Double Bubble: An Anatomic Analysis and Management Algorithm

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Introduction

"Double-bubble" deformity is an uncommon complication of breast augmentation surgery that denotes the appearance of two asymmetric and separate breast mounds ("bubbles"). The superior mound, bounded inferiorly by a transverse crease across the lower pole of the breast, represents the native breast tissue. The inferior breast mound represents downward descent of the prosthesis below the level of the native IMF (Fig. 2.1).

Much of this phenomenon is due to violation of the inframammary fold (IMF), and a better understanding of IMF anatomy is critical to not only avoiding this complication but correcting this if it occurs. This chapter reviews IMF anatomy: etiologies, incidence, risk factors, prevention of double bubble, and techniques for repairing a double bubble when it does occur.

What Is the IMF?

Historically, debate has existed over whether the IMF arises from a ligamentous structure or not. The ligamentous and fascial networks of the breast were first described by Sir Astley Cooper in 1845. Additional anatomic reports initially described a ligamentous structure arising from the fifth rib periosteum medially and the space between the fifth and sixth ribs laterally, creating the IMF [1–3].

More recent cadaveric and histologic studies, however, have failed to identify a true ligamentous structure and rather depict the IMF as a complex fascial network. Lockwood was one of the first to detail the superficial fascial systems throughout the body, including the breast [4]. He described a fascial zone of adherence at the level of the IMF. Later histologic exams of the IMF by other authors have confirmed connections between the deep fascia of the breast and superficial fascia of the chest muscles [5]. In addition to these deep fascial connections, the IMF is also created more superficially by changes in the intradermal collagen network. Collagen fibers at the IMF demonstrate an intradermal condensation. These fibers are organized and oriented parallel to the IMF axis, unlike subdermal collagen fibers found elsewhere in the body (Fig. 2.2) [6].

Multiple authors have described the IMF as a two-part structure (Fig. 2.3). Muntan performed 12 cadaver dissections and described 2 horizontal membranous sheets at the IMF with varying degrees of fusion between cadavers [7]. The more superficial horizontal sheet continued as a fascial layer anterior to the breast gland, while the posterior horizontal sheet continued posterior to the breast gland. Salgarello and Visconti described their findings from 4 cadaver dissections and over 200 intraoperative breast augmentation dissections. They identified a two-part fascial structure whereby the superficial pectoral fascia fanned into two wings at the level of the IMF: a superior wing that inserts into the subcutaneous tissue of the IMF and an inferior wing that continues caudal to blend into the rectus abdominis fascia [8]. Matousek further identified a triangular fascial condensation at the level of the IMF with two directions of fibers: superior fibers inserting into the lower pole glandular tissue and inferior fibers inserting into the dermis at the level of the IMF [9].

There is direct clinical relevance to this two-part structure of the IMF: when performing cranio-caudal dissection, the IMF position can change if dissection proceeds inferiorly and deep enough between fascial layers, but the crease is retained due to the more superficial structural components [6].

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Fig. 2.1 Example of double deformity in the left breast. The transverse crease across the lower breast represents the native inframammary fold. The mound below this crease is created by downward descent of the implant. The mound above this crease is the native breast tissue

Translating IMF Anatomy to Iatrogenic Deformities: Pathophysiology of Double-Bubble Deformities

As described in the previous anatomy section, the IMF can be thought of as a two-part structure: a superficial structure that inserts into the dermis and a deeper structure that anchors the fascial condensation to the chest wall. With this framework, we can now understand how double-bubble deformity occurs and why it is more prone to occur in a submuscular augmentation plane. When dissecting under the pectoralis, violation of the deeper fascial structures anchoring the breast gland to the chest wall can occur without violation of the more superficial inframammary crease attachments. This results in double bubble when the implant slides inferiorly. Figure 2.4a, b demonstrates this anatomic relationship between the plane of dissection, implant descent, and the location of the IMF crease.

While the focus of this chapter is on double-bubble deformity, there are also proximate IMF-related deformities, most notably the clinical complication known as "bottoming out."

Bottoming out is the consequence of inferior pocket overdissection in addition to violation of the IMF. While both bottoming out and double-bubble deformity are a consequence of IMF violation, the specific deformity that manifests is dependent on the depth of fascial dissection [8]. Violation of the superficial fascial structures releases the inframammary crease, effectively destroying it and allowing the implant to slide inferiorly (bottom out). Figure 2.4b, c demonstrates how the two deformities develop with violation at these different fascial levels. Sub-glandular implant placement may lead to bottoming out but rarely leads to double-bubble deformity since inferior overdissection would release this superficial fascial network. Moreover, subglandular pocket conversion is one technique for correction of double bubble after subpectoral augmentation.

