Original Article

To acellular dermal matrix or not to acellular dermal matrix?—outcomes of pre-pectoral prosthetic reconstruction after nipple-sparing mastectomy with and without acellular dermal matrix

Elizabeth E. Bushong[1], Nicholas Wesely[2], Ewa Komorowska-Timek[2,3]

[1]Michigan State University College of Human Medicine, Grand Rapids, MI, USA; [2]Corewell Health/Michigan State University College of Human Medicine, Integrated Plastic Surgery Residency, Grand Rapids, MI, USA; [3]Advanced Plastic Surgery, Grand Rapids, MI, USA

Contributions: (I) Conception and design: EE Bushong, E Komorowska-Timek; (II) Administrative support: EE Bushong, E Komorowska-Timek; (III) Provision of study materials or patients: EE Bushong; (IV) Collection and assembly of data: EE Bushong; (V) Data analysis and interpretation: EE Bushong; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Ewa Komorowska-Timek, MD. Corewell Health/Michigan State University College of Human Medicine, Integrated Plastic Surgery Residency, Grand Rapids, MI, USA; Advanced Plastic Surgery, 3855 Burton St. SE, Grand Rapids, MI 49546, USA. Email: etimek@sbcglobal.net.

Background: Acellular dermal matrix (ADM) has been the go-to biomaterial in post-mastectomy breast reconstruction, particularly in pre-pectoral reconstruction. ADM is thought to decrease capsular contracture, control the pocket, and increase soft tissue, but may yield more complications. This study evaluated whether ADM is even needed.

Methods: All patients undergoing immediate breast reconstruction with pre-pectoral tissue expander (TE) or direct-to-implant (DTI) after nipple-sparing mastectomy (NSM) by the senior author between April 2013 and January 2021, were included in this study. Cohorts were stratified into breasts with ADM or no-ADM. Complications within 30 days post-operatively were analyzed.

Results: A total of 115 pre-pectoral reconstructions were performed in 66 patients. ADM was applied to 75 breasts. TEs were used in 80 breasts and DTI in 35 breasts. Controlling for implant type, breasts with ADM exhibited more nipple necrosis (28.0% *vs.* 10.0%, P=0.02). Controlling for ADM status, DTI compared to TE was associated with less necrosis of the nipple (11.4% *vs.* 26.3%, P=0.04), implant loss (5.7% *vs.* 38.8%, P=0.004), and surgery for any complication (14.3% *vs.* 27.5%, P=0.04).

Conclusions: Outcomes of prosthetic reconstructions with ADM and no-ADM were similar. DTI reconstruction was associated with less complications, which was likely due to intraoperative bias and placement of TEs more often in breasts with perceived poorer vascularity.

Keywords: Acellular dermal matrix (ADM); pre-pectoral implant; breast reconstruction; nipple-sparing mastectomy (NSM)

Submitted Jan 15, 2024. Accepted for publication May 27, 2024. Published online Jun 21, 2024.
doi: 10.21037/gs-24-23
View this article at: https://dx.doi.org/10.21037/gs-24-23

Introduction

Acellular dermal matrix (ADM) has been the go-to biomaterial in post-mastectomy breast reconstruction. Harvested from human, bovine, or porcine skin grafts, ADM is devoid of cellular components and immunogenic elements to prevent graft rejection. What remains is a framework rich in collagen, elastin, fibrillin, and glycosaminoglycans; structural elements necessary for wound repair (1,2). ADM can then be incorporated into tissues and provide structural support (2). In breast reconstruction surgery, ADM can help define and control a breast pocket, prevent implant displacement, and increase soft tissue bulk (3-6).

© Gland Surgery. All rights reserved.

Previous reports have noted that ADM is associated with less capsular contracture and might be a protective factor against its formation (3-6). One main downside to ADM use is its significant cost which varies by thickness and brand. The average cost of ADM amounts to \$30/cm^2 (7,8). Additionally, ADM use has been reported to increase risk of seroma formation, infection, and implant loss (3-6).

In pre-pectoral breast reconstruction, ADM serves as a biologic sling for the implant in replacement of the traditional pectoralis muscle in sub-pectoral techniques. Compared to implant placement below the muscle, pre-pectoral reconstruction avoids animation deformity and is associated with less post-operative pain (9-14). Pre-pectoral prosthetic breast reconstruction after nipple-sparing mastectomy (NSM) has also shown reduced complications related to ischemia, such as nipple and flap necrosis, and improved psychosocial well-being compared to submuscular implants (15,16). Although NSM may pose an increased risk of nipple ischemia due to reduced vascularity with glandular resection, NSM are aesthetically superior and psychologically advantageous to skin-sparing mastectomies and reconstructed nipples (17,18).

Previous studies have analyzed ADM use in immediate prosthetic reconstruction without controlling for plane of implant placement or solely analyzed outcomes by plane of implant placement without controlling for use of ADM (5,19-25). The existing reports analyzing ADM use in pre-pectoral breast reconstruction after NSM, are low powered, allowing for less accurate outcome profiles (26-30). We hypothesized that in pre-pectoral breast reconstruction after NSM, ADM use will result in less post-operative complications compared to no-ADM. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-23/rc).

Highlight box

Key findings

- Outcomes of nipple-sparing prosthetic reconstructions with acellular dermal matrix (ADM) and no-ADM were similar. ADM was also associated with higher rates of nipple necrosis. Controlling for ADM use or not, this study also investigated direct-to-implant (DTI) compared to tissue expanders (TEs) and found that DTI reconstruction was associated with less complications, such as nipple necrosis and implant loss.

What is known and what is new?

