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Review

Tissue expansion for breast reconstruction: Methods and techniques

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HIGHLIGHTS

- Diagnosis of breast cancer at increasingly earlier stages has encouraged the development of more conservative mastectomy.
- Breast reconstruction is an integral part of the management of breast cancer providing both psychosocial and aesthetic benefits.
- Tissue expander/implant-based reconstruction constitutes almost 65% of all breast reconstructions.
- Tissue expander/implant-based reconstruction can be performed as a two-stage procedure either in immediate setting or delayed.
- Most studies on breast reconstructions are single-center observations and no evidence-based guidelines are available yet.

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ABSTRACT

Objective: In this work, the authors review recent data on the different methods and techniques of TE/implant-based reconstruction to determine the complication profiles and the advantages and disadvantages of the different techniques. This information will be valuable for surgeons performing breast reconstructions.

Materials and methods: A thorough literature review was conducted by the authors concerning the current strategy of tissue expander (TE)/implant-based breast reconstruction following breast cancer surgery.

Results: Loss of the breast can strongly affect a woman's personal and social life while breast reconstruction reduces the sense of mutilation felt by women after a mastectomy, and provides psychosocial as well as aesthetic benefits. TE/implant-based reconstruction is the most common breast reconstructive strategy, constituting almost 65% of all breast reconstructions in the US. Although numerous studies have been published on various aspects of alloplastic breast reconstructions, most studies are single-center observations. No evidence-based guidelines are available as yet. Conventional TE/implant-based reconstruction can be performed as a two-stage procedure either in the immediate or delayed setting. Moreover, the adjunctive use of acellular dermal matrix further broadened the alloplastic breast reconstruction indication and also enhanced aesthetic outcomes.

Conclusions: TE/implant-based reconstruction has proved to be a safe, cost-effective, and reliable technique that can be performed in women with various comorbidities. Short operative time, fast recovery, and absence of donor site morbidity are other advantages over autologous breast reconstruction.

Contents

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1. Introduction

Breast cancer (BC) is by far the most common cancer in women, affecting about 12.5% women in the United States [1]. Its diagnosis at increasingly earlier stages has encouraged the development of more conservative mastectomy procedures, such as nipple-sparing, skin-sparing, and skin-reducing mastectomies [2–5]. The loss of a breast can be a traumatic experience, with serious effects on the quality of life [6,7]. For women who have undergone a mastectomy, breast reconstruction provides psychosocial as well as aesthetic benefits [8–13]. Breast reconstruction has therefore come to be regarded as not just a cosmetic procedure but an integral part of the management of BC [14,15] (see Fig. 1).

Although different approaches for post-mastectomy breast reconstruction exit, tissue expander (TE)/implant-based reconstruction constitutes almost 65% of all breast reconstructions in the US because it is considered a safe, cost-effective, and reliable technique that can be performed in women with a wide variety of comorbid states [16–20]. Even though autologous breast reconstruction provides a better cosmetic outcome and more natural-appearing breast reconstruction, TE-based reconstructions have the advantages of shorter operative time, faster recovery, and no donor site morbidity [21]. Moreover, autologous breast reconstruction can still be performed in case TE-based reconstruction fails.

Conventional TE/implant-based reconstruction can be performed as a two-stage procedure either in immediate setting at the time of the mastectomy or delayed. During the first step, a complete submuscular pocket is created for the TE by elevating the inferolateral portion of the pectoralis major muscle and the anterior insertion of the anterior serratus muscle. The second step—TE-implant exchange—is performed once the desired breast expansion is achieved. A technical modification to TE-based breast reconstruction is the use of the acellular dermal matrix (ADM) of either human or bovine origin, which allows creation of the submuscular pocket by mobilization of only the pectoralis major muscle [22,23]. The use of ADM provides numerous advantages over the conventional technique, but there are also potential disadvantages, including higher cost [24]. More recently, autologous dermal grafts have been proposed as an alternative to ADM [25,26].

There are numerous works in the literature on the methods, timing, complications, and safety of TE-based reconstruction, but most are based on empirical observations from single centers and do not provide evidence-based results [27e30]. Our work attempts to help both surgeons and their patients in the decision-making stage of breast reconstruction by collating recent data on the different method and techniques of TE-based breast reconstruction in order to determine the complication profiles and improve the health care quality.

