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Comparison of Breast Measurement Ratios Before and After Breast Augmentation Using Photogrammetric Ratio Measurements (PRM)

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Objective: The purpose of this study was to determine breast shape and ratio of breast enlargement women prior to development of breast enlargement patient's bra.

Background: Although there are many previous studies on women's breast that did not undergo breast augmentation surgery, no studies have examined the breast type and proportion of women with breast augmentation.

Method: In this study, we analyzed ratios and angles with photographs taken before and after breast augmentation on the frontal and lateral views of the breast, UPF and projection were analyzed too. We also compared the pre-operative and post-operative rates with those of previous breast studies, as well as the post-operative breast types for the desirable breast types.

Results: The length and width of the breast base and the height of the breast projection increased after the operation. The rate of increase in width is larger than the vertical distance in the breast base, and the rate of increase in height of the projection is larger than the increase in the width. Specifically, in the vertical distance, the rate of increase in the lower portion is larger than that in the upper portion. In the width, the rate of increase on the inside is larger than that on the outside.

Conclusion: The angles of the static relationship with the projection increased and the angles of the minor relation decreased. The changes in the size of the breast were visually observed in the overlapping of the triangle shape before and after the surgery. The changes were composed of the line connecting the angle and the measurement points. The pre-operative upper pole fullness (UPF) was mostly 0 and -1, but after the surgery, +1, 0, -1, +2 were distributed, while post-operative levels of projection were distributed in the order of level 3> level 1> level 2. In comparison with the desirable breast type, it was found that the anatomical type was a more natural breast type than the round type of implant.

Application: These results can be useful as basic data for the breast analysis of breast enlargement patients and their bra patterns.

Keywords: Breast augmentation, Breast enlargement, Upper pole fullness (UPF), Projection, Triangle shape

1. Introduction

Cosmetic surgery to improve a breast shape, such as smaller than normal size and

breast drooping or reduction according to childbirth or aging, becomes mainstream in modern breast augmentation (enlargement) surgery, rather than breast reconstruction or the correction of an abnormal breast shape (Yoo et al., 2012).

According to a survey of the complaints on the breast of women in their 20s, a complaint on lacking breast volume was highest at 46%. The other main complaints were impossible presentation of cleavage due to widening breast, and breast drooping due to insufficient elasticity, huge breast, and asymmetric breast. To solve such problems, wearing correction underwear took up the highest ratio at 50%, followed by exercising, undergoing plastic surgery, and receiving dietary treatment. The ideal bra size that the respondents thought was B cup or C cup, which took up 88% of the total respondents. To such an extent, those women preferred a large-sized breast (Choi, 2017).

Recently, increasing breast enlargement surgery has been carried out with a method to insert a special viscous material such as cohesive gel in the hypodermic tissue or beneath the skin of the breast or an implant including silicon and saline solution in various cut portions including the armpit or underbreast line. Although a breast implant was generally conducted to create a round breast, an anatomical breast (tear drop breast) type has been recently carried out, and therefore the breast augmentation implant surgery can be divided into the round breast and anatomical breast types. The round breast implant shows a somewhat unnatural breast silhouette by which the upper breast becomes somewhat bulgy, and the length between bust point and lower point is long in some cases, and thus some differences are shown from the natural breast. Meanwhile, the anatomical breast implant can turn the natural chest line into a slightly downward tilting shape due to breast weight. For this reason, the anatomical (tear drop) breast implant is said to reflect an anatomical shape, compared to the round breast implant. However, round breast implants are mostly used, given that the round breast takes up 73.6% of the total breast implant type, according to a study result of Yi et al. (2016).

Beautiful breast needs to be adequately curvaceous and elastic. Concerning beautiful breast, there is a study of Smith et al. (1986) that measured detailed items related to the breast and that reported mean, median, maximum, and minimum measurements as individual measurements. In addition, a study of Melvyn (1997) calculated the measured data on 21 items and breast volume as a regression equation targeting 50 women with an almost perfect breast, presenting guidelines on proper volume increase in a surgery.

In an attempt to reproduce aesthetic breasts through breast enlargement surgery, the selection of implant height and width is important. Because the selection of an implant is related with a patient's anatomical structure, it is difficult to use a projection-shaped implant if the bottom area of the breast is wide and an implant cannot be used. If it is small, the use of a wide-shaped implant cannot be used. Therefore, an implant suitable for anatomical structure needs to be selected. According to a patient's breast type and volume, the breast types after an implant is inserted can differ, and it is difficult to always regard the breast after a breast enlargement surgery as aesthetically beautiful. Although one received a breast enlargement surgery, a brassiere needs to be worn, and a brassiere fitting the changed breast is particularly necessary. In actuality, studies on securing the bra cup area considering breast size and volume are necessary from the clothing construction aspect, especially proper cup height on the nipple height reflecting extended lower length, shoulder straps to minimize increased load, and breast measurements including underbust circumference that becomes smaller as underbust circumference comes down because of the downward extension of the breast bottom contour. This study aims to examine changes in ratios related to the breast before and after a breast augmentation surgery using photogrammetric ratio measurements (PRM) from the front and lateral directions targeting women in their 20s who received the surgery in Korea and to analyze the shape changes of the breast, compared with the breast shapes before the surgery. Towards this end, we compared the changes before and after the surgery through the construction and superimposition of triangular shapes using the angles and ratios of the measurement points. We also compared with ratios in the aesthetic breast measurements and ratios in the existing studies of Hwang et al. (2005) and Sohn and Kweon (2013) in order to find out the differences between each part's measurement ratio and angle before and after the surgery and the breast measurement ratios and angles generally regarded as beautiful. Further, we evaluated the upper pole fullness (UPF) and projection indicating the convexity of the upper breast portion.

Such data can be used as baseline data for foundation garment including a bra for post-operative patients. The data also can be utilized as a method to observe some changes in the patients who underwent breast augmentation surgery before and after the surgery. Finally, the data can be used as a guideline to present aesthetic breast shape using a bra, even not through a breast enlargement surgery.

2. Theoretical Background

2.1 Shape and projection of implants for breast augmentation

As for the implant shape used for breast augmentation, there are a round breast implant and anatomical (tear drop) breast implant reflecting a human's anatomical structure (Breast Implant Profiles: How to Choose, 2016). Projection is classified as low, moderate, moderate plus, high, and ultra high according to a breast's projection level as shown in Figure 1 (High Profile Breast Implants - Projection Types, 2015). However, projection changes in relation with basic diameter, and thus it changes according to base diameter. Low level shows the lowest projection and is suitable for a patient with wide frame. Moderate level is middle level projection and is a basic implant; women with narrow chest prefer this as the breast can widen. Moderate plus level is the middle level between the middle and high levels, and is selected by women who want some attractive breasts, but do not want the high level of projection. High and ultra high levels are the highest projection levels, and these can give desired breast depth to women whose breast depth is low. Figure 2 presents surgery examples according to a breast implant's profile.

