Aesth Plast Surg (2023) 47:1751–1758
https://doi.org/10.1007/s00266-023-03432-w

ORIGINAL ARTICLE BREAST SURGERY

Assessment of Three Breast Volume Measurement Techniques: Single Marking, MRI and Crisalix 3D Software®

Aleksandra Markovic[1] · Salustiano Gomes de Pinho Pessoa[1] · José Alberto Dias Leite[1] · Fernando Soares de Alcântara[1] · Bernardo Gabriele Collaço[1] · Diego Ariel de Lima[2]

Received: 14 March 2023 / Accepted: 15 May 2023 / Published online: 19 June 2023

Abstract
Introduction Measuring breast volume is important to obtain satisfactory breast surgery results, and many techniques are used for this purpose. Thus, the aim of the present study was to compare 3 breast volume techniques: Pessoa's single marking technique, magnetic resonance imaging (MRI) and Crisalix 3D software®.
Methods Fourteen patients indicated for mammoplasty were selected. Three breast volume measurement techniques were compared: Pessoa's single marking technique, MRI and Crisalix 3D software®. The volumes were tabulated and analyzed using R software.
Results Average age was 30.93 ± 10.25 years. The breast volume was 1554.54 ± 512.54 cm^3, as measured by the MRI technique (considered the gold standard), 1199.64 ± 403.13 cm^3 using Crisalix 3D software® and 1518.04 ± 468.72 cm^3 by Pessoa's single marking technique. Comparison between the Crisalix 3D software® and MRI techniques using the pairwise *t* test demonstrated a statistically significant difference ($t = 4.3957$, $df = 27$, p value = 0001543), but no significant difference between the single marking and MRI techniques ($t = 1.3841$, $df = 27$, p value = 0.1777).
Conclusion When compared to MRI, breast volume measurement using Pessoa's single marking technique showed no statistically significant difference between them. However, the Crisalix 3D® technique exhibited a difference in relation to MRI. Anthropometric measurements are useful in measuring breast volume because they are easy to obtain, practical and inexpensive, and should be part of a plastic surgeon's arsenal.
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 · Mammoplasty · Organ volume

✉ Diego Ariel de Lima
arieldelima.diego@gmail.com

Aleksandra Markovic
19quepasa19@gmail.com

Salustiano Gomes de Pinho Pessoa
salustianogppessoa@gmail.com

José Alberto Dias Leite
josealberto_leite@hotmail.com

Fernando Soares de Alcântara
fernandosalc@gmail.com

Bernardo Gabriele Collaço
bernardo.collaco00@gmail.com

1 Department of Surgery, UFC - Universidade Federal do Ceará, Fortaleza, CE, Brazil

2 Department of Health Sciences, UFERSA - Universidade Federal Ruraldo Semi-Árido, Rua Francisco Mota, 572, Pres. Costa e Silva, Mossoró, RN 57259625-900, Brazil

Introduction

Reduction Mammoplasty is still a challenge to plastic surgeons, with several techniques described in the literature [1-6]. One of the obstacles to this procedure is the correct measurement of breast volume, since one of the primary aims of all breast surgeries is symmetry. Quantifying breast volume is vital to obtaining ideal results [7].

There are a number of breast volume measurement techniques described in the literature, including anthropometric methods, 2D imaging (such as mammography and ultrasound), 3D imaging involving the summation of segmented monolayers [such as computed tomography (TC) and magnetic resonance imaging (MRI)], 3D scanners, and more recently, 3D and 4D virtual reality human anatomy software [7–9].

Despite being extremely useful, breast volumes are often not measured in daily plastic surgery practice because the techniques are impractical and costly, or due to lack of accuracy and sometimes knowledge. [8]

Thus, the aim of the present study was to compare 3 breast volume measurement techniques: Pessoa's single marking [6], MRI and Crisalix 3D®.

Methods

This prospective cohort study, approved by the Research Ethics Committee (69467517.5.0000.5045), was conducted with patients submitted to breast reduction surgery between January and December 2021.

Twenty-eight breasts (14 patients) were selected from the preoperative list of the outpatient facility indicated for mammoplasty. Three breast volume measurement techniques were compared: Pessoa's single marking [6], MRI and Crisalix 3D®.

