Aesth Plast Surg (2023) 47:1–7
https://doi.org/10.1007/s00266-022-03087-z

Evaluation of Vectra® XT 3D Surface Imaging Technology in Measuring Breast Symmetry and Breast Volume

My Pham[1] · Robert Alzul[1] · Elisabeth Elder[1] · James French[1] · Jaime Cardoso[2] · Ahmad Kaviani[3] · Farid Meybodi[1]

Received: 2 June 2022 / Accepted: 28 August 2022 / Published online: 23 September 2022

Abstract
Background Breast symmetry is an essential component of breast cosmesis. The Harvard Cosmesis scale is the most widely adopted method of breast symmetry assessment. However, this scale lacks reproducibility and reliability, limiting its application in clinical practice. The VECTRA® XT 3D (VECTRA®) is a novel breast surface imaging system that, when combined with breast contour measuring software (Mirror®), aims to produce a more accurate and reproducible measurement of breast contour to aid operative planning in breast surgery.
Objectives This study aims to compare the reliability and reproducibility of subjective (Harvard Cosmesis scale) with objective (VECTRA®) symmetry assessment on the same cohort of patients.
Methods Patients at a tertiary institution had 2D and 3D photographs of their breasts. Seven assessors scored the 2D photographs using the Harvard Cosmesis scale. Two independent assessors used Mirror® software to objectively calculate breast symmetry by analysing 3D images of the breasts.
Results Intra-observer agreement ranged from none to moderate (kappa − 0.005–0.7) amongst the assessors using the Harvard Cosmesis scale. Inter-observer agreement was weak (kappa 0.078–0.454) amongst Harvard scores compared to VECTRA® measurements. Kappa values ranged 0.537–0.674 for intra-observer agreement ($p < 0.001$) with Root Mean Square (RMS) scores. RMS had a moderate correlation with the Harvard Cosmesis scale ($r_s = 0.613$). Furthermore, absolute volume difference between breasts had poor correlation with RMS ($R^2 = 0.133$).
Conclusion VECTRA® and Mirror® software have potential in clinical practice as objectifying breast symmetry, but in the current form, it is not an ideal test.
Level of Evidence IV This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Breast · Symmetry · Volume · Harvard · Vectra · Technology

✉ My Pham
my.b.pham@gmail.com

1 Westmead Breast Institute, Westmead, NSW, Australia

2 Department of Engineering, University of Porto, Porto, Portugal

3 Department of Medical Sciences, University of Tehran, Tehran, Iran

Introduction

Breast symmetry is a key marker of aesthetic outcome after breast surgery and an important factor for patient satisfaction [1, 2]. The ability to objectively and reliably measure and quantify symmetry has, therefore, a vital place in surgical planning and in the overall assessment of cosmesis [3–5].

The most commonly used method of breast symmetry analysis is the Harvard Cosmesis scale, developed by Harris et al. [1]. This scale uses a 4-point Likert scale from 1 (excellent) to 4 (poor). It can be easily employed either during direct observation by surgeons, nurses, patients or applied to 2D photographs [2] since it is accessible and inexpensive. However, low reproducibility values have been reported in many studies [1, 2, 6]. Furthermore, it has limited value when evaluating patients at different stages of treatment [2].

VECTRA® XT 3D technology (Canfield Scientific) is an alternative method to the Harvard Cosmesis scale using 3D symmetry assessment. Mirror® software measures breast symmetry by recording digital photographs of the patient's right and left breasts in multiple views individually, then assessing differences in symmetry by overlaying the corresponding views of the right and left breast onto each other [7]. The software calculates the average distance between the two breast surfaces and produces a number reflective of breast symmetry, calculated as the Root Mean Square (RMS) [8]. The RMS is generated by taking measurements from over 1000 automated reference points over every square centimetre of breast surface area and then taking the square root of the distance value, squared to account for both positive and negative distances [8]. A score of 0 corresponds to perfect symmetry, and increasing breast asymmetry corresponds to a larger RMS score.