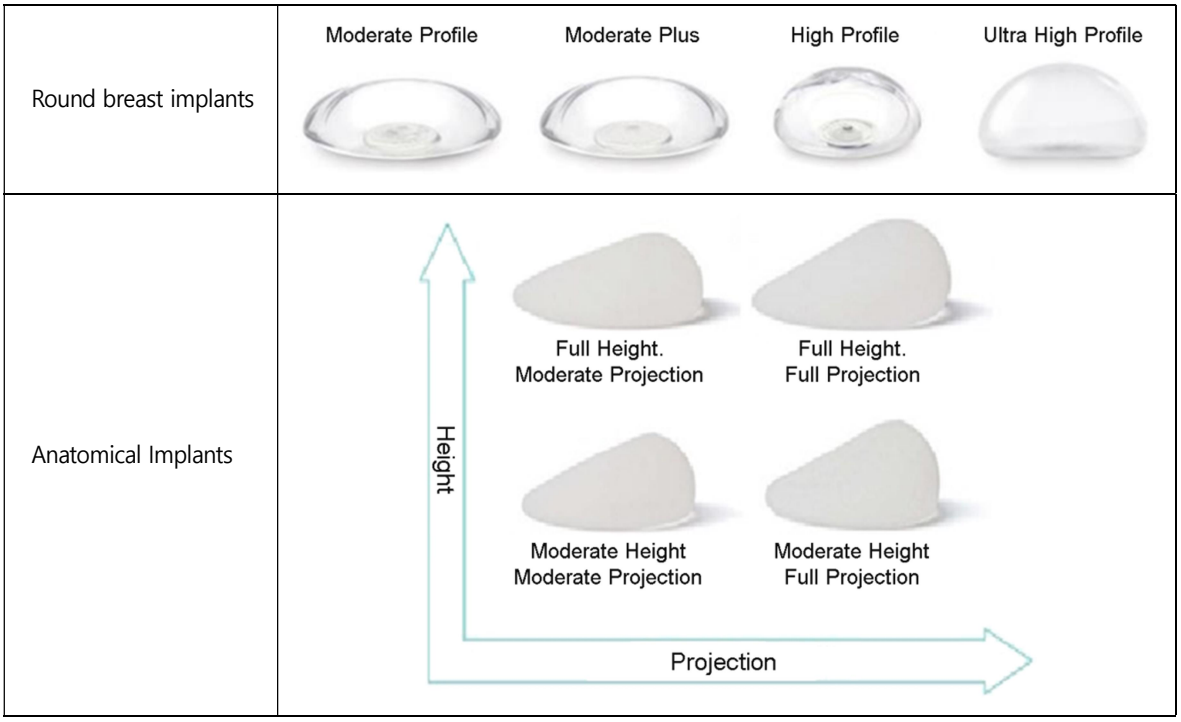
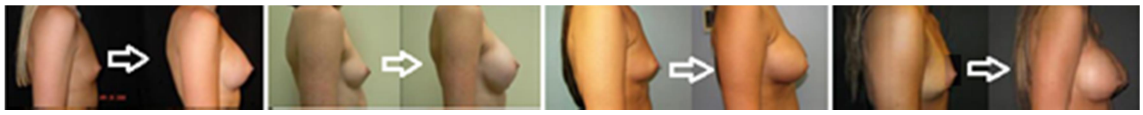


Figure 1. Breast implant profiles



Moderate Moderate plus High Ultra high

Figure 2. Examples of projection

2.2 UPF (Upper Pole Fullness)

Upper Pole Fullness (UPF) means upper convexity, and is used as a method to analyze breast type. As shown in Figure 3, the upper shape viewed from the side is evaluated as -1 and -2 according to receding level, based on 0, and it is evaluated as 1 and 2 according to rising level. The UPF preferred generally is -1, 0, +1, and the anatomical breast is said to belong to this category.

-2 -1 0 0 +1 +2

Figure 3. Level of UPF

In the case of breast enlargement surgery with a round implant, the possibility of UPF distortion is high (Scott et al., 2004). In a study of Graf et al. (2000), an operation method to receive better UPF, a method operating by raising breast in an oval skin shape using a pectoralis loop was proposed.

3. Method

3.1 Photogrammetric Ratio Measurements (PRM)

The breast photographs used in this study were 95 patients' photographs taken before and after the breast augmentation (after recovery stage) of women in their 20s and 30s in five plastic surgery centers in Seoul. To remove errors before and after the surgery and photograph sizes among the medical centers, we did not use the original measurements, but used measurements done by calculating the ratios on the measurement items with no change in size before and after the surgery, calculating angles having a certain angle regardless of photograph size. Through the superimposition of a triangle consisting of an anterior neck point and a line from the left bust point to the right bust point, a triangle consisting of an anterior neck point, a bust point, and a waist center front point seen from the side, and a triangle consisting of an anterior neck point, a bust point, and a lower point, the breast shape change was analyzed. Figure 4 shows the measurement method and measurement points.

The changes before and after surgery, along with the distribution, were analyzed by assessing the UPF indicating the upper portion convexity of the breast. Evaluation of lateral projections after the surgery were evaluated for an analysis.