The inclusion criteria were female patients, aged 18 years or older; breast volume greater than 300 cm^3, whose main preoperative complaints were physical discomfort, poor posture and spinal pain; absence of metabolic, cardiac and other diseases, according to clinical assessment, that could compromise the surgical result. Participant privacy was respected, that is, their name or any other identifying information was kept confidential. All the methodology was explained to the participants, who were only included if they gave informed consent.

The exclusion criteria were body mass index (BMI) $\geq$ 30; psychologic disorders; patients indicated for prosthesis with no skin and/or areola reduction; and presence of breast disease, with tumors or not.

Breast Volumetry Using the Pessoa's Single Marking Technique [6]

The Pessoa's single marking technique was created based on a cone shape, considering breast morphology and its anatomic relationships with the thoracic wall [6].

In order to take breast measurements that will determine its initial volume, thoracic reference lines (TRLs) located anthropocentrically to the breasts on the thoracic wall must be marked.

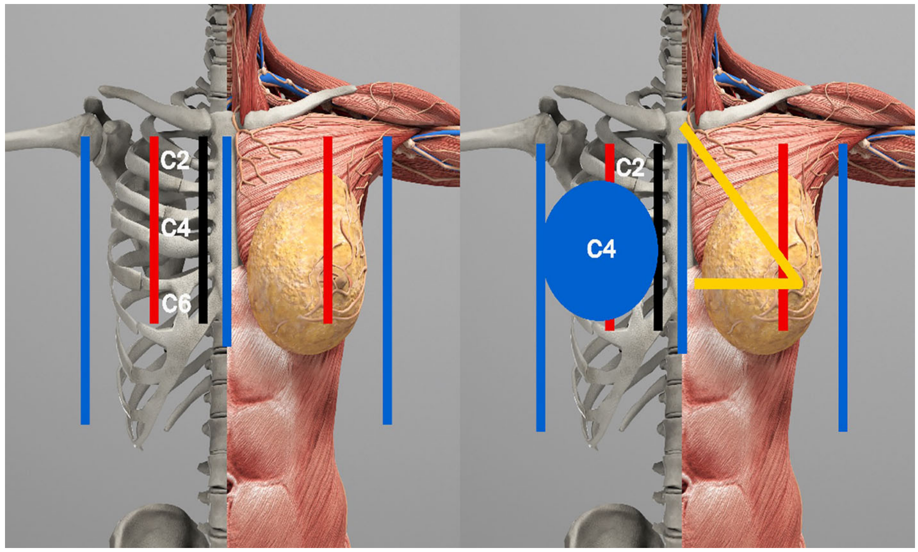
The TLRs are marked in the following sequence (Figs. 1, 2):

a. The chest midline (CML) is the first line traced. It is a vertical line, traced in the cranial caudal direction from the sternal notch, crossing the manubrial junction and forming the angle of Louis at the level of the second rib. Continuing in the same direction, it crosses the sternal body, its lower portion near the xiphoid appendix, where C6 and C7 articulate, ending in a transverse line on the abdominal wall 5 cm above the umbilicus.
b. Next, the supramammary folds (SMF) are traced from right to left on the second rib (angle of Louis); they start on the CML and go as far as the anterior axillary lines. The right and left inframammary folds (IMF) also start from the CML at the junction between the sternal body and xiphoid appendix, on C6 or C7, up to the right and left axillary lines.
c. Next are the right and left axillary lines (AAL), which are traced after palpation in the coracoid process on the anterior surface of the humerus, descending in the cranial caudal direction on the anterolateral surface of the thoracic wall to the horizontal line traced 10 cm above the umbilicus.
d. The next line is called the midclavicular line (MCL), which divides the breast into two parts and is used to do all the surgical planning of the new breast. To trace it, the surgeon centers the breast, aligning the papilla with the midpoint of the clavicle, and traces the line that crosses C2, the areole and the papilla (CAP) and C6, ending 10 cm above the umbilicus. This procedure is done right to left (RCL and LCL). The lines divide the breast into two parts, marking the distance between C2 and P1 and P1 and P3 with the upper and lower generatrix, respectively.
e. The new areole is 4cm in diameter, as determined by Lejour [10], with its upper limit at P1 and lower limit 4cm below where P2 is marked on the MCL. To complete the marking on the new areole site, the surgeon starts at P1 and draws an inverted U (Figs. 1, 2), whose diameter is equal to the patient's areole. This inverted U must be drawn accurately since it is the pedicle area of the CAP and the site of the new areole.

