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Review

Review of three-dimensional (3D) surface imaging for oncoplastic, reconstructive and aesthetic breast surgery

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ABSTRACT

Three-dimensional surface imaging (3D-SI) is being marketed as a tool in aesthetic breast surgery. It has recently also been studied in the objective evaluation of cosmetic outcome of oncological procedures. The aim of this review is to summarise the use of 3D-SI in oncoplastic, reconstructive and aesthetic breast surgery.

An extensive literature review was undertaken to identify published studies. Two reviewers independently screened all abstracts and selected relevant articles using specific inclusion criteria.

Seventy two articles relating to 3D-SI for breast surgery were identified. These covered endpoints such as image acquisition, calculations and data obtainable, comparison of 3D and 2D imaging and clinical research applications of 3D-SI.

The literature provides a favourable view of 3D-SI. However, evidence of its superiority over current methods of clinical decision making, surgical planning, communication and evaluation of outcome is required before it can be accepted into mainstream practice.

Introduction

Contour, shape, position, volume and symmetry of the breasts are the most important factors which influence cosmesis and patient satisfaction after breast surgery [1,2]. In the pre-operative stages, all of these aspects should be critically analysed by the surgeon to determine whether surgery is indicated and, if so, what is the most appropriate type of operation. In breast cancer surgery, the primary aim of removing the cancer must be reconciled with the secondary aim of preserving (or even enhancing) breast aesthetics. Traditionally pre-operative planning and "on table" decisions are based on the surgeon's experience, anthropomorphic measurements and weight of the tissue removed.

The cosmetic success of the operation can be subjectively evaluated by patients' and surgeons' visual assessment. Independent clinicians (and/or lay people) may be recruited to perform a 'panel assessment' of photographs in which the various aspects of cosmesis such as breast shape, size and cleavage are considered in addition to overall appearance [3,4]. Such assessments are subjective and often lack accuracy and reproducibility [5,6]. Patient-reported outcome measures (PROMs) measure any aspect of a patient's health status. Various PROMs have been used to evaluate patients' satisfaction after breast surgery, for example BREAST-Q [7,8]. Despite many of these PROMs being well designed and validated, the results are the subjective views of the patient and it is not uncommon for patient satisfaction and panel assessment to give divergent results [9].

There have been many attempts to derive objective measures of outcome. Breast volume is a potentially useful measurement in planning and evaluating breast surgery. Traditionally, breast volume has been calculated using anthropomorphic methods [10,11], mammogram [12], Archimedes principle of water displacement (where the patient lowers her breast into a water-filled vessel of known volume) [13], thermoplastic/plaster casting of the breast and subsequently filling the cast to determine volume [14,15], computed tomography (CT) [16] and magnetic resonance imaging (MRI) [17]. These methods are time consuming and expensive or awkward and cumbersome for the patient. During mammography, CT and MRI the patient is leaning into the machine, supine or prone and the breast may be compressed or elongated depending on position, therefore is not representative of the patient's appearance

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when standing. Further details of comparison of these techniques are summarised in a review [18].

In the 1970s, Edstron described‘ split and reversed negatives’ where photographic negatives of the left and right breast were processed and laid next to the non-negative right and left breast. The constructed images of perfectly symmetrical breasts were compared with the original photographs of the patients' breasts [19,20]. Linear measurements between two landmarks on the torso, known as anthropometry have been used to objectively quantify aesthetics. Measuring parameters such as breast projection has limitations due to correctly identifying the underlying chest wall, and is prone to intra- and inter-observer error. Calculating measurements from photographs, known as photogrammetry an alternative though it may be more difficult to identify some of the anatomical landmarks [21]. Two software systems have been developed to objectively evaluate the aesthetic surgical outcomes of breast surgery using two-dimensional (2D) photographs. The Breast Analysing Tool (BAT©) [22] evaluates symmetry by comparing breast area, breast circumference and nipple position between the breasts. The Breast Cancer Conservative Treatment cosmetic result (BCCT. core) software [23,24] performs similar symmetry calculations and also analyses colour differences and the appearance of the scar. Further details of methods of assessing cosmetic results after breast surgery are described in recent articles by Cardoso et al. [21,25,26], Oliveira et al. [27] and Kim et al. [6].