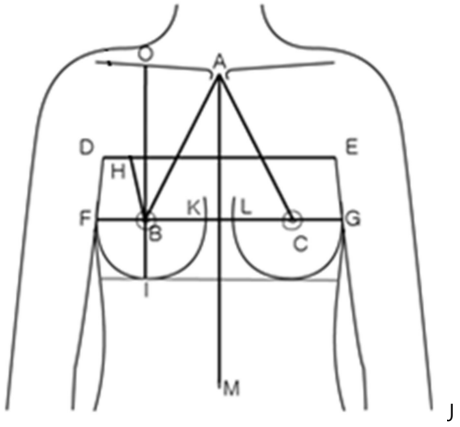
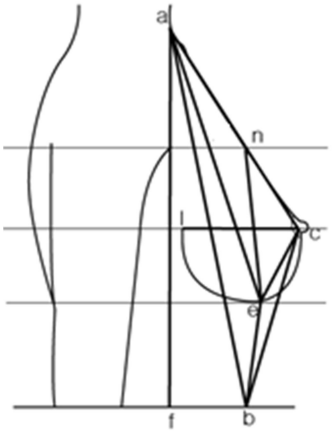
	Front	Side
Measurement method		
Measurement point	A : Anterior neck point B : Right bust point C : Left bust point D, E: Front axillary point F, G: Outer breast point H : Upper breast point I : Lower breast point J : Bishoulder point K : Inner breast point of right breast L : Inner breast point of left breast M : Waist front point	a: Anterior neck b: Waist front point c : Bust point e: Lower breast point f : Point drawn vertically from the waist line l : Outer breast point n: Upper breast point

Figure 4. Measurement method and measurement points

3.1.1 Analysis using ratios

21 ratios were calculated with the lines connecting the measurement points in Figure 4, and they are shown in Table 1. They were measured on distance, width, and thickness. Concerning the ratio of upper length and lower length (R19), the ratio was calculated by measuring the length from the upper breast point to the bust point and the length from the bust point to the lower point along the chest line.

Table 1. Measurement ratio

Ratio No.	Measurement method
R1	B.P.~B.P./chest width (BC/DE)
R2	F.N.P.~left B.P./chest width (AC/DE)
R3	F.N.P.~right B.P./chest width (AB/DE)

Table 1. Measurement ratio (Continued)

Ratio No.	Measurement method
R4	Clavicle bisector point~B.P./chest width (OB/DE)
R5	Breast width/Chest width (KF/DE)
R6	Clavicle bisector point~B.P./B.P.~B.P. (OB/BC)
R7	Upper breast point~lower breast points/breast width (HI/KF)
R8	Chest/distance between inner breast points (DE/KL)
R9	Inner breast point~B.P.outer breast point~B.P. (BK/BF)
R10	Upper breast point~B.P./B.P.~lower breast point (HB/BI)
R11	Upper breast point~lower breast points/center front length (HB+BI)/AM)
R12	F.N.P.~B.P./vertical length from F.N.P. to waist line (ac/af)
R13	F.N.P.~lower breast point/vertical length from F.N.P. to waist line (ae/af)
R14	Waist point(front)~B.P./vertical length from F.N.P. to waist line (bc/af)
R15	F.N.P.~waist point(front)/vertical length from F.N.P. to waist line (ab/af)
R16	B.P.~lower breast point/vertical length from F.N.P. to waist line (ce/af)
R17	Upper breast point~lower breast point/vertical length from F.N.P. to waist line (ne/af)
R18	Upper breast point~B.P./vertical length from F.N.P. to waist line (nc/af)
R19	Surface length of upper breast point to B.P./Surface length of B.P. to lower breast point (nc/ce)
R20	Outer breast point~B.P./upper breast point~lower breast points (lc/ne)
R21	Shoulder bisector point~lower breast point/shoulder bisector point~B.P. (JI/JB)

3.1.2 Analysis using angles

The angles consisting of lines were measured as a method to identify shape change before and after the surgery. Table 2 presents 10 angles measured from the side and three angles measured from the front. To identify the lateral breast shape, the following were employed: triangle 1 which connects the upper breast point, bust point, and lower point; triangle 2 which connects the anterior neck point, bust point, and lower point; and triangle 3 which connects the anterior neck point, bust point, and waist front point. The length and angle of a triangle connecting the anterior neck point and left and right bust points from the front were used as important data to identify the position and shape of the breast, and they are already used as the criteria to judge the aesthetic breast. For construction, the ratios and angles are needed.

Table 2. Measurement angle

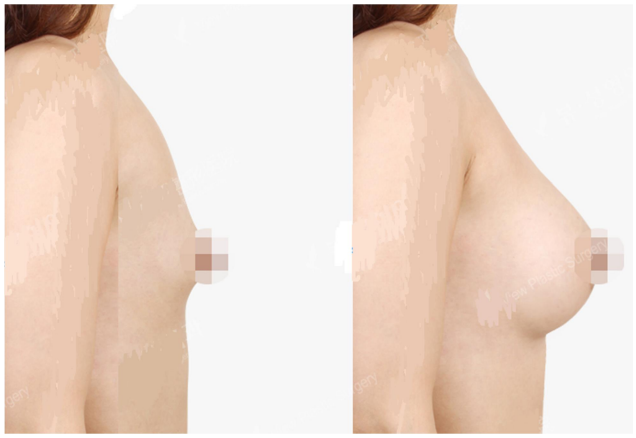
Angle No.	Angle in side	Angle No.	Angle in front
A1	∠fac	A11	∠BAC
A2	∠fbc		
A3	∠cne		

Table 2. Measurement angle (Continued)

Angle No.	Angle in side	Angle No.	Angle in front
A4	∠nec	A12	∠ABC
A5	∠nce		
A6	∠eac		
A7	∠aec	A13	∠ACB
A8	∠bac		
A9	∠abc		
A10	∠acb		

3.1.3 UPF and projection analysis method

UPF and projection levels of 95 patients who underwent a breast enlargement surgery were evaluated before and after the surgery as shown in Figure 5. The evaluation panel consisted of 2 experts who had experienced developing brassiere and majored in clothing construction. Based on Figures 2 and 3, each researcher evaluated, and then the results were compared. A third researcher assessed the photographs showing differences again.



Pre-operative view Post-operative view

Figure 5. Evaluation of UPF and projection before and after surgery

UPF was assessed to have five levels: -2, -1, 0, +1, and +2, and projection was assessed to have 1 to 3 levels. Although the projection level of an implant is classified as low, moderate, moderate plus, high, and ultra high, the projection level of post-operative patients is actually classified into 3 to 4 levels in reality. This study conducted an evaluation by classifying the projection level into three levels: level 1 (moderate), level 2 (moderate plus), and level 3 (high and ultra high) because low or ultra high projection level is rare based on the criteria in Figure 2.

3.2 Comparative analysis with previous studies' aesthetic breast ratios

We comparatively analyzed the ratios from a study on the Korean women's desirable breast position and size with the prize-winning works of some Art Awards (Hwang et al., 2005) and using the ratios before and after the breast enlargement surgery. We also comparatively analyzed what implants are suitable for more desirable breast type through a comparison of measurement ratios on the desirable breast type and the measurements ratios of the two groups of the breast augmentation patients (round breast and anatomical breast) (Sohn and Kweon, 2013).

