Review

Eur J Breast Health
DOI: 10.4274/ejbh.galenos.2025.2025-2-1

Techniques for Retaining the Inframammary Fold in Implant-Based Reconstructive Breast Surgery

Artem Mishin[1], Alla Kartasheva[1], Viktor Okhotin[1], Igor Ganshin[1,2]

[1]Department of Plastic and Aesthetic Surgery, Academy of Postgraduate Education, Federal Scientific Clinical Center for Specialized Medical Assistance and Medical Technologies, Moscow, Russia
[2]Department of Plastic Surgery, Patrice Lumumba Peoples' Friendship University of Russia, Moscow, Russia

ABSTRACT

Both reconstructive and aesthetic implant-based breast surgery are associated with the risk of damage or destruction of the inframammary fold (IMF). Such surgical complications lead to implant disposition and disruption of the natural shape of the breast. Various techniques are used to restore the IMF or prevent its damage, such as tissue rearrangement, sutures, capsular flaps, the use of biological matrices or synthetic meshes. In this review, all current methods of retaining the IMF and the frequency of complications reported over the past ten years are reviewed.

Keywords: Aesthetic plastic and reconstructive; breast reconstruction; implant; inframammary fold; review; surgery

Cite this article as: Mishin A, Kartasheva A, Okhotin V, Ganshin I. Techniques for retaining the inframammary fold in implant-based reconstructive breast surgery. Eur J Breast Health. [Epub Ahead of Print]

Key Points

- There are a number of methods for strengthening the inframammary fold in implant-based breast surgery, such as tissue rearrangement, sutures, capsular flaps, the use of biological matrices or synthetic meshes.
- All techniques can be highly effective, but the use of acellular dermal matrix is associated with slightly more complications.
- Not all synthetic or biological meshes/matrices are equally safe for the patients.

Introduction

The inframammary fold (IMF) is a critical structure in breast aesthetics, defining the lower pole of the breast and forming the acute angle with the chest wall (1, 2). To achieve a good and stable result in breast surgery, it is preferable to preserve the IMF. The ideal IMF has a semi-elliptical shape, which may become attenuated with age and may descend after some surgical procedures, such as implant-based breast surgery changing the position of the IMF or creating a new one (3).

Since the first description of the reconstruction of the IMF by Pennisi (4) and Ryan (5) using local tissue remodeling, new methods have emerged, based on suture techniques, and the use of biological or synthetic matrices. At the same time, these methods have gradually begun to be used not only in reconstructive surgery, but also in aesthetic breast surgery.

In this review, we would like to summarize the evidence of the past ten years publications for retaining or restoring the IMF in reconstructive and aesthetic breast surgery, and also try to identify the optimal methodology of achieving more predictable and durable outcomes with fewer complications.

Anatomy

The study of the anatomical structure of the IMF has been going on for about 200 years and there is still no clearly accepted optimal concept. In 1845, Cooper (6) suggested that the IMF was formed by turning the mammary gland under itself. Thus, something similar to a folded edge would be obtained. However, we now understand that the anatomy of the IMF is much more complex and includes a connective tissue component.

At the end of the 20th century, a theory was put forward about the formation of the IMF being due to the presence of a true ligament. The work of Bayati and Seckel (7) hypothesized for the first time a true ligament in regard of the IMF. According to their description, the ligament arises as a thickening of the fascia of the external oblique and serratus anterior muscles laterally and the fascia of the rectus abdominis muscle medially. The medial part of the inframammary ligament originates from the periosteum of the fifth rib, and the lateral part originates from the fascia between the fifth and sixth ribs, and then it grows into the deep layer of the dermis in the area of the IMF.

Corresponding Author:
Artem Mishin MD; mishin1997.20@gmail.com

Received: 03.02.2025
Accepted: 14.03.2025
Epub: 30.04.2025

However, these authors, having carried out studies on cadaveric bodies and with the help of histological studies, did not find the ligament (8-10). According to their research, the IMF was formed by dermal collagen fibers that are fixed to the thoracic fascia. Thus, the concept of the fascial origin of the IMF was formed. This concept was further generalized and supplemented by clinical observations (11). It was proposed that the formation of the IMF occurs due to the fusion of the sheets of the superficial fascial system (SFS) of the mammary gland. The entire thickness of the subcutaneous tissue of the human body is penetrated by collagen trabeculae that connect the skin to the deep fascia, this fascial network was called the SFS. The subcutaneous tissue is divided by the fascia of Scarpa into a stroma-rich, superficial, and deep layer. The superficial tissue layer has many strong transverse connective tissue fibers, between which small lobules of subcutaneous fat are enclosed. The surface layer is firmly connected to the skin, together with which it forms a cover for the rest of the mammary gland tissues. Deeper fascial fibers are less common, oriented radially, corresponding to the ductal-lobular structure. This fascial part is Cooper's ligaments system, which is involved in the formation and maintenance of the cone-shaped breast. Between the gland and the deep fascia, in the retromammary space, there are many fewer connective tissue fibers. As a result of the loose arrangement of the fibers, there are large lobules of fat between them, which ensures the sliding of the gland along the chest wall. Thinning of the deep fat layer occurs in the IMF area, as a result of which the superficial layer with the adjacent skin is fixed directly to the deep fascia. In fact, the skin grows into the fascia of the underlying muscle, which looks like a longitudinal groove. The latest study confirmed the IMF's fascial origin, and presents it not as a single membrane like Cooper's ligaments or other fascia, but as a multilayer structure formed by the gradual accretion of thin fascia and their interweaving into the dorsal fascia of the mammary gland and the superficial fascia above the rectus abdominis muscle (12).

Materials and Methods

A comprehensive search was performed in PubMed, Embase.com and the Cochrane Library from 2013 till 2024. Search terms included controlled terms (MesH in PubMed, Emtree in Embase), as well as free text terms. The reference lists of all identified publications were checked to retrieve other relevant publications. The search was limited to articles published in English. Search terms "inframammary fold" AND "implant" were used. The initial list included 154 articles. Based on the title and abstract, 115 articles were excluded. The exclusion criteria were: articles not related to implant-based mammoplasty and/or IMF surgery and articles not in English. In addition, 10 articles were excluded due to the impossibility of interpreting the results (a significant part of the data regarding the number of patients, surgical methods, and postoperative results were missing). However, the reference lists of eligible articles were analyzed, which led to the inclusion of seven more articles. A total of 36 articles were selected on the topic of strengthening the IMF in implant-based mammoplasty (Figure 1).