Determining Breast Volume

Concluding the TRLs, two variables are measured to calculate breast volume, whereby, according to Pessoa [6], the breast in its original state is a cone that can be equilateral, straight or oblique, and a breast in ptosis is an oblique cone, whose volume can be determined by the expression of the straight cone:

Fig. 1 Creating a mammary cone



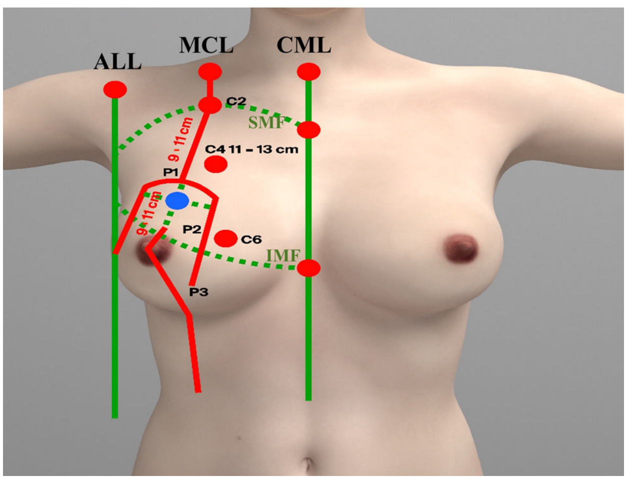


Fig. 2 Marking of thoracic reference lines (TRLs) and their references—planning of the new breast on the MCL with points P1. P2. P3. Reference lines. CML: Chest midline; SMF: Supramammary folds; IMF: Inframammary folds; AAL: axillary line; A: Areole; B: Breast; C: Intersection between the SMF and the midclavicular line (MCL) of the breast

$$V = 1/3\ h\pi r^2 (\text{where } V = \text{volume},\ h = \text{height}, \text{ and } r = \text{breast base radius}).$$

The volumes of both can be calculated using the mathematical expression under study.

The radius at the base of the breast cone is obtained by measuring the distance between C2 and C6 on the CML and dividing it by 2, obtaining the radius, which is the cathetus $\overline{bc}$ of the rectangular triangle that generates the breast cone under study (Fig. 3).

The second is the distance between C2 and the papilla, which corresponds to the $\overline{ab}$ side, rectangular triangle hypotenuse generator and the generatrix of the breast cone being assessed. The goal is to determine the length of the other cathetus of the rectangular triangle, denominated $\overline{ca}$, and the height of both the straight and oblique cones. In geometry, a generatrix is a point, curve or surface that, when moved along a given path, generates a new shape. A cone can be generated by moving a line (the generatrix) fixed at the future apex of the cone along a closed curve (the directrix); if that directrix is a circle perpendicular to the line connecting its center to the apex, the motion is rotation around a fixed axis, and the resulting shape is a circular cone.

In the field of plane geometry, the Pythagoras Theorem for right triangles states the square of the longest side of a right triangle (called the hypotenuse) is equal to the sum of the squares of the other two sides".

As mentioned earlier, the sides of a right triangle are the following:

$\overline{ab}$: hypotenuse, corresponding to the generatrix of the breast cone;
$\overline{bc}$: cathetus, corresponding to the radius of the breast base;
$\overline{ca}$: cathetus, corresponding to the height of the straight or oblique cone.
From the Pythagoras Theorem, we have the following Eq. (1):

$$\overline{ab} = \overline{bc} + \overline{ca} \tag{1}$$

If the goal is to find the height of the cone, Eq. (2) should be used as follows:

$$\overline{ca} = \sqrt[a]{\overline{ab}^2 - \overline{bc}^2} \tag{2}$$

Once the height of the breast cone is obtained, breast volume was measured using the equation $V = 1/3h\pi r^2$.