3.3 Statistical analysis method

Using SPSS 21.0, we carried out paired *t*-tests to find out the differences before and after a breast enlargement surgery with 21 ratios (R1-R21) and angles (A1-A3) before and after the surgery. A frequency analysis before and after the surgery with UPF evaluation data was conducted, and change before and after the surgery was investigated through a crosstab analysis. We also evaluated projection level from the photographs after a breast enlargement surgery and presented the result via a frequency analysis.

4. Results and Discussion

4.1 Analysis on the ratios and angles before and after breast augmentation

4.1.1 Differences examined with ratios before and after breast augmentation

Table 3 shows the differences examined by ratios before and after a breast augmentation. Upon looking at R1-R5 and R8 calculated on the basis of chest width that does not change even after the surgery from the front photos, the distance between the bust points increased (*t*-value: 3.64, $p<.001$), and the distance from the anterior neck point to the left and right bust points (B.P.) increased after the surgery; however, only the increase of left and right B.P. distance showed a significant difference (*t*-value 2.52, $p<.05$). The distance from clavicle bisector point to B.P. showed no significant difference, and width sharply increased (*t*-value 17.01, $p<.001$). The ratio between inner breast points on breast width was 9.46 before the surgery, but it was 20.22 after the surgery. Therefore, the distance between inner breast points narrowed (*t*-value 13.00, $p<.001$). This needs to be reflected to the setup of the distance between the inner breast points upon designing the front panel of a bra. From the result above, it was found that width sharply rose between the bust points after a breast augmentation and that the distance between inner breast points sharply narrowed. Also, it was found that the distance from the clavicle bisector point to the B.P. did not sharply change.

Table 3. Difference of ratio before and after surgery

	Item	Mean ratio (SD)		*t*-value
		Pre-operative	Post-operative	
R1	B.P.~B.P./chest width (BC/DE)	.62 (.05)	.65 (.08)	3.64***
R2	F.N.P.~left side B.P./chest width (AC/DE)	.65 (.05)	.66 (.05)	2.52*
R3	F.N.P.~right side B.P./chest width (AB/DE)	.66 (.05)	.67 (.05)	.92
R4	Clavicle bisector point~B.P./chest width (OB/DE)	.61 (.07)	.61 (.06)	.59
R5	Breast width/chest width (KF/DE)	.38 (.04)	.45 (.03)	17.01***

Table 3. Difference of ratio before and after surgery (Continued)

	Item	Mean ratio (SD)		*t*-value
		Pre-operative	Post-operative	
R6	Clavicle bisector point~B.P./B.P.~B.P. (OB/BC)	.98 (.13)	1.01 (.68)	.36
R7	Upper breast point~lower breast points/breast width (HI/KF)	1.74 (.69)	1.00 (.10)	-10.03***
R8	Chest width/distance between inner breast points (DE/KL)	9.46 (3.38)	20.22 (9.02)	13.00***
R9	Inner breast point~B.P./outer breast point~B.P. (BK/BF)	1.59 (.48)	1.85 (.39)	4.23***
R10	Upper breast point~B.P./B.P.~lower breast point (HB/BI)	2.20 (.73)	1.28 (.42)	-12.35***
R11	Upper breast point~lower breast points/center front length ((HB+BI)/AM)	.39 (.10)	.44 (.06)	4.33***
R12	F.N.P.~B.P./vertical length from F.N.P. to waist line (ac/af)	.60 (.06)	.64 (.05)	7.04***
R13	F.N.P.~lower breast point/vertical length from F.N.P. to waist line (ae/af)	.72 (.05)	.76 (.06)	7.83***
R14	Waist point (front)~B.P./vertical length from F.N.P. to waist line (bc/af)	.45 (.05)	.48 (.04)	7.95***
R15	F.N.P.~waist point (front)/vertical length from F.N.P. to waist line (ab/af)	1.03 (.02)	1.03 (.02)	1.90
R16	B.P.~lower breast point/vertical length from F.N.P. to waist line (ce/af)	.16 (.04)	.25 (.04)	23.69***
R17	Upper breast point~lower breast point/vertical length from F.N.P. to waist line (ne/af)	.26 (.07)	.27 (.07)	1.86
R18	Upper breast point~B.P./vertical length from F.N.P. to waist line (nc/af)	.26 (.07)	.27 (.07)	1.86
R19	Surface length of upper breast point to B.P./Surface length of B.P. to lower breast point (nc/ce)	1.50 (.43)	1.00 (.26)	-11.39***
R20	Outer breast point~B.P./upper breast point~lower breast points (lc/ne)	.54 (.15)	.74 (.14)	18.23***
R21	Shoulder bisector point~lower breast point/shoulder bisector point~B.P. (JI/JB)	1.36 (1.19)	1.32 (.08)	-.37

R7 that showed a significant difference with the ratio of the distance from the upper breast point to lower breast point to breast width, and the ratio decrease (*t*-value: -10.03, $p < .001$) can be inferred as the change of breast's use area; namely, the increase of width is higher, compared with the distance from the upper breast point to the lower breast point. Although the height of the wire used needs to be extended while the inner margin height and outer margin height of the bottom cup need to be extended for increased volume, it is necessary to extend the under wire of the brassiere.

Meanwhile, R9, which is the ratio of distance from the inner breast point to B.P. to the distance from the outer breast point to B.P. increased after the surgery (*t*-value: 4.23, $p < .001$). Therefore, the increase rate from inner breast area is bigger than the outer breast area. This is the part showing the difference from general bra patterns in the development of bra pattern for patients undergoing a breast enlargement surgery. With all this, it is found that a function to narrow breast distance, in addition to adequately covering the increase of the inner breast area, is required.

The reason why the ratio (R10) of the distance from the upper breast point to B.P. to the distance from B.P. to the lower breast point became lower after the surgery (t-value: -12.35, $p<.001$) was the increase rate from B.P. to the lower breast point is bigger than the increase rate from the upper breast point to B.P after the surgery. Therefore, the bra's bottom cup needs to be designed higher than that of general bras. When an implant is for the round breast rather than the anatomical breast in particular, extended lower length should be considered in setting up the bottom cup height. Although the top cup can be modified to 1/2 cup, 3/4 cup, or full cup according to design, the bottom cup needs to play a role as a vessel to adequately contain increased volume. Therefore, the bottom cup should be designed to adequately reflect lower breast length.

