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The Evolution from Subcutaneous to Prepectoral Prosthetic Breast Reconstruction

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ABSTRACT: Prosthetic breast reconstruction is the most common method of reconstruction offered to women following mastectomy. Prepectoral breast reconstruction has recently reemerged as an alternative technique to the partial and total muscle coverage methods. Though this technique has been demonstrated to be safe and effective in the recent published literature, many surgeons have been hesitant to adopt it out of fear of incurring the same complications associated with subcutaneous reconstructions of the past. However, recent advancements in plastic surgery including the use of acellular dermal matrices, autologous fat grafting, and improved breast implants and improved mastectomy techniques have enabled plastic surgeons to revisit the prepectoral space. In this review, the authors describe the evolution of prosthetic-based breast reconstruction from subcutaneous to prepectoral and review outcomes. *(Plast Reconstr Surg Glob Open 2018;6:e1797; doi: 10.1097/GOX.0000000000001797; Published online 11 June 2018.)*

INTRODUCTION

Breast reconstruction with prosthetic devices remains the most popular option following mastectomy.[1] Refinements in tumor treatment, mastectomy techniques, and reconstructive protocols have further broadened the indications for implant-based reconstructions. Rates of prosthetic reconstruction have increased in patients who were previously deemed to be high risk with comorbidities such as diabetes mellitus, advanced stage cancer, obesity, and prior radiotherapy.[2] This fact can be attributed to a variety of factors such as improved newer generation silicone implants, the popularity and success of neoadjuvant chemotherapy, and developing mastectomy flaps containing the identified layer of subcutaneous tissue between the dermis and breast epithelium.[3–6] As the indications for prosthetic-based reconstructions expand, reconstructive surgeons continue to develop new methods to improve upon adverse events, patient outcomes, and satisfaction. The evolution of prosthetic breast reconstruction has come full circle with its origins in the subcutaneous plane to its present-day prepectoral approach. Each technique aims to decrease pain, prevent animation deformity, and increase the projection and natural ptosis of the reconstruction. This article will highlight many of the advancements from an oncological and reconstructive perspective as we embark on this new paradigm.

SUBCUTANEOUS BREAST RECONSTRUCTION

The earliest descriptions of implant-based reconstructions were performed following subcutaneous mastectomy for benign disease in which a sufficient soft-tissue envelope was maintained.[7] Subcutaneous reconstruction for malignant disease was later performed following radical mastectomy. Breast implants at that time were created with a thin shell and soft silicone gel and were prone to failure.[8] Early studies following radical mastectomy and subcutaneous placement of implants demonstrated a 26% (13/50) and 31% (12/39) failure rate following immediate and delayed reconstruction, respectively. Nahai and Bostwick[9] noted that "The problems of capsular contracture, implant exposure, and malposition of the mound… are seen commonly with subcutaneous placement of the implant…"[9]

TRANSITION TO SUBMUSCULAR PLANE

With the advent of the modified radical mastectomy and preservation of the pectoralis major muscle, submuscular breast reconstruction provided an extra layer of tis-

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sue for implant coverage. The original description of a total submuscular coverage, including partial elevation of the serratus anterior muscle was in 1981.[10] In a review of 91 breast reconstructions, comparing 30 subcutaneous, 19 purely subpectoral, and 42 subserratus reconstructions, a 47% incidence of malposition for subcutaneous and prepectoral reconstructions, but only 19% for subserratus reconstructions was demonstrated.[11] The introduction of the Radovan tissue expander in 1985 facilitated the process of prosthetic reconstruction.[12] In their initial manuscript, all devices were placed in the subcutaneous or prepectoral position.

These early advancements were effective and improved outcomes; however, they did not alleviate all problems associated with subcutaneous implant placement such as capsular contracture. In a review of 76 patients following mastectomy with subcutaneous reconstruction, acute complications were noted in 39% of immediate and 16% following delayed reconstruction. Capsular contracture was demonstrated in 50% of submuscular and 100% of subcutaneous reconstructions.[13] Subsequent comparisons of submuscular and subcutaneous reconstruction demonstrated capsular contracture rates of 55% and 58%, respectively.[14]

