Use of Three-Dimensional Imaging to Assess the Effectiveness of Volume as a Critical Variable in Breast Implant Selection

AQ1

Dennis C. Hammond, M.D.
Kuylhee Kim, M.D.
Matthew H. Bageris, B.S.
Arif Chaudhry, M.D.

Grand Rapids, Mich.

Background: In breast augmentation, breast base diameter has been recognized as an important variable in implant selection. However, breast implant volume also has a tremendous impact on the final result. Previous methods of preoperative volume determination have been limited to external devices in a bra. Computer-based three-dimensional simulation technology now allows the physician to effectively communicate with the patient preoperatively regarding volume.
Methods: A cohort of 40 consecutive patients underwent routine breast augmentation with either anatomically shaped or round implants. Five methods of preoperative volume determination including the Crisalix three-dimensional computer imaging system (Crisalix Virtual Aesthetics, Lausanne, Switzerland), along with an associated virtual reality tool, were used to assess the preoperative desires of the patients. A postoperative questionnaire was used to assess patient satisfaction with each volume determination method. AQ4
Results: Of the 40 patients, 100 percent were satisfied with their result; however, given the opportunity, 12 percent would have chosen a larger implant. The virtual reality tool and external sizers were shown to be the most effective in choosing an implant. The virtual reality tool was judged to be very helpful (62 percent), very accurate (78 percent), and important (88 percent) in helping patients choose their desired implant size.
Conclusion: Prioritizing volume as an implant selection variable in breast augmentation results in a very high rate of patient satisfaction. (*Plast. Reconstr. Surg.* 149: 00, 2022.)
CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

Breast augmentation is one of the most commonly performed aesthetic procedures in plastic surgery.[1–6] One of the key concepts involved in planning the procedure includes various soft-tissue–based strategies for preoperatively measuring the patient to be certain the chosen implant matches the soft-tissue framework of the breast.[7–16] In this regard, implant selection that emphasizes the base diameter of the breast has been presented as one of the critical variables required to successfully choose a proper implant for a given patient. Despite this trend toward more measurement-based systems of preoperative evaluation, one of the most common reasons for returning to the operating room after breast augmentation is reoperation for size change.[6,12,17–28] One explanation for what should be a preventable complication may be related to the relative effect different implant variables have on the final result.[29] For instance, the difference between an 11-cm versus a 12-cm base diameter measurement is nuanced enough such that both choices would provide an acceptable result for the majority of patients. However, the change in volume that occurs for these two base diameters can vary from approximately 50 to 130 cc, depending on

AQ3

From Partners in Plastic Surgery.
Received for publication May 27, 2020; accepted June 29, 2021.

DOI: 10.1097/PRS.0000000000008682

Disclosure: *Dr. Hammond has a consulting agreement with Mentor Corporation, manufacturer of the implants used in this study. The remaining authors have no financial interests to report. Crisalix provided access to the three-dimensional platform used to generate the images used in these simulations at no cost.* AQ2

Related digital media are available in the full-text version of the article on www.PRSJournal.com.

lww	8/11/21	14:58	4 Color Fig(s): F1-7	Art: PRS-D-20-01693

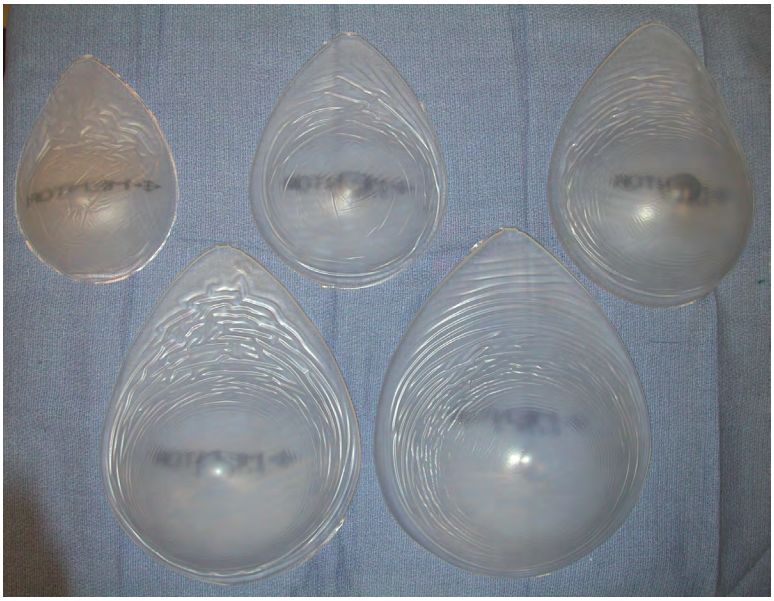
the projection of the device and the manufacturer. Therefore, as opposed to what amounts to small and generally acceptable changes in base diameter choice, the associated range of volumes can have a significant effect on how satisfied the patient is after undergoing breast augmentation. When viewed in this way, there is potential advantage in choosing the volume of the implant together with the patient as the primary variable in implant selection and then choosing other variables related to base diameter, projection, and implant height as indicated. In this regard, several different types of three-dimensional imaging systems based on the concept of surface imaging and photogrammetry have been developed. These systems can be used to create simulations that use the patient's own photographs to approximate what the result would appear like with different volumes and types of implants in place.[30–34] These systems have been shown to be variably effective in educating patients as to what type of result may be obtained after undergoing breast augmentation, specifically focusing on the volume of the imp lant.[1,3,21,31,35–51] Therefore, the goal of this study was to (1) describe the results in a series of consecutive patients undergoing breast augmentation where volume was used as the primary variable in implant selection and (2) evaluate several methods of volume determination, including three-dimensional simulation, to determine which were most effective.