As a result of calculating the ratio (R11) of the distance from the upper breast point to the lower breast point to center front length having no change after the surgery, the ratio increased (t-value: -12.35, $p<.001$) after the surgery. This means an increase of vertical distance of breast bottom after the surgery. Although a breast bottom's width increase is bigger than a breast bottom's vertical distance in R7, it means that the vertical distance of the breast bottom also increases as in R11. Consequently, there is a need to cope with the increase of length by increasing the height of inner margin or the height of outer margin on the top cup, while increasing the height of bottom cup in the designing of a bra cup pattern.

The ratios (R12-R18) were calculated with the vertical length from the anterior neck point to the waist which is estimated to have no change before and after the surgery. As a result, the distance from the anterior neck point to the lower point increased (t-value: 7.83, $p<.001$), and the distance from the waist center front point to B.P. increased (t-value 7.95, $p<.001$) due to a breast's projection. The distance from B.P. to the lower point sharply increased (t-value: 23.69, $p<.001$).

Meanwhile, R19, a ratio of upper length calculated with surface length from the breast upper point to the B.P. and from the B.P. to lower length, decreased after the surgery. The decrease of the ratio means that the increase in length from the B.P. to the lower breast point is bigger (t-value: -11.39, $p<.001$) than that from the upper breast point to the B.P. after the surgery. In addition to, the distance from the lower breast point to the B.P., the lower length's increase rate is bigger than the upper length's; therefore, it is required to be reflected in the pattern making.

R20, which is the ratio from the outer breast point to the B.P. to the distance from the upper breast point to the lower breast point increased after the surgery. This means that the distance from the outer breast point to the B.P increases more (t-value: 18.23, $p<.001$) than the distance from the upper breast point to the lower breast point and the breast's projection level can be seen.

The front and lateral ratios are generalized from the results above: the overall volume increases because the vertical distance, width of breast bottom, and height according to a breast's projection increase after a breast enlargement surgery. Upon looking at the increase rate, vertical distance increase of the breast bottom is higher than that of width, and the increase rate of height from the side is higher according to breast project than the width increase rate. In vertical distance, the increase rate of the lower distance is bigger than that of the upper distance. In width, the increase rate from the inner portion is higher than that from the outer portion. Such an increase should be reflected on the design of bra patterns.

4.1.2 Differences examined by angle before and after breast enlargement surgery

The angles made by lines are uniformly maintained, regardless of photograph size, and Table 4 shows the results used for the analysis by measuring the angles made by the lines. All the angles analyzed showed significant differences before and after the surgery.

The projection-related ∠fac, ∠fbc, ∠cne, ∠nec, ∠eac, ∠aec, ∠bac, and ∠abc related with projection are the angles increasing together with breast projection. Meanwhile, the ∠nce and ∠acb that become bigger, as breast is flat, showed a tendency of decrease after the surgery.

Table 4. Difference of angles before and after surgery

Item		Mean angle (S.D)		*t*-value
		Pre-operative	Post-operative	
A1	∠fac	22.66 (4.63)	31.67 (5.03)	16.62***
A2	∠fbc	92.56 (5.08)	99.04 (16.95)	3.72***
A3	∠cne	20.21 (5.42)	33.03 (7.40)	19.41***
A4	∠nec	30.81 (7.45)	37.26 (6.36)	8.48***
A5	∠nce	129.04 (9.46)	109.59 (6.54)	-21.79***
A6	∠eac	10.07 (2.43)	18.41 (2.43)	29.34***
A7	∠aec	40.22 (8.55)	51.96 (6.37)	13.77***
A8	∠bac	10.84 (3.21)	18.81 (2.96)	23.78***
A9	∠abc	15.64 (7.55)	26.97 (7.91)	19.49***
A10	∠acb	153.42 (9.55)	134.25 (8.66)	-25.60***
A11	∠BAC	57.32 (5.03)	59.57 (4.87)	5.75***
A12	∠ABC	61.35 (2.90)	60.67 (2.71)	-2.76**
A13	∠ACB	61.63 (2.77)	60.08 (3.04)	-5.21***

As breast volume becomes bigger at the front after a breast enlargement surgery, the distance between nipples widens. The angle ∠BAC made by connecting the left and right bust points and anterior neck point showed an increasing trend (*t*-value: 5.75, $p<.001$). Meanwhile, the angles ∠ABC (*t*-value: -2.76, $p<.001$) and ∠ACB (*t*-value: -5.21, $p<.001$) decreased.

4.1.3 Superimposition of triangles before and after surgery

In Figure 6, mean values are presented by calculating them before and after the surgery with the lines connecting breast detail measurement points and the angles made by the lines from the front and lateral photographs. After calculating the ratios with center front length (a measurement without change before and after the surgery) in terms of each line length in order to reduce errors according to photograph size, and then calculating the means, the means were converted to the mean center front length of those who are in their 20s under the Size Korea, and then they were drawn in the scale of 1:5. Since the angles maintained constant angles regardless of photograph size, they were used intact, and triangle models were constructed. These are the triangles using the distance between the breast detail measurement points and angles, through which the changing breast shape before and after the surgery could be grasped.

Upon looking at superimposition at the front, the position of bust points widened more horizontally due to increased breast volume, and it went up more vertically, and in all the outer diameters, upper diameter, lower diameter, and inner diameter of the breast increased. It was also confirmed that the distance between the inner breast points became narrow.

Upon looking at superimposition from the side, it was confirmed that the size of the triangles abc, aec, and nec sharply increased by reflecting increased volume after the surgery. The n-n length meaning the vertical distance of the breast bottom and the l-c length, through which projection level can be identified, increased. The n-c length, through which the upper diameter of the breast can be identified, and the c-e length, through which the lower diameter of the breast can be identified, increased.

