

# Advances in Prepectoral Breast Reconstruction

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**Abstract:** Breast reconstruction can be divided into prepectoral breast reconstruction (PPBR) and subpectoral breast reconstruction (SPBR) according to the implant plane. The original prepectoral breast reconstruction was abandoned for a long time due to the frequent and severe complications. Now, advances in materials technology and improved methods of mastectomy have made safe prepectoral breast reconstruction possible. Moreover, a number of studies have gradually demonstrated the advantages of prepectoral breast reconstruction. As prepectoral breast reconstruction becomes more and more attractive, it is time to review the current advances in prepectoral breast reconstruction.

**Keywords:** breast reconstruction, breast cancer, complications, patient report outcome, prepectoral, subpectoral

## Introduction

WHO released a report in early 2021, indicating that breast cancer has surpassed lung cancer to become the most common tumor in the world.<sup>1</sup> Surgical resection of tumors is a conventional treatment for breast cancer. Failure in breast preservation will cause physical deficiency, psychological inferiority, and lower social integration and life happiness of patients.<sup>2,3</sup> Breast reconstruction can reshape the appearance of the breast and restore the curves of women and has become an indispensable part of the comprehensive treatment of breast cancer.<sup>4</sup> Among them, implant-related breast reconstruction is the most commonly used reconstruction method, but the implant placement plane is still controversial.<sup>5</sup> According to the implant placement plane, there are two types: prepectoral breast reconstruction (PPBR) and subpectoral breast reconstruction (SPBR). In the past, prepectoral breast reconstruction has been abandoned for a long time due to its high incidence of complications. However, with the rapid development of surgical techniques and auxiliary materials, prepectoral breast reconstruction has attracted the attention of plastic surgeons again. Therefore, it is necessary to review its progress. We reviewed the literature on breast reconstruction published between 1980 and 2023 by prepectoral breast reconstruction and added elements such as one-step and two-step surgical techniques. Keywords used in our literature search included “breast reconstruction”, “prepectoral”, “subpectoral”, “complications”, “outcome”, “one stage”, “two stages”, “implant”, etc.

## Development History of Implant Placement

In the 1960s, the appearance of silicone gel prosthesis greatly promoted the development of implant-related breast reconstruction and breast augmentation, but at that time, there was no clear standard for implant placement plane.<sup>5</sup> At first, the surgeon placed the prosthesis in front of the pectoralis major muscle, but the probability of postoperative complications was high and severe, including necrosis of the skin flap and infection, and other complications such as external exposure of the prosthesis, capsular contracture, and corrugation on the skin surface, so that the prepectoral breast reconstruction was abolished for a long time.<sup>6</sup> After that, in order to reduce the incidence of complications and improve postoperative satisfaction, clinical workers continue to look for a suitable plane for implant placement. In the 1980s, the emergence of subpectoral breast reconstruction was popular in the field of breast plastic surgery.<sup>7</sup> Subpectoral

breast reconstruction was once favored by plastic surgeons because they were placed behind the pectoralis major muscle to increase the surface tissue coverage and reduce the incidence of the aforementioned complications. Even now, subpectoral breast reconstruction is still the main method for breast reconstruction in breast cancer patients.<sup>8</sup>

## Disadvantages of Subpectoral Breast Reconstruction and the Revival of Prepectoral Breast Reconstruction

As the main method of breast reconstruction at present, the number of cases of subpectoral breast reconstruction is increasing, but people gradually found that it also has some disadvantages. Because the implant is placed after the pectoralis major muscle, the muscle contraction often leads to the displacement of the implant, which is known as “animation deformity”<sup>9</sup> and seriously affects the aesthetic shape of the breast, especially for patients with frequent pectoralis movement needs, such as athletes. In addition, patients also have obvious pain due to muscle spasms, which greatly reduces breast satisfaction.<sup>10</sup> During reconstructive surgery, the separation of the posterior pectoralis major muscle space causes significant damage to muscle fibers, and the incidence of postoperative pain and shoulder dysfunction increases.<sup>11</sup> After implantation, due to the coverage of pectoralis major, its expansion and prolapse will be limited, resulting in the high position of the implant and unnatural submammary folds.<sup>12</sup>

