# An Interactive Web-Based Tool for Breast Reduction Surgery Simulation

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## ABSTRACT

In this work, we present a 3D web-based interactive tool for numerical modeling and simulation approach to breast reduction surgery simulation, to assist surgeons in planning all aspects related to breast reduction surgery before the actual procedure takes place, thereby avoiding unnecessary risks. In particular, it allows the modeling of the initial breast geometry, the definition of all aspects related to the surgery and the visualization of the post-surgery breast shape in a realistic environment.

**Keywords:** Breast Reduction Surgery, Numerical Surgery Simulation, Interactive visualization, X3D, X3DOM, HTML5.

**Index Terms:** H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical user interfaces (GUI); I.6.7 [Simulation and Modeling]: Simulation Support Systems—Environments; J.3 [Life and Medical Sciences]: Health

## 1 INTRODUCTION

Any surgery procedure has potential post-surgical risks for the patient's health, and should be planned in advance of the actual surgery. In the last decade, the number of health-related software simulation systems had continually increased, having become increasingly sophisticated, reaching a high level of realism, with a complete immersion in a 3D world to simulate a physician in a hospital. Another class of software is concerned with the numerical simulation of specific organs such as the heart, liver or bones, resorting to a physics-based model. In the case of surgery procedures, several models and studies have been carried out to numerically simulate [3] the operation and thereby assess the risks and results.

Breast reduction surgery is a very sensitive process which may generate potential post-surgery problems at both the aesthetic and functional levels. To prevent and minimize the risks associated with the surgery, simulation of the entire procedure; namely cutting, knitting and suturing, turns out to be an efficient tool in order to evaluate the final breast shape and to adapt the surgery procedure to get the optimal aspect.

The advantage of using simulation techniques to simulate surgeries is that surgeons can experiment with all parameters involved in a specific surgery and adjust them, in order to get the desired post-surgery result. In breast reduction surgery this is particularly important, as the breast shape is quite important for the patient, both from the aesthetic and functional points of view. With such a tool, the surgeon and patient can work together on the desired result, so that there will be no surprises or problems that would be hard fix once the procedure is completed.

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In this work we present a numerical modeling and simulation approach to breast surgery reduction, together with an easy to use, three dimensional user interface, that allows surgeons to model all aspects of the surgery, inspect and interact with the breast model in a 3D environment, in order to evaluate the post-surgery breast shape. In particular, it allows the modeling of the initial breast geometry, the definition of all aspects related to the surgery and the visualization of the post-surgery breast shape in a realistic environment. This enables surgeons to study the procedure prior to the surgery occurs, so as to take the necessary measures to obtain the desired breast shape.

## 2 MODELING AND SIMULATION PROCESS FOR BREAST SURGERY REDUCTION

Breast reduction surgery consists of three steps, all of them affecting the final breast shape. First, the surgeon moves the nipple into a new position and incisions are made on the breast. These are made along two planes orthogonal to the chest and two other planes, oblique to the chest. After all incisions are complete, the front incisions are sutured. In a final step, the incisions made by the oblique plane are sutured against the chest.

The simulation software we developed follows the same approach as that used by surgeons on real surgeries, namely:

1. **Step 1 - Breast geometry**: In the first step, the surgeon models the patient's breast and defines the incisions markers that will be used as guides to perform the surgery.

2. **Step 2 - Breast surgery**: Step 2 is where the surgery simulation takes place, allowing the surgeon to pre-evaluate the post-surgery breast shape in a gravity-free environment. The surgery simulation can be adjusted by tweaking parameters, related to physical laws governing the breast dynamics and the suturing process.

3. **Step 3 - Final evaluation**: In a final step, surgeons can evaluate the final breast shape under the effect of gravity and under different conditions. If the resulting post surgery shape is not the intended one, the surgeon can make the necessary upstream parameter adjustments, in order to reach the desired final shape.

### 2.1 Modeling and numerical method

The breast model we use is based on the non-linear elasticity system presented in [2], where the unknown is the displacement field $u$ with respect to an initial configuration. The initial breast (before cutting) is a portion of sphere where we distinguish three specific sub-domains: the breast skin, the inner breast and the contact interface between the breast and the body called the *Chassignac space*. For each sub-domain, we define an energy functional, parametrized by the displacement field $u$ which physically represents the energy one has to bring to obtain the new configuration characterized by $u$. Applying external forces such as gravity, a new resting equilibrium configuration provides the displacement $u$ given, by minimizing the sum of all the energies (internal and external). From the mathematical point of view, one has to determine the minimizer of the energy

functional, $u$. From the numerical point of view, we use a mesh of the three-dimensional domain made of tetrahedrons. We then evaluate the energy for each cell, as a function of the node displacements gathered in vector $U$. Summation over the cells provides the discrete energy parameterized by $U$. We seek the vector $U$ which minimizes the total energy using a Newton-like method; this corresponds to the new static equilibrium.

The procedure we have described does not take into account the cutting, knitting and suturing process. To this end, an extra effort is required to define the cut planes, to mesh the new domain and define the mathematical and numerical process to join the planes (the knitting condition) to perform the suturing. The resulting new static configuration is a displacement field $u$, which minimizes the energy after connecting the planes. The final configuration depends on the parameters of the cuts the practitioner has chosen and the suturing conditions (i.e. how the two parts are joined).

