



## Using CAD/CAM Technology to Prepare Skin Incision Template and Predict Size Reduction of Each Breast Separately and Final Shape of Breast After Reduction Mammoplasty Surgery

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### ABSTRACT

*Background:* Reduction mammoplasty is getting common in plastic surgery, and in preoperative marking process, the accuracy of the surgery and the satisfaction of patients are of the most debating subjects. For this issue, the current study investigated the use of computer-aided design and computer-aided manufacturing (CAD CAM) to assess changes in marking process and projection of breasts following vertical reduction mammoplasty.

*Methods:* Reduction mammoplasty could encounter many difficulties as misunderstanding between surgeon and patients about the dimensional perception and dissatisfaction of the patients after the surgery. CAD CAM was used in this study to offer a solution for predicting breast volume, shape, size and preparing a 3D template for patients to try. The marking criteria were evaluated on 16 patients using two methods; A) classic and B) use of CAD CAM technology for compatibility of these methods' results with each other, and their effects on the rate of the patients' satisfaction.

*Results:* Classic marking techniques require much more time for the process. However, CAD CAM could decrease the time period of marking to 9.1 minutes less than the classic process. Marking criteria were assessed by these two methods, and did not show any significant differences (compatibility approved) before and after the reduction mammoplasty. Projection level was evaluated using CAD CAM. It is noteworthy, 3D template and involvement of the patients led to 100% satisfaction of the patients (8.8 of 10).

*Conclusion:* Because of many beneficial uses of new 3D technologies in the field of cosmetic plastic surgeries, CAD CAM is a promising tool for attaining patients' ideal results and saving surgeons' time.

**Keywords:** Mammoplasty, CAD CAM, Three-dimensional template

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### INTRODUCTION

Breast largeness can cause systemic problems such as breast pain, infection, standing problems, back pain, and pressure on the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> intercostal nerves, which leads to sensory disorder in nipples [1]. Studies have

shown that the complications of breast largeness are not limited to physical problems, but they can also result in the increased probability of depression and disorders in women's social life. Activity limitation and inability in climbing the stairs or running due to

chest pain or tightness are among other problems associated with breast largeness, which can impose significant negative effects on women's quality of life [2]. Hence, most of the women are looking for ways to reduce their breast size; in this regard, weight loss, proportionate diets, and the use of supplements are considered as auxiliary (complementary) methods. However, those individuals who have failed to reduce their breast size pick up surgery for this purpose. Reduction mammoplasty has been among the most prevalent surgical procedures for breast size reduction since nearly 50 years ago, and various techniques of which have undergone some changes over the past years. Studies in developed countries have indicated that mammoplasty is the most common surgery performed by plastic surgeons in the United States [2]. Statistical studies show that, in 2007, nearly 106179 reduction mammoplasty surgeries have been performed in the US [2]. On the other hand, in developing countries, the mammoplasty surgeries are often due to the physical complications of breast largeness rather than aesthetic issues; so that, in Nigeria and Ghana, the number of referrals for this purpose was very low, and the average age of the patients is lower than that in the US [2-4]. Over two decades, the T-scar and L-scar techniques, due to the long duration of operation as well as major, short-term, and chronic complications, have been replaced by Vertical Reduction Mammoplasty techniques [4-6]. Marking is considered as one of the most important preoperative actions, through which the surgeon performs the surgery programming by measuring the main characteristics of each patient and comparing them with their standard levels [5, 6]. These characteristics include: diameter of Nipple Areolar Complex (NAC), Supra notch-NAC distance, NAC-middle line distance (the line passing through Supra notch and navel), and Inferior Mammillary Fold (IMF) [7]. Marking is commonly time-consuming, and the use of this technology can reduce the time for visiting the patients; besides, the use of computer for marking by CAD CAM (computer aided design and computer aided manufacturing) in a short time can, by designing the template, give the patients an opportunity to express their opinion on the post-surgery final shape and size of their breasts, since one of the major problems in breast cosmetic surgery is the impossibility of applying the patients' opinions on the final result [8,9]. For this purpose, in the present study on the use of CAD CAM design technology, 16 patients referring to Panzdah-e-khordad Hospital for breast cosmetic

surgery for breast size and volume reduction were included in the study after obtaining their consent and providing them with required explanations. The marking measurement criteria were assessed by the surgeon via CAD CAM and classical methods, and the obtained results were compared in order to evaluate their consistency.