With the continuous development of skin-sparing mastectomy (SSM) and nipple-sparing mastectomy (NSM), the thickness and conditions of breast flaps have improved.<sup>13</sup> Acellular dermal matrix (ADM) increases tissue coverage, reduces complications, and improves aesthetic effects of breast reconstruction.<sup>14</sup> Significant progress has been made in the monitoring technology of skin flap blood supply, such as indocyanine green angiography, which makes it possible to accurately evaluate the blood supply of skin flap before and during operation and reduces the occurrence of ischemic necrosis of skin flap.<sup>15</sup> Due to the above scientific progress and the shortcomings of the existing subpectoral breast reconstruction, people began to pay attention to the prepectoral breast reconstruction and initiated many studies, most of which achieved good initial results.

Because the implant is placed in front of the pectoralis major muscle, the implant is not affected by muscle contraction, so patients with prepectoral breast reconstruction basically have no animation deformity.<sup>16</sup> At the same time, there is no need to separate the pectoralis major muscle during the operation, resulting in less damage, less postoperative pectoralis major dysfunction, and faster recovery.<sup>17</sup> It is worth mentioning that prepectoral breast reconstruction can achieve better breast ptosis. For patients with obvious breast ptosis, anterior pectoralis major breast reconstruction combined with skin resection can often achieve good clinical results.<sup>18</sup>

## Emergence of ADM and Its Application in Prepectoral Breast Reconstruction

ADM is a biosynthetic substance derived from humans, cows, or pigs, in which the immune antigens are processed in the production process, but the scaffold structure is retained to promote angiogenesis and tissue growth.<sup>19</sup> ADM was first applied to burn patients in 1995. Since then, ADM has been popularized by surgeons. In 2001, ADM was first used in breast reconstruction, opening its door to the field of breast reconstruction. In the following 20 years, ADM has been widely used in various forms of breast reconstruction.<sup>20</sup>

ADM has many advantages in breast reconstruction. Headon et al<sup>21</sup> found that the use of ADM could reduce the capsular contracture rate through a single-center clinical trial, and Liu et al<sup>22</sup> also found the same conclusion through meta-analysis. Experiments have confirmed that ADM can reduce the local inflammatory response and inhibit capsule formation.<sup>23</sup> In addition, ADM suturing to the submammary fold can mediate better fitting between the implant and the submammary fold, reducing the occurrence of window shading and making the shape more beautiful.<sup>24</sup>

Because of these advantages, ADM is widely used in prepectoral breast reconstruction. Onesti et al carried out a single-center clinical study and found that the use of ADM could reduce the incidence of seroma and capsular contractures, and meanwhile improve the subjective indicators of postoperative breast satisfaction and sexual satisfaction in BREAST-Q scale, proving the rationality of ADM in prepectoral breast reconstruction.<sup>25</sup>

ADM can be used in prepectoral breast reconstruction in two ways<sup>26</sup>: (1) the ADM is first sutured under the flap to form a pocket in front of the pectoralis major, and then the prosthesis is placed in this pocket. Finally, the ADM was sutured and fixed. (2) The prosthesis was wrapped by ADM on the sterile instrument table, and then the prosthesis wrapped with ADM was placed in front of the pectoralis major muscle for suturing and fixation. It is worth mentioning that intraoperative damage to the flap blood supply and subdermal nerve plexus should be avoided, and since the diameter of the base of the implant is always narrower than the width of the base of the breast, the lateral breast groove (a potential dead space) needs to be eliminated with 2 layers of 2/0 Vicryl suture.