ACELLULAR DERMAL MATRICES

The introduction of acellular dermal matrices (ADM) into the realm of breast reconstruction has produced a major paradigm shift.[15] Benefits of ADM include soft-tissue support, compartmentalization of implants, and control of the inferior position of the pectoralis major muscle during dual plane reconstruction.[16] The ability of ADM to improve aesthetic outcomes was demonstrated by Ibrahim et al.[17] in a review of 18 reconstructions with ADM and 20 without. Reconstructions incorporating ADM scored significantly higher in the categories of contour, implant placement, and in total aesthetic score.[17] Forsberg et al.[18] analyzed aesthetic outcomes in 183 implant-based breast reconstructions (58 with ADM, 125 total submuscular) demonstrating improved aesthetic outcomes with respect to, shape, symmetry, and overall outcome with the exception of contour and position.[18] Salzberg et al.[19] in a review of 1,584 reconstructions in 863 patients, demonstrated a grade 3/4 capsular contracture rate of 0.8% (12/1,584) at a mean follow-up of 4.7 years.[19] In a recent meta-analysis of 15 studies using ADM, the rate of grade 3–4 capsular contracture ranged from 0% to 3.8%.[20]

Complications associated with ADM use are well studied and established. Chun et al.[21] compared 269 submuscular reconstructions utilizing ADM and 146 reconstructions without ADM and demonstrated that the only statistically significant increase was for postoperative seroma with ADM use.[21] Vardanian et al.[22] compared 337 immediate implant-based reconstructions, of which 208 breasts had ADM and 129 did not, demonstrating no statistically significant increases in seroma, infection, dehiscence, or wound healing.[22] In a meta-analysis of all articles providing outcomes of breast reconstructions with (2,037) and without (12,867) ADM, Kim et al.[23] demonstrated no statistically significant difference in complications between the ADM and non-ADM cohorts. The overall complication rate was 15.4% versus 14.0%, seroma rate was 4.8% versus 3.5%, and infection rate was 5.3% versus 4.7%.[23]

MODERN PREPECTORAL BREAST RECONSTRUCTION

The modern era of prepectoral breast reconstruction differs in many ways from the subcutaneous reconstructions of old. Improvements in mastectomy techniques and outcomes have paralleled advancements in the field of plastic surgery. An increase in the propensity of many women, especially younger women, to elect for prophylactic mastectomy has allowed for better quality skin flaps during resection and a resurgence of prepectoral prosthetic reconstruction. The "prepectoral" space lies in the subcutaneous plane, but refers specifically to reconstruction utilizing modern techniques and devices.

Prepectoral reconstruction can be performed in 1 or 2 stages. Reported outcomes are similar for both methods with rates of capsular contracture, implant malposition, and rippling generally being less than 5%.[24,25] Caution and proper patient selection must be strictly adhered to with 1-stage prepectoral reconstruction; otherwise, device removal may be more likely.[26] Consideration for 1-stage requires optimal perfusion and thickness of the mastectomy skin flaps, whereas for 2 stage depends primarily on optimal perfusion. Excessive pressure on the mastectomy skin flaps associated with prefilled implants can result in skin flap necrosis and reconstructive failure. Strategies to offload pressure include the use of tissue expanders that are partially filled wit air rather than saline to avoid dependent pressure when standing and because air is evenly distributed within the tissue expander.

Prepectoral Reconstruction without Soft-tissue Support

Prepectoral breast reconstruction can be performed with or without additional soft-tissue support (Table 1). In a recent study of 107 women with prepectoral saline implants without ADM, the overall rate of implant failure was 5.6% (6/107), and the rate of capsular contracture was 20.6%.[27] In a similar study of 155 patients and 250

Table 1. Prepectoral Breast Reconstruction Not Utilizing Soft-tissue Support

Authors	No. Patients/ Breasts	Capsular Contracture (Grade III/IV) (%)	Explantation (%)	Rippling (%)	Skin Necrosis (%)	Infection (%)
Schlenker et al.[39]	89	56	28	NR	13.5	13.5
Radovan[12]	68/NR	12	5.9	NR	2.9	7
Benediktsson and Perbeck[27]	107/107	20.7	NR	NR	NR	NR
Eskenazi[40]	322/NR	19	2.2	NR	9	2.1
Salibian et al.[28]	155/250	7.6	6.8	3.6	6.8	2.4

NR, not reported.

breasts following nipple-sparing mastectomy and prepectoral tissue expander reconstruction without ADM, the rate of implant failure was 6.8%, and the rate of capsular contracture was 7.6%.[28] These studies highlight the ongoing problem of capsular contracture despite the technical feasibility of prepectoral reconstruction.

