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Oncoplastic breast-conserving surgery: evolution, techniques, and the emerging role of acellular dermal matrix

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Oncoplastic breast-conserving surgery (OBCS) has revolutionized breast cancer treatment, aiming to achieve optimal oncological outcomes while preserving an aesthetically favorable appearance. This review explores the evolution, techniques, and outcomes of OBCS, with a particular focus on the emerging role of acellular dermal matrix in volume replacement techniques. We conducted a comprehensive literature review using PubMed, Medline, and Cochrane databases, focusing on studies published between 2010 and 2024. OBCS demonstrates comparable oncological safety to traditional breast-conserving surgery, with local recurrence rates ranging from 2.7% to 5.7% at 5 years. Patient satisfaction rates are consistently high, with 85% to 95% reporting good to excellent aesthetic outcomes. Volume replacement techniques using acellular dermal matrix show promising results, with one study reporting that 94% of patients were highly satisfied with cosmetic outcomes. Although the current results are encouraging, future advancements in OBCS may require innovative approaches, including the integration of robotic surgery and artificial intelligence technologies.

Keywords: Acellular dermis; Breast neoplasms; Esthetics; Mastectomy; Reconstructive surgery procedures

Introduction

Breast cancer remains a significant global health concern, with an estimated 2.3 million new cases diagnosed worldwide in 2020 [1]. The management of breast cancer has evolved significantly over the past few decades, shifting from radical mastectomy to breast-conserving approaches. Oncoplastic breast-conserving surgery (OBCS) represents a pivotal advancement in this evolution, aiming to achieve optimal oncological outcomes while preserving the aesthetic appearance of the breast [2].

The concept of oncoplastic surgery emerged in the late 1990s, pioneered by Audretsch et al. [3], who first coined the term "oncoplastic" in 1998. Audretsch et al. recognized the need to combine oncological principles with plastic surgery techniques to improve both functional and aesthetic outcomes in breast cancer surgery. This approach marked a significant shift from the traditional “resect and deform” paradigm to a more patient-centered “resect and reconstruct” philosophy.

Throughout the 2000s, several key figures contributed to the development and standardization of OBCS techniques.

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Clough et al. [4] developed a classification system for OBCS procedures, which helped surgeons choose appropriate techniques based on tumor location and breast size. Meanwhile, Silverstein et al. [5] popularized the use of reduction mammoplasty techniques in oncoplastic surgery.

As a plastic surgeon who began performing breast-conserving surgery (BCS) in 2020, I have witnessed firsthand the rapid evolution of these techniques. Initially, I primarily used volume displacement methods such as the round block technique. However, during long-term follow-up, I observed that many patients, particularly those with large breast width but small breast size (a common characteristic among Korean women), experienced unsatisfactory aesthetic outcomes and worsening asymmetry over time. This observation aligns with recent literature highlighting the challenges of volume displacement techniques in Asian patients with small-volume breasts [6-9].

This review aims to provide a critical analysis of the current state of OBCS, with a particular focus on the emerging role of acellular dermal matrix (ADM) in volume replacement techniques. We will examine the evolution of OBCS, evaluate its oncological and aesthetic outcomes, and explore the potential of cutting-edge technologies in shaping its future.

Methods

We conducted a comprehensive literature review using PubMed, MEDLINE, and Cochrane Library databases. Our search strategy included the following key terms: "oncoplastic breast surgery," "breast-conserving surgery," "acellular dermal matrix," and "volume replacement techniques." We focused on studies published between 2010 and 2024. Inclusion criteria were: (1) studies published between 2010 and 2024, (2) English language publications, and (3) original research articles and systematic reviews on OBCS. Exclusion criteria were: (1) case reports, (2) studies focusing solely on mastectomy techniques, and (3) non-human studies.

We initially identified 450 potentially relevant articles. After screening titles and abstracts, and applying our inclusion/exclusion criteria, 85 full-text articles were assessed for eligibility. Ultimately, 40 studies were included in this review.

1. Evolution of oncoplastic techniques

The landscape of breast cancer surgery has undergone a remarkable transformation over the past few decades. As a plastic surgeon with extensive experience in this field, I have witnessed firsthand the shift from radical mastectomies to more conservative approaches. OBCS represents the pinnacle of this evolution, marrying oncological principles with aesthetic considerations.