- ADM has been known as the go-to biomaterial in post-mastectomy breast reconstruction. ADM is harvested from human, bovine, or porcine skin grafts and devoid of cellular components and immunogenic elements to prevent graft rejection. ADM is thought to decrease capsular contracture, control the pocket, and increase soft tissue, but may yield more complications, such as seroma. ADM is also costly and can add thousands of dollars to operative costs.
- This study evaluated whether ADM is even needed. We determined that ADM increases the odds for nipple necrosis. We refuted our hypothesis and determined that ADM in the prepectoral plane with nipple-sparing mastectomy does not reduce infection, capsular contracture, or implant loss.

What is the implication, and what should we change now?

- Use of ADM in breast reconstruction is not without its own risks. ADM use incurs a high cost to the medical system and has the added conceptual risk of introducing a foreign material to the surgical environment. As the use of ADM did not demonstrate superior outcomes, we recommend not to ADM.

Methods

Patients were included in this study if they underwent immediate pre-pectoral breast reconstruction after NSM by the senior author at Corewell Health in Grand Rapids, MI, USA. Surgical dates occurred between April 2013 and January 2021. Patients were excluded if their surgical procedures involved mastopexy or local tissue flaps. This study was approved by the Institutional Review Board of Corewell Health (IRB# 00000883). Informed consent was obtained from the patients for this study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Data collection

Data collected included patient age, diabetes, body mass index (BMI), hypertension, smoking, history of chemotherapy and radiation, and mastectomy surgeon. Smoking status was defined as: 0—no history, 1—former smoker that quit more than 2 months prior surgery, or 2—current smoker or quit less than 2 months prior surgery. Patients were stratified into groups that received ADM (ADM) (*Figure 1A*,*1B*) and those that did not (no-ADM) (*Figure 1C*,*1D*). ADM brand name was recorded. The type of implant the patient received in the pre-pectoral plane was recorded as either tissue expander (TE) or direct-to-implant (DTI). If patients received a DTI, they did not receive ADM. However, breasts with TE exhibited both ADM and no-ADM groups. Details describing the breast side, TE initial and final fill volume or permanent implant volume,

© Gland Surgery. All rights reserved.

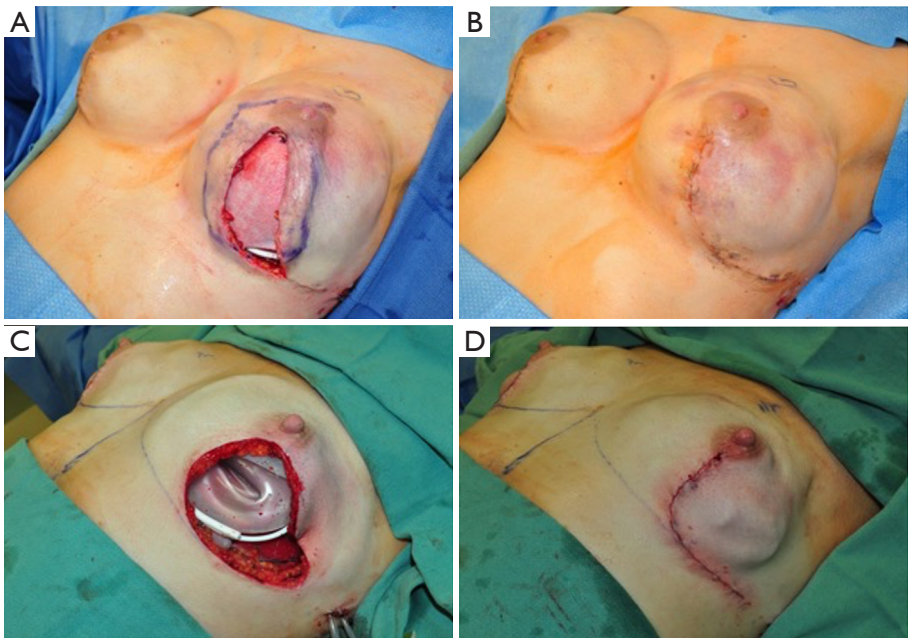

Figure 1 ADM *vs.* no-ADM procedures. (A,B) NSM with ADM was applied in a female patient, age 27 years. (C,D) NSM without ADM was applied in a female patient, age 30 years. Written informed consent was obtained from the patient for publication of this article and accompanying images. ADM, acellular dermal matrix; NSM, nipple-sparing mastectomy.

date of first follow-up visit after surgery, and last follow-up date, were noted.

Physical examination performed by the senior author to determine the patients' breast anatomy with regards to breast envelope skin laxity and degree of nipple areola complex (NAC) ptosis. The breast envelope's skin laxity was expressed on a 1–4-point scale as 1—tight, 2—mild, 3—moderate, and 4—loose. NAC ptosis was established based on Regnault's classification (31).

Surgical approach

NSM

Oncological NSM candidacy was established by the breast surgeon and confirmed during pre-operative assessment. In every case, nipples were cored out and tissue containing the milk ducts was pathologically analyzed under frozen section control and further processed as routine permanent specimens. All preserved nipples were found to be negative for atypia or cancer by intra-operative biopsy which was confirmed by permanent biopsy. All breasts received a J-incision starting below the NAC and carried down and out towards the infra-mammary fold. Intra-operative perfusion mapping system was not available due to high cost at the time of this study.

