

A Novel Approach for Quantifying Skin Growth in Patients Undergoing Expander-Based Breast Reconstruction

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Introduction

Tissue expansion protocols for breast reconstruction are highly variable among surgeons and institutions. Animal studies in a porcine model of tissue expansion have relied on skin tattooing to standardize and predict expansion-induced skin growth, as estimated by the amount of total in-vivo deformation calculated by multi-view stereo and isogeometric analysis (IGA). However, an investigation of expansion-induced skin growth has not been performed in humans, and studies are limited by absence of a standardized methodology. Here, we will utilize our knowledge of IGA in the porcine model to develop a standardized approach for tracking skin growth in human patients undergoing expander-based breast reconstruction without the use of invasive tattoo-based methodology.

Methods

Female Yucatan minipigs underwent tattooing of 10-by-10 cm grids and placement of subcutaneous tissue expanders below the grids. Female human patients were marked at several fixed bony anatomic landmarks that remain unchanged throughout reconstruction, including the clavicle, sternal notch, xyphoid, and midline connecting the notch and xyphoid. Four additional marks were made between the nipple and base of the breast in each quadrant to further orient the 3D camera (VECTRA®H2 from Canfield Scientific, Parsippany, NJ, USA) to the breast topography. All markings were made with patients lying flat to avoid variation due to skin draping. In both models, 3D images were generated based on the fixed markings and compared across a consistent coordinate system to allow for direct calculation of skin growth from pre- to post-expansion.

Results

Expanded swine skin demonstrates spatial differences of skin growth within each grid, with highest growth experienced at the point of maximal stretch (Fig. 1). Total deformation in female patients is determined by superimposing pre- and postoperative 3D photographs standardized to markings of fixed landmarks (Figs. 2 and 3).

Results

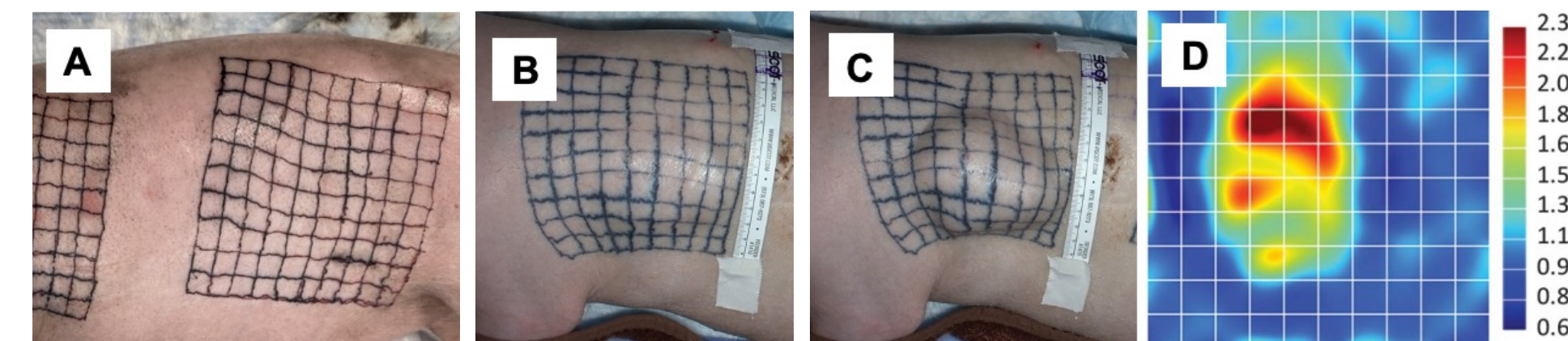


Figure 1. (A) 10 x 10 cm grids were tattooed onto anterior and posterior flanks. (B) Tissue expanders were placed into subcutaneous pockets deep to the grids and (C) inflated with 30cc of sterile saline. (D) Isogeometric analysis demonstrates deformation of the skin. Each colored box corresponds to a square of grid. Deformation values are reported as coefficients representing the relative change in area of each square from pre- to post-expansion.

