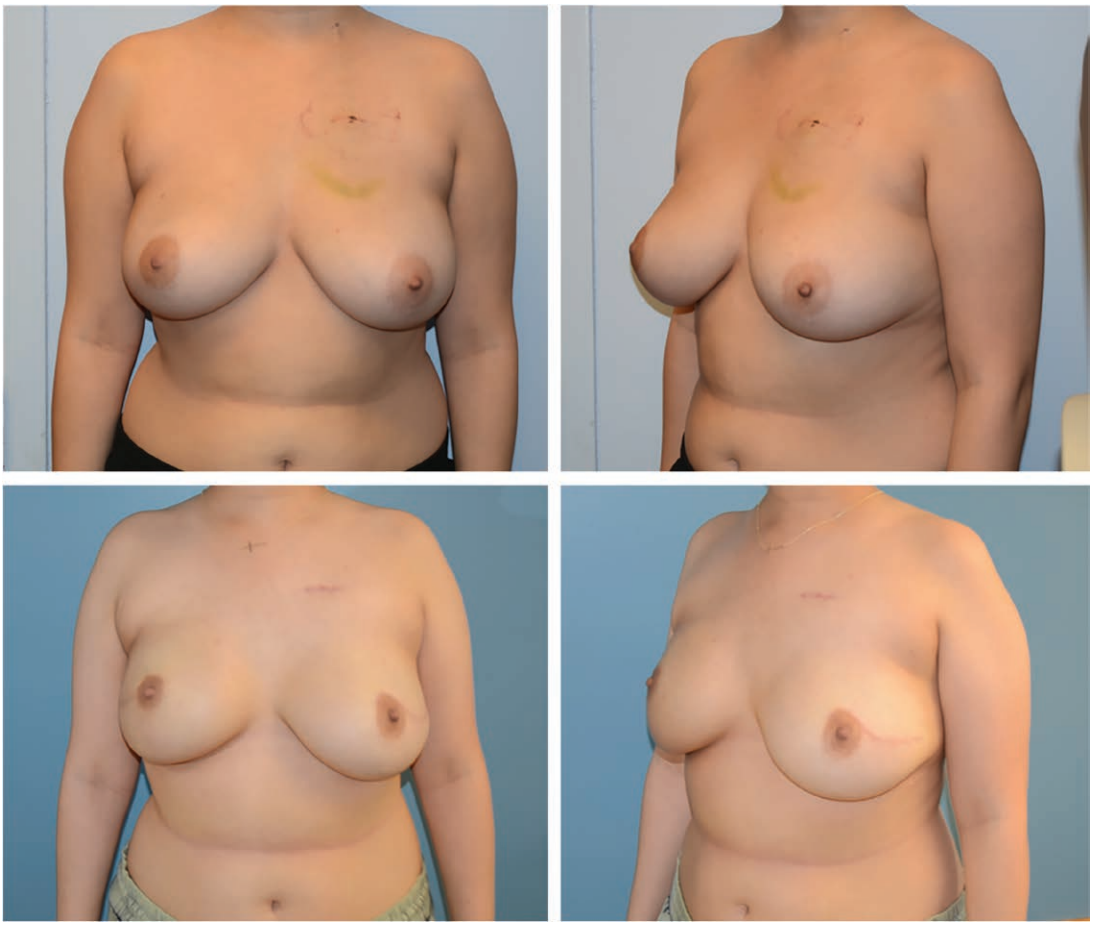

Fig. 1. Preoperative and postoperative views of staged bilateral prepectoral breast reconstruction with round smooth gel implants and fat grafting in the setting of right whole-breast radiation therapy. (*Above*) Preoperative views before bilateral nipple-sparing mastectomies. (*Below*) One-year postoperative views following bilateral staged expander to round smooth cohesive 685-cc gel implants and fat grafting. The right breast received 50 Gy of whole-breast radiation between surgical stages and completed radiation therapy 20 months before photographs were taken. The right breast exhibits Baker grade III capsular contracture, whereas the left breast implant is soft. Both breasts are functionally asymptomatic, and the patient can achieve symmetry in clothing.

exhibited grade III and IV capsular contracture, showing a statistically significant increase above all other groups, suggesting better performance with prepectoral implant placement for adjuvant radiation therapy.