2. History of TE/implant-based breast reconstruction

The first report of tissue expansion dates back to the 1957, when Neumann demonstrated its feasibility for achieving coverage of a subauricular defect [31]. However, more than 20 years had to pass prior that interest in tissue expansion rose again following the work of Radovan in the 1978 and Austad in 1982 [32–34]. The safety and efficacy of tissue expansion has since been thoroughly proven, and it has gained wide acceptance. The design of the TE has improved over time, and with the port incorporated in the surface of the implant, there is no longer any need for creation of a distal pocket for valve location. Moreover, textured expanders reduced the issue of their migration from the area of higher skin tightness (e.g., the inferior quadrants of the skin envelope) ensuring a better definition of the inframmamary line. Like breast implants, TEs are available in different shapes, including round and contoured shapes, which allow for greater lower pole expansion, thus increasing the upper pole slope.

The history of breast implants is even older than that of TEs and starts in the 19th century when a lipoma of the back was grafted into the breast in an attempt to provide breast augmentation [35]. Since then, different materials have been investigated, but it was only in the early 1960s that silicone implants, as currently designed, started being widely adopted [36]. The early generations of silicon implants experimented with varying thicknesses of the outer silicon layer and with silicon gel of different densities in the attempt to reduce the occurrence of capsule contracture, fluid migration, and ruptures [36]. Modern silicon implants are made of a three-dimensional matrix of cross-linked silicone molecules that do not leak out even in case of rupture of the outer layer [36]. Moreover, the introduction of textured implants has reduced capsular contracture rates and the possibility of implant malposition [36].

The latest generation of silicon implants display a vast range of shapes and volumes, varying implant width, height, and projection on the chest wall. Some manufactures provide silicon implants characterized by a more cohesive silicon gel on the top to ensure

over-projection, and a softer gel in the remaining portion to provide a more natural feeling when touched.

3. General considerations

TE/implant-based reconstruction aims to achieve a highly projected, medium-sized breast (400–500 cc), with little to moderate ptosis, rather than to create an exact match of the contralateral breast contour [37]. Therefore, patients undergoing unilateral reconstruction must be aware that they may eventually need to undergo contralateral breast augmentation, reduction, or mastopexy for breast symmetrization [38].

Small-to medium-sized breasts can be reconstructed with implants of the proper size and shape. Indeed, extra-projected, anatomically-shaped prostheses filled with highly cohesive silicon gel can ensure outstanding cosmetic outcome as well as a safe surgical procedure, and thus help the patient avoid autologous breast reconstruction with its associated donor site morbidity [39,40]. Even a large-breasted patient can be made eligible for implant-based, one-step reconstruction by means of skin reducing mastectomy [2]. However, autologous breast reconstruction is indicated in the patient with large ptotic breasts, who is willing to maintain a large-sized breast and refuses contralateral surgery.

Both stages of TE/implant-based reconstruction can be performed as a one-day surgery procedure; the entire procedure takes only $1^1/_2$ h, causes minimal morbidity and, unlike autologous breast reconstruction, leaves no donor site scar [36]. However, complications related to implant use, as well as contour deformities, are possibilities that must be taken into the reckoning. In addition, an adequate skin envelope is needed to support the expansion process, and hence history of smoking, scleroderma, or radiotherapy is relative contraindications [36].

Thus, almost every patient is eligible for immediate or delayed (from the 3rd postoperative month) TE/implant-based reconstruction [36]. For the previously irradiated breast, however, other reconstructive strategies are advisable, given the unacceptable rate of severe complications (e.g., implant extrusion, capsular contracture, or implant displacement) in this setting [41e46]. The same consideration is due for patients undergoing radiotherapy prior to TE/implant exchange. When post-mastectomy radiation is planned, the patient should be discouraged from undergoing immediate TE-breast reconstruction and be informed of the high risk of implant extrusion, which may require switch to autologous breast reconstruction.

Radiation therapy may be administered since prior to mastectomy till the completion of tissue expansion. Patients with up to T2-stage BC may not require radiotherapy after mastectomy [47]; however, given the increasing prevalence of BC and the growing indications for adjuvant radiotherapy, the number of patients who are willing to undergo TE-breast reconstruction, and at the same time are eligible for radiotherapy, keep rising [48].

