



International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
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ARTICLE TITLE	CONTEMPORARY APPROACH TO AUTOLOGOUS BREAST RECONSTRUCTION IN ONCOLOGICAL PATIENTS: A LITERATURE REVIEW
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DOI	https://doi.org/10.31435/ijitss.4(48).2025.4308
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RECEIVED	02 October 2025
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ACCEPTED	19 December 2025
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PUBLISHED	30 December 2025
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CONTEMPORARY APPROACH TO AUTOLOGOUS BREAST RECONSTRUCTION IN ONCOLOGICAL PATIENTS: A LITERATURE REVIEW

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ABSTRACT

Breast cancer still stands as the most frequently diagnosed cancer among women globally. The increasing prevalence of breast cancer is closely linked to the rising demand for breast reconstruction surgery following oncological treatments. This study aims to synthesise modern understanding of the autologous reconstructive techniques in breast cancer patients based on literature reviews, including meta-analyses published from 2020 to 2025.

In the review, three major aspects were identified: considerations of surgical timing and its implications, outcomes of autologous versus alloplastic reconstruction, and operative techniques, comprising tissue flaps and fat grafting. Study showed emerging data relevant to timing concerning oncological interventions like radiotherapy and chemotherapy. Studies focused on inter-method comparison provided varying results in regard to patient-reported outcome measures, complication statistics, and long-term aesthetic evaluations. The review also included all known autologous approaches but concentrated on fat grafting and the latest research on adjunctive measures and safety concerning optimisation. Final aesthetic refinement methods were discussed as well.

Recent studies show the outcomes of autologous breast reconstruction are positive, however more research needs to be done due to methodological caveats and contradicting outcomes. More advanced technologies are being implemented in the field, and in order to determine the best options and stratification process for patients, more focus on high-quality research is a necessity.

KEYWORDS

Breast Reconstruction, Breast Cancer, Oncological Safety, Autologous Reconstruction, Flap, Fat Grafting

CITATION

Jadwiga Kleinrok, Hubert Kostka, Damian Dolata, Adrian Zagórski, Anna Bereta-Kostaś, Rafał Kuśmider, Małgorzata Leśnik, Patrycja Wierzbowska (2025) Contemporary Approach to Autologous Breast Reconstruction in Oncological Patients: A Literature Review. *International Journal of Innovative Technologies in Social Science*. 4(48). doi: 10.31435/ijitss.4(48).2025.4308

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1. Introduction and Purpose

The aim of this study is to present the current state of knowledge regarding autologous reconstructive procedures in patients surgically treated for breast cancer. During the literature review, particular attention was paid to the latest scientific reports. For this purpose, the PubMed database was searched for meta-analyses published between 2020-2025, and publications corresponding to the study topic were selected. Relevant supplementary literature was also utilised to provide a comprehensive discussion of the presented issues.

1.1. Epidemiology

Breast cancer is currently the most frequently diagnosed malignancy among women worldwide. Despite the gradual increase in breast cancer incidence, mortality rates show a declining trend due to advances in early detection and improved treatment methods that enhance patient prognosis. Progress in breast cancer treatment means that more women return to full health, though they often face the consequences of disfiguring mastectomy. The number of patients requiring breast reconstruction after oncological therapy is significantly increasing.

1.2. Evolution of Autologous Reconstruction Techniques

The first reports of breast reconstruction after mastectomy date back to the late 19th century. The pioneering procedure in this field was performed in 1893 in Vienna by Vincenz Czerny, who transplanted a lipoma from the spinal region in a patient following left-sided breast cancer surgery, restoring the woman's natural appearance and enabling her return to work on stage [1].

Reconstructions based on autologous tissue transfer have developed since the 1970s. Subsequent innovations, including the use of perforator flaps, autologous fat grafts, and the discovery of stem cell potential, have made modern breast reconstruction less invasive whilst offering broader surgical possibilities [2].

Breast cancer treatment typically involves surgical intervention. In advanced disease stages, mastectomy (complete breast removal) is most commonly used. An alternative for less advanced stages is breast-conserving therapy (BCT), which involves tumour excision whilst preserving as much breast tissue as possible, followed by radiotherapy [3]. Neoadjuvant chemotherapy reduces primary tumour size, facilitating breast-conserving surgery [4].

Mastectomy is also employed as a prophylactic procedure aimed at reducing breast cancer risk in women with confirmed BRCA1 or BRCA2 gene mutations. Simple subcutaneous mastectomy with nipple-areolar complex preservation is recommended in such cases [5].

1.3. Current Clinical Practice and Trends

According to data from the SEER (Surveillance, Epidemiology, and End Results) database, encompassing approximately 25% of the female breast cancer population in the USA, approximately 40% of patients opt for mastectomy. A notable increase in bilateral mastectomies aimed at reducing breast cancer risk and prophylactic contralateral breast procedures has been observed. The growing interest in mastectomies can be attributed to factors including the introduction of magnetic resonance imaging in breast disease diagnostics, widespread genetic testing, and increased availability of breast reconstruction procedures [6].

Reconstructive procedures are performed both in post-mastectomy patients and those who have undergone breast-conserving operations with unsatisfactory aesthetic outcomes. In patients with small breasts or requiring significant glandular tissue resection, as well as following post-operative radiotherapy, breast deformities are frequently observed. A key element in achieving satisfactory aesthetic appearance is the use of oncoplastic techniques, which allow breast shape preservation whilst removing larger or unfavourably positioned tumours [7,8].

1.4. Quality of Life Considerations

Many studies show that breast cancer treatment often reduces patients' quality of life beyond physical aspects. Mastectomy can cause profound feelings of disfigurement and difficulties with body acceptance, which may negatively impact self-esteem, lead to sexual problems, and cause depressive symptoms. This phenomenon is sometimes termed "half-woman complex," reflecting its serious psychological impact [9].

Breast reconstruction aims to restore the natural shape of the female chest by rebuilding the breast to ensure satisfactory appearance without requiring external prostheses. Such procedures significantly impact improved psychological and physical comfort for patients, positively affecting their quality of life across all dimensions of life activities [10].

1.5. Contemporary Advances in Breast Reconstruction

Advances in reconstructive techniques and scientific achievements in the second decade of the 21st century have revolutionised the approach to treating breast cancer patients. Currently, every patient has the opportunity for breast reconstruction, and the procedure can be performed immediately, simultaneously with oncological surgery, with the sole exception of inflammatory breast cancer cases [11,12].

In earlier clinical practice, patients with more advanced disease stages typically underwent delayed reconstruction, often after at least one year following radiotherapy completion. However, this trend is currently changing, with increasing numbers of breast reconstructions performed immediately, combining the procedure with oncological surgery. The development of reconstructive techniques, which are becoming increasingly advanced, comprehensive, and innovative, enables more complete breast reconstruction during the same operation as tumour removal, further raising the standard of patient care [13,14].

2. Description of the State of Knowledge

2.1 Surgical Timing: Immediate vs Delayed Reconstruction

Breast reconstruction can be performed either during oncological surgery or at a later, delayed time point. This procedure can be carried out at any time after glandular tissue removal. Depending on the technique used, reconstruction can be classified as single-stage or two-stage. Autologous tissue reconstruction can also be an immediate procedure. In the two-stage method, a tissue expander is first placed after mastectomy. After several to over ten weeks, once the overlying tissues have been adequately stretched, the expander is removed and autologous reconstruction is performed. Additionally, hybrid reconstruction is possible, combining implants with autologous tissues, allowing for a more personalised approach to breast reconstruction.

The decision between immediate and delayed reconstruction remains an open question, as studies provide conflicting results [15]. Some studies indicate benefits associated with immediate reconstruction, others support delayed reconstruction, whilst still others suggest no significant differences between these approaches in terms of clinical outcomes. However, it should be emphasised that the quality of available studies is not optimal, as there is currently a lack of comprehensive literature reviews and meta-analyses that thoroughly compare complication rates between immediate and delayed reconstruction.

A meta-analysis published in 2022 [15] shed new light on complications associated with different breast reconstruction methods. The results showed that immediate breast reconstruction carries a statistically higher risk of surgical complications compared to delayed reconstruction. The credibility of this meta-analysis is supported by the fact that it used studies with observation periods for complications ranging from a minimum of 3 months to a maximum of 12 months. This is particularly important because the meta-analysis authors had previously established that only 50% of surgical complications were detected within the first month after breast reconstruction, whilst nearly 90% were identified within 3 months post-surgery. This approach provided a more comprehensive assessment of complication risk, accounting for both early and later post-operative complications.

Regarding patient satisfaction with breast reconstruction outcomes, data from the early 21st century provide interesting insights. Studies conducted in the year 2000 [16] suggest that in the long-term perspective (i.e., after 12 months post-surgery), no significant differences in patient satisfaction levels are observed between immediate and delayed reconstruction. This applies to both overall satisfaction and aesthetic aspects of the outcome. This observation highlights that the timing of reconstruction may have less significance for ultimate patient satisfaction than originally assumed, providing valuable input to the discussion on reconstruction procedure planning.