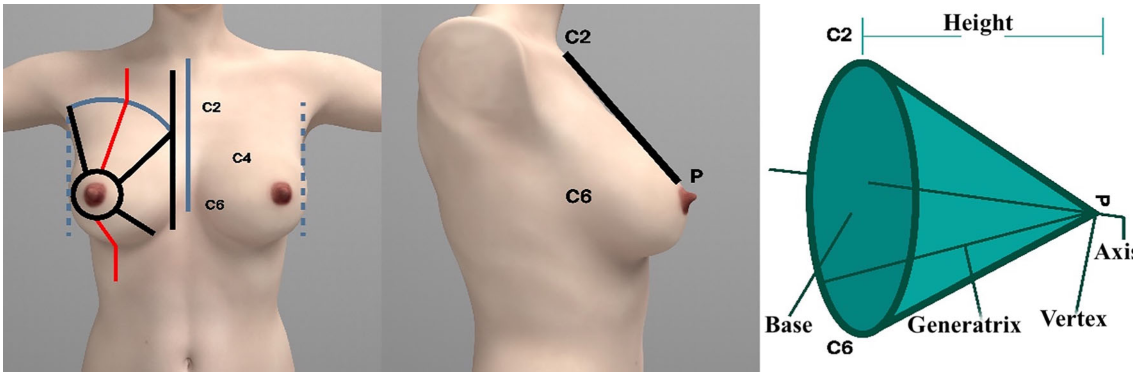


Fig. 3 Breast cone. The figure on the left shows the conical structure of the breast with sagging due to gravitational forces (ptosis). In the figure on the right, measuring the distance from C2 to P and from C2 to C6 and dividing it by two determines the r or cathetus. These measurements are used to find hypotenuse h

Breast Volume by Magnetic Resonance

Breast volume was measured using the GE Healthcare™ 1.5 T Imaging System via volumetric acquisition in the 1 mm-thick axial plane without spacing. Subsequent multiplanar reconstructions can be performed using the VIBRANT (Volume Image Breast Assessment) sequence without fat saturation, a 512 × 512 pixel matrix and no paramagnetic contrast medium. VIBRANT is a 3D gradient echo sequence weighted in T1 and was selected for its physical characteristics that enable fine cuts in a short period, exhibiting good spatial and temporal resolutions, with the option of unsaturated fat in order to achieve even greater tissue resolution at the borders of the breast. The exam was performed in the prone position, with a specific coil and lasted around two minutes.

The images were post processed and analyzed in a workstation by two radiologists using the Horos™ program, and the pencil tool to determine the ROIs (regions of interest) in the axial plane of each breast for every ten images, that is, at every 10 mm thickness in the breast, with subsequent automatic extrapolation of the ROIs using the software tool. Based on an ROI defined in the reconstructed sagittal plane, at the level of the nipple, the cranial and caudal borders were established, delimiting the convex contour of the breast to define its lower and upper borders, following the model proposed by Killaars et al. [11] (Fig. 4).

The references used to draw each ROI also included axillary extension of the breast laterally, posteriorly to the thoracic wall (dorsal aspect of the pectoral muscles), using reference points similar to those of Eriksen et al. [12], Gopper et al. [13] and Kovacs et al. [7].

After the volume was calculated a 3D image of the breasts could be seen, enabling assessment of their contours and symmetry.

Breast Volume Using Crisalix 3D®

The 3D Crisalix simulator creates 3D surface images from three 2D camera images, measurements of the distance from the patient's anatomy and a set of reference points.

All the participants were photographed using the Crisalix 3D-SI system, on the same day and by the same surgeon (ROC).

Patients were mapped using an infrared point sensor, coupled to an iPad®.

The patients were asked to place their hands on their hips and the 3D infrared sensor was kept 1 m away, raised slowly, then lowered and finally moved from side to side in order to capture the individual's entire torso, according to manufacturer's instructions. The software formed a 3D image, markers (points) were placed on the sternal furcular, nipples and breasts, estimating the width and loop around the breast base. The distances between each point were recorded to construct a standard 3D geometry according to how the user moves the iPad® around the patient's torso. Nest, the surgeon takes three 2D photographs and sends them to the Crisalix website in order to create a 3D image, on which anthropometric measures are taken and breast volume calculated (Fig. 5).

Statistical Analysis

The categorical and numerical variables were tabulated and analyzed in R software, for Mac OS X GUI 1.73 (7892 Catalina build), which provided measures of central tendency, percentiles and dispersion.