VECTRA® technology has the added advantage of assessing the breast as a 3D structure and considering breast volume or projection data that 2D photography is unable to capture [1, 7, 8]. It uses more than one camera to obtain photos of the breast [8]. Mirror® software uses a computer algorithm that plots the coordinates of the surface image based on the intercepting points from different camera angles and then estimates the thoracic wall of the patient [8]. The breast volume is subsequently computed using the distance between the breast surface and this virtual chest wall. It is a convenient and inexpensive method for calculating breast volume and has been shown to have an average accuracy of about 2.2% underestimation of the true breast volume (range − 2.17 to − 2.28%) [7].

The purpose of this study was to compare subjective (2D) and objective (VECTRA® 3D technology) assessment of breast symmetry and assess the influence of breast volume on overall breast symmetry using 3D surface imaging.

Method

Ethics approval was obtained from the Westmead Hospital Institution (reference: HREC Ref: AU RED LNR/Q6/WMEAD/56).

From January 2015 to December 2016, patients from the Westmead Breast Cancer Institute were consented and enrolled in this study. Inclusion criteria were patients who successfully had both 2D and 3D photographs. Patients with prior breast surgery were not excluded from the study. Patients who received radiotherapy were excluded.

An online survey was created for 2D assessment of breast symmetry. The survey involved the assessment of 2D photographs of de-identified patient breasts using the Harvard Cosmesis scale by seven independent breast assessors at three institutions. These assessors were a combination of male and female surgeons. Each patient had three 2D photographs of each breast: frontal, oblique (45° right and left sides) views (Fig. 1a, b). The median score between the seven assessors was calculated to be the Harvard score. To test for intra-observer variability, 17 randomly selected patient measurements out of the study population were repeated and dispersed throughout the survey. Cohen's kappa statistic was used to measure intra-observer and inter-observer agreement. A kappa value of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement equivalent to chance. A P value < 0.001 was considered statistically significant.

For the 3D assessment of breast symmetry, two independent breast assessors used Mirror® software program (Canfield Scientific) to measure breast symmetry and volume of 3D patient photographs. The 3D photographs were captured using VECTRA® XT 3D surface scanning technology (Canfield Scientific) with a shutter speed of 3.5 ms. Each assessor measured and repeated breast symmetry and volume using the following protocol [8] (Fig. 2):

- The patient was instructed to spread their arms horizontally and exhale when the photographs were taken. The breast boundaries (sterno-manubrial joint after palpation, infra-mammary fold, mid-axillary line) and mid-clavicular surface markings were marked directly on the patient when the 3D photographs were obtained. The assessor used these markings to align the photograph in the anterior-posterior view, to minimise the effect of thoracic rotation that may have been present at the time of photograph when the patient was not standing parallel to the VECTRA® cameras.
- The images were imported into Mirror® software, and gridlines with each grid cube being 2cm on each side were placed onto the image so that the y axis ($x = 0$) bisected the torso. The clavicles were aligned along the line of $z = 0$. The surface area of the breast was selected as the region of interest for analysis. The region of interest was specifically defined: superiorly by a horizontal line two cm below the sternal notch, inferiorly one cm below the infra-mammary fold, laterally at the mid-axillary line and medially at the thoracic midline. Specific landmarks were automatically detected by VECTRA® software: jugular notch, mid-clavicular, and medial and lateral aspects of the infra-mammary fold. If automatic landmark detection was unsuccessful, the landmarks were manually placed or adjusted. The Mirror® software then calculated the RMS score (Fig. 3) by measuring the shortest distance difference between the right and left breasts when the

Fig. 1. **a** Standardised 2D photographs were taken of each patient, **b** standardised 2D photographs were taken of each patient

