

EXPERIMENTAL BRA DESIGN MODEL FOR POST BREAST RECONSTRUCTION

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ABSTRACT

People wear bras for various reasons; they may wear bras to limit breast movement, relieve pain, or achieve a desired body shape. A well-fitted bra reduces discomfort and pain and may enhance one's appearance and carry psychological significance in that it could increase emotional confidence. Nevertheless, at least 80% of women are wearing bras with incorrect size and fit.. Furthermore, women who have undergone breast surgery face even more significant challenges when it comes to bras, and tend to be less satisfied with the fit and design of bras after surgery. In addition, every woman's surgical experience and recovery are unique and thus the type of bra and its use and function will also vary greatly. This paper outlines the critical aspects of bra fit and comfort for post-mastectomy patients and presents a parametric model for designing and developing bra components based on an individual's breast reconstruction experience.

Keywords: breast reconstruction, bra fit, post-surgery bra design, breast cancer, design criteria

INTRODUCTION

Bras can be an integral part of a person's wardrobe and a salient aspect of their daily routine. Most participants in our study wore a bra all day, from when they woke up until when they went to sleep. This result correlates with previous research on bra preferences for breast cancer survivors, which similarly found that people with mastectomies or reconstructive surgery wore bras regularly [1]. Bras can be an instrument to generate positive feelings of self. A well-fitted bra can improve self-confidence and body image by altering the perceptions of one's body [2]. For people who have undergone reconstructive surgery, the bra can be an even more powerful tool of transformation; it can reshape feelings of femininity, normalcy, and confidence lost through a mastectomy and reconstructive surgery. Commonplace bra fit issues have been widely assessed in recent years (see, for example, [3] and [4]), including limitations in the current bra fitting methods [5] and the validation of measurements needed to obtain a good fit [4]. However, there has been little research into understanding women's specific bra design needs after breast surgery, particularly reconstruction surgery once breasts have healed.

Asymmetry is one of the most salient issues for correct bra fit. Asymmetry in reconstructed breasts can occur through distinct breast sizes and placement on the body. Although breast asymmetry naturally occurs for most people, retailers do not address this vital issue [6]. For women with unilateral reconstructive surgery, breast asymmetry can be an even more acute problem, with some women having two or three cup size differences between breasts [6]. In addition, reconstructed breasts, particularly implant reconstructions, tend to sit higher on the chest and lack the gravitational pull of a natural breast [7]. This can result in two breasts that look and feel significantly different from one another. In addition, breast asymmetry can cause emotional and physical distress in finding a bra to support both the reconstructed breast and natural breast.

DATA COLLECTION AND ANALYSIS

We conducted a survey to explore how women in New Zealand who have had a mastectomy and reconstructive surgery experience their post-surgical bodies, specifically to provide a deeper understanding of their experience with their reconstructed breasts, bras, and body image. A total of 148 people volunteered to participate in this survey, but only 110 met the criteria (e.g., mastectomy and reconstruction). Invitations for participant involvement were conducted via online, offline and snowball sampling. In addition, online recruitment reached out to diverse groups such as the Victoria University Facebook group and different breast cancer support forums (BCAC: Breast Cancer Aotearoa Coalition, Cancer Chat NZ, Breast Cancer Support, Breast Cancer Foundation NZ, etc.). The survey consisted of 20 questions, using a mix of Likert scale answers, multiple-choice, and open-ended questions to ensure varied data and comprehensive responses.

SURVEY DATA AND THE EMERGING THEMES

Reasons for Wearing a Bra

For women who have undergone reconstructive surgery, the bra can serve as a multifaceted tool. Therefore, there are various reasons why women reported wearing a bra. However, for the women in our sample, the most important reason for wearing a bra was to support breasts (23%). Breast support comes from a bra that slightly lifts and compresses the breasts to prevent excess movement and a wide band to distribute breast weight evenly. Inadequate breast support from a bra can lead to muscular pain and inhibit women from participating in physical activity [8].