PATIENTS AND METHODS

A consecutive series of patients presenting for uncomplicated bilateral breast augmentation were considered for enrollment in the study cohort. Exclusion criteria included the presence of ptosis, desire for mastopexy, tuberous breast deformity, and previous malignancy. All enrolled patients first underwent volume-based decision planning as an aid to implant selection using five methods of volume estimation. These methods of desired volume assessment included the following: (1) viewing photographs of previous patients, (2) having an in-depth verbal discussion of the desired result with the surgeon, (3) using specially designed external contoured silicone sizers in a bra (Figs. 1 through 3), (4) having a computer simulation performed using the Crisalix computer simulation system (Crisalix Virtual Aesthetics, Lausanne, Switzerland) (Fig. 4), and (5) using the virtual reality feature provided through the Crisalix system to generate a three-dimensional image that was then viewed through an Oculus Go (Facebook, Inc., Menlo Park, Calif.) headset. (**See Figure, Supplemental Digital Content 1**, which shows appearance of a patient during the preoperative consultation wearing the virtual reality headset, ***http://links.lww.com/PRS/E757***. **See Figure, Supplemental Digital Content 2**, which shows appearance of the image seen by the patient through the virtual reality headset showing the anteroposterior, 45-degree, and lateral views of the computer-simulated image, ***http://links.lww.com/PRS/E758***. **See Figure, Supplemental Digital Content 3**, which shows when the patient looks straight down while wearing the virtual reality headset; the computer simulation showing the position and projection

F1 - F3

F4



AQ11

Fig. 1. Anatomically configured external sizers.

lww | 8/11/21 | 14:58 | 4 Color Fig(s): F1-7 | Art: PRS-D-20-01693

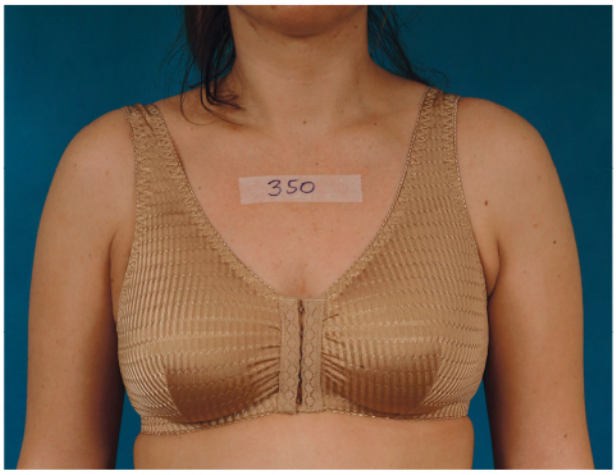


Fig. 2. Anteroposterior view of a patient showing the appearance of a 350-cc external sizer in a bra.

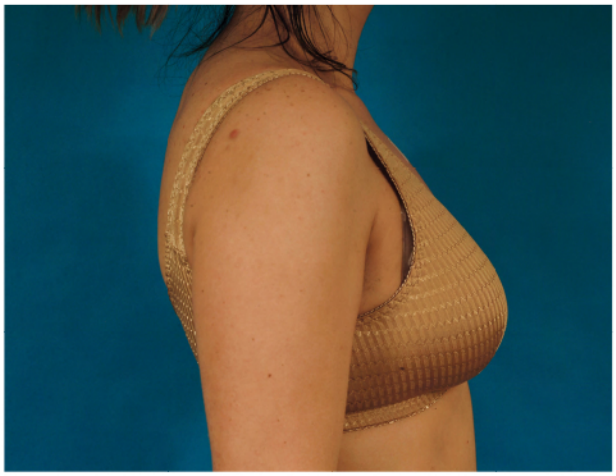


Fig. 3. Lateral view of a patient showing the appearance of a 350-cc external sizer in a bra.

of the breasts can be seen, *http://links.lww.com/PRS/E759*.) After determining the desired volume, the appropriate base diameter range for a given patient was measured with the aid of measuring calipers. The base diameter was estimated by determining the most medial and lateral extent of the desired breast footprint that would be created after the augmentation (Fig. 5) and then F5 subtracting the soft-tissue thickness on each side from this measurement. This thickness was measured using body fat calipers. By pinching the skin and fat along the medial and lateral aspect of the breast and dividing the measured thickness of this fold by 2, the actual soft-tissue thickness at each point could be measured (Figs. 6 and 7). As long F6, T7 as the base diameter of the desired breast implant did not exceed the measured base diameter of the patient by more than 0.5 cm or fall short by more than 1.5 cm, it was determined that the particular volume chosen by the patient would be an acceptable choice. Adjustments in implant projection were made as needed to allow for comfortable matching of the volume and base diameter variables. In cases where patient desires for volume went beyond the ability of the soft tissues to accept that particular device, patient education was used to better align patient expectations with sound implant selection.

All patients underwent uncomplicated breast augmentation under general anesthesia in an outpatient setting performed by the same surgeon. At the time of surgery, a target implant that had been identified and approved by the patient preoperatively was set as the primary implant for consideration; however, in every case, an implant of one size greater volume (usually 25 cc more) and one

