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ORIGINAL ARTICLE BREAST SURGERY

Correlation of Prediction and Actual Outcome of Three-Dimensional Simulation in Breast Augmentation Using a Cloud-Based Program

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Abstract
Background Breast augmentation is among the most frequently performed cosmetic plastic surgeries. Providing patients with "realistic" 3D simulations of breast augmentation outcomes is becoming increasingly common. Until recently, such programs were costly and required significant equipment, training, and office space. New simple user-friendly cloud-based programs have been developed, but to date there remains a paucity of objective evidence comparing these 3D simulations with the post-operative outcomes.
Objectives To determine the aesthetic similarity between pre-operative 3D simulation generated by Crisalix and real post-operative outcomes.
Methods A retrospective review of 20 patients receiving bilateral breast augmentation was conducted comparing 6-month post-operative outcomes with 3D simulation using Crisalix software. Similarities between post-operative and simulated images were measured by three attending plastic surgeons and ten plastic surgery residents using a series of parameters.
Results Assessment reveals similarity between the 3D simulation and 6-month post-operative images for overall appearance, breast height, breast width, breast volume, breast projection, and nipple correction. Crisalix software generated more representative simulations for symmetric breasts than for tuberous or ptotic breasts. Comparison of overall aesthetic outcome to simulation showed that the post-operative outcome was more appealing for the symmetric and tuberous breasts and less appealing for the ptotic breasts.
Conclusions Our data suggest that Crisalix offers a good overall 3D simulated image of post-operative breast augmentation outcomes. Improvements to the simulation of the post-operative outcomes for ptotic and tuberous breasts would result in greater predictive capabilities of Crisalix. Collectively, Crisalix offers good predictive simulations for symmetric breasts.
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 http://www.springer.com/00266.

Keywords Breast augmentation · Pre-operative planning · Three-dimensional simulation

Introduction

Breast augmentation is the most commonly performed cosmetic surgery, with over 300,000 procedures performed in the USA in 2011 alone [1]. The demand for breast augmentation coupled with the numerous surgeons available to perform this procedure drives the evolution of the pre-operative assessment to improve patient-reported surgical outcomes. Tebbetts developed the "High Five" system which evaluates factors including soft-tissue coverage, implant characteristics, inframammary fold location, and incision location [2]. Of these, breast base diameter and implant volume have been shown to have the greatest impact on patient-reported outcomes [3]. While assessment of these criteria yielded substantial increases in patient satisfaction, careful understanding of the patients' wishes and desires remains of paramount importance in surgical planning.

Recent developments have emerged allowing patients to better understand how they will look and feel post-

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operatively. Commonly patients will be sized using an implant in a larger bra, which has been demonstrated to improve post-operative patient satisfaction overall and with respect to breast size [4]. Computer imaging has also evolved, allowing patients to visualize how their breasts could look post-operatively. The Vectra 3D system has recently been reported to improve overall patient satisfaction and to increase the consult-to-surgery conversion rate [5]. Despite the significant technical advances with the Vectra 3D system, it requires substantial initial costs and specialized three-dimensional photography equipment [6].

A recent review highlights the several technological advancements in aesthetic surgery imaging and describes the relative ease and low costs associated with the Crisalix system for three-dimensional breast augmentation simulation [7]. The Crisalix system is cloud based, requiring the surgeon to upload digital photographs and to input minimal information to compute the three-dimensional simulation [8]. However, despite the vast potential of this program, only a few cases of the three-dimensional simulation compared with post-operative results have been published.

The present study evaluates the extent to which Crisalix software generates three-dimensional simulation of actual post-operative outcomes.

Materials and Methods

Image Acquisition

Images of pre-operative assessment and 6-month post-operative follow-up were collected from 20 consecutive patients receiving breast augmentation in 2014 performed by a single surgeon. One frontal and two lateral two-dimensional pre-operative images were retroactively uploaded to the secure Crisalix (Crisalix Corporate, Lausanne, Switzerland) server to generate three-dimensional simulation for the purpose of this study. Three-dimensional simulations were not shared with the patients. Input parameters of the simulation including implant size, shape, and insertion plane (sub-glandular or sub-muscular) were determined by what was used intra-operatively. Images were then assembled to include pre-operative photographs, 3D simulations, and post-operative photographs for assessment by the evaluators (Fig. 1). For this type of study, formal consent is not required. Patient photographs did not show patient faces, and no identifying information was uploaded to Crisalix.

Inclusion Criteria

Twenty consecutive patients with pre-operative photographs presenting for 6-month follow-up were included in the study. The sample size of 20 was chosen to gain a preliminary assessment of the similarity of Crisalix simulations to post-operative outcome. Each patient underwent breast augmentation with smooth, round implants manufactured by Mentor (Johnson and Johnson, Santa Barbara, CA, USA). There were no exclusions based on original breast symmetry, ptosis, or tuberous breasts. No patients reported any post-operative complications at their 6-month follow-up visit.