ADM application

ADM utilized were either Alloderm (AlloDerm; Allergan, Dublin, Ireland) or FlexHD (FlexHD STRUCTURAL Acellular Hydrated Dermis; Musculoskeletal Transplant Foundation, Edison, NJ, USA) (*Figure 1A*,*1B*). ADMs measured 8 cm × 16 cm and were cut in half. Each half, 8 cm × 8 cm, was applied per breast. Thin (1.0±0.2 mm) or medium (1.6±0.4 mm) thick ADM was projected onto the skin evenly underlying the J-incision line and the undersurface of the nipple. ADM was sutured to the undersurface of the mastectomy flap using PDS at each of the four corners (Ethicon; Johnson and Johnson Medical, N.V., Machelen, Belgium) (*Figure 2*). Implants used were either silicone smooth round gel implants (DTI group) (Mentor; Mentor Worldwide LLC, Irvine, CA, USA) or TE (TE group) (Mentor; Mentor Worldwide LLC). Two drains were always placed.

Assessment of surgical outcomes

Complications that occurred within 30 days post-surgery were observed during follow-up and analyzed. Capsular contracture was the only variable that was assessed long-term

© Gland Surgery. All rights reserved.

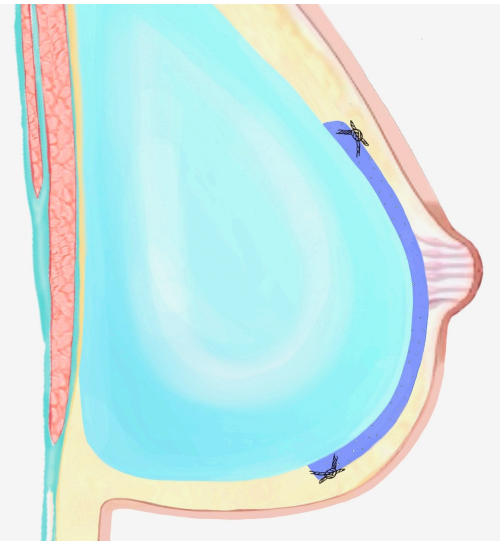

Figure 2 Schema of ADM application to mastectomy flap. All four corners of the ADM are tacked to the mastectomy flap, as demonstrated in black suture loops. This is pre-pectoral and anterior to the implant. Original artwork by Elizabeth Bushong. ADM, acellular dermal matrix.

and beyond the 30-day window. Complications were analyzed as individual outcomes and within their respective "minor" or "major" complication groups. Minor complications included erythema, requirement of extra post-operative antibiotics, flap necrosis, nipple necrosis, and seroma. Major complications included capsular contracture, dehiscence, hematoma, hospitalization, infection, loss of implant, necrosis that required surgical debridement, and any surgical intervention.

Statistical analysis

For purposes of comparison, the unit of analysis was defined as a single breast. Exceptions to this occurred when patients were used as the units of analysis for: demographics, comorbidities, extra-antibiotics, and hospitalization. Quantitative data are expressed as the mean, standard deviation, and median, while nominal data are expressed as a percentage. Comparisons between the two groups for quantitative variables was performed using a two-tailed *t*-test.

A generalized estimating equation (GEE) ran a logistic regression model while accounting for the repeating breast sides per patient, with complications as the dependent variables. For the GEE model, the independent variables were ADM *vs.* no-ADM and DTI *vs.* TE. Because breasts with DTI did not receive ADM but breasts with TEs received either ADM or no-ADM, we controlled for implant type in the ADM *vs.* no-ADM model.

The first analysis measured the effect of no-ADM compared to ADM while holding implant type constant. The subsequent analysis measured the effect of implant type when holding ADM status constant. P values were noted, along with adjusted odds ratios (ORs) and OR 95% confidence intervals. Significance was defined by P<0.05.

Results

In the study, 66 patients underwent 115 immediate breast reconstructions with implants placed in the pre-pectoral plane. ADM was utilized in 75 breasts (*Table 1*, *Figure 1*). Implant devices were either TE or DTI, 80 and 35 breasts, respectively.

Patient characteristics and operative details

Patient demographics for ADM and no-ADM groups are summarized in *Tables 1*,*2*. All patients included in this study identified as female. The mean patient age overall was 48±11 years, with a range from 26 to 77 years old. Age did not vary significantly between cohorts. The mean BMI was 27±5.3 kg/m^2, with patients in the ADM group exhibiting a greater BMI median of 27.4 kg/m^2 than the no-ADM group of 24.4 kg/m^2 (P=0.049). No-ADM patients underwent significantly more chemotherapy (35.0% *vs.* 10.0%, P<0.01) prior reconstruction. There were no significant differences between ADM and no-ADM groups regarding breast weight, laterality, TE initial and final fill volumes, and implant size. There were also no statistically significant differences in smoking status and comorbidities, such as diabetes and hypertension. FlexHD and AlloDerm were the only two ADM types utilized. FlexHD was used more than AlloDerm, with 81.3% and 18.7% respectively.

Seven breast surgeons performed mastectomies in this study. A single breast surgeon was involved in 63.5% of cases overall (*Table 2*). This breast surgeon contributed to 70.7% of the mastectomies that received ADM and 50.0% in the no-ADM cohort. The second most involved breast surgeon contributed to 13.9% of all cases. The remaining five breast surgeons were involved in 22.6% of all cases. The majority of nipple ptosis grade was a grade 0 at 53.0% and grade 1 with 32.2%. Breast laxity was mostly a three-moderate grade with 41.3% of all cases. While nipple ptosis grade did not vary between groups (P=0.35), the grade of breast envelope laxity was greater in the no-ADM group (P=0.01).

© Gland Surgery. All rights reserved.