## 3 HYBRID WEB INTERFACE FOR BREAST REDUCTION SURGERY

To allow an easy usage of the simulation software by surgeons, we decided to adopt a web based interface, relying on both 2D and 3D interactive graphics to model and visualize all aspects related to the surgery simulation process as well as to interact with with the breast model. Surgeons may easily tweak several surgery related parameters and quickly evaluate the outcome. The interface is divided in 3 parts, following the same structure as the simulation process described in Sec. 2.

We adopted JSXGraph [4] for the 2D graphics, a JavaScript library that enables the creation of interactive 2D geometric graphics. As for 3D graphics, we used X3DOM [1], an open-source framework and runtime for presenting interactive 3D graphics in web pages.

### 3.1 Step 1: Breast Geometry

In this first step, the surgeon can perform two major activities: (1) model the basic geometry of the breast and (2) define the incisions that will be made to achieve the desired reduction.

To do so, surgeons can alternate between have two input methods to define the breast model and the surgery incisions: (1) They can interact with a 2D model of the breast model, including the surgery incisions; or (2) they can enter specific numerical values for each of the parameters that define the breast model and surgery incisions. Figure 1 presents the interface for this step. Surgeons can interact with the 2D model by moving the control points (in red), thereby changing the parameters that define both the breast model and surgery incisions.

To help visualize the breast model and the incisions, surgeons can visualize and interact with a 3D model of the breast shape. Surgeons can interact with the 3D model by using their mouse to change the view and to rotate rotate the model, the scroll wheel to zoom, and the middle button to pan. By default, this 3D model is *minimized*, and can be *maximized* at any given moment, taking over the main pane of the interface.

### 3.2 Step 2: Breast Surgery

The results of the surgery simulation process are presented at this stage. Since the suturing process doesn't take into account the gravity field, which can be neglected [2], the results of this stage consider a gravity-free environment. This allows for an immediate pre-evaluation of the breast shape after the suturing process, while the breast is on it's free form. Surgeons may navigate around the post-surgery breast model in a 3D environment, in the same way as in the previous step, thereby allowing a preliminary evaluation of the overall surgery.

If the surgeon is not satisfied with results, adjustments may be made to several parameters related to the physical laws of the breast
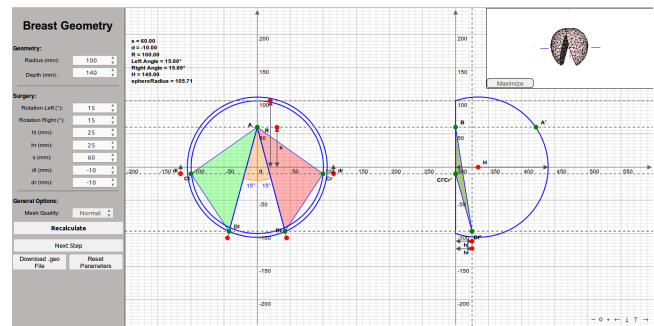


Figure 1: Step 1 - Breast geometry and surgery incision.

dynamics, e.g. breast skin thickness and density, all influencing the post-surgery breast shape. The surgeon may also go back to step 1 and redefine the basic breast geometry and surgery incisions.

### 3.3 Step 3: Final evaluation

In this final step, surgeons can visualize and interact with the post-surgery breast model in a 3D environment, as in the previous steps, while the breast is affected by gravity force. This allows surgeons to visualize the breast deformation in realistic conditions and evaluate if the post-surgery breast shape is the desired one for the patient, considering both aesthetic and functional aspects.

During this evaluation, the surgeon may also simulate several patient positions, e.g.: *Standing up, Lying face up, Lying face down e Lying on the side, Standing while bending forward (45º)*. This allows studying the breast deformation in different conditions. This is achieved by changing the gravity vector applied to the breast. The surgeon may also dial in a specific gravity vector, in order to evaluate the behavior in any situation.

## 4 CONCLUSIONS AND FUTURE WORK

Although this work is still at an early stage, our tool has already been used by surgeons for evaluation purposes. This revealed that the simulation results are quite close to reality. It also became clear that the simulator tool is useful for surgeons, helping in planning surgeries in advance.

There remains work to be done, namely in the underlying mathematical models and in the methods used to model a specific patient's breast. We plan to use several forms of 3D scans of actual patient's breasts, in order to construct the base model parameters, thereby increasing the accuracy of the breast model.

### REFERENCES

[1] J. Behr, P. Eschler, Y. Jung, and M. Zöllner. X3DOM: a DOM-based HTML5/X3D integration model. In *Proceedings of the 14th International Conference on 3D Web Technology*, pages 127–135. ACM, 2009.

[2] S. Clain, G. J. Machado, R. M. S. Pereira, and G. Smirnov. Soft tissue modelling for analysis of errors in breast reduction surgery. *11th World Congress on Computational Mechanics (WCCM XI)*, pages 1–10, 2014.

[3] A. N. Cotin S., Delingette H. A hybrid elastic model for real-time cutting. *The Visual Computer*, 16(8):437–452, 2000.

[4] M. Gerhauser, B. Valentin, and A. Wassermann. Jsxgraph–dynamic mathematics with javascript. *International Journal for Technology in Mathematics Education*, 17(4):211–215, 2010.