Outcomes Measures

The images were evaluated by three attending plastic surgeons who routinely perform breast augmentation and by ten plastic surgery residents for all of the following

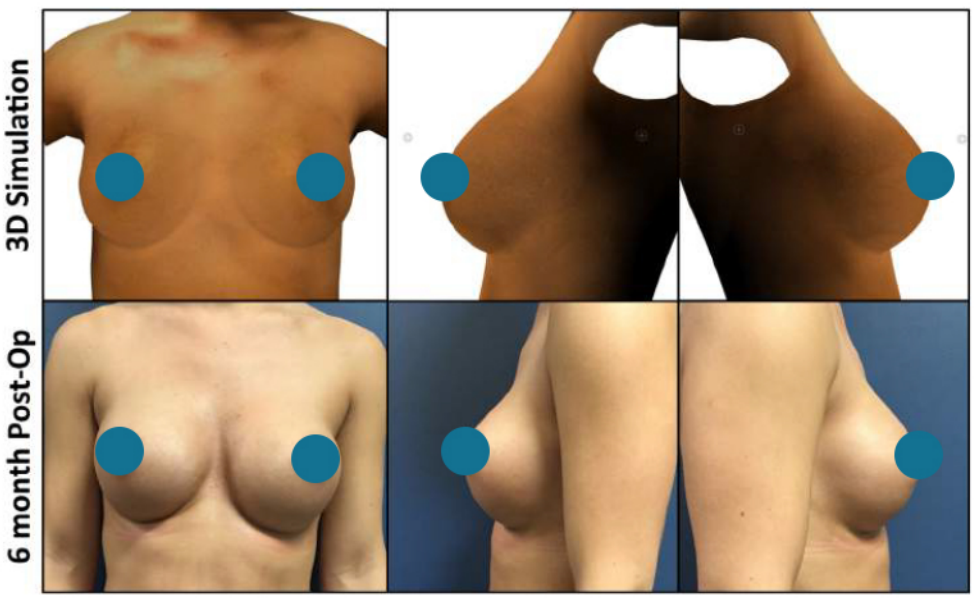


Fig. 1 Example of slide presented to evaluators. For each patient, evaluators were presented with images depicting anterior, left lateral, and right lateral views of the 6-month post-operative outcome and the three-dimensional simulation. The image shown here was selected at random from one of the 20 patients included in this study

parameters comparing the three-dimensional simulation to the post-operative outcome. Images were assessed for overall appearance, breast width, breast height, projection, volume, and nipple correction. Each evaluator assigned a score from 0 to 100 reflecting the degree of similarity between the three-dimensional simulation and the photograph of the actual post-operative outcome for each of the aforementioned parameters. Evaluators were advised that a score of 75 represents a good simulation. Each evaluator also assigned each patient a score to indicate whether the post-operative outcome was superior (+1), similar (0), or inferior (−1) to the three-dimensional simulation.

Data Analysis

The mean and standard deviation of each of the six measured parameters comparing the three-dimensional simulation and post-operative images were calculated and stratified by resident/attending and by symmetric/tuberous/ptotic breasts. Stratification was processed after data collection to assess for variability in accuracy of simulation. Consensus among attending plastic surgeons participating in the study classified pre-operative breasts as symmetric, tuberous, or ptotic. In cases of partially completed scores for a given simulation, all scores from that observer for that case were omitted. The proportion of the overall scores assigned to assess the overall difference between the three-dimensional simulation and the actual post-operative outcome was calculated as an average. Assessment of correlation between the resident and attending groups was evaluated with *t* test using Microsoft Excel, with a value of $p < 0.05$ being deemed significant. Assessment of correlation by breast deformity among symmetric, tuberous, and ptotic breasts was assessed using one-way ANOVA with the StatPlus:mac (Analystsoft Inc, Walnut, CA, USA) plugin for Microsoft Excel.

Results

Quantitative Assessment of Three-Dimensional Simulation

Three-dimensional simulation of post-operative breast augmentation was conducted retrospectively on 20 consecutive female patients with a mean age of 31.7. Comparison of post-operative outcomes to three-dimensional simulation generated by Crisalix software by attending plastic surgeons and plastic surgery residents reveals moderate similarities across each of the evaluated parameters (Table 1; Fig. 2). Evaluators were instructed that a score of 75 represents a good simulation. The parameters overall appearance, width, height, projection, volume, and nipple correction received scores ranging from 54.8 to 59.4.