2.1.1. Oncological Treatment and Surgical Timing

The decision regarding the timing of breast reconstruction following mastectomy is an important clinical question, particularly when additional oncological treatment such as chemotherapy or radiotherapy is required. Some studies suggest that immediate reconstruction may provide beneficial psychological effects [17]; however, there is a risk that the side effects of oncological therapy may worsen the aesthetic outcome of the reconstruction. Alternatively, delayed reconstruction, performed after the completion of oncological treatment, may reduce the risk of these complications, but prolongs the time to achieving aesthetic results. Oncological therapy affects tissue condition and alters operative conditions, which may make it difficult to achieve a satisfactory reconstruction outcome. In the scientific literature, there is ongoing discussion regarding the optimal approach, taking into account the benefits and risks associated with each.

2.1.1.1. Adjuvant Chemotherapy

In light of current research and clinical practice, planned adjuvant chemotherapy does not constitute a contraindication for breast reconstruction following mastectomy. Contemporary medical protocols permit the performance of reconstructive procedures immediately after completion of the surgical oncological treatment phase [18]. A meta-analysis conducted in 2023 [19] demonstrated that whilst immediate breast reconstruction may delay the initiation of adjuvant chemotherapy—with the mean time to initiation being 3.5 days longer—this does not significantly affect treatment efficacy. The adjuvant chemotherapy is initiated within an appropriate timeframe, not exceeding 90 days. This approach enables integrated treatment planning, combining oncological and reconstructive aspects, which may potentially contribute to optimising the overall treatment process and patient recovery.

2.1.1.2. Adjuvant Radiotherapy

The situation with radiotherapy as an adjuvant oncological treatment differs considerably from that of chemotherapy. The necessity of its application represents an important consideration in decisions concerning both the timing of breast reconstruction (immediate versus delayed) and the selection of specific reconstructive methods. It is important to emphasise that radiotherapy following immediate breast reconstruction may significantly affect the cosmetic outcome of the procedure. Radiation affects reconstructed tissues, which may lead to deterioration of the aesthetic result achieved during surgery [20]. It should also be noted that breast reconstruction in tissues previously subjected to radiotherapy presents additional challenges. This process is more complex and may yield less predictable results compared to operations performed on non-irradiated tissues [21].

Matar et al. [15], authors of a 2022 meta-analysis comparing postoperative complication rates in patients undergoing immediate versus delayed breast reconstruction following mastectomy, found no statistically

significant differences in outcomes when analysing results for patients receiving radiotherapy after mastectomy. This may suggest that radiotherapy causes complications with similar frequency in both immediate and delayed reconstruction groups. However, they cautioned that to definitively confirm this hypothesis, more detailed studies might be necessary, particularly analysing a larger number of post-mastectomy patients receiving radiotherapy exclusively or not undergoing this therapy at all. This could help draw more definitive conclusions regarding complication rates in patients receiving irradiation in the context of different breast reconstruction methods.

This remains consistent with the trend described by Cordeiro et al. in their 2015 article [22], characterised by an increasing number of immediate reconstruction procedures being performed, even in cases where post-mastectomy radiotherapy is planned. Traditionally, when radiotherapy was anticipated, delayed reconstruction was recommended, with at least six months following completion of irradiation. However, there is an increasingly observed departure from this practice, with a growing tendency to perform reconstruction before radiotherapy or even immediately after mastectomy, despite planned subsequent radiotherapeutic treatment.

2.1.2. Immediate Reconstruction

Immediate reconstruction is performed during the same operation as the mastectomy. It can be carried out using all available reconstructive techniques: allogenic, autologous, and hybrid approaches. Immediate reconstruction may be associated with psychological benefits for the patient, although the evidence in this regard remains inconclusive [17]. One of the primary concerns is the potential for increased complication rates. This results from the longer operative time typically required for immediate reconstruction due to the performance of two consecutive procedures. Another possible explanation for the increased risk of complications, such as infection, haematoma, or seroma, relates to the conditions present in the postoperative site—significant dead space and reduced vascularity compared to the surgical field in delayed reconstructions [15].

2.1.3. Delayed Reconstruction

Delayed reconstruction may be recommended for various reasons. These include the necessity of completing oncological therapy, individual patient preferences related to psychological aspects or other personal factors, and situations where the mastectomy was performed by a surgical team not specialising in reconstructive procedures. Delayed breast reconstruction typically occurs within a period ranging from several months to several years following the initial oncological operation. This method is particularly significant for patients with advanced-stage malignancy who have undergone comprehensive treatment, including postoperative radiotherapy. The question of optimal timing between completion of radiotherapy and delayed reconstruction remains a subject of discussion within the medical community [23]. Current evidence suggests that the minimum interval should be approximately 12 months, allowing for appropriate tissue regeneration following intensive treatment [13].

2.2. Comparison with Alloplastic Reconstruction

Breast reconstruction can be classified according to the type of materials and techniques employed. The main categories include autologous methods, utilising the patient's own tissues, and alloplastic methods, based on synthetic materials. Contemporary reconstructive surgery also offers hybrid solutions, combining both approaches. The selection of an appropriate reconstruction method is a complex process, considering numerous factors. Key aspects include individual patient preferences, competence and experience of the surgical team, cancer stage, potential need for postoperative radiotherapy, availability of suitable tissues for transplantation, and the patient's overall health status following oncological treatment. Furthermore, the choice of specific reconstructive technique is influenced by factors such as the size and shape of the breast to be reconstructed, patient age, BMI, medical history, and previous surgical procedures. Individual risk factors for postoperative complications, such as smoking, comorbidities, or obesity, are also significant. The size and location of the breast tumour, which may determine the extent of the primary oncological procedure and consequently affect reconstructive possibilities, remain equally important [24].

In the past, planned chemotherapy and radiotherapy were often treated as relative contraindications to the use of implants or expanders in breast reconstruction. In such cases, reconstruction utilising the patient's own (autologous) tissues was preferred. This approach is now considered outdated, although certain clinical observations remain relevant. Indeed, the use of radiotherapy is associated with increased risk of postoperative complications following immediate breast reconstruction. Studies indicate that these complications occur less

frequently in patients who underwent reconstruction methods utilising their own tissues, compared to those who received implants [25]. It is worth emphasising that autologous tissue demonstrates better tolerance to radiation damage compared to implant-based reconstructions [13]. Similarly, when delayed reconstructive surgery is performed following previous radiotherapy, procedures utilising autologous tissues are preferred. This is because irradiation leads to progressive tissue fibrosis, weakening of chest wall muscles, and closure of microcirculation vessels. This results in poor wound healing, scar retraction, and deterioration of chest wall integument, which may negatively affect the final aesthetic outcome and increase complication rates [13]. This observation suggests that despite the evolution of reconstructive techniques and materials, reconstruction using autologous tissues may still offer certain advantages in the context of treatment combined with radiotherapy.

The strategies available for autologous techniques include the following approaches. In cases of delayed breast reconstruction following previous radiotherapy, chest wall skin with radiation damage should be excised and replaced with flap skin (skin graft). This is important to avoid a negative impact on the final cosmetic outcome of reconstruction. However, when reconstruction is performed immediately after radiotherapy, transplantation of an autologous tissue flap with good vascularisation is of paramount importance. This allows avoidance of delays in further treatment due to complications such as flap necrosis or wound infection, and prevents scar contracture following irradiation [26].

2.2.1. Patient Satisfaction and Quality of Life Outcomes

An important issue emerging in recent studies is the discussion regarding the superiority of alloplastic versus autologous reconstruction methods in terms of patient satisfaction and quality of life following mastectomy. A 2024 meta-analysis [27] included studies from Europe and the USA concerning this patient group. The results indicate that compared to implant reconstruction, autologous breast reconstruction may lead to better psychological and sexual well-being in patients, as well as greater overall satisfaction with the procedure performed. The remaining evidence was highly uncertain. It suggested that autologous reconstruction compared to implants may improve women's satisfaction with the appearance and feel of the reconstructed breast, and lead to fewer long-term adverse effects. However, the choice of this method may have little or no impact on patients' overall physical well-being, risk of short-term adverse effects, or the need for additional surgical procedures. Conversely, operations using implants allow the intended aesthetic goal to be achieved in a shorter timeframe.

2.2.1.1. Conflicting Evidence in Recent Literature

The authors of the aforementioned meta-analysis [27] express reservations about the obtained results. They indicate having little or very limited confidence in the presented evidence, resulting from the fact that women participating in the primary studies were not randomly assigned to different treatment groups. Consequently, the observed differences between groups may have resulted from discrepancies between the patients themselves, rather than the reconstruction methods employed. The studies did not provide information about the characteristics of women who might benefit most from the chosen breast reconstruction technique—alloplastic or autologous. The meta-analysis authors emphasise that many diverse factors influence the choice of reconstruction method. Due to these methodological limitations, the conclusions obtained in the meta-analysis, whilst suggesting certain trends, are burdened with considerable uncertainty.

Different results are presented in a meta-analysis published in 2023 by Shauly et al. [28]. This study compared outcomes in patients undergoing immediate breast reconstruction following mastectomy. Its results indicate that immediate breast reconstruction using synthetic implants significantly improves patient satisfaction with the final outcome and their sexual well-being, compared to autologous reconstruction. Despite certain study limitations, the preliminary results of this meta-analysis also suggest that immediate reconstruction using implants may equally effectively, and sometimes even more effectively, enhance patient satisfaction in terms of body image perception and improve health-related quality of life (HR-QoL) compared to autologous reconstruction. Simultaneously, results from patient questionnaires regarding satisfaction with their own breasts often demonstrate the superiority of autologous reconstruction. Regarding other aspects reported by patients, such as psychological and physical well-being, no significant differences were observed between methods.

