Review Article

Current status prepectoral and subpectoral breast reconstruction in the USA

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Abstract: Breast cancer remains the most commonly diagnosed cancer in women in the United States. In the setting of a mastectomy, implant-based reconstruction (IBR) remains the most common type of breast reconstruction performed. IBR is typically performed in two-stages (tissue expander – implant) or one stage [direct-to-implant (DTI)]. As a consequence of the limitations associated with submuscular placement of implants, prepectoral implant placement has been gaining more acceptance worldwide. The prepectoral plane eliminates the need for chest wall muscle dissection, disinsertion and manipulation avoiding the muscle related complications of the subpectoral approach such as increased pain, spasm and animation deformity. In addition, prepectoral placement shortens the recovery time and provides greater control of breast shape and contour. With the latest generation form-stable silicone implants coupled with the wide use and acceptance of acellular dermal matrices (ADMs) and other meshes to support the implant, this technique is becoming the mainstay of implant-based reconstruction, under these circumstances the subpectoral technique will continue to be the benchmark to which the prepectoral technique will be compared to. The authors sought to review the literature emanating from North America that pertains to this topic and provide an up-to-date assessment of the current practices of the prepectoral and submuscular technique.

Keywords: Breast reconstruction; prepectoral breast reconstruction; subpectoral breast reconstruction

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Introduction

Breast cancer remains the most commonly diagnosed cancer in women in the USA (1). It is estimated that in 2023, invasive breast cancer will be diagnosed in approximately 298,000 women with an additional 55,720 cases of ductal carcinoma in situ. In the setting of a mastectomy, implant-based reconstruction (IBR) remains the most common type of breast reconstruction performed according to data from the American Society of Plastic Surgeons (2). Although prepectoral placement of devices has become increasing accepted and now performed by the majority of plastic surgeons, there are a number of plastic surgeons still placing implants under the pectoralis major muscle.

Since the early 1970s, prosthetic breast reconstruction has remained a mainstay treatment for women following mastectomy. Its evolution over the past 50 years has been remarkable and resulted in technical modifications that have resulted in improved outcomes. During the initial years when radical mastectomy was common, subcutaneous placement of implants resulted in high rates of capsular contracture and reconstructive failure (3,4). With the transition to modified radical mastectomy, devices were placed under the pectoralis major muscle with complete muscle coverage resulting in fewer failures but with

compromised aesthetics and high rates of malposition. With the introduction of acellular dermal matrices (ADMs) in the 2000s, reconstructive techniques evolved once again towards partial muscle coverage resulting in improved aesthetic outcomes and less capsular contracture (5-7).

With the acceptance of nipple sparing mastectomy (NSM) and optimized mastectomy techniques, prepectoral placement of devices with or without ADM has become commonplace. This has certainly been the evolution in the USA; however, the adoption of these prosthetic reconstruction techniques from a global perspective has varied and there remain differences in technique throughout the world.

IBR is typically performed in two-stages (tissue expander – implant) or one stage [direct-to-implant (DTI)]. With both techniques, the placement of the devices varies between total submuscular, partial submuscular (with or without ADM or mesh) and prepectoral reconstruction (with or without ADM or mesh). The indications, safety and efficacy of the prepectoral technique and subpectoral techniques has been extensively studied (8-11). As a consequence of the limitations associated with submuscular placement of prosthetic devices, the pendulum has been shifting from subpectoral to prepectoral implant placement. The prepectoral plane eliminates the need for chest wall muscle dissection, disinsertion and manipulation avoiding the muscle related complications of the subpectoral approach such as increased pain, spasm and animation deformity. In addition, prepectoral placement shortens the recovery time and provides greater control of breast shape and contour. With the latest generation form-stable silicone implants coupled with the wide use and acceptance of ADMs and other meshes to support the implant, the rates of capsular contracture between the two types of technique have become more comparable.

This supplement will focus on the status of the prepectoral and subpectoral implant-based techniques in the USA. PubMed database was searched using search terms: implant-based breast reconstruction, prepectoral, subpectoral, direct-to-implant breast reconstruction, tissue expander breast reconstruction. The authors sought to review the literature specifically emanating from North America that pertains to this topic and provide an up-to-date assessment of the current practices of the prepectoral and submuscular technique. A total of 41 papers were reviewed. The manuscript is divided into different topics to help guide the reader through important aspects of the techniques.

