Dual-Plane Tissue Expander Reconstruction With Acellular Dermal Matrix

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The utility of human acellular dermal matrices (ADMs) as a soft tissue replacement has been demonstrated in pelvic, abdominal, and chest wall reconstructions,[1-3] in hand surgery,[4] urethral reconstruction,[5] dural repair,[6] and in breast reconstruction.[7-20] Studies have also determined the efficacy and relative safety of human acellular dermis in breast reconstruction.[7-20]

More than 50,000 breast reconstructions using tissue expander implants are performed annually, accounting for approximately 60% of all postmastectomy breast reconstructions.[21] For these cases, an increasing number of surgeons are electing to use ADMs.[7-19] In 2005, Breuing and Warren[7] reported on the use of a human ADM in prosthetic breast reconstruction. Since then several authors, including Spear et al,[9] Salzberg,[10] Zienowicz and Karacaoglu,[11] Topol et al,[12] Bindingnavele et al,[13] Sbitany et al,[16] Chun et al,[17] and Losken,[19] have reported favorable outcome studies. Although some authors have reported increased complication rates, none have refuted the benefits of ADMs.[17]

By disinserting the pectoralis muscle and re-creating the lower pole with an ADM sling, surgeons can more precisely define the inframammary fold and place the expander to re-create the soft tissue shape of a normal, ptotic breast.[7-20] Furthermore, by producing a larger pocket that is not limited by the pectoralis muscle inferiorly, the ADM permits greater intraoperative tissue expander fill volumes. Early and rapid expansion may help improve the overall cosmetic outcome.[8,9,16]

ADM modification of traditional expander placement also allows significant acceleration of the overall expansion process—fewer postoperative expansions are necessary, because greater intraoperative volume fills are possible. Moreover, given sufficient skin excess, single-stage reconstructions are possible with direct implant placement.[10-12] The critical step in this new technique is the release of the pectoralis muscle and the re-creation of the lower pole with an ADM sling.[8] There are a number of biologic matrices available, and they are covered in The Science Behind Tissue Biologics in this issue. Direct comparative studies evaluating the efficacy of and differences among different ADMs are sparse.[18]

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PATIENT SELECTION

Patients who select reconstruction with a tissue expander should be informed of the possible use of a dual plane technique with ADM. A basic knowledge of the screening and sterilization processes used for the chosen ADM helps patients understand the nature of the material being used. Typically, patients with medium or large breasts benefit the most from intraoperative expansion, because excess skin can be used more aggressively when the pectoralis muscle is released. However, the final decision to use an ADM may depend on intraoperative factors: reasonably robust, vascularized mastectomy flaps are needed to avoid flap necrosis. If there is a possibility of radiation treatment postoperatively, patients can elect to have delayed autogenous reconstruction with a DIEP or TRAM flap. Controversy exists about the role of using a dual plane with an ADM in patients who will receive radiation therapy, because radiation therapy increases the complication rate.[20,22] However, in some patients this technique can achieve satisfactory results that may be difficult to achieve with a tissue expander alone. Ideal candidates include those receiving bilateral reconstructions, women receiving unilateral reconstructions who have small to moderate-sized breasts, and those who either have or desire contralateral augmentation. The ability to create a more natural ptosis with this approach has broadened the indications for expander/implant breast reconstruction.

TECHNIQUE

The inframammary fold is marked, and a modified skin-sparing periareolar incision is made. A key element to the mastectomy incision is limiting the vertical component of the defect. A vertically smaller incision preserves more skin, which allows more intraoperative fill.