Table 1 Patient demographics: overall and ADM *vs.* no-ADM

Variables	Overall				ADM				No-ADM				P value
	N	%	Mean ± SD	Median	N	%	Mean ± SD	Median	N	%	Mean ± SD	Median	
Age (years)	115		48±11.2	48	75		49.5±11.9	49	40		45.3±9.4	46	0.06
BMI (kg/m^2)	115		27±5.3	26.3	75		27.4±4.5	27.4	40		24.4±6.6	24.4	0.049*
Diabetes	4	3.5			4	5.3			0	0.0			0.30
Hypertension	30	26.1			22	29.3			8	20.0			0.28
Smoking status													0.98
Never	74	64.3			48	64.0			26	65.0			
>2 months	27	23.5			18	24.0			9	22.5			
Current/quit <2 months	14	12.2			9	12.0			5	12.5			
Prior chemotherapy	24	20.9			10	13.3			14	35.0			<0.01*
Prior radiation	6	5.2			4	5.3			2	5.0			>0.99

*, statistical significance. ADM, acellular dermal matrix; SD, standard deviation; BMI, body mass index.

Post-operative complications

ADM *vs.* no-ADM

Out of all 115 breasts, 32 (27.8%) demonstrated partial or full-thickness necrosis (*Table 3*). Necrosis requiring surgical excision occurred in 24 breasts total, of which encompassed 20.9% (24/115) of all breasts in the study and 75.0% (24/32) of breasts with partial or full-thickness necrosis. When controlling for implant type and measuring the effect of ADM use, nipple necrosis was the only complication with a statistically significant difference between the cohorts. ADM use was significantly associated with more nipple necrosis (21/75, 28.0%) compared to no-ADM (4/40, 10.0%) (P=0.02). No-ADM was associated with an 80% (OR =0.20) reduction of nipple necrosis compared to ADM use.

Breasts with ADM also appeared to demonstrate more necrosis requiring surgical debridement (25.3% *vs.* 12.5%) however, due to the sparseness of the data, the GEE failed to converge. Therefore, the assumptions of the model were not met, and the associated P value was unable to be calculated. A *t*-test or other simpler methods were not appropriate as these do not account for repeating patient variables (e.g., one patient with bilateral necrosis).

Capsular contracture presentation was measured by the latest follow-up appointment, with patient visit timelines averaging 557±453 days (*Table 3*). While not demonstrated in the table, the range of follow-up was 28 to 1,302 days (3.6 years). Only eight breasts of 115 (6.9%) were assessed with a follow-up less than 100 days. There was no difference in capsular contracture formation between ADM and no-ADM cohorts.

DTI *vs.* TE

When controlling for ADM status, TE demonstrated significantly more complications than DTI (*Table 4*). Due to the lack of convergence in the model, no difference was appreciated in 'at least one minor complication' between DTI and TE. Of the total 34 breasts featuring partial and full thickness necrosis (overall and nipple), 11/34 (32.4%) involved DTI and 23/34 (67.6%) TE. Stratified by device type, TE was associated with more nipple necrosis compared to DTI, with 26.3% and 11.4% respectively (P=0.042). TE also appeared to be associated with more necrosis requiring surgical excision than DTI, with 26.3% and 8.6%, respectively. However, similar to the ADM *vs.* no-ADM analysis, a P value was unable to be calculated for this complication. Implant loss occurred more often with TEs than DTIs: 31/80 of breasts with TE compared to 2/35 with DTI (38.8% *vs.* 5.7%, P=0.004). Surgery for any complication was also greater in the TE group than permanent implant group, 35.0% and 14.3% respectively (P=0.04).

Discussion

Use of ADM as an adjunct for breast reconstruction has been brought under scrutiny in recent years. Since ADM's advent, the past two decades have demonstrated an evolution

© Gland Surgery. All rights reserved.

Table 2 Breast reconstruction details: overall and ADM *vs.* no-ADM

Variables	Overall				ADM				No-ADM				P value
	N	%	Mean ± SD	Median	N	%	Mean ± SD	Median	N	%	Mean ± SD	Median	
Specimen weight (g)	115		459±240	425	75		445±188	450	40		485±317	390	0.69
Breast side													0.053
L	41	35.7			22	29.3			19	47.5			
R	74	64.3			53	70.7			21	52.5			
Mastectomy surgeon													0.01*
1	73	63.5			53	70.7			20	50.0			
2	16	13.9			7	9.3			9	22.5			
3	11	9.6			2	2.7			9	22.5			
4–7	15	13.0			13	17.3			2	5.0			
Implant type													–
TE	80	100.0			44	55.0			36	45.0			
DTI	35	100.0			0	0.0			35	100.0			
DTI volume (mL)	35		472±119	450	–		–	–	35		472±119	450	–
TE—initial fill (mL)	80		229±130	200	44		218±132	200	–		242±129	300	0.41
TE—final fill (mL)	80		275±114	290	44		283±121	280	–		265±105	300	0.49
ADM type													–
AlloDerm	14	12.2			14	18.7			0	0.0			
FlexHD	61	53.0			61	81.3			0	0.0			
Skin envelope grade	80				44				36				0.01*
1—tight	21	26.3			13	29.5			8	22.2			
2—mild	23	28.8			15	34.1			8	22.2			
3—moderate	33	41.3			16	36.4			17	47.2			
4—loose	3	3.8			0	0			3	8.3			
Ptosis grade													0.35
0	61	53.0			40	53.3			21	52.5			
1	37	32.2			23	30.7			14	35.0			
1.5	1	0.9			1	1.3			0	0.0			
2	9	7.8			6	8			3	7.5			
3	7	6.1			5	6.7			2	5.0			

*, statistical significance. ADM, acellular dermal matrix; SD, standard deviation; L, left; R, right; TE, tissue expander; DTI, direct-to-implant.

of ADM application techniques and its uses (32). While early reports of ADM use in prosthetic breast reconstruction believed its long-term benefits of reducing capsular contracture outweighed short-term complications, surgeons are now suggesting few if any superior outcomes with ADM use and transitioning away from its application (2-5,19,24-39).