Table 1 Quantitation of image evaluation

Parameter	Average	SD
Overall appearance	54.8	21.7
Width	59.4	45.5
Height	55.9	23.3
Projection	55.6	24.7
Volume	55.8	24.1
Nipple correction	56.2	26.1

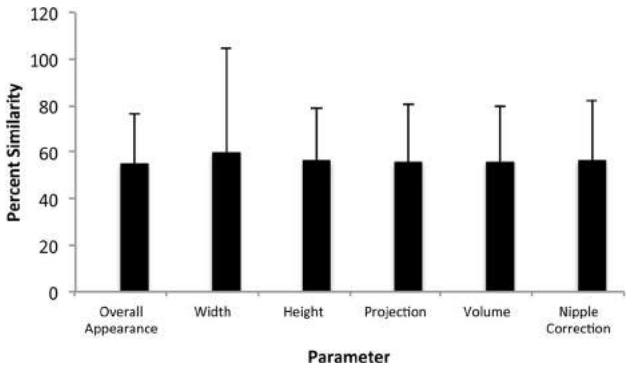


Fig. 2 Quantitation of image evaluation graph depicting quantification of similarity between three-dimensional simulation and post-operative outcome for overall appearance, width, height, projection, volume, and nipple correction from all 20 subjects evaluated. Data listed represent mean scores ± SD. Please see Table 1 for numerical data

Attending Plastic Surgeons Noted Greater Similarities in Simulation than Plastic Surgery Residents Between Three-Dimensional Simulations

Stratification of the quantitative assessments of the Crisalix generated three-dimensional simulation of breast augmentation by attending surgeons compared to residents demonstrates that attending surgeons noted greater similarity compared to plastic surgery residents (Table 2; Fig. 3). On average, attending plastic surgeons assigned 16.2 more points to the simulations than the plastic surgery residents. As outlined in Table 2, the plastic surgery residents assigned scores ranging from 51.3 to 55.9 for the evaluated parameters, while the attending plastic surgeons assigned scores ranging from 61.5 to 71.5. Significant differences in scores assigned were observed between residents and attendings, with $p < 0.05$ for each parameter evaluated.

Table 2 Quantitative image evaluation—stratified by resident and attending

Parameter	Resident		Attending		
	Average	SD	Average	SD	*p* value
Overall appearance	52.8	19.9	61.5	26.1	0.003
Width	55.9	50.2	71.5	19.2	0.010
Height	51.7	21.8	70.2	22.9	0.000
Projection	52.1	22.9	67.5	27.6	0.000
Volume	51.3	22.6	71.1	23.1	0.000
Nipple correction	51.8	23.9	71.4	27.8	0.000

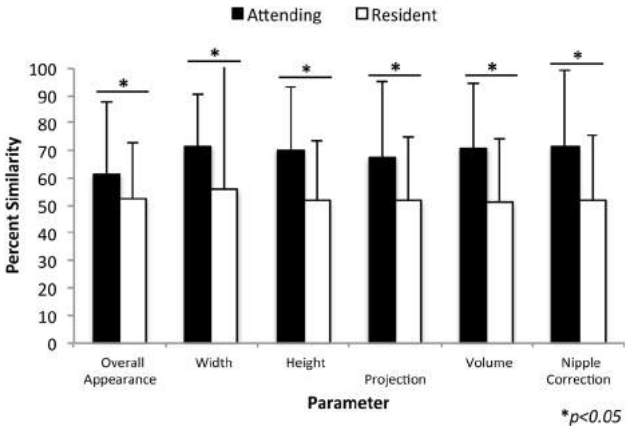


Fig. 3 Quantitative image evaluation stratified by resident and attending. Graph depicting quantification of similarity between three-dimensional simulation and post-operative outcome for overall appearance, width, height, projection, volume, and nipple correction from all 20 subjects evaluated stratified by resident (ten evaluators) and attending (three evaluators). Please see Table 2 for numerical data. Data listed represent mean scores ± SD and were compared between groups by *t* test. $*p < 0.05$

Breast Deformity Compromises Quality of Three-Dimensional Simulation of Breast Augmentation

Three-dimensional simulation of symmetric breasts demonstrated greater resemblance to post-operative outcomes than simulation of ptotic or tuberous breasts (Tables 3, 4; Figs. 4, 5, 6, 7). As described in Table 3, scores assigned by attending surgeons to symmetric breasts ranged from 67.9 to 76.3, while for tuberous breasts they only ranged from 55 to 75 and for ptotic breasts from 50.6 to 65.6. Plastic surgery residents similarly assigned lower scores to the simulations for the ptotic and tuberous breasts compared to the symmetric breasts, although with lower scores for each of the three categories compared to the attending plastic surgeons. Differences between residents and attendings were significant ($p < 0.05$) for all parameters and breast types except for tuberous overall score ($p = 0.122$), ptotic height ($p = 0.051$), and ptotic projection ($p = 0.069$). Further assessment of correlation between the symmetric, tuberous, and ptotic breasts (Table 4; Fig. 4) reveals significant differences ($p < 0.05$) across each parameter for the resident evaluations and the residents and attending evaluations combined, but only for width, height, and volume for the attending evaluations as assessed by *one-way ANOVA*.