By directing more of the incision in an oblique to horizontal direction, the surgeon can gain access to all quadrants of the breast (and the same surface area of exposure), while minimizing the vertical skin defect and maximizing the excess skin available for expansion.[23] For nipple-sparing mastectomies, lateral incisions are made that avoid the areolar border (Fig. 1). The perioareolar approach leads to a higher rate of nipple necrosis and should be avoided. An inframammary incision has the benefit of being cosmetically inconspicuous, but it can create exposure problems when performing mastectomies on patients with larger breasts.[24]

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Document Name: 04 Innov v2n1_r2_033-044

Once the skin excess and flap thickness are assessed and the surgeon decides to use the dual plane approach with an ADM, the ADM may be prepared. If it is prehydrated, the ADM can be rinsed in antibiotic solution; if it is freeze-dried, then the hydration sequence can be initiated. The pectoralis muscle is disinserted, and a 6 by 16 cm, thick piece of ADM is secured to the anatomic lower pole defect using 2-0 Vicryl® suture (Ethicon, Somerville, NJ) (Fig. 2).

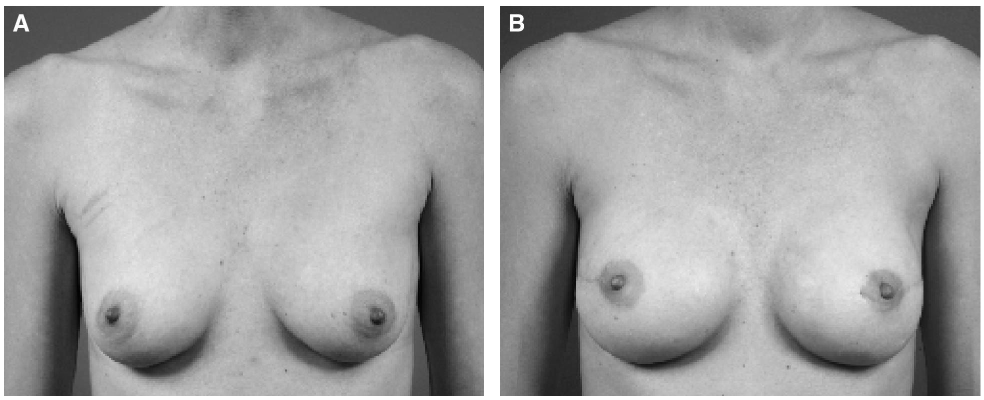

FIG. 1 This 33-year-old woman with BRCA-1 mutations underwent bilateral breast reconstruction with ADM following a nipple-sparing mastectomy with a lateral incision. **A,** Preoperative. **B,** Postoperative results at 11 months.

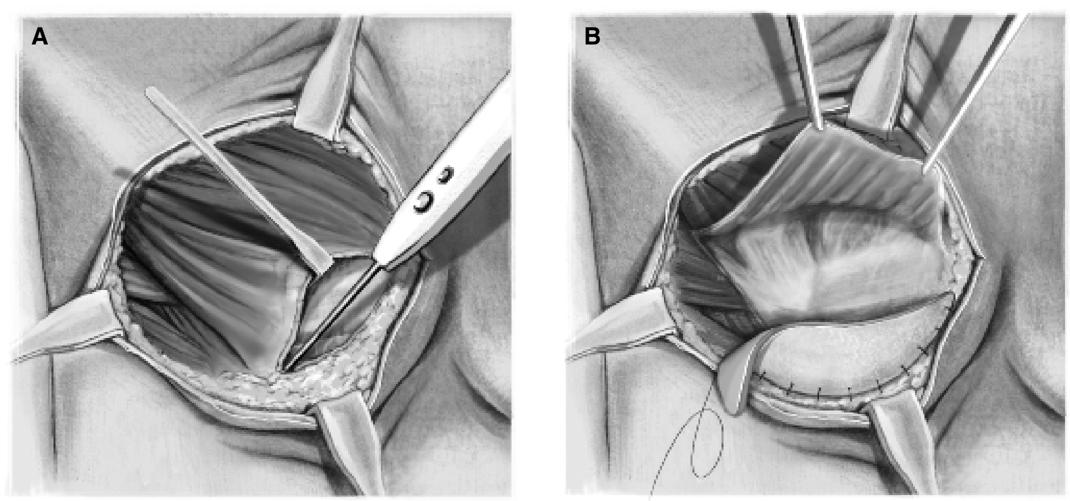

FIG. 2 **A,** The lower border of pectoralis major is disinserted with Bovie electrocautery. **B,** Intraoperative placement of prehydrated human ADM. Inferiorly, the ADM is secured to the chest wall to re-create the inframammary fold.