Prepectoral Breast Reconstruction with Non-ADM Soft-tissue Support

In an attempt to further improve outcomes, surgeons have used adjunct materials to provide additional soft-tissue support (Table 2). Kobraei et al.[29] performed 23 reconstructions in 13 patients utilizing a prepectoral sling made of Vicryl mesh, which was reinforced with ADM in 3 cases. No cases of capsular contracture were identified, and all other complications were reported within acceptable limits at 10-month follow-up.[29] In a direct-to-implant study comparing reconstruction with a prepectoral titanium mesh wrap (n = 39) to subpectoral titanium sling (n = 34), there was only 1 implant failure in the prepectoral cohort. There were no significant differences between the 2 groups with any complication, including infection, implant loss, skin necrosis, hematoma, or reoperation at 1-year follow-up.[30] Two-year follow-up demonstrated no capsular contracture in the prepectoral cohort and 12% in the partial subpectoral cohort.[31] In a similarly designed tissue expander study using the same titanium mesh, the rate of implant loss was 0%, infection was 12%, and hematoma was 4%.[32] To the authors' knowledge, titanium mesh is not approved for use in breast reconstruction in the United States. These non-ADM adjuncts have demonstrated success with prepectoral breast reconstruction.

Prepectoral Reconstruction with ADMs

ADM is the most common material used for prepectoral breast reconstruction and can be applied with a partial or circumferential lining of the mastectomy pocket. In general, the preferred thickness of ADM is 2–3 mm; however, 1–2 mm thickness can also be used. Becker et al.[33] using an adjustable saline implant in the prepectoral space lined with Flex HD in 52 breasts (Musculoskeletal Transplant Foundation, Edison, N.J.) or vicryl in 10 breasts demonstrated high patient satisfaction and low complications that included a seroma (1/62, 1.6%), implant loss (2/62, 3.2%), and capsular contracture (2/62, 3.6%).[33] Caputo et al.[34] utilized wise pattern skin resection with an inferior dermal sling and a superior lining that consisted of a porcine ADM (Native; MBP, Neustadt-Glewe, Germany). After a mean follow-up of 14.7 months, there was no implant loss and no capsular contracture.[34] Reitsamer and Peintinger[35] utilized another porcine ADM, Strattice (LifeCell Corporation, Bridgewater, N.J.) to perform a complete wrap of the prepectoral implant in 13 patients (22 breasts). Six-month follow-up demonstrated 1 hematoma and no capsular contractures.[35] Figures 1–6 illustrate a patient following nipple-sparing mastectomy followed by immediate 2-stage prepectoral prosthetic breast reconstruction.

Several European studies have utilized a porcine ADM, Braxon (MBP, Neustadt-Glewe, Germany) for prepectoral implant reconstruction (Table 3). Berna et al.[36] used Brax-

Table 2. Prepectoral Breast Reconstruction Utilizing Non-ADM Soft-tissue Support

Author	No. Patients/ No. Breasts	Mastectomy Type	Body Mass Index	Type of Mesh	Follow-up	Type of Reconstruction	Complications	Revisions	Outcomes
Kobraei et al.[29]	13/23	SSM (5 pts); NSM (8 pts)	28 (Mean)	Vicryl (23 breasts); ADM (3 breasts)	10 mo (Mean)	Direct-to-implant	Caps Cont: 0; seroma: 3; infection: 1; explant: 0; rippling: 1; skin necrosis: NR	0	Satisfied
Bernini et al.[31]	34/39	SSM (3 breasts); NSM (36 breasts)	23 (Median)	Titanium mesh	25 mo (Median)	Direct-to-implant	Caps Cont: 0; seroma: 0; infection: 0; explant: 2; rippling: 3; skin necrosis: 1	6	91% "Excellent Aesthetic Outcome"
Casella et al.[32]	25/25	SSM (13 breasts); NSM (12 breasts)	22 (Median)	Titanium mesh	14 mo (Median)	Tissue expander/ implant	Caps Cont: NR; seroma: 0; infection: 4 (3 with TE; 1 with exchange); explant: 0; rippling: NR; skin necrosis: 1 (at first stage only)	5 (All at first stage)	Mean score BREAST-Q 99/100 satisfaction with outcome

MBP, medical biomaterial products; NR, not reported; NSM, nipple-sparing mastectomy; SSM, skin-sparing mastectomy; TE, tissue expander.