## MATERIALS AND METHODS

### Patients

The study population included the women with breast largeness referring to Panzdah-e-Khordad educational hospital, affiliated to Shaheed Beheshti University of Medical Sciences, for breast cosmetic surgery and breast size reduction of breasts. The subjects were selected based on the following inclusion (A) and exclusion (B) criteria: (ia) Aged 35-45; (iia) Ptois grade 3 or 4 in breast size examination; (iiia) Non-pregnant, non-lactating, and non-menopause; (iva) Lack of any diagnosed medical disease such as diabetes or metabolic diseases and immunosuppressive diseases/anemia/history of kidney or other organs transplant/history of breast-related problems including pain, mastitis, and cyst; (va) CUP breast size of D or larger; (vib) Unwillingness to continue participating in the study; (viib) An underlying disease or diagnosis of the disease during the study; (viii) The number of subjects was calculated as n=16 after consulting with the statistics professor and using the relevant formula. After applying the exclusion criteria and selecting the patients, the marking steps via CAD CAM and classical techniques were started.

### Surgical process

Sampling was performed using simple "objective-based" method. After obtaining the permission from Committee of Ethics of Shaheed Beheshti University of Medical Sciences and written Introduction Letter from the University, School of Medicine, and obtaining the permission from the President of Panzdah-e-Khordad Hospital, first, some questionnaires were prepared for the patients referring to the medical centers and completed by them. In case of unwillingness to participate in the study while having the inclusion criteria, full explanations were given to the patient on the purpose of study, and after completing the written consent, they were examined for marking. The breast size reduction surgery has been always associated with problems such as the lack of common understanding between the surgeon and the patient, followed by the patient's dissatisfaction from the surgical

outcome. In this study, using CAD CAM technology, it was attempted to overcome the above-mentioned problems by predicting the required size reduction and designing the template for marking before the surgery. Therefore, to evaluate this method, the patients were examined twice, a) marking design via conventional method and b) marking design via CAD CAM technology, and then compared in terms of compliance of the marking criteria as well as their satisfaction level. First, after the primary examinations, the patients sat undressed on a standard seat designed for 3D-imaging via CAD CAM. The criteria, including NAC, sternal notch-NAC distance, middle line-NAC distance (the line passing through SN and navel), and IMF-NAC distance, were measured by the specifically designed camera, and then the designed image was printed for the surgery. Furthermore, the lens-less laser (model: V910; Konica Minolta, Tokyo, Japan) was used, which was located at 1m distance from the patient and at the same level with the breasts. Imaging was performed at angles of -90, -45, 0, +45, and +90 degrees by laser. For the inferior view, the camera was placed upward at the knees' level, and the resulted images were analyzed in CAD CAM software leading to 3D images. The 3D template was designed based on the measurements, and then was given to the patient for expressing their opinions. The patient could wear the 3D template and come to the final conclusion on the probable changes in the design by consulting the doctor. Then, marking was performed on the patients using the classical method, and the criteria measured by CAD CAM were compared. It should be noted that the time required for marking in both phases was recorded. After the surgical operation, the criteria were again measured for each patient and then compared with their preoperative values. The postoperative satisfaction was also set as a questionnaire ranging from 1 to 10 (so that 1 and 10 indicated completely dissatisfied and completely satisfied, respectively). The postoperative complications would be evaluated in all the patients.

#### Data analysis

In order for data description, frequency, percentage, mean, standard deviation, median, interquartile range, and range were used; furthermore, confidence interval of 95% was used to express accuracy of the estimations. Finally, in order to eliminate the effect of probable confounders or effect of interaction, the regression methods such as covariance analysis and logistic regression were used. All the analyses were performed in SPSS 20.0

software, and  $p < 0.05$  was considered as the significant level.