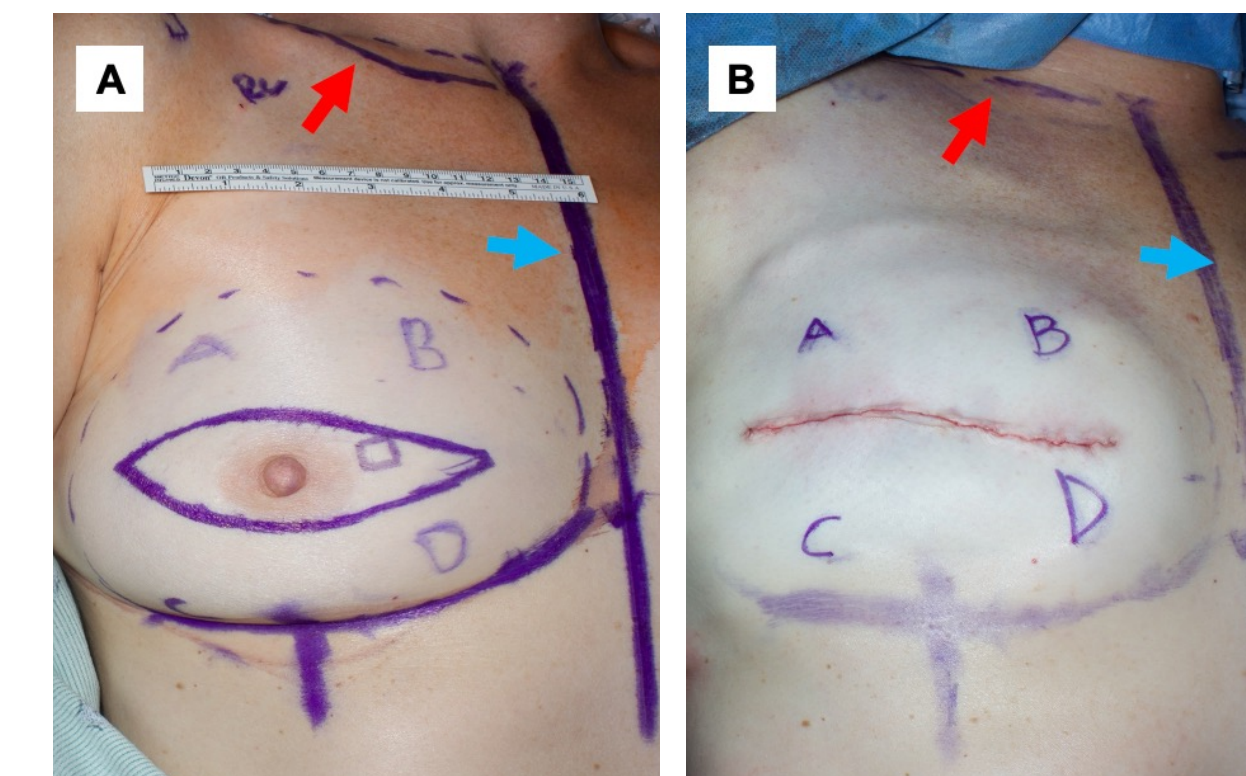


Figure 2. Markings of fixed landmarks with patient supine and flat (A) preoperatively and (B) postoperatively after mastectomy and tissue expander placement without base fill. Markings include the clavicle (red arrows), midline overlying the sternum from sternal notch to xyphoid process (blue arrows), and letters A-D in each of the breast quadrants.

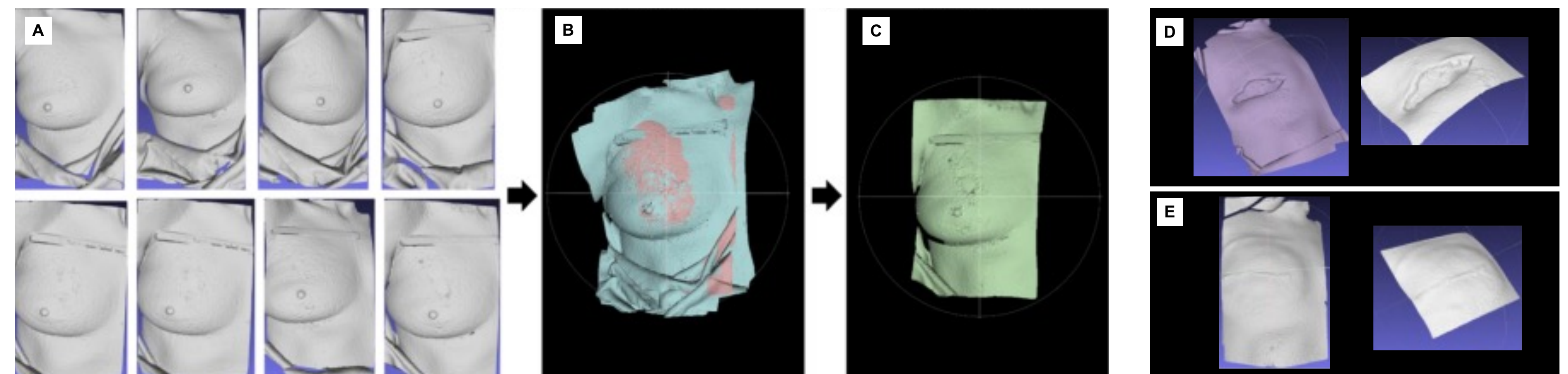


Figure 3. (A) Collection of 3D photographs for human patient. (B) Photographs are aligned and (C) create a single 3D geometry prior to mastectomy, (D) after mastectomy, and (E) after expander placement and skin closure.

Conclusions

We demonstrate clinical translation of our prior work and proof of concept of a new approach to study human skin growth in response to tissue expansion. Further patient enrollment is needed to validate this framework in clinical settings; however, our novel breast model has the potential to optimize reconstructive efforts with respect to expansion variables such as fill volumes and frequency of expansion. This new standardized methodology for the study of breast tissue expansion can be modified and applied to other areas where tissue expansion reconstruction is used and understand variable responses of human skin to different expansion protocols, as well as the mechanics of skin in different anatomic sites subjected to expansion.

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