Adjuvant radiation therapy improves the outcomes of patients whose risk of BC locoregional recurrence exceeds 25%–30% [49–51]. There is unanimous agreement that radiotherapy is indicated in patients with at least four positive axillary nodes and/or locally advanced disease (T3, T4, or skin involvement) [52–54]. However, the need for radiation is determined only after pathologic analysis of lymph nodes and tumor margins. Thus, when the need for radiation therapy seems likely, but it is not required in the preoperative setting, a delayed-immediate strategy may be advisable [55–58]. In this approach, a partially inflated TE is placed at the time of mastectomy, so that the initial shape and thickness of the breast skin flaps is preserved for 3–4 days, till the pathologic analyses are completed. If pathologic analysis shows that adjuvant radiation therapy is not needed, conventional tissue expansion can be performed, with outcomes similar to those obtainable with immediate breast reconstruction. On the other hand, if the patient requires postmastectomy radiation therapy, the TE will have to be completely deflated, to leave a flat chest wall surface that will permit modern, three-beam radiation delivery. Once radiation therapy is completed, skin-preserving delayed reconstruction can be performed. Alternatively, patients may undergo tissue expansion during postoperative chemotherapy and receive radiation therapy only after TE/implant exchange [36]. This approach broadens the eligibility for TE-based reconstruction to also include women requiring adjuvant radiotherapy. Complications and extrusion rates are lower than in patients who undergo radiation with the TE in situ. The capsular contracture rate is still high, but the satisfaction rate is not significantly different from that of patients who have not received radiation [59].

Nevertheless, the best reconstructive strategy in patients, who will receive or have already received radiation therapy, is delayed autologous tissue reconstruction after adjuvant radiation therapy has been completed [60].

4. Preoperative planning

The preoperative project should be made the day before the operation by the oncologic surgeon together with the plastic surgeon. BC localization, BC dimensions, and nipple-areola involvement have to be evaluated cautiously. Preoperative markings should favorably locate the mastectomy scar, while preserving the required skin envelope. The inframammary fold (IMF) and the borders of the breast, must be marked with the patient in a standing position. The upper pole border should match the level of the contralateral one, which can be delineated by gently compressing the contralateral breast against the chest wall. Nipple-to-sternal notch distance, areola-to-IMF distance, and breast width are measured at this stage. Skin quality, elasticity, and thickness are also assessed. When matching surgery on the contralateral breast is to be performed at the same time as the mastectomy, the preoperative markings on the contralateral breast are also drawn; breast augmentation, breast reduction, and mastopexy are the usual procedures required.

Fig. 1. Preoperative pictures (a, b) of a 46-year old patient prior to skin-preserving mastectomy and sentinel lymph node biopsy. (c) Intraoperatively, the expander can be seen within the submuscular pocket. The big arrow indicates the pectoralis major muscle, while the small one indicates the anterior serratus muscle. The final result after TE/implant exchange and secondary procedures (nipple-areola complex reconstruction and tattooing). (d, e).

At this stage, the surgeon should already have a clear picture in mind of the final result of the reconstructed breast, so that the best TE dimensions and location can be selected most wisely. The base diameter and volume of the eventually placed implant determines the choice of the TE, while the habitus of the patients guides the selection of the contour profile of the TE. The choice of the TE is also influenced by the surgeon's preferences, the project for the contralateral breast, and the patient's wishes. The surgeon must be aware that the patient's main concern is her attractiveness after the breast reconstruction and that the final breast size interacts with body size to influence the patient's satisfaction with her self-image [61]. However, as a general rule, a TE with base diameter >15 cm should be avoided even for reconstruction of a large breast as it can limit the mobility of the homolateral arm. Furthermore, while the TE height should generally match that of the contralateral breast, TEs with too much or too little height are not advisable.

Full-projection TEs help recruit upper pole tissue to highly expand the lower pole, giving a naturally ptotic appearance to the reconstructed breast [62]. To prevent nipple-areola complex (NAC) displacement, precise location of the TE is mandatory when reconstructing a breast after a nipple-sparing mastectomy.

With the increase in the range of reconstructive strategies available in BC surgery, the complexity of the decision-making process has increased [63–65], and algorithms, flow charts, and nomograms have been proposed by different researchers to aid the less-experienced surgeon [64,66–69]. More recently, surgical planning systems have been devised, as also virtual simulator systems, to train surgeons outside of the apprenticeship model [70–72].

5. Surgical technique

The mastectomy prior to TE-breast reconstruction can be either a simple skin-sparing, skin-reducing, NAC-sparing mastectomy or a skin-reducing NAC-sparing mastectomy. In the last 20 years, mastectomy incisions have changed; the oblique incision placed in the medial aspect of the mastectomy as inferiorly as possible has given way the to the horizontal incision used during skin sparing mastectomies today. For nipple-sparing mastectomies, a periareolar incision is performed instead, with or without a small lateral extension. Indeed, oblique incisions tend to result in a medial dog-ear and difficult lower pole expansion [73]. Moreover, compared to the older IMF incision, the newer incisions provide better exposure during mastectomy and also reduce the risk to the blood supply to the skin flaps and the NAC, while allowing easier TE-implant exchange and circumferential capsulotomy [43–77].