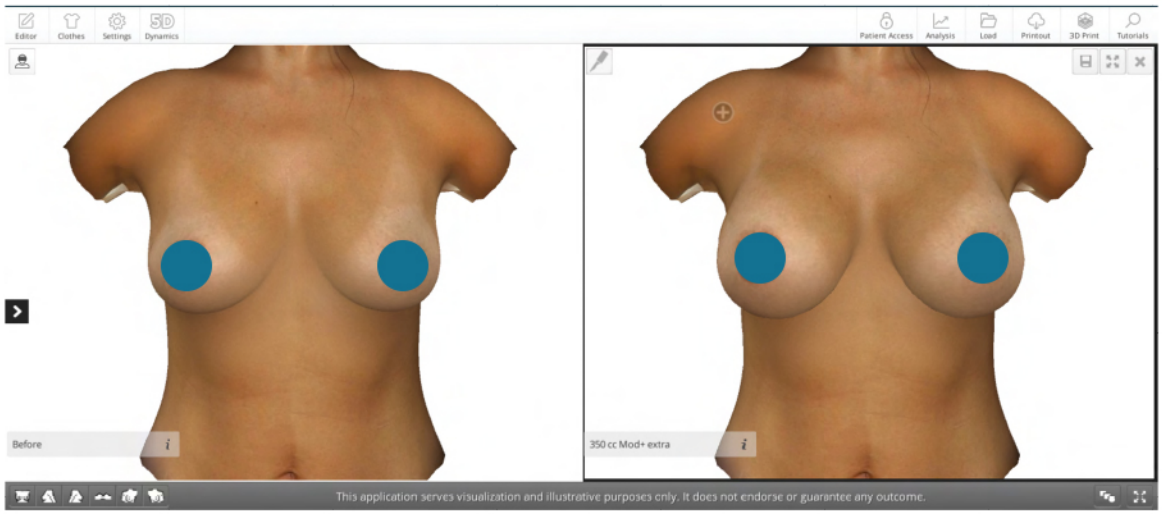


Fig. 4. Crisalix simulation as viewed on a computer screen showing the effect of a 350-cc round gel implant.

lww | 8/11/21 | 14:58 | 4 Color Fig(s): F1-7 | Art: PRS-D-20-01693

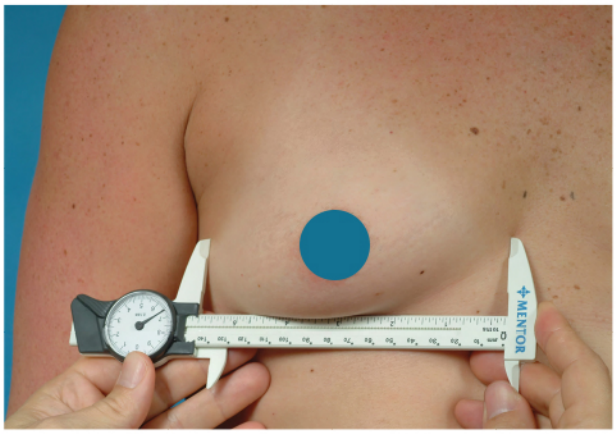


Fig. 5. Beast base diameter as measured by calipers.

size lesser volume (usually 25 cc less) was available for use as needed. Final implant selection was guided by the use of intraoperative sizers, and all patients were consented to allow the operating surgeon to make the final implant selection based on the intraoperative findings at the time of the procedure.[52] It was the philosophy of the primary surgeon to use a "one-size-up" strategy in selected cases where patients had requested to be as "big as possible" as long as it did not create inordinate stress on the soft tissues or result in an overly augmented appearance in patients who requested a "natural" result.

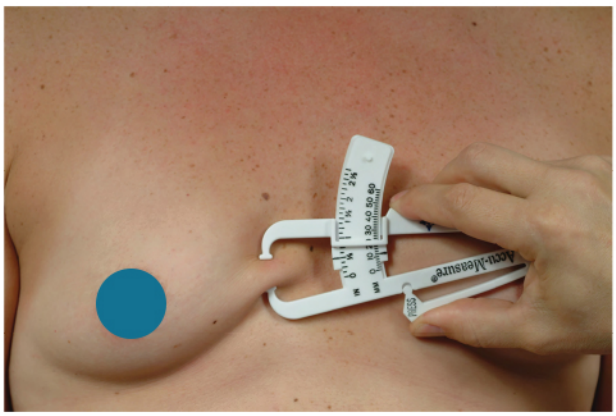


Fig. 6. Medial pinch measured with calipers.

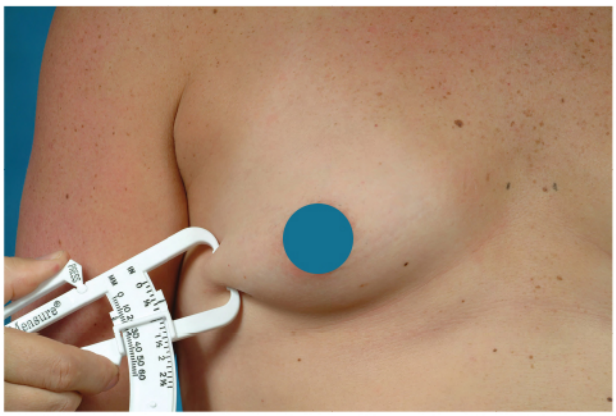


Fig. 7. Lateral pinch measured with calipers. The overall base diameter measurement that is then used to guide implant selection is the overall breast base minus one-half of the sum of the medial and lateral pinch thicknesses.

Postoperatively at each visit, a seven-item questionnaire was filled out under the direction of the operating surgeon. The goal of the questionnaire was to assess the overall satisfaction of the patient with her result and, also, have the patient grade the utility of each method of volume determination. The wording of the questions was chosen to duplicate that of the questionnaire used by Donfrancesco et al.[45] in their analysis of the results using three-dimensional simulation with the Vectra system (Canfield Imaging Systems, Fairfield, N.J.). In doing so, direct comparison between the two patient cohorts evaluated with two different three-dimensional imaging systems could be performed. In addition, an attempt was made to assess which method of volume estimation was the most helpful during the preoperative evaluation process. In particular, each of the five methods of volume selection was graded excellent to poor, and the top three methods were ranked first to third. The results were tabulated and only those patients who had completed the entire process from preoperative evaluation, computer simulation, and postoperative follow-up were included in the study. AQ5