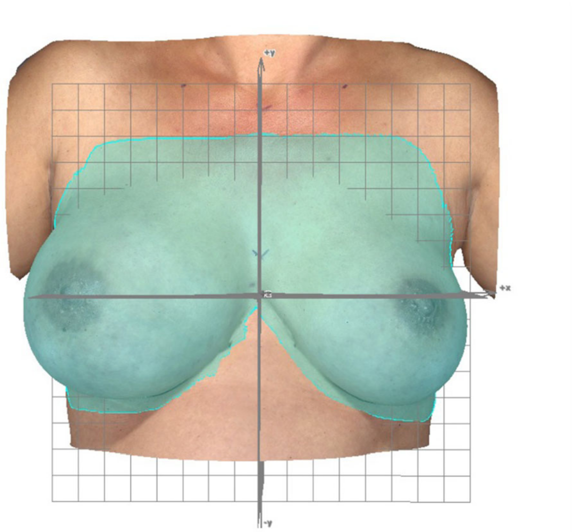

Fig. 2. Defined area of interest of breasts using a standardised protocol

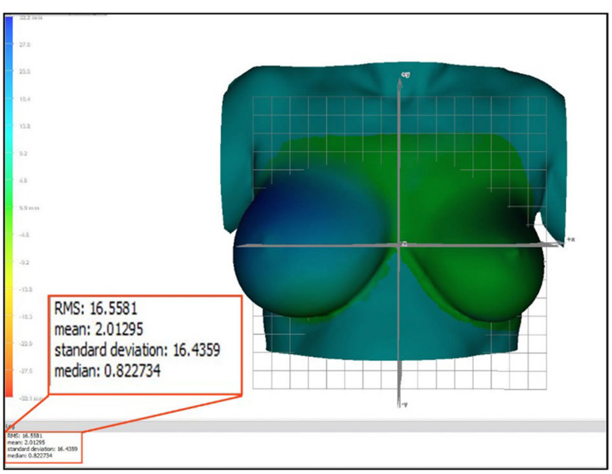

Fig. 3. Mirror® software calculation of RMS

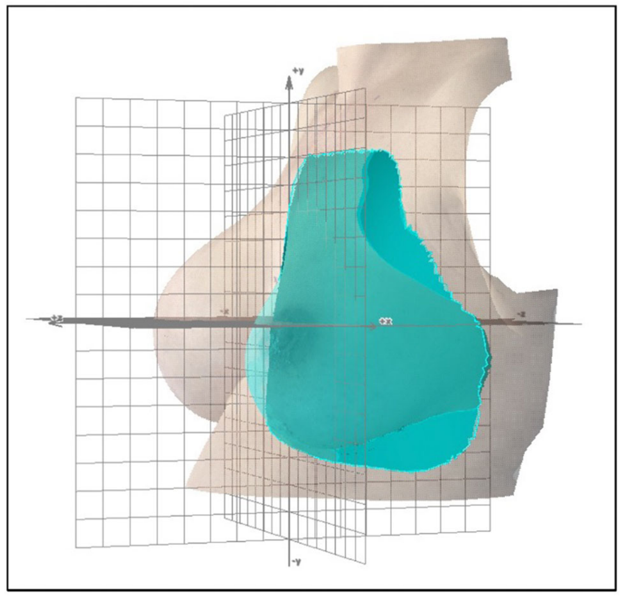

Fig. 4. Generation of virtual thoracic wall using the contours of the patient's 3D photographs by Mirror® software

photographs reflected upon each other. A Bland–Altman plot was constructed to identify any statistical difference between the two assessors. Spearman's rank correlation was used to assess the relationship between the Harvard and RMS scores.

For the 3D assessment of breast volume, two independent assessors used a protocol similar to that used for breast symmetry measurement [8] (Fig. 4). The same region of interest was used for the analysis. This region was bisected at the sternal midline to separate the right and left breast volumes. The Mirror® software generated a virtual thoracic wall using the contours of the patient's 3D photographs and then extrapolated the volume of the overlying breast tissue (Fig. 5). Breast volume was measured in cubic centimetres. Linear regression modelling was used to determine the effect of breast volume on the RMS score.

The difference between the right and left breast volumes was considered the independent variable, and the RMS score was defined as the dependent variable. The value of *R* squared was calculated, and $p < 0.001$ was taken as significant where the comparison was conducted.

Data were entered into an excel spreadsheet (Microsoft Corp., Redmond, Washington) and analysed using SPSS statistical software (SPSS v22; SPSS, Inc., Chicago).