Images of the Actual Post-operative Outcomes for Symmetric and Tuberous Breasts were Cosmetically Superior, and Ptotic Breast Outcomes were Cosmetically Inferior to Three-Dimensional Simulation

Each evaluator was instructed to assess whether the actual post-operative breast augmentation outcome was superior, similar, or inferior to the three-dimensional simulation by assigning a score of +1, 0, and −1, respectively, to each of the image sets (Table 5; Fig. 8). The three-dimensional simulations were more representative of symmetric breasts (more equal) than tuberous or ptotic breasts. Also, the three-dimensional simulation was deemed to be aesthetically superior to the actual post-operative outcome for the evaluated ptotic breasts, while the simulation was aesthetically inferior to actual operative outcome for tuberous breasts. Stratification by plastic surgery resident and attending plastic surgeons yielded similar perceptions of the proportion of simulations that were superior to the post-

Table 3 Quantitative image evaluation—stratified by breast deformity, sub-stratified by resident and attending

Parameter	Symmetric			Tuberous			Ptotic		
	Resident	Attending	*p* (*t* test)	Resident	Attending	*p* (*t* test)	Resident	Attending	*p* (*t* test)
Overall appearance	57.9 ± 17.9	67.9 ± 20.6	0.001	45.4 ± 18.5	55 ± 28.6	0.122	36.2 ± 19.6	55.6 ± 23.5	0.009
Width	58.6 ± 18.2	76.1 ± 15.4	0.000	37.9 ± 17.9	55.6 ± 20.8	0.009	39.8 ± 19.8	63.3 ± 28.3	0.004
Height	56.5 ± 20.3	74.9 ± 18.1	0.000	41.2 ± 19.7	63.3 ± 25.5	0.005	39.3 ± 21.7	55.6 ± 35.4	0.051
Projection	56.4 ± 21.9	71.2 ± 25.4	0.000	46.3 ± 19.0	75 ± 12.2	0.000	36.9 ± 21.6	50.6 ± 29.5	0.069
Volume	55.5 ± 22.0	76.3 ± 18.9	0.000	44.1 ± 16.6	58.3 ± 25.7	0.030	39.8 ± 23.2	59.4 ± 25.1	0.018
Nipple correction	55.8 ± 22.6	73.8 ± 24.6	0.000	43.0 ± 21.3	66.1 ± 29.8	0.007	41.3 ± 27.6	65.6 ± 40.0	0.024

Table 4 Quantitative image evaluation—correlation of parameters stratified by breast deformity

	Symmetric	Tuberous	Ptotic	*p* (ANOVA)
Overall appearance				
Resident	57.9	45.4	36.2	1.57E−08
Attending	67.9	55	55.6	0.145
Combined	60.2	47.7	40.8	3.27E−08
Width				
Resident	58.6	37.9	39.8	7.51E−10
Attending	76.1	55.6	63.3	0.00668
Combined	62.6	42.2	45.4	2.90E−10
Height				
Resident	56.5	41.2	39.3	6.14E−06
Attending	74.9	63.3	55.6	0.0455
Combined	60.7	46.6	43.2	2.26E−06
Projection				
Resident	56.4	46.3	36.9	0.00279
Attending	71.2	75	50.6	0.0568
Combined	59.9	53.2	40.1	1.58E−05
Volume				
Resident	55.5	44.1	39.8	3.30E−04
Attending	76.3	58.3	59.4	0.0172
Combined	60.3	47.6	44.5	3.84E−05
Nipple correction				
Resident	55.8	43	41.3	0.00120
Attending	73.8	66.1	65.6	0.602
Combined	59.9	48.6	47.1	0.00315

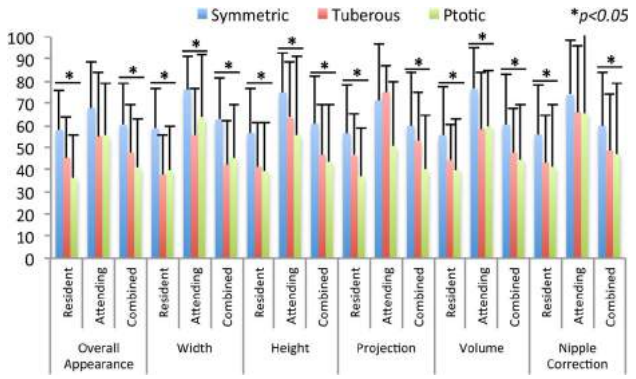


Fig. 4 Quantitative image evaluation—stratified by breast deformity, sub-stratified by resident and attending. Graph depicting quantification of similarity between three-dimensional simulation and post-operative outcome for overall appearance, width, height, projection, volume, and nipple correction, stratified by patients with symmetric ($n = 14$), tuberous ($n = 3$), and ptotic ($n = 3$) breasts. Data were further stratified by resident, attending, and combined (resident + attending) evaluations. Please see Table 4 for numerical data. Data listed represent mean scores ± SD, and assessment of correlation of breast deformity within each evaluator group was conducted by *one-way ANOVA*. *$p < 0.05$