The absence of the pectoralis major muscle over the upper pole of the breast leaves the upper mastectomy skin flap and acellular dermal matrix as the only form of soft-tissue coverage after immediate expander or implant placement. This absence of soft-tissue camouflage can contribute to unwanted rippling and implant palpability (Figs. 2 and 3). Despite concerns that thinner patients are likely at greater risk for implant palpability and rippling of the upper pole, published algorithms focus on avoidance of higher body mass indices to avoid the risks of skin dehiscence and fluid collections. Fat grafting and the application of additional acellular dermal matrix are useful adjuncts to provide more soft-tissue thickness to minimize implant rippling and palpability in these cases (Fig. 4) To date, research has not stratified implant palpability or rippling to preoperative body mass index to confirm this clinical observation.[46,47]

Patient selection for prepectoral reconstruction is based on skin flap viability and thickness, among other criteria. Thicker skin flaps will have less implant palpability and rippling and will likely need fewer revision operations to achieve an aesthetically acceptable result. Thinner skin flaps also carry a greater risk of delayed wound healing and possible soft-tissue contracture. In contrast to breast augmentation, implant-based breast

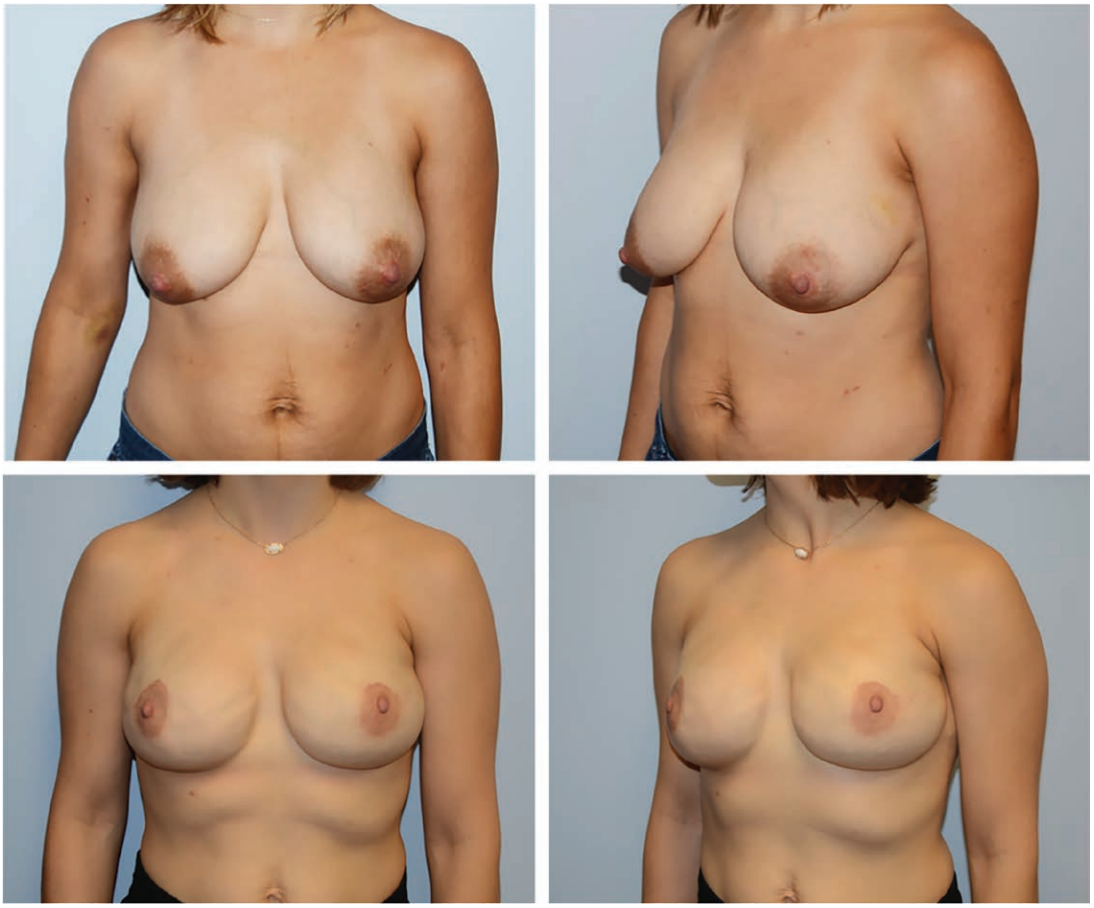

Fig. 2. Preoperative and postoperative views of bilateral breast reconstruction with anatomical textured cohesive gel implants. (*Above*) Preoperative views before bilateral nipple-sparing mastectomies. (*Below*) Two-year postoperative views of bilateral textured anatomical, low-height, moderate plus profile 330-cc gel implants. The patient had limited fat grafting donor sites and exhibits rippling bilaterally.

