This is the accepted version of the publication Zheng L, Zhou B, Liang R, Yip J. The use of external breast prostheses in post-operative care for women after breast cancer mastectomy: A scoping review. Textile Research Journal. 2025;95(13-14):1757-1768. Copyright © 2025 (The Author(s)). DOI: 10.1177/00405175241303532.

The use of external breast prostheses in post-operative care for women after breast cancer mastectomy: A scoping review

Abstract

This paper provides a comprehensive scoping review of external breast prostheses, an essential component of post-operative care for breast cancer patients, the most common cancer globally. Mastectomy, a frequent treatment, often leads to physical and psychological issues. External breast prostheses help improve body image and psychosocial well-being post-surgery. We included studies on the views, evaluations, opinions, and experiences of post-mastectomy women and medical personnel regarding external breast prostheses, as well as the assessment, design, and simulation of these prostheses. A scoping review was conducted using Web of Science Core Collection, PubMed, Medline, Scopus, and Google Scholar. We reviewed relevant English research articles published in peer-reviewed journals up to December 2023, focusing on “breast cancer,” “mastectomy,” “post-mastectomy recovery,” “breast prosthesis satisfaction/dissatisfaction,” and “external breast prosthesis/prostheses”. Thirty-four studies were analyzed, covering various prosthesis types, user feedback, impacts on daily activities, and new technologies and designs. The review revealed the prosthesis’ significantly positive impact on post-mastectomy women's lives, but also persistent issues like weight, price, and body movement compatibility. Moreover, the paper suggests potential for advancements to improve comfort, aesthetics, and affordability.

Keywords: Breast Cancer, Mastectomy, External Breast Prosthesis, Post-operative care

Introduction

Breast cancer is a significant global health concern, with over 2 million new cases reported in 2020 alone [1]. The primary treatment modalities for this prevalent disease include surgery, radiation therapy, chemotherapy, endocrine therapy, and targeted therapy [2]. Approximately 90% of women diagnosed with breast cancer undergo surgery as part of their treatment [3-5]. This surgery can be a lumpectomy, which removes the tumor but keeps most of the breast [6], or a mastectomy, which removes the entire breast [7]. The latter is required for 28% to 60% of breast cancer patients, a percentage that is on the rise [8].

However, mastectomy has side effects. Physical challenges include loss of breastfeeding ability, reduced sensation in the chest area, and negative impacts on body image and sexual function. Body imbalance is also a problem [7,9], which needs to be fixed for pain relief, better function, and overall well-being [10,11]. Emotional disruptions such as anxiety and depression can also occur [12]. Therefore, post-operative care is crucial for women who have undergone mastectomy, to help them regain their normal body shapes and boost their confidence.

Even though breast reconstruction is available after surgery, fewer people choose this option compared to those who don't [13]. The reasons women were hesitant to undergo reconstruction surgery included the extended recovery time and the increased risk of infection and other postoperative complications.[14] When breast reconstruction surgery isn't chosen, the use of an

external breast prosthesis becomes a vital aspect of their post-operative care. These prostheses are designed to mimic the shape and feel of a natural breast, providing a sense of confidence for the patients [15]. However, current literature reveals several disadvantages regarding these prostheses, primarily concerning their weight, comfort, mobility, and potential to impede exercise [16-20]. Moreover, a poorly fitted prosthesis can cause health problems, including muscle pain, hunched shoulders, and spinal curvatures [21]. Therefore, it is important to investigate existing studies on external breast prostheses to examine the most recent developments and evaluate current designs, in order to provide future guidelines. However, there is a lack of research on how these prostheses help women after mastectomy and how their design can be improved. In addition, a preliminary search of MEDLINE, the Cochrane Database of Systematic Reviews, and JBI Evidence Synthesis was conducted, and no scoping reviews on the topic were identified. This paper aims to fill the gap in the literature by providing a comprehensive review of external breast prostheses for women after mastectomy.

Review question

To further analyze the progress and explore the frontiers within each research branch, the following research subquestions have been proposed. Firstly, the question on the global distribution of research on external breast prostheses until 2023 aims to map the research landscape, highlighting overlooked groups, especially non-native English speakers. [15] Secondly, the question regarding the different types of external breast prostheses and how they cater to the diverse needs of women post-mastectomy is concerned to categorize the various options available. This is crucial to ensure that all women can find suitable prostheses that address their specific requirements. [22] User feedback identifies common issues to improve design and satisfaction. The impact on daily activities and psychological well-being is assessed for a holistic understanding. [23] Therefore, improvements can be guided in design and functionality to enhance user satisfaction. Lastly, innovative designs and materials are explored to enhance comfort and health, emphasizing the importance of new technologies. [24]

1. How has the research on external breast prostheses been distributed globally until 2023?

2. What are the different types of external breast prostheses available, and how do they cater to the diverse needs and preferences of women post-mastectomy?