Tissue expander and implant considerations

Perhaps one of the most significant differences between the USA and much of the world is the lack of implant diversity in this country. Beginning in 1992, plastic surgeons were restricted to the use of smooth or textured surface saline implants following the moratorium on silicone gel breast implants. In 2005, the moratorium was lifted and smooth round silicone gel breast implants became available for wide spread use; however, the use of textured surface devices was restricted except under study protocols. In 2012, textured surface devices became available for all purposes and by 2013, all three implant and tissue expander manufacturers in the USA were distributing them. It was during this time that anaplastic large cell lymphoma (ALCL) concerns began to manifest and in 2019, the Food and Drug Administration requested that Allergan discontinue distribution of all macrosurface textured implants because of the association with ALCL. Although other implant manufacturers were still able to distribute textured surface devices, the vast majority of plastic surgeons in the USA no longer use them.

As of 2023, the vast majority of plastic surgeons in the USA use smooth round silicone gel implants and a minority use saline filled implants. This is in contrast to many countries where textured implants including polyurethane implants remain in use. Thus, when analyzing the data for the highlighted factors regarding subpectoral and prepectoral prosthetic breast reconstruction, it should be remembered that the published studies were based on the use of smooth surface, round silicone gel breast implants. Tissue expanders remained textured until 2019 with the transition to smooth tissue expanders beginning at that time.

Complications (*Table 1*)

Complications following prosthetic breast reconstruction are well known. Periprosthetic infection, hematoma, seroma formation, mastectomy skin flap necrosis, implant loss and capsular contracture are common complications following these surgeries. As the submuscular or partial submuscular methods are the benchmark for comparison in IBR, much has been written in comparing the subpectoral and prepectoral implant-based techniques (*Table 1*).

In an early study comparing pre and subpectoral reconstruction, Nahabedian and Cocilovo analyzed the data of 89 patients undergoing immediate implant-based reconstruction (one or two-stage) using either a prepectoral

Table 1 Complication

Reference	No. of patients (breasts)	Prepectoral	Subpectoral	Surgical technique	Results
Nahabedian and Cocilovo, 2017 (12)	89 patients	39 patients	50 patients	Immediate TE or DTI reconstruction with prepectoral (full ADM coverage) or submuscular (dual-plane with ADM)	Patients having at least 1 adverse event was 20.5% in the prepectoral and 22% in the partial subpectoral cohorts
Sbitany, 2017 (8)	270 breasts	84 breasts (total anterior coverage with ADM)	186 breasts (dual plane with ADM sling)	Immediate TE reconstruction in NSM	No statistically significant differences in infection, hematoma, seroma or explantation rates
Momeni, 2019 (13)	80 patients (138 breasts)	69 breasts	69 breasts	Immediate TE reconstruction with ADM	No difference in postoperative complication rate
Avila, 2020 (14)	228 (405 breasts)	203 breasts	202 breasts	Immediate DTI (53.6%), or TE reconstruction with ADM	Increased flap necrosis in the subpectoral group
Gabriel, 2020 (15)	133 (257 breasts)	129 breasts	128 breasts	Immediate 2 stage breast reconstruction	Increased seroma, postsurgical site infection, capsular contracture, any complication in dual plane group (subpectoral)
Bekisz, 2022 (16)	510 (826 breasts)	76 breasts	Total submuscular: 392 breasts; dual plane: 358 breasts	Immediate 2 stage or single stage breast reconstruction using prepectoral, dual-plane or total submuscular technique	Overall reconstructive complication rates were comparable. Compared with total submuscular, the dual-plane cohort was more likely to develop a major infection or require explantation, whereas the prepectoral group had significantly higher rates dehiscence, seroma, and explantation
Asaad, 2023 (17)	481 patients (694 breasts)	573 breasts	121 breasts	Two stage reconstruction prepectoral or submuscular (dual-plane with ADM)	Similar scores for satisfaction, psychosocial and sexual well-being on Breast-Q
Nelson, 2022 (23)	921 patients unmatched; 238 matched cohort	119 patients	119 patients	Immediate TE reconstruction; specifically, 90-day postoperative clinical and patient reported outcomes	Higher rates of seroma in the prepectoral group
Haddock, 2021 (27)	260 patients unmatched; 204 matched; all bilateral cases	102 patients	102 patients (dual plane)	Immediate TE reconstruction	Prepectoral tissue expander placement permitted greater intraoperative filling of TE, with no increase in adverse outcomes compared to partial subpectoral placement

TE, tissue expander; DTI, direct-to-implant; ADM, acellular dermal matrix; NSM, nipple sparing mastectomy.

