

Functional and Volumetric Analysis of the Pectoralis Major Muscle After Submuscular Breast Augmentation

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Aesthetic Surgery Journal
2017, Vol 37(6) 654–661
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DOI: 10.1093/asj/sjw239
www.aestheticsurgeryjournal.com

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Abstract

Background: Dual plane breast augmentation is a technical variation of the submuscular plane described as a technique that reduces contour deformities due to contraction of the pectoralis major muscle and lower risk of double-bubble deformity associated with breast ptosis. Despite improvement in the aesthetic aspect, there is still no consensus whether this technique affects the function of the pectoralis major muscle.

Objectives: The aim of this study was to correlate functional with volumetric changes associated with dissection of the muscle origin in submuscular breast augmentation.

Methods: Thirty women who desired to undergo breast augmentation were selected prospectively and randomly allocated to 2 groups: 10 patients in the control group and 20 patients in the interventional group, who underwent submuscular breast augmentation. Magnetic resonance imaging and volumetric software were used to assess muscle volume and isokinetic dynamometry was used to assess function of the pectoralis major muscle. Preoperative measurements were compared with those at 3, 6, and 12 months after surgery.

Results: Magnetic resonance imaging revealed significant decrease in muscle volume at 6 and 12 months follow-up. The isokinetic test conducted during adduction showed a significant difference in muscle strength between groups from baseline to the 12-month follow-up, and between the 3- and 12-month follow-up. No significant differences in muscle strength during abduction were observed from baseline to the 3-, 6-, and 12-month follow-up.

Conclusions: Submuscular breast augmentation reduced muscle strength during adduction 12 months after surgery, but without a significant correlation with volumetric muscle loss.

Level of Evidence: 2



Editorial Decision date: November 9, 2016; online publish-ahead-of-print January 20, 2017.

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Submuscular breast augmentation, first described by Dempsey and Latham in 1968,¹ has been regarded as a technique with low incidence of capsular contracture, rippling, and contour deformities, and that provides a natural-appearing aesthetic result. There is a consensus that subpectoral breast implants are indicated for breast reconstruction, especially in specific groups of patients.²⁻⁵ The same is not true for cosmetic breast augmentation, because both submuscular and subglandular implant placements produce comparable immediate postoperative results, when properly performed and under normal conditions.

Dual plane breast augmentation is a technical variation of the submuscular technique,⁶ in which the pectoralis major muscle is dissected from its origin on the inframammary fold, with medial dissection extending to the inframammary fold or up to the upper edge of the nipple-areolar complex. The advantages of this technique include reduction of contour deformities due to contraction of the pectoralis major muscle⁷ and lower risk of double-bubble deformity associated with breast ptosis.⁸ Despite improvement in the aesthetic aspect, there is no consensus whether this technique affects the function of the pectoralis major muscle.

The aim of this study was to correlate functional with volumetric changes in the pectoralis major muscle after submuscular placement of implants, associated with partial release of the muscle origin.

METHODS

This prospective, analytical, interventional, randomized trial was conducted between March 2013 and September 2015 at Pedro Ernesto University Hospital, University of State of Rio de Janeiro. The study was approved by the Institutional Research Ethics Committee (approval number 14299213.2.0000.5259) and performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all patients prior to their inclusion in the study and anonymity was assured.

Thirty women who expressed a desire to undergo breast augmentation were selected from a plastic surgery outpatient clinic of the University Hospital.

Inclusion criteria were age between 18 and 30 years and absence of comorbidities. Patients with smoking habit, history of intense muscle activity, breast ptosis, history of breast diseases, and family history of breast cancer were not included in the study. Patients with weight loss or weight gain of more than 5% of initial weight were also excluded from the study.

The patients were randomly allocated to 2 groups using the Research Randomizer software (<http://www.randomizer.org>). Patients in the control group ($n = 10$) were not operated on. The intervention group ($n = 20$) underwent

submuscular breast augmentation. Patients in both groups were followed up for at least 12 months.

After completion of the study, all patients in the control group underwent breast augmentation.

Radiological Examination

The radiological examination was performed at a diagnostic center, Rio Imagem. All patients underwent magnetic resonance imaging (MRI) with a 1.5-T MRI unit (Siemens Vision, Erlangen, Germany), using a sagittal T1 fat-suppressed sequence. Volumetric analysis was always performed by the same radiologist (RS), using the AW Server 2.2 Workstation (GE Healthcare, Waukesha, WI).