Results

One hundred thirty-four patients were enrolled in this study. Five assessors reviewed and rated 134 patients, one assessor reviewed 133 patients, and one reviewed 132 patients using the Harvard Cosmesis scale. The distribution of scores is shown in Table 1. Kappa values ranged from − 0.005 to 0.700 for intra-observer agreement, and this was significant in two assessors ($p < 0.001$) (Table 2). All kappa values (range 0.078–0.454) for inter-observer agreement (Table 3) were statistically significant amongst all assessors ($p < 0.001$) except between assessors 5 and 7.

RMS for 8 out of 134 patients could not be calculated due to technical errors in the Mirror® computer software. The minimum RMS scores were 1.74 and 2.21, and the maximum RMS scores were 20.44 and 16.26, for assessor 1 and 2, respectively. Kappa values ranged from 0.537 to 0.674 for intra-observer agreement ($p < 0.001$). Inter-observer agreement between the assessors was good, and there was no significant bias of measurements between the assessors when calculating RMS ($p = 0.986$). The mean RMS value was 0.66 with a variation of − 2.11 to 3.43 (Standard deviation 1.96) (Fig. 6). Furthermore, a moderately strong positive relationship existed between the Harvard and RMS scores ($r_s = 0.613$) (Fig. 7). There was a weak positive relationship between the absolute volume difference between the left and right breasts and the RMS scores ($R^2 = 0.133$) (Fig. 8). Right breast mean volume was 519.80 cc (median: 491 cc; range 67.37–1841.00 cc). Left breast mean volume was 493.05 cc (median: 464 cc; range 77.56–1580 cc).

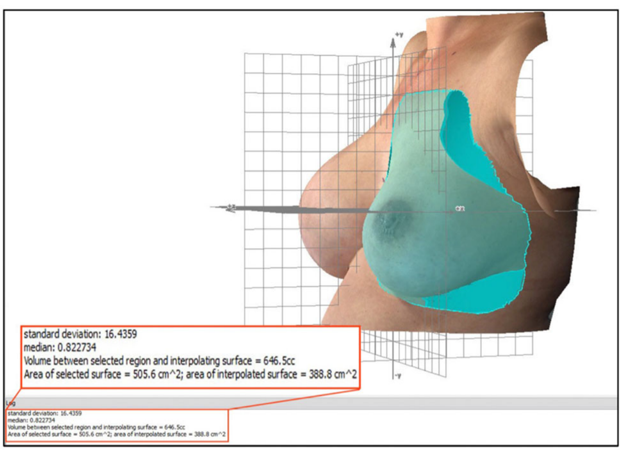

Fig. 5. Breast volume calculation using Mirror® software

Table 2 Kappa values for intra-observer agreement

Assessor	Kappa	Level of agreement [11]	*p* value
1	0.360	Minimal	0.048
2	−0.005	None	0.972
3	0.614	Moderate	0.001
4	0.181	None	0.282
5	0.700	Moderate	< 0.001
6	0.609	Moderate	0.001
7	0.536	Weak	< 0.001

Table 3 Kappa values for inter-observer agreement

Assessor	1	2	3	4	5	6	7
1		0.333	0.430	0.295	0.364	0.356	0.208
2			0.372	0.367	0.236	0.454	0.370
3				0.344	0.424	0.389	0.272
4					0.401	0.376	0.140
5						0.320	0.078
6							0.279
7							

Table 1 Distribution of Harvard Cosmesis scores amongst the assessors

	Harris score 1 (Excellent) (%)	2 (Good) (%)	3 (Fair) (%)	4 (Poor) (%)
Assessor 1	25.95	48.10	18.99	6.32
Assessor 2	33.96	30.19	19.50	16.35
Assessor 3	40.00	35.00	15.00	10.00
Assessor 4	49.38	27.50	16.88	6.25
Assessor 5	43.13	35.63	17.50	3.75
Assessor 6	43.13	28.75	13.13	15.00
Assessor 7	18.75	34.38	20.00	26.88