Closely following breast support (see Figure 1) was the the bra comfort (20.5%) and provide breast shape (20.5%). Although bra comfort is a highly individualized feeling, it can be attributed to a distinct sets of factors such as material, fit, style, and support [9]. Likewise, two of essential elements in bra shape are cups seams and material [9]. These two factors can mold the naked breast in the bra to create the desired breast shape image. For example, a minimizer bra has shallow cups to create a flatter breast profile, and a contour cup has firm pads to create a rounder breast image [10]. Although desired breast

shape is distinct for every individual, 17.7% of the participants listed breast shape as an important reason for wearing a bra, specifically to create breast symmetry.

Additionally, 11.2% of participants listed wearing a bra because of the need to conform to social norms. Social norms being described as “I feel like I need to wear a bra.” The notion of *need* can be interpreted in multiple ways. For many, it is considered a social mandate to wear a bra in a public space. Disrupting this social requirement can often lead to unwanted attention, comments, and stares.

Moreover, participants may have felt that they need to wear a bra to restore a feeling of femininity, something that is often lost through the experience of breast cancer. Finally, 9.8% reported the importance of wearing a bra for “style” as an “accessory to complete any outfit.” For many individuals, a bra can change the way certain clothes fit and appear on the body and wearing a bra can enable an individual to wear certain clothes.

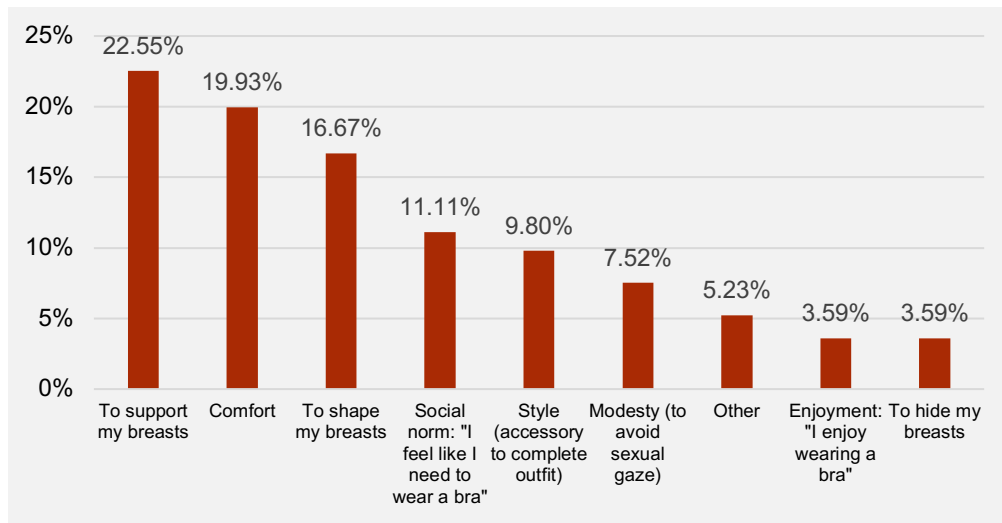


FIGURE 1: REASONS FOR WEARING BRA

Further, 7.5% of the responses listed “Modesty” as an important reason to wear a bra. Although modesty was described as “avoiding a sexual gaze,” like most undergarments, the bra can protect the visibility of the naked breast. Specifically, it can hide the appearance of exposed nipples and cleavage and constrict the bare breast's natural movement, attracting sexual looks and attention. Lastly, a minority of responses listed “Enjoyment” (3.6%) and “To hide my breasts” (3.6%) as important reasons for wearing a bra. Enjoyment can be understood as the sense of happiness or satisfaction gained from wearing a bra. And lastly, bras can hide perceived abnormalities, scarring, or any aspect of the breast that women may find uncomfortable or are embarrassed about.

Bra discomfort

The majority of the participants (92%) listed some form of breast discomfort, mainly stemming from incorrect bra size and fit. For example, 11% of the responses indicated that the band of the bra was either too tight or too loose (see FIGURE 2 and Table 1). Closely following incorrect band measurement was

the incorrect cup size (too tight or loose). The list of other related problems includes bra moving around or not sitting right on the body (a further indication of a wrong cup bra, particularly for asymmetrical breasts) and bra straps digging into the body.