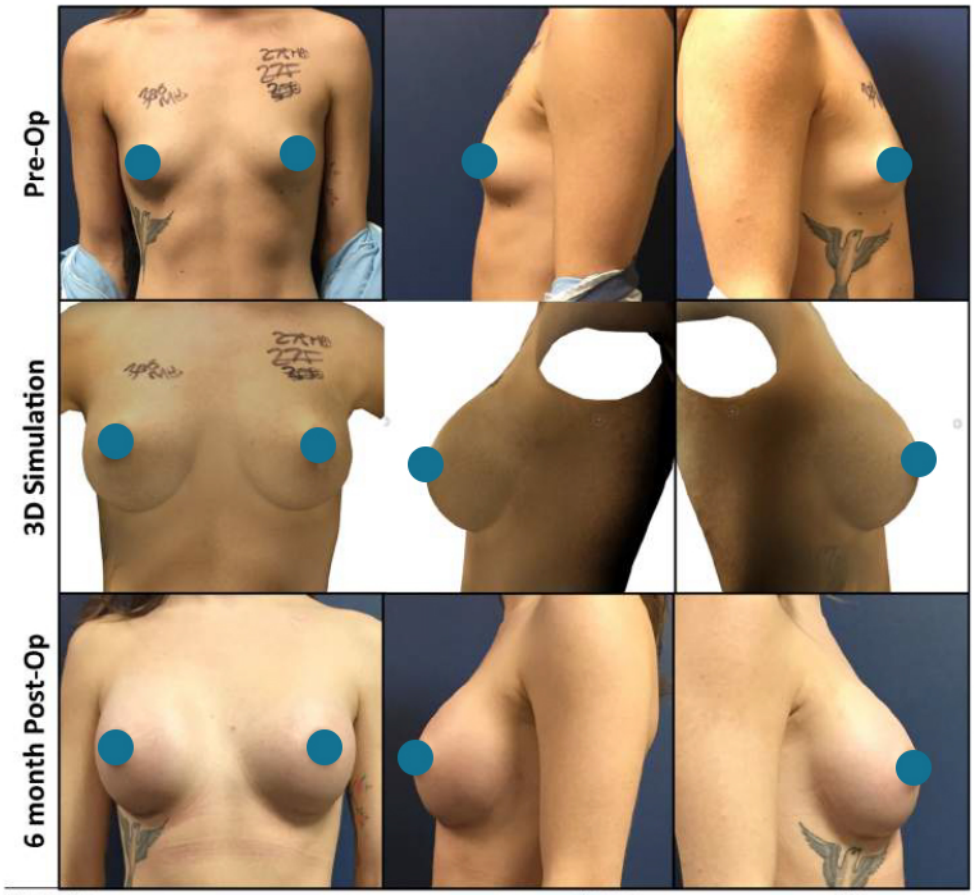
operative outcome. However, attending plastic surgeons deemed more of the simulations to be similar to the post-operative outcome than plastic surgery residents. Differences between scores across the various breast deformities assigned by attending surgeons, residents, and the two groups combined were found to be significant by *one-way ANOVA* ($p < 0.05$).

Discussion

Three-dimensional simulation of breast augmentation by Crisalix appears to be useful for pre-operative planning. The data presented herein demonstrate moderate global similarities between the simulations and post-operative outcomes. Attending plastic surgeons noted greater similarities between the simulations and post-operative outcomes than plastic surgery residents, but both groups found that the simulations were more representative for symmetric breasts than for tuberous or ptotic breasts.

The increase in perceived similarity between three-dimensional simulation by Crisalix and post-operative outcome by attending plastic surgeons who routinely perform breast augmentations compared to plastic surgery residents supports the use of Crisalix generated three-dimensional simulation. Due to their more extensive experience with breast augmentation surgery, the greater scores attributed to the simulations by the attending surgeons are more reliable than the scores assigned by plastic surgery residents. The significant differences in results between attending plastic surgeons and residents reported here could be attributed to their increased familiarity with the various measured parameters. Furthermore, when stratified by breast deformity, attending surgeons assigned an average overall score of 67.9/100 to symmetric breasts, which is close to the assigned "good" simulation score of 75/100 and is also close to the score of 7.6/10 observed in a similar study conducted using the Vectra 3D imaging system [5]. Collectively, these data suggest Crisalix software has some utility in pre-operative planning of breast augmentation.

Further stratification of the pre-operative images used in this study reveals that Crisalix generates more representative three-dimensional simulations for symmetric breasts than for tuberous or ptotic breasts. Various components of the shape the tuberous and ptotic breasts could contribute to their substantially lower scores than the symmetric breasts. Attending surgeons in our study noted worse simulation of the width of tuberous breasts, and of the projection and height of ptotic breasts. It is interesting that these parameters coincide with the geometric deformities associated with tuberous and ptotic breasts, and this discrepancy could be further investigated by inquiring about