3. What user feedback has been reported by women wearing external breast prostheses, and what specific features of the prostheses contribute to satisfaction or dissatisfaction?

4. How do external breast prostheses impact the daily activities and psychological well-being of women post-mastectomy?

5. What innovative designs and materials are being developed, or are anticipated to be developed, to improve comfort and affordability?

Inclusion criteria

Participants

Relevant individuals including post-mastectomy women, medical personnel and designers who provided their views, evaluations, opinions, and experiences related to external breast prostheses.

Concept

The concept of interest is the assessment, design, and simulation of external breast prostheses. Studies should explore the technical aspects, user satisfaction, and the impact on quality of life. Studies that do not focus on external breast prostheses or their use in post-mastectomy care were excluded. Additionally, studies must be published in English and have full texts available for review.

Context

The context for the included studies encompassed the design and use of external breast prostheses for post-mastectomy women in various settings and considered cultural, sub-cultural, geographic, and specific demographic factors, such as age, that influenced the use and perception of the prosthesis.

Types of sources

For this review paper, all types of scholarly articles were considered that contributed valuable information to the subject.

Methods

The present scoping review was conducted using the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension (PRISMA) for Scoping Reviews checklist [25] and followed the methodological framework of the Joanna Briggs Institute (JBI) methodology for scoping reviews [26].

Search strategy

English relevant research articles published in peer-reviewed journals for all years available up to December 2023 were searched in the Web of Science (WoS) Core Collection, PubMed, Medline, Scopus, and Google Scholar. PIO criteria (Population, Intervention, and Outcome) were used to guide this research. The selected keywords, extracted from relevant studies, fell into five main categories: "breast cancer," "mastectomy," "external breast prosthesis/prostheses" “post-mastectomy recovery” and “breast prosthesis satisfaction/dissatisfaction”.

Study of evidence selection

First, all identified citations were collated and uploaded into EndNote 21 (Clarivate Analytics, PA, USA) and duplicates removed. Then, titles and abstracts were then screened by two independent reviewers for assessment against the inclusion criteria for the review. The exclusion criteria were as follows: studies not involving external breast prostheses or not intended for post-mastectomy use, non-English publications, and those for which the full text was not available. The study selection process was carried out by two researchers, and any disagreements about a study's eligibility were settled through a consensus among the authors. Third, a draft extraction form was developed using Microsoft Excel including the lead author's name, the year of publication, the setting of the study, the target participants, and the main findings.

Data extraction

The search produced 469 original records, of which 34 articles were ultimately included and reviewed. The reasons for excluding the 435 articles are detailed in Figure 1. Specifically, 483 articles were duplicates found in different databases. Additionally, one review article was excluded, as well as three articles for which the full text could not be found. A total of 457 articles were excluded based on their title and abstract because they were not relevant to the topic of this manuscript. Finally, 25 articles were excluded because they did not include external breast prostheses, did not involve mastectomy, or were not in English. Table 1 lists the characteristics of the articles, including the publication year, primary author/authors, journal names, participants involved, and main findings.