## RESULTS

### Physical examination

After examining the information of the patients referring to Panzdah-e-Khordad hospital and considering the inclusion and exclusion criteria, the patients were provided with full explanations on the study, and the use of CAD CAM method in the marking stage and the classical method, which are performed by a surgeon for all the patients, and then the written consents were taken from all of them. Afterwards, through physical examinations, the breast size and ptosis grade were evaluated for each patient. The age of candidate patients for breast cosmetic surgery ranged from 35 to 45 with average age of  $39.8 \pm 3.5$ ; furthermore, the breast size was measured with regard to the bra (cup) size criteria, so that 11 patients (68.8%) were of D+ size, and ptosis grade of most of them (81.3%) was 4.

### Preoperative marking

The essential criteria for preoperative marking included NAC, supra notch-NAC distance, NAC-middle line distance, and IMF-NAC distance. First, using the classical method (Fig.1), these criteria were measured by the surgeon and recorded for each patient (Table 1). The average time for performing the marking via classical method was 13.7 min, which was reduced to 4.6 min by CAD CAM method; therefore, according to the statistical analysis, the use of CAD CAM would lead to a significant reduction in duration of marking. According to Table (1), comparing the values obtained from marking via classical method and CAD CAM in measuring the NAC diameter for all the patients indicated no significant difference in measurements ( $p = 0.00097$ ).



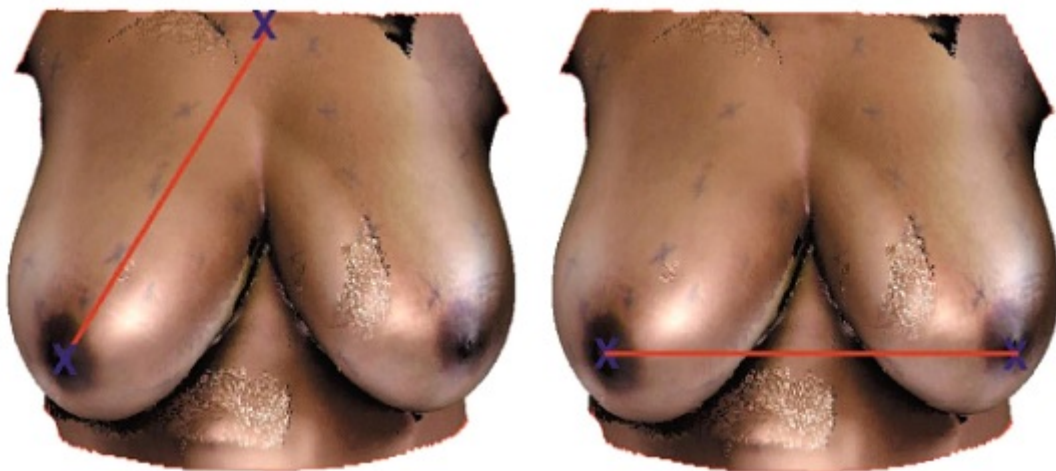
**Figure 1.** Marking by the classic method and design model before surgery.

**Table 1.** Comparing of the patient marking before surgery between classic and CAD-CAM method.

No	NAC Diameter		SN-NAC Distance		NAC-Midline Distance		IMF-NAC Surface Distance		Mean of Duration	
	Classic	CAD-CAM	Classic	CAD-CAM	Classic	CAD-CAM	Classic	CAD-CAM	Classic	CAD-CAM
1.	5.1	5	27	26.5	12.3	12.2	13.8	13.5		
2.	5.5	5.4	26.5	26.1	12.7	12.5	14.2	14		
3.	5	5	27	26.4	12.6	12.5	14	13.6		
4.	5.8	5.7	30	29.6	12.1	12	13.5	13.2		
5.	5.3	5.3	25.5	25.8	13	12.8	14.4	14.5	13.7	4.6
6.	5.5	5.5	27	27	12.3	12.1	15	14.6		
7.	6	4.8	25	23.5	12.9	11.8	14.6	13		
8.	5.7	5.8	28.5	27.8	12.5	12.4	13.1	13		
9.	5.8	5.7	27	26.7	12.8	12.6	14.7	14.8		
10.	6	5.9	29	28.3	12	12	13.3	13.3		
11.	5.2	5.1	26	25.6	12.4	12.2	14.3	14.5		
12.	5	5	26.5	26.7	13	12.7	14	14		
13.	5.6	5.4	29	28.4	12.2	12	14.8	14.5		
14.	6	5	30	28.7	12.9	11.7	15	13.6		
15.	5.9	5.7	26.5	25.7	12.8	12.6	13.5	13.2		
16.	5.6	5.5	29	29	13	12.6	13	13		
P-value	0.00097		0.00174		0.00133		0.00128		0.40237	