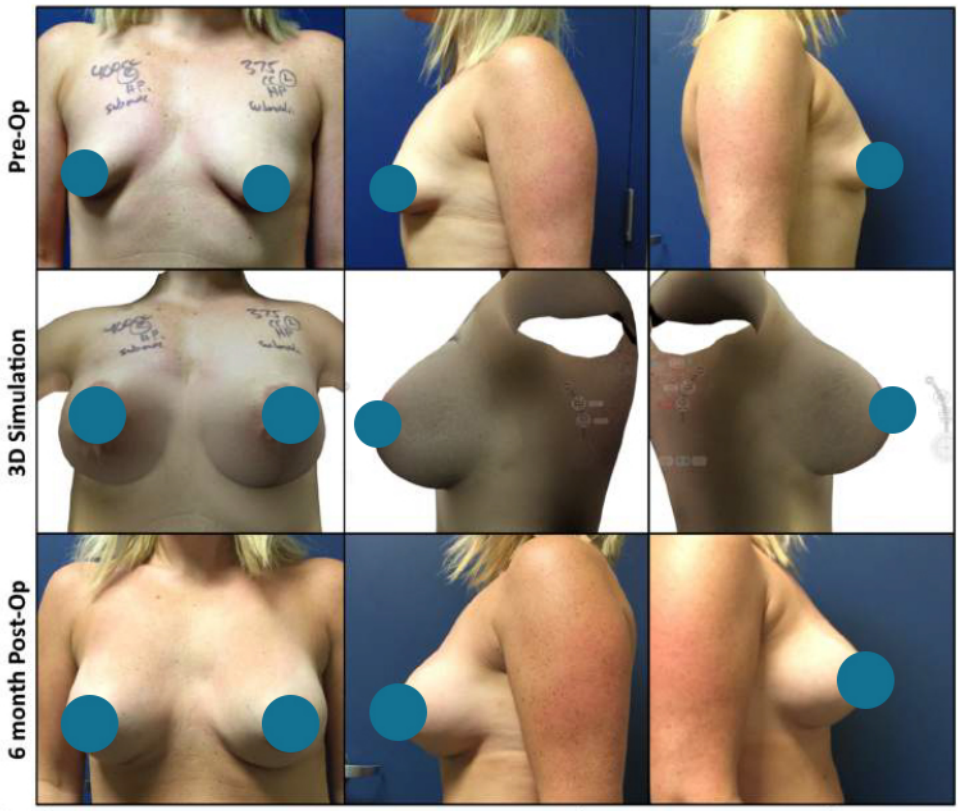


Parameter	Average	SD
Overall Appearance	70.4	11.3
Width	73.8	17.1
Height	79.6	10.3
Projection	79.2	17.7
Volume	76.5	14.6
Nipple Correction	70.8	20.6
Overall Score	**-0.38**	

Fig. 5 Three-dimensional simulation of symmetric breasts. Representative slide of symmetric breast simulation. The pre-operative images were not included in the slide presented to evaluators, but shown here to confirm pre-operative symmetry. Associated pooled scores listed in table for reference. The scores assigned to this patient demonstrate good representative simulation for all of the parameters evaluated. The overall negative score indicates that the evaluators found this simulation to be cosmetically superior to the post-operative outcome

whether optimization of the simulation algorithm took into account various pre-operative breast deformities. While differences in the scores between groups stratified by breast deformity are significant for the resident and resident + attending groups, the overall appearance, projection, and nipple correction parameters were not significant for the attending group. This could be due to low numbers in the ptotic and tuberous breast groups coupled with lower power for attendings than residents. Furthermore, the only other study published to date assessing three-dimensional simulation of breast augmentation evaluated only symmetric pre-operative breasts using the Vectra 3D system, precluding comparison between Crisalix and Vectra for these breast deformities. However, comparison of the results of the symmetric breast simulations evaluated here to those published in the Vectra study shows comparable quality of simulation. Stratification of these cases by breast symmetry suggests that Crisalix would be better employed in pre-operative assessment of patients possessing symmetric than tuberous or ptotic breasts.

Comparison of the cosmetic appearance of the three-dimensional simulations to post-operative outcomes reveals that the actual surgical outcome was superior for symmetric and tuberous breasts but inferior for ptotic breasts, with differences shown to be significant by *one-way ANOVA*. This is an important finding that should be considered when counselling patients pre-operatively for breast augmentation. Showing a simulation that routinely appears better than the post-operative outcome could result in patient dissatisfaction. The attending plastic surgeons and residents in this study noted that the post-operative outcome was superior for both the symmetric and tuberous breast groups, with the surgical outcome being more superior to the simulation for the tuberous breast and the surgical outcome being more similar to the simulation for the symmetric breasts. It is worthwhile to consider the