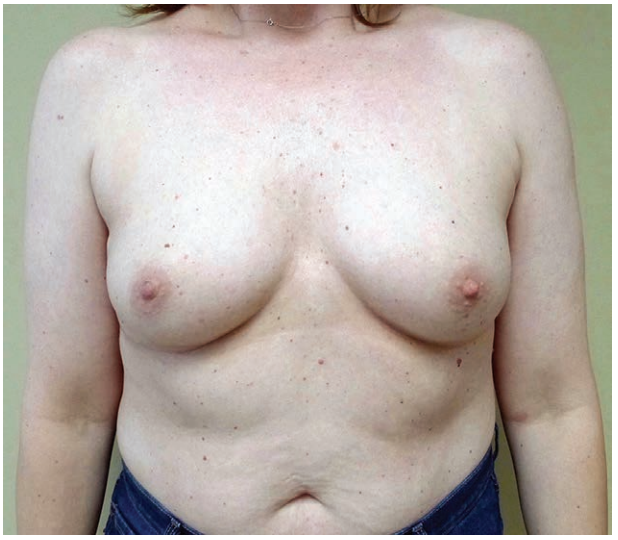

Fig. 1. Preoperative picture of a patient scheduled for nipple-sparing mastectomy and prepectoral breast reconstruction with a tissue expander followed by a permanent implant. Patient has Grade 1 ptosis, moderate size breasts, and good skin quality.

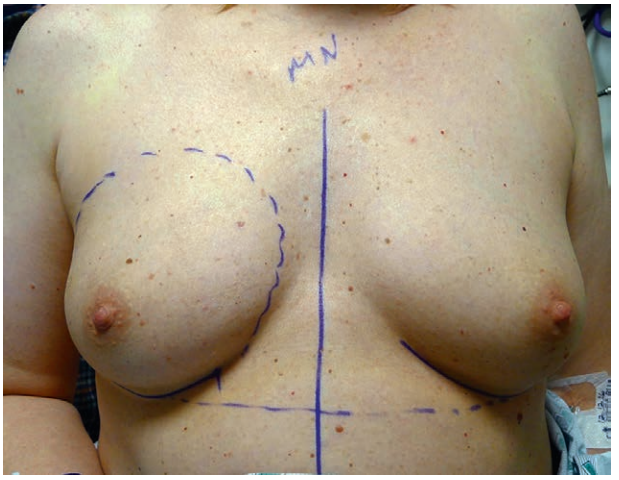

Fig. 2. Preoperative markings before prepectoral breast reconstruction. Markings include the inframammary fold, midline, and superior pole of the breast.

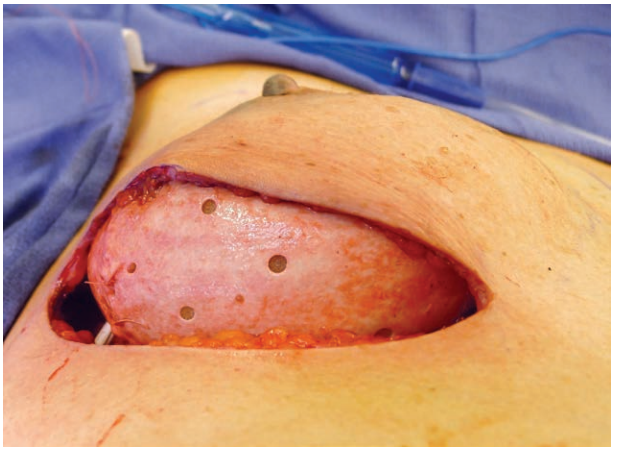

Fig. 3. Intraoperative view of prepectoral breast reconstruction. Note the fenestrated ADM wrapped tightly around the tissue expander.

Fig. 4. The patient has completed expansion. Preoperative photograph before exchange of tissue expander for permanent implant. Markings are the same as for tissue expander placement.

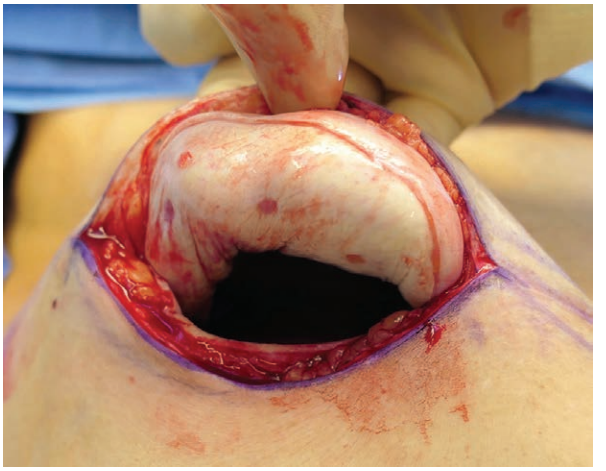

Fig. 5. Intraoperative view of the implant pocket during the exchange of tissue expander to permanent implant. Note the complete incorporation of the ADM.