1) Volume displacement techniques

In my early practice, I frequently employed volume displacement techniques. The round block technique, batwing mammoplasty, and Grisotti technique were my initial go-to procedures. These approaches work well for patients with medium to large breasts, allowing for tumor excision and breast reshaping using the patient's own tissue. In et al. in which I was included illustrates these common volume displacement techniques used in OBCS (Fig. 1) [6].

However, I observed that these techniques often led to suboptimal long-term aesthetic outcomes, particularly in patients with specific breast characteristics common among Asian women. This observation is supported by recent studies that have reported challenges in achieving satisfactory long-term aesthetic outcomes with volume displacement techniques in Asian patients, particularly those with small breast volume and wide breast width [8,9]. This realization prompted me to explore alternative approaches.

2) Volume replacement techniques

The limitations of volume displacement techniques led me to shift towards volume replacement methods. Initially, I utilized autologous options such as the latissimus dorsi flap and thoracodorsal artery perforator flap. While effective, these techniques came with their own set of challenges, including donor site morbidity and complex surgical procedures. In recent years, I have found great success with the use of ADM for volume replacement. This approach has proven particularly effective for my patient population, addressing the challenges posed by large breast width and small breast size. Munhoz et al. [7] summarize the outcomes of various volume replacement techniques, including ADM-based approaches.