If the graft material has revascularization polarity, then care must be taken that the dermal side is in contact with the mastectomy skin flap to improve incorporation (the epidermal surface has relatively poor porosity compared with the dermal surface) (Fig. 3). Our preferred technique for attaching the ADM is to suture the lateral aspect to the serratus fascia. Concomitantly, the superolateral aspect of the expander is secured by shifting the lateral border of the pectoralis muscle to the serratus muscle. Careful suturing of the ADM to the fascia and muscle is critical, because folds or inversions can create granulomas.[25]

A tissue expander is placed in the submuscular and subgraft space (Fig. 4, *A*). Once the muscle and graft interface is secured, two 7 mm Clot Stop® drains (Axiom, Torrance, CA) are placed in the inferior space between the mastectomy flap and the graft and in the axillary and superior subcutaneous planes (Fig. 4, *B*; Fig. 5). The pocket and the implants are rinsed with antibiotic irrigation during the procedure. After complete muscle and graft coverage of the expander has been accomplished, the expander is judiciously inflated to the point where it takes up all skin excess but does not create tension on the skin closure. Postoperatively the drains remain in place until the output is less than 30 ml in 24 hours, which is typically after 7 to 10 days. If drainage of more than 30 ml in 24 hours persists beyond 21 days, the drain is removed because of the infection risk along the drain track. Routine perioperative antibiotic prophylaxis is given.

Serial expansion of the tissue expander is initiated after the incision has healed—typically at 2 to 3 weeks. The intervals between and the volumes of the expansions are determined per patient. After adjuvant therapy and tissue expansion are completed, second-stage reconstruction is performed to exchange the tissue expander for an implant, and procedures for contralateral symmetry are performed at the time if they were not performed initially.

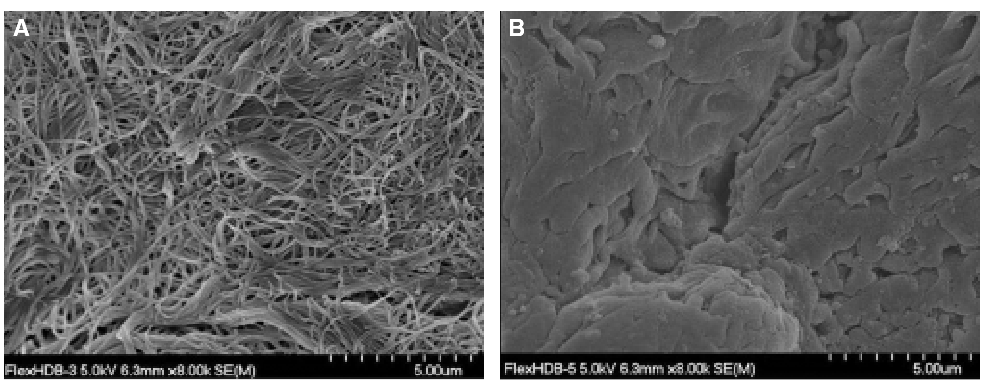

FIG. 3 Electron microscopic images of a prehydrated ADM graft. **A,** The dermal side is porous and promotes incorporation and vascularization. **B,** The epidermal side is less porous and presumably less able to revascularize.