The IMF is a crucial landmark of the breast. It extends from the bottom of the fifth rib medially to the top of the seventh rib laterally, and is usually easily preserved during mastectomy [36]. Gross anatomic and histologic studies have shown that it is a specialized part of the superficial fascial system, where organized collagen fibers in the dermis and/or an actual ligament arising from periosteum and the intercostal fascia join the superfi cial fascial layer of the subcutaneous tissue [78,79]. When disrupted during mastectomy, it must be restored, either immediately or during a subsequent surgery, using 4–5 braided silk or Vicryl ® sutures [38].

5.1. First stage

5.1.1. Immediate breast reconstruction

After completing the mastectomy, and before commencing reconstruction, the surgeon assesses the blood supply of the skin flaps. Traditionally, this done on the basis of skin flap color, capillary refill, temperature, turgor, and dermal bleeding [80]; however, fluorescein angiography and laser-assisted indocyanine green angiography are now available as adjunctive diagnostic tools [81,82]. Some authors suggest a second dose of prophylactic antibiotics and re-application of the surgical prep in order to reduce the risk of postoperative infection, even though no definite evidence of benefit has been demonstrated [38].

If the mastectomy flaps are deemed viable, the surgeon can proceed with immediate reconstruction by creating the pocket for the TE. Either a partial or complete submuscular pocket is created, with the same dimensions as the selected expander. The chosen TE should have the same base width and height as the contralateral breast. It is important to avoid implant visibility or exposure and so complete soft tissue coverage of the TE must be ensured.

Some authors advocate complete muscular coverage to maximize vascularity and to prevent any contact of the TE with the overlying mastectomy incision [36,38].

For submuscular pocket creation, the patient in placed in the supine position with the homolateral upper arm adducted at 60 °; the pectoralis major muscle is dissected from its insertion on the ribcage, starting with the lateral edge. The aponeurosis of the anterior rectus and external oblique muscles are thus exposed. The pectoralis major is then also dissected medially from its sternal attachment, from the inferior edge of the pocket up to the second rib [36]. The pectoralis major can now be elevated, and the subpectoral pocket can be superiorly dissected in a relatively avascular plane, following the preoperative markings. At this stage, care should be taken not to injure the thoracoacromial vessels or the perforator from the internal mammary artery in the medial second intercostal space.

Complete muscular coverage of the TE is initially obtained by raising the serratus anterior muscle completely [83]. However, once the muscle is lifted off its insertion on the ribcage, the chest wall remains uncovered and painful; furthermore, the suture for the inferolateral definition of the breast profile may be unreliably positioned at this level [73]. The alternative is to only dissect the lower slips of the serratus anterior muscle to complete the inferolateral portion of the submuscular pocket. Care should be taken not to interrupt the bridging fascia between the pectoralis major and the serratus anterior. Dissection through the intercostal spaces should also be avoided. At this stage, the lateral edge of the pectoralis minor muscle can be raised in continuity with the lower slips of the serratus anterior muscle to ensure superolateral retention of the TE and prevention of migration toward the axilla.

Conversely, a partial submuscular pocket for the TE can be obtained by creating a musculofascial one. Once the pectoralis major muscle has been raised, the serratus anterior muscle is elevated in a plane within the muscle along with its overlying fascia [73]. With this approach, a portion of the muscle will still cover the rib cage.

To avoid malposition or rotation of the expander, the submuscular pocket should be designed to suit the selected TE. However, in all cases, the medial border should be at least 1–2 cm away from the midline, and the lateral border should be at the anterior axillary line.

Inferior coverage of the TE is normally achieved by elevating the fascia of the anterior rectus muscle; however, for patients undergoing skin-reducing mastectomy, the dermal-adipose inferior flap is used for coverage of the lower pole [36].

Traditionally, anatomically-shaped TE were placed just at the IMF. It was widely accepted that preserving the IMF and placing an anatomically shaped TE should be sufficient to maintain the breast contour [84]. As a result, the anatomical TE could eventually be replaced with an anatomical implant of the same size and contour [85,86]. However, the TE tends to assume a round shape as its volume increases and, given the restrictive capacity of the IMF, the point of maximal expansion would not be at the lower pole; this tended to result in a breast with very constricted lower quadrants.