This evolution is in part due to the conflicting evidence on whether ADM improves or reduces capsular contracture rates, and increased or null association with infection, seroma formation, and implant loss (5,21-25,33-38).

© Gland Surgery. All rights reserved.

Table 3 Logistic regression analysis results: effect of ADM *vs.* no-ADM when controlling for implant type

Variables	ADM *vs.* no-ADM									
	No-ADM (n=40)		ADM (n=75)		GEE analysis					
	N or n/N	%	N or n/N	%	Parameter estimates	Standard error	Odds ratio	95% confidence limits	Z	Pr>|Z|
Minor complications										
At least one minor complication	26	65.0	57	76.0	−0.98	–	0.37	–	–	–
Extra-antibiotics	21	52.5	41	54.7	−0.37	0.59	0.7	−2.33, 0.33	−1.47	0.14
Partial or full thickness necrosis—overall	7	17.5	25	33.3	−0.99	0.68	0.37	−2.16, 2.10	−0.02	0.98
Partial or full thickness necrosis—nipple	4	10.0	21	28.0	−1.65	0.72	0.20	−3.07, −0.24	−2.29	0.02*
Seroma	12	30.0	21	28.0	−0.17	0.54	0.84	−1.23, 0.88	−0.32	0.75
Major complications										
At least one major complication	27	67.5	38	50.7	0.44	0.59	1.5	−0.71, 1.58	0.75	0.46
Capsular contracture	15	37.5	12	16.0	1.03	0.70	2.8	−0.35, 2.4	1.46	0.14
Dehiscence	1	2.5	5	6.7	−1.5	–	0.2	–	–	–
Infection	4	10.0	10	13.3	−0.50	0.65	0.6	−1.14, 1.1	−0.02	0.98
Hospitalization	5	12.5	7	9.3	0.65	0.75	1.9	−0.81, 2.1	0.87	0.38
Loss of implant	14	35.0	19	25.3	−0.01	0.58	1.0	−1.31, 3.34	–	0.10
Necrosis requiring surgical debridement	5/7	71.4	19/25	76.0	−0.11	–	0.9	–	–	–
Surgery for any complication	10	25.0	23	30.6	−0.66	0.52	0.52	−1.68, 0.36	−1.3	0.21

*, statistical significance. Two percentage values are reported for "necrosis requiring surgical debridement". The percentage in parentheses reflects the number of cases requiring debridement out of all breasts with or without necrosis. The value not in paratheses reflects the percentage of cases requiring debridement out of those with necrosis. Parameters were measured in relation to no-ADM status. ADM, acellular dermal matrix; GEE, generalized estimating equation; n/N, number/total.

There has also been an evolution of where ADM is applied, implant placement, and implant device type (32). Ideally, breast reconstruction is started immediately post-mastectomy and a single-stage reconstruction with permanent implant rather than two-stage TEs (19,36,38,39). Implants, once placed sub-muscularly, are now often placed pre-pectorally with ADM as an adjunct supporting structure. While submuscular implants might have improved vascularity and coverage, they are associated with increased post-operative pain and animation deformity. Modern prosthetic reconstruction also frequently implements fat grafting, which may play a role in reducing post-operative complications (40,41).

Most recent reports on ADM fail to control for differing planes of implant placement and/or type of mastectomy. Other studies investigate pre-pectoral breast reconstruction without ADM use or mesh, thus lack a control group (42). While these findings can be valuable for comparing and improving applications, they do not adequately assess the inherent risk profile of ADM. One striking finding in our study was the higher nipple necrosis rates with ADM use. Despite this increased rate of necrosis, the rate of surgical intervention for necrosis could not be statistically confirmed due the statistical model employed. To prevent implant infection and exposure, we have a low threshold for impending signs of necrosis. Therefore, we intervene for even superficial necrosis which likely explains our higher complication rates compared to other reports (3-6).

The GEE model failed to converge when analyzing "necrosis requiring surgical debridement" due to the need

© Gland Surgery. All rights reserved.

Table 4 Logistic regression analyses: effect of implant type when controlling for ADM *vs.* no-ADM

Variables	DTI *vs.* TE									
	DTI (n=35)		TE (n=80)		GEE analysis					
	N or n/N	%	N or n/N	%	Parameter estimates	Standard error	Odds ratio	95% confidence limits	Z	Pr>|Z|
Minor complications										
At least one minor complication	21	60.0	62	77.5	−1.23	–	0.3	–	–	–
Extra-antibiotics	14	40.0	48	60.0	−0.96	0.63	0.38	−2.2, 0.28	−1.52	0.13
Partial or full thickness necrosis—overall	9	25.7	23	28.8	−0.46	0.67	0.63	−1.77, 0.85	−0.69	0.49
Partial or full thickness necrosis—nipple	4	11.4	21	26.3	−1.49	0.73	0.23	−2.9, −0.055	−2.03	0.042*
Seroma	6	17.1	27	33.8	−0.96	0.65	0.38	−2.2, 0.31	−1.49	0.14
Major complications										
At least one major complication	13	37.1	52	65.0	−1.03	0.57	0.36	−2.15, 0.08	−1.81	0.07
Capsular contracture	5	14.3	22	27.5	−0.46	0.80	0.63	−2.03, 1.1	−0.57	0.57
Dehiscence	0	0.0	6	7.5	−26.2	–	<0.01	–	–	–
Infection	3	8.6	11	13.8	−0.74	0.85	0.5	−2.4, 0.92	−0.87	0.38
Hospitalization	4	11.4	8	10.0	0.45	1.00	1.6	−1.5, 2.4	0.45	0.65
Loss of implant	2	5.7	31	38.8	−2.4	0.84	0.09	−4.1, −0.78	−2.9	0.004*
Necrosis requiring surgical debridement	3/9	33.3	21/23	91.3	−3.24	–	0.04	–	–	–
Surgery for any complication	5	14.3	28	35.0	−1.42	0.67	0.24	−2.74, −0.1	−2.1	0.04*