As can be seen, the results of the two aforementioned meta-analyses are divergent and do not allow for unambiguous indication of which breast reconstruction method is more beneficial. Internal discrepancies in achieved results within each study and lack of consistency between studies mean that the superiority of either one of the techniques cannot be determined with certainty. Although current evidence does not definitively establish the optimal approach, the data suggest a slight preference for autologous grafts over alternative

methods. This highlights the need for further research into this problem and an individualised approach to selecting the optimal strategy for patients.

In this context, the results of another meta-analysis published by Stefura et al. [29] in the same year appear surprising. Their findings clearly demonstrate the advantages of autologous reconstruction: patients reported higher levels of satisfaction with both breast aesthetics and the overall reconstruction process. Moreover, this method appears to be comparable in terms of safety to implant-based reconstruction. According to the authors, the disadvantages of using autologous grafts are primarily higher treatment costs in this group.

2.2.1.2. Considerations in Obese Patients

A 2022 study by ElAbd et al. [30] focusing on obese patients highlights both advantages and disadvantages of autologous reconstruction, challenging its comparable safety to implant insertion procedures. This meta-analysis, examining patients with a BMI above 30, suggests that autologous reconstruction outperforms implant-based reconstruction in terms of surgical complication frequency. Specifically, it is associated with lower risks of infection, hematoma/seroma, and reconstruction failure, without significantly affecting the risk of skin necrosis or wound dehiscence.

However, the study notes a higher incidence of thromboembolic complications, such as deep vein thrombosis and pulmonary embolism, in autologous reconstruction cases within this patient group. This increased risk may be attributed to longer operative durations, but could also relate to perioperative anticoagulation protocols and postoperative patient mobilization strategies employed by individual hospitals. Given the potential severity of thromboembolic complications, further research is crucial to better understand this phenomenon and develop effective prophylactic methods. Regarding patient quality of life assessment, the comparison yielded no clear winner. While results on the BREAST-Q scale were higher for autologous reconstruction, this difference did not reach statistical significance [30].

2.2.2. Oncological Treatment

Analogously to the decision regarding the choice between immediate and delayed reconstruction, consideration of the necessity for further oncological treatment constitutes an important aspect when contemplating breast reconstruction methods – autologous or allogenic.

2.2.2.1. Radiotherapy

Available meta-analyses from recent years [31,32] indicate a significant relationship between post-mastectomy radiotherapy and the risk of breast reconstruction failure. In cases of reconstruction utilising implants, this risk is significantly higher than in autologous reconstruction using the patient's own tissues. However, it should be noted that autologous reconstructions, whilst less prone to failure in the context of radiotherapy, may more frequently be associated with the necessity of performing additional corrective procedures. For this reason, in the process of informing the patient, it is crucial to present both aspects: the increased risk of complications following implant reconstruction in cases of radiotherapy and the potential need for additional surgical interventions following autologous reconstruction.

The aim of the 2021 meta-analysis [32] was to find the optimal sequence of combined surgical and radiotherapeutic treatment. Using network meta-analysis, the authors evaluated all possible combinations of procedures, including autologous flap reconstruction performed immediately (flap reconstruction/radiotherapy), two-stage autologous reconstruction with immediate use of tissue expander (expander/radiotherapy/flap reconstruction), and delayed reconstruction (radiotherapy/flap reconstruction). The analysis also included breast reconstructions based on implants, encompassing immediate implantation of tissue expander, followed by post-mastectomy radiotherapy and conversion to permanent implant (expander/radiotherapy/implant), delayed insertion of tissue expander (radiotherapy/expander/implant), and replacement of expander with implant before commencing radiotherapy (expander/implant/radiotherapy).

The results of this meta-analysis demonstrated two key benefits associated with autologous flap reconstruction. Firstly, autologous flap reconstruction performed immediately, followed by adjuvant radiotherapy (flap reconstruction/radiotherapy) proved to be the optimal approach to avoid reconstruction failure. Secondly, post-mastectomy radiotherapy followed by autologous flap reconstruction (radiotherapy/flap reconstruction) is associated with the lowest risk of infection.

2.2.2.2. Chemotherapy

Analysis of data from patients undergoing breast reconstruction conducted in a 2024 meta-analysis by Nag et al. [33] demonstrated that the use of neoadjuvant chemotherapy was not associated with significant differences in the overall rate of complications, reconstruction loss, or frequency of surgical site infections. Additionally, the choice of reconstruction method based on implants or autologous tissues did not affect

outcomes regarding overall complications, infections, or reconstruction loss. Consequently, in women considering mastectomy and breast reconstruction, neoadjuvant chemotherapy does not appear to increase the risk of serious complications related to wound healing, reconstruction loss, or infection, and these outcomes are independent of the chosen reconstruction method.

Similar conclusions are provided by a meta-analysis of immediate reconstruction outcomes published in 2023 by Sabitovic et al. [34], demonstrating that neoadjuvant chemotherapy does not increase the rate of major or minor complications, regardless of whether autologous tissues or implants were used in the immediate procedure. This suggests that induction chemotherapy may be considered a safe procedure in breast cancer patients undergoing immediate reconstruction.

2.2.3. Comparison Results

Making the choice of optimal breast reconstruction method constitutes a significant challenge, and determining the unequivocal superiority or inferiority of autologous approach is not possible. However, analysis of available literature indicates a possible shift in preferences towards autologous techniques. Reconstruction using tissue flaps, whilst remaining a method with a long tradition, has gained popularity in recent years. The collected data suggest that the effects of autologous reconstruction do not significantly fall short of results obtained using alloplastic prostheses, and in some aspects may surpass them. Particularly significant is the noticeable equalisation of patient satisfaction levels between both methods, and even the emergence of a slight advantage for flap reconstructions. This tendency may suggest that further progress in autologous techniques and resolution of associated technical difficulties may make them the preferred method in the future. It is probable that the development of clinical practice will follow precisely this direction, which should also be reflected in the intensification of scientific research into autologous techniques. Systematic monitoring of scientific literature will be necessary to track progress in this field and assess the evolution of treatment standards.

2.3. Methods and Techniques

Autologous breast reconstructions use the patient's own tissues to recreate breast shape, which usually requires transfer of excess skin, adipose tissue, and sometimes muscle structures from donor areas to the defected site created after mastectomy.

Advances in regenerative medicine, stem cell therapies, and fat transfers provide hope for improvement in aesthetic and functional outcomes. Mesenchymal stem cells (MSC) secrete bioactive factors that modulate inflammation and stimulate collagen remodeling, leading to softer, more elastic scar tissue. Fat grafting, often combined with adipose-derived stem cell (ASC) therapy, when injected into scarred areas improves scar appearance and skin quality.[35] Enriching fat graft in ASC also seems to improve the general volume of maintained graft.

2.3.1. Classification and Characteristics of Tissue Flaps

Autologous reconstruction usually provides better aesthetic results compared to implant methods but involves prolonged operative time, hospitalization period, and rehabilitation. Reconstructive methodology choice is determined by many elements, including patient age, breast size, BMI, comorbidities, as well as skin quality, subcutaneous tissue layer thickness, stretch mark presence, and skin damage resulting from previous surgical or gynecological interventions.

In reconstructive procedures, pedicled flaps with preserved blood supply and free flaps requiring microsurgical vascular anastomoses are used. Various flap types are utilized for breast reconstruction procedures. Most commonly used are: TRAM (Transverse Rectus Abdominis Myocutaneous Flap) in pedicled or free version, free DIEP flap (Deep Inferior Epigastric Perforator Flap), and pedicled LD (Latissimus Dorsi Flap). Occasionally used are also free SIEA (Superficial Inferior Epigastric Artery Flap), RUBENS (Rectus Abdominis Myocutaneous Flap), SGAP (Superior Gluteal Artery Perforator Flap), IGAP (Inferior Gluteal Artery Perforator Flap), and TUG (Transverse Upper Gracilis Flap) flaps.

Patients with lean body build are traditionally qualified for implant reconstruction due to difficulties in obtaining adequately sized autologous flaps. TRAM flap can be used in lean patients thanks to the possibility of harvesting larger amounts of muscle tissue to increase its volume, but this method is no longer preferred due to reports of potential donor site complications.

DIEP flap, sparing fascia and rectus abdominis muscle, is characterized by significant dimensions and volume. Its pedicle has large diameter and considerable vessel length, with minimal, preoperatively assessable

anatomical variability. Due to structural similarity of breast and abdominal wall tissues, this technique allows achieving more natural breast appearance. Compared to TRAM grafts, it enables preserving abdominal wall strength and stability. Currently, DIEP flaps have become the basic approach in obtaining free transplants for breast reconstruction, resulting from better clinical results, fewer complications, and higher patient satisfaction levels [35,36,37].