(total ADM coverage) or a submuscular dual-plane (with ADM) approach (12). They demonstrated that at least 1 adverse event was noted in 20.5% in the prepectoral and 22% in the partial subpectoral cohorts. Surgical-site infection (SSI) was noted in 8.1% of the prepectoral cohort and in 4.8% of the partial subpectoral cohort. Seroma formation was noted in 4.8% of prepectoral and in 2.4% of partial subpectoral reconstructions. Interestingly, hematoma was more common in the partial subpectoral cohort (4.8% *vs.* 0) and was most likely due to the additional

manipulation of the pectoralis major muscle. The incidence of explantation was 6.5% for the prepectoral and 7.2% for the partial subpectoral.

In two similar studies by Sbitany *et al.* and Momeni *et al.*, Sbitany *et al.* reviewed patients undergoing a two-stage tissue expander – implant reconstruction following nipple-sparing mastectomy and compared outcomes following submuscular dual-plane reconstruction with ADM (186 breasts) to the prepectoral reconstruction with ADM (84 breasts) (8). The patients were documented in a prospectively maintained breast reconstruction database The analysis revealed no difference in total complication rate between the two groups and no differences in any of the individual complications measured that included infection, seroma and explantation. In the second study, Momeni *et al.* analyzed the data of 80 patients (138 breasts) who underwent 2 stage reconstruction using a submuscular or a prepectoral reconstruction technique. No difference in postoperative complication rate and mastectomy skin necrosis rate was noted. Other major complications such, infection, and loss of reconstruction did not differ between the two cohorts and did not generate statistical significance (13).

Thirty day or short-term complication rates have also been compared. Avila *et al.* analyzed the data of 228 patients (405 breasts) who underwent NSM and demonstrated that prepectoral reconstruction is associated with similar overall 30-day postoperative complications and reoperations compared to traditional subpectoral implants. The authors noted however that prepectoral reconstruction was associated with significantly decreased ischemic complications that included less mastectomy skin flap necrosis and less necrosis of the nipple-areola complex (14).

The role of obesity in the setting of prepectoral and subpectoral techniques has also been examined. In a comparison between dual plane *vs.* prepectoral reconstruction in the setting of two-stage implant-based breast reconstruction, Gabriel *et al.* demonstrated that complication rates in obese patients were significantly higher in dual plane reconstruction when compared to prepectoral. Dual plane reconstruction, among other findings, was an independent predictor of complication in multivariate logistic regression. Specifically, seroma (13.3% *vs.* 3.1%), SSI (9.4% *vs.* 2.3%), capsular contracture (7.0% *vs.* 0.8%), and any complication were higher in dual plane reconstruction patients (15).

Comparisons of total versus partial muscle coverage to prepectoral placement of devices has been studied. Bekisz *et al.* retrospectively compared the outcomes of patients who underwent immediate one or two stage reconstruction using one of the three techniques that included total submuscular, dual-plane or prepectoral reconstruction. A total of 826 breasts were analyzed. The majority of patients underwent a total submuscular reconstruction (47.5%), followed by dual-plane (43.3 %) and prepectoral (9.2%). Overall reconstructive complication rates were comparable among the cohorts. Compared with those undergoing total submuscular reconstruction, the dual-plane cohort was more likely to develop a major infection or require explantation, whereas the prepectoral group had significantly higher rates of isolated dehiscence, seroma formation, and explantation (16).

The role of patient co-morbidities has also been analyzed with subpectoral and prepectoral reconstruction. In a retrospective study of 694 patients, Asaad *et al.* demonstrated that the overall complication rate was very similar at 29.3% in the prepectoral and 28.9% in the subpectoral group (P=0.887). Rates of individual complications were also similar between the two cohorts. A multiple frailty model showed that device location was not associated with overall complications, infection, major complications, or device explantation. The authors were also able to demonstrate that body mass index (BMI), tobacco use, hypertension, and preoperative chemotherapy were found to be independent predictors of major complications, while BMI and preoperative chemotherapy were independent predictors of device explantation (17).