Results

General information about the studies, the methods used, and the number of complications is presented in Table 1.

Local Tissue Rearrangement

The patient can benefit from cost-effective methods of strengthening the IMF using their own tissues, such as dermis flaps or breast parenchyma, as "supportive structures". The composition of these flaps depends on the type of surgery, whether aesthetic or reconstructive.

De Vita et al. (13) studied the results of primary bilateral augmentation-mastopexy using an inferior dermoglandular flap in 182 patients. The technique involved isolating a parenchyma flap of the lower pole of the breast and creating a "balcony" with sutured edges to the pectoralis major muscle. Over four years, minor complications were identified, and six patients required revision surgery for hematoma, capsular contracture, or "bottoming out". The majority of patients rated their results as "good" and there were no dissatisfied patients. This technique allows surgeons to stabilize the implant in the projection of the IMF and from the medial and lateral sides, and protects the implant from exposure in case of suture failure. AboShaban and Abdelaty (14) shared their results on revision bilateral augmentation-mastopexy in 53 patients, covering the implant in two layers: the pectoralis major muscle and dermoglandular flap, the NAC-flap on top, and breast pillars on the bottom. No serious complications were identified, indicating that this technique allows surgeons to stabilize the IMF and implant position.

A study by Han et al. (15) reported on 170 primary and 14 secondary augmentations using the adipofascial flap. They partially dissected the pectoralis major muscle fascia with retromammary fat, covered the implant's lower slope, and sutured it to the mammary gland tissues or the lower edge of the muscle. This technique strengthened the IMF with dense, vascularized tissue. A cadaver study showed a flap thickness of 3–4 mm. However, doubts remain about the possibility of fixing the flap to the gland tissue and its cutting, and there was no information on reoperations with similar complications.

In oncological breast reconstruction, surgeons often cannot use glandular tissue for the lower covering flap, but the dermis can be used. A technique by Ellabban et al. (16) used a de-epithelialized skin "hammock" for immediate implant-based breast reconstruction, suitable for patients with severe breast ptosis undergoing skin-reducing mastectomy. In 42 cases, the skin flap was de-epithelialized, forming two upper edges and sutured to the lower pectoralis major muscle. This method is an alternative to the dermoglandular flap but has a risk of flap necrosis if excessively thinned.

Capsular Flap

Capsule formation around the implant is a natural delimiting reaction of the body against any foreign object. Replacing implants, surgeons used to remove the capsule to prevent further capsular contracture. In 2002, a technique using the capsule to strengthen the IMF and stabilize the position of new implant was first described (17).

In 2013, Bogdanov-Berezovsky et al. (18) published two clinical cases using a capsular flap. The first patient had an implant rupture and underwent bilateral implant replacement. They performed a partial capsulotomy on both sides and created a pocket with bipedical capsular flaps from the posterior segment of the peri-implant capsule. The second patient underwent augmentation mammoplasty after previously installed and removed implants. The lower distal edge of the capsule was raised in the form of a flap with an upper base from the chest wall to the calculated level of the newly created pocket. The postoperative period proceeded without complications.

In the same year, Persichetti et al. (19) published a study of 30 patients who underwent revision mammoplasty to correct IMF. The surgical

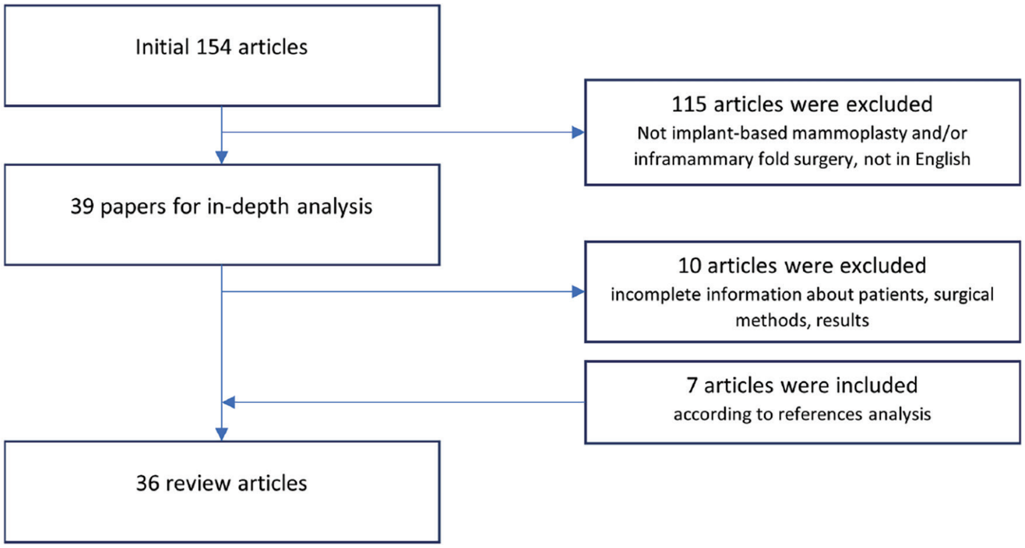

Figure 1. Diagram depicting the process of searching and selecting articles for review

Table 1. The table briefly describes all the articles included in this review

Author, y.	Surgical intervention	Methods	Number of patients	Number of complications (major and minor)	Follow-up period
Local tissue rearrangement					
de Vita et al. (13), 2017	Augmentation-mastopexy	"Balcony" technique	182 (n = 364 breasts)	Major: 6 Minor: 20	4 years
Han et al. (15) 2018	Augmentation mammoplasty	Adipofascial flap	184 (n = 368 breasts)	Major: 0 Minor: 21	21 mo
Ellabban et al. (16), 2020	Implant-based breast reconstruction	"Hammock" dermal flap	42 (n = 52 breasts)	Major: 4 Minor: 6	13 mo
AboShaban MS, Abdelaty (14) 2022	Revision bilateral augmentation-mastopexy	Dermoglandular flap	53 (n = 106 breasts)	Major: 0 Minor: 9	3.6 years
Capsular flap					
Bogdanov-Berezovsky et al. (18), 2013	Implant replacement/ augmentation mammoplasty	Capsular flap	2 (n = 4 breasts)	0	0/2 years
Persichetti et al. (19), 2013	Revision mammoplasty	"Slingshot" Capsular flap	30*	Major: 0 Minor: 5	0.5–3 years
Mayer et al. (20), 2014	Revision mammoplasty	Capsular flap/graft	21 (n = 23 breasts)	Major: 2 Minor: 5	16 mo
Wessels et al. (21), 2014	IMF reconstruction	"Hammock" Capsular flap	12 (n = 21 breasts)	0	N/A
Ismagilov et al. (22), 2017	Expander-based breast reconstruction	Posterior sheet of the expander capsule	321*	Major: 0 Minor: 42	5–6 years
Cogliandro et al. (23), 2018	Expander-based breast reconstruction + mastopexy	Dermo-capsular flap	20 (n = 40 breasts)	Major: 0 Minor: 2	12 mo