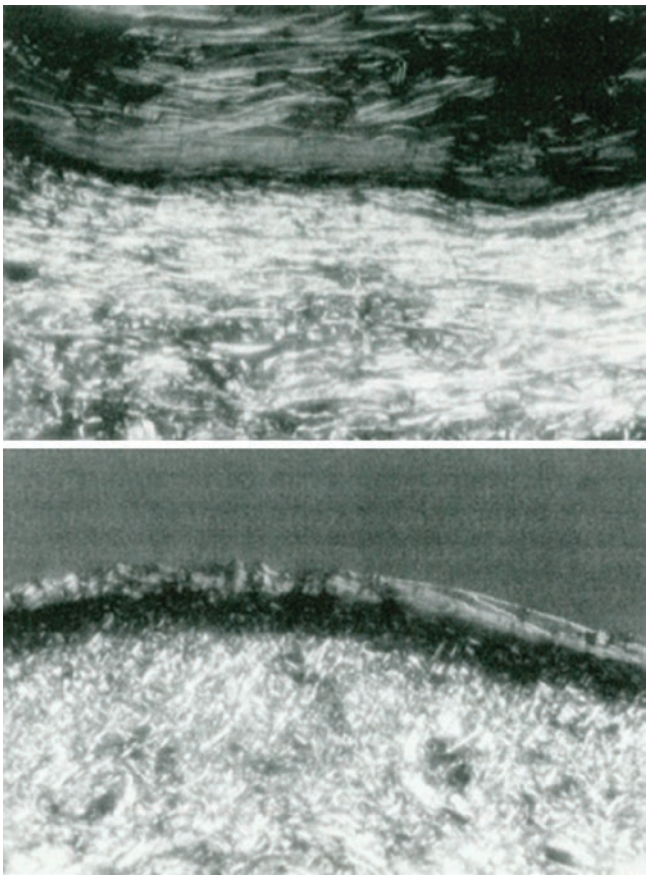


Fig. 2.2 Photomicrograph of collagen staining below the dermis. The inframammary fold (above) demonstrates dense, organized collagen fibers that run parallel to the IMF. Control sections (below) demonstrate disorganized collagen fibers that insert perpendicularly into the dermis. (Reprinted with permission from Boutros et al. [6])

Etiology, Incidence, and Risk Factors

With a deeper understanding of IMF anatomy and how this relates to the double-bubble deformity, one can begin to consider the etiology, incidence, and risk factors for double bubble. A study by Salgarello and Visconti reviewed 207 breast augmentations and identified 6 cases (3%) of double-bubble deformity over an average 28-month follow-up [8]. Four of the six cases occurred in breasts with constricted lower poles/tuberous breasts, and the other two cases occurred in breasts with high IMFs. In a review of 200 primary breast augmentations, Chardon and colleagues identified "double breast contour" in 7% of cases [12]. However, these were all Type I, also known as waterfall deformity, which many plastic

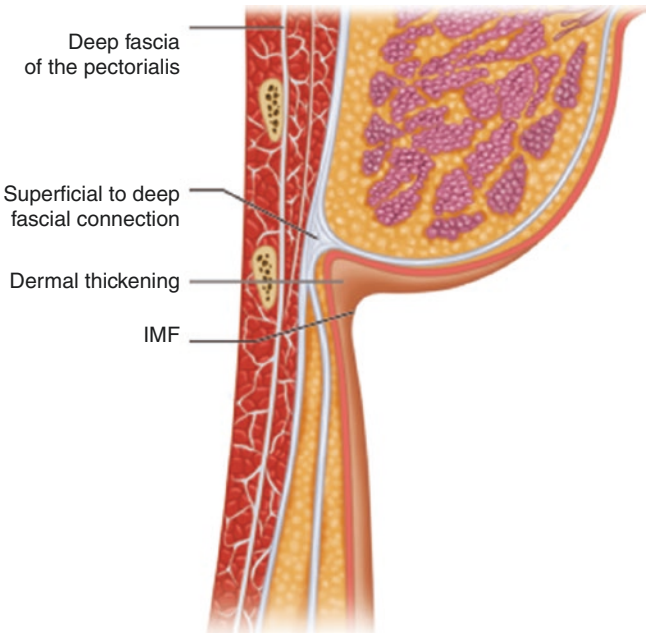


Fig. 2.3 The IMF can be thought of as a two-part structure, consisting of a superficial condensation of dermis and superficial fascial fibers, as well as a deeper structure that fuses superficial and deep fascial fibers together

surgeons – including the authors – attribute to a very distinct pathophysiology than double bubble. They had no instances of Type II double inframammary crease deformities at an average 36-month follow-up. Notably, tuberous breasts were excluded from this analysis which would be more prone to develop double-bubble deformity. It is important to note that waterfall deformity, although sometimes blended into the spectrum of IMF abnormalities, is a distinct entity from double bubble with different anatomic issues (high-riding implant with intact IMF in the setting of ptotic breast tissue) [10, 11]. This distinction is highlighted in Fig. 2.4d. Waterfall deformity is discussed further in Chaps. 23 and 24.

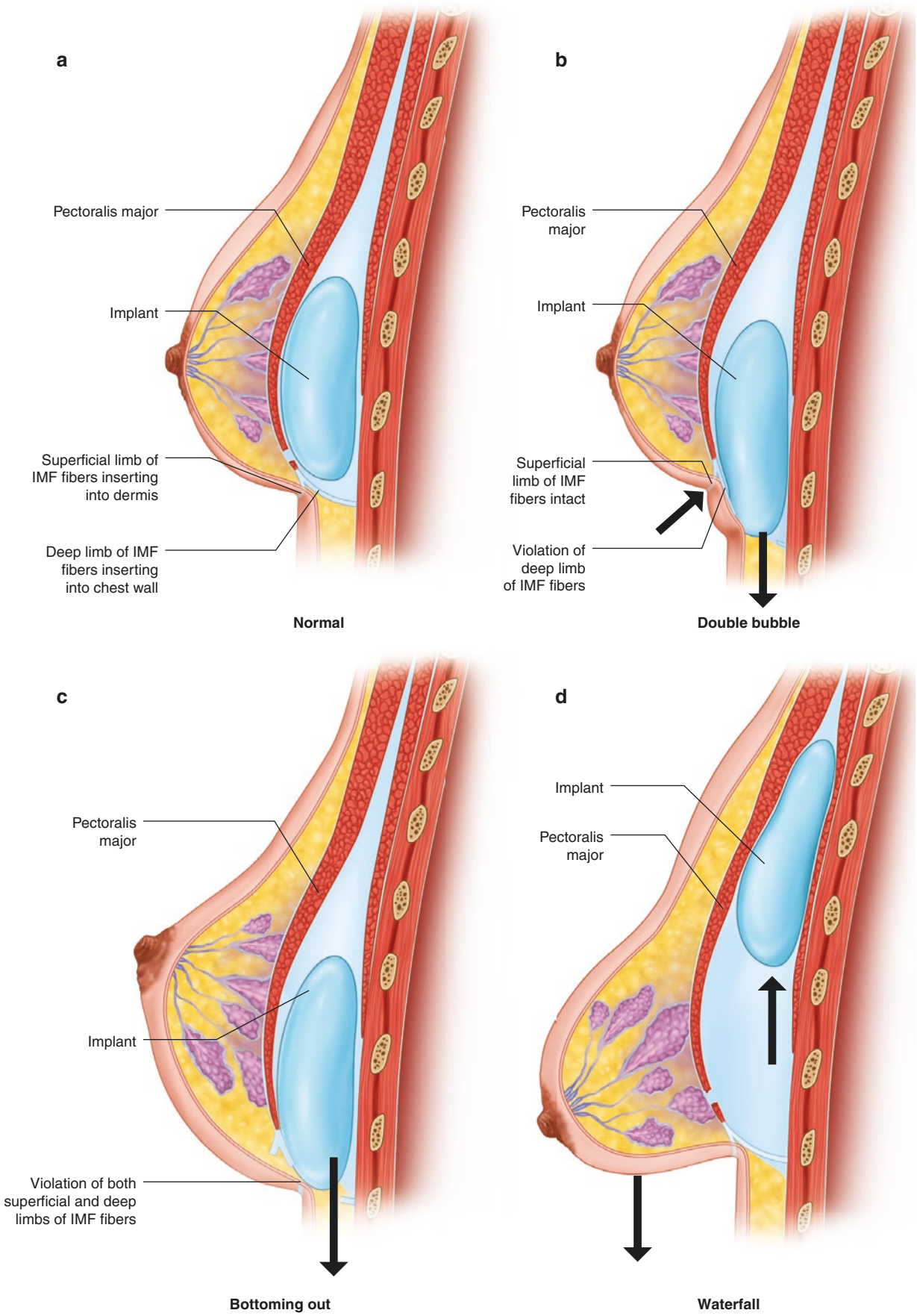
Risk factors for double-bubble deformity include anatomical variants that would make it difficult for the lower pole breast gland to conform to the underlying implant and tight IMFs with excessive memory. Thus, tuberous breasts, breasts with a constricted lower pole, high-riding IMF, narrow base width, dense/highly formed breasts, and generally tight IMFs are all prone to developing double bubble after augmentation.