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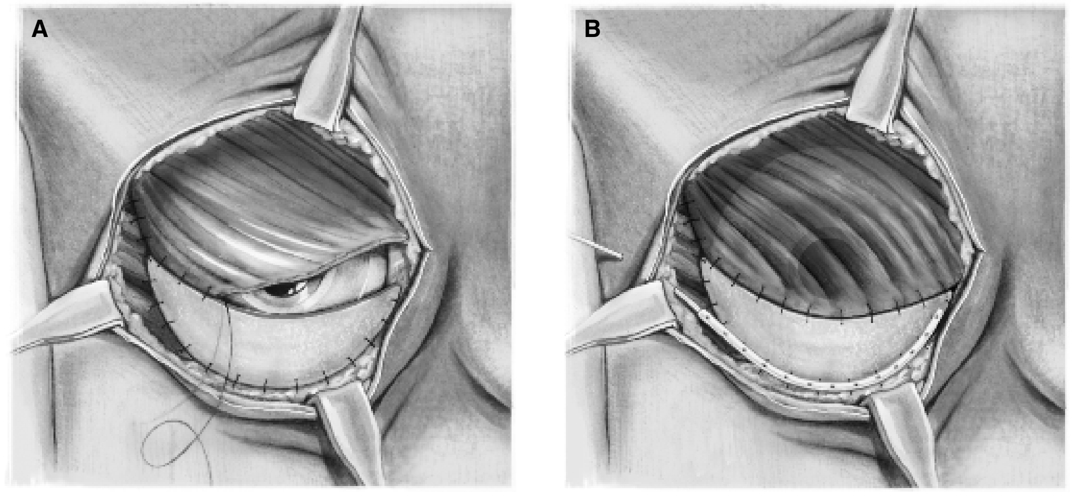

FIG. 4 **A,** Laterally, the prehydrated human ADM is secured directly to the serratus muscle to create the lateral portion of the mammary fold. The pectoralis major muscle is secured inferiorly to the ADM and laterally to the serratus muscle to provide complete coverage of the expander or implant. **B,** The tissue expander is placed in the submuscular and subgraft plane, and the opposing muscle and graft are secured with suture. A drain is placed in the space between the graft and the mastectomy flaps. Another drain (not shown) is placed in the axillary and superior subcutaneous plane.

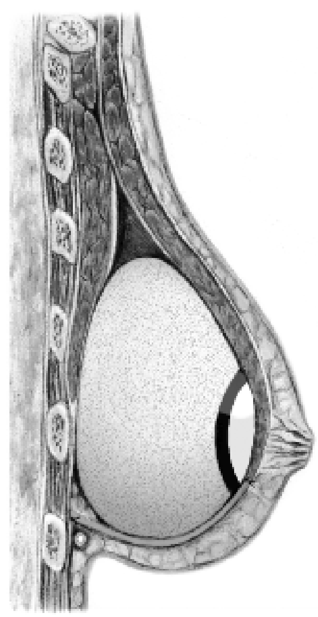

FIG. 5 Expander beneath the muscle and dermal matrix graft.

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OUTCOMES

We recently reviewed 170 reconstructions using the dual-plane technique with a tissue expander and an ADM, and we analyzed results from 121 completed reconstructions (after the second stage). The mean age of patients at the time of the first stage of reconstruction was 50.2 years (range 26-81 years). Forty-seven patients (56%) received unilateral reconstruction, and 37 (44%) received bilateral reconstruction. Therapeutic mastectomies were performed on 90 breasts (74.4%). Prophylactic mastectomies were performed on 31 breasts (25.6%). Nipple-sparing mastectomies were performed on 10 breasts (8.3%). Neoadjuvant radiation therapy was performed on 3 breasts (2.5%), and adjuvant radiation therapy was performed on 23 breasts (19%) between the first- and second-stage reconstructive procedures. Forty-nine patients (58.3%) received chemotherapy. Mean follow-up time after the second-stage expander-implant exchange was 44 weeks (SD 26.5). Mean initial intraoperative tissue expander fill volume was 256.6 ml (SD 133), resulting in a mean intraoperative fill percentage of 60% final volume. The mean number of expansions was 3.2 for all patients. Twenty-four patients (28.5%) in the unilateral cohort also underwent a procedure on the contralateral breast for symmetry.