Radiation therapy (*Table 2*)

It is well established that post-mastectomy radiation reduces locoregional recurrence risk and improves survival in patients with locally advanced breast cancer (18). It is also well understood that post-mastectomy radiation therapy has a negative impact in implant-based breast reconstruction with more capsular contracture, infection, implant failure (19). It has been suggested that placing the prosthesis in a submuscular plane may provide the implant with vascularized coverage which could in turn counteract the effects of the radiation on the device. With the popularization of the prepectoral technique, the protective role of the pectoralis major after radiation has come into question.

In a study comparing two stage prepectoral and submuscular IBR, Sbitany *et al.* specifically compared the incidence of complications following radiation therapy to the TE. In their cohort of patients (31 submuscular and

Table 2 Radiation therapy

Reference	Number of patients (breasts)	Prepectoral	Subpectoral	Surgical technique	Results
Sbitany, 2017 (8)	411 breasts	31 breasts with post-radiation	26 breasts with post radiation	Immediate TE reconstruction—specifically analyzing patients who underwent postoperative radiation	No statistically significant differences in infection, hematoma, seroma or explantation rates
Sbitany, 2017 (8)	270 breasts	84 breasts (total anterior coverage with ADM)	186 breasts (dual plane with ADM sling)	Immediate TE reconstruction in NSM	Higher rates of TE migration in patients who received radiation in submuscular group
Elswick, 2018 (21)	54 patients (93 breasts)	93 breasts	0	Immediate two-stage reconstruction with ADM	No statistical difference in complication between radiated and non-irradiated breasts
Hassan, 2023 (22)	172 (179 breasts)	101 breasts	78 breasts	Immediate TE reconstruction with ADM	No difference in postoperative complication rate

TE, tissue expander; ADM, acellular dermal matrix; NSM, nipple-sparing mastectomy.

26 prepectoral) the authors found no significant difference in rates of infection, hematoma, seroma or explantation between groups (20). In a different study cited earlier, Sbitany *et al.* (8) also demonstrated that the incidence of tissue expander migration during postmastectomy radiation therapy was significantly higher in the partial submuscular cohort—likely because of the fibrosis and tightening of the pectoralis major muscle during postmastectomy radiation therapy in its expanded and stretched position over the tissue expander.

In a similar study, Elswick compared two stage prepectoral implant-based reconstruction with and without postoperative radiation therapy and demonstrated a slight increase in overall postoperative complications (infection, seroma, skin flap necrosis, wound dehiscence, capsular contracture, hematoma or extrusion); however, these differences were not statistically significant thus demonstrating the safety of prepectoral reconstruction in the setting of radiation therapy (21).

Hassan *et al.* directly compared surgical outcomes between patients who underwent two-stage prepectoral and two-stage subpectoral IBR in the setting of post-mastectomy radiation. In this retrospective review, the authors identified 172 patients (179 breasts) of which 99 were prepectoral and 73 were subpectoral. There were no significant differences between the groups with regard to breast-related complications, device infection, skin flap necrosis or device explantation. In addition, placement of prosthetic devices in the submuscular position was not associated with a lower risk of device related complications (22).

Patient reported outcomes (*Table 3*)

Studies that have emphasized patient reported outcomes using the validated Breast-Q questionnaire, patient reported pain scores and others have been published. Nelson *et al.* reviewed 921 patients who underwent either a prepectoral or submuscular 2 stage breast reconstruction. The emphasis was on the first 90 days after surgery. A propensity matched analysis of clinical and patient reported outcomes was performed. A matched cohort of 238 patients were analyzed that included 119 prepectoral and 119 submuscular reconstructions. The authors found lower early postoperative pain in prepectoral tissue expander patients but no long-term patient-reported differences. Although prepectoral reconstruction patients experienced a higher rate of seroma, this did not translate to a difference in tissue expander loss (23).