To address this issue, surgeons started placing a full-height TE 1–2 cm below the IMF; this approach minimized overexpansion of the upper pole and maximized that of the lower quadrants [73]. This approach necessitated a curvilinear fasciotomy through the inferolateral fascial layer into the subcutaneous fat, at or just below the IMF, to allow proper lower pole expansion and avoid TE displacement. Indeed a fascial band across the lower pole can often prevent anterior expansion and compression of the TE. Once the pocket has been created, it is thoroughly irrigated to remove any cautery char or loose fat, and to highlight any bleeding points. Various irrigant solutions have been proposed; the most popular ones are triple antibiotic of Adams (comprising 80 mg of gentamicin, 1 g of cefazolin, and 50,000 U of bacitracin [or equivalent vancomycin], diluted in 500 mL of normal saline); single antibiotic solution; diluted povidone–iodine; and normal saline [87–89]. Subclinical pocket infection has been identified as a possible etiology of capsular contracture, but this has not yet been conclusively demonstrated. No comparative study on the efficacy of different irrigation solutions has been carried out either [38].

The TE is completely evacuated of any retained air and then inflated with saline up to 20%–30% of its final volume to facilitate its insertion into the pocket. However, Hall-Findlay et al. [38] have suggested that it be inserted in a completely de-inflated state so as to minimize the risk of damage to tissues, and that it be unfurled by inflation with 60–120 cc of saline only after it is in position.

If the pocket is of the correct size, the properly positioned TE will have the integrated valve at its upper pole and will not be folded on itself. Once the TE is in place, the pocket is closed with reabsorbable interrupted sutures. One or two drains should have been placed prior to TE placement.

Final intraoperative expansion may vary widely. Earlier, very small amounts of fluid were use to inflate the TE to avoid provoking mastectomy flap necrosis [90]. However, studies have demonstrated that intraoperative expansion with large volumes did not result in higher rate of skin flap necrosis and that, in fact, lower TE volumes were associated with higher risk of postoperative complications such as hematoma and seroma formation [19,91]. Nowadays, TEs are filled with saline up to 50% of the final volume intraoperatively, depending on the overlying soft tissue laxity and appearance. Generally, 20% of the final TE volume is usually well tolerated by most patients [19,36,38,73,91].

Recently, Breuing [22] and Salzberg [92] have used ADM for complete coverage of the TE, which represents a remarkable adjunction in the field of alloplastic breast reconstruction. The ADM, which may be of fetal bovine, porcine, or human cadaver origin, acts as a pectoralis extender, covering the inferolateral portion of the TE and obviating the need for elevation of the serratus anterior muscle, the pectoralis minor muscle, and the rectus abdominis fascia [22,92–97]. The ADM is typically a 8 × 16 cm sheet of dermal matrix that is sutured to the detached pectoralis major muscle edge and functions as a sling or hammock for the TE. Advocates of ADM point out the many advantages deriving from its use: for example, larger pocket size; higher intraoperative fill volume (even double) [38]; increased expansion and enhanced definition of the lower pole, resulting in more natural shape and ptosis; less lower pole rippling; increased control over the IMF and the lateral mammary border; reduced postoperative pain; faster postoperative expansion; and lower capsular contracture formation [97e112]. However, these aesthetic advantages have mostly been accepted on the basis of empirical or anecdotal evidence [113e115]. Some authors have reported increased early complication rates (hematoma, seroma formation, and infection) with the use of ADM [103,116]. Moreover, ADM can cost between $2100 and $3400, depending on the size of the dermal sheet required [117]. Despite this, Krishnan et al. [118] found ADM to be a cost-effective therapeutic adjunct for breast reconstruction due to its better long-term aesthetic and clinical benefits, and reported that it is particularly suited for patients undergoing two-stage, immediate, TE-based breast reconstruction. In a recent review, Kim et al. [119] reported acceptable complication rates of 8.6%–19.5% after ADM breast reconstruction. Finally, in view of the popularity of ADM and the uncertainties regarding its indications and contraindications, both Vu et al. [120] and Jordan et al. [121] have recently proposed an algorithmic approach to aid decision-making with regard to the use of ADM.

A polyester mesh (SurgiMesh® PET) has been proposed as an alternative to ADM in alloplastic breast reconstruction and has shown promising results [122,123]. SurgiMesh® PET is a safe synthetic mesh that has been used in surgery as an alloplastic material for over 40 years and can ensure aesthetic benefits similar to those obtained with ADM, without the drawbacks of high cost and local policy restrictions.

A few authors have also proposed dermal autografts as an alternative to ADM [124e126]. The autologous dermal graft can be harvested during the time of the mastectomy as a horizontally-oriented ellipse in the lower abdomen if a preexisting scar is present (mainly resulting from a Pfannenstiel incision) or from the contralateral breast if a reductive mastoplasty is planned. Lynch at al [126] conducted a prospective study to compare the outcomes of TE-breast reconstruction by means of dermal autografts and ADM. They reported that the dermal autograft group had a higher intraoperative final TE volume, but no difference was seen in the number of postoperative in-office expansions or the time to TE/implant exchange. Major and minor complication rates, as well as total costs, were higher in the ADM group. Cosmetic outcome was similar in the two groups. Histologic analysis showed that integration into the surrounding tissue was better with the autograft, with extensive revascularization and vessel ingrowth.