Overall, complications occurred in 20 breasts (16.5%) (Table 1). There were 9 soft tissue infections (7.4%), 8 partial mastectomy flap necroses (6.6%), 2 seromas (1.7%), 8 implant exposures (6.6%), and no hematomas. Eleven expanders (9.1%) ultimately required removal. Five of these patients received a salvage procedure using a pedicled latissimus dorsi flap.

Although the patients who received radiation therapy demonstrated a trend toward more complications, this trend did not reach statistical significance (see Table 1). The overall incidence of complications after radiation therapy was 30.8%, compared with 13.7% when radiation therapy was not provided ($p = 0.0749$). When considering complications individually, radiation therapy did not significantly increase the incidence of seromas (0.0% versus 2.1%, $p = 0.999$) or soft tissue infection (11.5% versus 6.3%, $p = 0.402$), however, there was a trend toward more mastectomy flap necrosis (15.4% versus 5.2%, $p = 0.098$) and wound dehiscence and implant exposure (15.3% versus 4.2%, $p = 0.064$).

TABLE 1 Complication Rates in 121 Consecutive Prosthetic Breast Reconstructions With Prehydrated Human ADM, According to Radiation Therapy

	No Radiation Therapy n = 95	Radiation Therapy n = 26	Total n = 121	*p* Value
Overall Complications	13.7%	30.7%	16.5%	0.0749
Soft Tissue Infection	6.3%	11.5%	7.4%	0.402
Flap Necrosis	5.3%	15.4%	6.6%	0.098
Seroma	2.1%	0.0%	1.7%	0.999
Exposure	4.2%	15.4%	6.6%	0.064
Explantation	8.4%	7.7%	9.1%	0.6790

Histologic analysis of tissue samples obtained during second-stage reconstruction revealed evidence of robust revascularization and incorporation of the ADM into native soft tissues. Clear differences in collagen staining density were apparent between the ADM and surrounding soft tissues (presumably from the collagen of a forming capsule). No foreign body giant cell reactions were noted (Fig. 6). Neovascularization was confirmed by immunohistologic staining against CD31 and CD34 endothelial cell markers (Fig. 7).

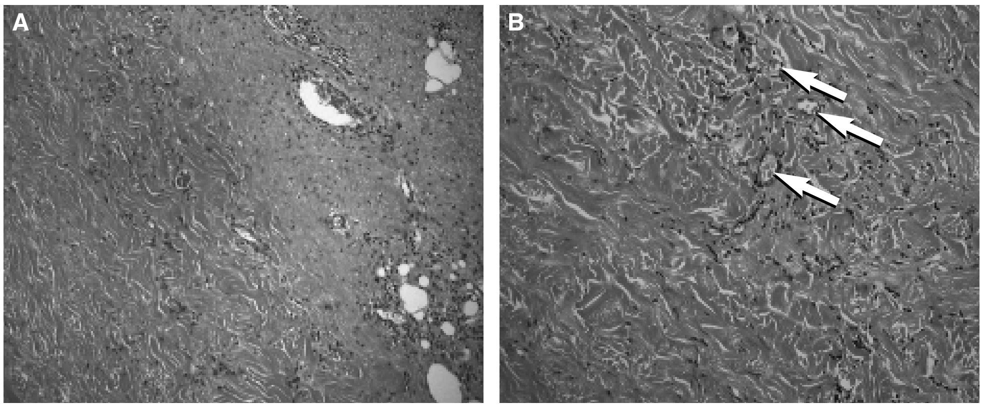

FIG. 6 Incorporation of prehydrated human ADM. A histologic specimen, shown here with hematoxylin and eosin, was taken 3 months after placement during second-stage expander-to-implant exchange. **A,** At 10× magnification a clear distinction in collagen staining density is apparent between the prehydrated human ADM and native soft tissue. **B,** At 40× magnification, the ADM is visibly populated with fibroblasts, indicating integration of the ADM into soft tissues. Also, red blood cells are apparent in blood vessels *(arrows)* within the ADM, indicating neovascularization. There is no evidence of a giant cell reaction that would signify rejection.