RESULTS

Of the original cohort of 48 patients, 40 completed the preoperative evaluation and measurements, underwent the preoperative sizing process with imaging, filled out the postoperative questionnaire, and were enrolled in the study. All patients underwent primary breast augmentation performed by the senior author placing silicone gel implants through an inframammary fold incision. A subglandular pocket was used in one patient, with the rest of the implants being placed in a partial subpectoral pocket using a dual-plane technique. A cohesive gel shaped implant (MemoryShape; Mentor Corp., Irvine, Calif.) was used in 28 patients and a smooth round silicone gel implant (MemoryGel; Mentor) was used in 12 patients. Postoperative follow-up evaluation and completion of the questionnaire were performed together with the patient and the operating surgeon in every instance. The median average

follow-up time for the entire cohort was 24 weeks (6 months). The results of the survey are summarized in Table 1. Of the 40 patients, 100 percent responded that they were satisfied with the final outcome of their procedure and, furthermore, felt that what they desired from the operation had been accomplished. Despite this high level of patient satisfaction, five of the 40 patients (12 percent) stated that, on direct questioning and with the benefit of hindsight, if they could change something, they would have chosen a larger implant. No patient desired a smaller device. In no instance was this potential desire for size change a source of patient dissatisfaction. With regard to the virtual reality simulation, 62 percent of the patients found the virtual reality tool to be very helpful in deciding implant size, whereas 30 percent felt it to be helpful but not decisively. In all, 93 percent of the patients found the virtual reality tool to be very (78 percent) or rather (15 percent) accurate. When asked what role the virtual reality simulation played in their overall breast augmentation experience, 88 percent of the patients felt it played a very important (58 percent) or important (30 percent) role.

Of the five methods of volume determination used during the preoperative evaluation process, the virtual reality simulation and the external sizers were judged to be the most helpful in choosing implant size, being ranked as a top three choice in 80 percent and 75 percent of the responses, respectively (Table 2). All five methods of volume determination were judged to be effective with physician discussion (88 percent), use of external sizers (81 percent), use of computer simulation (83 percent), and use of virtual reality simulation (88 percent) all being graded as very good to excellent. The use of preoperative photographs was the least helpful of the five methods used. Overall, the virtual reality simulation was graded as excellent most commonly (73 percent) (Table 3) and was also most commonly ranked first as the most helpful modality (43 percent) (Table 2).

When analyzing the data separately according to shaped versus round implants, very similar results were obtained in that viewing photographs was the least helpful means of choosing a volume, with all other methods of size determination being graded mostly as very good to excellent. The virtual reality simulation and external sizer methods continued to rank highest in helping choose a device for anatomical implants; however, for round implants, the utility of the external sizer (58 percent) lagged well behind the virtual reality simulation technique (92 percent) as far as being a top-three choice (Tables 3 through 7). When comparing the results of this study to the results obtained by Donfrancesco et al.,[45] very similar percentages were noted using the exact same wording in three different assessment questions. Comparing the results using the Vectra imaging system with the virtual reality system used in this study, 97 percent versus 92 percent of patients, respectively, felt the simulations were either very helpful, or helpful but not decisively in helping decide on an implant, 97 percent versus 93 percent felt the simulations were very or rather accurate, and 89 percent versus 88 percent felt the simulations played a very important to important role in their breast augmentation experience (Table 8).

DISCUSSION

There are many factors that come together to determine the degree of satisfaction a patient experiences after undergoing breast augmentation. Issues such as breast shape, symmetry, proportion, nipple position, and absence of complications all combine to define the final result. Breast implant volume is also a critical variable that plays a major role in defining the final outcome. It is a variable that is readily apparent to the patient by means of simple visual inspection and is a focal point of how the patient perceives her result. Clearly, volume is important, and several authors have recognized the utility of speaking in terms of volume when counseling a patient about the procedure.[16,17,19,40]

Historically, several methods of attempting to demonstrate to the patient the effect of increased breast volume have been described, with techniques ranging from the simple including the use of bags filled with rice or water,[17,53,54] to the use of external sizers placed in a bra,[16,19,55] to now more complex techniques related to three-dimensional imaging.[30–34] Regardless of which method is used, all embrace the philosophical concept that the patient should, within reason, have a voice in describing what kind of result she desi res.[17,19,21.24,29,46,54]

With recent advances in technology, digital imaging followed by computer simulation of the proposed result has become a common technique for surgeons and patients to communicate about expected outcomes preoperatively in breast augmentation. In particular, these systems are very effective at demonstrating changes in volume. To this end, several different systems have been introduced designed specifically for helping to