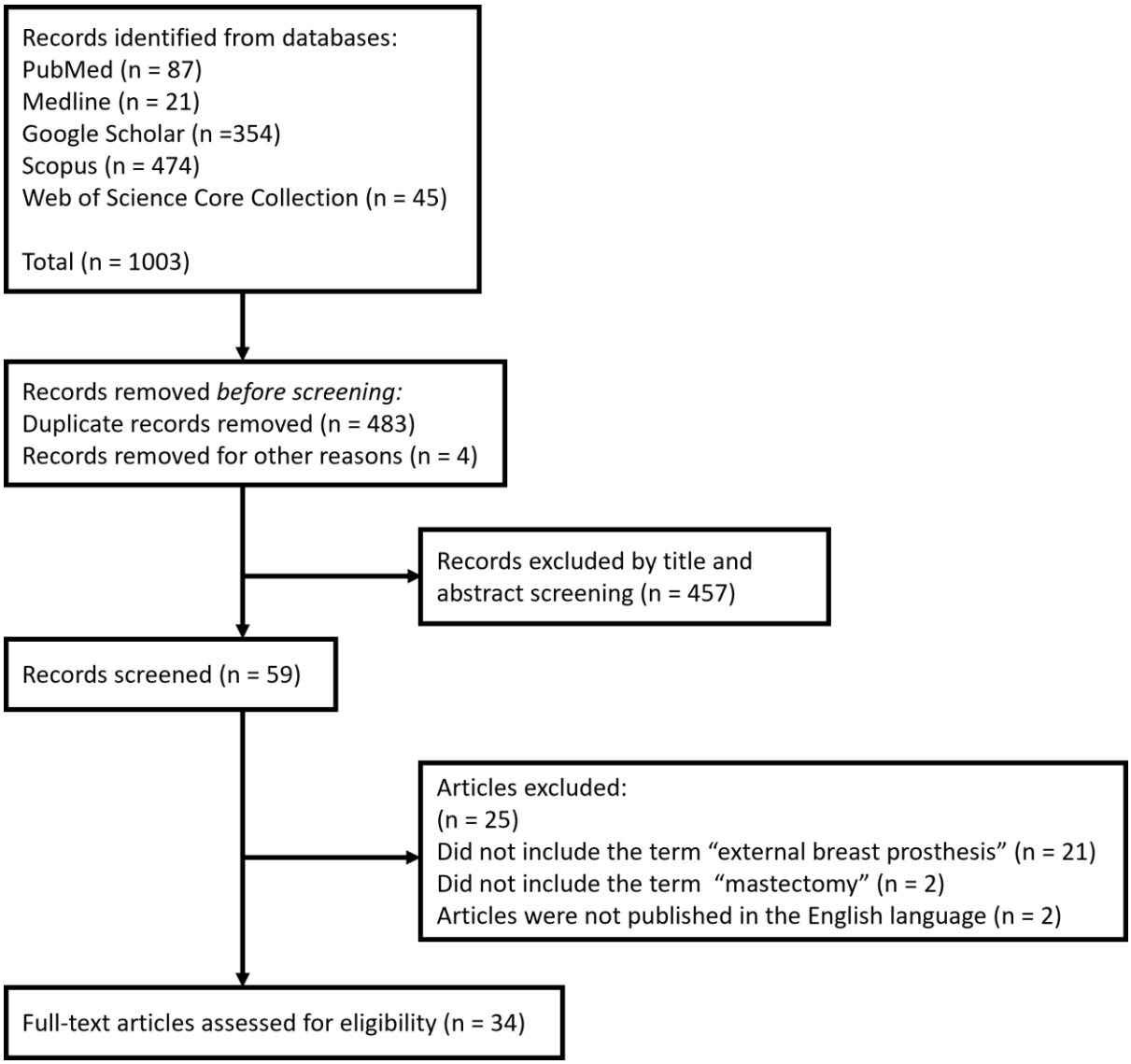

Figure 1 Flowchart illustrating screening and selection process

Table 1 The 34 sample publications

Published year	Authors	Journal	Country	Method	Involved participants
1981	Kiernan et al. [27]	*The American Journal of Surgery*	USA	Questionnaire	300 post-mastectomy women, aged 27-87 (average 60).
1983	Tanner, Abraham, & Llewellyn-Jones [28]	*Medical Journal of Australia*	Australia	Survey	49 patients, post-mastectomy for 3 months to 17 years, aged 26-80 (average 54).
1995	Reaby, & Hort [29]	*Journal of Behavioral Medicine*	Australia	Questionnaire	95 women with mastectomies from 1986-1990, excluding those with recurrent cancer.
1997	Hart et al. [30]	*Tumori Journal*	Italy	Questionnaire	592 mastectomy patients who had not had previous malignancies.
1998	Reaby [31]	*Plastic and Reconstructive Surgery*	Australia	Interview	95 women with mastectomies from 1986-1992, excluding those with recurrent cancer.
1998	Reaby [32]	*Cancer Nursing*	Australia	Interview	95 women with no recurrence post-modified radical mastectomy.
2001	Thijs-Boer et al. [33]	*Cancer Nursing*	Netherlands	Randomized crossover study using a questionnaire	91 women who underwent one-sided mastectomy for breast cancer.
2003	Roberts et al. [15]	*Cancer Nursing*	Australia	Focus group	39 women, aged 44-71 (average 62), mostly from public hospitals, post-mastectomy.
2003	Livingston et al. [34]	*Evaluation Review*	Australia	Interview	87 women who had approached

