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Preoperative implant selection for two stage breast reconstruction with 3D imaging ☆

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ABSTRACT

Implants used for two-stage breast reconstruction are selected exclusively on the basis of the directly measured linear parameters. Therefore, the relevant implant is not always chosen despite the wide range of available products. The aim was to analyze the clinical usefulness of three-dimensional (3D) imaging in the breast implant selection.

In 50 patients after unilateral two-stage breast reconstruction, height, width, projection and total volume of both breasts were triply obtained with measuring tape (anthropometric method), thermoplastic casting (thermoplastic method) and 3D imaging (optical method). We measured skin fold thickness with skin caliper. In the optical method, we subtracted the covering tissues and calculated the parameter – "estimated breast implant volume" (EBIV), together with the corresponding "anthropometrically estimated breast implant volume" (aEBIV) in the anthropometric method. Reliability of the three methods was described as repeatability and accuracy, both quantified with parameters: "technical error measurement" (*TEM*) and "reliability factor" (*R*). Repeatability showed variation among the repeated measurements. Accuracy determined variability between the real volume of the implant used for reconstruction and the obtained volumetric parameters.

Repeatability was the highest for the optical method, comparing to anthropometric and thermoplastic methods ($p < 0.0001$). Accuracy was the highest in the optical method for EBIV, comparing to aEBIV in the anthropometric method and the total volume in three methods ($p < 0.0001$). Level of accuracy for EBIV was in the range of variability among the commercially available implants ($p > 0.05$).

In conclusion, implants for breast reconstruction are precisely selected with the 3D scanning method, in comparison to widely used direct measurements or thermoplastic casting.

1. Introduction

In the clinical practice, breast implants for unilateral breast reconstruction are chosen on basis of the directly measured linear parameters (height, width and projection) taken from the healthy breast [1]. The above preoperative planning contributes to the postoperative esthetic outcome with the unacceptably high degree of asymmetry seen in up to one third of patients [2]. Therefore, identification of a clinically useful, reliable method selecting the optimal implants is required in order to reduce the trauma caused by mastectomy by improving the ratio of the symmetrical reconstructed breasts [3].

Breast volume is an underrated parameter, because its standardized reliable measurement can be challenging. Numerous methods for the volumetric breast measurements were described previously, but none of them was implemented to the clinical practice [4–6]. Indeed, the water displacement method of determining breast volume is not applicable to the everyday health service [7]. The volume of the breast can also be measured with a "cast" made from gypsum or a thermoplastic material and filled with sand or water [8]. It may act as a reference method for determining breast volume in the scientific scenario; however it does not represent potential for the clinical usefulness [6]. Among

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the imaging methods used in the radiology departments, none of them is potentially useful for the breast implant selection in the clinical practice due to the high radiation dose (computed tomography), a significant cost of the test (magnetic resonance imaging), imprecision of measurements (ultrasonography, mammography), or low acceptability by patients (mammography) [9–12]. In turn, Roundner–Grossman device, approximating the breast shape into a cone, is a partially useful tool with some limitations and with no existing guidelines using it for the implant selection [13,14].

In contrast, 3D imaging is a modern, non-invasive, safe method of reproducing the digital three-dimensional copy of the patient's body contour, including the breast mound. Reliability of the method in the linear and volumetric breast measurements was confirmed in numerous reports [15–26]. However, 3D imaging is still not widely used by the surgeons, since there has been no reports describing the clinical applications of the core three-dimensional data, such as in case of the breast implant selection. Therefore, the aim of the study was to analyze the clinical usefulness of the 3D scanning method for the breast implant selection.

2. Materials and methods

In 2010–2011 we performed a prospective, randomized study after approval from the Bioethics Committee of the Medical University of Lodz in Poland (RNN/56/10/KE), from The National Health Service Lothian Research & Development Committee (NHS R&D) (2010/SJ/PS/02) and The National Health Service Research Ethics Committee (NHS REC) (10-S1101-33) in the United Kingdom.

The study was conducted in the 1st University Hospital, Lodz, Poland and in the St. John's University Hospital, Livingston, United Kingdom. The inclusion criterion was the state after unilateral two-stage breast reconstruction accomplished at least 6 months earlier. The exclusion criteria were: bilateral breast reconstruction, adjuvant radiation therapy, complications after breast reconstruction requiring additional surgery, recurrent breast cancer or apparent lymphedema. Initially, we enrolled 156 women, including 85 patients in Poland and 71 patients in the United Kingdom. The participation in our study was randomized with use of the computer program. After randomization, 32 patients in Poland and in 18 patients in the United Kingdom (altogether 50 women) aged 52.6 ± 9.7 years were ultimately included to the study.