In a study by Le *et al.*, patient reported outcomes following DTI reconstruction was retrospectively assessed in a review of 101 patients of which 64 patients were prepectoral and 37 were subpectoral. They were able to demonstrate comparable satisfaction rates between prepectoral and subpectoral breast reconstruction techniques. Relative to prepectoral implants, the subpectoral implant cohort reported a higher score for sexual well-being (24). More recently, Asaad *et al.* retrospectively analyzed the data from 694 patients who underwent two-stage implant reconstruction over the course of 2 years (96% were immediate). The majority of patients underwent prepectoral reconstruction (573 breasts). The

Table 3 Patient reported outcomes

Reference	Number of patients	Prepectoral	Subpectoral	Surgical technique	Results
Nelson, 2022 (23)	921 patients unmatched; 238 matched cohort	119 patients	119 patients	Immediate TE reconstruction; specifically 90-day postoperative clinical and patient reported outcomes	Higher use of ketorolac in the immediate postoperative period in the submuscular group; higher pain scores in subpectoral group in POD 2–3, but no difference after that; there were no significant differences in postoperative physical well-being of the chest Breast-Q scores between cohorts at all time points
Le, 2021 (24)	101 patients	64 patients (114 breasts)	37 patients (68 breasts)	Immediate DTI	Breast-Q satisfaction scores for most modules regardless of implant plane. The subpectoral implant cohort scored higher for sexual well-being
Asaad, 2023 (17)	481 patients (694 breasts)	573 breasts	121 breasts	Two stage reconstruction prepectoral or submuscular (dual-plane with ADM)	Similar scores for satisfaction, psychosocial and sexual well-being on Breast-Q

TE, tissue expander; POD, postoperative day; DTI, direct-to-implant; ADM, acellular dermal matrix.

Breast-Q response rate was 37% (121 prepectoral and 28 subpectoral). The mean scores for satisfaction with the breast, psychosocial well-being, and sexual well-being were similar (17).

Time to tissue expansion (*Table 4*)

One of the presumed benefits of prepectoral placement of tissue expanders is a decreased time to full expansion. Various studies have investigated whether this is accurate.

Zhu *et al.* compared patients undergoing immediate two stage reconstruction using either prepectoral or subpectoral techniques. Patient undergoing prepectoral reconstruction included patients who had 2-stage techniques in which the TE was covered with either an inferior dermal flap, ADM, or no coverage at all. Submuscular placement of tissue expanders varied between total submuscular or dual plane placement with either an inferior dermal flap or ADM sling. The prepectoral group had a higher intraoperative expansion ratio, higher first postoperative expansion ratio, shorter duration of expansion and fewer expansion visits. The prepectoral group also had less average pain during admission (25). Sbitany *et al.* also demonstrated that the mean number of fills to complete expansion was statistically lower in the prepectoral cohort. They also found that the final fill volume was less in the prepectoral cohort compared to the subpectoral one because it was advantageous to underfill the tissue expanders in the prepectoral group in order to ensure a tighter pocket resulting in less implant rippling (8).

In a study with a larger cohort of patients, Wormer *et al.* compared consecutive patients who underwent immediate tissue expander breast reconstruction grouped into subpectoral (partial submuscular/partial ADM) or prepectoral (complete ADM coverage) techniques (26). The goal of this study was to evaluate the differences in tissue expansion between prepectoral and subpectoral TE techniques. The authors observed that prepectoral patients completed expansion over 3 weeks sooner than subpectoral patients and required nearly half the number of expansion office visits to reach final fill volume. They also observed decrease postoperative pain medication usage in the prepectoral group and there were no differences in overall complication rates between the two groups.

Still with regard to the number of office visits required to attain complete expansion, other papers corroborate the same findings. Assad *et al.* in demonstrated that the prepectoral group required fewer office visits to complete expansion (3 *vs.* 4, P<0.001) (26). Hassan *et al.* in their radiated patients also demonstrated that the prepectoral cohort required fewer visits to complete expansion (3 *vs.* 4, P<0.001) (22).