Surgical causes of double bubble include excessive dissection along the deep portion of the IMF fascia resulting in a path of least resistance inferiorly for displacement of the implant. This is typically coupled with persistent superficial fascial attachments which create the groove appearance of the double bubble. Beyond this primary etiology, double bubble can be exacerbated with the use of an implant with an excessive base width or by the smooth surface of the implant creating micromotion and continuous erosion of the soft tissue constraints along a weakened IMF. Notably, Baxter described cases of double bubble occurring in conjunction with animation deformity in breasts with otherwise normal anatomy [13]. Pectoralis animation accentuated the double-bubble deformity, and the external transverse crease across the breast corresponded to the termination of pectoralis fibers in the anterior implant capsule. Thus, submuscular augmentation increases risk of double-bubble deformity both by preventing release of more superficial fascial fibers and by surgically creating a fusion line between muscle and capsule that will naturally lie cranial to the IMF after pectoralis fiber release. The pectoralis muscle can also contribute to double-bubble deformity by the deforming forces that push the implant down, deep and inferior the native IMF. Ultimately these forces contribute to the creation of two separate breast mounds: that of the implant displaced inferiorly and that of the native breast superiorly. Figure 2.5 depicts a patient with simultaneous animation deformity and accentuated double-bubble deformity.

Prevention

Two of the most obvious ways to prevent double-bubble deformity include (1) respecting the boundaries of the IMF and (2), in the situation where the IMF must be lowered to obtain desired aesthetics and volume enhancement, ensuring sufficient release of superficial fascial IMF attachments and creating a durable support for the new lowered fold by capsulorrhaphy and/or mesh.

Because tuberous breasts manifest anatomic variants that also predispose to double-bubble deformity, many of the same techniques specific to augmentation of the tuberous breast can be helpful to prevent double-bubble deformity. Radial scoring allows expansion of the lower pole breast tissue and can widen the base diameter in an otherwise narrow breast [14]. Beyond widening the breast, radial scoring also allows otherwise dense glandular tissue to conform more naturally to the underlying implant. Radial scoring at and perpendicular to the axis of the IMF itself can help obliterate the old IMF when creating a lower fold. Similar to radial scoring, Puckett described the unfurling technique for primary prevention of double-bubble deformity in the narrow-based breast [15]. This description utilizes a peri-areolar incision to dissect in the subcutaneous plane to pectoralis fascia. Dissection then proceeds cranially in the subglandular plane until the midpoint of the breast (about the level of the nipple). The gland is then incised from posterior to anterior, and the lower pole flap of glandular tissue is unfurled inferiorly to advance the constricted lower pole (Fig. 2.6). The unfurled flap is then sutured in place to the inferior extent of the breast pocket.


a
Pectoralis major
Implant
Superficial limb of IMF fibers inserting into dermis
Deep limb of IMF fibers inserting into chest wall
Normal
b
Pectoralis major
Implant
Superficial limb of IMF fibers intact
Violation of deep limb of IMF fibers
Double bubble
c
Pectoralis major
Implant
Violation of both superficial and deep limbs of IMF fibers
Bottoming out
d
Implant
Pectoralis major
Waterfall

Traditionally, IMF incisions have been placed slightly below the IMF to anticipate recruitment of lower pole skin once the implant is in place, thereby hiding the scar more discreetly in the newer cusp of the breast and torso. The incision must be beveled cephalad to ensure a dissection plane that does not inadvertently violate the IMF. Alternatively, Swanson described the use of a supra-inframammary fold incision to avoid the IMF altogether and correspondingly avoid double-bubble deformity [16].

In the early postoperative period, if a patient is deemed at risk for double bubble or if an incipient deformity is seen, then the concept of "breast casting" can be utilized. Mills describes a technique by which shoelaces are strung around the neck, circumferentially around the chest and at the level of the desired IMF to promote adhesion in the correct position [17] (Fig. 2.7). Another permutation of this technique is advocated by Handel who uses elastic compression in the superior pole of the breast to push the implant down and help expand the lower pole breast tissue while maintaining the IMF with tape or an underwire bra.