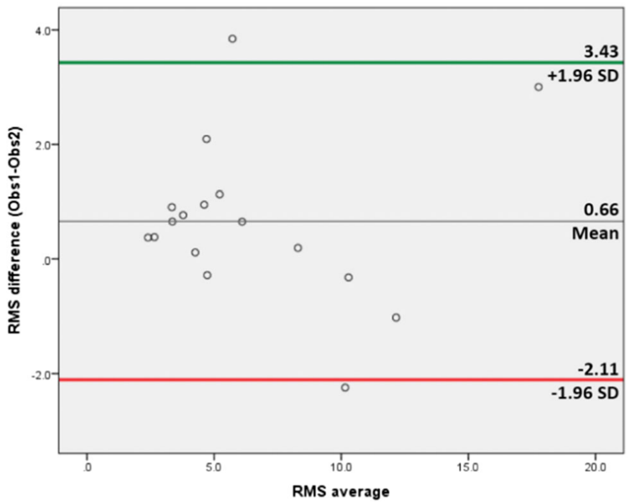

Fig. 6. Bland–Altman plot of RMS inter-observer agreement

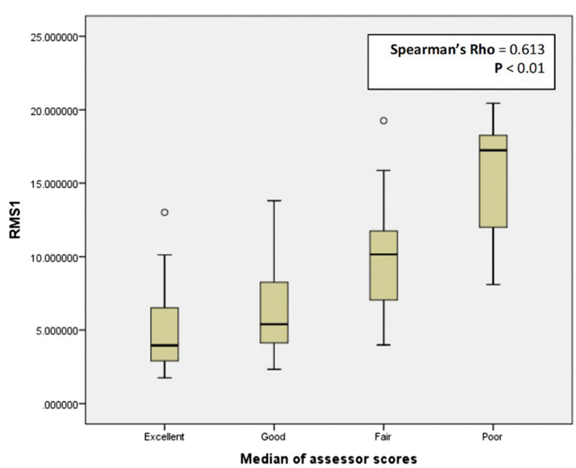

Fig. 7. Relationship between RMS scores and Harvard Cosmesis scores

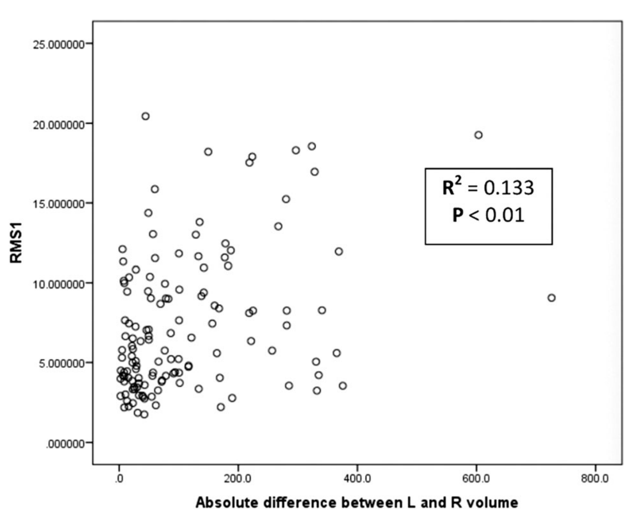

Fig. 8. Relationship between RMS measurements and breast volume differences

Discussion

Whilst easily applied clinically, the Harvard Cosmesis scale is an inaccurate and poorly reproducible method of measuring breast symmetry [6, 9]. This is supported by this study which shows a weak inter-observer agreement amongst seven independent assessors. Intra-observer agreement was also weak in all assessors except in two cases, where the agreement was moderate. Reported intra-observer agreement with the Harvard Cosmesis scale in the literature has been variable [1]. Even when assessors were selected from a group of experts based upon their agreement of previous scores, 30% of the time, their individual Harvard Cosmesis score was incongruent with group consensus scores [1].

The main limitation of the Harvard Cosmesis scale is the lack of detail provided in the scale itself which, coupled with the inherent variation in the assessor's experience, results in variable classification between poor, fair, good and excellent score results [3, 10]. This also implies that the scale has limited discriminative power amongst patients [2].

This study demonstrates that Vectra® produced better inter-observer agreement, and repeatability (intra-observer) than the Harvard Cosmesis scale.