With the objective of determining by means of large-scale propensity matching the safety of prepectoral reconstruction and benefits to clinic-based expansion, Haddock *et al.* compared dual plane submuscular reconstruction with a prepectoral technique in two stage breast reconstruction (27). They analyzed 260 patients of

Table 4 Time to expansion of tissue expander

Reference	Number of patients	Prepectoral	Subpectoral	Surgical technique	Results
Zhu, 2016 (25)	88 (158 breasts)	50 breasts (subdermal flap, ADM or no coverage)	108 breasts (total submuscular, dermal flap sling, ADM sling)	Immediate TE reconstruction	Prepectoral group had higher intraoperative expansion ratio, higher first postoperative expansion ratio, shorter duration of expansion and less expansion visits
Sbitany, 2017 (8)	270 breasts	84 breasts	186 breasts	Immediate TE reconstruction in NSM	Decreased number of visits to reach final expansion in the prepectoral group
Wormer, 2019 (26)	101 (184 breasts)	60 breasts (prepectoral with total ADM coverage)	124 breasts (submuscular dual plane with ADM)	Immediate TE reconstruction	Type of ADM was not significantly associated with overall complications, infection, major complications, or device explantation. No difference in patient reported outcome
Asaad, 2023 (17)	481 patients (694 breasts)	573 breasts	121 breasts	Two stage reconstruction prepectoral or submuscular (dual-plane with ADM)	Less postoperative visits to complete expander fill (3 *vs*. 4, P<0.001)
Hassan, 2023 (22)	172 (179 breasts)	101 breasts	78 breasts	Immediate TE reconstruction with ADM	Less postoperative visits to complete expander fill (3 *vs*. 4, P<0.001)
Haddock, 2021 (27)	260 patients unmatched; 204 matched; all bilateral cases	102 patients	102 patients (dual plane)	Immediate TE reconstruction	Prepectoral tissue expander placement permitted greater intraoperative filling of TE, with no increase in adverse outcomes compared to partial subpectoral placement

ADM, acellular dermal matrix; TE, tissue expander; NSM, nipple sparing mastectomy.

which all were bilateral and consisted of 122 prepectoral and 138 subpectoral cases. After propensity score matching, 102 patients in each group were analyzed. Although prepectoral placement was associated with prolonged time to drain removal, those patients completed the expansion process twice as fast, were expanded further in the operating room, and were more than twice as likely to forgo clinic-based expansion, with no increase in adverse outcomes compared to partial subpectoral placement. Of note, in this study, the authors found that hypertension and was the strongest predictor of overall complication in any type of reconstruction.

Intraoperative tissue expander filling (*Table 5*)

In a two-stage breast reconstruction tissue expanders are traditionally filled with saline during the intraoperative and postoperative period until the desired volume is reached leading to the exchange to a silicone implant. Recently attention has been directed towards initially filling the tissue expander with air intraoperatively and then converting to saline 2 weeks postoperatively. The rational for this is that air is evenly distributed through the expander obviating a gravitational effect—air is much lighter than saline with less likelihood of suture tab detachment, and finally it will exert less pressure on the mastectomy skin flaps.

Yesantharao *et al.* performed a retrospective analysis of 87 patients (144 breast) undergoing a two-stage IBR where they compared the complication rates following intraoperative tissue expander fill with saline versus air. In their cohort, patients who received intraoperative air fill were found to have significantly lower rates of overall complications and salvage reoperations (28). More recently Plotsker *et al.* (29) in a retrospective study of 560 patients (928 breasts) undergoing two-stage breast reconstruction compared complications and early patient-reported outcomes (PROs) with Breast-Q based on fill type in prepectoral breast reconstruction patients. The authors

Table 5 Tissue expander fill

Reference	Number of patients (breasts)	Prepectoral	Subpectoral	Air fill	Saline fill	Results
Yesantharao, 2022 (28)	87 (144 breasts)	144 breasts	0	66.7%	33.3%	Less overall complications in the air fill cohort
Plotsker, 2023 (29)	560 (928 breasts)	928 breasts	0	67%	33%	No difference in overall complication rate after propensity matching; no difference in patient reported outcomes