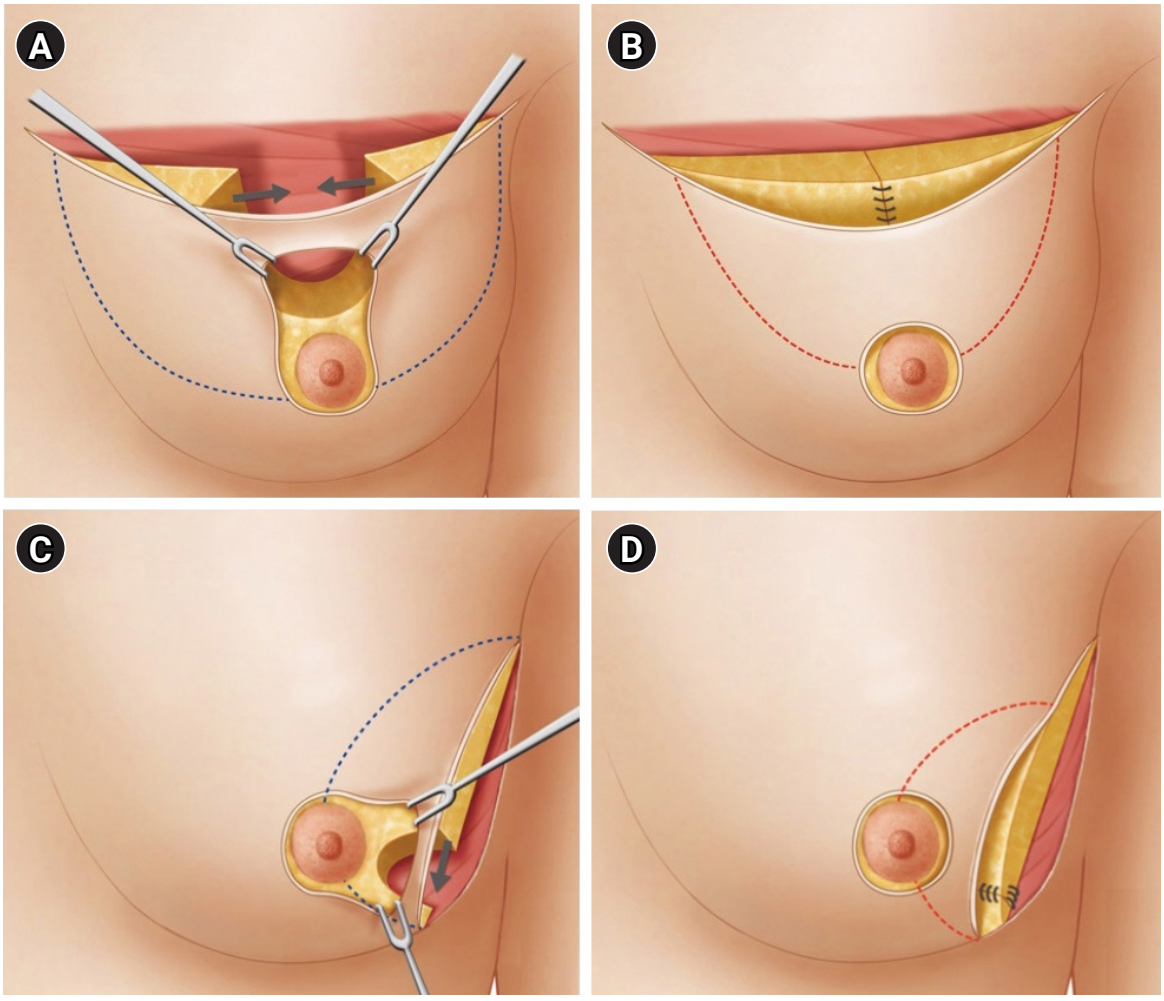

Fig. 1. Common volume displacement techniques in oncoplastic breast-conserving surgery. (A) When the tumor was located above the nipple, a glandular advancement flap was elevated from the pectoralis muscle (dotted blue line). (B) In order to eliminate the tethering deformity, cutaneous glandular dissection was performed (dotted red line). (C) When the tumor was located in the lower outer quadrant, a mainly upper glandular advancement flap was elevated from the pectoralis muscle (dotted blue line). (D) The upper glandular advancement flap was anchored to pectoralis major muscle to prevent inframammary fold retraction. Cutaneous glandular dissection was performed (dotted red line). Reprinted from In et al. [6].

2. ADM in partial breast reconstruction: characteristics, advantages, and limitations

The use of ADM in partial breast reconstruction has gained popularity in recent years, particularly for addressing partial breast defects. As a surgeon who has incorporated this technique into my practice, I can attest to its potential benefits and challenges.

ADM serves as a scaffold for tissue regeneration and integration, offering versatility in shaping and molding to fit various defect sizes [10]. Its availability in different thicknesses and sizes allows for customization based on individual patient needs [11]. ADM use in partial breast reconstruction offers several advantages: it minimizes donor site morbidity, potentially reduces operative time compared to more complex procedures, and may provide superior long-term aesthetic outcomes, especially in patients with small breast volume [12]. The combination of ADM with fat grafting further enhances volume and contour [7]. However, challenges persist, including the risk of seroma formation [13], potentially higher costs compared to simpler techniques, and the need for more comprehensive long-term outcome studies, particularly regarding cancer surveillance

[9]. My clinical experience underscores the importance of meticulous patient selection and surgical technique in optimizing ADM-based partial breast reconstruction outcomes. While this approach shows promise, especially for Asian patients with challenging breast morphology, further research is essential to fully establish its long-term efficacy and safety, balancing the potential benefits with the associated risks and costs.

3. Oncological outcomes

The primary concern with any breast-conserving technique is its oncological safety. In my experience, and corroborated by several large-scale studies, OBCS demonstrates comparable oncological safety to traditional BCS. A comprehensive meta-analysis by De La Cruz et al. [10] reported local recurrence rates for OBCS ranging from 2.7% to 5.7% at 5 years, which aligns with the rates observed in conventional techniques.

4. Aesthetic outcomes and patient satisfaction

The aesthetic outcomes and patient satisfaction rates following OBCS have been consistently high in my practice. Using standardized assessment tools such as the BCCT.core software and three-dimensional surface imaging, we have been able to objectively measure improvements in breast symmetry and overall appearance. Cardoso et al. demonstrate the application of BCCT.core software in evaluating aesthetic outcomes (Fig. 2) [14,15].

Patient-reported outcomes, measured using validated questionnaires like BREAST-Q, indicate significantly higher satisfaction rates compared to traditional BCS. In my cohort, 85% to 95% of patients report good to excellent