					the government's Aids and Equipment Program for the purchase of prosthesis.
2009	Gallagher et al. [16]	*European Journal of Cancer Care*	Ireland	Survey	527 women aged 27-90 (average 58.6), at least 1-year post-diagnosis and wearing a breast prosthesis. 32 breast care nurses and 12 retail prosthesis fitters.
2009	Simone et al. [35]	*The Breast Journal*	USA	Questionnaire	59 women with a history of simple, modified radical or radical mastectomy who had not undergone breast reconstruction.
2010	Gallagher et al. [36]	*European Journal of Cancer Care*	Ireland	Focus group	47 women, aged 38-80 (average 57.8), with an average of 8.1 years post-breast cancer diagnosis.
2012	Kubon et al. [37]	*Current Oncology*	Canada	Cohort study	65 women who had undergone lumpectomy or mastectomy before rehabilitation.
2014	Hojan et al. [22]	Cancer Nursing	Poland	Observational study	40 postmastectomy women aged 37-70 and 38 healthy control women aged 38-69.

2014	Borghesan et al. [38]	*Asian Pacific Journal of Cancer Prevention*	Brazil	Survey	76 women aged 55.7 years old (SD 11.5) who used an external breast prosthesis.
2015	Ramu et al. [39]	*Indian Journal of Surgical Oncology*	India	Descriptive study	63 people diagnosed with carcinoma breast.
2016	Hojan et al. [40]	*Journal of Back and Musculoskeletal Rehabilitation*	Poland	Analysis of electromyography	51 women with unilateral mastectomy (age 58 ± 11.39 years).
2017	Hojan, & Manikowska [41]	*BioMed Research International*	Poland	Analysis of electromyography	51 patients with a history of unilateral mastectomy, aged 35–70 years.
2017	Jetha et al. [42]	*Asia-Pacific Journal of Oncology Nursing*	Pakistan	Qualitative descriptive exploratory design	15 women with breast cancer who were using external breast prosthesis.
2018	Cruz et al. [21]	*Applied Sciences*	Mexico	Finite element modeling	1 medical mannequin.
2019	Manikowska, Ozga-Majchrzak, & Hojan [43]	*Homo: Internationale Zeitschrift fur die Vergleichende Forschung am Menschen*	Poland	Experimental trial using baropodometric tool	Women after mastectomy and healthy subjects.
2020	McGhee, Mikilewicz, & Steele [44]	*Clinical Biomechanics*	Australia	Comparative analysis of pressure, discomfort and perceived pressure	17 women, post-unilateral mastectomy, average aged 68.4 years, 1.61m tall, 78.2kg, wore an external breast prosthesis.
2020	Hojan [45]	*Reports of Practical*	Poland	Survey	125 breast cancer women

		Oncology and Radiotherapy			who had undergone unilateral mastectomy.
2020	Shin et al. [46]	*Textile Research Journal*	China	Thermoregulation performance experiment	9 healthy men (mean age: 31.9 ± 5.9 y & mean under-bust circumference: 35.3 ± 2.8 in)
2020	Qiu et al. [47]	*Medicine*	China	A Randomized controlled study	30 participants with breast cancer (mean age: 48.5)
2021	Qiu et al. [48]	*Gland Surgery*	China	Questionnaire	635 medical staffs from 24 provinces and municipalities across China.
2021	Leung et al. [49]	*Applied Ergonomics*	China	Experiments with physiological and subjective measurements	9 healthy men aged 31.9 ± 5.9 years, 170.2 ± 6.4 cm tall, 71.0 ± 6.4 kg, BMI 24.5 ± 1.9, chest 35.3 ± 2.8 inches.
2022	Koralewska et al. [50]	*Frontiers in Oncology*	Poland	Cross-sectional study	52 women who underwent mastectomy whose average age was 61.8 ± 10.8 years (range: 38–84 years).
2022	Krishna, & Srinath [51]	*Indian Journal of Surgical Oncology*	India	Survey	NA
2023	Koralewska et al. [52]	*Journal of Clinical Medicine*	Poland	Anthropometric measurement and moiré topography method to evaluate posture	52 women who underwent mastectomy whose average age was 61.8 ± 10.8 years

					(range: 38–84 years).
2023	Regina, & Foggiatto [24]	*Rapid Prototyping Journal*	Brazil	Computer-aided design	20 mastectomized Brazilian women.
2023	Tao et al. [53]	*Indian Journal of Surgery*	China	Body measurements and questionnaire	722 women with breast cancer who underwent elective surgery.
2023	Leme et al. [54]	*Clinical Biomechanics*	Brazil	Projected light method and additive manufacturing	1 healthy woman, aged 29 years, weight of 69 kg, 1.69 m height and bra size 36 B.
2023	Ng et al. [55]	*Breast Disease*	Singapore	Questionnaire	148 participants consecutively used the conventional bra-prosthesis and the customized one, each for at least 3 months.