Measured differences between the right and left breast volume did not correlate to the extent of perceived asymmetry of the breasts, which is consistent with the previous studies [8]. This may be due to volume distribution in the breasts playing a more prominent role in the overall symmetry as opposed to absolute volume difference.

This is the first study that compares Vectra® XT 3D technology to the Harvard Cosmesis scale for assessing breast symmetry in a large cohort of patients. One of the strengths of this study is that a standardised protocol was used [1, 3, 9] This included analysis with seven surface markers with Vectra technology, which has been shown to yield the most accurate measurements compared to a lesser number of surface markers [11]. Whilst the Harvard Cosmesis 4- point scale is easy to understand, RMS scores are slightly challenging to interpret. However, Vectra® is more objective (removes inherent assessor bias) and is more clinically useful when comparing breast symmetry and aesthetic outcomes between patients.

Vectra® XT 3D technology is becoming more accessible for breast surgeons albeit it is costly [12]. The technology can be easily integrated in clinical practice. In the pre-operative setting, it can be used to facilitate patient assessment of their breast volume and anthropometric measures objectively. This would be helpful in guiding surgeon discussion on operative goals such as correcting breast symmetry. Furthermore, it can be a powerful tool from the patient's perspective as it increases their understanding of their breasts. The technology can be used to engage patients, build rapport and aid shared surgical decision making, thereby reducing decisional conflict. This process may lead to better management of patient expectation, particularly in reconstructive surgery and post-surgical satisfaction [3, 13]. In the post-operative setting, the technology can be used to objectively record, and document breast examination findings, and serve as a reproducible marker of outcome for quality control or research purposes from the surgeon's perspective.

A limitation with Vectra® is that the Mirror® software measures breast symmetry as an average of the global surface symmetry. This implies that when there are asymmetrical focal areas of the breast, this asymmetry can be masked by the rest of the breast, which may be very symmetrical, and the final reading may be that the breasts are very symmetrical [1]. Furthermore, data analysis is not yet automated and can be impacted by user error. Whilst the protocol for measuring the region of interest is defined, the assessor is required to manually place markers on the photographs to select areas of interest which can introduce variability and impact on reproducibility [14]. It is hoped that further software updates would reduce operator input error with increased automation of data points, making it a faster and simpler process [1].

Furthermore, patient thoracic rotation whilst obtaining the 3D photographs (particularly anterior-posterior view) can affect the accuracy of RMS measurements [8]. The assessor can manually correct small rotations using the computer software to align the *xyz* coordinates though this can be variable amongst users. To minimise the effect of rotation, anatomical landmarks are marked prior to photography. However, larger degrees of rotation will likely lead to inaccurate RMS scores.

Lastly, symmetry measurements may be affected by large-breasted women where ptosis or body mass index precludes the 3D camera from obtaining the under surface of the breasts. The software makes up for this deficit by mathematically modelling these areas using the available images. There is also further potential for VECTRA® and Mirror® software to integrate other characteristics such as the position of the nipple-areolar complex; breast shape and projection collectively and in the 'quadrant by quadrant' approach; and scar appearance. These factors are also very important to breast symmetry assessment [5, 15].

Conclusion

Breast symmetry is one of the dominant indicators of overall aesthetic outcome. VECTRA® XT 3D technology produces objective and reproducible measurements of breast symmetry compared to the Harvard Cosmesis scale. There is no gold standard available yet, but 3D surface scanning, with better reproducibility and less bias, has some potential. With modifications, it can be used as a standard tool for the assessment of aesthetic outcomes in the future. This study is unique in that the comparison was between VECTRA® XT technology and multiple international assessors in rating the breast symmetry in a large population. Volume differences between the breasts had little effect on 3D measured symmetry scores.

Acknowledgement The authors would like to thank all staff members at the Westmead Breast Institution who were involved in recruitment, obtaining the 2D and 3D photographs of all patients according to the standardised requirements, and measurements. The authors would like to particularly acknowledge Bronwyn Chalmers, Breast Clinical Nurse Consultant, for her tremendous support in the study.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

Ethical Approval This study contains human participants and this study had ethical approval under the institution. For this study, informed consent was gained from every human participant.