Table 1. Postoperative Questionnaire with Tabulated Patient Responses

Question	All Implants (%)	Round Implants (%)	Anatomical Implants (%)
1. In general, are you satisfied with the final outcome of the operation?			
a. Yes	40/40 (100)	12/12 (100)	28/28 (100)
b. No	0/40 (0)	0/12 (0)	0/28 (0)
2. Did you achieve the result you were looking for?			
a. Yes	40/40 (100)	12/12 (100)	28/28 (100)
b. No	0/40 (0)	0/12 (0)	0/28 (0)
3. Knowing what you know now, would you change something?			
a. Yes	5/40 (12)	2/12 (17)	3/28 (11)
b. No	35/40 (88)	10/12 (83)	25/28 (89)
4. In terms of the size of the implant, would you choose the same or a different one if you were to change?			
a. Choose a smaller implant	0/5 (0)	0/2 (0)	0/3 (0)
b. Choose a larger implant	5/5 (100)	2/2 (100)	3/3 (100)
c. Choose the same implant	0/5 (0)	0/2 (0)	0/3 (0)
d. I would not undergo surgery	0/5 (0)	0/2 (0)	0/3 (0)
5. How much has the virtual reality simulation helped you in deciding the implant?			
a. Very much	25/40 (62)	7/12 (58)	17/28 (60)
b. Yes, but not decisively	12/40 (30)	5/12 (42)	8/28 (29)
c. Not so important	2/40 (5)	0/12 (0)	2/28 (7)
d. Not at all	1/40 (3)	0/12 (0)	1/28 (4)
6. How accurate do you feel the virtual reality simulation you were shown during consultation was if you compare it with your actual result in yourself?			
a. Very accurate	31/40 (78)	8/12 (67)	23/28 (82)
b. Rather accurate	6/40 (15)	3/12 (25)	3/28 (11)
c. Little	3/40 (7)	1/12 (8)	2/28 (7)
d. No similarity at all	0/40 (0)	0/12 (0)	0/28 (0)
7. Overall, what role do you that the virtual reality simulation had in your breast augmentation experience?			
a. Very important	23/40 (58)	8/12 (67)	16/28 (57)
b. Important	12/40 (30)	3/12 (25)	8/28 (29)
c. Not so important	5/40 (12)	1/12 (8)	4/28 (14)
d. A waste of time	0/40 (0)	0/12 (0)	0/28 (0)

produce computer simulations of a postoperative result based on the actual preoperative appearance of the patient. Early versions of this technology were expensive and somewhat cumbersome to use, and for many, this proved to be somewhat time consuming and intrusive to the overall consultation process. Concerns were also raised as to the accuracy of the generated images and what affect this could have on the patient's expected outcomes.[56–59]

Recent advances in this field have focused on converting two-dimensional images captured either with photographs or surface scanners into three-dimensional simulations with much less effort and device requirements. The Crisalix system used in this study is one of these types of systems.[3,32,33,44,50,56] The technology is based on an artificial intelligence system capable of accurately modeling, in three dimensions, the body of the patient simply using three standard digital photographs without the need for any specific hardware. The result is a three-dimensional model that can be viewed and manipulated using cloud-based technology through the Crisalix app on a computer, tablet, or mobile phone. A three-dimensional rendering of the patient can also be viewed through a three-dimensional virtual reality headset linked to the Crisalix program. Implant variables including volume, base diameter, shape, texture, and fill can be input using the

Table 2. Ranking of Each Method of Volume Determination with Patients Choosing Top Three Methods*

	Rank			
	First (%)	Second (%)	Third (%)	In Top 3 (%)
Review of photographs	4 (10)	5 (12)	7 (18)	16 (40)
Discussion with physician	3 (8)	8 (20)	11 (28)	22 (55)
Use of external sizers	13 (33)	8 (20)	9 (23)	30 (75)
Computer simulation	3 (8)	8 (20)	9 (23)	20 (50)
Virtual reality simulation	17 (43)	11 (28)	4 (10)	32 (80)

*n = 40 patients.

Table 3. Characterization of the Five Volume Estimation Methods*

	Review of Photographs (%)	Discussion with Physician (%)	Use of External Sizers (%)	Computer Simulation (%)	Virtual Reality Simulation (%)
Excellent	9 (23)	24 (60)	21 (53)	22 (55)	29 (73)
Very good	17 (43)	11 (28)	11 (28)	11 (28)	6 (15)
Good	11 (28)	5 (12)	7 (18)	7 (18)	3 (8)
Fair	2 (5)	0 (0)	0 (0)	0 (0)	2 (5)
Poor	1 (3)	0 (0)	1 (3)	0 (0)	0 (0)

*n = 40 patients.

Table 4. Ranking of Each Method of Volume Determination with 28 Patients with Anatomically Shaped Implants Choosing the Top-Three Methods

	Rank			
	First (%)	Second (%)	Third (%)	In Top 3 (%)
Review of photographs	2 (7)	6 (21)	5 (18)	13 (46)
Discussion with physician	3/ (11)	6 (21)	6 (21)	15 (54)
Use of external sizers	10 (36)	5 (18)	8 (29)	23 (82)
Computer simulation	1 (4)	4 (14)	7 (25)	12 (43)
Virtual reality simulation	12 (43)	7 (25)	2 (7)	21 (75)

Table 5. Characterization of the Five Volume Estimation Methods in 28 Patients with Anatomically Shaped Implants

	Review of Photographs (%)	Discussion with Physician (%)	Use of External Sizers (%)	Computer Simulation (%)	Virtual Reality Simulation (%)
Excellent	8 (29)	18 (64)	17 (61)	17 (61)	22 (79)
Very good	10 (36)	8 (29)	9 (32)	6 (21)	2 (7)
Good	9 (32)	2 (7)	2 (7)	5 (18)	2 (7)
Fair	1 (4)	0 (0)	0 (0)	0 (0)	2 (7)
Poor	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 6. Ranking of Each Method of Volume Determination with 12 Patients with Round Implants Choosing the Top-Three Methods

	Rank			
	First (%)	Second (%)	Third (%)	In Top 3 (%)
Review of photographs	2 (17)	0 (0)	3 (25)	5 (42)
Discussion with physician	0 (0)	2 (17)	4 (33)	6 (50)
Use of external sizers	3 (25)	4 (33)	0 (0)	7 (58)
Computer simulation	0 (0)	3 (25)	4 (33)	7 (58)
Virtual reality simulation	7 (58)	3 (25)	1 (8)	11 (92)

Table 7. Characterization of the Five Volume Estimation Methods in 12 Patients with Round Implants

	Review of Photographs	Discussion with Physician	Use of External Sizers	Computer Simulation	Virtual Reality Simulation
Excellent	2 (17)	7 (58)	4 (33)	6 (50)	8 (67)
Very good	6 (50)	2 (17)	3 (25)	4 (33)	3 (25)
Good	2 (17)	3 (25)	4 (33)	2 (17)	1 (8)
Fair	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)
Poor	1 (8)	0 (0)	1 (8)	0 (0)	0 (0)