reconstruction occurs in a clinical setting where the skin and subcutaneous tissues have to recover from a mastectomy. The skin becomes edematous and significant serous fluid production occurs during this process. Thinner mastectomy skin flaps result in greater insult to the subdermal plexus and create an environment where the incorporated acellular dermal matrix (or capsule in cases without acellular dermal matrix) are closely approximated to the dermis without sufficient intervening adipose tissue. The result can be a reconstructed breast that is firm to palpation; however, it is difficult to discern whether the firmness is the result of a contracted capsule versus a soft-tissue envelope that has healed by contraction.

Visible rippling of breast implants was reported as an outcome variable in 11 studies, with a range of 0.5 to 17 percent in the majority of patient series reviewed,[13,18,19,25,26,29,32,34,38] with outlier rates at 35 percent[34] and 54 percent[21] reported in two additional series. Three of these outcome studies statistically compared rippling rates to partially submuscular cohorts, with two studies finding prepectoral implant rippling significantly increased over the partially submuscular cohort[21,26] and one study not finding a significant difference.[27] Other variables reported that were related to soft-tissue camouflage included contour differences reported at rates of 17, 30, 48, and 83 percent in four patient series[17,18,25,26] and visible and palpable implants reported in one series at 6 percent and 9 percent, respectively.[38]

Follow-up ranged from 6 months to greater than 4 years for these outcome variables, without a discernible pattern in variation of reported rippling, contour, or palpability rates over time.[17,18,23] The proportion of patients undergoing fat grafting in each study differed based on physician preference, with 4 to 83 percent of patients among the series undergoing fat grafting for rippling or upper pole contour differences. In one patient