In measuring the supra notch-NAC distance (Fig.2), comparing the values obtained from the two marking methods, the consistency and insignificance between the two methods was ( $p = 0.0174$ ); furthermore, evaluating the NAC-middle line distance and comparing the two marking methods indicated consistency of the results of the two methods ( $p = 0.00133$ ).

Applicability of CAD CAM with regard to 3D imaging and analysis in volume (size) measurement methods has been proven, and is consistent with measurement of the IMF-NAC distance via classical method ( $p=0.00128$ ). In general, comparing the data resulted from marking via both methods indicated statistical and clinical consistency of the results despite the differences of 0.1 to 0.2.

**Figure 2.** Measurement of the surface distance of supra notch to NAC and NAC to the middle by CAD-CAM

**Evaluating postoperative marking criteria**

After the surgery, two patients (12.5%) were afflicted by ischemic nipple, which was controlled with regard to their relative congestion by prescribing aspirin as well as supportive measures. Then, the patients, who were monitored for 54.3 hours on average in Plastic and Repair Surgery ward in Panzdah-e-Khordad hospital, were discharged with appropriate general status and also were asked to refer to the Plastic and Surgery Clinic for further visits after two weeks. The patients' satisfaction level with the use of CAD CAM method was assessed through a questionnaire;

accordingly, satisfaction level of all the patients ranged between 7-10 (8.8%). This information showed the positive effect of using 3D template, and applying the patients' opinions on proportion of the marking criteria. Such a possibility was provided by CAD CAM method.

To ensure non-contradiction of the CAD CAM and classical techniques, in the second reference (two weeks after discharge), the marking criteria were evaluated using both methods. As seen in Table 2, the results of marking via CAD CAM and classical techniques in NAC diameter measurement had no statistically significant difference (p-value = 0.00091).

**Table 2.** Comparing of the patient marking after surgery between classic and CAD-CAM method.

No	NAC Diameter		SN-NAC Distance		NAC-Midline Distance		IMF-NAC Surface Distance		Projection/Elevation CAD CAM	
	Classi c	CAD- CAM	Classi c	CAD- CAM	Classi c	CAD- CAM	Classi c	CAD- CAM	Lower pole	Maxima l Projecti on
1.	3.9	4.0	21.2	21.1	10.1	10.0	6.3	6.3	4.8	4.8
2.	3.8	3.8	21.0	20.9	10.5	10.4	6.5	6.5	5.0	4.2
3.	3.9	4.0	21.5	21.3	11.0	10.8	6.1	6.1	4.5	5.1
4.	3.9	3.8	21.3	21.2	10.3	10.2	6.0	6.0	4.6	5.2
5.	4.0	4.1	21.0	21.1	10.8	10.7	6.5	6.5	4.8	4.5
6.	4.1	4.0	20.8	20.8	10.5	10.5	6.8	6.8	4.9	4.6
7.	4.2	4.1	20.9	20.7	10.3	10.4	7.0	7.0	5.0	5.1
8.	4.0	3.9	21.0	21.1	10.9	10.8	6.3	6.3	5.1	4.8
9.	4.1	4.0	21.0	20.9	10.2	10.0	6.5	6.5	4.7	4.6
10.	3.9	4	21.5	21.4	11.0	11.1	6.2	6.2	4.9	4.8
11.	4.1	4.2	21.1	21.0	10.3	10.1	6.6	6.6	5.0	5.0
12.	4.2	4.1	20.9	20.8	10.1	10.0	6.1	6.1	4.9	4.9
13.	3.8	3.8	21.0	21.1	10.0	10.0	6.0	6.0	4.5	4.4
14.	4.0	4.0	21.0	21.0	10.2	10.2	6.4	6.4	5.1	5.2
15.	4.0	3.9	21.4	21.3	10.4	10.3	6.5	6.5	5.0	4.3
16.	3.9	3.8	21.2	21.0	10.5	10.5	6.3	6.3	5.0	4.5
P-value	0.00091		0.00182		0.00151		0.00125		-	