Results and discussions

Distribution of the publications

Research on external breast prostheses has seen a significant increase from 1981 to 2023, with over 60% of the papers published in the last decade (2014-2024). This trend suggests a growing interest in and focus on this field. An analysis of 34 papers revealed a diverse range of contributions from various countries. Poland leads with seven papers, closely followed by Australia with six. The United States and China have each contributed four papers, Brazil three, and Ireland and India two each. Single contributions have come from the Netherlands, Canada, Pakistan, Mexico, and Singapore. This global distribution underscores the widespread attention external breast prostheses have received.

The papers were published across 27 different journals, with the majority (23) appearing in unique journals. Cancer Nursing published four papers, while the European Journal of Cancer Care, the Indian Journal of Surgical Oncology, and Clinical Biomechanics each published two. Most of the journals (23) are medical or health-related, with one social science journal, two design-focused journals, and one textile-related journal. Many of these studies are published in Q1 journals, which have good impact factors, such as The Breast Journal, Frontiers in Oncology, and the Journal of Clinical Medicine. This distribution highlights the interdisciplinary nature of research on external breast prostheses, indicating that not only medical and health fields but also social science, design, and textile areas are integral to studying this topic.

Notable cultural differences

Significant gaps in knowledge and access to treatment persist in different countries and regions. A mere 5% of global funding for cancer screening and treatment was directed toward developing countries, leading to a disproportionate number of late-stage breast cancer diagnoses [56]. In the early stages of breast cancer, breast-conserving surgery is often possible. However, as the disease advances, a total mastectomy becomes necessary for most patients [57]. Financial limitations also restricted options, with few patients able to afford breast reconstruction surgery after mastectomy. [51] Consequently, the demand for external breast prostheses is particularly high in developing countries. In these countries or regions like India and Brazil, where social welfare systems were less robust, there were few institutions providing breast prostheses to patients. Although these prostheses were available online or in stores, many patients were unaware of their existence or faced significant financial barriers that made them inaccessible to low-income families [51, 58]. In contrast, developed countries such as Ireland provided extensive support for women who undergo mastectomies. The government ensured that every woman received a free initial silicone prosthesis and two bras, with regular replacements as needed [36]. Not only due to economic differences, but also due to cultural differences, the acceptance of breast prostheses varies significantly across different regions. In most Western countries, patients generally view breast prostheses not only to improve appearance but also as psychological comfort to help them cope with the physical changes after a mastectomy [59]. However, in some Arab Muslim countries in the Middle East and North Africa, religious and cultural influences often lead to cancer being perceived as a source of shame. This cultural stigma often restricts doctors in their cancer diagnoses, resulting in many breast cancer patients being diagnosed at a late stage and being unable to access prostheses and postoperative care. [60-62] Asia also has its own unique cultures, and the emphasis on bodily "integrity" in some of these cultures may lead women to prefer breast reconstruction over the use of breast prostheses [23]. Due to these differing circumstances, international collaboration and the sharing of diverse perspectives and approaches are important and should be encouraged.

Types of external breast prostheses

External breast prostheses, designed to mimic the natural shape, size, and feel of the breast, can be divided into various types based on materials and attachment methods to cater to the diverse needs and preferences of women after a mastectomy. [15, 17] Table 2 compares the different types of prostheses. Temporary lightweight prostheses are usually provided to patients within 6 weeks after surgery. [17] They are typically made of materials such as cotton wool, lightweight polyester textile, or soft plastic. [28] Afterwards, the patients should wear a permanent prosthesis. The most common material used for permanent prostheses is soft, flexible silicone gel, which closely mimics the feel and color of natural breast tissue [39]. The silicone gel is covered by different materials, which may cause different sensations, such as a film of polyurethane [33] and silk; however, silk has low thermal comfort.[42] Because of the heavy weight and high cost of silicone prostheses, some patients chose cotton breast prostheses instead [42]. For various reasons, especially economic concerns, some patients opt to create homemade external breast prostheses using easily accessible household materials such as cotton wool, rice, shoulder pads, or sponges from old clothes [16]. In one survey conducted in India, it was found that 44.4% of patients were using homemade breast prostheses [39].