Additionally, discomfort stemmed from bra irritation, categorized as aspects of the bra that created discomfort for the post-surgical body. Most of this discomfort stemmed from skin sensitivity and irritation from the underwire and scar aggravation. Other elements of discomfort are difficulty fastening the bra, temperature issues, lack of nipples, humidity issues, and post-surgical side effects such as fat necrosis, post-surgical swelling, and chest wall pain from surgery.

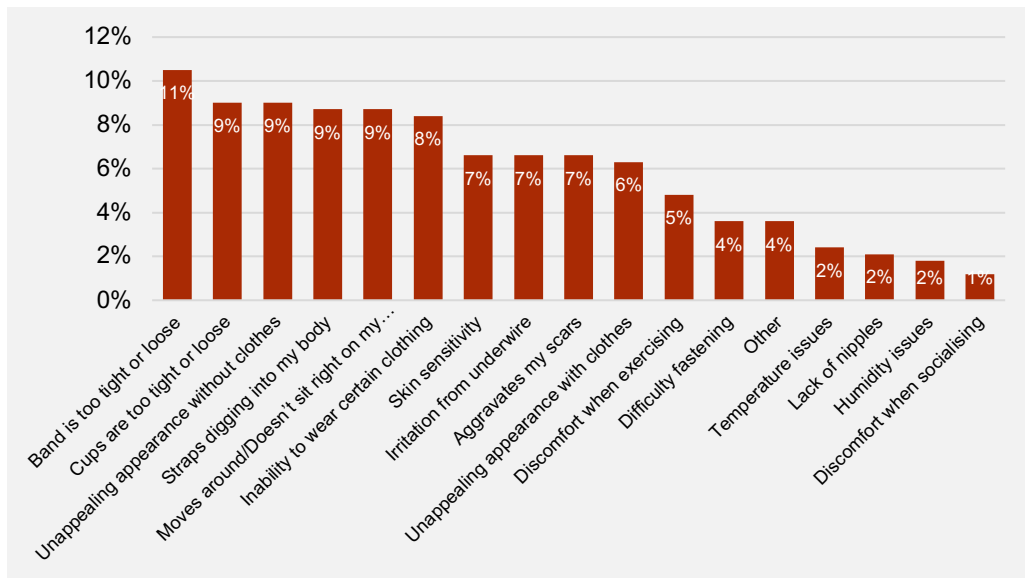


FIGURE 2: SOURCES OF BRA DISCOMFORT CHART

Bra Fit and Asymmetry

Bra fit refers specifically to issues concerning how the bra shapes, supports, and fits the breast. This issue was exemplified by free answer statements such as, “not all of my breast fitting correctly in the cup due to reconstruction shape.” Notably, 42% of these responses were related to issues with breast asymmetry. Breast asymmetry is the appearance of uneven breast size or breast placement, which can cause significant issues for bra fit. Breast asymmetry is highlighted in statements such as “now that I have an uneven cup size, bras tend to twist around my body” or “one side is tighter than the other due to size difference of breasts.”

The distinct shape, feel, and placement of reconstructed breasts can present unique problems for bra consumption. 80% of the women interviewed expressed some issue with their current bra fit and lack of satisfaction in the current bra market. A salient point for many women who underwent unilateral reconstructive surgery was the lack of symmetry between their reconstructed and non-reconstructed breasts. A bra can help increase the symmetry between the breasts, creating an equal shape by lifting the natural breast or shaping the breasts to fit into a molded cup. However, many women expressed

difficulty finding a bra that could meet their post-surgical needs. Some women described the need to make uncomfortable adjustments and experience pain and discomfort to attain that symmetry.