## Application of Indocyanine Green Angiography (ICGA) in Prepectoral Breast Reconstruction

For prepectoral breast reconstruction, adequate perfusion of the vascularized flap is a necessary condition because the implant is close to the skin flap.<sup>27</sup> Flap necrosis may lead to infection around the prosthesis, leading to serious consequences.<sup>28</sup> The importance of preoperative and intraoperative evaluation of flap blood supply is self-evident.

The traditional intraoperative evaluation method of skin flap blood supply is to trim the skin flap until it has fresh bleeding,<sup>29</sup> but this method has obvious shortcomings and is highly subjective for the surgeon, which may lead to unnecessary skin flap removal. However, the emergence of indocyanine green angiography solves this problem. Indocyanine green is a fluorescent chemical substance that can bind to plasma proteins.<sup>30</sup> When activated by laser or led, indocyanine green can absorb light with a wavelength of 805nm–835nm to develop, which is widely used in various disciplines.<sup>31</sup> Malagon et al found in a single-center clinical study that ICGA could significantly reduce the incidence of flap necrosis in patients with breast reconstruction.<sup>32</sup> In a meta-analysis published in the Cochrane database, Pruimboom et al found that the use of ICGA can reduce the rate of flap repair after breast reconstruction.<sup>33</sup> Because the ICGA has many advantages and indocyanine green can be quickly inactivated in the human body (half-life is only 3–4 minutes), many scholars recommend ICGA to evaluate the blood supply of skin flap before or during breast reconstruction. ICGA is especially helpful for prepectoral breast reconstruction. However, the application specifications and applicable groups of ICGA have not been fully clarified and need further study.<sup>34</sup>

## Contraindications and Indications of Prepectoral Breast Reconstruction

The placement plane of prepectoral breast reconstruction is under the flap. The implant is close to the flap, and flap-related complications may affect the surgical outcome. Adequate blood perfusion of the flap is a necessary condition for surgery, and insufficient blood supply of the flap and recent tobacco use are absolute contraindications for surgery.<sup>26</sup> Diabetes, obesity, immune system diseases, thin skin flap, and history of local radiotherapy often lead to adverse events and are relative contraindications for surgery.<sup>27</sup> It should be emphasized that prepectoral breast reconstruction will affect breast palpation and thus affect the detection of recurrent lumps, so it is not recommended to use prepectoral breast reconstruction for patients with a high risk of recurrence.<sup>5</sup>

Prepectoral breast reconstruction can be completed under local anesthesia because of minor injury and is suitable for patients who want to be discharged quickly and recover quickly.<sup>35</sup> The posterior pectoralis major space is not separated during the operation, and the postoperative implant is not affected by muscle contraction, so it is suitable for patients with high pectoralis major functional requirements or can be used as a repair plan for patients with subpectoral breast reconstruction with animation deformity.<sup>36</sup> At the same time, because the implant is not limited by muscles, the implant has better expansion and breast ptosis, so prepectoral breast reconstruction is suitable for patients with obvious breast ptosis.<sup>37</sup>

## Discussion

Breast reconstruction is a surgical procedure that aims to restore the shape and size of the breast after a mastectomy or lumpectomy.<sup>38</sup> Depending on the timing of the surgery, there are two main approaches to breast reconstruction: two-stage reconstruction and single-stage reconstruction.<sup>39</sup>

During two-stage breast reconstruction, the breast are reconstructed by two separated surgeries.<sup>40</sup> During the first surgery, a tissue expander will be inserted under the chest muscle. The tissue expander is then slowly filled with saline over several weeks to stretch the skin and muscle, expand the volume of tissue in preparation for the final implant.<sup>41</sup> In the second surgery, the tissue expander will be removed and replaced with a permanent implant.<sup>41</sup> Single-stage breast reconstruction, on the other hand, involves placing a permanent implant during the initial surgery.<sup>42</sup> This approach is typically used when there is enough remaining breast tissue to cover the implant and provide a natural-looking result.