Table 1. Continued

Author, y.	Surgical intervention	Methods	Number of patients	Number of complications (major and minor)	Follow-up period
Sutures					
Mohmand and Ahmad (24) 2013	Augmentation mammoplasty	3 sutures	32 (*n* = 32 breasts)	Major: 0 Minor: 3	N/A
Hirsch et al. (25), 2014	Expander-based breast reconstruction	Barbed sutures	45*	Major: 0 Minor: 2	N/A
Terao et al. (26), 2015	Implant-based breast reconstruction	Drawstring method	95 (*n* = 95 breasts)	Major: 0 Minor: 10	N/A
Nakajima et al. (27), 2018	Implant-based breast reconstruction	Vertical pendulum suture	9 (*n* = 9 breasts)	Major: 0 Minor: 0	11 mo
Goddard et al. (28), 2022	Various mammalogical surgeries	Hemostatic net	24 (*n* = 48 breasts)	Major: 0 Minor: 2	12.9 mo
ADM					
Hanna et al. (30), 2013	Expander-based breast reconstruction	ADM/submuscular procedure	31 (*n* = 40 breasts)/44 (*n* = 62 breasts)	Major: 7 patients Minor: 6 patients/Major: 4 patients Minor: 13 patients	N/A
Avashia et al. (31), 2013	Immediate or delayed implant-based breast reconstruction	ADM + additional antibiotic prophylaxis	96 (*n* = 138 breasts)	Major: 14 Minor: 21	6.5 mo
Kornstein (39), 2013	Augmentation mammoplasty	PADM	3 (*n* = 6 breasts)	Major: 0 Minor: 0	18 mo
Spear et al. (32), 2014	Revision mammoplasty	ADM	118 (*n* = 154 breasts)	Major: 2 Minor: 6	N/A
Ibrahim et al. (33), 2015	Expander-based breast reconstruction	ADM/non-ADM	18 (*n* = 32 breasts)/20 (*n* = 32 breasts)	Major: 0 Minor: 9/Major: 0 Minor: 6	19 mo
Roh et al. (34), 2017	Expander-based breast reconstruction	ADM	25 (*n* = 50 breasts)	Major: 0 Minor: 7	≈12 mo
Brichacek et al. (35), 2017	DTI breast reconstruction	ADM	19 (*n* = 35 breasts)	Major: 0 Minor: 25	6 mo
Tsay et al. (36), 2018	Expander or implant-based breast reconstruction	ADM/non-ADM	23 breasts/16 breasts	Major: 0 Minor: 3/Major: 0 Minor: 2	6-9 mo
Kim et al. (37), 2020	Implant-based breast reconstruction	ADM (IMF incision/Rd incision)	19 (*n* = 22 breasts)/69 (*n* = 75 breasts)	Major: 1 Minor: 0/Major: 9 Minor: 11	9.5 mo/7.9 mo
Luan et al. (38), 2021	Expander-based breast reconstruction	ADM	62 (n = 108 breasts)	Major: 16 Minor: 16	18 mo
Gao et al. (40), 2020	Implant-based breast reconstruction	SIS matrix/non-SIS matrix	79 (*n* = 79 breasts)/76 (*n* = 77 breasts)	Major: 5 Minor: 9/Major: 3 Minor: 5	≥12 mo

Table 1. Continued

Author, y.	Surgical intervention	Methods	Number of patients	Number of complications (major and minor)	Follow-up period
ADM					
Gao et al. (41), 2021	Implant-based breast reconstruction/ expander-based breast reconstruction	SIS matrix/non-SIS matrix	79 (*n* = 79 breasts)/45 (*n* = 46 breasts)	Major: 5 Minor: 9/Major: 3 Minor: 0	≥12 mo
Synthetic meshes					
Becker et al. (43), 2013	Various mammalogical surgeries	TIGR® matrix	62 (*n* = 112 breasts)	Major: 17 Minor: 6	16.5 mo
Hansson et al. (45), 2021	Expander-based breast reconstruction	TIGR® matrix/bovine pericardium matrix	48 (*n* = 24 breasts/*n* = 24 breasts)	Major: 2 Minor: 5/Major: 5 Minor: 15	16.4 mo
Dieterich et al. (47), 2013	Immediate or delayed implant-based breast reconstruction	Titanium-coated polypropylene mesh	207 (*n* = 231 breasts)	Major: 31 Minor: 36	14 mo
Haynes and Kreithen (46), 2014	Expander-based breast reconstruction	Vicryl mesh	38 (*n* = 46 breasts)	Major: 4 Minor: 3	43 mo
Dieterich et al. (48), 2015	Immediate or delayed implant-based breast reconstruction	Titanium-coated polypropylene mesh/non mesh	48 (*n* = 51 breasts)/42 (*n* = 47 breasts)	Major: 6 Minor: 1/Major: 10 Minor: 2	18 mo
Baldelli et al. (50), 2016	Immediate or delayed expander-based breast reconstruction	Polyester mesh/non mesh	63 (*n* = 70 breasts)/133 (*n* = 136 breasts)	Major: 10 Minor: 18/ Major: 17 Minor: 31	N/A
Hallberg et al. (44), 2018	Immediate or delayed implant-based breast reconstruction	TIGR® matrix	49 (*n* = 65 breasts)	Major: 4 Minor: 11	12–24 mo
Schüler et al. (51), 2021	Implant-based breast reconstruction	PADM/ polypropylene + polyglycolic acid mesh/ titanium-coated polypropylene mesh	34 (*n* = 40 breasts)/48 (*n* = 54 breasts)/75 (*n* = 94 breasts)	Major: 11 Minor: 11/ Major: 6 Minor: 7/Major: 14 Minor: 9	11.7 mo
Patzelt et al., 2022[54]	Implant-based breast reconstruction	Dermal flap/ polyglycolic acid mesh	32 (*n* = 64 breasts)/32 (*n* = 64 breasts)	Major: 0 Minor: 12/ Major: 1 Minor: 5	17.7 mo

*: No data about the number of breasts; IMF: Inframammary fold; ADM: Acellular dermal matrix; PADM: Porcine ADM

technique consisted of cutting the implant capsule at the level of its transition to the chest wall, advancing the anterior edge cranially along the chest wall in the form of a "Slingshot" and then fixing it to the posterior leaf of the capsule and costal periosteum. During postoperative follow-up, two patients had a slight recurrence of breast ptosis and three had hypodefinition of the IMF.