In a 2020 meta-analysis, Kiely et al. attempted to determine precision of various preoperative perforator localization methods for breast reconstruction using free DIEP flap. Six diagnostic techniques were compared: handheld Doppler, color duplex ultrasonography, computed tomography angiography, magnetic resonance angiography (MRA), infrared thermography with and without Doppler. Analysis showed that 94% of DIEP perforators identified as "dominant" in preoperative diagnostics were selected as dominant during surgical intervention. Weakest agreement was observed in color duplex ultrasonographic examination, while highest in MRI imaging. Three-dimensional imaging methods (CT/MR) for preoperative DIEP mapping are characterized by similar accuracy and surpass ultrasonography in terms of effectiveness [38].

Venous congestion constitutes the most frequent vascular complication in deep inferior epigastric artery perforator (DIEP) flaps. Solution to this problem may be performing additional venous anastomosis between the superficial venous system and recipient vein (so-called super-drainage). Pignatti et al. decided to verify this assumption and procedure effectiveness. They showed statistically significant benefit from super-drainage use in reducing flap venous congestion, partial and total flap necrosis, and need for reintervention due to perfusion complications [39].

Although the abdomen remains the most popular donor site for autologous breast reconstruction, some patients lack sufficient tissue to recreate an aesthetic breast mound using single vascular pedicle DIEP flap, especially with large reconstructed breast size. Christopoulos et al. evaluated safety and outcomes of breast reconstruction with undivided DIEP flap with double vascular pedicle. Observation period averaged 18 months after surgery. They found that double-pedicled DIEP flap for unilateral breast reconstruction in difficult cases after mastectomy constitutes technique with low complication rate, including minimal (3%) fat necrosis rate and sporadically occurring (0.8%) flap loss [40].

Beyond popular abdominal flaps, breast reconstruction also utilizes flaps from other anatomical regions. Transverse flap harvested from the upper part of gracilis muscle (TUG) is characterized by anatomy favoring its use as an alternative to reconstruction based on abdominal tissues. However, limited tissue material availability prevents reconstruction of significantly voluminous breasts. Christopoulos et al. performed systematic literature review and case analysis using bilateral TUG flaps. Surgical interventions were performed both directly after mastectomy and in delayed mode, engaging two operative teams (oncologists and plastic surgeons). Postoperative observation period ranged from 12 to 55 months. All transferred flaps survived. Two patients required urgent reintervention due to progressive hematoma at recipient site and flap venous outflow disorders. Complications in the donor region were observed, where the dominant complication was seroma in the thigh area. Bilateral TUG flap use constitutes an effective, safe, and recommended option relative to conventional abdominal flaps, especially in women with limited abdominal tissue reserves [41].

As secondary options relative to the most popular DIEP flaps in breast reconstruction, flaps from thigh area are also used: transverse upper gracilis flap (TUG) harvested from inner thigh along gracilis muscle and PAP flap from posterior thigh based on profunda femoris artery perforators. Borrelli et al. showed that TUG and PAP flaps are characterized by comparable effectiveness rates and complication frequency, including hematomas, flap loss, and healing process. However, TUG flap is associated with significantly greater number of vascular complications (venous thrombosis, venous hyperemia, and arterial thrombosis) than PAP flap, as well as clearly higher rates of unplanned reinterventions in acute postoperative period [42].

Increasingly recognized in breast reconstruction is transverse musculocutaneous gracilis flap (TMG), harvested from inner thigh along gracilis muscle and including skin, adipose tissue, and gracilis muscle itself. Siegwart et al. collected scientific data regarding donor region morbidity. Total flap loss occurred sporadically and was 2%. All studied patients were characterized by normal body weight. Incidence of wound dehiscence, seroma, hematoma, and infection at TMG harvest site was minimal. Functional disorders included sensation deficits, motor limitations, and modifications in genital organs, all of which had low occurrence frequency. Meta-analysis confirmed TMG flap safety and low donor site morbidity in normal weight patients [43].

Another reconstructive strategy is latissimus dorsi muscle flap (LD) use, often combined with adipose tissue augmentation techniques. Escandón et al. in their meta-analysis evaluated effectiveness of increasing latissimus dorsi flap volume through simultaneous fat transfer (LIFT) and analyzed postoperative results of this approach. Studies showed low frequency of both general and local complications at donor and recipient

sites, with flap loss occurring in only 3% of cases. Over 60% of patients needed additional lipofilling sessions to achieve optimal reconstruction results. In the authors' assessment, LIFT methodology represents a less invasive form of breast reconstruction in women after mastectomy who do not qualify for free flap reconstruction [44].

Gaining popularity in recent years for breast reconstruction is unilateral superficial breast flap (USB) use, also called "breast splitting" technique. Although the concept itself is not new, recently, thanks to surgical technique improvement, this method is becoming more widely used. It constitutes a valuable option for patients with large volume or ptotic contralateral breasts [45].

Breast splitting technique is based on utilizing tissue from the healthy breast, involving its simultaneous reduction and achieving breast symmetry. This is a very precise intervention, whose particular complexity lies in the necessity of transferring not only excess mammary parenchyma with covering skin but also its blood supply system to prevent partial or total necrosis of transplanted breast flap [46].

Satake et al. [45] conducted a study evaluating USB flap effectiveness with double pedicle, harvested from healthy breast, for unilateral breast reconstruction with contralateral scar-reducing mammoplasty. The study included 14 patients. The USB flap consisted of half of contralateral breast tissues with 3rd or 4th perforators from the internal mammary artery and lateral mammary vessel. Flap perfusion was assessed using indocyanine green fluorescence angiography (ICGFA).

Study results showed that the procedure can be effectively performed even in obese patients and may constitute a real alternative to DIEP flap. No serious complications such as flap necrosis were recorded, although one case of hematoma and one case of hypertrophic scar occurred. ICGFA showed weak perfusion in the distal, lateral part of the flap. Final aesthetic assessment was high - 75% of cases were evaluated as "good" or "excellent," and 3 cases as "poor" or "adequate." Patient observation period ranged from 15 to 84 months, with none developing second primary breast cancer or recurrence in either breast.

However, it should be remembered that patients burdened with high hereditary breast cancer risk are not appropriate candidates for this technique. Additionally, this method carries inherent threats such as pneumothorax and is characterized by significant technical execution difficulty [46].

Omental flap constitutes one of the most invasive breast reconstruction techniques. This method involves using greater omentum, which is harvested from the abdominal cavity through laparotomy or, in a less invasive variant, laparoscopy. The greater omentum is characterized by rich vascularization and high elasticity, making it valuable material in reconstructing various body areas. In breast reconstruction, the omental flap can be used both as free and pedicled flap (mainly with right or left gastroepiploic artery). This technique is particularly valuable in cases when other popular flap use is impossible. An important advantage of omental flap, besides rich vascularization and elasticity enabling precise modeling, is lack of negative impact on abdominal muscle function. Omental flap finds application in post-mastectomy reconstruction, especially in patients after radiotherapy or with insufficient tissue amount in other body areas. However, it should be noted that this method is not recommended for obese patients and those who underwent previous abdominal cavity operations. Meta-analysis authors from 2025 prove that the omental flap in breast reconstruction is safe and effective, providing good cosmetic effects and low complication frequency [47].

2.3.1.1. Clinical Indications and Oncological Safety

The analysis of oncological safety regarding various techniques and timing of autologous reconstruction after mastectomy did not demonstrate statistically significant differences in the frequency of local, regional, and locoregional recurrences between immediate and delayed autologous reconstruction.[48]

Reconstruction using flaps is considered in patients after radiotherapy and in women with extensive soft tissue defects. Radiotherapy can lead to wound healing problems or infections of reconstructed breasts, so some women may prefer delaying reconstruction until irradiation completion.

Liew et al. conducted a meta-analysis comparing postoperative outcomes of immediate autologous reconstruction in patients who underwent radiotherapy and those who did not. The study revealed that patients subjected to adjuvant radiotherapy exhibited an elevated risk of fat necrosis, flap contracture, and volume reduction, as well as an increased likelihood of secondary surgical interventions. However, breast appearance satisfaction scores and overall patient satisfaction remained comparable between the irradiated and non-irradiated groups. This suggests that radiotherapy does not appear to negatively impact patients' subjective assessment of their reconstruction results.[49]

Despite advances in surgical techniques and radiotherapy making immediate implant-based reconstruction usually available even for patients requiring radiotherapy, autologous tissue reconstruction is nevertheless typically reserved for post-irradiation individuals. This method enables replacement of radiation-

damaged skin and chest wall tissues with healthy tissue from another location. Prospective studies indicate that women choosing autologous reconstructions show greater satisfaction with aesthetic results than patients opting for implant reconstruction. Simultaneously, the overall satisfaction level in both groups two years post-operation is comparable [16].

2.3.1.2. Sensation Restoration in Reconstructed Breast

Breasts are innervated by lateral and anterior branches of intercostal nerves from the second to the sixth, which are cut during mastectomy. Consequently, reconstructed breasts may be devoid of sensation or regain it partially after several months, with a maximum recovery period of two years. This spontaneous recovery occurs thanks to innervation from adjacent peripheral nerves, despite the absence of operative nerve anastomoses.

Flap transplantation obligatorily requires arterial and venous anastomosis, unlike preserving sensation in flaps recreating breasts, which although not obligatory, remains an important issue affecting patients' quality of life. Surgical reinnervation techniques include direct nerve anastomosis, nerve graft, or nerve guide use. Nerve stumps in the chest cut during mastectomy are connected with nerves located in transplanted tissue, thus creating pathways that may enable sensation return to the reconstructed breast. An alternative approach is direct connection of the flap with the mastectomy skin or nipple, with clinical practice based on surgeon preferences.