Both two-stage and single-stage breast reconstruction have their pros and cons, and the choice between the two depends on a variety of factors, including the patient's individual requirements and preferences, the extent of the breast tissue removal, and the surgeon's expertise.<sup>43,44</sup> Advantages of two-stage reconstruction include: 1. Allows for a more gradual, controlled expansion of the skin and muscle, which can reduce the risk of complications such as implant displacement or infection; 2. Can provide a better cosmetic outcome for women who have undergone radiation therapy or have thin, fragile skin and tissue; 3. Gives patients time to adjust to the reconstructed breast and decide if they want additional procedures, such as nipple reconstruction or fat grafting.<sup>45</sup> Advantages of single-stage reconstruction include: 1. Requires fewer surgeries overall, which can be more convenient for patients; 2. Can provide a quicker return to normal activities, as there is no need for tissue expansion. 3. May be a better option for women who have undergone a unilateral mastectomy and want to achieve symmetry with their remaining breast.<sup>46</sup>

Both two-stage and single-stage breast reconstruction can be effective options for women seeking to restore their breasts after a mastectomy or lumpectomy. Patients should consult with their surgeon to determine which approach is best for their individual needs and goals.

Now, many studies have tentatively shown patient-reported outcomes (PRO) for breast reconstruction. The Mastectomy Reconstruction Outcomes Consortium (MROC) study is a multi-center research initiative launched in 2012 to investigate the safety, effectiveness, and outcomes of different types of breast reconstruction surgery.<sup>47</sup> The study involves over 2000 women who underwent mastectomy, with the goal of understanding how to improve patient outcomes and quality of life.<sup>48</sup> The initial findings from the MROC study have already yielded important insights into breast reconstruction surgery. For example, the study found that women who underwent immediate breast reconstruction reported higher levels of satisfaction with their reconstruction than women who underwent delayed reconstruction.<sup>49</sup> The study also found that women who underwent autologous reconstruction (using the patient's own tissue) reported higher satisfaction with their reconstruction than those who underwent implant reconstruction.<sup>49</sup> This results, however, may show conflicts between the existing clinical trail, can offer clinical evidence for selection of operation methods.

Breast reconstruction can also be divided into prepectoral breast reconstruction and subpectoral breast reconstruction depending on where the prosthesis is placed. Prepectoral breast reconstruction has been reported in many countries recently and is a research hotspot in the field of breast reconstruction. Bozzuto et al<sup>50</sup> found that the pain score, opioid usage, and length of hospital stay of patients with prepectoral breast reconstruction were significantly smaller than those with subpectoral breast reconstruction, with statistically significant differences. Schaeffer et al<sup>51</sup> found in a single-center clinical study that prepectoral breast reconstruction had lower pain scores, opioid usage, and shorter shoulder obstruction time and drainage tube placement time. Gabriel et al<sup>52</sup> used prepectoral breast reconstruction to repair subprepectoral breast reconstruction patients with animation deformity, and the results showed that all patients were repaired. Maruccia et al<sup>53</sup> applied the combination of prepectoral breast reconstruction and skin resection to patients with large and saggy breasts, and the results showed that the postoperative breast shape was satisfactory and the patient obtained breast ptosis. Abbate et al,<sup>54</sup> through a meta-analysis of 13 literature, pointed out that prepectoral breast reconstruction had a lower rate of capsular contracture, flap necrosis, delayed healing, hematoma, seroma, infection, prosthesis removal, and retro-pectoral breast reconstruction.