Table 8. Comparison of Questionnaire Responses between Crisalix Virtual Reality Simulations and Vectra Simulations*

	VR (%)	Vectra (%)
8. How much has the Crisalix Virtual Reality/Vectra simulation helped you in deciding the implant?		
a. Very much	62	81
b. Yes, but not decisively	30	16
c. Not so important	5	3
d. Not at all	3	0
9. How accurate do you feel the Crisalix Virtual Reality/Vectra simulation you were shown during consultation was if you compare it with your actual result in yourself?		
a. Very accurate	78	86
b. Rather accurate	15	11
c. Little	7	3
d. No similarity at all	0	0
10. Overall, what role do you think that the Crisalix Virtual Reality/Vectra simulation had in your breast augmentation experience?		
a. Very important	58	55
b. Important	30	34
c. Not so important	12	11
d. A waste of time	0	0

VR, virtual reality.
*Donfrancesco A, Montemurro P, Hedén P. Three-dimensional simulated images in breast augmentation surgery: An investigation of patients' satisfaction and the correlation between prediction and actual outcome. *Plast Reconstr Surg.* 2013;132:810–822.

selection tool, and any implant from the embedded implant library that contains the implants from every major manufacturer can be chosen to create a simulation. In particular, the virtual reality technology is a new feature associated with this system, and early adoption in the practice of the senior author seemed to be extremely well received by the patients. [**See Video (online)**, which shows the patient reaction to viewing the predicted postoperative result using the Oculus Go glasses and the virtual reality program.] Using this mode of presentation of a simulated image to the patient yields a visually impactful representation of her projected result. By wearing the glasses, an enhanced three-dimensional experience was created for the patient as a result of combining the simulated images with motion as the head is moved to view the image. A particularly well-received feature of the virtual reality glasses was the ability of the patient to look straight down and see the enhanced projection and cleavage generated by the simulation (Fig. 7). It was this observation that prompted this study, which in a more organized fashion, confirmed what was observed clinically. The use of the virtual reality technology was graded as the most effective and most helpful technique of result simulation of the five methods studied. It also graded better than viewing the standard three-dimensional simulations on a computer screen and was rated as sufficiently accurate and helpful such that the overall breast augmentation experience was enhanced. These findings mirrored very closely the results noted previously using the Vectra imaging system, thus further supporting the utility of three-dimensional imaging in breast augmentation.[45]

Given the encouraging findings noted in this study, the question then becomes what role does preoperative volume determination play in helping a patient choose a breast implant? As opposed to strict adherence to tissue-based strategies that prioritize exact base diameter measurements as the primary variable with one specific implant identified as the implant of choice, it is proposed that a hybrid approach is preferable. Because base diameter can easily vary up to 1 cm and still comfortably "fit" within the soft-tissue framework, several implants of different dimensions and volumes could be effectively used to provide an aesthetic result. It is here that preoperative volume determination can play a decisive role, as 1 cm of variance in base diameter measurement can be associated with 80 cc or more of volume difference, enough to create a noticeable effect of the final appearance of the breast. By first being certain that the volume of the chosen implant will create the result desired by the patient, and then confirming that the base diameter of the chosen implant matches well with the soft-tissue framework, any chance for patient dissatisfaction with size postoperatively is minimized.[40,45–47,60]

This approach allows the "largest" implant possible to be used without risking damage to the soft tissues. When patient requests for volume are such that the soft tissues would be subjected to too much stress, patient education can then be used to redirect patient requests to a more appropriate volume. In this study, a small number of patients would have chosen a larger implant even after undergoing the entire described preoperative evaluation process. However, in no instance did this result in a reoperation for size change, as proper preoperative education had prepared each patient for the implant that most optimally fit her soft-tissue framework, a process that each patient fully accepted. It is interesting to note that the virtual reality tool outperformed external sizers when using round implants. This may be related to the fact that the external sizers were more anatomically configured than the actual round implants that were ultimately used; however, because of the low numbers of patients

in this cohort, further study is indicated to assess whether or not this is really a factor.

CONCLUSIONS

Using volume as a primary variable in breast implant selection is an effective way to communicate with patients seeking breast augmentation. Incorporating discussions regarding volume along with other measured parameters results in high levels of patient satisfaction, with no reoperations for size change occurring in this cohort of patients. The most effective methods of volume estimation include the use of three-dimensional imaging and external sizers. The Crisalix virtual reality tool offers particular advantage in allowing effective communication between the physician and the patient.

Dennis C. Hammond, M.D.
Partners in Plastic Surgery
4070 Lake Drive, Suite 202
Grand Rapids, Mich. 49546
drhammond@pipsmd.com