Table 6 Types of implant coverage in prepectoral/subpectoral reconstruction

Reference	Number of patients	Prepectoral	Subpectoral	Surgical technique	Results
Nealon, 2020 (30)	256 (421 breasts)	238 breast	183 breasts	Immediate DTI reconstruction	No difference in postoperative seroma, hematoma, infection or explantation; increase in capsular contracture and rates of revision in the submuscular group
Sigalove, 2022 (32)	263 (499 breasts)	499 breasts	0	Immediate 2 stage (expander-implant) with Alloderm or Galaflex-Alloderm	No major complication difference between the two groups
Johnson, 2022 (36)	151 (241 breasts)	80 breasts	161 breasts	Immediate 2 stage (expander-implant) with Alloderm or Dermacell	Increased in seroma formation in the Alloderm group. Prosthesis plane did not influence the findings
Powers, 2021 (37)	79 patients	79 patients	0	Immdiate DTI, expander-implant with Alloderm or Dermacell	Significantly increased infection rate in the Alloderm group
Asaad, 2023 (17)	383 (557 breasts)	557 breasts (Alloderm: 438; Surgimend: 78; Dermacell: 41)	0	Immediate 2 stage (expander-implant) with Alloderm, Dermacell or Surgimend	Type of ADM was not significantly associated with overall complications, infection, major complications, or device explantation. No difference in patient reported outcome
Chen, 2023 (41)	220 patients (393 breasts)	161 breasts (prepectoral no mesh)	122 breasts (dual-plane with ADM); 96 breasts (dual-plane with P4HB); 14 breasts (total submuscular)	Two stage reconstruction with P4HB, dual-plane with ADM, total submuscular or prepectoral with no mesh	Prepectoral and submuscular cohort with lowest incidences of capsular contracture. P4HB with significantly higher risk of capsular contracture. No difference in infection, necrosis, and revision surgery

DTI, direct-to-implant; ADM, acellular dermal matrix; P4HB, poly-4-hydroxy-butyrate.

concluded that tissue expanders initially filled with air have no significant advantage over saline-filled expanders in maintaining mastectomy skin flap viability or PROs. They observed no difference in any complication rates or PROs based on expansion type following propensity matching.

Type of mesh or implant coverage (*Table 6*)

The use of ADMs or synthetic meshes have become a mainstay of a subpectoral as well as prepectoral reconstruction. In the subpectoral technique, these devices are generally used as an inferolateral sling to support the implant/tissue expander and allow for better lower pole projection. In prepectoral reconstruction these matrices are used for anterior coverage or as a wrap to provide support for the prosthesis in the subcutaneous plane with the primary intent of compartmentalizing the device, potentially reducing the incidence of capsular contracture,

and to provide additional tissue support to the compromised mastectomy skin flaps. The choice of matrix may vary from human or animal derived ADM to permanent and resorbable synthetic meshes. The cost of these meshed vary widely amongst different manufacturers. The global availability of these meshes differ significantly across the globe due to cost considerations and regulations regarding the use of human and animal tissues. In the USA, the use of human derived mesh is the most common; whereas in other countries the use of bovine or porcine meshes as well as synthetic meshes may be more common. Several studies have analyzed the role of mesh in prepectoral as well as subpectoral IBR and will be reviewed.

A retrospective study by Nealon *et al.* specifically analyzed patients who underwent DTI reconstruction using either a submuscular approach (total submuscular or dual plane) or a prepectoral approach (30). The authors used a combination or either Vicryl mesh or ADM when performing the dual plane technique and Vicryl mesh, ADM or both when performing the prepectoral technique. Their cohorts consisted of 421 breasts (238 submuscular and 183 prepectoral) with a follow-up >16 months. The authors saw no difference in postoperative seroma, hematoma, infection or explantation between the groups. Interestingly, an increase in capsular contracture and rates of revision were observed in the submuscular group.

In a meta-analysis, DeLong *et al.* performed a systematic review of all English language articles reporting original data for prepectoral implant-based breast reconstruction with the objective of determining if the safety profile of prepectoral prosthetic breast reconstruction was impacted by the introduction of mesh (31). A total of 58 articles were included encompassing 3,120 patients from 1966 to 2019. Reported complication outcomes were variable, with no significant difference between groups in hematoma, infection, or explantation rates. Capsular contracture rates were higher in historical no-mesh cohorts, but this was not true with what was referred to as the "contemporary no-mesh cohort" (studies after 2006). The authors concluded that this data provided preliminary evidence that capsular contracture rates are more significantly impacted by improvements in implant devices and surgical practice rather than the introduction of mesh.