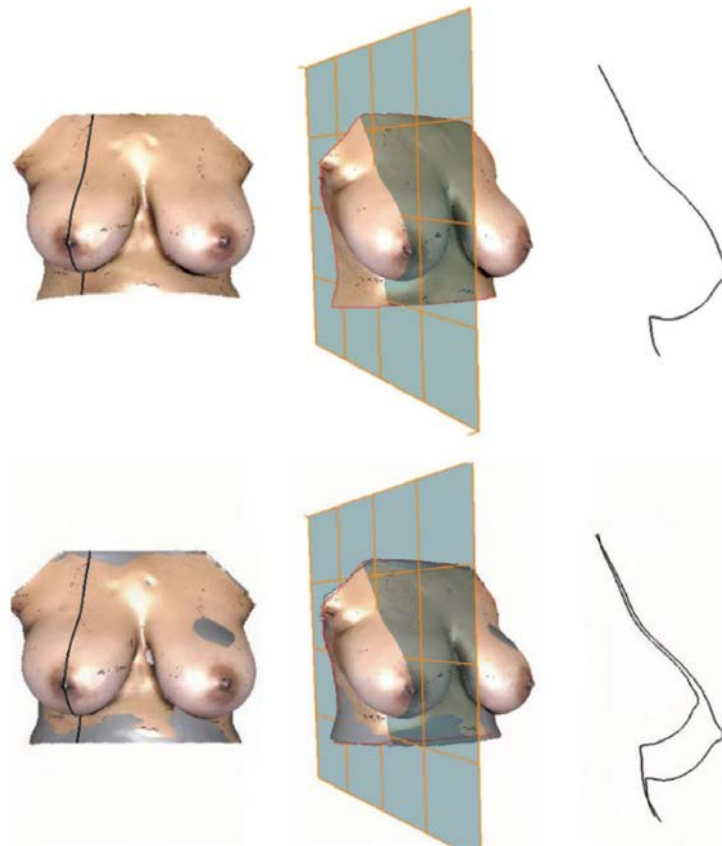
The supra notch-NAC distance in both marking methods showed statistical consistency of the two methods (p = 0.00182). The NAC-middle line distance in both techniques indicated no significant differences in measurements (p-value = 0.00151). Furthermore, the postoperative IMF-NAC distance was evaluated and recorded via both methods, comparison of the results of which confirmed the agreement between the two methods (p = 0.00125). IMF

was modeled using Sagittal imaging by CAD CAM (Fig.3).

One of the major volumetric criteria in pre & post-operative breast variations is the projection rate. Due to the impossibility of calculating the projection rate in the classical technique, only the information derived from CAD CAM is presented in Table 2. Accordingly, on average,  $4.8 \pm 0.3$  cm of the inferior breast pole and  $4.8 \pm 0.6$  cm of the maximal point was changed with regard to the spatial form of the breast images in order for the surgeon and

patients to achieve their ideal projection rate. Furthermore, the preoperative anterior-posterior projection was evaluated on average equal to  $6 \pm 0.3$  cm by CAD CAM, which was

measured equal to  $4 \pm 0.2$  after the surgery, indicating a reduction of 2 cm in this criteria reported by CAD CAM.



**Figure 3.** Use the Sagittal view to design the IMF model, before and after surgery

### DISCUSSION

Today, the use of cephalography and CT scan imaging techniques has been considerably helpful in the preoperative procedures of the craniomaxillofacial surgeries; however, unfortunately, the 3D evaluation methods are not widely used in breast restoration and plastic surgeries. In the present study, for the first time in Iran, the use of CAD CAM technique for pre & post-operative marking on candidate patients for reduction mammoplasty was assessed. The earlier studies had limitedly used the 3D methods among African and American patients [10, 11]. In this study, adding the inferior breast images resulted in a better understanding of the 3D space of the breasts by CAD CAM device, so that it could measure IMF-NAC surface distance. Color mapping had been previously used by Isogai et al. to assess symmetry of the breasts [12], but in this study, it was made more applicable by designing a 3D template. The use of sagittal view in 3D design led to an accurate assessment of the pre & post-operative NAC location, which was of great importance in estimating the breasts' projection rate. The

projection rate was investigated qualitatively in classical techniques, and 3D measurement of the breasts' spatial location was very difficult for the surgeon, and thus the patients do not have a visual perception of the postoperative size and projection of the breasts, which can lead to their dissatisfaction. One of the most important applications of 3D modeling is the calculation of the volumetric variations (changes), the assessment of which has been pointed out in previous studies [13, 14].