5.1.2. Delayed breast reconstruction

When delayed breast reconstruction is required to allow time for completion of chemotherapy and/or radiotherapy, the contralateral breast can be used as a template to design the boundaries of the pocket. The surgical procedure is similar to that of immediate reconstruction. Once the preexisting scar is excised, the skin flaps are elevated till the lower margin of the pectoralis major muscle is exposed; the muscle is then lifted in the same fashion as in immediate reconstruction. Alternatively, the subpectoral space can be approached through the muscle itself by a splitting incision running parallel to the muscle fibers. This access spares muscle fibers that will naturally close the incision when they contract. Moreover, as the muscle fibers run perpendicular to the skin incision, the muscle will provide coverage to the TE if skin necrosis should occur. The main drawback is that relatively more extensive skin flap dissection is needed. During delayed reconstruction complete lateral coverage of the TE is not mandatory; thus, the anterior rectus fascia, serratus anterior muscle, and pectoralis minor muscle can be spared without compromising TE coverage and the final cosmetic outcome. Just as in immediate breast reconstruction, precise dissection of the pocket must be achieved by utilizing the same anatomic landmarks, so that proper TE placement is possible. A closed-bulb suction drain is usually placed over the pectoralis muscle prior to skin closure, preventing it from being in contact with the TE [127]. ADM can be applied too, in which case a tunneled drain is placed inside the pocket. The final intraoperative volume of the TE follows the rules of immediate setting.

5.2. Expansion

Tissue expansion is normally started from the 10th to the 14th

postoperative day (POD) as outpatient expansion, and is usually repeated every 1–4 weeks according to the patient will [38]. The TE is inflated with 60–120 cc of saline each time, the volume being decided by the clinical appearance of the mastectomy flaps and patient discomfort.

Early and fast tissue expansion makes the process easier, because the more one waits the more scar is produced [128]. Indeed, tissue expansion becomes hard at 6–8 weeks after surgery [73]. The desired expansion is usually achieved by 2 months. However, second stage reconstruction takes place only after 6 months (even though exchange to final implant is also reported at 6 weeks after the final expansion) in order to let the tissues relax so that, once the TE is replaced with the definitive implant, the breast will have a naturally ptotic appearance [62,73,129]. For the same reason, it is common practice to overexpand the TE to 110%–120% of the required volume.

5.3. Second stage

As in delayed breast reconstruction, the preexisting scar (which usually appears widened as a consequence of tissue expansion) is excised. Once the pectoralis major muscle is exposed, access to the submuscular pocket is achieved either by the muscle-splitting approach or via a layered technique. Indeed, muscle and capsule are often not easily discernible and therefore both muscle and capsule are incised as close as possible to the IMF by raising the inferior mastectomy skin flap. At this point, there is no consensus on whether a capsulotomy or a capsulectomy is to be performed. Nava et al. [36] advocates complete capsulectomy followed by the redefinition of the IMF by suturing the lower edge of the superficial fascia to the chest wall musculature using continuous absorbable 1/0 stitches. Hall-Findlay et al. [38] deem complete capsulectomy unnecessary as it can lead to loss of soft tissue coverage, jeopardize blood supply to the overlying skin, and increase inflammation. They recommend a circumferential capsulotomy into the subcutaneous fat, along with a zigzag inferior pole capsulotomy, to allow lower pole distension and overhang. Moreover, direct capsulotomies can be added in areas that need to expand further, while capsulorrhaphy by means of 2-0 silk sutures is used for correcting overexpanded areas. When necessary, the IMF is re-established by suturing the undersurface of the mastectomy flap to the expander capsule by means of absorbable braided sutures.

Cordeiro et al. [73] also perform a circumferential capsulotomy. Indeed, radial scoring of the capsule ensures centripetal release only, with no anterior release, and is best suited for a constricted tuberous breast but not for the more frequent anteroposteriorly constricted breast. Circumferential capsulotomy is performed at the level of the tightest portion of the capsule (i.e., 1–2 cm anterior to the chest wall) and usually ensures a 1–7 cm anterior release.

The selected implant can then be inserted in place. A closed suction drain is usually placed prior to wound closure with double-layered braided absorbable sutures.

6. Postoperative care

TE-implant based reconstruction usually does not require any special postoperative care. Prophylactic antibiotics are commonly administered, but should be limited to the first 24 postoperative hours since longer use increases the risks of drug-resistant bacteria and more severe infections [130]. Postoperative pain is usually not long lasting and can be easily managed with analgesics.