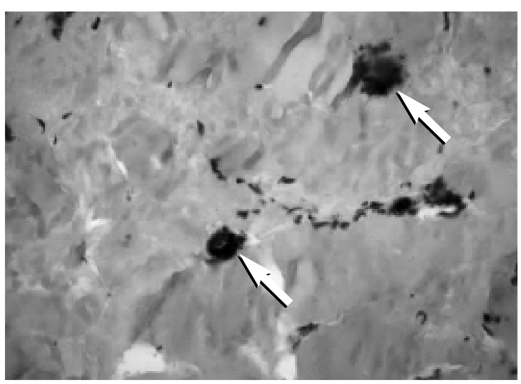

FIG. 7 Endothelial cell-specific immunohistochemistry of prehydrated human ADM. The specimen was taken 3 months after ADM placement during second-stage expander-to-implant exchange. It is shown at 60× magnification after immunohistochemical labeling to endothelial cell CD31 markers. Several blood vessel lumens are apparent *(arrows).*

We feel that the dual plane approach using an ADM yields results that are cosmetically superior and more predictable than traditional expander techniques that use complete submuscular coverage. A recent direct comparison of 50 reconstructions with ADM against 50 traditional expander reconstructions did not reveal a statistically relevant difference in overall complication rates (18% versus 14%), although the sample size was relatively small.[16] A second matched-cohort study with 45 subjects showed a trend toward increased complication rates when an ADM was used (15.6% versus 6.7%, $p = 0.18$).[14] A third comparative study separated the complications and found breast reconstruction with an ADM to be associated with more postoperative seroma (14.1% versus 2.7%, $p = 0.0003$), infection (8.9% versus 2.1%, $p = 0.032$), and necrosis (23.4% versus 8.9%, $p = 0.0005$).[17] Although these studies suggest possible differences, the small study sizes may hamper making any definitive conclusions. It makes sense that the enhanced cosmetic and functional outcomes may be associated with an increased incidence of flap necrosis and seroma, because fuller intraoperative expansion and an implant graft material is being used.[16] Larger detailed prospective studies will help clarify these potential differences.

With respect to outcome differences among the various ADMs, few studies have been done that directly compare the different constructs. The overall complication rates for human-derived ADMs range from 3.2% to 18%.[9,10,16,19,20] There are certainly differences among the ADMs in processing and sterilization, and potential alterations in collagen and protein structure, that could affect the revascularization and recellularization process.

COMPLICATIONS

The use of ADMs in our series has an acceptable complication rate of 16.5%, which is within the range of other reported studies with human ADM products. Few authors have argued against the overall safety of reconstruction with an ADM,[17] and most studies have reported improved aesthetic outcomes with acceptable complication rates that are not statistically different from traditional subpectoral or dual-plane prosthetic breast reconstruction.[7-13,15,18-20]

There is an important difference between expander infections and noninfectious erythema of a breast reconstruction with an ADM, which is known as *red breast syndrome.* True infection always needs to be ruled out, but red breast syndrome often resolves with conservative management. Clinical findings include early erythema over the lower pole of the breast (superimposed over the anatomic extent of the ADM) without systemic signs of infection, such as fever and leukocytosis, and without any radiographic evidence of seroma or abscess. The cause of this erythema may be inflammatory and may be the host's response to the ADM itself. Under normal conditions, mastectomy flaps are healthy enough to begin the revascularization process and integrate the graft. However, if the flaps are burdened by relative avascularity, or if the graft has a mechanical or physiologic impediment to accepting revascularization, then the host may respond with an inflammatory reaction. Such impediments may include a seroma or fluid between the flap and the graft or inadvertent inversion of the graft polarity (the epidermal surface has been placed in contact with the skin flap).[26] Indeed, red breast syndrome may be seen when thicker ADM grafts are used: revascularization from already thin mastectomy flaps may be further hampered by the deeper penetration required for these thicker grafts, and the prolonged integra-