Fig. 6. Postoperative photograph of the patient following exchange of expanders for permanent implants. She has appropriate size match, ptosis, and nipple position.

Table 3. Prepectoral Breast Reconstruction Utilizing Porcine ADM

Author	No. Patients/ No. Breasts	Mastectomy Type	Body Mass Index	Type of Mesh	Follow-up	Type of Reconstruction	Complications	Revisions	Outcomes
Berna et al.[36]	19/25	SSM, NSM (Qty NR)	25.4 (Mean)	Braxon 0.9 mm (10) 0.6 mm (15)	14 mo (Mean)	Direct-to-implant	Caps Cont: 0; seroma: 4; infection: 1; explant: 3; rippling: 0; skin necrosis: NR	NR (2 cases were revisions)	"Symmetrical and natural breasts with good shape, ptosis, and softness to the touch"
Reitsamer and Peintinger[35]	13/22	NSM	NR	Strattice 8×16 cm sheets × 2	6 mo (Median)	Direct-to-implant	Caps Cont: 0 (III or IV); seroma: NR; infection: NR; explant: NR; rippling: 0; skin necrosis: (nipple) 2	NR	"Cosmetic results were excellent" Patient satisfaction "excellent"
Caputo et al.[34]	27/33	Skin-reduction	NR	Native by MBP	14.7 mos (median)	Direct-to-implant	Caps Cont: NR; seroma: NR; infection: 0; explant: 0; rippling: NR; skin necrosis: 3	NR	"Good results in terms of aesthetics, effectiveness, manageability, and hospitalization"
Vidya et al.[37]	79/100	SSM, NSM (Qty NR)	24.4 (Mean)	Braxon 0.6 mm	17.9 mo (Mean)	Direct-to-implant	Caps Cont: NR; seroma: 5; infection: 0; explant: 2; rippling: 0; skin necrosis: 1 (nipple)	NR	"Esthetic results in terms of symmetry, shape, and ptosis was highly satisfactory"
Onesti et al.[38]	52/64	SSM	25 (Mean)	Braxon 0.6 mm	"Up to 24 months"	Direct-to-implant	Caps Cont: I: 28; II: 24; III/IV: 0; seroma: 0; infection: 1; explant: 2; rippling: NR; skin necrosis: NR	3	VAS scale: patients: 9 (mean); Physicians: high (6–10): 41, moderate (2–5): 11 EORTC C-30 and BR-23 questionnaires: "excellent results in terms of global health status, functioning domains, and symptoms" "Complete integration of the matrix" on histology and ultrasound

NR, not reported; NSM, nipple-sparing mastectomy; SSM, skin-sparing mastectomy; TE, tissue expander.

on in 25 patients demonstrating a seroma rate of 20%, of which 12% required explantation with the remaining 8% being managed conservatively.[36] Vidya et al.[37] conducted a multicenter trial of 100 patients utilizing Braxon mesh for prepectoral reconstruction with a low complications that included seroma (5%), implant loss (2%), and no infection.[37] Onesti et al.[38] reported on 64 direct-to-implant reconstructions utilizing Braxon with a 3.1% incidence of explantation. Serial ultrasound examination revealed an initial fluid layer between the ADM and the implant and the ADM and the skin flap that resolved by 12 months in all patients.[38]

The most widely used ADM for breast reconstruction in the United States is Alloderm (LifeCell Corporation, Bridgewater, N.J.). Down and Hedges[26] performed 79 prepectoral direct-to-implant reconstructions in 45 patients utilizing an Alloderm wrap. Complications included implant loss in 17.7% (11 due to skin necrosis, 3 due to infection) and capsular contracture in 10.1%.[26] Sigalove et al.[24] performed 353 reconstructions in 207 patients utilizing Alloderm for total implant coverage. Complications included infection in 4.5%, seroma in 2%, skin necrosis in 2.5%, and no clinically significant capsular contracture at 6- to 26-month follow-up. Contraindications to prepectoral reconstruction included a body mass index > 40, poor quality mastectomy flaps, active smokers, or those patients with deep tumors[24] (Table 4).