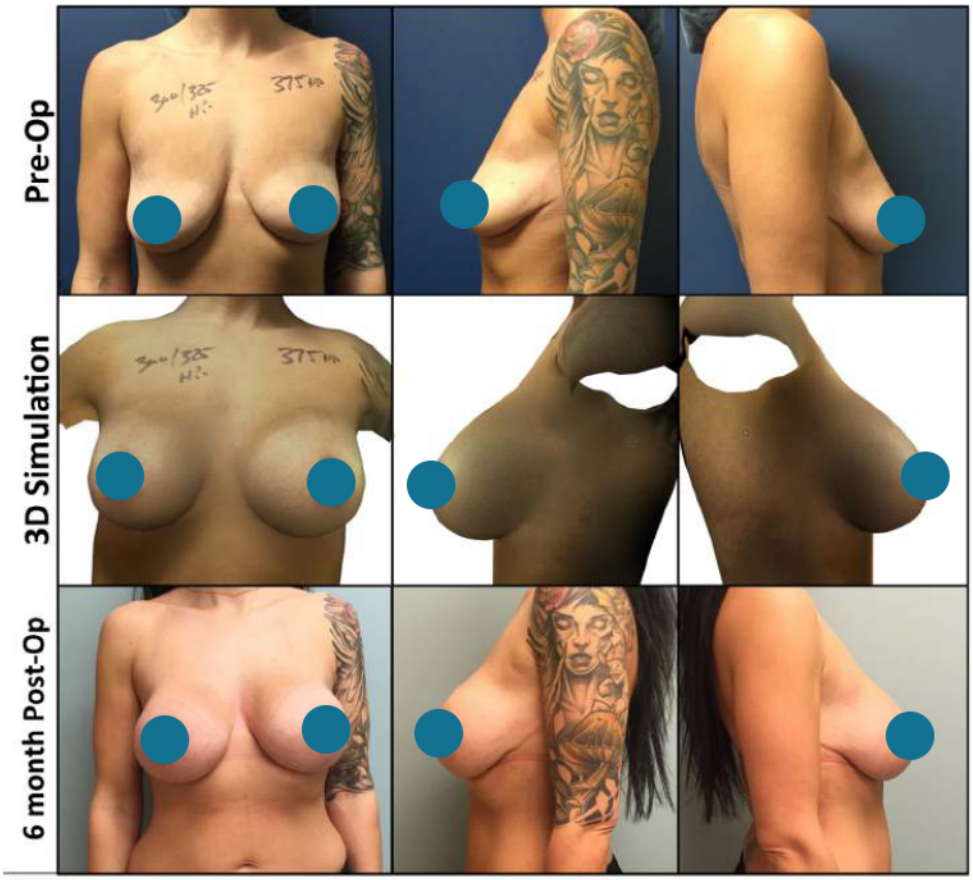
Parameter	Average	SD
Overall Appearance	29.2	22.4
Width	31.2	16.3
Height	27.7	14.8
Projection	38.5	24.1
Volume	31.2	17.6
Nipple Correction	38.1	32.3
Overall Score	**1**	

Fig. 6 Three-dimensional simulation of tuberous breasts. Representative slide of tuberous breast simulation. The pre-operative images were not included in the slide presented to evaluators, but shown here to confirm pre-operative tuberous breasts. Associated pooled scores listed in table for reference. The scores assigned to this patient demonstrate poor representative simulation for all of the parameters evaluated. The overall score of *1* indicates that the evaluators unanimously found this simulation to be cosmetically inferior to the post-operative outcome

extent to which the Crisalix software simulations predict the post-operative outcome when counselling patients for breast augmentation. In the case of the symmetric breasts, three-dimensional simulation with Crisalix offers a good simulation, which could help convince patients to opt for breast augmentation. However, while with the tuberous breasts the outcomes are superior to the simulations, the cosmetically inferior three-dimensional simulation could deter patients from augmentation. The data presented herein thus support the use of Crisalix for three-dimensional simulation in patients with symmetric breasts, but at present our data suggest caution should be exercised when utilizing Crisalix with patients who have tuberous or ptotic breasts.

While the present study highlights some of the applications of the Crisalix software, it is important to note the limitations of the data collected here. Foremost, the study consists of only 20 patients, with smaller sub-samples when stratified by breast deformity. While more patients would strengthen these data, the consistency of the results obtained stratified by experience and breast type supports the trends noted here. Additionally, the patients included in this study received round implants in the sub-glandular plane. It would be interesting to compare how the Crisalix software simulates outcomes with round versus anatomic implants, as well as for different insertion planes. Furthermore, the utility for assessing patient satisfaction is speculated based upon assessed aesthetic appeal of the simulation compared to the post-operative outcome. Analysis of patient perspectives of the simulation, particularly for different breast deformities, and how it might impact their choice to undergo breast augmentation would provide additional information about the clinical utility of the Crisalix software.

In practice, we find that the Crisalix simulation program helps in conversion of patients when used appropriately. In general, some surgeons have found that some 3D simulation programs can be unpredictable and may provide unrealistic simulations. Thus, when generating 3D simulations, we suggest the surgeon review all images prior to the patient seeing the simulation to determine whether it is an appropriate representation of an expected outcome. This is especially important if the simulation is poor and may



Parameter	Average	SD
Overall Appearance	51.5	16.1
Width	60.4	15.9
Height	55.4	19.4
Projection	40.7	17.7
Volume	42.3	20.4
Nipple Correction	73.8	14.1
Overall Score	**-1**	

Fig. 7 Three-dimensional simulation of ptotic breasts. Representative slide of ptotic breast simulation. The pre-operative images were not included in the slide presented to evaluators, but shown here to confirm pre-operative breast ptosis. Associated pooled scores listed in table for reference. The scores assigned to this patient demonstrate weak representative simulation for all of the parameters evaluated except nipple correction, which was well represented here. The overall score of -1 indicates that the evaluators unanimously found this simulation to be cosmetically superior to the post-operative outcome

deter a patient from undergoing a breast augmentation. If determined to be adequate, the simulation can be shown to the patient during their consultation. It should be stated during this process that the simulations may not represent final surgical outcome. Consent should be obtained that states that the overall outcome may be different than that simulated and that no legal action may be taken if such a difference exists. To date we have not had any concerns with regard to this. Additionally, we have found Crisalix to be particularly useful for helping patients selected between close implant volumes (i.e. 325 or 350 cc). This is important in clinical practices where final implant volume must be agreed upon between the patient and surgeon pre-operatively. Overall, our experience with Crisalix has been positive and has facilitated pre-operative planning for breast augmentation.