Techniques for Correction

Once double-bubble deformity occurs, correction depends on etiology, anatomy, degree of deformity, and patient factors including expectation. Because double-bubble deformity manifests as an implant residing in a problematic pocket, the concept of changing to a new pocket and resetting to a new, more secure IMF is a mainstay of revision surgery. As mentioned previously, double bubble rarely occurs after sub-glandular augmentation. This is because inferior sub-glandular dissection will naturally release more superficial fascial attachments, thereby obliterating the native IMF if dissection proceeds too far inferior. This generally results in bottoming out rather than double-bubble deformity.

Pocket Conversion Techniques

For double-bubble deformity after submuscular augmentation, pocket conversion to a sub-glandular plane can alleviate the deformity [14]. However, not all patients are good candidates for sub-glandular augmentation, particularly after an implant has already stretched and thinned the overlying glandular tissue. For these patients, two alternatives include conversion to a dual-plane/split muscle pocket or conversion to a neo-subpectoral pocket [18].

Split muscle augmentation, described by Khan and Baxter, likewise places the implant in a subpectoral plane superiorly and a sub-glandular plane inferiorly, but does so by splitting the muscle fibers at a desired level to eliminate inferior pectoralis fibers' action on the anterior implant capsule [13, 19]. Whereas in a dual-plane technique these inferior pectoralis fibers would be released and sit anterior to the implant, a split muscle technique places these most inferior pectoralis fibers posterior to the implant. A split-muscle technique can therefore be helpful in cases where animation deformity is contributing to a transverse crease across the breast mound because it places these released muscle fibers posterior to the implant and only superior muscle fibers with retained sternal attachments (and inability to exert their action on the breast mound) now lie anterior to the implant. Figure 2.8 demonstrates the split muscle bi-plane technique.

For patients in whom submuscular coverage is still desired, Maxwell and colleagues described the neo-subpectoral pocket [20, 21]. This dissection is performed by separating the anterior implant capsule from the overlying pectoralis, which becomes the new implant pocket (Fig. 2.9). The prior pocket space is then obliterated by suturing the prior anterior and posterior capsule together.

Inferior Support with Suture or Mesh-Assisted Capsulorrhaphy

After pocket conversion, most implants will need some inferior support to prevent secondary bottoming out deformity or attenuation on the newly created inframammary crease. Support for the inferior pole can be provided in two main ways: suture capsulorrhaphy or mesh-supported capsulorrhaphy. Commonly used meshes include biologics (such as human cadaveric acellularized dermal matrix) or absorbable meshes (such as poly-4-hydroxybutyrate or polydioxanone).

Suture capsulorrhaphy was initially described by Spear and colleagues in 1988 [22]. The inferior capsule can be reinforced with stitches placed from the dermis to the chest wall at the desired position of the new IMF. We prefer to do capsulorrhaphy in two layers with a buried interrupted PDS sutures oversewn with running PDS sutures.

Fig. 2.4 Differences in fascial dissection lead to various implant malposition deformities. (**a**) demonstrates the normal, correct location of a submuscular implant. Double-bubble deformity and bottoming out can both occur from inferior pocket overdissection. Double-bubble deformity occurs if pocket dissection is deep and only violates the deep fascial fibers, leaving the superficial IMF fascial fibers intact (**b**). Bottoming out occurs if pocket dissection is more superficial and those superficial fascial fibers are released (**c**). Waterfall deformity (**d**) is a distinct phenomenon that, although sometimes confused with double-bubble deformity, results from a high-riding rather than low-riding implant

Fig. 2.5 Patient with simultaneous animation deformity and double-bubble deformity at rest (**a**). Patient shows accentuation of the double bubble with pectoralis animation (**b**)

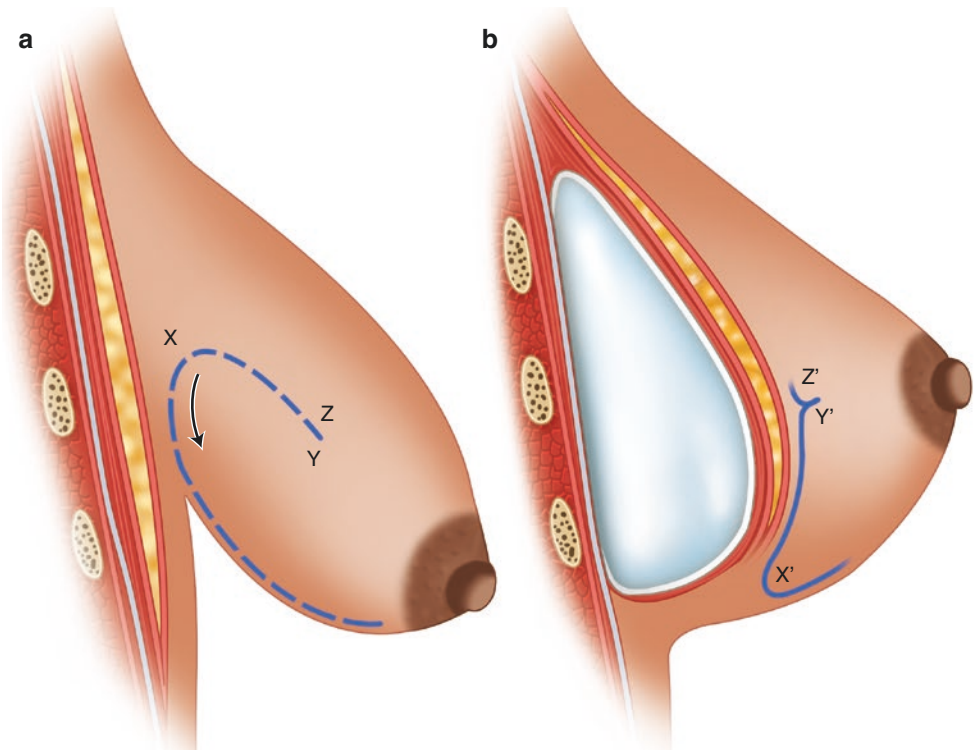


Fig. 2.6 Example of Puckett's unfurling technique to prevent double-bubble deformity in the breast with a constricted lower pole. In this technique, a sub-glandular dissection proceeds from caudal to cranial until the midpoint of the gland is reached (about the level of the nipple) (**a**). The breast tissue is then split in a posterior to anterior direction and unfurled inferiorly, thereby expanding the lower pole of the breast (**b**)