Data normality was verified by the Shapiro–Wilk test. Between-group homogeneity of variance of the groups was verified by Levene's test. Comparison of group measures to reject or not a null hypothesis was conducted using the t-test for independent samples and the pairwise t-test. The

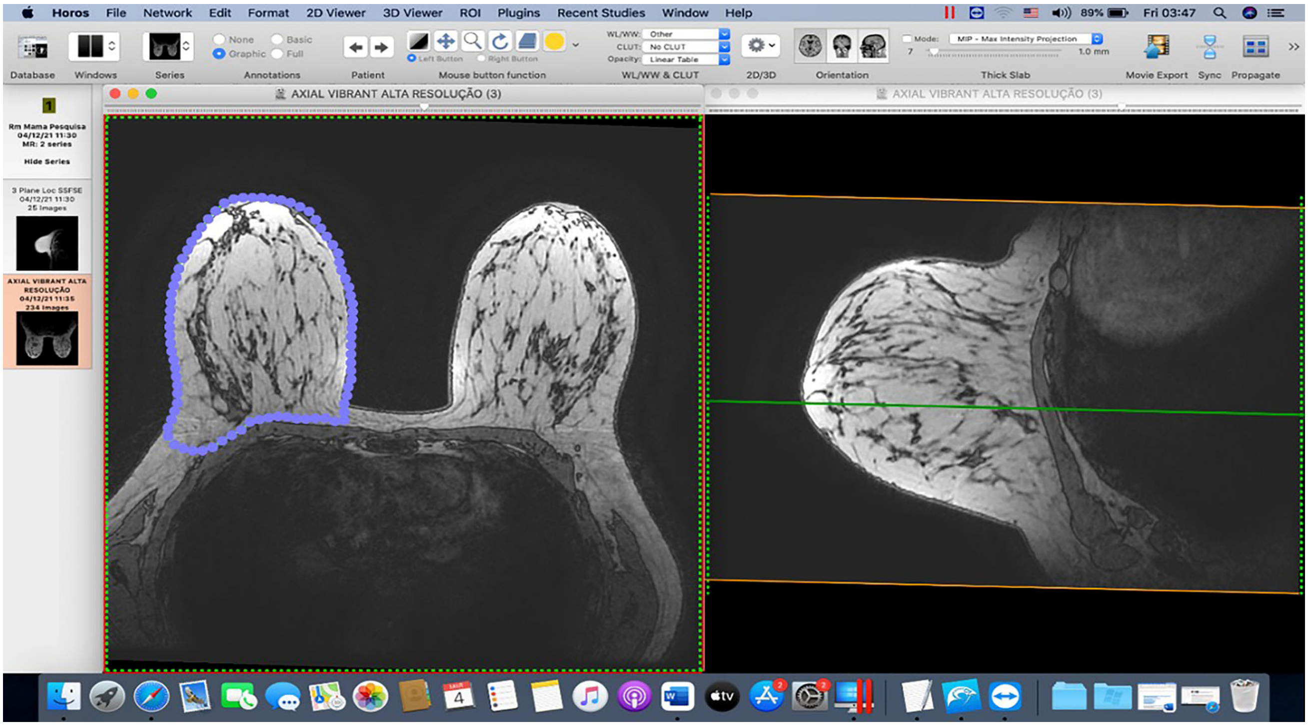


Fig. 4 The pencil tool was used to determine the ROIs (regions of interest) in the axial plane of each breast for every ten images. The cranial and caudal borders of the breast were defined, delimiting the convex contour of the breast to establish its upper and lower borders

Fig. 5 3D image, on which anthropometric measures are taken and breast volume calculated by Crisalix 3D *software*®

presence of outliers was determined by constructing box-plots. Homoscedasticity was tested by constructing a linear regression model between variables.

A 95% confidence level and $p < 0.05$ were considered statistically significant.

Results

Fourteen patients (all women), with a mean age of 30.93 ± 10.25 years, were assessed (Table 1).

With respect to breast volume measured by the MRI technique (considered the gold standard), we obtained an average volume of 1554.54 ± 512.54 cm^3 (with 1555.64 ± 524.66 cm^3 for the right breast and 1553.43 ± 519.93 cm^3 for the left). The t test demonstrated no statistically significant difference between right and left breast volume (t = 0.011217, df = 26, p value = 0.9911). In this assessment, $p > 0.05$ confirmed the null hypothesis (H_0) of no inter-group difference. That is, in the study, the patients exhibited breasts (right and left) with similar volumes.