The use of CAD CAM method provided the possibility of 3D imagining before the surgery and predicting its 3D space after the surgery; therefore, after the CAD CAM design, the resulting images were given to the patients, and then their comments on the size and projection rate were applied considering the consultations with the surgeon. The next point in using the CAD CAM technique is to prepare a physical 3D template for the patients to wear, which was performed in the present study and led to the patients' satisfaction, a real understanding of the images is achieved when the virtual image is converted into a real image. Various techniques



have been so far investigated the 3D evaluation of the breasts, including water changes, water displacement (Archimedean), or mechanical plasters, which cause operational problems and difficulties for the patients. In this regard, the use of ultrasound radiologic methods, CT, and MRI were also investigated in recent studies, but the routine use of such methods resulted in some consequences for the patients such as high costs, radiation exposure for the candidate patients for elective surgery, as well as positioning problems [15-17]. The cost of using CAD CAM method is much lower than other marking evaluation methods, which cost nearly 20000-100000 \$; of course, regarding the diversity of the provided devices, lower prices can be expected [18]. Due to the speed of marking, which was on average 4.6 min in the present study (i.e. 9.1 min less than the classical method), the CAD CAM method significantly helped the patients' comfort and time-saving. The major issue in using the CAD CAM method was its accuracy in measuring the marking criteria, so that in the present study, all the calculated criteria were statistically and clinically consistent with those of the classical marking techniques, which can confirm applicability of this method in clinical fields. Another feature of this technique is the possibility of 3D reconstruction in volumetric distribution of the breasts, which can help surgeons in evaluating the volumetric deficits and estimating the symmetry. However, in the present study, due to the lack of required software, the application of this feature of CAD CAM during the surgery was avoided; whereas, the volumetric distribution of breasts in fat graft has been widely used in previous studies [19, 20]. The primary evaluation and physical examination before the surgery determine the appropriate technique proportionate to the patients' conditions, including size, volume, and ptosis of the breasts; accordingly, based on the studies, the inferior pedicle method is more appropriate for larger breasts [21-24], while the internal pedicle method is more suitable for smaller breasts [25, 26]. On the other hand, the classical method does not provide the surgeon with a proper understanding of the breast size, which can lead to selection of an inappropriate surgical technique due to the ambiguity of the evaluation. Investigating the marking criteria after the surgery using this method again confirms the accuracy of measurements in CAM CAD technique; besides, the possibility of evaluating the anterior-posterior projection rate can help the surgeons in following their patients after the surgery. In the present study, all the

patients referred to the surgical clinic after two weeks and underwent the necessary evaluations in a short time; however, in fact, the use of CAD CAM can facilitate more accurate assessment of the surgical techniques (after the surgery) over time as well as comparison of their changes using the quantitative data derived from CAD CAM method, which requires further studies in this regard. Finally, the use of CAD CAM technique for marking, regarding the capabilities and features mentioned in the present study, can play a major role in improving the quality of cosmetic mammoplasty services and promoting the patients' satisfaction level. It is hoped that we can achieve a better understanding of the 3D technologies in plastic and restoration surgeries, in particular for mammoplasty, by continuing the applied researches.

### CONCLUSION

With respect to the consistency of the measurements in the marking stage, which is considered as one of the most important processes before the breast cosmetic surgery, it is proposed to conduct more studies to evaluate and confirm accuracy of CAD CAM technique, because applying the patients' role as well as their satisfaction in cosmetic surgeries is one of the major concerns of the surgeons.

### Conflict of Interest

The authors declare that they have no conflict of interest.

### Ethics

This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.MSP.REC.1396.42).

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