Mayer and Loustau (20) published a study involving a small group of patients who underwent immediate prosthetic breast reconstruction using capsular grafts and flaps. Capsular grafts were used in small strips to imitate anatomical structures supporting the implant's lower edge - the lateral tape was sutured distally to the serratus anterior muscle and to the lateral edge of the pectoralis major muscle, the lower tape was sutured between the lower edge of the pectoralis major muscle and the IMF. With a large implant size or a high IMF position the distal part of the capsular flap was sutured to the free edge of the pectoralis major muscle. The flap's length was created with an aspect ratio of 1:2/1:3 to maintain its viability. Two patients experienced complications, while others experienced superficial epidermolysis, rippling, seroma, and mild contractures after irradiation (20).

The reverse method to the Persichetti method was published by Wessels et al. (21) Instead of dissection of the capsule at the level of the chest, the capsulotomy was performed in front of the implant and then dissection was carried out downwards with the formation of a "hammock". The length of the upper part of the capsular pocket was corrected for the size of the implant, taking into account the IMF. Thus, 12 patients were operated on, and, according to the authors, none of them had any complications.

Ismagilov et al. (22) demonstrated a new method of using the capsular flap in 321 patients. They supplemented the capsular flap technique with local tissue rearrangement, replacing the expander with an implant, cutting off the lower capsule horizontally in front and behind, dissecting it along the chest wall, and lifting tissues to the neo-IMF level. The lower capsule was then sutured to the upper capsule. It was reported that 42 patients had minor aesthetic defects, some of which resolved spontaneously.

Cogliandro et al. (23) developed a dermo-capsular flap for breast reconstruction and mastopexy in patients with severe weight loss. They performed bilateral or unilateral breast reconstruction with contralateral mastopexy on 20 patients. The flap, formed from the lower capsule and de-epithelized skin with fiber, was expected to increase the volume of the lower breast due to its thickness, but would be more dependent on blood supply.

Sutures

The simplest technique for strengthening the IMF, in our opinion, is suturing the bottom of the implant pocket. So, in 2013 Mohmand and Ahmad (24) shared their experience of primary periareolar augmentation mammoplasty in 32 women with three sutures under the implant in the IMF projection. During the study, only two cases of a slightly stretched scar and one case of a high implant position were noted.

Hirsch et al. (25) also strengthened the IMF using sutures, but they used barbed sutures. Forty-five patients had previously undergone a skin-sparing mastectomy and had tissue expanders placed. After capsulotomy at the IMF level, barbed sutures were applied, connecting the dermis and fascia of the rectus abdominis muscle, periosteum, or other tissues. Only two patients experienced asymmetry recurrence, leading to reoperation. The advantage of such sutures lies in controlled tension and the IMF level control.

Barbered suture was also used by Terao et al. (26) in 102 reconstruction patients. A distinctive feature of this method was the use of an epidural needle as a navigator and to control the complete passage of the thread through the entire dermis in the IMF projection. The authors noted the possibility of adjusting the IMF after implant placement by changing the tension of the barbered sutures. In 10 patients after reconstruction with implants, sagging of the sutures and a decrease in the definition of IMF were observed.

As the study of Nakajima et al. (27) has shown, the seam does not have to be internal. So, nine patients underwent unilateral breast reconstruction using implants. To recreate the IMF, the authors used several external vertical pendulum sutures with stitching of the chest wall. It has been shown that a scalloped IMF acquires a normal smooth structure after three months and the results do not differ from other methods. The advantage of this method is its simplicity and the absence of necessary control of seams, but this is associated with an increased risk of pneumothorax or infection.

In addition to the previous study, one can also consider the use of a hemostatic net as in the study of Goddard et al. (28). This is only a preliminary report, but the authors have already highlighted several key aspects of using such external sutures. Various bilateral implant-based mammoplasties (also one using a latissimus dorsi flap) were performed in 24 patients and good stable results with minimal complications were obtained. The authors concluded that skin redraping with a hemostatic net cannot be considered as an alternative to mastopexy, but in conjunction with the application of internal supporting sutures, a hemostatic net reduces the risk of their rupture.

Acellular Dermal Matrix

The use of acellular dermal matrix (ADM) was first described in 2005 by Breuing and Warren (29), whose research goals were to shorten the reconstructive process, improve results, and provide additional options for women seeking mastectomy. Biologic matrices provide the ability to create a pocket for an implant or tissue expander without using local tissues, such as serratus anterior or rectus abdominis muscles. Currently, most dermal matrices used for breast reconstruction include human, porcine or bovine matrix. Despite the widespread use of ADM, it is also associated with various complications, particularly seromas and infections.

A study by Hanna et al. (30) examined 75 patients who underwent two-stage breast reconstruction using tissue expanders. Of these, 44 patients underwent submuscular reconstruction, and 31 patients had reconstruction with ADM (AlloDerm, LifeCell Corp). If the IMF was violated during mastectomy, it was reconstructed with a 3–0 absorbable monofilament suture. The ADM was sutured to the pectoralis major muscle medially and to the serratus anterior muscle laterally, thus forming a new pocket for the expander. As a result, the ADM group included more major complications but fewer minor complications. The use of ADM allowed for intraoperative filling of expanders, reducing the reconstruction period by an average of a week.

A retrospective study by Avashia et al. (31) examined 96 patients who underwent expander-based breast reconstruction using ADM (AlloDerm, LifeCell Corp). The authors argued that ADM increased the risk of infectious complications during breast reconstruction, suggesting the use of additional antibiotic therapy for over 48 hours after surgery. The study involved 84 patients who received postoperative cephalosporins, vancomycin, clindamycin, or ciprofloxacin for ≥48 hours, depending on their allergic reactions. Twelve patients were prescribed antibiotic therapy not exceeding 24 hours. The study found that infectious complications leading to implant removal were detected in 6.7% of cases in the first group and 31.6% in the second group. The authors suggest that additional antibiotic prophylaxis reduced the risk of postoperative infectious complications when using ADM.