The volume of the pectoralis major muscle was calculated by measuring differences in density with MRI. Patients in the intervention group underwent MRI at three time points: preoperatively (baseline) and at 6 and 12 months after surgery. Controls underwent MRI at inclusion (baseline) and 6 and 12 months later. Between- and within-group comparisons of changes in volumetric measurements were performed for both groups at the three time points (baseline, 6 and 12 months).

Muscle Strength Assessment

Functional assessment of the pectoralis major muscle was conducted in a Neuromuscular Research Laboratory of the National Institute of Traumatology and Orthopedics using an isokinetic dynamometer (Humac Norm, Computer Sports Medicine Inc., Stoughton, MA). Maximal voluntary force was assessed always in the dominant arm, using isokinetic concentric/concentric testing performed during shoulder horizontal abduction and adduction, with the patient in the supine position.⁹ After the patient was able to correctly perform the movement, 5 repetitions were completed at an angular velocity of 60°/s. The highest torque determined for the dominant arm was considered the peak torque (Nm) and was used for analysis. Comparisons were made between torque measurements obtained at baseline and 3, 6, and 12 months postoperatively. For the intervention group, the correlation between the volumetric and muscle strength measurements was investigated.

Surgical Procedure

The surgical procedure was performed under general anesthesia with the patient supine and arms abducted. After antisepsis with an alcoholic solution of 0.5% chlorhexidine, the patient received 0.75% ropivacaine with 1:200,000 epinephrine by infiltration. The dual plane technique was performed with incision of the inframammary fold. After visualization of the free lateral edge of the pectoralis major muscle, the lower edge of the muscle

(inframammary fold) was dissected in the latero-medial direction, without dissection in the retroglanular plane. The upper limit of the medial dissection of the muscle was 1 cm superior to the inframammary fold.¹⁰

The previously marked limits of pocket dissection were defined by the regions of lateral, medial, upper, and lower projection of the mammary gland. The implants were inserted after rigorous hemostasis. Patients received textured silicone implants with a round base, high projection, and volume ranging from 245 to 350 mL (Silimed, Rio de Janeiro, Brazil). The implant volume was chosen based on breast measurements assessed according to the manufacturer's instructions. The incision was closed with nonabsorbable 3-0 nylon suture (Mononylon, Ethicon Inc., Summerville, NJ) in the deep plane, and absorbable 4-0

poliglecaprone suture (Monocryl, Ethicon Inc.) in the subdermal and intradermal planes.

All patients were allowed to return to work 15 days after surgery and perform physical activity 2 months after the operation and instructed to avoid implant massage.

Patients in the control group underwent the procedure (augmentation mammoplasty) at the end of the research period on a complimentary basis after completion of the study.

Statistical Analysis

The GraphPad Prism version 5 for Windows (GraphPad Software, San Diego, CA) was used for data analysis. The assumption of distributional normality was tested using