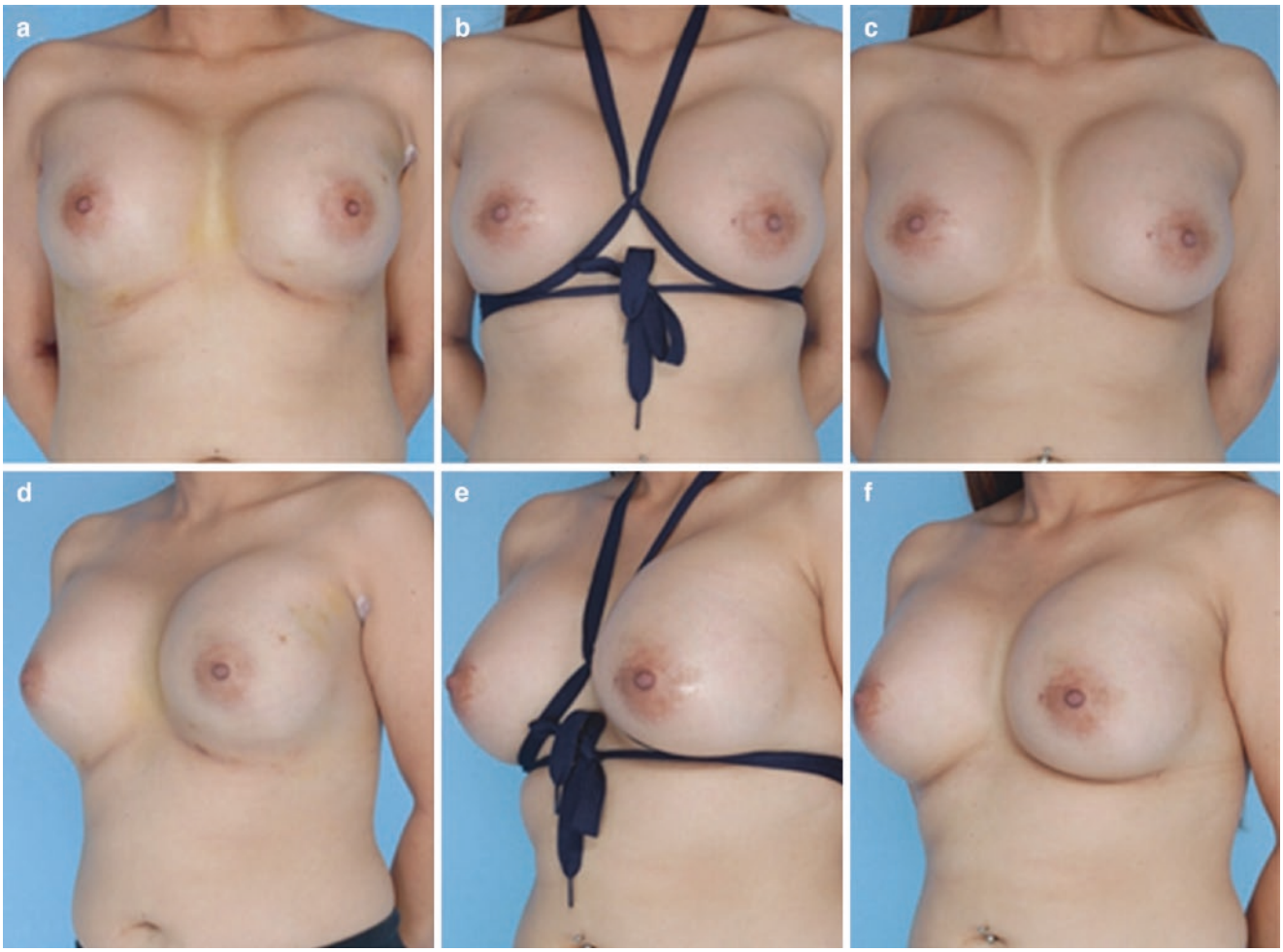


Fig. 2.7 Example of the shoelace breast cast. (**a**, **d**) Patient presented 4 days after trans-axillary breast augmentation with slight double-bubble deformity and implant malposition. (**b**, **e**) Shoelace breast cast in place. (**c**, **f**) The patient's double-bubble deformity was corrected, and the inframammary crease was better defined after 19 days in the shoelace breast cast. (Reprinted with permission from Mills [17])

Inferior pole support with biologic or absorbable synthetic mesh has been described in a multitude of techniques, utilizing a variety of pockets (sub-glandular, neopectoral, muscle splitting bi-plane) [23–26]. We prefer to use absorbable synthetic mesh as we have found that this results in superior long-term outcomes with less need for revisions (unpublished results). We use a butterfly-shaped mesh, with one wing of the butterfly secured to the chest wall and the other wing of the butterfly resting against the underside of the anterior breast tissue. 2.0 PDS sutures are used to secure this butterfly mesh along the chest wall and the gutter of the inset "sleeve" of mesh represented by the analogous body or thorax of the butterfly shape. The anterior wing of the mesh is then tensioned appropriately to the anterior breast to secure the implant without creating a tethering or flattening of the lower pole. If mesh is to be used, then the aforementioned suture capsulorrhaphy is still used slightly inferior to the mesh neo-IMF so that the weight of the implant rests on the mesh and not directly on the more vulnerable suture line. The case example to follow highlights our use of mesh, demonstrated in Fig. 2.10.