The use of 3D-SI in the clinical setting was first described by Burke and Beard [28,29] in 1967 to analyse facial structures. Recently 3D-SI has been used as a research and clinical tool in aesthetic, oncoplastic and reconstructive breast surgery (which will hereafter be referred to as breast surgery). Initial studies established the optimal technique to obtain images and tested accuracy and reproducibility [30–38]. Subsequent case series have examined the use of 3D-SI in clinical practice.

The aim of this review is to summarise the use of 3D-SI (photography and laser) in the field of breast surgery to give the reader a broad overview of the research and clinical uses of 3D-SI and to consider whether current limitations are likely to be overcome.

Methods

Search criteria

A literature search was conducted in January 2015 using PubMed, MEDLINE, EMBASE, SCOPUS, CINAHL, Thomas Reuters Web of Science, The Cochrane Library, including the Cochrane Database of Systematic Reviews (CDSR), Cochrane Central Register of Controlled Trials (CENTRAL), Database of Abstracts of Reviews of Effect (DARE), the Cochrane Methodology Register, Health Technology Assessment Database, the NHS Economic Evaluation Databases and Cochrane Groups. The search terms used were: ‘3D’, ‘3-D’, ‘3-Dimensional’, ‘3 Dimensional’, ‘three-dimensional’, ‘three dimensional’, ‘stereo-photogrammetry’ and ‘breast’.

Inclusion, exclusion criteria and endpoints

Two reviewers independently screened all results and selected the relevant articles using specific criteria (Table 1). The references from all the articles identified were examined for further relevant studies.

Specific endpoints were identified:

1. Image acquisition
2. Calculations and data obtainable with 3D-SI
3. Comparison of 3D-SI with 2D imaging
4. Clinical research applications of 3D-SI

Table 1
Predetermined inclusion and exclusion criteria for literature search.

Inclusion criteria
Primary data from prospective and retrospective studies
Human studies
Data included outcome results from 3D-SI
Exclusion criteria
Techniques, technical reports, letters
Did not undergo peer review
Outcomes were not related to oncoplastic or aesthetic breast surgery outcomes (e.g. radiotherapy planning)
No extractable outcomes
Not published in English

Data abstraction

The data were extracted from studies satisfying the inclusion criteria and verified by two independent authors. Disagreements were resolved by consensus. Included studies investigated the use of 3D surface imaging (3D-SI), but none compared patient outcomes with and without 3D-SI as part of their management, therefore no specific statistical analysis or meta-analysis was possible.

Results

Four thousand and fifty citations were identified by the search. The search was narrowed as shown in the attrition diagram (Fig. 1). In order to summarise the literature we will explain the methods of 3D-SI, describe their use in the calculation of volume and contour asymmetry and report on clinical applications and limitations.

Image acquisition

3D surface imaging of the breast can be achieved by laser scanning or photography (also known as stereo-photogrammetry). 3D laser scanning images are achieved by the principle of triangulation: a laser beam is projected on the patient's torso, the rays are reflected and captured by a detector which is sensitive to their orientation [32,39]. The locations of all of the reflecting point on the torso's surface can then be determined in three dimensions. Several single images are taken from multiple angles. This may be done using one laser taking sequential shots or simultaneous lasers. The breast region of interest is either marked on the patient before the scan according to a pre-defined protocol or can be placed on the 3D image. Using computer software, a 3D image is constructed from which calculations can be made.

3D photographic images are achieved by perceiving the same object from several different viewpoints (as in binocular vision) [40]. Up to twelve synchronized cameras located in pairs at various heights and angles take photographs of the breast region. Spatial computation of x, y and z coordinates of individual points are then configured using computer software to generate a 3D image. As with 3D laser scanning, marks are placed on the patient's torso or on the image generated to define the region of interest.

A recent review by Tzou et al. compared five of the current 3D-SI technologies on the market, 3dMD, Axisthree, Canfield, Di3D and Crisalix [41], therefore further details of these devices have not been documented in this review. Fig. 2 shows one of the 3D-SI systems available. The majority of the systems currently in use are heavy and bulky which limits the use of the imaging to one room or a single hospital. However newer versions of the equipment are have been developed that smaller, more portable and cost effective [42–45].