Print Time: 6/4/10 1:53 PM
Last Time Saved: 6/3/10 4:56 PM
Document Name: 04 Innov v2n1_r2_033-044

tion attempts may stimulate an inflammatory response. Clearly, further studies are needed to evaluate the role of graft composition on revascularization potential (and concomitant host response). A more chronic inflammatory process can be seen when there is an inversion or when granulomas form around folded acellular dermis (Fig. 8).[25,26]

The effects of radiation and tissue expander reconstruction merit discussion. In our series, the overall incidence of complications after radiation therapy was 30.8%, compared with 13.7% when radiation therapy was not provided ($p = 0.0749$).[20] Despite this higher complication rate, we think that tissue expander reconstruction with an ADM seems to resist radiation effects better than tissue expander reconstructions without an ADM (Fig. 9). Contracture amelioration may result from some barrier effect of the ADM, perhaps in combination with a stretch effect from the rapid and early expansion. Future studies will help confirm this phenomenon and explain the underlying physiologic processes.

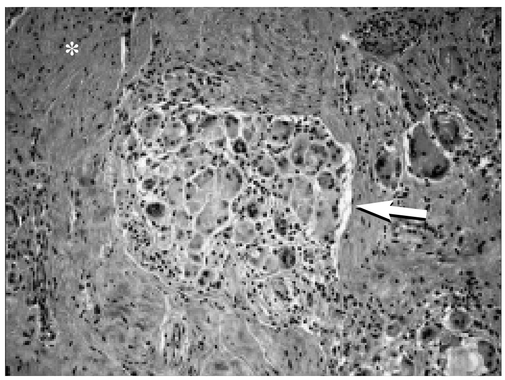

FIG. 8 A hematoxylin and eosin stain of a new breast mass reveals chronic inflammation, dense fibroconnective tissue *(asterisk)* that is consistent with the ADM, and diffuse foreign body giant cell reaction *(arrow).*

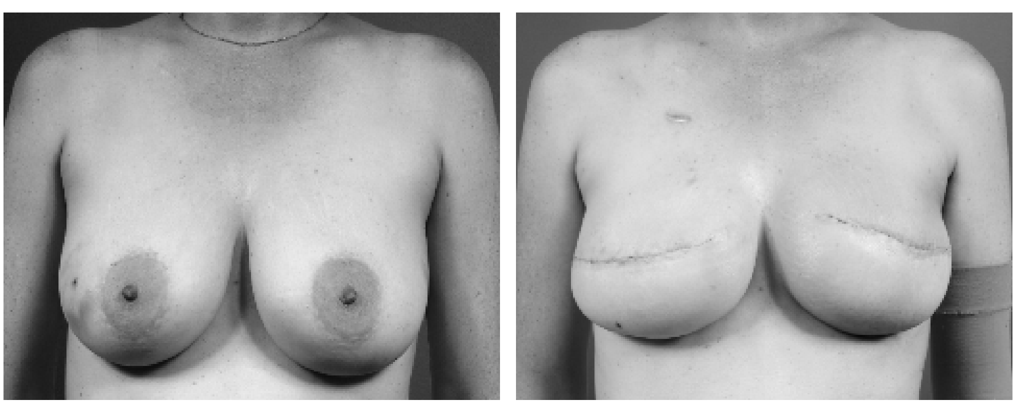

FIG. 9 This patient received bilateral tissue expander reconstruction with prehydrated ADM and subsequently underwent radiation therapy. Notice the robust volume and reasonable degree of symmetry in the shape of the irradiated left breast compared with the right.