Table 1 Breast volumes measured by MRI, Crisalix 3D software® and the Pessoa's single marking technique [6]

Name	Age	MRI right breast	Crisalix right breast	Pessoa right breast	MRI left breast	Crisalix left breast	Pessoa left breast
ABP	32	1416	1101	1321	1400	1232	1608
AKHA	18	1351	889	1337	1426	978	1443
ARRN	31	1483	1791	1444	1489	1808	1515
CSSP	35	866	797	928	900	721	928
FASN	39	1060	801	929	1044	752	906
LMS	33	790	1367	805	875	1453	890
LLB	32	2043	1047	1794	2073	1196	1748
LIFD	22	1711	1179	1797	1467	1146	1727
LVMP	19	1979	1429	1797	2109	1503	1832
MFGO	25	2683	1629	2514	2586	1604	2426
MGCM	19	2058	1838	2075	2250	1905	2213
MKSR	40	1780	1186	1794	1578	1065	1608
TJSR	56	1143	414	1080	1151	426	1117
ABP	32	1416	1101	1321	1400	1232	1608

In regard to breast volume measured by Crisalix 3D software®, we obtained an average volume of 1199.64 ± 403.13 cm^3 (1183.50 ± 401.06 cm^3 for the right breast and 1215.79 ± 419.15 cm^3 for the left). With respect to breast volume measured by Crisalix 3D software®, when compared to MRI, the pairwise t test demonstrated a statistically significant difference between them (t = 4.3957, df = 27, p value = 0.0001543). There was an average difference of 354.89 cm^3 in breast volume between these two techniques (95% CI of 189.23 to 520.55 cm^3). In this assessment, $p < 0.05$ rejected the null hypothesis (H_0) of no intergroup difference.

In relation to breast volume measured by the Pessoa's single marking technique [6], we obtained an average volume of 1518.04 ± 468.72 cm^3 (1495.43 ± 489.45 cm^3 for the right breast and 1540.64 ± 464.36 cm^3 for the left). With respect to breast volume measured by the Pessoa's single marking technique [6] when compared to MRI, the pairwise t test demonstrated that there was no statistically significant difference between them (t = 1.3841, df = 27, p value = 0.1777). There was an average difference of 36.5 cm^3 in breast volume between these two techniques (95% CI of − 17.60 to 90.60 cm^3). In this assessment $p > 0.05$ confirmed the null hypothesis (H_0) of no intergroup difference.

Discussion

The main finding in the present article was that the Pessoa single marking technique [6] was similar when compared to MRI for breast volume. Postoperative prediction of breast volume is important in breast surgery planning, whether reconstructive or esthetic.

Itsukage et al. [14] reported that measuring breast volume using magnetic resonance is highly accurate, but very costly and requires data analysis software. In this study, the authors indicate mammography as an alternative to this measurement. Breast volume measurement by mammography requires only a simple formula and is sufficiently accurate, albeit less so than magnetic resonance [14].

MRI is considered the gold standard for preoperative measurement of breast volume. Reliable volumetric data can be obtained using MRI for breast implant volume and to optimize mammoplasty [15]. With a view to determining breast volume accuracy using magnetic resonance, Yoo et al. [16] assessed preoperative breast volume based on MRI and real postmastectomy volume, demonstrating a significant correlation with real breast volume and MRI. As MRI calculates breast volume with the aid of software that takes tissue density characteristics into account, similarly to that proposed by the Archimedes' principle, the position of the breast will not significantly change the calculation of volume. That is, even the prone position with the breast hanging on the breast coil, a decidedly nonanatomic position to look at the breast, will not change the volume measurement, as the breast density is the same, regardless of the position (another advantage of MRI) [15, 16].

Kayar et al. [17] studied five breast volume measurements using a comparative study of volume measurements in 30 cases of total mastectomy. In this study, preoperative breast volume was measured by five different methods: mammography, anatomic (anthropometric), thermoplastic plaster, Archimedes' principle and the Grossman–Roudner device. Kayar et al. [17] Kayar et al. [17] demonstrated that mammography is the most accurate breast volume measurement method, followed by Archimedes' method. However, when patient comfort, ease of application and cost are considered, the Grossman–Roudner device and anatomic measurements are relatively cheaper and easier to use, with an acceptable accuracy level.