AQ8

REFERENCES

1. Mailey B, Freel A, Wong R, Pointer DT, Khoobehi K. Clinical accuracy and reproducibility of Portrait 3D Surgical Simulation Platform in breast augmentation. *Aesthet Surg J.* 2013;33:84–92.
2. The American Society for Aesthetic Plastic Surgery. 2015 cosmetic surgery national data bank statistics. Available at: http://www.surgery.org/sites/default/files/Stats2015.pdf. Accessed xxx.
3. Vorstenbosch J, Islur A. Correlation of prediction and actual outcome of three-dimensional simulation in breast augmentation using a cloud-based program. *Aesthetic Plast Surg.* 2017;41:481–490.
4. Heidekrueger PI, Sinno S, Hidalgo DA, Colombo M, Broer PN. Current trends in breast augmentation: An international analysis. *Aesthet Surg J.* 2018;38:133–148.
5. Wilson SC, Daar DA, Sinno S, Levine SM. Public interest in breast augmentation: Analysis and implications of Google trends data. *Aesthetic Plast Surg.* 2018;42:648–655.
6. Montemurro P, Fischer S, Hager S, Hedén P. Secondary breast augmentation: Is there a trend for bigger implants? *Aesthetic Plast Surg.* 2019;43:59–69.
7. Tebbetts JB. A system for breast implant selection based on patient tissue characteristics and implant-soft tissue dynamics. *Plast Reconstr Surg.* 2002;109:1396–1409; discussion 1410–1415.
8. Tebbetts JB, Adams WP. Five critical decisions in breast augmentation using five measurements in 5 minutes: The high five decision support process. *Plast Reconstr Surg.* 2005;116:2005–2016.
9. Tebbetts JB. Wishes and tissues: A concern about dimensional planning systems that lack volume restrictions and do not prioritize long-term soft-tissue coverage. *Plast Reconstr Surg.* 2006;117:318–320.
10. Tebbetts JB. Achieving a zero percent reoperation rate at 3 years in a 50-consecutive-case augmentation mammaplasty premarket approval study. *Plast Reconstr Surg.* 2006;118:1453–1457.
11. Tebbetts JB, Adams WP. Five critical decisions in breast augmentation using five measurements in 5 minutes: The high five decision support process. *Plast Reconstr Surg.* 2006;118:35S–45S.
12. Adams WP Jr. The process of breast augmentation: Four sequential steps for optimizing outcomes for patients. *Plast Reconstr Surg.* 2008;122:1892–1900.
13. Tebbetts J. Bra stuffing for implant sizing? Satisfaction? Who, when, and compared to what? *Plast Reconstr Surg.* 2011;127:1001–1002.
14. Adams WP Jr, Small KH. The process of breast augmentation with special focus on patient education, patient selection and implant selection. *Clin Plast Surg.* 2015;42:413–426.
15. Adams WP Jr, Mckee D. Matching the implant to the breast: A systematic review of implant size selection systems for breast augmentation. *Plast Reconstr Surg.* 2016;138:987–994.
16. Wan D, Rohrich RJ. Modern primary breast augmentation: Best recommendations for best results. *Plast Reconstr Surg.* 2018;142:933e–946e.
17. Brody GS. Breast implant size selection and patient satisfaction. *Plast Reconstr Surg.* 1981;68:611–613.
18. McCafferty LR, Casas LA, Stinnett SS, Lin S, Rho J, Skiles M. Multisite analysis of 177 consecutive primary breast augmentations: Predictors for reoperation. *Aesthet Surg J.* 2009;29:213–220.
19. Hidalgo DA, Spector JA. Preoperative sizing in breast augmentation. *Plast Reconstr Surg.* 2010;125:1781–1787.
20. Codner MA, Mejia JD, Locke MB, et al. A 15-year experience with primary breast augmentation. *Plast Reconstr Surg.* 2011;127:1300–1310.
21. Gladilin E, Gabrielova B, Montemurro P, Hedén P. Customized planning of augmentation mammaplasty with silicon implants using three-dimensional optical body scans and biomechanical modeling of soft tissue outcome. *Aesthetic Plast Surg.* 2011;35:494–501.
22. Choudry U, Kim N. Preoperative assessment preferences and reported reoperation rates for size change in primary breast augmentation: A survey of ASPS members. *Plast Reconstr Surg.* 2012;130:1352–1359.
23. Hammond DC, Migliori MM, Caplin DA, Garcia ME, Phillips CA. Mentor Contour Profile Gel implants: Clinical outcomes at 6 years. *Plast Reconstr Surg.* 2012;129:1381–1391.
24. Brown T. Patient expectations after breast augmentation: The imperative to audit your sizing system. *Aesthetic Plast Surg.* 2013;37:1134–1139.
25. Stevens WG, Harrington J, Alizadeh K, Broadway D, Zeidler K, Godinez TB. Eight-year follow-up data from the U.S. clinical trial for Sientra's FDA-approved round and shaped implants with high-strength cohesive silicone gel. *Aesthet Surg J.* 2015;35(Suppl 1):S3–S10.
26. Brown MH, Somogyi RB, Aggarwal S. Secondary breast augmentation. *Plast Reconstr Surg.* 2016;138:119e–135e.
27. Hammond DC, Canady JW, Love TR, Wixtrom RN, Caplin DA. Mentor Contour Profile Gel Implants: Clinical outcomes at 10 years. *Plast Reconstr Surg.* 2017;140:1142–1150.
28. Nichter LS, Hardesty RA, Anigian GM. IDEAL IMPLANT structured breast implants: Core Study results at 6 years. *Plast Reconstr Surg.* 2018;142:66–75.
29. Hammond DC. Discussion: Matching the implant to the breast: A systematic review of implant size selection systems for breast augmentation. *Plast Reconstr Surg.* 2016;138:995–996.
30. Creasman CN, Mordaunt D, Liolios T, Chiu C, Gabriel A, Maxwell GP. Four-dimensional breast imaging, part I: Introduction of a technology-driven, evidence-based