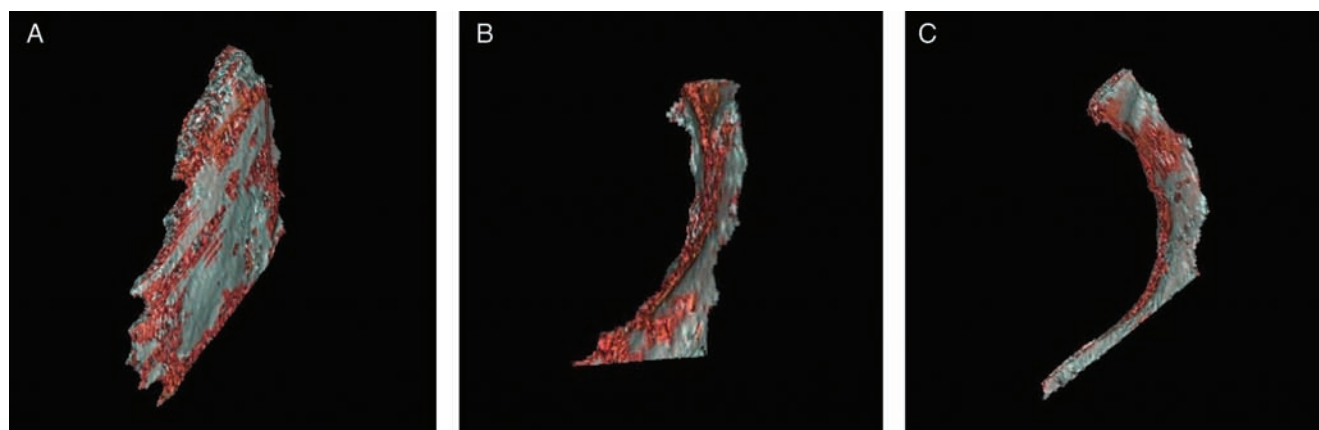


Figure 1. MRI volumetric analysis of the pectoralis major muscle in a 24-year-old woman in the intervention group. (A) Preoperative image, anterior view of the pectoralis major muscle (muscle volume, 52.57 cm³). (B) Six-month postoperative image, lateral view of the pectoralis major muscle (muscle volume, 23.73 cm³). (C) Twelve-month postoperative image, lateral view of the pectoralis major muscle (muscle volume, 28.33 cm³).

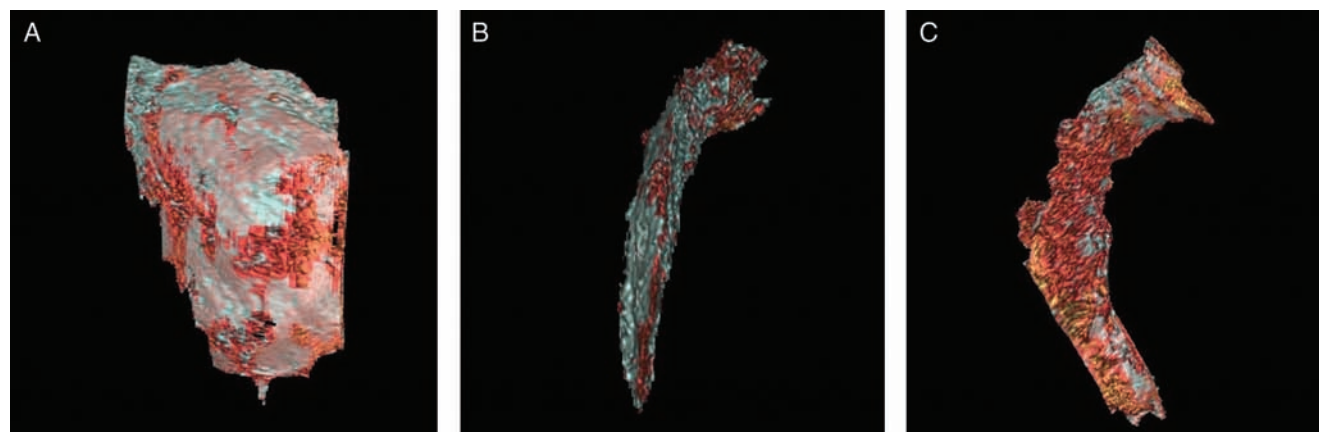


Figure 2. MRI volumetric analysis of the pectoralis major muscle in a 22-year-old woman in the intervention group. (A) Preoperative image, anterior view of the pectoralis major muscle (muscle volume, 82.40 cm³). (B) Six-month postoperative image, lateral view of the pectoralis major muscle (muscle volume, 32.78 cm³). (C) Twelve-month postoperative image, lateral view of the pectoralis major muscle (muscle volume, 38.45 cm³).