Adjunct procedures to ameliorate the IMF correction include fat grafting. This can be performed in conjunction with open or percutaneous release of persistent superficial retained condensations of the IMF to the skin. Bresnick used fat grafting as the primary modality for correction of double bubble in a small series of patients, reporting an average of 2.1 sessions of fat grafting in 28 patients for correction of double-bubble deformity with no additional revisional surgery required [27].

Algorithm for Double-Bubble Treatment

When a patient presents with a double-bubble deformity, the surgeon should first consider if this is something that can be treated with conservative means. In patients who are relatively early postoperatively (even up to 4–6 months after

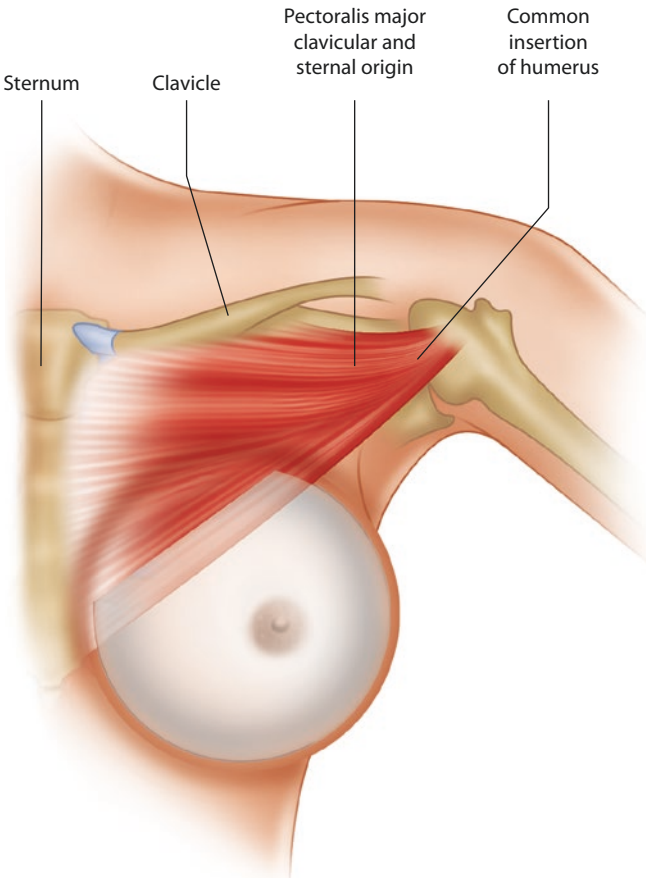


Fig. 2.8 Example of the split muscle bi-plane technique. This technique allows superior pole coverage of the implant with pectoralis muscle while placing the inferior pole of the implant in a sub-glandular pocket. Unlike dual-plane augmentation in which all pectoralis fibers sit anterior to the breast implant, this technique splits the pectoralis fibers parallel to their orientation and places the implant superficial to the most inferior pectoralis fibers

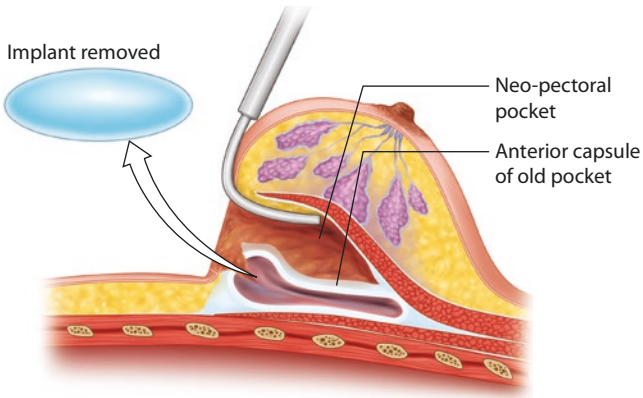


Fig. 2.9 Example of the neopectoral pocket, created by developing the space between the prior anterior capsule and pectoralis

breast augmentation), breast casting alone can fix the deformity by repositioning the implant and promoting scarring with the implant "externally held" in its desired pocket

Fig. 2.10 Mesh is cut into the shape of a butterfly. One wing will be secured to the chest wall. The thorax of the butterfly will be placed at the level of the desired IMF and secured in place. The other wing of the butterfly will sit anterior to the implant and will abut the anterior glandular flap, thereby creating a hammock of support for the implant in its new sub-glandular position to prevent bottoming out

(Fig. 2.11, *green pathway*). When this does not fix the problem, or in patients who are further out from surgery or with more severe deformity, then surgical correction is considered.

The most important consideration is whether the implant is inferiorly displaced from its desired position on the chest mound (Fig. 2.11, *purple pathway*). When this is the case, a capsulectomy is performed, resetting the IMF to the desired position. Often, a pocket change can provide greater stability than capsulorrhaphy of the existing pocket alone. If adequate soft tissue is present, a sub-glandular pocket is advocated to promote release of superficial fibrous attachments contributing to the double-bubble deformity. If inadequate soft tissue is present, then a neo-subpectoral pocket will suffice.