For the study we measured the breast shape with three methods: anthropometric method, thermoplastic method and optical method. The anthropometric method used the measuring tape for direct measurements. In the thermoplastic method, a thermoplastic cast (Orfit-Eco 60 cm × 45 cm, 3.2 mm thick) was fixated and filled with dry sand. In the optical method, we took images with the customized 3D camera, which comprised two high quality video cameras with lenses uEye 5Mpix with a fixed focal length of 16 mm [4]. The resulting 3D images were subjected to computer analysis with the Antroposcan3D program, developed by one of the authors (PS) (Figs. 1a and b, 2).

Patients were positioned in the standardized manner on a calibrated seat with thighs abducted, hands placed on the hips and arms adducted [27]. In the dorsal aspect, only the interscapular area was stabilized with the customized seat, which allowed for the natural posture of the patients.

In both anthropometric method and optical method, we obtained linear parameters: width, height and projection of both breasts [28]. In the three methods we measured the volumetric breast parameters. In the anthropometric method, the total breast volume was calculated with the following formula: $V=1/3Pirh$, where r=width/2 and h=projection. In the optical method, the total breast volume was determined with the mathematical algorithm implemented to the Antroposcan3D program, as illustrated in detail in Fig. 2. In the thermoplastic method, the total volume of the reconstructed breast corresponded to the volume of the sand, which filled the "cast" of the breast mound.

In the optical method, we determined "the estimated breast implant volume" (EBIV) parameter, apart from the total volume of the breast (Figs. 1b and 2). EBIV represents the exclusive implant volume in case of the reconstructed breast or approximates the breast gland volume in the healthy breast, excluding the covering tissues. In the clinical setting, implants selected on the basis of EBIV measured from the healthy breast and used for two-stage unilateral breast reconstruction would contribute to the symmetrical breasts postoperatively. In our study, we performed preclinical trial and analyzed whether EBIV can precisely determine the implant volume in the previously reconstructed breast, which constitutes the approximated model of the breast gland lying beneath the skin envelope (obviously beneath the pectoralis major muscle). In order to determine EBIV, points on the skin surface of the 3D breast computer model are shifted automatically by the length of the vector in the direction towards the "basis" of the breast, which determines the anterior surface of the breast gland. The thickness of the skin, which was the length of the vector, was measured manually with caliper around the reconstructed breast, divided by two and used in the Anthroposcan3D program for further calculations.

In the anthropometric method, we calculated the corresponding parameter "the anthropometrically estimated breast implant volume" (aEBIV) for both reconstructed and healthy breasts. Formula for aEBIV subtracted the skin thickness from the previously mentioned formula, which calculated the total breast volume, and was modified as follows: $\mathrm{aEBIV}=1/3Pi(r-g)^2(h-g)$, where g=the skin thickness [6]. In each patient, all the above parameters, designated with three methods, were triply repeated during the same visit.

Reliability of the three methods was described by two parameters: accuracy and repeatability. Accuracy is the degree of compliance between the expected/actual/reference value and the measured value of the parameter. The reference parameter in our study for any volumetric measurements was "the actual breast implant volume" (ABIV), which was obtained from the medical records. In order to assess the accuracy, the reference parameter ABIV was compared with the volumetric parameters measured in three methods. Repeatability is the degree of variability/compliance among the repeatedly done measurements of the specific parameter. In the study, the parameters were measured three times in order to evaluate the repeatability.

The accuracy and repeatability of the analyzed parameters were described by the "technical error of measurement" (*TEM*) and the "reliability factor" (R) [29,30]. TEM was calculated with the following formula:

$$TEM=\sqrt{\frac{\sum_{i=1}^{N}\left[\sum_{j=1}^{K}(M^2)-\left(\sum_{j=1}^{K}M\right)^2\right]}{N(K-1)}}$$

where: N – number of subjects, K – number of measurements of each parameter for each patient, M – value of single measurement. *TEM* is the average difference among measurements of a specified parameter and is expressed in the defining units. The lower *TEM* value the higher is the compliance between the measurements. *TEM* was used to calculate the reliability factor $R=1-(TEM^2/SD^2)$. Value of R is between 0 and 1, specifying the degree of compliance between the measurements. The higher R value, the greater is the compliance between the measurements.