A supportive brassiere should be worn for the first postoperative month. Patients should avoid intense physical activity for the first 2–3 weeks. The usual surgical wound care practices should follow. Drainage can be safely removed once the output is <30 mL/day.

7. Secondary procedure

NAC reconstruction can be performed as early as the 2nd postoperative month after second stage reconstruction by means of local flaps; tattooing is delayed till 6 weeks after NAC reconstruction [131].

Rigotti et al. [132] were the first to describe the effectiveness of autologous fat grafting (AFG) for the treatment of radio-induced damage to soft tissue in the reconstructed breast. Serra et al. [133] reported improved outcome in irradiated patients who have undergone AFG plus TE-based breast reconstruction. Indeed, AFG has been shown to thicken the subcutaneous tissue and also to improve the texture of the irradiated skin by enhancing its vascular supply [134].

This regenerative potential and therapeutic effect of the AFG that go beyond simple filling capability is mainly due to the presence adipose-derived stem cells (ASCs) [135e140]. ASCs are an adult population of mesenchymal stem cells that can differentiate into multiple cell lineages and secrete paracrine factors [141e145]. Thus, angiogenesis and wound healing are strongly enhanced, leading to higher fat-graft survival as well as dermal and subcutaneous tissue regeneration [146–148].

In addition to being able to reduce radio-induced damage, AFG can also correct any residual contour deformities following implant breast reconstruction [149,150]. AFG appears to be a feasible and effective technique for correction of the many deformities that may occur in any breast quadrant, including medially located parasternal deformities, upper visible implant edges, asymmetry with the contralateral breast, and upper outer defects underneath the anterior axillary fold [151].

8. Complications

Complications following TE-based breast reconstruction are divided into early (occurring by the 3rd postoperative month and/or prior to any adjuvant therapy) and late complications [152]. Early complications can be further divided into minor and major ones [153]. Complications include infection, hematoma, seroma, pain, skin flap necrosis, huge wound healing breakdown, capsular contracture, NAC necrosis, and implant exposure/loss. Any complication that can be managed conservatively is identified as a minor complication; a major complication is usually one that calls for secondary procedures.

Hematoma formation, seen in 0%–5.8% of patients, is usually clinically recognized by the first or second POD [154]. If drainage is functioning properly, the bleeding can be recognized and managed immediately. However, when clots obstruct the drainage, blood may gather within the pocket, and revision surgery is usually necessary. Hematoma of any size should be immediately evacuated as it may lead to capsular contracture. Seroma can usually be avoided with a closed suction system, but if extensive, open drainage may be necessary.

Erythema, per se, is a normal body reaction and will eventually resolve by itself. However, when associated with the classical signs and symptoms of infection, intravenous antibiotics should be administered as soon as possible. Infection rates range from 0% to 7% and if not correctly treated, the TE/implant will have to be removed and reinserted at about 3–6 months [155].

Skin envelope necrosis occurs in 0%–21% of patients [154]. Partial or complete mastectomy flap necrosis may be seen, usually starting from the suture line; however, the muscles of the pocket should be able to cover the implant. A limited area of necrosis may be managed conservatively with topical antibiotics and local wound care, but for wider areas curettage of the superficial layer and advanced wound dressing are mandatory. When the area of

skin necrosis is very large, implant removal may be the only solution; TE/implant reinsertion should not be rescheduled earlier than 3–6 months after surgery. Salvage surgery, with local advancement of the remaining envelope after excision of the necrotic area or distant flap, may also be performed.

Reported rates of necrosis of the NAC range from 0% to 48%, but is <10% in most series [156].

Malfunction of the expander implant in the early postoperative period is rare. Proper placement of the expander and confirmation of port patency after skin closure during the operative procedure should be sufficient to avoid need for any revision surgery.

Late complications may occur at any time in the patient's lifetime, starting from the 3rd postoperative month. Delayed implant deflations and rupture rate increase as the implants ages, with the reported rate being 15% at 3–10 years after implantation [36]. Diagnosis may not be easy; breast size and shape will not necessarily change, and mammograms do not always detect implant rupture. Magnetic resonance imaging, with sensitivity of 86.7% and specificity of 88.5%, is the gold standard for detecting implant rupture [157]. In case of documented implant rupture, exploration and implant exchange are required.

Capsular contracture (Baker III/IV) is generally the more frequent complication, occurring in 16%–30% of patients [158]. The incidence of capsular contracture increases by 1% per breast per year [159]. Wrinkling may also occur in 20%–25% of patients.