Ghumman et al.[50] evaluated the impact of surgical reinnervation during breast reconstruction on postoperative sensation compared to lack of reinnervation in adult patients. Presented meta-analysis provided evidence that surgical reinnervation during breast reconstruction correlates with significantly better sensation recovery results compared to reconstructions without reinnervation.

Although reinnervation techniques differ between studies (e.g., direct nerve anastomosis, nerve grafts, nerve guides), overall effect was positive regardless of method. Analysis showed a consistent trend indicating the advantage of flaps with reinnervation. Reinnervation may beneficially affect patients' quality of life and reduce postoperative pain. Operation time was slightly longer in reinnervation groups, but no increased complication risk was noted.

Higher was the percentage of sensation recovery cases and better results in the BREAST-Q questionnaire among individuals who underwent neurotization. This means that surgical sensation restoration may be safe and bring significant improvement to patients [50].

2.3.1.3. Complications Analysis and Risk-Modifying Factors

Operations using own tissues leave additional scars and are associated with complications resulting from transplant material harvesting, such as prolonged pain, abdominal wall weakening, hernias, or physical activity limitations. Contemporary studies enable better understanding of these complications and factors modifying them.

2.3.1.3.1. Donor Site vs Recipient Site Complications

Choosing an optimal tissue flap requires detailed knowledge of typical complications for individual techniques. Mortada et al. conducted meta-analysis of donor site morbidity and complication frequency after reconstructions using autologous abdominal flaps, including assessment of procedures using pedicled and free TRAM, DIEP, and SIEA flaps. They showed that free TRAM flaps, compared to DIEP, were characterized by less frequent fat necrosis, hematomas, and thrombotic complications, but more frequently associated with hernia risk in donor area. Pedicled TRAM flaps correlated with increased wound infection and donor site hernia risk, while flap hematomas occurred less frequently. SIEA flaps showed lowest donor site hernia risk, simultaneously characterized by high wound infection risk [51].

Supplementing these observations, results of meta-analysis presented by Xing et al. revealed more detailed complication patterns. TRAM flaps are characterized by greater complication tendency, particularly abdominal wall hernias and perfusion disorders (flap necrosis, venous hyperemia). Interventions using pedicled LD flap more frequently involve hematomas and seromas, with combination of pedicled LD flaps with prosthesis or lipotransfer not causing significant postoperative complication risk increase. In DIEP flaps, fat necrosis is relatively frequently observed. SGAP flaps are burdened with limitations resulting from necessity of using microsurgical techniques and patient position change during flap harvesting, which more frequently leads to asymmetry between the reconstructed and the healthy breast. SIEA flaps are characterized by smaller dimensions, and increased seroma and hematoma formation risk in the donor site may result from inguinal lymphatic system damage during preparation [52].

Besides flap type choice, important significance have technical procedure factors. Espinosa-de-Los-Monteros et al. performed literature review comparing abdominal wall hernia or bulge frequency depending

on mesh use or omission during donor site closure. In unilateral reconstructions, MS-2 TRAM (transverse rectus abdominis myocutaneous - with maximum muscle sparing) and DIEP flaps show similar, low hernia risk regardless of mesh use, while mesh use with classic TRAM significantly reduces hernia risk compared to technique without mesh. In bilateral reconstructions, lowest hernia risk is shown by TRAM flaps with mesh and MS-2 TRAM without mesh, while highest risk was found with classic TRAM flaps without mesh. Clinical conclusion indicates that mesh is particularly valuable with classic TRAM flaps, while muscle-sparing techniques naturally reduce hernia risk [53].

2.3.1.3.2. Mechanisms and Complication Classification

For better understanding of complication nature, Tan et al. presented detailed analysis of their occurrence and frequency in 2022. Complications after autologous reconstructions are classified as flap-related and concerning the harvest site. Flap-related complications include total or partial flap loss and fat necrosis and are largely determined by postoperative graft vascularization. Although the difference does not reach statistical significance, total flap loss occurs more frequently in lean patients. Based on CT angiography assessment, larger perforators and better flap perfusion were found in patients with higher BMI, but heavier flaps may lead to perforator stretching and weakening, which may reduce blood flow. [54]

An important factor affecting flap-related complications is ischemia time. Arellano et al. showed that despite microsurgical technique progress, when average time from harvest to free tissue flap implantation is 70 minutes, exceeding 60 minutes of ischemia is associated with significantly increased risk of total and partial flap loss, hematoma, and infection [55].

Harvest site complications include seroma, infections, and healing disorders (suture dehiscence, delayed healing). Low patient BMI limits tissue availability in the donor site, and primary closure of too extensive wounds may cause excessive tension along the suture line. However, it was found that BMI differences do not significantly affect healing processes in the harvest site, because previous pregnancies and abdominal adipose tissue distribution enable harvesting larger flaps without closure difficulties, regardless of BMI [54].

Patient characteristics significantly modify complication risk. Chung et al. conducted comparative analysis of patients with previous abdominal wall scars, showing that scar presence significantly increased overall flap complication risk and donor site complications, particularly wound healing problems. In patients with vertical midline scar, particularly careful preoperative planning including CT angiography is necessary [56].

2.3.1.3.3. Systemic Complications

Important complication also remains postoperative venous thromboembolism (VTE). Patients who developed VTE in the postoperative period were characterized by significantly higher average age, body mass index, and prolonged surgical intervention time. Comparative analysis of different breast reconstruction methods revealed that VTE threat was significantly greater with DIEP flap use compared to TRAM flaps and latissimus dorsi LD flaps. Early reconstruction also correlated with clearly higher VTE incidence compared to delayed procedures. Smoking history, hospitalization time, and Caprini scale scoring did not show significant association with increased VTE threat [57].

These observations remain consistent with meta-analysis results conducted by ElAbd et al., which indicated increased thromboembolic complication risk in the obese patient group undergoing autologous breast reconstruction [30].

2.3.1.4. Hybrid Techniques in Reconstruction

In specific clinical situations, a combination of implants and autologous tissues - hybrid procedures - is used. For example, in case of flaps harvested from lower extremity or buttock areas, prosthesis is often used to provide adequate breast volume. Own tissues may serve to cover implant in situations when insufficient amount of skin and muscle structures remained after mastectomy, enabling expansion and prosthesis use [22].

2.3.1.5. Modern Supporting Technologies

2.3.1.5.1 Robotics Application in Reconstructive Surgery

Progress and expansion of robotic technology applications led to development of robot-assisted techniques used in breast reconstruction - robotic autologous breast reconstruction. Methodologies using robotic systems for pedicled flaps from latissimus dorsi muscle (LD) and DIEP flap (deep inferior epigastric perforator), used in breast reconstruction, have been described. Cited studies evaluated robot-assisted flap harvesting, aimed at maximizing operation reliability and reducing harvest site morbidity without compromising flap success.

Roy et al. study results showed comparable complication rates and prolonged operation time compared to NSQIP (National Surgical Quality Improvement Program) data regarding corresponding standard techniques [58].

Allen et al. analyzed robotic platform use for LD and DIEP flaps in terms of donor site morbidity improvement. They found that in the LD flap case, robot-assisted flap harvesting reduces donor site morbidity, incision length, and hospitalization time, with similar complication rates regarding seroma, hematoma, and infection, but with prolonged operation time [59].

Further development of robotic systems in surgery and minimally invasive techniques creates perspectives for improving traditional open flap harvesting methods for reconstructive purposes.

2.3.1.5.2 Flap Perfusion Monitoring Methods

In the case of autologous reconstructions, a critical factor is the precise assessment of flap perfusion, as perfusion-related abnormalities are the cause of the most severe complications threatening the success of reconstruction, namely total or partial flap loss, fat necrosis, or flap skin necrosis.[60]

2.3.1.5.2.1. Indocyanine Green Fluorescence Angiography

An equally important aspect of modern autologous reconstruction is precise assessment of transplanted tissue blood supply. Indocyanine green fluorescence angiography (ICG-FA) gains importance in plastic and reconstructive surgery, used in intraoperative reconstructive flap perfusion assessment and microsurgical procedures [61].

The method enables real-time assessment of vessels and tissue flap perfusion, identifying hypoperfusion areas and indicating flap regions with highest necrosis risk. ICG presence in tissues after intravenous administration can be visualized on screen using specially adapted near-infrared (NIR) cameras directed at the area of interest. Substance is characterized by short half-life (3-4 minutes) and minimal adverse effects, enabling procedure repetition if necessary.

Singaravelu et al. conducted systematic literature review comparing flap perfusion assessment using indocyanine green fluorescence angiography with standard clinical perfusion assessment, performing meta-analysis regarding complications and costs. Meta-analysis showed significant reduction in flap necrosis, fat necrosis, and infection frequency and need for surgical revision. No significant reduction in total or partial flap loss or increase in dehiscence was observed. ICG-FA appears to be a useful, cost-effective tool for identifying undetected hypoperfusion in breast reconstruction [62].