*, statistical significance. Two percentage values are reported for "necrosis requiring surgical debridement". The percentage in parentheses reflects the number of cases requiring debridement out of all breasts with or without necrosis. The value not in paratheses reflects the percentage of cases requiring debridement out of those with necrosis. Parameters were measured in relation to DTI. ADM, acellular dermal matrix; DTI, direct-to-implant; TE, tissue expander; GEE, generalized estimating equation; n/N, number/total.

for more data points. Thus, future studies with larger power might unveil that surgical debridement for flap and NAC necrosis is statistically significant with ADM use. The reason for the higher NAC necrosis with ADM use remains unclear. We speculate that the ADM anchoring technique applied by us might have caused additional compromise of the vulnerable mastectomy skin flaps. However, the application of interrupted sutures to attach the ADM likely permitted distribution of tension within both, the artificial and native dermal layers. We also suggest deflation of a TE to decrease pressure on the skin when ADM is employed. We also believe that the primary driver for the increased nipple necrosis seen with use of ADM is increased outward tension on the mastectomy flaps. Anatomically, the nipple is supplied by the terminal extent of several arterial systems which put it at higher risk for ischemic changes when untoward pressure is applied to these systems.

In prior reports, ADM has been associated with more seroma formation, infection, and implant loss (5,19,21,39,43). When confined to the pre-pectoral plane, we found no difference in these outcomes. Other studies reported decreased capsular contracture with ADM use (5,36). Of note, if a patient received a TE that was exchanged for a permanent implant, capsular contracture that occurred during any point of follow-up counted as a TE cohort complication. However, more recent analyses align with our findings and demonstrate no difference in capsular contracture rates with ADM use, which was corroborated in our study (23,44).

When comparing DTI and TE based reconstructions, we found a significant reduction in overall major complications with DTI. Moreover, less flap and nipple necrosis and

© Gland Surgery. All rights reserved.

implant loss seen with DTI reconstruction resulted in a reduced need for surgical intervention in our study. These findings could be explained by factors observed intraoperatively and selection bias, such as the viability of the skin flaps. If a mastectomy flap appeared to be thin and with poor blood supply, a lower volume TE rather than a set volume DTI would be placed to reduce skin tension. Thus, the increased complication profile seen with TE use may be a result of a less favorable healing environment rather than the device itself. This selection bias was an additional reason why we controlled implant type in the model comparing complications rates in ADM *vs.* no-ADM. As more surgeons are transitioning from TE to DTI, it is imperative to pay careful attention to the integrity of mastectomy flaps and use intra-operative perfusion mapping when available.

This study demonstrates how a senior surgeon's surgical techniques evolve over time. In the surgeon's early years in practice, and between 2013 and 2019 within this study, ADM was administered to all breasts that received TE. In 2019, the senior surgeon began experimenting with no-ADM in breast reconstructions and began noticing fewer complications. From 2019 and onwards, the senior surgeon abandoned the use of ADM with TEs. These observations were the impetus for this study. The decision to forgo ADM use was not based on the appearance of the mastectomy skin flaps intraoperatively nor patient characteristics. Rather, it was this surgeon's experimentation with adjunctive technologies and evolution of practice that informed her decision to not use ADM.

Limitations

Limitations to this study include differing mastectomy surgeons, being done by a single surgeon at a single institution, and a selection bias for DTI *vs.* TE. This study is also retrospective in nature, thus not randomizable and with uneven cohorts. Through evolution of the surgical technique, ADM patients occurred earlier in the collection period as the surgeon with enhanced experience transitioned to not using ADM. Additionally, the mean BMI for this study was 27±5.3 kg/m^2, which might not be generalizable to the entire American population.

Two types of ADM were investigated in unequal amounts, which might introduce variability based on manufacturing differences. The wide range of follow-up (28 days to 3.6 years) and patients lost to follow-up might limit our findings regarding capsular contracture. And while capsular contracture was assessed throughout the follow-up period, duration of time between TE placement and exchange with a permanent implant is very likely to be shorter than the follow-up duration for the DTI cohort. Because of these varied length in times and that we assigned capsular contracture as a complication to the original implant cohort, our findings regarding capsular contracture might be inconclusive.

Conclusions

Use of ADM in breast reconstruction is not without its own risks. ADM use incurs a high cost to the medical system and has the added conceptual risk of introducing a foreign material to the surgical environment. We refuted our hypothesis and determined that ADM in the prepectoral plane with NSM does not reduce infection, capsular contracture, or implant loss. ADM use demonstrated higher rates of NAC necrosis. Subsequent studies with higher power are needed to ascertain whether this increased NAC necrosis leads to more surgical interventions. As ADM use did not demonstrate superior outcomes compared to No-ADM, our answer is: not to ADM.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-24-23/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-24-23/dss

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-24-23/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-23/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was

© Gland Surgery. All rights reserved.

conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of Corewell Health (IRB# 00000883). Informed consent was obtained from the patients for this study.