Based on attachment methods, there are two types of external breast prostheses, adhesive and conventional. For the adhesive breast prosthesis, on the inner side of the breast prosthesis (the side that comes into contact with the skin), there is an adhesive material of the same shape as the inner side of the prosthesis, such as a Velcro skin strip or a coating on both sides with medical silicone adhesive, allowing it to adhere directly to the skin. [33, 59] Conventional prostheses, on the other

hand, are placed inside mastectomy bras that have special pockets to hold them. [42] Patients tended to prefer adhesive prostheses as they felt more natural, while traditional prostheses were suitable for patients with irregular mastectomy scars or with profuse perspiration because of easy application and lack of skin irritation. [33] The variety of materials and attachment methods available offers a wide range of prosthesis types, with each individual's preferences and choices varying greatly. These choices depend on various factors, including age, lifestyle, and personal preference. The influence of age and education level on the choice, needs, and practical use of external breast prostheses is significant. [38] This may be because elderly women place greater emphasis on comfort and ease of use. [63] Additionally, women with higher levels of education tend to have greater access to medical and post-care information, which helps them understand the importance and necessity of external breast prostheses.

This suggests that personalized customization could potentially be a future trend, aiming to satisfy everyone's unique needs and preferences.

Table 2. Comparison of different types of external breast prostheses

Category	Type of Breast Prostheses	Advantages	Disadvantages
Source of production	Commercial	1) Natural appearance and comfortable fit 2) Durable and long-lasting 3) Wide range of options 4) Available for custom fitting [64]	1) Expensive 2) Not easily accessible in all areas
	Homemade	1) Low cost 2) Easily accessible materials [16]	1) Less durability and quality 2) Lack the comfort and appearance of silicone prostheses [16]
Utility Time	Temporary	1) Lightweight 2) Comfortable for early post-surgery use 3) Made from easily accessible materials [17,25]	1) Designed for short-term use only 2) Limited durability [17,25]
	Permanent	1) Closely mimics the feel and appearance of natural breast tissue 2) Durable and long-lasting 3) Offers a natural look under clothing [40]	1) Heavy and potentially uncomfortable 2) High cost 3) Thermal discomfort depending on covering material [40]
Type of Attachment	Adhesive	1) Natural appearance and feel 2) Greater freedom of movement 3) No need for additional support like bras or straps [30, 45]	1) Can cause skin allergies and discomfort 2) May irritate unhealed wounds and delay healing [30]
	Conventional	1) High stability 2) Relatively low cost 3) Suitable for a wide range of users 4) Easy to replace [45]	1) Not suitable for high-intensity activities 2) Less comfortable for long-term wear 3) Less natural appearance 4) May limit clothing choices [45]

User Feedback

Existing studies were conducted using methods such as questionnaires, interviews, and focus groups. They focused primarily on evaluating the comfort, feelings and satisfaction associated with wearing external breast prostheses. Notably, all studies conducted from 1981 to 2003 were dedicated to this specific topic. The first study on external breast prosthesis found by the author mailed questionnaires to 300 breast cancer mastectomy survivors, of which 278 responded to the questionnaires. [27] Only four survivors were dissatisfied with the appearance of the external breast prosthesis, and this percentage (1%) was very low. However, the reasons for dissatisfaction with the prosthesis have not been specified. Two years after this study, Tanner, Abraham, & Llewellyn-Jones interviewed 49 post-mastectomy patients and also asked them to fill out a questionnaire. [28] They listed the unsatisfactory features of the external breast prosthesis, which included unfitness for some clothes, incorrect sizes, and inappropriate textures. This study also investigated the length of time the prosthesis was worn, and most of the patients (77%) wore the prostheses all day. This demonstrated that prostheses were an essential part of their lives, and it was highly important to ensure satisfaction. Three studies involved more than 500 women after mastectomy. [16, 30, 53] The proportion of women who were dissatisfied was noticeably higher than in the first study, with 34.7% of 592 women and 11.5% of 527 women expressing dissatisfaction. The study in the year of 2023 also found that women using external breast prostheses had lower quality of life scores than women who had immediate breast reconstruction. [53] The unsatisfactory features were further defined using close-ended questions and ranked based on the percentage of women who expressed dissatisfaction with the aspect of the prosthesis they wore most regularly. [16] The order of dissatisfaction from high to low was as follows: weight, comfort, movement with the body, fit, value for money, shape, temperature, appearance when worn, texture, durability, color, and quality. These studies identified specific defects in existing external breast prostheses and provided a clear guide for future design.