Table 1: SOURCES OF BRA DISCOMFORT

Survey Questions – “My bra discomfort stems from: (check all that apply)”	
Answer	# of responses
Band is too tight or loose	35
Cups are too tight or loose	30
Unappealing appearance without clothes	30
Straps digging into my body	29
Moves around/Doesn't sit right on my body	29
Inability to wear certain clothing	28
Skin sensitivity	22
Irritation from underwire	22
Aggravates my scars	22
Unappealing appearance with clothes	21
Discomfort when exercising	16
Difficulty fastening	12
Other	12
Temperature issues	8
Lack of nipples	7
Humidity issues	6
Discomfort when socialising	4

Many women felt that an underwire bra was the only bra that could help lift their natural breasts to create the desired symmetry. However, the underwire can cause discomfort and pain, with some women reporting that it cut into the edges of their reconstruction or irritated their skin, particularly near their ribcage. Additionally, because of the difference in breast sizes, an underwire also causes the bra to shift towards the larger breast, skewing the center of the bra and causing further irritation. Further, the distinct shape of the reconstructed breast causes difficulties to fit into a standard bra shape; this often relegates women to wear maternity, sports or a soft leisure bra that has a less structured formed breast shape and aesthetic appeal. 50% of the women stated that they currently wear an “Ah-Bra” styled bra strictly due to the comfort of this style. However, because of the lack of aesthetic appeal, many women lacked a sense of attractiveness and bodily confidence when wearing this bra.

DESIGN MODEL BASED ON USER NEEDS

Though the bra is a necessary tool for people who have undergone breast reconstruction, the effects of surgery has added additional fitting and comfort issues including mild to intense pain, leaving women to make sacrifices or uncomfortable adjustments when wearing a bra. In order to develop systematic

design process, we have categorized the bra discomfort issues, expressed by the survey participants into the following general categories of bra comfort and fit issues:

1. Correct bra size and fit
2. Asymmetry
3. Skin sensitivity (including scar tissues irritation, humidity etc.).

As discussed earlier, many broad comfort issues described by participants are due to incorrect bra size and fit. In order to have alleviate or at least minimize this issue, accurate breast measuring methods and models are vital. However, current breast measuring system for bra fit is unreliable and lacks accuracy needed to respond to multi-parameter complexities of correct bra fitting such as breasts, asymmetry or impact of breast surgeries. Moreover, as outlined earlier, the reconstructed breast does not behave the same way as the non-reconstructed (“natural”) breast, and commercially available bra designs do not account for these differences. This is particularly acute for those who have undergone unilateral breast reconstruction. Asymmetry is not merely the breast size (main characteristic for commercially available bras) but it also refers to the breast shape and breast behavior. For example, a breast reconstructed using a silicone implant will restrict its movements altogether and stays fixed against the chest wall, compared to a non-reconstructed breast that deforms, sags, and moves with ease. Thus a vastly different behavior in a bra designed with two symmetrical shaped cups. Lastly, providing soft and breathable materiality will be integral for post-reconstructive breast surgery bra design to prevent skin and scar irritation. The underwire will also need to be appropriately sized to prevent unwanted digging into the breast tissue.

Bra design criteria

To address the issues outlined above, specific measurements and design features were made (see

Table 2). It should be noted that we did not address issues such as “lack of nipples” and “unappealing appearance without clothes” in the design criteria below and will need further research to better understand the impact of the bra on these specific issues. Another issue raised by participants, “difficulty fastening,” is also not being directly addressed, but our model will consider both front fastening and back fastening bra design options, which may offer some ease of use.