Similar conclusions come from Lauritzen & Damsgaard meta-analysis, which analyzed results of patients subjected to breast reconstruction. Study shows that ICG-A use significantly correlates with lower risk of serious complications and flap loss after reconstruction and with lower risk of minor and major complications in autologous breast reconstruction. Use of intraoperative indocyanine green angiography provides important tissue perfusion information, supporting evidence-based decision making. Further studies with higher credibility level are necessary, particularly to investigate ICG-A use in autologous breast reconstruction [63].

2.3.1.5.2.2. Smartphone-Based Thermal Imaging

Smartphone-based thermal imaging (SBTI) constitutes an easy-to-use, contactless, and economical alternative to standard imaging methods in identifying autologous flap perforators, monitoring flap perfusion, and detecting its disorders. Hudson et al. attempted to evaluate SBTI accuracy in perforator identification, then assess SBTI usefulness in tissue flap perfusion monitoring and ability to predict flap complications. The SBTI device evaluated in all included studies was FLIR ONE.

Smartphone-based thermal imaging correctly identified perforators, similarly to computed tomography angiography, with no significant difference found between SBTI and CTA. SBTI surpassed Doppler ultrasound in early microvascular change detection, enabling rapid flap rescue intervention. SBTI appears to be a promising method for postoperative flap perfusion monitoring, which may reduce complication rate, although further studies are justified [64].

2.3.2. Autologous Fat Grafting

Autologous fat grafting (AFG, lipotransfer) has developed dynamically over the past decades, particularly in plastic and cosmetic surgery, since its proposal in 1893. Illouz first described autologous fat grafting to the breast using adipose tissue harvested by liposuction in 1983 [65].

Autologous fat is recognized as an ideal filling material due to its availability, bio- and histocompatibility, plasticity, safety, and simplicity of transplantation technology. Currently, lipotransfer

constitutes an alternative strategy for breast augmentation, correction, and reconstruction without concerns about complications associated with more invasive procedures.

Lipotransfer (lipofilling) involves transplanting adipose tissue harvested by liposuction from other body parts (most commonly thighs, abdomen, or buttocks) to reconstructed breast area. After mastectomy, lipotransfer is used as a component of hybrid procedures supplementing implant-based or autologous tissue reconstructions, as well as independent reconstruction technique in sequential procedures [66].

During autologous fat grafting, adipose tissue is harvested using metal cannulas from the torso or lower extremity area. After appropriate preparation, material is transferred to the selected area using a syringe. Due to physiological graft resorption, introducing larger amounts of adipose tissue than target reconstruction volume is necessary. Partial reduction of transplanted material constitutes a normal and predictable process. Graft resorption, probably due to ischemia and lack of neoangiogenesis, ranges from 25-80% [67].

2.3.2.1. Methodology and Factors Affecting Effectiveness

Maintaining autologous fat graft volume is unpredictable, and volume retention rate reported in literature falls within a wide value range. Hu et al. in their meta-analysis undertook assessment of volume retention rate and associated factors affecting autologous fat grafting performed for reconstructive and aesthetic purposes. Observation time ranged from 3 to 36 months. Overall graft volume retention rate was 54%, with 52% based on preparation methods for centrifugation and higher than for sedimentation (39%). Graft enrichment with stem and vascular cells obtained after centrifugation is associated with higher volumetric retention coefficient with weighted mean difference of 17.36 [68].

Factors affecting volume retention include fat processing techniques, injection methods and site, body mass index (BMI), and menstrual cycle phase. Additionally, it was reported that enrichment with adipose-derived stromal cells ASC or SVF increases volume retention and reduces the number of operations required to achieve ideal results. Scientific literature provides limited data regarding megavolume grafts exceeding 300 ml [68,69,70,71].

2.3.2.2. External Volume Expansion Systems (EVE)

A crucial consideration is the volume of the tissue pocket designated for graft accommodation. Prior tissue expansion utilising internal or external expanders is advisable. In a 2021 meta-analysis, the authors highlighted the considerable variation in autologous fat grafting methodologies, including lipotransfer techniques augmented by external volume expansion (EVE) systems. The EVE system serves to prepare the recipient site either for internal expander placement or for direct fat graft reception. Upon evaluating the efficacy and safety of the EVE system, the authors determined that autologous fat grafting demonstrates superior effectiveness when combined with EVE compared to its isolated application, exhibiting enhanced fat retention rates relative to conventional fat grafts. Nevertheless, the complication rate proves higher in the EVE-utilising cohort [72].

Objective methodologies for evaluating fat graft volume retention rates may encompass widely accessible imaging modalities, including magnetic resonance imaging and three-dimensional imaging systems [68].

2.3.2.3. Management Methods

Lipofilling techniques may represent the primary choice for autologous reconstruction following skin-sparing and nipple-sparing mastectomy [73]. Whilst theoretically the breast mound can be recreated through repeated procedures, prior tissue expansion utilising internal expanders or external vacuum-assisted tissue stretching systems is recommended to prepare the breast skin and prevent fat necrosis. Breast reconstruction employing autologous adipose tissue is characterised by a multi-stage approach. The initial fat graft within the planned reconstruction area constitutes a procedure performed under local anaesthesia. This intervention facilitates an increase in adipose tissue thickness of up to 1 cm and exerts a beneficial effect upon post-mastectomy scar condition. Following a one-month interval, an expander with appropriately selected parameters is implanted. Subsequent therapeutic stages encompass gradual expander deflation with concurrent fat grafting in the surrounding space. The minimum interval between grafting sessions is 3-6 months [66,74].

In a 2018 meta-analysis, the estimated number of procedures required to achieve post-mastectomy reconstruction ranged from 2.84 to 4.66. No significant difference was observed in the quantity of fat grafting sessions necessary to complete breast reconstruction following modified radical mastectomy compared with skin-sparing mastectomy. The frequency of fat grafting interventions required to complete breast reconstruction was significantly higher amongst patients who had undergone irradiation [75].

Comparable findings were documented in a 2024 meta-analysis, which demonstrated that an average of 1.7 fat grafting sessions was required to complete reconstruction in patients who had undergone breast-

conserving therapy (BCT), with a mean injected volume of 114.2 ml. In the case of post-mastectomy patients with irradiated breasts, an average of 4.7 sessions was necessary, with a mean volume of 556.8 ml required to complete reconstruction, compared with the non-irradiated patient cohort who required only 2.6 sessions and 207.2 ml of adipose tissue for complete breast reconstruction [76].

2.3.2.4. Timing Relative to Radiotherapy

The general practice is to wait with fat grafting until the completion of oncological treatment. Immediate lipotransfer is not performed if radiotherapy is indicated. Radiotherapy is effective in treating residual cancer cells, but radiation damage also occurs in local tissue, making freshly transplanted adipose tissue susceptible to ischaemia, fibrosis, and necrosis. Graft stabilisation occurs between the 2nd and 4th month after the lipotransfer procedure, overlapping with the window when adjuvant radiotherapy occurs [65,64].

Encouraging results were presented by Ribuffo et al. describing procedures using a protective lipofilling technique in immediate expander/implant reconstruction in patients undergoing post-mastectomy radiotherapy. Ulceration and implant exposure rates in the radiotherapy area dropped to 0%, while in the control group without fat grafting, the implant extrusion rate ultimately was 31.25% and was statistically significant [77].

2.3.2.5. Hybrid Approach and Procedure Staging

Fat grafting is commonly performed as a third-stage procedure in patients with staged implant-based breast reconstruction. However, fat grafting performed during the second stage of reconstruction, during expander-to-permanent implant exchange, provides better and faster results without an additional procedure and associated risk. Maheta et al. investigated patient satisfaction with fat grafts performed in the second and third stages of reconstruction and confirmed that fat grafting during the second stage did not increase the clinical complication risk or need for revision surgery compared to fat grafting in the third stage [78].

Hybrid procedures, which supplement reconstructions performed through alternative methods, more frequently serve to correct tissue defects, encompassing breast reconstruction, modelling, and symmetrisation [79,80]. Although the indication most commonly comprises minor deformations arising during breast-conserving treatment (BCT), lipofilling techniques can also be utilised to enhance the outcomes of various procedures, as they permit the filling of tissue defects and softening of postoperative scarring. The patient's adipose tissue is also employed in treating ulcerations caused by radiotherapy.

2.3.2.6. Complications Analysis

Complication rates at the recipient site are higher with increased transfer volume, greater number of grafting sessions, and radiotherapy history [75,66].

AFG has minimal complications and low donor site morbidity compared to other breast reconstruction techniques. The most commonly reported donor site complications were ecchymoses, pain, hematoma, body contour irregularities and unevenness, burns, and infection. Donor site complications tend to intensify with larger lipoaspirate volume and depend on surgeon experience and technique, contributing to aesthetic effect achievement at donor site, which has clinical significance for patient quality of life [81,82].

2.3.2.7. Oncological Safety

Fat grafting represents an alternative methodology to implant- or flap-based reconstruction techniques following mastectomy or breast-conserving procedures. Concerns have been expressed regarding the oncological safety of this procedure and the possibility of tumour recurrence or distant metastases associated with autologous fat grafting (AFG).

Hansen et al. demonstrated no increase in local, locoregional, or distant cancer recurrence rates following breast reconstruction during a patient observation period ranging from 6 months to 10 years. Whilst more cases of fat necrosis were observed, resulting in an increased biopsy rate for radiologically detected changes, the overall complication rate remained lower than that of other reconstructive procedures. The majority of AFG-related complications, including palpable masses, occurred during the early postoperative period. The authors found no increased frequency of cancer recurrence, fat necrosis, palpable masses, or abnormal radiographic findings amongst patients undergoing breast-conserving treatment and AFG, thereby demonstrating the oncological safety of this method [81].