It is not only the drawbacks of external breast prostheses themselves that lead breast cancer survivors to not want to wear them, but also the insufficient counselling provided by medical professionals, which leaves some individuals unaware that they need to wear a prosthesis or how to wear it. [47] In response, medical professionals, especially specialist breast care nurses, should offer comprehensive education and information to help patients better understand and use these prostheses. Qiu et al. found that the education for medical professionals in this area is not enough, indicating a need for improvement in the future. [47]

The impact on daily activities

Previous studies claimed that the use of an external breast prosthesis could influence a woman's daily activities in several ways. For the psychological impact, the changes in physical appearance due to the mastectomy can lead to psychological negative impacts such as anxiety and depression. [42] The external breast prosthesis has been proven to be beneficial in reducing stress and improving women's self-esteem by restoring the pre-surgery appearance and balancing body image. [42] It makes daily activities such as socializing and outdoor chores more comfortable and less self-conscious. Women report feeling more confident in their clothing choices and experiencing fewer instances of social anxiety. [16] Even more surprisingly, some women found self-adhesive prostheses to be suitable for physical activities, feeling like their own natural breasts. This made the wearer feel free of psychological barriers to exercise, which in turn promotes both physical and mental health. [47] Compared to other post-mastectomy interventions, such as reconstructive surgery, external breast prostheses offer a non-invasive option with immediate cosmetic results and fewer medical risks. From the study of Gallagher et al., a significant majority of women wore their prosthesis during various

activities. For instance, 95.4% wore it during social activities, 93.7% for daily outdoor chores, and 89.9% for household chores. [16] However, this study also found almost half of the participants felt limited in swimming, sports, and sexual activity. Participation in sports is one of the activities suggested for breast cancer survivors. [64, 65] Even though there are already external breast prostheses specifically designed for swimming available on the market [35], there are still some people who do not know this information, or they find the available options unsatisfactory. Therefore, custom-made external breast prostheses suitable for different sports should be optimized and developed, such as improving the attachment method to ensure it doesn't slide during physical activity, as well as incorporating waterproof function.

Moreover, Hojan et al. stated that women after mastectomy could experience alterations in their gait parameters due to anatomical changes in the trunk. However, the use of external breast prostheses has been shown to improve this issue, making their walking patterns during daily life more similar to those of women who have not had breast cancer. [22] This further demonstrates the positive impact of external breast prostheses on daily activities.

Potential side effects

As previously mentioned, there are currently two types of external breast prostheses: conventional and adhesive. Each type has its own potential side effects. For adhesive prostheses, though convenient, they can cause skin allergies in patients with sensitive skin, leading to redness, itching, and discomfort. Additionally, for patients with wounds that have not fully healed, the adhesive material may irritate the wound, delaying healing and increasing the risk of infection [33]. On the other hand, prostheses that require a bra for support provide better stability but can restrict movement, especially during strenuous activities or daily physical tasks [41]. The weight of the prosthesis and its attachment method can increase pressure on the shoulders and back, causing muscle soreness and fatigue. The non-breathable materials used in prostheses may lead to discomfort from heat and excessive sweating, particularly in hot or humid conditions [42].

Psychological effects are also important. Some patients may feel stress about wearing a prosthesis, worry that others might notice it, or feel anxious about relying on an external device for body image restoration. This anxiety can affect self-esteem and daily life [36]. New designs and technologies have been developed to improve and address these side effects. Detailed information can be found in the next section.

New technologies and new designs

With advancements in technology, more realistic and low-cost external breast prostheses can be achieved by advanced manufacture, such as 3D scanning and printing. [24,63] 3D scanning can capture the precise contours of the body and the breast, ensuring a better fit and greater comfort. 3D printing allowed for the creation of customized prostheses that could closely match a woman's unique shape and size, providing a more natural look and feel. Additionally, 3D printing materials, such as thermoplastic polyurethane filaments, can reduce the weight of the prostheses. [63] Another advantage of technological advancements is the low cost. For example, compared to using printers that work with resin and printers that use extrusion, open-source machines are a cheaper option, and their quality was also validated. [24]

Special designs were also developed to increase comfort, such as the external breast prosthesis with a hollow air chamber inside with ventilation holes, which was invented by Shin et al. [46] This design