Post-mastectomy radiation therapy (PMRT), as a common treatment for breast cancer, can impact the outcomes of breast reconstruction.<sup>55</sup> Researches in PMRT and breast reconstruction mainly focused on identifying the best timing and approach to breast reconstruction in patients who require PMRT.<sup>56</sup> A study published in JAMA Surgery found that patients who underwent immediate breast reconstruction followed by PMRT had a higher rate of complications such as infections and wound healing problems compared to those who underwent delayed reconstruction after PMRT.<sup>57</sup> Another area of research progress in PMRT and breast reconstruction is the use of autologous reconstruction, which involves

using the patient's own tissue to reconstruct the breast. Zhang et al found that autologous reconstruction was associated with lower rates of complications and improved cosmetic outcomes compared to implant-based reconstruction in patients who require PMRT.<sup>58</sup>

Overall, the research progress in PMRT and breast reconstruction continues to focus on identifying the best timing and approach to reconstruction in patients who require radiation therapy after mastectomy.<sup>59</sup> Naoum et al found that in patients with neoadjuvant chemotherapy, one-step reconstruction had fewer complications and was capable of PMRT compared to two-stage reconstruction.<sup>60</sup> While immediate reconstruction may not be the best option for all patients, delaying PMRT until after breast reconstruction or using autologous reconstruction may offer improved outcomes and lower rates of complications.<sup>61</sup>

Post-mastectomy radiation therapy can have a significant impact on the reconstructed breast after both prepectoral and subpectoral breast reconstruction.<sup>62</sup> In the context of PMRT, both prepectoral and subpectoral reconstruction techniques have their own unique advantages and challenges.

Prepectoral breast reconstruction may be a better option for patients who require PMRT because it involves less dissection of the chest muscle, which can minimize the risk of muscle damage and improve postoperative recovery.<sup>63</sup> However, PMRT can impact the quality and stability of the skin and tissue, potentially leading to complications such as capsular contracture (scar tissue formation around the implant), implant displacement, or infection.<sup>64</sup>

Subpectoral breast reconstruction, on the other hand, involves placing the implant or expander beneath the chest muscle, which can provide additional tissue coverage and support for the implant. However, PMRT can impact the muscle tissue, leading to muscle damage, weakness, and potential reconstruction failure.<sup>65</sup>

Recent studies have shown that prepectoral breast reconstruction may be a viable option for patients who require PMRT, with comparable outcomes to subpectoral reconstruction.<sup>66</sup> For example, a study published in *Plastic and Reconstructive Surgery Global Open* found that prepectoral reconstruction had lower rates of complications and higher patient satisfaction compared to subpectoral reconstruction in patients who underwent PMRT.<sup>67</sup>

Overall, the impact of PMRT on prepectoral and subpectoral breast reconstruction techniques continues to be an area of active research. The choice of reconstruction technique should be individualized to each patient based on their anatomy, preferences, and the potential impact of PMRT on the skin and muscle tissue.

Although prepectoral breast reconstruction has many advantages, some problems have been found in clinical application. First of all, the implant is placed directly under the skin, which may lead to the risk of visible, palpable, and exposed prosthesis.<sup>68</sup> Currently, it has been found that adjunctive therapeutic measures such as autologous fat transplantation can reduce the occurrence of these adverse events.<sup>69</sup> Secondly, the economic benefits of ADM are also considered by many clinicians and patients. In many countries, the insufficient source and high price of ADM make it difficult to widely promote prepectoral breast reconstruction.<sup>70</sup> It is worth noting that in some clinical centers, ADM substitutes such as Vicryl mesh have also been successfully used in prepectoral breast reconstruction to reduce patient costs, but further studies are needed to determine whether there is a difference in clinical efficacy.<sup>71</sup> Currently, there are few randomized clinical trials (RCTs) on prepectoral breast reconstruction. It is hoped that more high-quality studies will confirm its safety and clinical efficacy in the future.

## Conclusion

Plastic surgery is an evolving discipline and its clinical thinking is not static. As science and technology advance, new ideas emerge, and old methods are improved. The stereotype of prepectoral breast reconstruction as having very high complications led to its being abandoned for a long time. However, the development of NSM and SSM has improved the conditions of breast flaps, and advances in materials science and angiography have made it possible to reconstruct the breast safely in front of the pectoralis major. At present, prepectoral breast reconstruction has achieved good initial results worldwide, but long-term follow-up data are still needed to confirm.

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