Spear et al. (32) studied in depth the issue of using ADM to control IMF in 118 patients. All patients underwent revision breast reconstruction. The authors identified five indications for ADM use: capsular contracture (Baker class III/IV), inferior fold malposition, inferior pole support, medial fold support or symmastia and rippling/palpability. The authors also considered the presence of a capsule around the implant during revision. They used an additional ADM at the site of the inferior capsulorrhaphy for additional implant support and considered lowering the IMF. They performed all manipulations with the ADM without an implant installed to reduce the risk of damage. One patient developed complications leading to implant removal, including cellulitis and lack of IMF support. Other complications included capsular contractures in five patients and rippling in one patient.

The use of ADM is associated with improved aesthetic performance compared to non-ADM techniques. So, assessment by independent experts in the study of Ibrahim et al. (33), reported that the group of patients with ADM had significantly better assessments of the breast contour, the projection of the lower pole and the position of the implant than in the group of patients without ADM. Both groups experienced similar minor complications typical for two-stage breast reconstruction.

Expander-based breast reconstructions often require radiation therapy, and experienced surgeons aim to predict changes in the breast after radiation. So, for example, Roh et al. (34) deliberately created asymmetry for its further compensation during the passage of irradiation. ADM was used to strengthen the lower pole of both breasts in 25 patients, while on the side of the planned irradiation, the inferior edge of the ADM was not fixed to the chest wall, creating a “bottoming-out” effect. After radiation therapy, upward migration of the skin was noted, approaching the level of the contralateral breast. Thus, when replacing expanders with implants, six patients required a slight reduction in IMF, and one patient required an increase in IMF. This technique better predicted the position of the IMF in patients with planned radiation and improve the final aesthetic result.

Another feature of the use of ADM is that it allows reduction of surgical aggression on the pectoralis major muscle by increasing the area of implant coverage with matrix. In a study by Brichacek et al. (35), the pectoralis major covered only a few centimeters of the implant, with most being covered with ADM. This technique reduced the risk of animation deformities but increased operation costs, despite encountering some complications treated conservatively or in the outpatient clinic.

Most studies of the use of ADM or other methods, are based on the subjective opinions of the authors, a few involve independent experts, and even fewer question the patients themselves. In 2018, an attempt was made to objectify the results of ADM implantation and compare with techniques without ADM. Tsay et al. (36) enrolled 24 patients in the study and eventually performed ADM reconstruction on 23 breasts and 16 without ADM. Three-dimensional imaging and mammometrics were used to evaluate the difference between these two methods. The results reported a significantly better reconstruction with ADM compared to without ADM. Breasts reconstructed with ADM had a higher point of maximum projection and mean lower pole curvature, but this difference was clinically and aesthetically insignificant.

Based on the studies described above, it can be concluded that ADM is a viable option for breast reconstruction, but further research should focus on specific surgical techniques to establish the gold standard. In particular, it is necessary to determine the most effective surgical approach. Kim et al. (37) compared implant-based reconstruction through an IMF incision and through a radial incision and found that a radial incision increased infection and necrosis risks. Moreover, patients reported greater satisfaction with the IMF incision, as indicated by the Breast-Q questionnaire.

Another study, aimed at improving the technique of breast reconstruction, was described by Luan et al. (38) for expander-based reconstruction. Tissue expanders have tabs in their structure for attachment to surrounding tissues. The authors proposed a technique in which perforations were created in the ADM, through which these tabs were threaded and sutured with the matrix. Thus, the ADM and expander were implanted as a single unit, resulting in a single implant unit improving aesthetic prognosis and IMF position.

Both human and porcine ADM (PADM; Strattice, LifeCell Corp) are available for reconstructive surgery. So in 2013, Kornstein (39) described a series of clinical cases of PADM use in women with poor mammary soft-tissue quality with primary cosmetic breast augmentation. Three patients, two had a history of pregnancies and the third had a history of 10% weight loss. In all three patients, PADM was sutured along the IMF and pulled to the breast parenchyma and/or the caudal edge of the pectoralis major muscle. The matrix and implant pockets were flushed with antibiotic solution, and all patients received antibiotic therapy for seven days to prevent biofilms and colonize the chest pocket. The patients and physician were satisfied with the results of the operation, and it was also noted that the use of PADM with radial plication could replace the mastopexy step in patients with breast ptosis.

Another material that can be considered within the framework of this subsection is porcine small intestine submucosa (SIS). Gao et al. (40) conducted two retrospective analyses using this matrix for lower pole implant coverage and IMF reinforcement. SIS was compared with the standard technique of implant coverage with the pectoralis major muscle and with the technique of two-stage breast reconstruction. In general, the technique using SIS was associated with a higher number of complications (both major and minor), however, according to the results of the Breast-Q 2.0 questionnaire, breast satisfaction in both studies was higher in the SIS groups. Based on the data from these two analyses, it can be assumed that the use of SIS increases the risk of complications, but improves the aesthetic result of reconstruction (41, 42).

Synthetic Meshes

ADM is gradually being replaced by synthetic meshes, although the first attempts to use them were made at the same time as ADM. In 2002, Amanti et al. (42) published pilot results using a polypropylene mesh to create a subpectoral pocket for an implant. At the moment, there is no consensus on the use of biological or synthetic matrices, and the situation is complicated by the fact that today there are already a large number of synthetic analogues.

Becker and Lind (43) conducted research on the use of resorbable synthetic mesh TIGR® Matrix in various breast surgeries. A total of 62 patients took part in the study. The following surgeries were performed: primary reconstruction, reconstruction revision, augmentation/mastopexy revision, augmentation/augmentation mastopexy, mastopexy. TIGR® Matrix is a macroporous network consisting of two types of biodegradable fibers-fast-degradable (copolymer of glycolide and trimethylene carbonate) and slow-degradable (copolymer of lactide and trimethylene carbonate) and completely biodegrades within about three years. Due to the fact that the study did not provide for strict criteria for selecting patients (including 9 patients who had previously undergone radiation therapy), 23 operated breasts had some complications, of which 17 required surgical intervention. However, in other cases, good aesthetic results were obtained. During repeated operations, the initial resorption of the surgical mesh, initial invasion by connective tissues was revealed. In a later study, Hallberg et al. (44) showed slightly better results - out of 65 immediate breast reconstructions with TIGR® mesh, minor complications occurred in 11 cases and major complications in 4 cases. The authors did not identify any specific risk factors with the use of this mesh.