allowed for better sweat evaporation and ensured thermal comfort. Additionally, to gain a better understanding of the current market, patents have been searched online, and several innovative designs have emerged. Similar to the purpose of Shin et al. [46], which aimed to improve thermal comfort for wearers, an invention (Patent No.: US20180325700A1) described a breast prosthesis comprising an elastically deformable outer body shaped like a breast and a plastically deformable inner body that adapted to tissue irregularities. The inner surface had a three-dimensional structure or textile designed to ventilate the tissue surface. [67] The same inventor updated his product (Patent No.: US20190021881A1) by adding an intermediate body with an intermediate chamber between the outer and inner bodies, which can be filled with fluid to adapt its volume. This allowed the prosthesis to conform to the shape of scar tissue without hindering air exchange. [68] This is also the second key improvement of the design, enabling the prosthesis to adapt its volume to the individual needs of the wearer, based on the size of the still healthy breast. A US patent (Patent No.: US20150190244A1) describes a breast prosthesis consisting of two layers, each with sealed films forming front and back chambers, and a pocket between them. The pocket has an opening for stuffing material, allowing the user to adjust the prosthesis to meet different preferences and body shapes. [69] Recently, a simple-structure design featured a breast prosthesis with two connected shell bodies and a fluid-filled space between them for volume adaptation, including a medium to reduce adhesion between the inner surfaces (Patent No.: US20220079779A1). [70] These advancements not only improve the physical comfort and convenience of women using external breast prostheses but also contribute to their psychological well-being by making the prostheses look and feel more natural. However, these designs are rarely reported in research papers. Scientific studies should be further conducted and published to provide evidence and credibility for medical professionals and patients, and to encourage more patients to wear external breast prostheses.

In addition to addressing the issues of weight, shape, fit, price, and thermal comfort with the aforementioned technologies, there are other user concerns such as movement with the body, appearance when worn, texture, durability, color, and quality. This indicates that future research should explore the application of advanced technology and the development of innovative materials and designs to benefit women worldwide who have undergone mastectomy surgery. Especially, innovative textile solutions can be considered. For instance, advanced materials such as 3D knitted fabrics and silicone textiles offer a seamless, custom-fit experience that moves naturally with the body. In addition, memory foam and gel inserts conform to the body's shape, ensuring a snug fit that adapts to movement. Further advancements include the use of smart textiles, biofabricated materials and nanotechnology-enhanced fabrics, which can provide monitoring and adjustable functions, as well as improve sustainability. Smart textiles embedded with sensors can respond to changes in body movement and environment, offering a more adaptive and comfortable experience. Additionally, these textiles could specifically monitor the health status of women after mastectomy, such as the timely detection of a recurrence of breast cancer. Biofabricated materials, derived from natural sources such as algae, provide eco-friendly options, and nanotechnology-enhanced fabrics add another layer of durability and functionality, making the prostheses resistant to wear, stains, and bacteria.

Limitations

The literature included in this review may not be exhaustive. For instance, this review used five keywords for retrieval (breast cancer, mastectomy, post-mastectomy recovery, breast prosthesis satisfaction/ dissatisfaction, and external breast prosthesis/prostheses), but there might be other

papers related to this topic that do not contain these specific words. Additionally, some articles may be included in other databases and were not retrieved by the authors.

Conclusions

Breast cancer is the most prevalent cancer worldwide, and external breast prostheses, as a significant post-operative care method, require focused attention and research. This paper aims to objectively describe the characteristics of external breast prostheses and provide an analysis based on studies up until December 2023. A total of 34 articles were retrieved and analyzed. The analysis of publication time, country, and journal indicates that external breast prostheses are increasingly gaining the attention of researchers from various countries and fields.

Current external breast prostheses vary in materials and attachment methods, with women making different choices based on their age, preferences, economic conditions, and lifestyle. However, some women are not satisfied with the existing prostheses, citing issues such as weight, price, and movement with the body. Additionally, many women report feeling limited during activities like swimming, sports, and sexual activity. Despite these challenges, the positive impact of prostheses on their lives has been widely proven, providing women post-mastectomy with more confidence, restoring body shape, and ensuring balance.

To address these shortcomings and enhance functionality, new technologies and designs have been developed. For example, hollow designs can improve thermal comfort, and adjustable designs using multi-layer structures can customize volume. However, many issues remain unresolved, including movement with the body, appearance when worn, texture, durability, color, and quality. In the future, advanced technologies and innovative materials like 3D knitted fabrics, silicone textiles, memory foam, gel inserts, smart textiles, biofabricated materials, and nanotechnology-enhanced fabrics can offer improved fit, comfort, and functionality. These innovations can provide a seamless, adaptive experience, monitor health status, and enhance sustainability, benefiting women worldwide who have undergone mastectomy surgery.

In conclusion, while significant progress has been made in the development of external breast prostheses, there is still much room for improvement. As technology continues to advance, we can look forward to a future where these prostheses are more affordable, accessible, and beneficial to the health and well-being of women who have undergone mastectomy surgery.

Funding

The work was supported by the Start-up Fund for RAPs under the Strategic Hiring Scheme [P0048675] titled “Enhancing Well-being with Post-care Shape-controllable Pneumatic Breast Prosthesis for Women after Mastectomy” from School of Fashion and Textiles, The Hong Kong Polytechnic University.

Conflicts of interest

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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