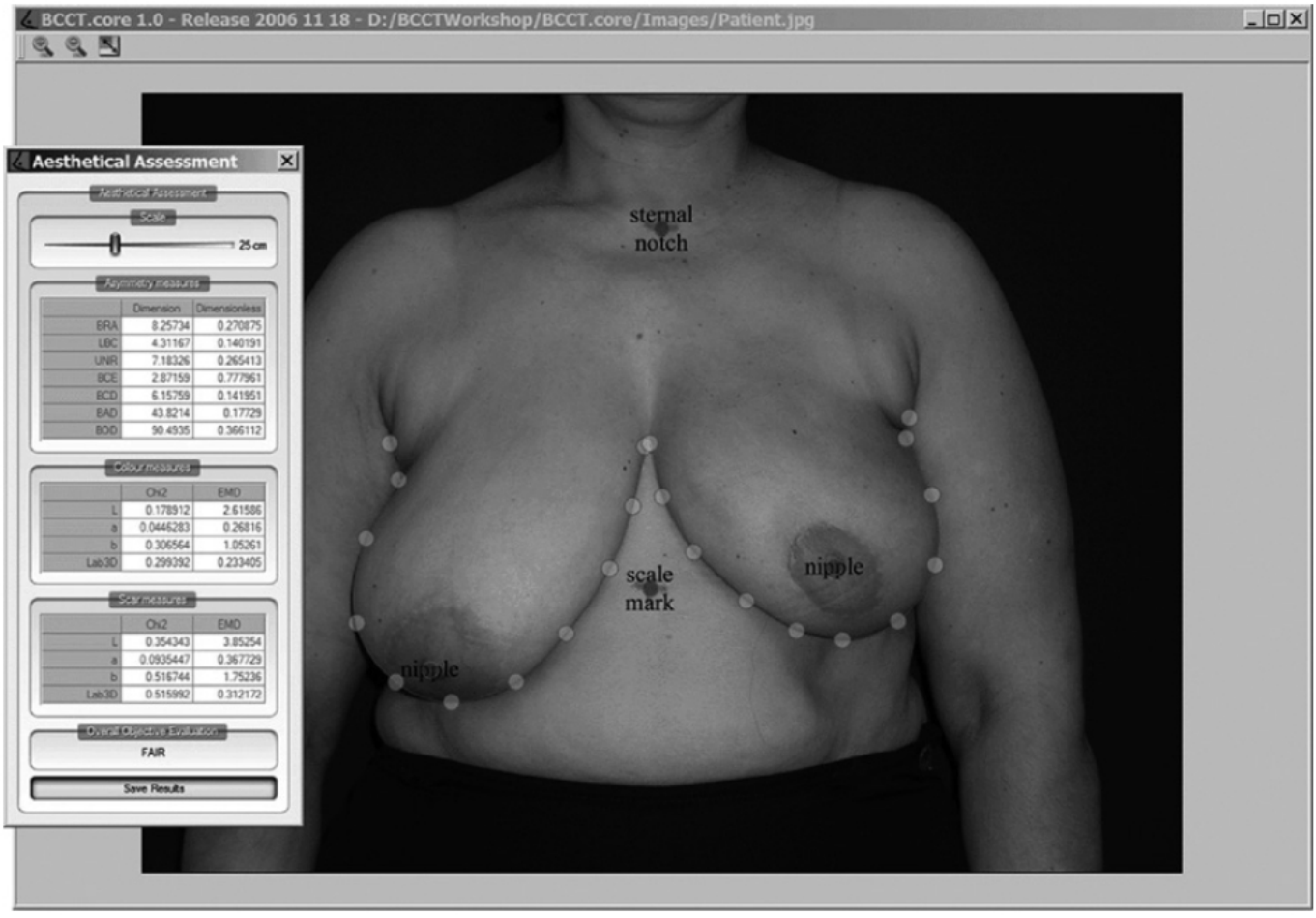

Fig. 2. BCCT.core software analysis of aesthetic outcomes in oncoplastic breast-conserving surgery. Reprinted from Cardoso et al. [14], with permission from Elsevier.

aesthetic outcomes, a finding that aligns with broader systematic reviews in the field [16,17].

5. Comparison with traditional BCS

In my experience, OBCS, particularly with ADM-based volume replacement, often allows for more extensive tumor resection while maintaining better breast shape and symmetry compared to traditional BCS. This is especially beneficial for patients with smaller breasts or those requiring larger volume excisions.

A meta-analysis by Chen et al. [18], which I find particularly compelling, compared OBCS and BCS across 13 studies involving 1,328 patients. They found that OBCS was associated with significantly higher patient satisfaction (odds ratio [OR], 2.83; 95% confidence interval [CI], 1.43–5.56; p=0.003) and better aesthetic outcomes (OR, 2.20; 95% CI, 1.43–3.39; p<0.001) compared to BCS, with no significant difference in overall survival or disease-free survival between the two groups.

6. Integration with adjuvant therapies

In my practice, I have observed that ADM appears to be more resistant to the effects of radiation therapy compared to autologous tissue, which is a significant advantage in the context of adjuvant treatment. This observation is supported by studies showing no significant difference in complication rates between immediate and delayed radiotherapy following OBCS [19].

7. Challenges and future directions

While OBCS techniques, particularly those involving ADM, have shown promising results, several challenges remain. One key issue is determining the optimal amount of ADM to use in volume replacement procedures. In my ongoing research, we are exploring this question, aiming to establish guidelines that balance aesthetic outcomes with the risk of complications.