A unique and valuable study was conducted by Hansson et al. (45), comparing the TIGR® mesh with a biological mesh made of bovine pericardium. Twenty-four patients underwent bilateral two-stage breast reconstruction, with a synthetic mesh used on one side and a biological mesh on the other. In addition to the results showing a higher number of seromas and, as a result, infectious complications in the biological matrix group, it was also shown that this study design yielded unsatisfactory aesthetic results due to asymmetry.

Haynes and Kreithen (46) used Vicryl mesh to support the lower pole of the implant in breast reconstruction in 38 patients. All meshes were used at the stage of tissue expanders implantation, and by the time the expander was replaced with an implant, the mesh was completely biodegraded. Three infectious complications were noted, two of which were in patients who underwent radiotherapy. Moreover, the expander was lost in a patient from the radiotherapy group. The study found that Vicryl mesh was more than 20 times cheaper than ADM, allowing more patients to receive high-quality breast reconstruction.

Separately, we can highlight the methods of strengthening the lower pole of the implant and IMF with non-bioabsorbable meshes, such as titanium coated polypropylene or polyester. In terms of surgical technique, there are no differences from the use of any other meshes or matrices, but their features may manifest in the long term. Titanium-coated meshes have been used in Europe since 2008 for breast reconstruction. They are cheaper than acellular matrices and have proven their safety. However, based on the results of the largest studies, in a lack of subcutaneous tissue or radiotherapy, it is possible to palpate the mesh. It is also worth noting that it cannot be determined with complete certainty whether the use of this mesh has a negative or positive effect on breast satisfaction due to insufficient data (47-49). Similar results were obtained with a polyester mesh, but due to the short observation period, late surgical complications were not taken into account (50).

Few studies have directly compared biological and synthetic meshes. Schüler et al. (51) found that synthetic meshes SERAGYN® (polypropylene + polyglycolic acid) and TiLOOP® led to a lower but not significant number of complications and implant loss than the use of PADM. The authors also note a correlation between radiation therapy and complications. We can also refer to the results of Eichler et al. (52). In their study, they compared SERAGYN® and TiLOOP® with ADM, finding similar complication rates and slight differences. However, a patient survey using the BREAST-Q method showed no significant difference between satisfaction and the mesh material, indicating a need for further research (53).

Patzelt et al. (54) compared the techniques of strengthening the IMF with a de-epithelialized skin flap and SERAGYN® mesh in 64 patients divided equally into two groups. In the first group, the skin flap covered the lower pole of the implant and was sutured to the edge of the pectoralis major muscle. In the second group, a synthetic mesh played the role of a "hammock". The first group had 12 complications treated conservatively, while the second group had five minor complications and one full necrosis of NAC. The authors believe that the synthetic mesh is more reliable in terms of strengthening the IMF and implant position, however, the results of the Breast-Q questionnaire did not show a significant difference between the two groups.

Discussion and Conclusion

Strengthening the IMF is important not only for reconstructive surgeries, but also for aesthetic ones. Unlike implants with a polyurethane foam, microtextured and especially smooth ones stretch the lower pole of the breast in the postoperative period, further lowering the position of the IMF. This effect also depends on the elasticity of the patient's breast tissue - the higher the elasticity, the lower the implant will drop (55). Thus, additional support of the implant and IMF can help to prevent excessive lower pole expansion.

In this review, we have summarized modern methods of strengthening the IMF and stabilizing the implant in reconstructive and aesthetic breast surgeries. It can be cautiously stated that some of the described methods are associated with lower risks of complications (such as suture techniques and local tissue rearrangement), while the use of biological and synthetic matrices not only increases the risk of complications, but also the cost of the operation, and, as a consequence, the cost of an error.

It can also be cautiously noted that the results of some studies may differ greatly from those in similar studies. This may suggest that sometimes the authors may unintentionally give preference to the investigated or more proven techniques.

Most studies do not present data from surveys of patients themselves and independent specialists. We understand that these assessments are subjective, but it is necessary to remember that we perform all operations, regardless of the indications, for our patients. We can endlessly admire our results, while our patients may be dissatisfied.

In plastic surgery, as in any other branch of surgery, the essential point is the surgeon's experience. The choice of the optimal and effective method of strengthening the IMF during breast reconstruction also depends on many factors and can be extremely individual, which makes it difficult to form identical groups of patients for study. For a more evidence-based analysis of the effectiveness of various techniques, a clear study design, randomization, a large sample of patients, and a long study time are required.

Footnotes

Authorship Contributions

Concept: A.M., A.K.; Design: A.M.; Data Collection or Processing: A.M., A.K., V.O.; Analysis or Interpretation: A.M., A.K., I.G.; Literature Search: A.M., A.K., V.O., I.G.; Writing: A.M., A.K.

Conflict of Interest: No conflict of interest declared by the authors.

Financial Disclosure: The authors declare that this study received no financial disclosure.

References

1. Bogetti P, Cravero L, Spagnoli G, Devalle L, Boriani F, Bocchiotti MA, et al. Aesthetic role of the surgically rebuilt inframammary fold for implant-

based breast reconstruction after mastectomy. J Plast Reconstr Aesthet Surg. 2007; 60: 1225-1232. (PMID: 17950185) [Crossref]