Open Access Statement: This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: https://creativecommons.org/licenses/by-nc-nd/4.0/.

References

1. Wainwright DJ. Use of an acellular allograft dermal matrix (AlloDerm) in the management of full-thickness burns. Burns 1995;21:243-8.
2. Fosnot J, Kovach SJ 3rd, Serletti JM. Acellular dermal matrix: general principles for the plastic surgeon. Aesthet Surg J 2011;31:5S-12S.
3. Colwell AS, Damjanovic B, Zahedi B, et al. Retrospective review of 331 consecutive immediate single-stage implant reconstructions with acellular dermal matrix: indications, complications, trends, and costs. Plast Reconstr Surg 2011;128:1170-8.
4. Dikmans RE, Negenborn VL, Bouman MB, et al. Two-stage implant-based breast reconstruction compared with immediate one-stage implant-based breast reconstruction augmented with an acellular dermal matrix: an open-label, phase 4, multicentre, randomised, controlled trial. Lancet Oncol 2017;18:251-8.
5. Ho G, Nguyen TJ, Shahabi A, et al. A systematic review and meta-analysis of complications associated with acellular dermal matrix-assisted breast reconstruction. Ann Plast Surg 2012;68:346-56.
6. Lanier ST, Wang ED, Chen JJ, et al. The effect of acellular dermal matrix use on complication rates in tissue expander/implant breast reconstruction. Ann Plast Surg 2010;64:674-8.
7. Bindingnavele V, Gaon M, Ota KS, et al. Use of acellular cadaveric dermis and tissue expansion in postmastectomy breast reconstruction. J Plast Reconstr Aesthet Surg 2007;60:1214-8.
8. Chepla KJ, Dagget JR, Soltanian HT. The partial AlloDerm sling: reducing allograft costs associated with breast reconstruction. J Plast Reconstr Aesthet Surg 2012;65:924-30.
9. Fracol M, Feld LN, Chiu WK, et al. An overview of animation deformity in prosthetic breast reconstruction. Gland Surg 2019;8:95-101.
10. Kobraei EM, Cauley R, Gadd M, et al. Avoiding Breast Animation Deformity with Pectoralis-Sparing Subcutaneous Direct-to-Implant Breast Reconstruction. Plast Reconstr Surg Glob Open 2016;4:e708.
11. Campbell CA, Losken A. Understanding the Evidence and Improving Outcomes with Implant-Based Prepectoral Breast Reconstruction. Plast Reconstr Surg 2021;148:437e-50e.
12. Sbitany H. Important Considerations for Performing Prepectoral Breast Reconstruction. Plast Reconstr Surg 2017;140:7S-13S.
13. Reitsamer R, Peintinger F. Prepectoral implant placement and complete coverage with porcine acellular dermal matrix: a new technique for direct-to-implant breast reconstruction after nipple-sparing mastectomy. J Plast Reconstr Aesthet Surg 2015;68:162-7.
14. Vidya R, Berna G, Sbitany H, et al. Prepectoral implant-based breast reconstruction: a joint consensus guide from UK, European and USA breast and plastic reconstructive surgeons. Ecancermedicalscience 2019;13:927.
15. Avila A, Bartholomew AJ, Sosin M, et al. Acute Postoperative Complications in Prepectoral versus Subpectoral Reconstruction following Nipple-Sparing Mastectomy. Plast Reconstr Surg 2020;146:715e-20e.
16. Ching AH, Lim K, Sze PW, et al. Quality of life, pain of prepectoral and subpectoral implant-based breast reconstruction with a discussion on cost: A systematic review and meta-analysis. J Plast Reconstr Aesthet Surg 2022;75:2550-60.
17. Garcia-Etienne CA, Cody Iii HS 3rd, Disa JJ, et al. Nipple-sparing mastectomy: initial experience at the Memorial Sloan-Kettering Cancer Center and a comprehensive review of literature. Breast J 2009;15:440-9.
18. Wijayanayagam A, Kumar AS, Foster RD, et al. Optimizing the total skin-sparing mastectomy. Arch Surg 2008;143:38-45; discussion 45.
19. Antony AK, Poirier J, Madrigrano A, et al. Evolution of the Surgical Technique for "Breast in a Day" Direct-to-Implant Breast Reconstruction: Transitioning from Dual-Plane to Prepectoral Implant Placement. Plast Reconstr Surg 2019;143:1547-56.
20. Belmonte BM, Campbell CA. Safety Profile and

© Gland Surgery. All rights reserved.