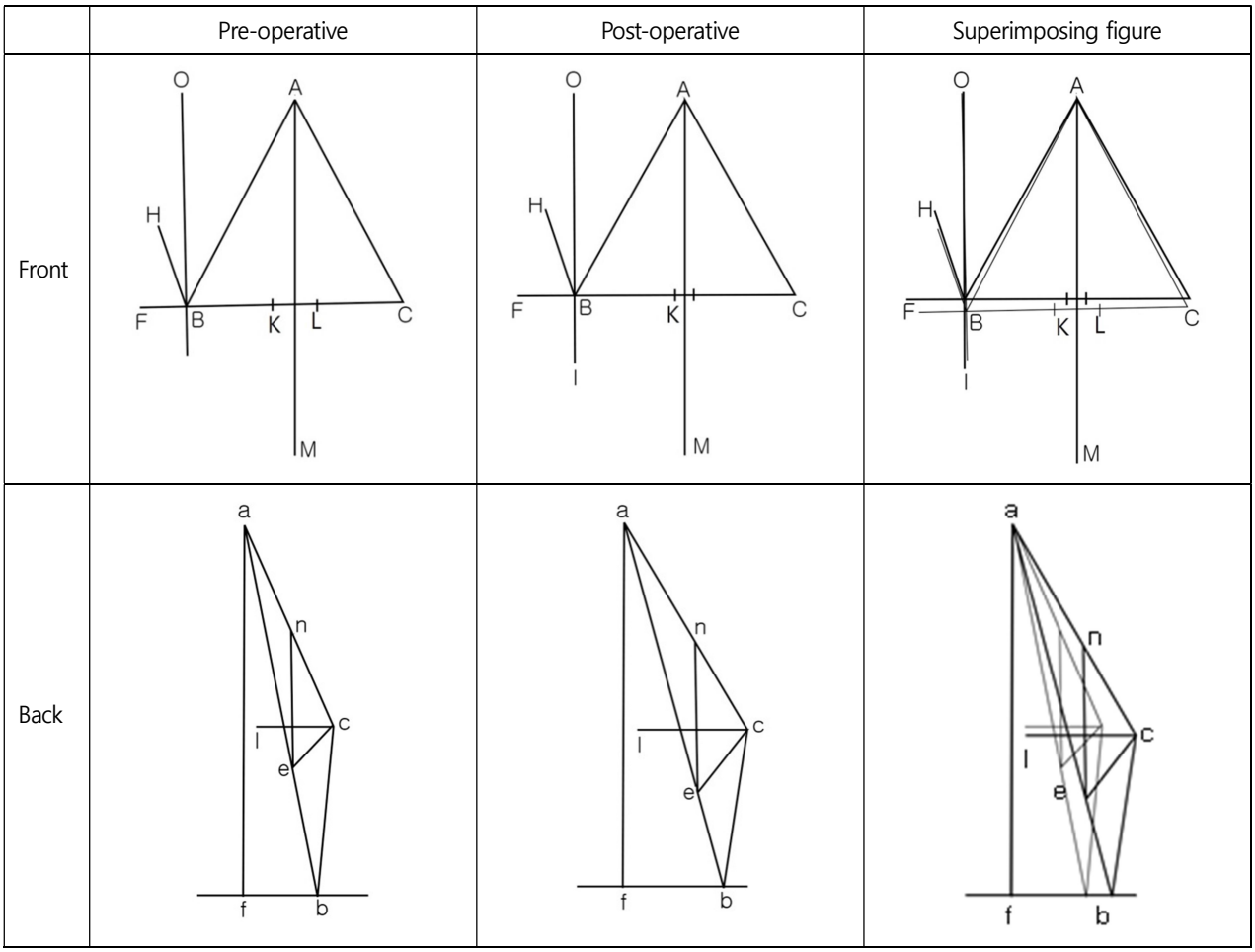


Figure 6. Overlapping triangles of before and after surgery
Note. The dull line represents pre-operative measurements and the bold line represents post-operative measurements.

4.2 Comparative analysis of UPF and projection before and after surgery

4.2.1 Comparison of UPF before and after surgery

We examined the distribution of UPF values evaluated as -2, -2, +1, and +2, based on 0 according to concavity and convexity with upper breast area shape from lateral photographs through a cross-tabulation analysis (See Table 5. Concerning UPF before the surgery, 57 patients (59.4%) out of 96 patients belonged to 0, and 29 (30.2%) belonged to -1, and thus most patients were distributed between 0 and -1. Upon looking at UPF after the surgery, 41 patients (42.7%) belonged to +1, and 24 patients (25.0%) belonged to 0, followed by 18 (18.8%) to -1 and 13 (13.5%) to +2. Figure 7 shows the distribution of UPF before and after the surgery in a graph. UPF of patients after surgery was changed to 0, 1. In the end, the upper chest became convex.

4.2.2 Projection distribution rate after surgery

Although UPF has the same value, projection level can be different. Although upper breast portion is not bulged, the projection

Table 5. UPF distribution before and after surgery Persons (%)

		Level of pre-operative UPF					Post-operative total
		-2	-1	0	1	2	
Level of post-operative UPF	-1	1 (1.0)	3 (3.1)	11 (11.5)	3 (3.1)	0 (0.0)	18 (18.8)
	0	0 (0.0)	7 (7.3)	15 (15.6)	1 (1.0)	1 (1.0)	24 (25.0)
	1	0 (0.0)	16 (16.7)	22 (22.9)	3 (3.1)	0 (0.0)	41 (42.7)
	2	0 (0.0)	3 (3.1)	9 (9.4)	0 (0.0)	1 (1.0)	13 (13.5)
Pre-operative total		1 (1.0)	29 (30.2)	57 (59.4)	7 (7.3)	2 (2.1)	96 (100.0)
Pearson χ^2		14.32					

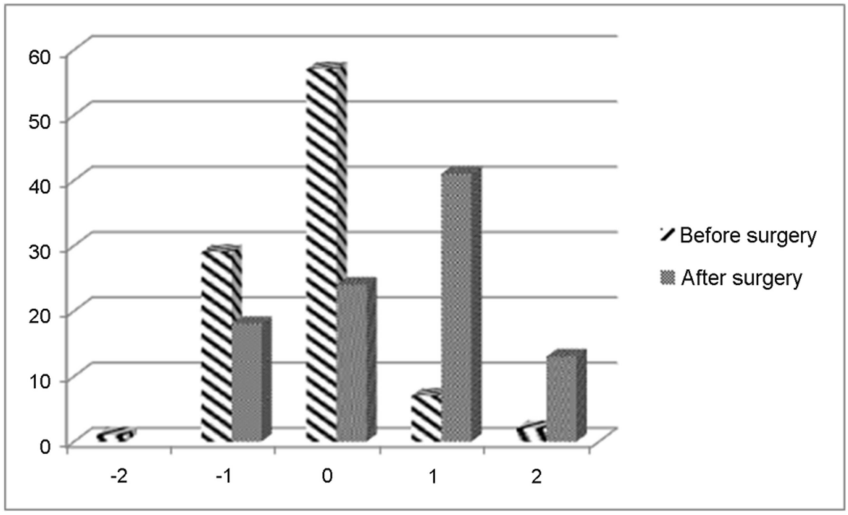


Figure 7. UPF before and after surgery

level can be revealed to be high. Although the anatomical breast implant's UPF value of upper breast portion can be lower than that of the round breast implant, the projection level can be high. Since projection level before the surgery does not reach evaluation criterion, only the projection level after the surgery was identified. Figure 8 shows the distribution: 42 patients (43.8%) belonged to projection level 3, the highest projection level, and 30 (31.3%) and 24 (25.0%) belonged to projection levels 1 and 2, respectively.