INCORPORATING PREPECTORAL BREAST RECONSTRUCTION

Patient selection is arguably the most important criteria for prepectoral breast reconstruction. Contraindications include poorly controlled diabetes mellitus, active tobacco use, and chronic immunosuppression. Increased risk is associated with prior radiation and morbid obesity. Determinants of success include well-perfused mastectomy skin flaps without visible dermis. Intraoperatively, skin flaps should be assessed clinically and when possible, intraoperative fluorescent angiography. If the flaps cannot be excised and closed without significant tension, the reconstruction should be delayed or converted to another reconstructive method.

ADMs are commonly utilized in the setting of prepectoral reconstruction to increase the soft-tissue support and provide optimal implant position and pocket control. The ADM should cover at least the entire anterior surface of the implant, but can be wrapped to include ADM on its posterior surface. ADM fenestration can improve incorporation and reduce fluid accumulation.

Postoperative care does not differ substantially from other forms of implant-based breast reconstruction. Antibiotic use is at the discretion of the surgeon. Patients should be followed closely for delayed healing or mastectomy flap skin necrosis. Areas of necrosis should be excised and closed immediately. Drain use is recommended for all patients with removal based on output and time. Expansion may be started within 3 weeks of implant placement, provided there are no issues with wound healing. Fat grafting is an important adjunct to prepectoral recon-

Table 4. Prepectoral Breast Reconstruction Utilizing Human ADM

Authors	No. Patients/ No. Breasts	Mastectomy Type	Body Mass Index	Type of Mesh	Follow-up	Type of Reconstruction	Complications	Revisions	Outcomes
Becker et al.[33]	31/62	Vertical SSM or NSM (NR)	NR	Vicryl (10 breasts) FlexHD (52 breasts)	2 y (Mean)	Direct-to-implant	Caps Cont: 2 (vicryl); seroma: 1; infection: 1; explant: 2; rippling: NR; skin necrosis: 3	13 Saline to silicone: 9; fat graft: 4	Cosmesis "excellent"
Downs and Hedges[26]	45/79	NSM	24.3 (Mean)	AlloDerm (69%); FlexHD (31%)	23.1 mo (Mean)	Direct-to-implant	Caps Cont: 8; seroma: 12; infection: 8; explant: 14; rippling: 28; skin necrosis: 22	Fat graft: 60–70%	Cosmesis "excellent" Patients "satisfied"
Sigalove et al.[24]	207/353	SSM (NR); NSM (NR)	22–39	AlloDerm	6–26 mo	Direct-to-implant: 23/46; immediate two-stage: 177/293; delayed two-stage: 7/14	Caps Cont: 0; seroma: 7; infection: 16; explant: NR; rippling: NR; skin necrosis: 9	"Fat grafting … at the second and/or the third stage"	"Aesthetically pleasing and predictable"
Woo et al.[41]	29/135	SSM (NR); NSM (NR)	26.9 (Mean)	AlloDerm	10 mo (Mean)	Direct-to-implant (10%); two-stage with expanders: (85%); two-stage expander then autologous (5%)	Caps Cont: NR; seroma: 2; infection: 3; explant: 3; rippling: NR; skin necrosis: none requiring surgical intervention	NR	Overall postoperative aesthetic score: 2.95/4; comparison of preoperative and postoperative aesthetics: 95% similar or improved, 5% poorer

NR, not reported; NSM, nipple-sparing mastectomy; SSM, skin-sparing mastectomy; TE, tissue expander.

structions. Fat grafting donor sites should be assessed at the initial consultation and a treatment plan should be formulated at that time.

CONCLUSIONS

Implant-based breast reconstruction continues to be the primary type of reconstruction offered by plastic surgeons. Early experience with subcutaneous reconstruction was fraught with reconstructive failure due to aggressive mastectomy and early generation implants that were prone to rupture and encapsulate. Prepectoral reconstruction is now possible based on the recent advancements in breast oncology and reconstruction. Skin and nipple-sparing mastectomy is considered safe and effective and has improved aesthetic outcomes. Accurate assessment of mastectomy skin flap perfusion is now possible and predictive of tissue survival. ADM has decreased the rate of capsular contracture and implant exposure without significantly increasing the risk for seroma, infection, or other untoward complications. Improvement in the quality of implants with regard to silicone gel cohesivity and shell durability have improved outcomes and decreased rippling and wrinkling. The use of autologous fat grafting has provided the ability to expand the thickness and enhance the quality of mastectomy skin flaps. We now reside in the era of the bioengineered breast, and prepectoral breast reconstruction represents a paradigm shift in our reconstructive algorithm. It is the hope of the authors that this technique will continue to be adopted, studied, and reported upon to further optimize the patient experience and surgical results.

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