In other patients, the implant is actually sitting at the desired level on the chest wall, but double bubble deformity is present due to predisposing factors such as an abnormally high native IMF that was not appropriately obliterated in the original augmentation (Fig. 2.11, *blue*

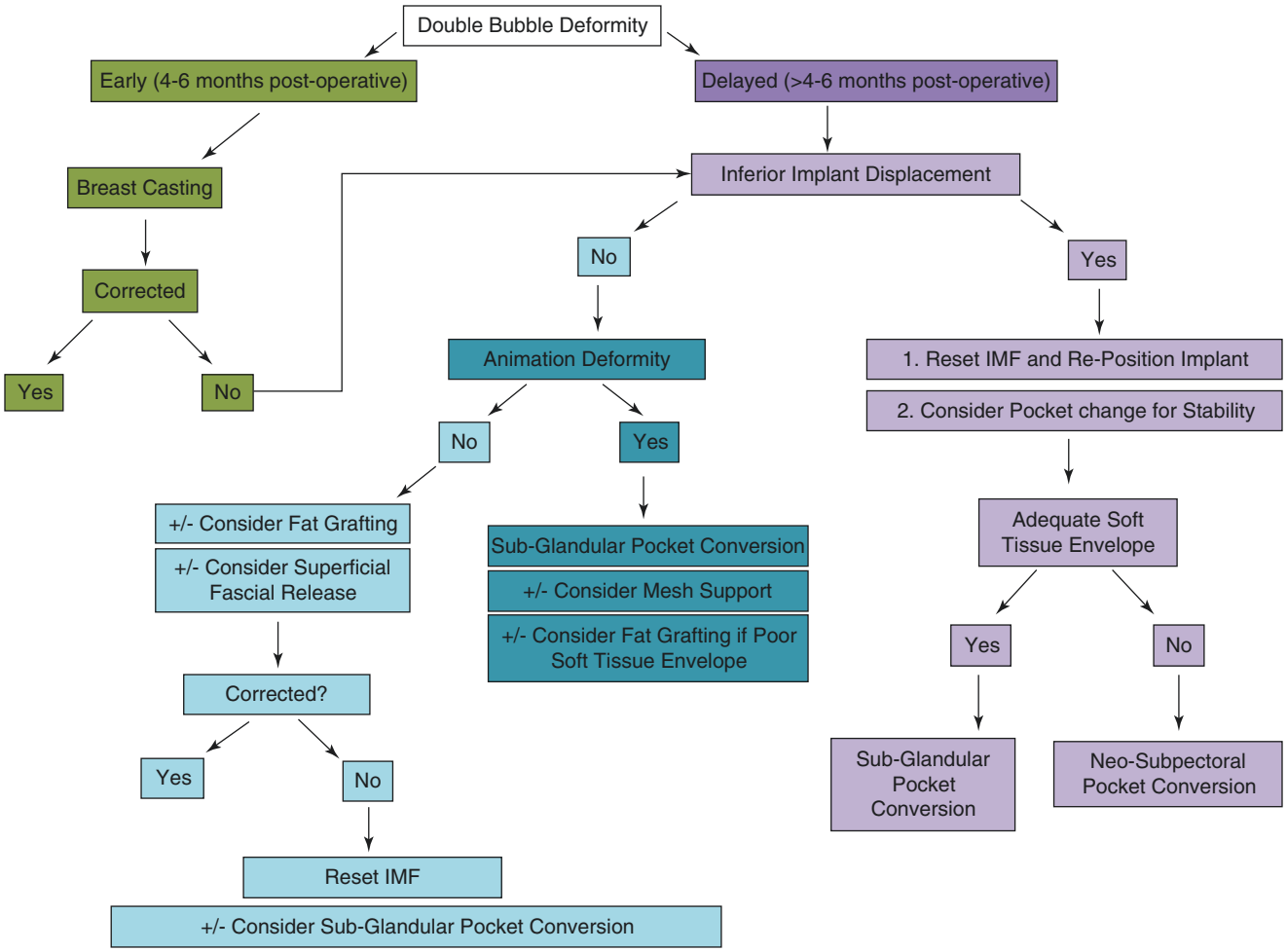


Fig. 2.11 Algorithm for management of double-bubble deformity

pathway). In these instances, it is important to ascertain whether animation deformity is present. If animation deformity is present (and perhaps contributing to the transverse crease on the breast mound), then a pocket change will be necessary regardless of the fact that the implant is sitting in the correct position. We advocate for a sub-glandular pocket for all animation deformity cases and fat grafting and lower pole mesh to support the soft tissue envelope, if needed.

When the implant is sitting at the desired level on the chest wall *and* there is no evidence of animation deformity, then slightly more conservative surgical approaches can be taken that simply rely on obliterating the transverse crease across the breast mound without opening the implant pocket. This can be as simple as fat grafting to disguise the crease or surgical release of these superficial fascial bands. Sometimes, this is not enough to correct the deformity, and in these instances the pocket must subsequently be reopened with resetting of the IMF (often with pocket conversion).

Case Example

The patient is a 27-year-old female who presented with bilateral double-bubble deformity after cosmetic breast augmentation (Fig. 2.12). She had undergone a submuscular augmentation 4 years previously via an IMF incision. On exam, she had a transverse crease across the inferior pole of both breasts, right worse than left, representing the double-bubble deformity. Compounding this static issue was the dynamic problem of animation that she had coincident with the double bubble. Finally, she also had keloiding of her prior IMF incision scar and modest ptosis.

The surgical plan included revision with exchange to a sub-glandular pocket via the prior IMF incisions with excision of keloid scars, lower pole support with absorbable mesh placement and circumareolar mastopexy.

In the operating room under general anesthesia, access to the breast was obtained through the pre-existing IMF incisions. Dissection proceeded into the capsule, and it was noted that the right breast implant was ruptured. Both