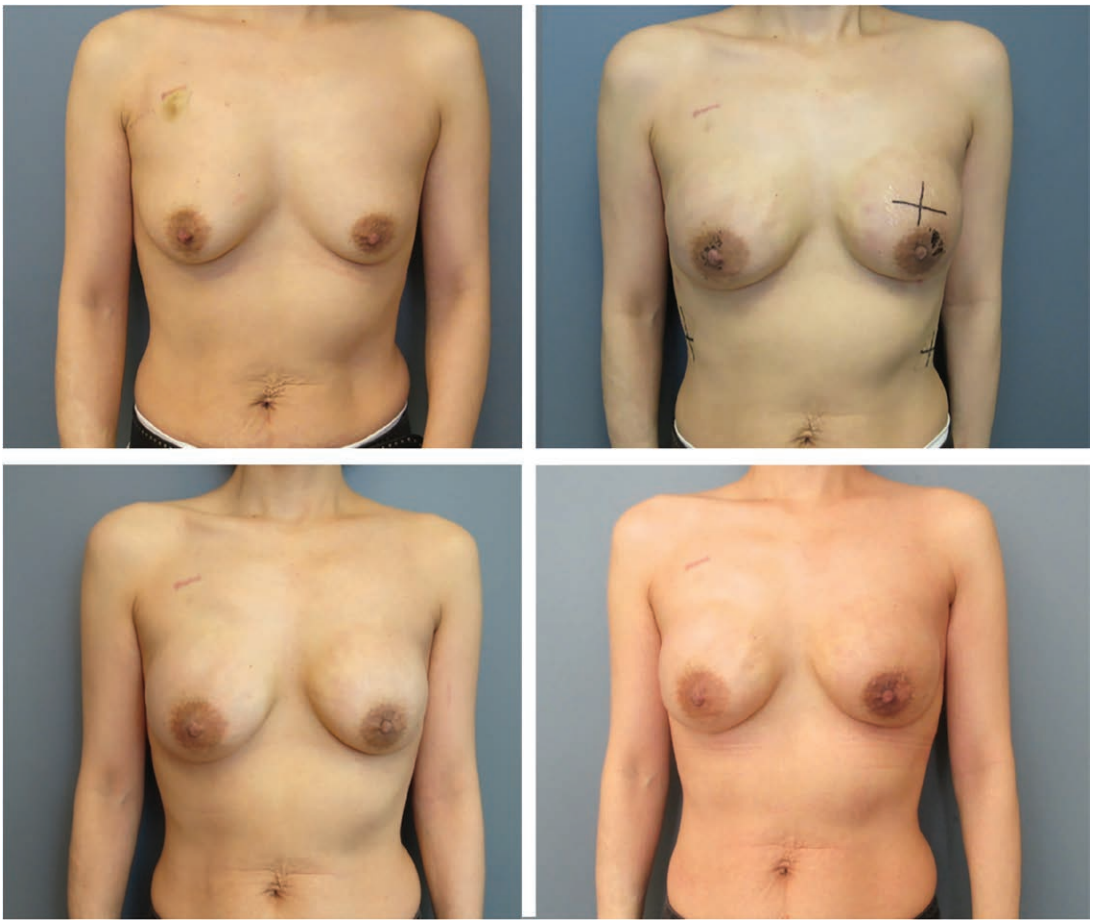

Fig. 3. A 39-year-old woman with left breast cancer who underwent bilateral nipple-sparing mastectomies and prepectoral direct-to-implant reconstruction with acellular dermal matrix anterior coverage and 250-cc moderate plus profile implants. She underwent postoperative radiation therapy on the left side and is shown shortly afterward with a slightly larger but soft left breast. She is shown 1.5 years after completion of left breast irradiation with a soft symmetric breast. She has some rippling in the upper pole on the left that could be addressed with autologous fat grafting.

series, additional acellular dermal matrix was added to improve upper pole contour differences in 15 percent of patients without altering the surgical safety profile.[38] Other ways to avoid rippling include thick skin flaps, underfilling the tissue expander in two-stage reconstructions, using an implant filled to capacity volume, and the use of more cohesive form-stable implants (Fig. 2). Cross-linking of silicone molecules allow the gel implant to maintain its shape against deforming forces but to remain soft while limiting rippling. Saline implants generally exhibit more rippling than gel implants; however, incorporation of flow-directing baffles into the saline implant is a mechanism to minimize rippling for those patients who prefer a saline-filled device.[61]

The majority of prepectoral reconstructions performed across these reports were anterior support. However, two articles described a complete acellular dermal matrix wrap of the device (0 to 10 percent grade III/IV capsules, rippling measured in only one series at 35 percent)[28,34]; and there was one report with fenestrated acellular dermal matrix sheet (0 percent capsular contracture, 17 percent rippling),[26] one report without acellular dermal matrix use at all (7.6 percent grade III/IV capsular contracture and 3.4 percent rippling),[29] and two synthetic mesh patient series (7 to 9 percent rippling and implant palpability without capsular contracture reporting).[32,38] No discernible differences in aesthetic outcome were demonstrated from differences in mesh technique.

Animation deformity is obviated by prepectoral placement of implants. The best measure of this phenomenon is a patient-controlled report