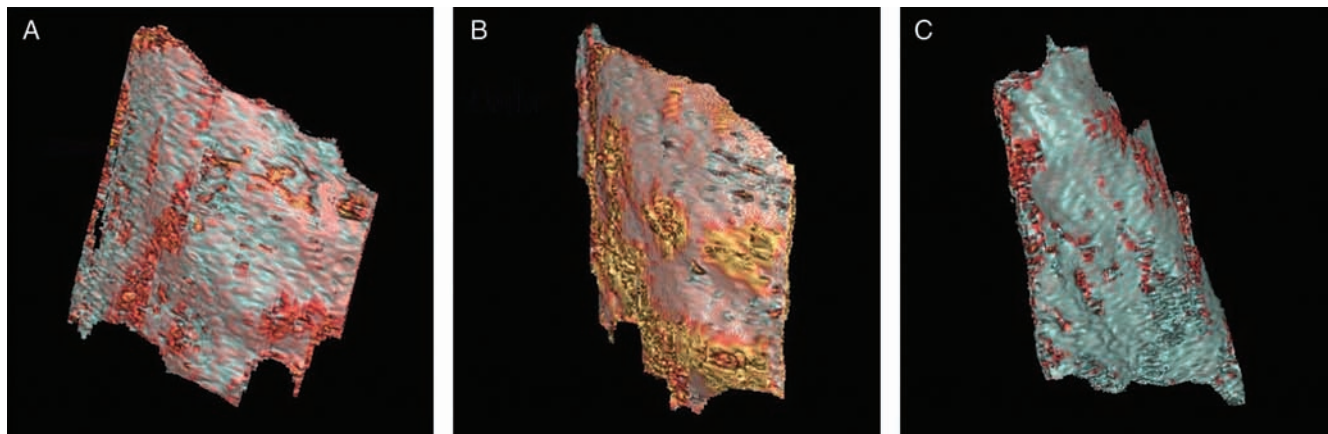


Figure 3. MRI volumetric analysis of the pectoralis major muscle in a 21-year-old woman in the control group. (A) Preoperative image, anterior view of the pectoralis major muscle (muscle volume, 55.85cm³). (B) Six-month image, anterior view of the pectoralis major muscle (muscle volume, 52.25 cm³). (C) Twelve-month image, anterior view of the pectoralis major muscle (muscle volume, 54.41cm³).

Table 1. Between-Group Comparisons of Differences in Volume of the Pectoralis Major Muscle

Difference in muscle volume (cm ³)	Groups		P-value
	Intervention	Control	
Baseline-6 months	-32.31	-2.88	0.0002*
Baseline-12 months	-35.13	0.44	<0.0001*

*Statistical significance (Mann-Whitney, $P < 0.05$).

the Shapiro-Wilk test. Because the data were not normally distributed, comparisons of two variables were carried out using the Wilcoxon test for paired groups and the Mann-Whitney test for unpaired groups. All statistical tests were performed at a significance level α of 0.05 ($P < 0.05$).

RESULTS

Twenty patients underwent submuscular breast augmentation (intervention group) and 10 patients were not operated on (control group). All patients in the control group underwent three radiological examinations, but only 7 performed all muscle strength assessments. In the intervention group, 19 patients underwent all radiological examinations and muscle strength assessments. The mean age was 24 years (range, 18-30 years) and the mean body mass index was 22 kg/m² (range, 18-23 kg/m²). The mean operative time was 47 minutes (range, 40-55 minutes) and the mean implant volume was 290 mL (range, 245-335 ml). No patient had animation deformity or

Table 2. Within-Group Comparisons of Muscle Strength During Adduction at Different Time Intervals (Intervention Group)

Time interval	Mean peak torque (Nm)		P-value
Baseline-3 months	28.8	26.5	0.087
Baseline-6 months	28.8	25.7	0.055
Baseline-12 months	28.8	24.05	0.006*
3-6 months	26.5	25.7	0.484
3-12 months	26.5	24.5	0.048*
6-12 months	25.7	24.5	0.323

*Statistical significance (Wilcoxon test, $P < 0.05$).

distortion of the breast on contraction of the Pectoralis muscle.

MRI revealed significant 46.38% and 49.80% (mean, 35.13 cm³) decreases in muscle volume 6 and 12 months after surgery, respectively, compared with baseline ($P = 0.0003$) (Figures 1-2). There was no significance on muscle volume in the control group (Figure 3). There were also significant differences between groups in muscle volume at the 6- and 12-month follow-up (Table 1).

The isokinetic test conducted during adduction at an angular velocity of 60°/s showed a significant difference in muscle strength between groups from baseline to the 12-month follow-up, and between the 3- and 12-month follow-up (Table 2). No significant correlation was found between muscle strength and muscle volume at 6 ($P = 0.106$) and 12 months after surgery ($P = 0.462$). There was also no clinical correlation with this loss.

No significant within-group differences in muscle strength during abduction were observed from baseline to the 3-, 6-, and 12-month follow-up (Table 3). There was

Table 3. Within-Group Comparisons of Muscle Strength During Abduction (Intervention Group)

Time interval	Mean peak torque (Nm)		P-value
Baseline-3 months	37.05	35.63	0.175
Baseline-6 months	37.05	37.31	0.715
Baseline-12 months	37.05	34.94	0.162

*Statistical significance (Wilcoxon test, $P < 0.05$).

a significant between-group difference in muscle strength during adduction only at the 12-month follow-up (Table 4).