Table 2: BRA CRITERIA AND DESIGN SOLUTION

Bra criteria and design solution		Measurement(s) needed	Bra section(s) impacted	Participant concerns
1. Correct bra size and fit	Band fits firm and secure around the under-breast line. It does not lift in the back. Band is wide to provide extra support. The support of a bra comes from the band, therefore the design of the band should be wide.	<ul style="list-style-type: none"> Under breast circumference 	Band	<ul style="list-style-type: none"> Band is too tight or too loose Cups are too tight or loose Straps digging in Irritation from underwire Bra moves around/doesn't sit right on Discomfort when exercising
	Cup fully encapsulates the breast tissue. The cup does not cut into the breast tissue and does not leave wrinkles/gapping between the cup and tissue. The cup design should be a full-cup style to full encase the breasts and also disguise any asymmetrical padding.	<ul style="list-style-type: none"> Breast outline Shape Volume 	Cup	
	The straps sit firm but comfortably on the shoulders. They do not dig-in and do not slide off. Strap design include adjusters to custom fit. The straps should be thick and stretchy.		Straps	
	Front band (also known as the gore) sits flat against the chest.	<ul style="list-style-type: none"> Inner-breast point distance 	Front band	
	Follows the breast line and shape. Does not dig into the breast tissue.	<ul style="list-style-type: none"> Breast outline 	Underwire	
2. Asymmetry	Measuring each breast individually to assess the breast size and shape difference.	<ul style="list-style-type: none"> Breast outline Shape Volume 	Cups	<ul style="list-style-type: none"> Cups are too tight or loose Irritation from underwire Bra moves around/doesn't sit right on Uneven breast size or breast placement Inability to wear certain clothing Unappealing appearance with clothes Discomfort when socializing
	Padding in the cup of the smaller breast.			
3. Skin sensitivity	Breathable fabric		All	<ul style="list-style-type: none"> Skin sensitivity Scar aggravation Temperature issues Humidity issues
	Thermal comfort fabric			
	Underwire only used once breasts have healed after surgery.			

Parametric design model to address fit issues

A parametric breast measuring for individualized bra design system, based on previous research was adapted for this study [3]. Landmarking and measurements were obtained for each breast to meet the “correct bra size” and account for asymmetry. A 3D scanned model of the upper torso is input into Rhino Grasshopper where minimal manual landmarking are added (see Figure 3). By using this landmarking and measuring technique, we can accurately assess the parameters needed to fit breasts into a bra but also develop a design methodology for manufacturing bras. Measurements such as the circumference of the under-bust directly influences the band size and fit. The under-breast line of each breast (inner breast point to bottom breast point to outer breast point) helps identify the breast root shape which directly influences the underwire shape and measurement.