The present study was designed to assess the clinical utility and quality of simulations using Crisalix. Collectively, the data presented herein find that three-dimensional simulation using Crisalix has good clinical utility in pre-operative planning for breast augmentation. Beyond providing patients with an image to help them envision the potential post-operative outcome, the cloud-based nature of Crisalix makes it very user-friendly for patients. Furthermore, it requires little more than a digital camera and an online subscription allows for flexibility and little start-up needs for both patient and surgeon to create the three-dimensional simulation. Regarding the quality of the simulations, the present study advocates for use of Crisalix in symmetric breasts but cautions against using the program for simulations of ptotic and tuberous breast augmentations. However, we recognize that elaboration of the study could refine in greater detail the best applications of Crisalix and guide further software development to broaden its utility in pre-operative planning for breast augmentation.

Table 5 Global comparison of three-dimensional simulation of breast augmentation to post-operative outcome

Which breast looks aesthetically better?				Resident	Attending	Combined
Total	Frequency	Simulation	−1	60 (30%)	17 (28.3%)	77 (29.6%)
		Equal	0	30 (15%)	17 (28.3%)	47 (18.1%)
		Post-op	1	110 (55%)	26 (43.4%)	136 (52.3%)
	Mean			0.25	0.43	0.23
Symmetric	Frequency	Simulation	−1	33 (23.6%)	9 (21.4%)	42 (23.1%)
		Equal	0	27 (19.3%)	15 (35.7%)	42 (23.1%)
		Post-op	1	80 (57.1%)	18 (42.9%)	98 (53.8%)
	Mean			0.33	0.21	0.31
Tuberous	Frequency	Simulation	−1	8 (26.7%)	2 (22.2%)	10 (25.6%)
		Equal	0	2 (6.6%)	1 (11.1%)	3 (7.7%)
		Post-op	1	20 (66.7%)	6 (66.7%)	26 (66.7%)
	Mean			0.43	0.44	0.41
Ptotic	Frequency	Simulation	−1	60 (30%)	17 (28.3%)	25 (64.1%)
		Equal	0	30 (15%)	17 (28.3%)	2 (5.1%)
		Post-op	1	110 (55%)	26 (43.4%)	12 (30.8%)
	Mean			−0.34	−0.44	−0.33
	p value (ANOVA)			4.75E − 04	5.08E − 02	2.47E − 05

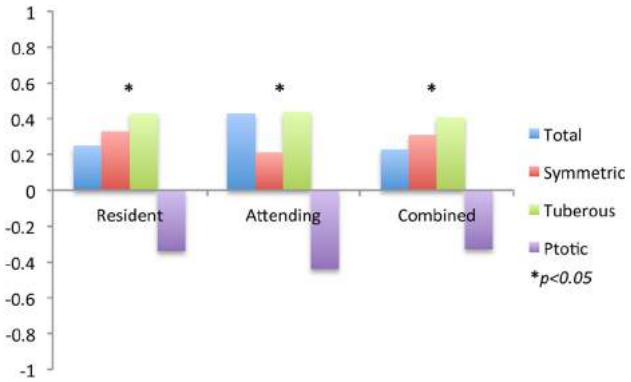


Fig. 8 Global comparison of three-dimensional simulation of breast augmentation to actual post-operative outcome. Evaluators were asked to assess which image was most aesthetically pleasing and assign a score of (−1) for the three-dimensional simulation, (0) if there was no difference, and (+1) for the actual post-operative outcome. Data listed represent means stratified by total (all patients) and patients with symmetric, tuberous, and ptotic breasts. Data listed by resident evaluation, attending surgeon evaluation, and combined (resident + attending) evaluation. Assessment of correlation of breast deformity within each evaluator group was conducted by *one-way ANOVA*. $*p < 0.05$

Conclusions

Three-dimensional simulation is becoming increasingly common in pre-operative planning for breast augmentation. The present study aimed to assess the degree of similarity of three-dimensional simulations generated using Crisalix and found that it provided a good representation for patients with pre-operative symmetric breasts. However, the results were more variable for tuberous and ptotic breasts. Thus, we recommend discretion on behalf of the surgeon before offering pre-operative three-dimensional simulation with Crisalix and encourage surgeons to offer this tool for patients with symmetric breasts but carefully consider possible outcomes before offering the tool to patients with ptotic or tuberous breasts.

Compliance with Ethical Standards

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

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