Patients in the intervention group neither reported a perceived decrease in muscle strength nor had functional complaints. This information was accessed by asking the patients about their own perception of strength and about their workout habits. No functional questionnaires were applied, but none of the patients has their workout habit changed because of lost strength.

DISCUSSION

Subpectoral implantation is the technique of choice for breast reconstruction following skin-sparing mastectomy and it is also recommended by some surgeons in aesthetic breast augmentation. Its main advantages include adequate tissue coverage and low rates of capsular contracture and contour deformity.¹¹ This surgical technique involves the dissection of the abdominal origin and partial dissection of the sternal origin of the pectoralis major muscle, which may affect muscle function.

Muscle tissue has low tolerance to mechanical compression and is more susceptible to damage under constant pressure than other soft tissues, such as the skin.^{12,13} According to Stekelenburg et al,¹⁴ isolated ischemia leads to reversible damage to muscle tissue, whereas muscle compression maintained for 2 h results in irreversible damage to the muscle, suggesting that large deformations in conjunction with ischemia may represent the main mechanism of irreversible muscle damage. Based on the hypothesis of cellular metabolic changes, a high tension applied to muscle fibers by compression results in an axial tension in the cell membrane, creating invaginations and breakages, and leading to the opening of calcium channels and disruption of cellular homeostasis.¹⁵ This calcium-induced instability may cause degenerative processes, resulting in cell damage.¹⁶

Compared to baseline, a significant reduction in muscle volume was observed among patients in the intervention group 6 months after surgery and was maintained to the 12-month follow-up. The important loss of muscle volume is directly related to the compression of muscle tissue by the implant.

Table 4. Between-Group Comparisons of Differences in Muscle Strength During Adduction and Abduction at Different Time Intervals

Time interval	Difference in mean peak torque (Nm)		P-value
	Intervention	Control	
Adduction			
Baseline-3 months	−2.3	0.16	0.52
Baseline-6 months	−3.1	−3.5	0.80
Baseline-12 months	−4.75	2.83	0.04*
Abduction			
Baseline-3 months	−5.73	0.16	0.40
Baseline-6 months	0.26	−1.66	0.38
Baseline-12 months	−2.10	−1.66	0.72

*Statistical significance (Mann-Whitney, $P < 0.05$).

Previous studies have reported reduction in breast parenchyma after subglandular breast augmentation,¹⁷ and loss of muscle volume following submuscular breast augmentation.¹⁸ This study not only assessed changes in muscle volume after breast augmentation by comparing the intervention and control groups, but also searched for a correlation between muscle volume loss and changes in muscle function. Interestingly, no correlation was found between reduced muscle volume and functional changes in operated patients.

Some studies have shown that volumetric losses of musculocutaneous free flaps were associated with muscle atrophy, radiation, and weight loss.¹⁹⁻²¹ In such cases, muscle atrophy is related to denervation and not to ischemia. The pectoralis major muscle is innervated by branches of the medial and lateral pectoral nerves. The lateral pectoral nerve has a constant course parallel to thoracoacromial vessels and inferomedial to the posterior surface of the pectoralis major muscle, below its fascia.²² The medial pectoral nerve has two variations; however, anatomical studies have shown that the branches of the lateral and medial pectoral nerves enter the pectoralis muscle at a substantial distance from the lateral edge of the sternum, bilaterally.^{23,24} Thus, the dissection of the lower and medial edges of the pectoralis major muscle (sternal and abdominal origins), which is part of the subpectoral implantation technique, is a safe procedure without risk of nerve injury. Therefore, the hypothesis of muscle denervation atrophy can be discarded. However, the dissection of the abdominal origin and partial dissection of the sternal origin of the pectoralis major muscle may also have contributed to muscle atrophy. Even if only a small portion of muscle was involved, atrophy caused by the split of some muscle fibers has to be considered. Changes in body weight above 5% of the baseline value were an exclusion criterion of the

study and therefore the volumetric muscle loss may not be attributed to changes in body mass.

There was a relative stability in volume loss between the 6- and 12-month time periods what support the theory of acute ischemic damage as a single insult rather than progressive.