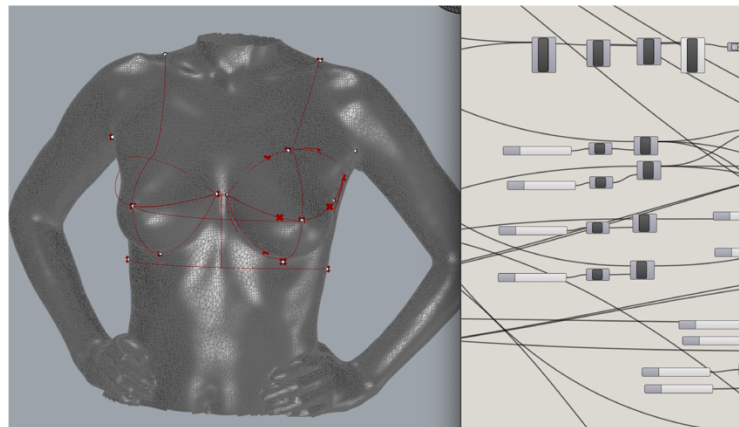


Figure 3: BREAST LANDMARKING AND MEASURING

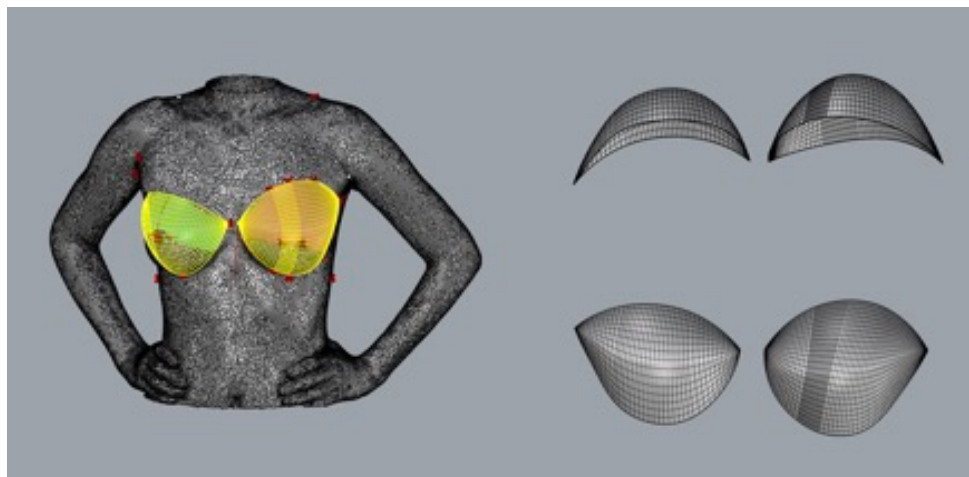


Figure 4: INDIVIDUAL BREAST SHAPE

To address the concerns about the impact of asymmetry on bra fit, additional parameters were added to this model. For example, the volume measurement can be taken from each breast outline (see **Error! Reference source not found.**). The volume measurement is vital to better understand the difference in sizing between each breast and the level of asymmetry. This will in turn assist with understanding how much cup padding will need to be designed. Though the resulting bra design provides an appearance of “symmetrical” cups, the padding within the cups is customized to the needs of the wearer and in response to the asymmetry of the breasts. This will address participant concerns of uneven breast size as well as assist with the appearance underclothes. The below bra design (see Figure 5) utilizes the criteria as explained in Table 2 and incorporates a bra padding design to account for asymmetry. The parametric model automatically assesses the 3D scan of the upper-torso and obtains necessary measurements needed to ensure a good bra design and fit. These measurements can then be used to feed into the proposed bra design below. For instance, the difference in breast volume will determine the cup padding projection.