2. Hudson DA. The role of the inframammary fold (IMF) in aesthetic and reconstructive surgery: a critical analysis and surgical solution. Aesthetic Plast Surg. 2024; 48: 2663-2667. (PMID: 37957392) [Crossref]
3. Atiyeh B, Ibrahim A, Saba S, Karamanoukian R, Chahine F, Papazian N. The inframammary fold (IMF): a poorly appreciated landmark in prosthetic/alloplastic breast aesthetic and reconstructive surgery-personal experience. Aesthetic Plast Surg. 2017; 41: 806-814. (PMID: 28374293) [Crossref]
4. Pennisi VR. Making a definite inframammary fold under a reconstructed breast. Plast Reconstr Surg. 1977; 60: 523-525. (PMID: 909961) [Crossref]
5. Ryan JJ. A lower thoracic advancement flap in breast reconstruction after mastectomy. Plast Reconstr Surg. 1982; 70: 153-160. (PMID: 7100307) [Crossref]
6. Cooper A. On the anatomy of the breast. London: Longman, Orme, Green, Brown, and Longmans; 1840. Accessed March 22, 2023. [Crossref]
7. Bayati S, Seckel BR. Inframammary crease ligament. Plast Reconstr Surg. 1995; 95: 501-508. (PMID: 7870774) [Crossref]
8. Nava M, Quattrone P, Riggio E. Focus on the breast fascial system: a new approach for inframammary fold reconstruction. Plast Reconstr Surg. 1998; 102: 1034-1045. (PMID: 9734421) [Crossref]
9. Boutros S, Kattash M, Wienfeld A, Yuksel E, Baer S, Shenaq S. The intradermal anatomy of the inframammary fold. Plast Reconstr Surg. 1998; 102: 1030-1033. (PMID: 9734420) [Crossref]
10. Muntan CD, Sundine MJ, Rink RD, Acland RD. Inframammary fold: a histologic reappraisal. Plast Reconstr Surg. 2000; 105: 549-556; discussion 557. (PMID: 10697160) [Crossref]
11. Rehnke RD, Groening RM, Van Buskirk ER, Clarke JM. Anatomy of the superficial fascia system of the breast: a comprehensive theory of breast fascial anatomy. Plast Reconstr Surg. 2018; 142: 1135-1144. (PMID: 30511967) [Crossref]
12. Takaya K, Sakamoto Y, Imanishi N, Kishi K. The fascial structure of the breast: new findings on the anatomy of the inframammary fold. J Plast Reconstr Aesthet Surg. 2022; 75: 1632-1638. (PMID: 34998682) [Crossref]
13. de Vita R, Zoccali G, Buccheri EM. The balcony technique of breast augmentation and inverted-T mastopexy with an inferior dermoglandular flap. Aesthet Surg J. 2017; 37: 1114-1123. (PMID: 29040405) [Crossref]
14. AboShaban MS, Abdelaty MA. The inferior-based dermoglandular flap with partial subpectoral implant transposition and revision mastopexy for subglandular breast augmentation complications. Aesthetic Plast Surg. 2022; 46: 686-693. (PMID: 34677641) [Crossref]
15. Han HH, Kim KK, Lee KH, Kim IB, Lee PK. The use of a retromammary adipofascial flap in breast augmentation for patients with thin soft tissue. Aesthetic Plast Surg. 2018; 42: 1447-1456. (PMID: 30132110) [Crossref]
16. Ellabban MA, Nawar A, Milad H, Ellabban MG. Single-stage immediate breast reconstruction using anatomical silicone-based implant and the hammock technique of dermal-muscle flap in large and ptotic breasts: a multicenter study. World J Surg. 2020; 44: 1925-1931. (PMID: 32076771) [Crossref]
17. Gargano F, Moloney DM, Arnstein PM. Use of a capsular flap to prevent palpable wrinkling of implants. Br J Plast Surg. 2002; 55: 269. (PMID: 12041996) [Crossref]
18. Bogdanov-Berezovsky A, Silberstein E, Shoham Y, Krieger Y. Capsular flap: new applications. Aesthetic Plast Surg. 2013; 37: 395-397. (PMID: 23435509) [Crossref]
19. Persichetti P, Langella M, Filoni A, Cagli B, Tenna S. How to redefine the inframammary fold: the “slingshot” capsular flap. Ann Plast Surg. 2013; 70: 636-638. (PMID: 23392260) [Crossref]
20. Mayer HF, Loustau HD. Capsular grafts and flaps in immediate prosthetic breast reconstruction. Aesthetic Plast Surg. 2014; 38: 129-138. (PMID: 24337173) [Crossref]
21. Wessels L, Murphy S, Merten S. The capsular hammock flap for correction of breast implant ptosis. Aesthetic Plast Surg. 2014; 38: 354-357. (PMID: 24477521) [Crossref]
22. Ismagilov A, Vanesyan A, Kamaletdinov I. Small refinements in breast reconstruction: a technique for inframammary fold creation. Gland Surg. 2017; 6: 132-140. (PMID: 28497016) [Crossref]
23. Cogliandro A, Barone M, Cassotta G, Salzillo R, Persichetti P. Mastopexy on reconstructed breast following massive weight loss: an innovative technique using dermo-capsular flaps. Aesthetic Plast Surg. 2018; 42: 396-399. (PMID: 29075821) [Crossref]
24. Mohmand MH, Ahmad M. Periareolar extra-glandular breast augmentation. World J Plast Surg. 2013; 2: 93-98. (PMID: 25489511) [Crossref]
25. Hirsch EM, Seth AK, Fine NA. Reconstruction of the inframammary fold using barbed suture. Ann Plast Surg. 2014; 72: 388-390. (PMID: 24618739) [Crossref]
26. Terao Y, Taniguchi K, Tomita S. A new method for inframammary fold recreation using a barbed suture. Aesthetic Plast Surg. 2015; 39: 379-385. (PMID: 25828587) [Crossref]
27. Nakajima Y, Kondoh S, Nishioka H, Kasuga W. A new percutaneous method for inframammary fold reconstruction in implant-based breast reconstruction: Vertical pendulum suture. Medicine (Baltimore). 2018; 97: e11964. (PMID: 30113501) [Crossref]
28. Goddard NV, Pacifico MD, Campiglio G, Waterhouse N. A novel application of the hemostatic net in aesthetic breast surgery: a preliminary report. Aesthet Surg J. 2022; 42: NP632-NP644. (PMID: 35294963) [Crossref]
29. Breuing KH, Warren SM. Immediate bilateral breast reconstruction with implants and inferolateral AlloDerm slings. Ann Plast Surg. 2005; 55: 232-239. (PMID: 16106158) [Crossref]
30. Hanna KR, DeGeorge BR Jr, Mericli AF, Lin KY, Drake DB. Comparison study of two types of expander-based breast reconstruction: acellular dermal matrix-assisted versus total submuscular placement. Ann Plast Surg. 2013; 70: 10-15. (PMID: 21862915) [Crossref]
31. Avashia YJ, Mohan R, Berhane C, Oeltjen JC. Postoperative antibiotic prophylaxis for implant-based breast reconstruction with acellular dermal matrix. Plast Reconstr Surg. 2013; 131: 453-461. (PMID: 23446560) [Crossref]
32. Spear SL, Sher SR, Al-Attar A, Pittman T. Applications of acellular dermal matrix in revision breast reconstruction surgery. Plast Reconstr Surg. 2014; 133: 1-10. (PMID: 24105085) [Crossref]
33. Ibrahim AM, Koolen PG, Ganor O, Markarian MK, Tobias AM, Lee BT, Lin SJ, Mureau MA. Does acellular dermal matrix really improve aesthetic outcome in tissue expander/implant-based breast reconstruction? Aesthetic Plast Surg. 2015; 39: 359-368. (PMID: 25894022) [Crossref]
34. Roh DS, Treiser MD, Lafleur EH, Chun YS. Technique to promote symmetry in 2-staged bilateral breast reconstruction in the setting of unilateral postmastectomy radiation. Ann Plast Surg. 2017; 78: 386-391. (PMID: 28273056) [Crossref]
35. Brichacek M, Dalke K, Buchel E, Hayakawa TEJ. A limited submuscular direct-to-implant technique utilizing alloMax. Plast Reconstr Surg Glob Open. 2017; 5: e1408. (PMID: 28831349) [Crossref]
36. Tsay C, Zhu V, Sturrock T, Shah A, Kwei S. A 3D mammometric comparison of implant-based breast reconstruction with and without acellular dermal matrix (ADM). Aesthetic Plast Surg. 2018; 42: 49-58. (PMID: 28916881) [Crossref]