Predictors of Aesthetic Outcomes After Prepectoral Breast Reconstruction With Meshed Acellular Dermal Matrix. Ann Plast Surg 2021;86:S585-92.
21. Chun YS, Verma K, Rosen H, et al. Implant-based breast reconstruction using acellular dermal matrix and the risk of postoperative complications. Plast Reconstr Surg 2010;125:429-36.
22. Fin A, De Biasio F, Mura S, et al. Prepectoral Implant-Based Breast Reconstruction Using Meshed ADM. Plast Surg (Oakv) 2021;29:81-7.
23. Ganesh Kumar N, Berlin NL, Kim HM, et al. Development of an evidence-based approach to the use of acellular dermal matrix in immediate expander-implant-based breast reconstruction. J Plast Reconstr Aesthet Surg 2021;74:30-40.
24. Hong HK, Kim YH, Lee JS, et al. Prepectoral breast reconstruction with complete anterior implant coverage using a single, large, square-shaped acellular dermal matrix. BMC Surg 2022;22:234.
25. Jun D, Kim JK, Kwon BY, et al. Tissue Expansion after Non-Skin-Sparing Mastectomy: A Comparative Study of Expansion Courses of Prepectoral and Subpectoral Tissue Expander Placement with Acellular Dermal Matrix. J Clin Med 2021;10:4502.
26. Khalil HH, Malahias MN, Youssif S, et al. Nipple-Sparing Mastectomy and Prepectoral Implant/Acellular Dermal Matrix Wrap Reconstruction in Large Ptotic Breasts. Plast Reconstr Surg Glob Open 2019;7:e2289.
27. Luo J, Willis RN Jr, Ohlsen SM, et al. Meshed Acellular Dermal Matrix for Two-Staged Prepectoral Breast Reconstruction: An Institutional Experience. Arch Plast Surg 2022;49:166-73.
28. Manrique OJ, Huang TC, Martinez-Jorge J, et al. Prepectoral Two-Stage Implant-Based Breast Reconstruction with and without Acellular Dermal Matrix: Do We See a Difference? Plast Reconstr Surg 2020;145:263e-72e.
29. Reitsamer R, Peintinger F, Klaassen-Federspiel F, et al. Prepectoral direct-to-implant breast reconstruction with complete ADM or synthetic mesh coverage - 36-Months follow-up in 200 reconstructed breasts. Breast 2019;48:32-7.
30. Rathat G, Herlin C, Bonnel C, et al. Endoscopic Nipple-Sparing Mastectomy with Immediate Prepectoral Implant-Based Reconstruction: A Case Report. Am J Case Rep 2019;20:1812-6.
31. Regnault P. Breast ptosis. Definition and treatment. Clin Plast Surg 1976;3:193-203.
32. Margulies IG, Salzberg CA. The use of acellular dermal matrix in breast reconstruction: evolution of techniques over 2 decades. Gland Surg 2019;8:3-10.
33. Falk MW, Kullab RB, Lau A, et al. The association between rare complications and the use of acellular dermal matrix in patients undergoing implant-based breast reconstruction. J Plast Reconstr Aesthet Surg 2024;90:101-2.
34. Kilmer LH, Challa S, Stranix JT, et al. Case-matched Comparison of Implant-based Breast Reconstruction with and without Acellular Dermal Matrix. Plast Reconstr Surg Glob Open 2024;12:e5660.
35. Ng TP, Loo BYK, Yong N, et al. Review: Implant-Based Breast Reconstruction After Mastectomy for Breast Cancer: A Meta-analysis of Randomized Controlled Trials and Prospective Studies Comparing Use of Acellular Dermal Matrix (ADM) Versus Without ADM. Ann Surg Oncol 2024;31:3366-76.
36. Bassetto F, Pandis L, Azzena GP, et al. Complete Implant Wrapping with Porcine-Derived Acellular Dermal Matrix for the Treatment of Capsular Contracture in Breast Reconstruction: A Case-Control Study. Aesthetic Plast Surg 2022;46:1575-84.
37. Driscoll CR, Prabhu SS, Davidson AL, et al. Quantity of Acellular Dermal Matrix in Immediate Breast Reconstruction and Outcomes. Ann Plast Surg 2022;88:S410-3.
38. Ellsworth WA 4th, Hammer J, Luo L, et al. Acellular Dermal Matrices in Breast Reconstruction: CARE Trial 5-Year Outcomes Data for More Than 9500 Patients. Plast Reconstr Surg Glob Open 2022;10:e4258.
39. Caputo GG, Mura S, Albanese R, et al. Seroma Formation in Pre-pectoral Implant-Based ADM Assisted Breast Reconstruction: A Comprehensive Review of Current Literature. Chirurgia (Bucur) 2021;116:16-23.
40. Cogliandro A, Barone M, Tenna S, et al. The Role of Lipofilling After Breast Reconstruction: Evaluation of Outcomes and Patient Satisfaction with BREAST-Q. Aesthetic Plast Surg 2017;41:1325-31.
41. Gronovich Y, Winder G, Maisel-Lotan A, et al. Hybrid Prepectoral Direct-to-Implant and Autologous Fat Graft Simultaneously in Immediate Breast Reconstruction: A Single Surgeon's Experience with 25 Breasts in 15 Consecutive Cases. Plast Reconstr Surg 2022;149:386e-91e.
42. Urban C, González E, Fornazari A, et al. Prepectoral Direct-to-Implant Breast Reconstruction without Placement of Acellular Dermal Matrix or Mesh after

© Gland Surgery. All rights reserved.

Nipple-Sparing Mastectomy. Plast Reconstr Surg 2022;150:973-83.
43. Antony AK, McCarthy CM, Cordeiro PG, et al. Acellular human dermis implantation in 153 immediate two-stage tissue expander breast reconstructions: determining the incidence and significant predictors of complications. Plast Reconstr Surg 2010;125:1606-14.
44. Wilson RL, Kirwan CC, O'Donoghue JM, et al. BROWSE: A multicentre comparison of nine year outcomes in acellular dermal matrix based and complete submuscular implant-based immediate breast reconstruction-aesthetics, capsular contracture and patient reported outcomes. Eur J Surg Oncol 2022;48:73-81.

Cite this article as: Bushong EE, Wesely N, Komorowska-Timek E. To acellular dermal matrix or not to acellular dermal matrix?—outcomes of pre-pectoral prosthetic reconstruction after nipple-sparing mastectomy with and without acellular dermal matrix. Gland Surg 2024;13(6):885-896. doi: 10.21037/gs-24-23

© Gland Surgery. All rights reserved.