Given the issues of cost, ease of use and patient comfort, new alternative accurate methods to MRI were investigated, such as studies by Kayar et al. [17] and Bulstrode et al. [18]. With the increasing popularity of 3D scanners and virtual reality 3D and 4D anatomy software, new breast volume measurements have proven to be feasible and accessible.

Kwong et al. [19] assessed the accuracy of three-dimensional surface imaging in estimating breast volume, Crisalix S.A. (Lausanne, Switzerland), when compared to anthropometric estimates and the weight of intraoperative specimens. In this study, the authors assessed twenty-five patients (41 breasts) submitted to mastectomy by preoperative scanning with Crisalix Surface Imager, and a plastic surgeon estimated anthropometric volume. Intraoperative mastectomy weights were used as gold standard. Kwong et al. [19] concluded that for breast volumes of 600 cm^3 or less, Crisalix accuracy corresponds to the anthropometric estimates provided by experienced plastic surgeons.

Vorstenbosch and Islur [20] found an esthetic similarity between preoperative 3D simulation by Crisalix and the real postoperative results of augmentation mammoplasty. The authors [20] suggested that Crisalix provides a good overall simulated 3D image of the postoperative results of breast augmentation, but they did not emphasize the accuracy of the system or compare it with other methods.

Yang et al. [21] underscored that since 3D breast surface scanning cannot scan through breast tissue or reach the interspace between the chest and the posterior and dorsal border of the breast, the inframammary fold in large breasts cannot be correctly visualized. Thus, 3D digitizing is considered inaccurate in large and or ptotic breasts. Another fact that hinders the widespread application of 3D digitizing is its high cost and lack of access [21].

The surface scanning devices such as Crisilix and Vectra have both shown difficulty in accurately assessing large volume breasts. Given the design of most surface imaging devices, various factors may contribute to the underestimation of breast volume in larger breast sizes. Firstly, the Crisalix, Axis Three and Vectra XT systems are primarily marketed for use in breast augmentation procedures. As a result, these technologies are intended to be used in patients with smaller breast sizes, which may explain their higher accuracy in this patient group. Additionally, larger breasts have a smaller surface area to volume ratio. Since surface imaging attempts to determine volume from body surface contours, the decrease in surface area relative to the volume in larger breasts may be responsible for the decreased accuracy of these imaging devices in these specimens [19].

The estimation of breast volume in patients with large droopy breasts, prominent pectoral muscles or irregularities in the axillary region has been found to be generally more difficult and less precise. Particularly with breast ptosis, the lower breast pole is in close proximity to the chest wall. In such cases, the identification of breast landmarks, especially the boundary between fatty tissue and breast tissue, is poor, and the lower surface area of the breast is concealed. These factors may contribute to the underestimation of larger breast volumes by surface imaging devices [19]. That is, unlike the measurement of breast volume by MRI, slight variabilities in the defining landmarks can culminate in errors in the volumetric determination of the breast through the use of surface scanning devices and/or through anatomic/anthropometric measurement techniques, such as the Pessoa breast measurement [6].

In the present study, breast volume measurement by Crisalix 3D software® showed a statistically significant difference when compared to MRI. Unlike the study by Kwong et al. [19], which describes good accuracy for Crisalix for breast volumes of 600 cm^3 or lower, we found no breast measured by MRI with these volumes. A possible solution for an improvement in the accuracy of the Crisalix 3D method could be to take the supine measurement. Thus, in our sample, Crisalix 3D software® was not an accurate alternative to MRI.

As mentioned above, Kayar et al. [17] studied five breast volume methods and concluded that anatomic/anthropometric measurement is relatively inexpensive and easy-to-use, with acceptable accuracy. There are several breast volume measurement techniques, including those that use rulers and/or disks. In order to facilitate anthropometric breast measurement, some authors make an analogy of the breast based on a solid of revolution (cone) [6].

Applying this geometric concept of a breast cone, Pessoa et al. [6] developed a reproducible low-cost breast volume measurement technique (Pessoa single marking [6]) that uses only anatomic parameters and the cone analogy to measure volume.