Comparable findings were reported by Kuruvilla et al., who analysed the available literature from 1970 to 2021 to assess oncological outcomes in patients undergoing AFG during breast-conserving treatment. Oncological outcomes and complications were compared between patient cohorts following BCT with lipotransfer and those without. The mean observation period between groups was similar (58.7 months for patients who underwent BCT alone and 55.2 months for patients following BCT with AFG). Pooled analysis revealed no differences in local recurrence, metastases, or fat necrosis rates, thereby confirming fat grafting safety [83].

Further 2022 meta-analyses also demonstrated no significant differences in local and regional tumour recurrence risk or distant metastases amongst patients following lipotransfer who had been previously treated for breast cancer. Based upon clinical studies, the authors confirmed that AFG is oncologically safe and does not compromise prognosis [84,85,86].

The first of these was conducted by Li et al. In their final meta-analysis conclusions, they demonstrated that AFG was not associated with significantly increased local recurrence risk in patients with in situ or invasive cancer, and no significant increase in distant metastasis risk was observed in patients following breast-conserving surgery or mastectomy. The meta-analysis confirmed the safety of autologous fat grafting as a breast reconstruction procedure, providing evidence-based conclusions supporting the use of autologous fat grafting in breast reconstruction [84].

Following the publication of Li et al.'s study in *Aesthetic Plastic Surgery*, Andreoletti et al. published a commentary regarding the oncological safety of fat grafting. In Andreoletti's cohort, the study population included patients with early invasive breast cancer forms, stratified according to cancer biological prognostic subtype and AFG procedure utilisation. With a median observation period of 60 months, the authors confirmed the oncological safety of autologous fat grafting based upon local recurrence risk assessment and local recurrence-free survival in both control groups, irrespective of cancer subtype [87].

Chen et al. conducted a meta-analysis which evaluated the safety and effectiveness of autologous fat grafting in patients following radiotherapy. Within the analysed material, they identified a low overall AFG complication rate (<10%). The authors also reported a high percentage (>90%) of patients satisfied with AFG outcomes in breast reconstruction following mastectomy and radiotherapy [82].

2.3.2.8. Patient Satisfaction and Quality of Life

High (>90%) satisfaction rates for patients and surgeons after lipotransfer were also noted by other authors [88,89,90,91]. Positively received is gradual breast consistency change. Furthermore, performing liposuction in various body areas may affect silhouette improvement and, consequentially well-being, increasing motivation to fight disease.

2.3.2.9. Stem Cell Use

Adipose-derived stromal stem cells (ASC) constitute an attractive cell source for soft tissue regeneration due to their availability, multipotency, non-immunogenicity, and proangiogenic properties. They show preferential differentiation to adipocytes and support maintaining planned fat graft volume.

Yoshimura et al. introduced the concept of stem cell-enriched harvested fat (CAL, cell-assisted lipotransfer). Such prepared tissue was implanted in 40 patients, achieving minimal postoperative adipose tissue atrophy, which remained essentially unchanged after 2 months. Only 4 patients demonstrated cyst or microcalcification formation [92].

Further studies conducted by Kølle et al. confirmed the effectiveness of this technique in a comparative study involving healthy volunteers. The results of grafts enriched with stem cells were compared with procedures utilising adipose tissue alone. In patients who received fat enriched with stem cells, enhanced adipocyte development and new blood vessel formation necessary for their growth were observed. Grafts enriched with stem cells demonstrated 64% greater volume compared with the control group [93].

Subsequent analyses conducted in recent years by Li et al. confirmed the clinical effectiveness of CAL compared with conventional lipotransfer. Fat survival rates were significantly higher in the stem cell group than in the control group, with no significant differences in complication rates between groups. However, analyses comparing fat grafts enriched with another stem cell type - SVF (stromal vascular fraction - crude fraction after centrifugation) - with conventional fat grafts revealed no significant differences [94].

Results from randomised clinical trials published in 2020 demonstrated significant differences in retention - ASC-enriched fat grafts exhibited higher retention rates (mean = 80.2%) compared with conventional fat grafts (mean = 45.1%). ASC-enriched fat grafts resulted in superior clinical outcomes in breast augmentation, with high injected volume survival eliminating the need for secondary procedures. No adverse effects of high-concentration ASC injections were identified [95].

However, literature published after 2020 also presented reports that do not confirm the superiority of ASC-enriched fat grafts over standard fat grafting for breast augmentation [71]. The use of stem cells in breast cancer patients remains controversial due to oncological safety concerns. The ability of ASCs to regenerate cells and promote angiogenesis may potentially increase the risk of breast cancer recurrence.

2.3.2.9.1. Results

Preclinical data from in vitro and animal studies suggest that ASCs demonstrate pro-oncogenic features and participate in stimulating cancer cell progression and growth. In experimental studies, ASC cells

significantly increased breast cancer growth volume compared with the control group. Animal studies demonstrated that ASC injection with cancer cells enhances proliferation and cancer growth in terms of volume [96,97].

Contrary to concerns arising from preclinical studies, clinical study analysis demonstrated that autologous fat grafting, including stem cell-enriched procedures, does not increase breast cancer recurrence risk compared with the group without grafting. No increased recurrence risk was identified in patient groups with in situ and invasive tumours, following breast-conserving operations and modified radical mastectomy, as well as amongst patients following radiotherapy. No residual tumour volume increase following lipotransfer was identified, even with stem cell graft enrichment [96,98,99,100].

Valente et al. analysed the results of patients following mastectomy using enriched lipotransfer procedures and demonstrated no increased cancer occurrence or recurrence risk following risk-reducing mastectomy associated with BRCA mutation. However, there are conflicting reports regarding oncological outcomes in terms of locoregional recurrence in breast cancer patients utilising ASC-enhanced fat grafts [101].

In invasive breast cancer cases, ASC-enriched fat grafts demonstrate potential benefits in graft retention and survival rates. The lack of correlation with carcinogenesis may have various explanations. ASC cells probably favour the adipogenesis phenomenon rather than angiogenesis following co-transplantation with autologous fat. Furthermore, adipose tissue acts as a barrier, reducing ASC concentration in the tumour microenvironment. Finally, ASC concentration in experimental studies is significantly higher than in clinical studies, constituting an important reason for result differences between both study types [98].

The meta-analysis presented by Wang et al. combined basic and clinical studies, concluding that AFG does not increase breast cancer recurrence risk. In their conclusions, however, the authors suggest that adipose-derived stem cells (ASC) should be utilised carefully following breast cancer surgery [98].

2.3.2.9.2. Perspectives and Conclusions

The aesthetic effect of stem cell-enriched procedures is permanent and more natural compared with implants. Procedure invasiveness, complication risk, and graft rejection are practically negligible. The potential possibilities of this method are very promising and remain the centre of experimental and clinical research. However, it is necessary to determine which protocol is most beneficial for patients, establish standard SVF isolation methods or adipose-derived stromal cell (ASC) culture and constant cell percentage in grafts, as well as conduct further studies to assess long-term CAL effectiveness and safety [94].

The use of autologous adipose tissue grafting methods is fundamentally influenced by assessment of the oncological safety of the proposed medical procedure. Based upon available literature meta-analyses, no increased local recurrence risk or shortened overall survival and disease-free survival were identified amongst patients treated for breast cancer who underwent reconstruction using autologous fat grafting. Similar results were also obtained for breast-conserving oncoplastic operations [86,99,100].

2.4. Complementary Procedures

Subcutaneous breast amputation with nipple-areola complex preservation constitutes safe method providing significant aesthetic benefits by eliminating need for secondary reconstruction of this area. However, this procedure can be applied only in selected women, as qualification depends strictly on oncological parameters - cancer size and location - and breast anatomical characteristics, to avoid compromising anticancer treatment radicalism [102,103].

2.4.1. Nipple-Areola Complex Reconstruction

In cases of nipple-areola complex (NAC) loss during oncosurgical procedures, reconstruction is feasible as part of the breast reconstruction process. This procedure constitutes the final treatment stage, typically performed three months following mastectomy, enabling complete healing of the reconstructed breast tissues. Contemporary methods encompass a multi-stage approach utilising autologous tissues and advanced medical micropigmentation techniques. The initial stage involves forming a three-dimensional nipple structure using local skin flaps that are appropriately modelled to achieve a protruding anatomical form. Alternative methods include skin fragment transplantation from other anatomical sites or utilisation of NAC fragments from the contralateral breast. The reconstruction process is completed through colouristic matching via specialised micropigmentation that recreates the natural areola appearance. An advanced option includes tattoos performed by tattoo artists that create an optical protrusion illusion whilst maintaining a flat anatomical surface [104].

Although technical possibilities enable simultaneous NAC reconstruction during primary reconstruction, clinical practice favours postponing this procedure. The two-stage approach permits reconstructed breast shape stabilisation and precise planning of final aesthetic parameters.

Delaying NAC reconstruction creates the possibility of performing corrective interventions on both breasts, which is essential for achieving optimal bilateral symmetry. Such an approach ensures superior control over the final aesthetic effect of the entire reconstruction process.