approach to breast augmentation planning. *Aesthet Surg J.* 2011;31:914–924.
31. Chang JB, Small KH, Choi M, Karp NS. Three-dimensional surface imaging in plastic surgery: Foundation, practical applications, and beyond. *Plast Reconstr Surg.* 2015;135:1295–1304.
32. Tzou CH, Artner NM, Pona I, et al. Comparison of three-dimensional surface-imaging systems. *J Plast Reconstr Aesthet Surg.* 2014;67:489–497.
33. Chae MP, Rozen WM, Spychal RT, Hunter-Smith DJ. Breast volumetric analysis for aesthetic planning in breast reconstruction: A literature review of techniques. *Gland Surg.* 2016;5:212–226.
34. Ruiz G, Ramon E, García J, Sukno FM, Ballester MAG. Weighted regularized statistical shape space projection for breast 3D model reconstruction. *Med Image Anal.* 2018;47:164–179.
35. Losken A, Seify H, Denson DD, Paredes AA Jr, Carlson GW. Validating three-dimensional imaging of the breast. *Ann Plast Surg.* 2005;54:471–476; discussion 477–478.
36. Tepper OM, Small K, Rudolph L, Choi M, Karp N. Virtual 3-dimensional modeling as a valuable adjunct to aesthetic and reconstructive breast surgery. *Am J Surg.* 2006;192:548–551.
37. Tepper OM, Karp NS, Small K, et al. Three-dimensional imaging provides valuable clinical data to aid in unilateral tissue expander-implant breast reconstruction. *Breast J.* 2008;14:543–550.
38. Tepper OM, Small KH, Unger JG, et al. 3D analysis of breast augmentation defines operative changes and their relationship to implant dimensions. *Ann Plast Surg.* 2009;62:570–575.
39. Tepper OM, Unger JG, Small KH, et al. Mammometrics: The standardization of aesthetic and reconstructive breast surgery. *Plast Reconstr Surg.* 2010;125:393–400.
40. Creasman CN, Mordaunt D, Liolios T, Chiu C, Gabriel A, Maxwell GP. Four-dimensional breast imaging, part II: Clinical implementation and validation of a computer imaging system for breast augmentation planning. *Aesthet Surg J.* 2011;31:925–938.
41. Eder M, v Waldenfels F, Sichtermann M, et al. Three-dimensional evaluation of breast contour and volume changes following subpectoral augmentation mammaplasty over 6 months. *J Plast Reconstr Aesthet Surg.* 2011;64:1152–1160.
42. Hidalgo DA, Spector JA. Reply: Bra stuffing for implant sizing? Satisfaction? Who, when, and compared to what? *Plast Reconstr Surg.* 2011;127:1002–1003.
43. Losken A. Commentary on: Four-dimensional breast imaging, parts I and II. *Aesthet Surg J.* 2011;31:939–940.
44. de Heras Ciechomski P, Constantinescu M, Garcia J, et al. Development and implementation of a web-enabled 3D consultation tool for breast augmentation surgery based on 3D-image reconstruction of 2D pictures. *J Med Internet Res.* 2012;14:e21.
45. Donfrancesco A, Montemurro P, Hedén P. Three-dimensional simulated images in breast augmentation surgery: An investigation of patients' satisfaction and the correlation between prediction and actual outcome. *Plast Reconstr Surg.* 2013;132:810–822.
46. Hammond DC. Discussion: Three-dimensional simulated images in breast augmentation surgery: An investigation of patients' satisfaction and the correlation between prediction and actual outcome. *Plast Reconstr Surg.* 2013;132:823–825.
47. Roostaeian J, Adams WP Jr. Three-dimensional imaging for breast augmentation: Is this technology providing accurate simulations? *Aesthet Surg J.* 2014;34:857–875.
48. Epstein MD, Scheflan M. Three-dimensional imaging and simulation in breast augmentation: What is the current state of the art? *Clin Plast Surg.* 2015;42:437–450.
49. Weissler JM, Stern CS, Schreiber JE, Amirlak B, Tepper OM. The evolution of photography and three-dimensional imaging in plastic surgery. *Plast Reconstr Surg.* 2017;139:761–769.
50. de Runz A, Boccara D, Bertheuil N, Claudot F, Brix M, Simon E. Three-dimensional imaging, an important factor of decision in breast augmentation. *Ann Chir Plast Esthet.* 2018;63:134–139.
51. Oranges CM, Madduri S, Brantner P, et al. Three-dimensional assessment of the breast: Validation of a novel, simple and inexpensive scanning process. *In Vivo* 2019;33:839–842.
52. Gore SM, Lamberty BG. PERTHESE implant-identical cohesive-gel sizers in breast augmentation: A prospective report on 200 consecutive cases and implications for treatment of breast asymmetry. *Aesthet Surg J.* 2012;32:310–318.
53. Tezel E, Numanoğlu A. Practical do-it-yourself device for accurate volume measurement of breast. *Plast Reconstr Surg.* 2000;105:1019–1023.
54. Dionyssiou DD, Demiri EC, Davison JA. A simple method for determining the breast implant size in augmentation mammaplasty. *Aesthetic Plast Surg.* 2005;29:571–573.
55. Huemer GM, Wenny R, Aitzetmüller MM, Duscher D. Motiva Ergonomix Round SilkSurface silicone breast implants: Outcome analysis of 100 primary breast augmentations over 3 years and technical considerations. *Plast Reconstr Surg.* 2018;141:831e–842e.
56. Cruz NI. Breast augmentation: Patient satisfaction with 3D simulation of surgical outcomes. *Plast Reconstr Surg.* 2015;136(Suppl):161. AQ10
57. Swanson E. The limitations of three-dimensional simulations in breast augmentation. *Aesthet Surg J.* 2015;35:NP62–NP64.
58. Hall-Findlay E. Comments on "Three-dimensional imaging for breast augmentation: Is this technology providing accurate simulations?". *Aesthet Surg J.* 2015;35:NP68–NP72.
59. Overschmidt B, Qureshi AA, Parikh RP, Yan Y, Tenenbaum MM, Myckatyn TM. A prospective evaluation of three-dimensional image simulation: Patient-reported outcomes and mammometrics in primary breast augmentation. *Plast Reconstr Surg.* 2018;142:133e–144e.
60. Swanson E. Reply: Prospective outcome study of 225 cases of breast augmentation. *Plast Reconstr Surg.* 2013;132:1066e–1068e.