References

1. Godden AR, O'Connell RL, Barry PA et al (2020) 3-Dimensional objective aesthetic evaluation to replace panel assessment after breast-conserving treatment. Breast Cancer 27(6):1126–1136. https://doi.org/10.1007/s12282-020-01117-9
2. Cardoso MJ, Oliveira H, Cardoso J (2014) Assessing cosmetic results after breast conserving surgery. J Surg Oncol 110(1):37–44. https://doi.org/10.1002/jso.23596
3. O'Connell RL, Di Micco R, Khabra K et al (2017) The potential role of three-dimensional surface imaging as a tool to evaluate aesthetic outcome after breast conserving therapy (BCT). Breast Cancer Res Treat 164(2):385–393. https://doi.org/10.1007/s10549-017-4256-y
4. Lee WY, Kim MJ, Lew DH, Song SY, Lee DW (2016) Three-dimensional surface imaging is an effective tool for measuring breast volume: a validation study. Arch Plast Surg 43(5):430–437. https://doi.org/10.5999/aps.2016.43.5.430
5. Monton J, Torres A, Gijon M et al (2020) Use of symmetry assessment methods in the context of breast surgery. Aesthetic Plast Surg 44(5):1440–1451. https://doi.org/10.1007/s00266-020-01755-6
6. Henseler H, Smith J, Bowman A et al (2013) Subjective versus objective assessment of breast reconstruction. J Plast Reconstr Aesthet Surg 66(5):634–639. https://doi.org/10.1016/j.bjps.2013.01.006
7. O'Connell RL, Khabra K, Bamber JC et al (2018) Validation of the Vectra XT three-dimensional imaging system for measuring breast volume and symmetry following oncological reconstruction. Breast Cancer Res Treat 171(2):391–398. https://doi.org/10.1007/s10549-018-4843-6
8. Bai L, Lundström O, Johansson H et al (2022) Clinical assessment of breast symmetry and aesthetic outcome: can 3D imaging

be the gold standard? J Plast Surg Hand Surg. https://doi.org/10.1080/2000656x.2021.2024553
9. Godden AR, Micha A, Wolf LM et al (2021) Three-dimensional simulation of aesthetic outcome from breast-conserving surgery compared with viewing photographs or standard care: randomized clinical trial. Br J Surg 108(10):1181–1188. https://doi.org/10.1093/bjs/znab217
10. Alshehri SA, Singh SK, Mosahebi A, Kalaskar DM (2021) The current progress and critical analysis of three-dimensional scanning and three-dimensional printing applications in breast surgery. BJS Open. https://doi.org/10.1093/bjsopen/zrab025
11. Nakamura M, Mori H, Kubota M, Uemura N, Tanaka K (2021) Influence of marker number and position on accuracy of breast measurement with three-dimensional camera. Aesthetic Plast Surg. https://doi.org/10.1007/s00266-021-02629-1
12. Verhulst A, Hol M, Vreeken R, Becking A, Ulrich D, Maal T (2018) Three-dimensional imaging of the face: a comparison between three different imaging modalities. Aesthetic Surg J 38(6):579–585. https://doi.org/10.1093/asj/sjx227
13. de Vita R, Buccheri EM, Villanucci A, Ragusa LA (2019) Breast asymmetry, classification, and algorithm of treatment: our experience. Aesthetic Plast Surg 43(6):1439–1450. https://doi.org/10.1007/s00266-019-01489-0
14. Hartmann R, Weiherer M, Schiltz D et al (2021) New aspects in digital breast assessment: further refinement of a method for automated digital anthropometry. Arch Gynecol Obstet 303(3):721–728. https://doi.org/10.1007/s00404-020-05862-2
15. Reddy JP, Lei X, Huang SC et al (2017) Quantitative assessment of breast cosmetic outcome after whole-breast irradiation. Int J Radiat Oncol Biol Phys 97(5):894–902. https://doi.org/10.1016/j.ijrobp.2016.12.021