2.4.2. Contralateral Interventions and Symmetrization Procedures

The breast reconstruction process often necessitates supplementary procedures on the contralateral breast to achieve satisfactory symmetry. Patients undergoing unilateral reconstruction must be prepared for the possible requirement to perform procedures such as augmentation, reduction, mastopexy, or other plastic surgery interventions. The techniques employed in these procedures are based upon proven implant and autologous transplantation methods, adapted to the individual anatomical requirements of each patient.

The traditional approach assumes performing symmetrisation procedures on the healthy breast as the final stage of the entire treatment, enabling precise size and shape matching. Contemporary trends, however, indicate the possibility of simultaneous procedure performance, which may limit the total number of operations and shorten the period of asymmetry occurrence.

Recent data from a 2025 meta-analysis provide reliable information regarding the safety of different temporal approaches in symmetrisation procedures. Comparison of patient groups subjected to simultaneous symmetrisation with the control group where procedures were performed in delayed mode demonstrated no statistically significant differences in overall postoperative complication rates. Detailed analysis considering specific complication types - including surgical site infections, haematoma formation, and tissue necrosis incidents - also revealed no significant differences between both strategies. Similarly, the requirement for surgical reinterventions remained at comparable levels irrespective of the chosen temporal approach. The reliability of these conclusions is confirmed by the long-term observational character, covering a period from 12 to 47 months, allowing assessment of both early and distant effects of both therapeutic strategies [105].

3. Summary and Conclusions

3.1. Surgical Timing: Key Findings

The decision regarding the optimal timing of autologous breast reconstruction remains a complex clinical consideration. Current evidence demonstrates that whilst immediate reconstruction may be associated with a statistically higher risk of surgical complications compared to delayed reconstruction, these differences do not appear to significantly impact long-term patient satisfaction.

Regarding oncological treatment considerations, contemporary evidence supports the safety of immediate reconstruction even in patients requiring adjuvant therapy. Planned adjuvant chemotherapy does not constitute a contraindication for immediate reconstruction, with delays in chemotherapy initiation being minimal and clinically insignificant. However, radiotherapy considerations provide clearer guidance for reconstruction planning. Autologous flap reconstruction demonstrates superior tolerance to radiation compared to implant-based approaches, with immediate autologous flap reconstruction followed by radiotherapy being the optimal approach to avoid reconstruction failure. Conversely, the sequence of radiotherapy followed by delayed autologous reconstruction is associated with the lowest infection risk, providing evidence-based guidance for treatment sequencing.

Notably, the oncological safety of various timing approaches has been consistently demonstrated, with no statistically significant differences in local, regional, or locoregional recurrence rates between immediate and delayed autologous reconstruction strategies. Similarly, autologous fat grafting has been extensively validated from an oncological perspective, with multiple meta-analyses confirming no increased risk of local recurrence, distant metastases, or shortened overall survival in breast cancer patients. This safety profile extends to both post-mastectomy and breast-conserving therapy scenarios, effectively addressing historical concerns about potential tumour promotion.

3.2. Autologous vs Alloplastic Reconstruction Comparison

The comparative analysis of autologous versus alloplastic reconstruction reveals increasingly favourable evidence for autologous techniques. Recent meta-analyses suggest that autologous breast reconstruction may lead to superior psychological and sexual well-being compared to implant reconstruction, alongside greater

overall patient satisfaction. Particularly significant is the demonstrated better tolerance of autologous tissues to radiation damage, with reduced rates of reconstruction failure in the radiotherapy setting.

However, the evidence base remains characterised by methodological limitations, with most studies being non-randomised comparative analyses. This introduces potential selection bias, as observed differences between groups may result from patient characteristics rather than reconstruction methods themselves. Despite these limitations, the available evidence suggests a possible trend towards autologous reconstruction in certain domains of patient-reported outcomes, though conflicting results between meta-analyses prevent definitive conclusions.

In obese patients, autologous reconstruction demonstrates superior performance regarding surgical complication frequency, with lower risks of infection, haematoma/seroma, and reconstruction failure. However, this population exhibits an increased incidence of thromboembolic complications, necessitating enhanced prophylactic protocols and careful perioperative management.

3.3. Autologous Reconstruction Techniques: Current State

Contemporary autologous reconstruction has evolved significantly, with the deep inferior epigastric perforator (DIEP) flap emerging as the gold standard for abdominal-based reconstruction. This technique offers superior donor site morbidity profiles compared to traditional TRAM flaps whilst maintaining excellent reconstructive outcomes. The development of muscle-sparing techniques has substantially reduced risks of abdominal wall hernias and functional impairment.

Advanced preoperative imaging modalities, particularly three-dimensional computed tomography and magnetic resonance angiography, have enhanced surgical planning accuracy, providing high concordance between preoperatively identified "dominant" perforators and those selected during surgery. These technological advances contribute to improved flap survival rates and reduced operative complications.

The integration of microsurgical approaches, including super-drainage techniques for venous congestion management and use of bipedicle flaps for challenging reconstructions, has expanded the applicability of autologous reconstruction to a broader patient population. Furthermore, the utilisation of flaps from multiple possible donor sites, such as transverse upper gracilis (TUG) and profunda artery perforator (PAP) flaps, provides viable options for patients with insufficient abdominal tissue.

Surgical reinnervation techniques represent a significant advancement in functional outcomes, with recent meta-analysis demonstrating superior sensation recovery in reinnervated reconstructions compared to conventional approaches. This development addresses a critical aspect of patient quality of life previously considered an inherent limitation of reconstruction.

3.4. Fat Grafting: Emerging Role and Safety Profile

Autologous fat grafting has emerged as a versatile technique in breast reconstruction, functioning both as a standalone reconstruction method and as an adjunct to other approaches. The technique demonstrates particular utility in hybrid reconstructions, where it serves to optimise aesthetic outcomes and address contour irregularities. Volume retention rates remain variable, influenced by processing techniques, injection methodology, and patient factors. Enrichment with adipose-derived stromal cells (ASC) shows promise for improving retention rates.

Critically, extensive meta-analyses have consistently demonstrated the oncological safety of fat grafting, with no increased risk of local recurrence, distant metastases, or shortened survival in breast cancer patients. This finding extends to patients treated with breast-conserving therapy and those receiving radiotherapy, effectively addressing previous concerns regarding tumour promotion.

The technique's minimal invasiveness and low donor site morbidity make it particularly attractive for patients seeking less extensive reconstruction or those unsuitable for major flap procedures. However, the multi-stage nature of fat grafting reconstruction that necessitates extended treatment periods to achieve final outcome, is an obvious disadvantage, though it may be offset by patient satisfaction with the concomitant body contouring effects achieved through liposuction at donor sites.

3.5. Clinical Implications and Future Directions

The evolving evidence base supports an individualised approach to reconstruction selection, considering patient anatomy, oncological requirements, lifestyle factors, and personal preferences. The demonstrated safety and efficacy of immediate autologous reconstruction, even in complex oncological scenarios, enables more integrated treatment planning and potentially improved patient experiences.

Technological innovations, such as robotic-assisted flap harvesting and real-time perfusion monitoring with indocyanine green fluorescence angiography are enhancing surgical precision and outcomes whilst reducing complications. Other emerging technological ideas suggest a future where autologous reconstruction becomes increasingly accessible and reliable.

The integration of regenerative medicine approaches, particularly stem cell therapies and advanced fat grafting techniques, offers promising avenues for improving both aesthetic and functional outcomes. However, standardisation of protocols and long-term safety data remain necessary for widespread clinical adoption.

3.6. Limitations and Research Gaps

Current evidence suffers from significant methodological limitations, particularly the lack of high-quality randomised controlled trials comparing reconstruction modalities. Most available data derive from observational studies and case series, introducing potential selection and reporting biases.

Standardised outcome measures and longer follow-up periods are needed to adequately assess the durability of reconstruction outcomes and late complications. Additionally, cost-effectiveness analyses incorporating quality-adjusted life years and patient preferences require further development to inform healthcare policy decisions.

3.7. Final Conclusions

Autologous breast reconstruction represents a mature field with evolving techniques that can offer excellent outcomes for appropriately selected patients. The accumulated evidence suggests that autologous techniques may be equivalent to alloplastic approaches across several outcome domains, with some studies indicating potential advantages in patient satisfaction, radiation tolerance, and aesthetic results, though conflicting evidence prevents definitive conclusions.

Current trends suggest that autologous reconstruction may become more prevalent, supported by emerging evidence of favourable patient-reported outcomes and advancing surgical techniques. However, the superiority of autologous approaches remains to be definitively established through higher-quality comparative studies. As techniques continue to develop and evidence accumulates, this field is likely to experience further refinement.

The future of breast reconstruction appears to be moving towards more individualised approaches that balance oncological safety with patient preferences. Autologous techniques, with their inherent biocompatibility and potential for natural aesthetics, may play an increasingly important role in this evolution, though their optimal application will depend on continued research and technological advancement.

For optimal patient care, multidisciplinary teams should consider autologous reconstruction as a primary option for suitable candidates, whilst continuing to participate in research efforts that will further refine these techniques and expand their applicability to an even broader patient population.

Acknowledgements

The study did not receive any external funding. The authors declare no conflict of interest.

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