4.3 Comparison with aesthetic breast ratios of previous studies

4.3.1 Comparison between desirable breast ratio of previous study and breast ratios before and after surgery

According to a study that analyzed Korean women's desirable breast position and size through prize winning works in art awards (Hwang et al., 2005), chest width and breast width were similar, and the ratio between the chest width and nipples was 4:3. The

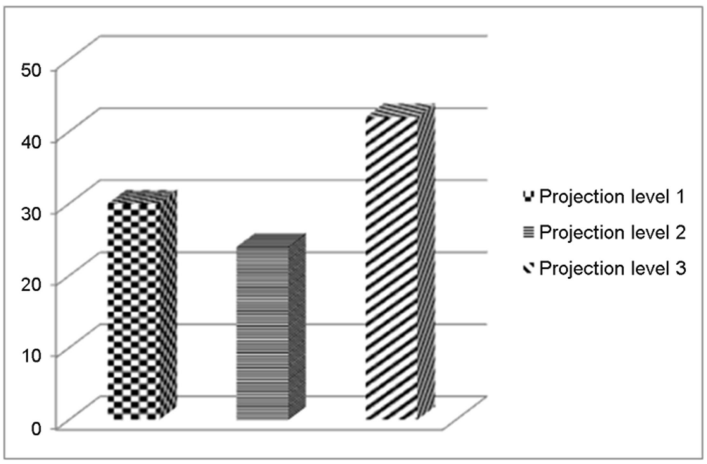


Figure 8. Projection rate after breast enlargement surgery

ratio of the distance between the inner breast points to chest width was 1:7, and the ratio of the distance from the anterior neck point to the left to the right bust points to the distance between the nipples was 1:1:1. Specifically, the 1:1:1 ratio is the ratio of beautiful breast (Beautiful breasts, Which breast size is beautiful? 2016), and it means making a regular triangle connecting the anterior neck point with the left and right bust points and distance between the bust points at the front. Also, the ratio of surface length from the upper breast point to the bust point and surface length from the bust point to the lower breast point was presented as 6:5. Table 6 presents the ratios of the participants before and after a breast enlargement surgery, and the ratios of a previous study (Hwang et al., 2005) in the remarks, with the differences being compared.

Table 6. Comparison with desirable breast ratio of Hwang et al.

Item		CM mean (S.D.)		Remarks*
		Pre-operative	Post-operative	
Ratio 1	Chest width (DE)	7.14 (1.20)	6.97 (1.02)	1
	Breast width (BC+2FB)	6.41	6.77	
	DE/(BC+2FB)	1.11	1.02	
Ratio 2	Chest width (DE)	7.14 (1.20)	6.97 (1.02)	1.3
	BP~BP (BC)	4.43 (0.83)	4.51 (0.70)	
	(DE/2)/(BC/2)	1.61	1.55	
Ratio 3	Chest width (DE)	7.14 (1.20)	6.97 (1.02)	7
	Distance between inner beast points (KL)	0.84 (0.29)	0.38 (0.13)	
	DE/KL	8.50	18.34	
Ratio 4	BP~BP (BC)	4.43 (0.83)	4.51 (0.70)	1
	FNP~right side BP (AB)	4.73 (0.88)	4.63 (0.79)	
	FNP~left side BP (AC)	4.67 (0.89)	4.61 (0.78)	

Table 6. Comparison with desirable breast ratio of Hwang et al. (Continued)

Item		CM mean (S.D.)		Remarks*
		Pre-operative	Post-operative	
Ratio 4	AB/BC	1.07	1.03	1
	AC/BC	1.05	1.02	
Ratio 5	Surface lengthof upper breast point to B.P (n^c)	2.05 (0.48)	2.18 (0.71)	1.2
	Surface length of B.P to lower breast point (c^e)	1.40 (0.34)	2.17 (0.42)	
	n^c/c^e	1.46	1.00	

*: Desirable breast ratio of Hwang et al.

As the desirable ratio of chest width and breast width in the previous study of Hwang et al., 2005 was 1, it was 1.11 and 1.02 before and after the surgery, and therefore the ratio after the surgery was closer to the desirable breast ratio. The ratio of chest width to distance between nipples was 1.33 in the study of Hwang et al. (2005); however, it was 1.61 before the surgery and 1.55 after the surgery, and thus the distance between nipples was narrow, compared with the desirable breast. Specifically, the distance between nipples before the surgery was narrower. The distance between the inner breast points became narrow after the surgery and showed a high ratio of 18.34. The distance from the anterior neck point to the left and right B.P. and the ratio of distance between the nipples was 1.07 and 1.05 each before the surgery. However, they were 1.03 and 1.02 after the surgery, and thus there was a slight difference from the ratio of 1:1:1. However, the ratio after the surgery showed a closer ratio. Meanwhile, the ratio of length from the upper breast point to the B.P. to length from the lower breast point to the B.P. was 1.2; however, it was 1.46 before the surgery and it was 1.0 after the surgery. In comparison with the desirable breast ratio, lower length was shorter than upper length before the surgery, and the lower length was longer than the upper length after the surgery.

4.3.2 Comparison of desirable breast ratio with previous study and breast types before and after surgery

The breast type after a breast enlargement surgery is divided into the round breast and anatomical breast. Therefore, the comparison with the ratios presented in a study of Sohn and Kweon (2003) on the desirable breast type of women in their 20s with mean ratio by type is presented in Table 7. Nowadays, women prefer a breast type with big breast circumference and volume, and chest width and thickness that are small and slim. The reference group (desirable breast type) therefore is a group with natural breasts with big volume.

Upon looking at the ratio of chest width to distance between nipples, it was 1.58 and 1.51 in the anatomical breast and round breast, each being bigger than the reference group's 1.46. The two types' distance between nipples was narrower, compared with the reference group. The ratio of chest width to distance between inner breast points was 20.46 for the anatomical breast and 16.92 for the round breast, which were smaller than 24.47 of the reference group. The reference group of desirable breast is the group having bigger breast volume than general women, and the distance between the inner breast points is narrow as shown from the patients after a breast enlargement surgery. In the case of a wire bra, the width of the upper end of the front part needs to be at least two times thicker than the wire thickness if the wearing comfort is reduced because of being pressed or having a gap or if distance between inner breast points is narrow due to big breast volume. Therefore, it is desirable to design a low center of gravity bra lowering the front center of the front bra part; however, a solution to this needs to be devised in order to properly cover the increased load and upper breast portion.