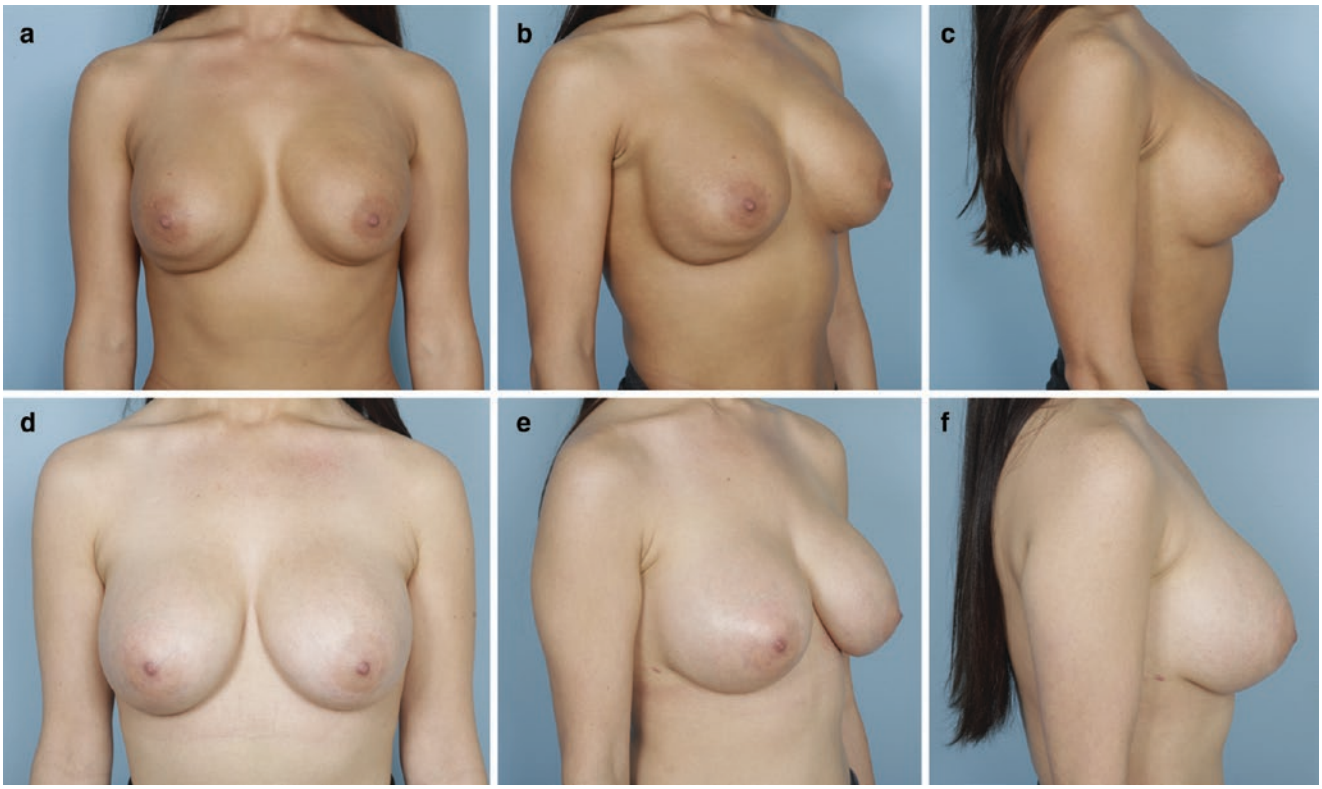


Fig. 2.12 Preoperative (**a**–**c**) and postoperative (**d**–**f**) photographs of a patient with double-bubble deformity, repaired with release of superficial fascial fibers, conversion to a sub-glandular pocket, and mesh capsulorrhaphy

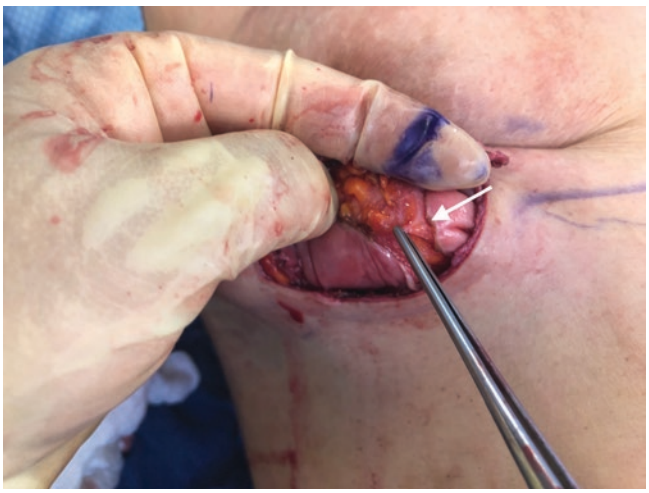


Fig. 2.13 This demonstrates the superficial fascial fibers of the native IMF of the patient in Fig. 2.12 during operative revision. This view is through an IMF approach, with the inferior breast parenchyma everted. The old implant capsule has been divided with radial scoring. Superficial to the capsule, the pick-ups are holding superficial fibers running transversely across the glandular tissue, which the white arrow also points to. These transverse fibers represent the native IMF and are found at the same level as the transverse skin crease across the breast mound

implants were removed, and multiple rounds of irrigation were performed. At the level of the double-bubble deformity, pectoralis fibers were noted to be inserting into the more superficial glandular tissue and region of the original IMF. The pectoralis muscle was dissected off the overlying breast tissue and sutured back into position on the chest wall. The new sub-glandular pocket for the breast implant was thus created. Additional superficial fascial fibers were noted, representing the original IMF, at the same level of the external transverse crease across the breast (Fig. 2.13 and Video 2.1). These fibers were released with radial scoring extending from this region through the breast parenchyma. Significant radial scoring of the breast parenchyma was required in order to get adequate release of the transverse skin crease across the lower pole of the breast mound. The IMF was then re-created at the appropriate position via 2.0 PDS sutures in two-layer fashion. Cephalad to this suture, absorbable mesh was inset in the same butterfly technique noted previously (see Fig. 2.10). The new silicone implants were then placed, and the other half of the mesh was judiciously secured to the anterior flap of breast mound. Pre- and postoperative photographs are shown in Fig. 2.12.

Conclusion

Double-bubble deformity occurs from a combination of (1) overdissection of the deep IMF fibers, resulting in implant displacement inferiorly, and (2) persistence of superficial fascial elements of the IMF, giving the appearance of a transverse band across the lower pole of the implant. Avoidance of this uncommon complication is predicated on understanding IMF anatomy and preserving it (and in cases where it must perforce be modified, ensuring that appropriate support is established at the reset IMF). Treatment is stratified by severity with initial nonsurgical approaches for modest deformities. More significant double-bubble deformities will generally require release of the superficial band with appropriate sizing of implants, augmented suture and mesh capsulorrhaphy, and possible pocket change.

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