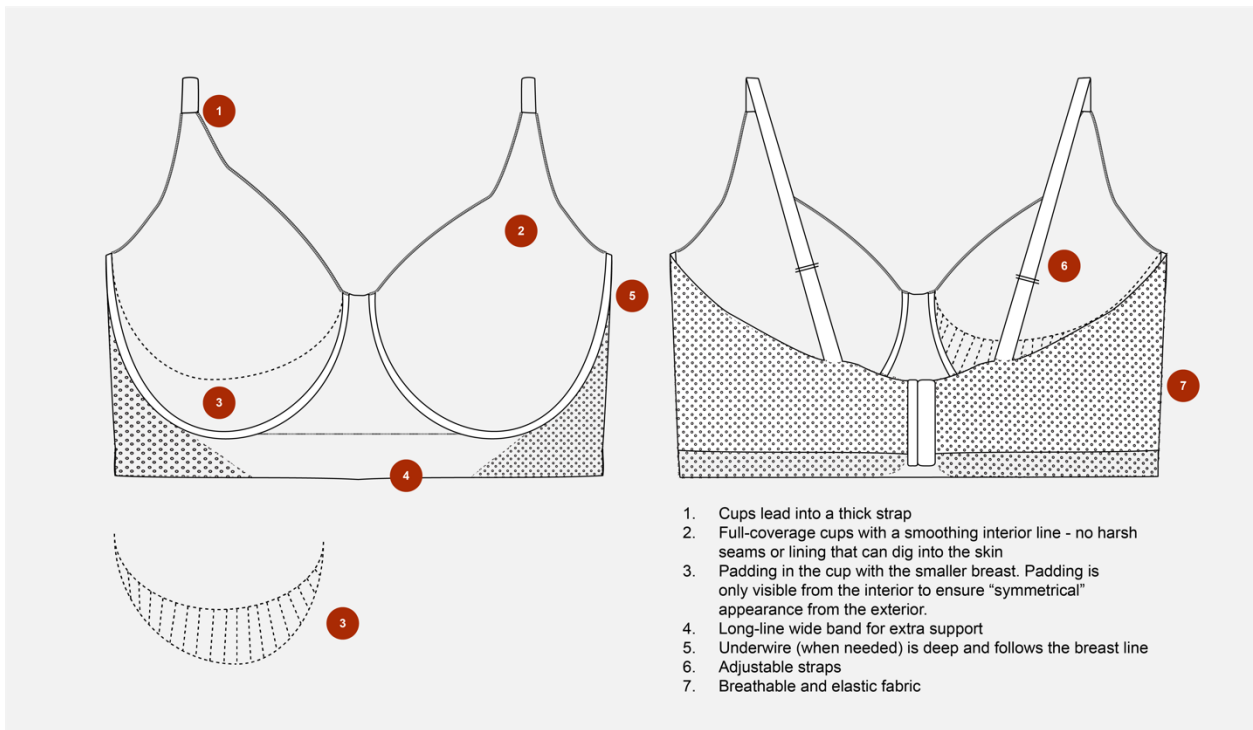


Figure 5: PROPOSED BRA DESIGN

CONCLUDING REMARKS AND NEXT STEP

The bra fit issues gleaned from a survey are examined to develop a set of parameters and criteria for a more body responsive bra design. Using breast landmarking off a 3D scanned model of the upper torso, measurements are gathered to ensure better bra fit and sizing which addresses participant concerns with bra fit. In addition, by individually assessing the breast volume, including the ever-present asymmetry of breasts. We have experimented with various sets of measuring parameters that are used to design and develop bras. We provide an experimental bra design to address the participant concerns and where the measurements from the parametric model can be utilized to size the bra. There is far more work to be done both in terms of improving the models but also understanding the complexity of comfort and fit. Future work includes testing the entire system from scanning, measuring, and altering the bra design size accordingly. It will be vital to test the system with end-users and assess the bra design for future iterations.

REFERENCES

1. Wroblewski, Susanne M., MacGillivray, Maureen S. & Cheng, Chin-I. “Bra preferences of breast cancer survivors treated with mastectomy and prosthetic reconstruction”, *International Journal of Fashion Design, Technology and Education*, 13:1, (2020): 31-44
2. Risius, Debbie, Thelwell, Richard, Wagstaff, Chris, and Scurr, Joanna. “Influential Factors of Bra Purchasing in Older Women.” *Journal of Fashion Marketing and Management: An International Journal* 16, no. 3 (July 6, 2012): 366–380.
3. Amoozegar-Montero, X. A. (2016). Parametric Modelling and Digital Manufacturing for Better Bra Fit [Masters Thesis, Victoria University of Wellington]. <http://researcharchive.vuw.ac.nz/handle/10063/9223>
4. Coltman, Celeste E, Julie R Steele, and Deirdre E McGhee. “Effects of Age and Body Mass Index on Breast Characteristics: a Cluster Analysis.” *Ergonomics* 61, no. 9 (2018): 1232–1245.
5. White, J, and J Scurr. “Evaluation of Professional Bra Fitting Criteria for Bra Selection and Fitting in the UK.” *Ergonomics* 55, no. 6 (2012): 704–711.
6. Nicklaus, Krista M, Karen Bravo, Chi Liu, Deepti Chopra, Gregory P Reece, Summer E Hanson, and Mia K Markey. “Undergarment Needs after Breast Cancer Surgery: A Key Survivorship Consideration.” *Supportive care in cancer* 28, no. 8 (2020): 3481–3484.
7. Cohen, Wess A et al. “Understanding and Optimizing the Patient Experience in Breast Reconstruction.” *Annals of plastic surgery* vol. 77,2 (2016): 237-41.
8. McGhee, Deirdre E, and Julie R Steele. “Optimising Breast Support in Female Patients through Correct Bra Fit. A Cross-Sectional Study.” *Journal of science and medicine in sport* 13, no. 6 (2010): 568–572.
9. McGhee, Deirdre E, and Julie R Steele. “Breast Volume and Bra Size.” *International journal of clothing science and technology* 23, no. 5 (2011): 351–360.
10. Filipe, Ana Brígida, Cristina Carvalho, Gianni Montagna, and Júlia Freire. “The Fitting of Plus Size Bra for Middle Aged Women.” *Procedia manufacturing* 3 (2015): 6393–6399.