In 2006, Cordeiro et al. [19] reported one of the largest series (1522) of TE-based breast reconstruction. The overall early complication rate (5.8%) and the complication rate after TE insertion (8.5%) were significantly higher than that after TE/implant exchange (2.7%). The most common perioperative complication was infection (2.5%), followed by native skin flap necrosis (2.0%). The complication rate was higher in immediate reconstruction than in delayed reconstruction (8.6% vs. 3.8%). Early complications caused expander explantation in 2.7% of the reconstructions.

Basta et al. [160] performed a head-to-head meta-analysis of outcomes, comparing conventional two-stage implantation with direct-to-implant reconstruction. It emerged that even though both are successful reconstructive strategies with similar infection, seroma, hematoma, and contracture rates, the direct-to-implant approach was associated with greater risk of flap necrosis and implant failure.

As previously stated, TE-based breast reconstructions after postmastectomy radiation therapy consistently show high rates of acute and chronic complications, as well as poor aesthetic outcomes [161]. Even modern radiation delivery techniques do not lower the complication rates. Severe capsular contracture is one of most common complications; it can occur when TE/implant exchange has been already performed prior to adjuvant radiation therapy. The reported incidence in literature ranges between 16% and 68% [27,28].

Ascherman et al. [162] conduced a retrospective study in which they evaluated the complications and aesthetic outcomes of 104 patients who underwent TE-based reconstruction; 27 of these patients also underwent radiation therapy, either before or after mastectomy. The overall complication rate was 40.7% for irradiated breasts vs. 16.7% for non-irradiated breasts. Removal or replacement of the implant was performed in 18.5% of the irradiated breasts vs. 4.2% of the non-irradiated breasts. The extrusion rate was also higher for the irradiated breasts (14.8% vs. 0%). Benediktsson and Perbeck [163] conducted a similar study and reported that the capsular contracture rate was significantly higher for irradiated breasts than for non-irradiated ones (41.7% vs. 14.5%). On the other hand, Codeiro et al. [59] reported an implant removal/replacement rate of 11.1% and acceptable aesthetic outcomes in most patients. Severe (Baker IV) capsular contracture occurred only in 5.9% of irradiated reconstructed breasts in their series.

9. Outcomes

Satisfaction rates in patients undergoing TE/implant-based breast reconstruction range from 61% to 78%; in comparison, patients undergoing autologous breast reconstruction have rates ranging from 72% to 79% [164,165]. Clough et al. [166] noted that satisfaction with aesthetic results shows a decline from the initial rate of 86% at 2 years to 54% at 5 years after implant reconstruction. This decrease is multifactorial but may be partly attributable to late complications, such as capsular contracture and asymmetric contralateral ptosis. Patients with bilateral prosthesis (contralateral augmentation) usually have relatively higher satisfaction rates (79.2%), which may be partly due to the improved shape of the breast and better symmetry achieved with bilateral reconstruction [167].

10. Conclusions

TE-based breast reconstruction is a safe, reliable, and efficacious procedure [19,91,168]. Skin- and nipple-sparing mastectomies allow preservation of native soft-tissue of the breast and thus enable breast contour reconstruction with little manipulation of surrounding tissues [170,171].

Due to refinements in surgical techniques and implant technology, improved cosmetic outcomes are being achieved. the adjunctive use of ADM had further broadened the alloplastic breast reconstruction indication and also enhanced aesthetic outcomes. While AFG is an effective secondary procedure to correct any residual asymmetry with the contralateral breast or improve the radio-induced skin damage thanks to the presence of ASCs [169]. Appropriate pocket positioning and expander placement are mandatory for a satisfactory final result. More realistic reconstruction, even in patients with aggressive surgical resections, can now be obtained, thanks to advances in cohesive-silicon implants. Autologous reconstruction results in a higher satisfaction rate and should be considered the gold standard for breast reconstruction in the setting of radiation injury. However, many patients ask for TE/implant-based reconstruction to avoid a donor defect, limit recovery time and potential morbidity, and to exercise choice in the size of the reconstructed breast. Surgeons must deal with the patient's desire and expectations and it is important to ensure that the patient has realistic expectations so that there is no disappointment with the final cosmetic results. The reconstructive surgeon must aim for balance and symmetry and ensure that the patient gets the best cosmetic outcome achievable.

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Author contribution

Dr. Nicolo' Bertozzi, writing.
Dr. Mariana Pesce, data collections.
Prof. Pierluigi Santi, data collections.
Prof. Edoardo Raposio, study design.

Con icts of interest

Nothing to declare.

Guarantor

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Consent

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