Isokinetic dynamometry is an effective and objective method to assess muscle strength,²⁵ especially in disturbances of the agonist-antagonist balance, and a reference method for evaluating shoulder muscle strength and detecting deficits in specific muscle groups.²⁶ In this study, the functional assessment of the pectoralis major muscle was performed during shoulder horizontal abduction and adduction at an angular velocity of 60°/s. Since angular velocity is inversely proportional to the force exerted to perform the movement,²⁷ a low angular velocity was chosen to evaluate the peak torque during isokinetic movement.

The pectoralis major muscle is active during horizontal shoulder adduction and less active during isokinetic trunk rotation, shoulder depression, and shoulder flexion movements. Despite the impossibility of the complete isolation of a muscle group, adduction and abduction movements were chosen to evaluate the strength of the pectoralis major muscle.^{28,29}

A significant difference in muscle strength from baseline was found only 12 months after surgery during adduction, but no significant difference was observed during abduction at all postoperative time points. There was also no correlation of muscle strength with volumetric measurements at the study time points. Beals et al³⁰ observed reduction in muscle strength two weeks after surgery in women who had undergone subpectoral breast augmentation, with almost complete restoration of muscle strength six weeks postoperatively. De Haan et al,³¹ however, reported a 20% reduction in muscle strength in patients who had undergone subpectoral implantation following subcutaneous mastectomy, which is consistent with our findings.

Despite a direct relationship between hypertrophy and increased muscle strength,^{32,33} muscle performance depends not only on its volume,³⁴ but also on the length and type of the muscle fiber.³⁵⁻³⁸ Twelve months after surgery, a significant decrease in muscle strength was detected during adduction, a movement in which the pectoralis major muscle acts as an agonist. However, no correlation was found between this reduction in muscle strength and a decrease in muscle volume within six months postoperatively.

Although acting as an agonist, the pectoralis major muscle is not the only muscle activated during adduction or any other movement assessed by dynamometry. Thus, a reduction in strength of this muscle can be compensated by synergistic shoulder muscles. Wickham and Brown³⁹ demonstrated by electromyography that all neuromuscular compartments in the latissimus dorsi muscle and in the sternal origin of the pectoralis major muscle, corresponding

to synergistic muscle groups that participate in this movement, are activated at the same time during adduction. The authors also found a weak synergistic interaction between the deltoid muscle and the pectoralis major muscle during adduction and a strong antagonism in the same movement.⁴⁰

No significant change in muscle strength was detected during abduction, a movement in which the deltoid muscle is a prime mover. This may be explained by the weak synergistic interaction of this muscle with the pectoralis major muscle during adduction, without an increase in the compensatory muscle activity of the deltoid muscle, which may be evidenced by the maintenance of muscle strength during abduction. Thus, a reduction in force during adduction may be related to the dissection of the abdominal origin or partial dissection of the sternal origin of the pectoralis major muscle. Despite the loss of muscle strength during adduction, patients neither reported a perceived decreased in muscle strength nor had functional complaints, which may be explained by the synergistic action of the latissimus dorsi muscle in this movement.

Besides submuscular breast augmentation reduces muscle strength during adduction it does not influence patient's workout habits and none of patients has the perception of muscle strength lost. Besides has a decrease in muscle strength in adduction there were no changes in abduction and there were no clinical relevance on strength with the sub muscular approach. Thus, submuscular breast augmentation is a safe approach. We cannot point anything out about the subglandular position on this paper as we did not access this technique in this study.

A potential limitation of the study is the sample size. The study did not evaluate any athlete, so we cannot tell anything about women who have intensive workout habit.

This study was conducted with young and nulliparous patients with dense breasts, who received implants with a round base and high projection. Further prospective studies are necessary to evaluate the relationship of implant shape and projection with the degree of functional and volumetric loss of the pectoralis major muscle, the use of submuscular implants in older patients, as well as assessing other muscles in the shoulder girdle to see whether these have a compensatory increase in strength.

CONCLUSION

Submuscular breast augmentation resulted in a significant reduction in muscle strength during adduction 12 months after surgery, but without a significant correlation with the volumetric loss of the pectoralis major muscle. Patients had no clinical complaint related to the reduction in muscle

strength. No changes in muscle strength were observed during abduction.

Disclosures

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Funding

The authors received no financial support for the research, authorship, and publication of this article.

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