PATIENT EXAMPLES

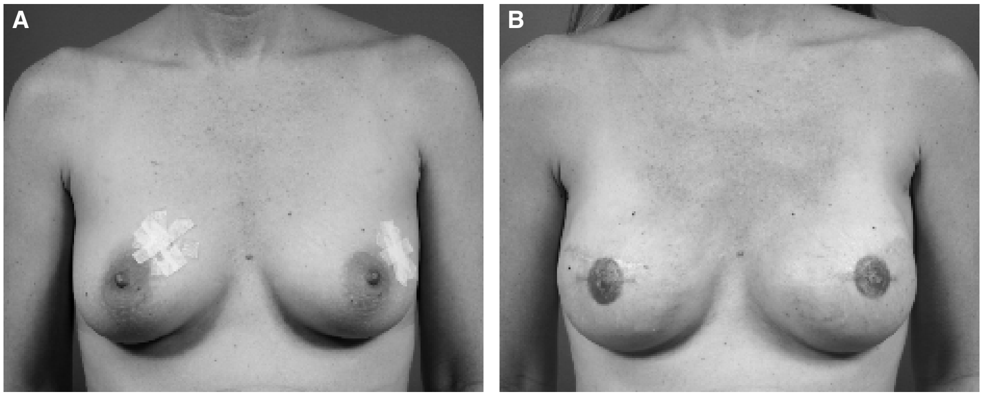

FIG. 10

This 35-year-old woman underwent bilateral mastectomies followed by two-stage bilateral breast reconstruction with an ADM. She is shown preoperatively and at 7 months postoperatively.

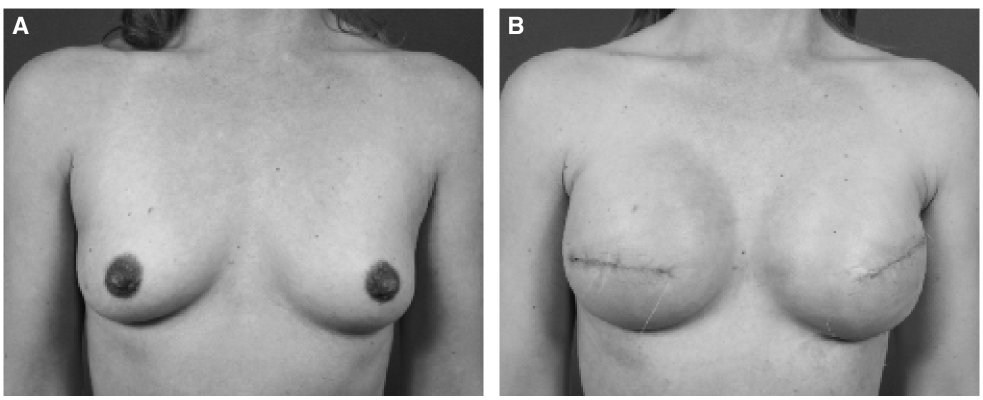

FIG. 11

This 36-year-old woman underwent bilateral mastectomies and requested a larger final breast size. She subsequently received two-stage bilateral breast reconstruction with an ADM. She is shown preoperatively and after expander placement.

CONCLUSION

Tissue expander reconstruction using the dual plane technique with an ADM is rapidly gaining popularity. The added control in shaping the expander pocket and the increased ability to fill the expander at the time of the mastectomy, limited only by the skin, offers a clear improvement over traditional breast reconstruction with a tissue expander. The key technical point involves releasing the pectoralis muscle from its inframammary attachments and redefining the lower pole with acellular dermis. The result is a more consistent ability to use larger fill volumes intraoperatively and achieve a more aesthetically enhanced shape and appearance. This technique produces less tension on the lower mastectomy skin flaps, better definition of the lateral mammary fold and IMF, compartmentalization of the tissue expander with better support, stabilization of the pectoralis muscle without the risk of retraction, improved coverage in the lower pole, and better projection of the lower pole, leading to a more natural-appearing breast mound. The complication profiles appear to be similar to traditional tissue expander breast reconstruction, although there may be a higher trend toward seroma, infection, mastectomy flap necrosis, and inflammation. Further longitudinal studies will clarify these issues. The introduction of ADMs to expander/implant breast reconstruction adds a component of control to the reconstruction and has provided a quantum improvement in our ability to obtain consistent favorable results with implant reconstruction.

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