37. Kim JH, Chun YS, Park HK, Kim SE, Kim YW, Cheon YW. Inframammary fold incision can reduce skin flap necrosis in immediate breast reconstruction with implant and conjoined fascial flap. Ann Plast Surg. 2020; 85: 488-494. (PMID: 32332387) [Crossref]
38. Luan A, Patel AA, Martin SA, Nazerali RS. Single-unit technique for the use of acellular dermal matrix in immediate expander-based breast reconstruction. J Plast Reconstr Aesthet Surg. 2021; 74: 981-986. (PMID: 33248935) [Crossref]
39. Kornstein A. Porcine-derived acellular dermal matrix in primary augmentation mammoplasty to minimize implant-related complications and achieve an internal mastopexy: a case series. J Med Case Rep. 2013; 7: 275. (PMID: 24378075) [Crossref]
40. Gao P, Wang Z, Kong X, Wang X, Fang Y, Wang J. Comparisons of therapeutic and aesthetic effects of one-stage implant-based breast reconstruction with and without biological matrix. Cancer Manag Res. 2020; 12: 13381-13392. (PMID: 33402848) [Crossref]
41. Gao P, Bai P, Ren Y, Kong X, Wang Z, Fang Y, et al. Biological matrix-assisted one-stage implant-based breast reconstruction versus two-stage implant-based breast reconstruction: patient-reported outcomes and complications. Aesthetic Plast Surg. 2021; 45: 2581-2590. (PMID: 34350500) [Crossref]
42. Amanti C, Regolo L, Moscaroli A, Lo Russo M, Macchione B, Coppola M, et al. Use of mesh to repair the submuscolar pocket in breast reconstruction: a new possible technique. G Chir. 2002; 23: 391-393. (PMID: 12611262) [Crossref]
43. Becker H, Lind JG 2nd. The use of synthetic mesh in reconstructive, revision, and cosmetic breast surgery. Aesthetic Plast Surg. 2013; 37: 914-921. (PMID: 23860816) [Crossref]
44. Hallberg H, Lewin R, Elander A, Hansson E. TIGR® matrix surgical mesh - a two-year follow-up study and complication analysis in 65 immediate breast reconstructions. J Plast Surg Hand Surg. 2018; 52: 253-258. (PMID: 29874964) [Crossref]
45. Hansson E, Edvinsson AC, Elander A, Kölby L, Hallberg H. First-year complications after immediate breast reconstruction with a biological and a synthetic mesh in the same patient: a randomized controlled study. J Surg Oncol. 2021; 123: 80-88. (PMID: 33051871) [Crossref]
46. Haynes DF, Kreithen JC. Vicryl mesh in expander/implant breast reconstruction: long-term follow-up in 38 patients. Plast Reconstr Surg. 2014; 134: 892-899. (PMID: 25347625) [Crossref]
47. Dieterich M, Paepke S, Zwiefel K, Dieterich H, Blohmer J, Faridi A, et al. Implant-based breast reconstruction using a titanium-coated polypropylene mesh (TiLOOP Bra): a multicenter study of 231 cases. Plast Reconstr Surg. 2013; 132: 8e-19e. (PMID: 23806958) [Crossref]
48. Dieterich M, Angres J, Stachs A, Glass A, Reimer T, Gerber B, et al. Patient-report satisfaction and health-related quality of life in TiLOOP® bra-assisted or implant-based breast reconstruction alone. Aesthetic Plast Surg. 2015; 39: 523-533. (PMID: 26085227) [Crossref]
49. Chen G, Zhang Y, Xue J, Zhu X, Liu C, Sun L, et al. Surgical outcomes of implant-based breast reconstruction using TiLoop bra mesh combined with pectoralis major disconnection. Ann Plast Surg. 2019; 83: 396-400. (PMID: 31524731) [Crossref]
50. Baldelli I, Cardoni G, Franchelli S, Fregatti P, Friedman D, Pesce M, et al. Implant-based breast reconstruction using a polyester mesh (surgimesh-PET): a retrospective single-center study. Plast Reconstr Surg. 2016; 137: 931e-939e. (PMID: 27219260) [Crossref]
51. Schüler K, Paepke S, Kohlmann T, Alwafai Z, Nawroth F, Zygmunt M, et al. Postoperative complications in breast reconstruction with porcine acellular dermis and polypropylene meshes in subpectoral implant placement. In Vivo. 2021; 35: 2739-2746. (PMID: 34410963) [Crossref]
52. Eichler C, Schulz C, Thangarajah F, Malter W, Warm M, Brunnert K. A retrospective head-to-head comparison between TiLoop Bra/tiMesh® and Seragyn® in 320 cases of reconstructive breast surgery. Anticancer Res. 2019; 39: 2599-2605. (PMID: 31092458) [Crossref]
53. Sewart E, Turner NL, Conroy EJ, Cutress RI, Skillman J, Whisker L, et al. Patient-reported outcomes of immediate implant-based breast reconstruction with and without biological or synthetic mesh. BJS Open. 2021; 5: zraa063. (PMID: 33609398) [Crossref]
54. Patzelt M, Zarubova L, Vecerova M, Barta J, Ouzky M, Sukop A. Risk comparison using autologous dermal flap and absorbable breast mesh on patient undergoing subcutaneous mastectomy with immediate breast reconstruction. Aesthetic Plast Surg. 2022; 46: 1145-1152. (PMID: 35165758) [Crossref]
55. Sforza M, Kul Z, Saghir R, Saghir N, Okhiria R, Okhiria T, et al. Predicting the expansion of the lower pole of the breast following smooth breast implant augmentation: a novel shear wave elastography study. J Plast Reconstr Aesthet Surg. 2023; 84: 574-581. (PMID: 37441854) [Crossref]