As for the ratio of the distance from the anterior neck point to left and right B.P. to the distance between nipples, it was 1.04 (right) and 1.03 (left) for the anatomical breast and it was 1.04 (right) and 1.03 (left) for the round breast, which were slightly smaller than 1.07 of the reference group, and were the values approximating 1:1:1, the ratio regarded as beautiful. Concerning the ratio of length from the upper breast point to the B.P. to length from the lower breast point to the B.P., it was 1.02 for the anatomical breast, and it was 0.99 for the round breast, which were lower than 1.40 of the reference group; however, the anatomical breast was closer to the reference group. Concerning the ratio of the upper diameter of the breast to the lower diameter of the breast, it was 1.35 for the anatomical breast and 1.18 for the round breast, which were lower than 1.40 of the reference group. Therefore, the lower diameter of the breast compared with the upper diameter of the breast was longer than that of the reference group. The anatomical breast showed a ratio similar to that of the reference group, but the round breast showed a big difference. In the ratio of breast width to vertical distance, the anatomical breast showed 0.95, and the round breast showed 1.01. The reference group showed 0.97, and therefore the anatomical breast was closer to the reference group. The anatomical breast showed 1.53 and the round breast showed 2.18. The reference group showed 2.12 in the ratio of chest width to breast width; therefore, the round breast showed a more approximate value. However, the anatomical breast was revealed to match the desirable breast type, compared with the round breast except this item, which implies that the anatomical breast is the more natural breast type.

Table 7. Comparison with desirable breast ratio of Sohn and Kweon

Item		CM mean (SD)		Remarks*
		Anatomical implant	Round breast implant	
Ratio 1	Chest width (DE)	6.88 (0.91)	7.06 (1.14)	26.92 (1.30)
	BP~BP (BC)	4.36 (0.60)	4.67 (0.81)	18.37 (1.23)
	(DE)/(BC)	1.58	1.51	1.46
Ratio 2	Chest width (DE)	6.88 (0.91)	7.06 (1.14)	26.92 (1.30)
	Distance between inner breast points (KL)	0.34 (0.11)	0.42 (0.15)	1.10 (0.46)
	DE/KL	20.46	16.92	24.47
Ratio 3	BP~BP (BC)	4.36 (0.60)	4.67 (0.81)	18.37 (1.23)
	FNP~right side BP (AB)	4.53 (0.68)	4.74 (0.89)	19.69 (1.28)
	FNP~left side BP (AC)	4.49 (0.65)	4.74 (0.90)	19.69 (1.28)
	AB/BC	1.04	1.02	1.07
	AC/BC	1.03	1.01	1.07
Ratio 4	Surface length of upper breast point to B.P. (n^c)	2.12 (0.73)	2.24 (0.69)	10.17 (1.14)
	Surface length of B.P to lower breast point (c^e)	2.08 (0.34)	2.26 (0.49)	7.26 (1.98)
	n^c/ c^e	1.02	0.99	1.40
Ratio 5	Upper breast point~B.P. (HB)	1.85 (0.38)	1.72 (0.44)	7.93 (1.22)
	B.P.~lower breast point (BI)	1.36 (0.33)	1.46 (0.36)	5.64 (1.16)
	HB/BI	1.35	1.18	1.40
	(BN+FB)/(HB+BI)	0.95	1.01	0.97

Table 7. Comparison with desirable breast ratio of Sohn and Kweon (Continued)

Item		CM mean (SD)		Remarks*
		Anatomical implant	Round breast implant	
Ratio 6	BC+2FB	4.67	6.99	30.47
	(BN)+(FB)	3.05	3.2	14.32
	(BC+2FB)/[(BN)+(FB)]	1.53	2.18	2.12

*: Desirable breast ratio of Sohn and Kweon.

5. Conclusion

This study examined breast shapes using photogrammetric ratio measurements (PRM) through the photographs taken from the front and side before and after a breast enlargement surgery. It analyzed the changed ratios and angles before and after the surgery, as well as UPF and projection level. Through a previous study review on desirable breast shape, this study compared with the ratios and the breast types after the surgery. With the results of this study, we aimed to present baseline data on the bra development for the patients after breast augmentation, and the following conclusion was acquired.

The height increased according to a breast bottom's vertical distance, width, and breast projection after the breast enlargement surgery. As for the ratio, the increase of a breast bottom's width was higher than that of the vertical distance, and the height increase rate was higher according to a breast's projection than the increase of width. Upon looking at further detail, the lower breast portion's increase rate was higher than that of the upper breast portion in vertical distance. The increase rate was higher in the inner portion than in the outer portion in width. Such increase rates will become important basic data in designing bra patterns for breasts among patients undergoing a breast enlargement surgery.

As for angle, the angles with a positive relation with projection increased, and those with a negative relation decreased. In the superimposition of triangles constructed with lines connecting angles and measurement points before after a surgery, the size change of breast could be found visually. UPF before the surgery mostly belonged to 0 and -1, and it was evenly distributed at +1, 0, -1, and +2 after the surgery. Regarding projection level after the surgery, it was distributed in the order of level 3, level 1, and level 2.

In comparison with the desirable breast type, the distance between inner breast points after the surgery was narrow, and there was a slight difference from the ratio of distance from the desirable breast's anterior neck point to the left and right B.P, and distance between nipples, 1:1:1; however, a more approximate ratio was shown after the surgery. As for the ratio of length from the upper breast point to the B.P. to the length from lower breast point to the B.P., the lower length before the surgery was relatively shorter than the upper length, in comparison with the desirable breast type. After the surgery, lower length was longer than upper length.

Meanwhile, in the ratio of length from the upper breast point to the B.P. to length from the lower breast point to the B.P, the ratio of upper diameter of the breast to lower diameter of the breast, and the ratio of breast width to vertical diameter of the breast, the anatomical breast was found to be more natural than the round breast.

The results of the study were analyzed using photogrammetric ratio measurements (PRM) before and after a breast enlargement surgery, and this study presented a method to analyze breast shapes through photographs in a difficult situation of securing

participants, although there can be some limitation. Through this study, the breast enlargement surgery-experiencing women's breast shapes including changed breast's measurement ratios and angles not known much yet can be identified. Therefore, the results are presumed to be helpful to the development of a bra suitable for changed breast characteristics or a top with high fitting attributes.

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