In the present study, the Pessoa breast measurement technique [6] exhibited a statistically significant difference when compared to MRI. Additionally, it is important to note that the Pessoa technique [6] shows acceptable accuracy, with an average difference of 36.5 cm^3 in breast volume measurements when compared to the gold standard. As described by Kayar *et al.* [17], anthropometric measurements are useful in measuring breast volume and should be part of a plastic surgeon's arsenal, because they are easy to obtain, practical and inexpensive.

Conclusion

When compared to MRI, breast volume measurement using Pessoa's single marking technique showed no statistically significant difference between them. However, the Crisalix 3D® technique exhibited a difference in relation to MRI. Anthropometric measurements are useful in measuring breast volume because they are easy to obtain, practical and inexpensive, and should be part of a plastic surgeon's arsenal.

Funding Authors' own funding.

Declarations

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

Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards

Informed Consent All present participants gave their written informed consent prior to enrollment in the study.

References

1. Schartzman E (1930) Die technik der mammaplastik. Chirurg 2:932
2. Ariê G (1957) Nova técnica em mamoplastia. Rev Latinoam Cir Plast 3:22–28
3. Strombeck JO (1968) Reduction mammaplasty. In: Grabb WC, Smith JW (eds) Plastic surgery. Little, Brown and Co, Boston
4. Pitanguy I (1966) Hipertrofias mamárias: estudo crítico da técnica pessoal. Rev Bras Cir 56:263
5. Skoog T (1974) Plastic surgery: new methods and refinements. Saunders, Philadelphia
6. Pessoa SGP, Dias IS, Pessoa LMGP (2009) Mastoplastia com marcação única: uma abordagem pessoal. Rev Bras Cir Plást 24(4):509–520
7. Kovacs L et al (2007) Comparison between breast volume measurement using 3D surface imaging and classical techniques. Breast 16(2):137–145
8. Cbulstrode N, Bellamy E, Shrotria S (2001) Breast volume assessment: comparing five different techniques. Breast 10(2):117–123
9. Tzou C-HJ et al (2014) Comparison of three-dimensional surface-imaging systems. J Plast Reconstr Aesthet Surg 67(4):489–497
10. Lejour M (1994) Vertical mammaplasty and liposuction of the breast. Plast Reconstr Surg 94(1):100–114
11. Killaars RC et al (2020) Clinical assessment of breast volume: can 3D imaging be the gold standard? Plastic and Reconstructive Surgery Global Open 8(11):e3236. https://doi.org/10.1097/GOX.0000000000003236
12. Eriksen C et al (2011) Evaluation of volume and shape of breasts: comparison between traditional and three-dimensional techniques. J Plast Surg Hand Surg 45(1):14–22
13. Göpper MW et al (2020) Improved accuracy of breast volume calculation from 3D surface imaging data using statistical shape models. PLoS ONE 15(11):e0233586
14. Itsukage S et al (2017) Breast volume measurement by recycling the data obtained from 2 routine modalities, mammography and magnetic resonance imaging. Eplasty 17:e39
15. Kim H et al (2015) Preoperative magnetic resonance imaging-based breast volumetry for immediate breast reconstruction. Aesthet Plast Surg 39(3):369–376
16. Yoo A, Minn KW, Jin US (2013) Magnetic resonance imaging-based volumetric analysis and its relationship to actual breast weight. Arch Plast Surg 40(3):203
17. Kayar R et al (2011) Five methods of breast volume measurement: a comparative study of measurements of specimen volume in 30 mastectomy cases. Breast Cancer Basic Clin Res 5:BCRCR2-S6128
18. Bulstrode N, Bellamy E, Shrotria S (2001) Breast volume assessment: comparing five different techniques. Breast 10(2):117–123
19. Kwong JW et al (2020) Assessing the accuracy of a 3-dimensional surface imaging system in breast volume estimation. Ann Plast Surg 84(5S):S311–S317
20. Vorstenbosch J, Islur A (2017) Correlation of prediction and actual outcome of three-dimensional simulation in breast augmentation using a cloud-based program. Aesthet Plast Surg 41(3):481–490
21. Yang J et al (2015) The three-dimensional techniques in the objective measurement of breast aesthetics. Aesthet Plast Surg 39(6):910–915