Looking to the future, I believe that technological advancements will play a crucial role in further improving OBCS outcomes. In my practice, we have begun incorporating robotic surgery, such as the da Vinci system, which has allowed us to minimize incision length while maintaining precise control. This is particularly beneficial in ADM-based procedures, where accurate placement of the material is crucial.

We are also exploring the use of artificial intelligence (AI) algorithms to predict the weight of tumors to be resected before surgery, which could allow us to more accurately estimate the amount of ADM required for each patient. This personalized approach could further optimize our aesthetic outcomes while minimizing complications.

In conducting and reporting our research on OBCS, we have adhered to the principles outlined by Kronowitz et al. [20] and Weber et al. [21] for writing original articles in medical science. This approach ensures that our findings are presented in a clear, concise, and scientifically rigorous manner, facilitating the dissemination of knowledge in this rapidly evolving field.

While the short-term outcomes of ADM use in OBCS are promising, it is important to acknowledge the limitations in our current understanding. Long-term data on complications and aesthetic durability are still lacking, particularly in the context of ADM-based volume replacement techniques. Some studies have reported increased seroma formation with ADM use [22,23], while others have not found this association [9,13], highlighting the need for larger, prospective studies with longer follow-up periods.

Additionally, the impact of ADM on cancer surveillance and detection of local recurrence requires further investigation. While initial studies suggest that ADM does not significantly interfere with mammographic interpretation [24], more comprehensive research is needed to confirm these findings across various imaging modalities.

Future research should focus on: (1) long-term oncological safety and aesthetic durability of ADM-based OBCS; (2) optimal patient selection criteria for ADM use in partial breast reconstruction; (3) cost-effectiveness analysis of ADM-based techniques compared to traditional approaches; or (4) the potential role of ADM in combination with emerging technologies such as robotic surgery and AI-assisted planning.

As a surgeon actively involved in this field, I am particularly interested in studying the long-term outcomes of ADM use in Asian patients with challenging breast morphology. This population may stand to benefit significantly from volume replacement techniques, but targeted research is needed to optimize our approach.

OBCS, particularly with the incorporation of ADM-based volume replacement techniques, represents a significant advancement in breast cancer treatment. As we continue

to refine our techniques and incorporate new technologies, the future of OBCS looks promising, offering patients the best possible outcomes in terms of both cancer control and aesthetic satisfaction.

Conclusions

OBCS has emerged as a significant advancement in breast cancer treatment, with the incorporation of ADM-based volume replacement techniques further expanding its potential. This review has examined the evolution, techniques, and outcomes of OBCS, with a particular focus on ADM applications.

The oncological safety of OBCS is well-established, with local recurrence rates comparable to traditional BCS, ranging from 2.7% to 5.7% at 5 years. Patient satisfaction rates consistently exceed 85%, with aesthetic outcomes reported as good to excellent in the majority of cases. These findings underscore the dual efficacy of OBCS in achieving both oncological and aesthetic goals.

ADM-based volume replacement techniques have shown particular promise in addressing the challenges posed by patients with unfavorable breast morphologies. The integration of ADM with adjuvant therapies, notably radiotherapy, has demonstrated favorable outcomes, expanding the applicability of OBCS to a broader patient population.

Despite these advancements, several challenges persist. Optimizing ADM usage, standardizing techniques across diverse patient populations, and long-term outcome assessment remain areas requiring further investigation. The potential of emerging technologies, including robotic surgery and AI-assisted planning, presents exciting avenues for future research and clinical application.

Moving forward, it is imperative that the field focuses on comprehensive long-term studies to elucidate the durability of aesthetic outcomes and confirm the oncological safety of newer techniques. Refinement of patient selection criteria and the development of standardized protocols for ADM use will be crucial in optimizing outcomes.

The complexity of OBCS necessitates specialized training for surgeons and the development of multidisciplinary infrastructures within healthcare institutions. This approach ensures the safe and effective implementation of these advanced techniques in clinical practice.

In conclusion, OBCS, particularly with ADM-based volume replacement, represents a paradigm shift in breast cancer surgery. By effectively combining oncological principles with advanced reconstructive techniques, OBCS addresses both the physical and psychological aspects of breast cancer treatment. As techniques continue to evolve and long-term data accumulates, OBCS is positioned to become the new standard of care, offering patients optimal outcomes in terms of cancer control, aesthetic satisfaction, and quality of life.

Article information

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

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Author contributions

Conceptualization: YK. Writing – original draft: YK, JHC. Writing – review & editing: YK, JHC. Final manuscript confirmation: YK.

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