Sigalove *et al.* published a retrospective review of prepectoral and subpectoral, two stage, expander-implant reconstruction using AlloDerm (Allergan, Irvine, CA, USA) coverage alone and compared it to a Galaflex-Alloderm construct for coverage of the prosthesis (32). A total of 499 reconstructions were reviewed. There was no major difference in complications between the two groups.

Multiple studies have compared rates of complications between different types of ADMs. Studies by Greig *et al.* (33), Salzberg and Zenn (34) and Pittman *et al.* (35) are some of the studies that have analyzed differences in complications between the use of Alloderm and Dermacell (Stryker, Kalamazoo, MI, USA) in subpectoral DTI or two stage implant reconstruction. Of these, Pittman *et al.* demonstrated increased rates of seroma in the Alloderm group whereas the other two studies failed to show a difference in complications between the groups.

More recently, Johnson (36) and Powers (37) have performed similar studies comparing Alloderm and Dermacell use. Johnson *et al.* compared the two ADM brands both in two stage IBRs in subpectoral and prepectoral planes. There was increase rates of seroma formation in the Alloderm group, but plane of reconstruction (prepectoral or subpectoral) did not influence the rate of complications. Powers *et al.* analyzed retrospective data of prepectoral DTI and 2 stage IBRs using either brand of ADM. In this study there were significantly increased rates of infection in the Alloderm group.

In the retrospective review of Asaad *et al.* (38), the authors also compared three types of ADM—Alloderm, Surgimend (Integra life Sciences, Princeton, NJ, USA) and Dermacell—in prepectoral 2 stage implant/expander reconstruction cohort of 694 patients. Type of ADM was not significantly associated with overall complications, infection, major complications, or device explantation. Patient reported outcomes were also reviewed and were similar for all three types of ADM.

It is important to mention that prepectoral reconstruction can also be successfully performed without the use of ADM or mesh. Historical data on prepectoral reconstruction without ADM have classically shown increased rates of capsular contracture, skin necrosis and implant failure (39). These substandard results following subcutaneous reconstruction are likely attributable in large part to the radical mastectomy techniques that were performed in the 1970s. Advancements in mastectomy techniques for both skin and nipple-sparing mastectomy have increased the ability to preserve the vascularity and reduce skin flap necrosis. The use of autologous fat grafting, as well as the use of cohesive and optimally filled prosthetic devices have increased our ability to perform adequate prepectoral reconstruction. Salibian and Harness (40) performed

a retrospective review of 151 (286 breasts) consecutive patients who underwent NSM and immediate 2 stage reconstruction with implant-expander in the prepectoral plane without the use of ADM or mesh with an average of 109-month follow-up. In this study among other findings, the authors demonstrated rates of 7.3% of Baker Grade III and IV capsular contracture. The rate of explantation was also low at 6.5% which were all attributable to radiation ulcers.

More recently, Chen *et al.* (41) compared 220 patients having 2-stage prepectoral breast reconstruction in which the use of poly-4-hydroxy-butyrate (P4HB) mesh was compared to ADM and to no mesh. The authors demonstrated that the lowest incidences of capsular contracture occurred in the prepectoral cohort without mesh (49/161, 30.4%) and total submuscular cohorts (3/14, 21.4%). Infection, necrosis, and revision surgery rates did not differ significantly between the groups. Interestingly however, was that the use of P4HB was correlated with a significant increase in the rate of capsular contracture (47.9%) whereas the lowest rate of capsular contracture occurred when no mesh was used (30.4%).

Conclusions

Implant-based reconstruction continues to be the most popular, widely available and accessible form of breast reconstruction and it will likely continue to be so in the foreseeable future. With the limitations of the submuscular techniques, in the past years, the pendulum has been shifting from subpectoral to prepectoral implant placement. The prepectoral plane eliminates the need for chest wall muscle dissection, disinsertion and manipulation avoiding the muscle related complications of the subpectoral approach (increased pain secondary to muscle dissection and animation deformity) shortens the recovery time, and provides greater control of breast shape and contour. With the latest generation form-stable silicone implants coupled with the wide use and acceptance of ADMs and synthetic meshes to support the implant, the rates of capsular contracture between the two types of technique have become more comparable. Techniques and technology will continue to evolve improving results and outcomes for our patients.

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Footnote

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