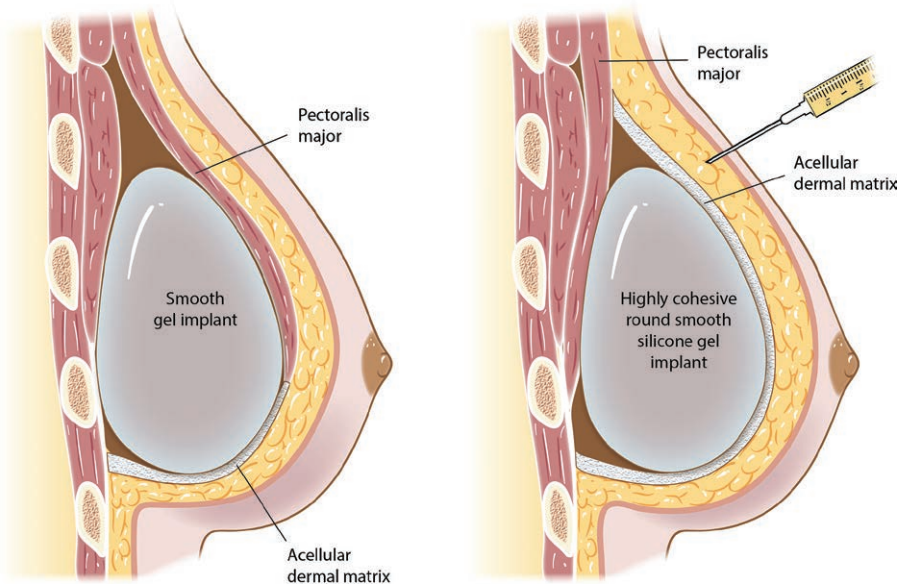

Fig. 4. Techniques to improve aesthetic outcomes in prepectoral breast reconstruction. (*Left*) Illustration demonstrating partially submuscular acellular dermal matrix–assisted breast reconstruction. (*Right*) Illustration demonstrating prepectoral breast reconstruction. Acellular dermal matrix is used for anterior soft-tissue support. Fat grafting has been used to duplicate the soft-tissue thickness that would have been afforded by the pectoralis major muscle but without the potential for animation deformity. Highly cohesive silicone gel implants can be used to further decrease rippling.

where a pocket change of subpectoral to prepectoral implant placement was performed as corrective surgery to remedy animation deformity in 102 breast reconstructions.[47] There was a complete corrective response, with no animation deformity and an overall 3.9 percent surgical complication rate in this series.

As longer follow-up is being reported, aesthetic ratings have been applied to prepectoral breast outcomes. In a patient series with 4-year follow-up of 25 reconstructed breasts, 85 percent of breast reconstructions were rated as very good or good, with 9 percent fair and 6 percent poor.[29] More quantitative and longer term studies will be needed to measure aesthetics and satisfaction. As an aggregate, these reports suggest that rippling but not capsular contracture is increased with prepectoral placement of gel implants over partially submuscular placement.

APPLYING OUTCOME DATA

One of the goals in postmastectomy implant reconstruction is to provide appropriate aesthetic results while minimizing complications. Available evidence on actual steps to reduce complications in prepectoral implant reconstruction is limited; however, many of the established principles for optimizing outcomes after implant-based reconstruction apply.

Although presenting patients are not always without risk factors, attention to risk reduction in the preoperative setting is important. Standardized use of preoperative antibiotics, smoking cessation, glucose control, and timing of reconstruction can contribute to improved outcomes. In obese patients with significant macromastia, an option is always to delay prepectoral implant reconstruction to allow skin flaps to heal and ensure exact pocket control when placing the implant.[15,16,62] Intraoperative details such as appropriate surgical skin preparation, pocket irrigation, sterile and no-touch techniques, ensuring healthy skin flaps, pocket control, selecting the appropriate acellular dermal matrix, and not being overly aggressive with implant size or expansion will contribute to minimizing complications.[8,9,63]

Postoperatively, aggressive management of complications such as seromas and skin necrosis, and having a low threshold for reexploration, are especially important in prepectoral reconstruction. Failure will invariably lead to implant exposure and necessitate implant removal or latissimus dorsi or autologous addition. In the setting of implant removal, without having previously elevated the pectoralis muscle, replacing the implant

in the prepectoral space months later when everything has healed is also a reasonable option.

CONCLUSIONS

Acute perioperative outcomes after prepectoral breast reconstruction demonstrate an equivalent and acceptable safety profile when compared to partially submuscular acellular dermal matrix–assisted breast reconstruction. Recovery analysis shows that patients having undergone prepectoral breast reconstruction report less pain and earlier return of function than patients having undergone partially submuscular breast reconstruction. Capsular contracture rates are similar to partially submuscular implant-based breast reconstruction and increase with a history of radiation therapy. Rippling and contour differences are reported at higher rates than with partially submuscular breast reconstruction. Secondary fat grating and acellular dermal matrix techniques are performed to address rippling and contour differences at rates that vary dramatically between surgeons. The effectiveness of these secondary techniques at improving soft-tissue camouflage has not been studied. It is also not known whether all-cause or aesthetic indications for reoperation after prepectoral breast reconstruction significantly exceed that of partially submuscular breast reconstruction. It remains to be seen whether prepectoral placement of round smooth implants will constitute a significant challenge for management of upper pole aesthetics when compared to anatomical textured implants.

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