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**ORIGINAL ARTICLE /** ARAŞTIRMA YAZISI

Radiology and Organ Imaging/Radyoloji ve Organ Görüntüleme

# Association Between Mastalgia and Elastographic Breast Stiffness in Patients with Subpectoral Silicone Implants: A Multiparametric Shear Wave Elastography Study

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## ABSTRACT

**Purpose:** In this study, it was aimed to evaluate the long-term effect of silicone implants on elastographic breast stiffness and the relationship between breast stiffness and mastalgia in cases with subpectoral silicone implants.

**Materials and Methods:** Cases with subpectoral silicone implants at least one year after surgery as the patient group (Group 1) and cases without silicone implants as the control group (Group 2) were included in the study. Shear wave velocity values (Vmean, Vmax, Vmin, Vsd) were measured by multiparametric shear wave elastography (mpSWE). All cases were asked to rate their mastalgia (Mastalgia Score, MS) using a verbal numerical rating scale (NRS, 0-10). The relationship between age, parity, mammographic breast density, menopausal status, mastalgia score, and elastographic breast stiffness was evaluated in each group.

**Results:** All mpSWE values in Group 1 were higher than in Group 2 ($p<0.05$). Mean breast parenchymal stiffness (Vmean) was significantly lower in women under 40 years of age than in women over 40, and in women who had not given birth than who had given birth ($p<0.05$). MS was significantly higher in women with dense breast structure ($p<0.05$). However, no significant difference was found between MS and other variables (age, parity, menopausal status, silicone implants).

**Conclusion:** Subpectoral silicone breast implants are associated with increased breast stiffness as measured quantitatively by elastography. However, no statistically significant relationship was found between elastographic breast stiffness and mastalgia in the long-term post-implantation period. Therefore, factors other than implants should be considered in cases of chronic post-implant mastalgia.

**Keywords:** mastalgia, breast pain, multiparametric Shear Wave Elastography, silicone implant, fibrocystic disease

## ÖZET

**Amaç:** Bu çalışmada subpektoral silikon implantlı olgularda silikon implantların elastografik meme sertliği üzerine uzun dönem etkisinin ve meme sertliği ile mastalji arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.

**Gereç ve Yöntemler:** Hasta grubu olarak; ameliyattan en az bir yıl geçmiş subpektoral silikon implant uygulanan olgular (Grup 1) ve kontrol grubu olarak silikon implant uygulanmayan olgular (Grup 2) çalışmaya dahil edildi. Multiparametrik Shear wave elasografi (mpSWE) hız değerleri (Vmean, Vmax, Vmin, Vsd) ile ölçüldü. Tüm olgulardan meme ağrılarını sözel sayısal derecelendirme ölçeği (NRS, 0-10) kullanarak değerlendirmeleri istenmiştir. Her grupta yaş, parite, mamografik meme yoğunluğu, menopoz durumu, mastalji skoru (MS) ve elastografik meme sertliği arasındaki ilişki değerlendirildi.

**Bulgular:** Grup 1'deki tüm mpSWE değerleri Grup 2'den daha yüksekti ($p<0.05$). Ortalama meme parankim sertliği (Vmean) 40 yaş altı kadınlarda 40 yaş üstü kadınlara göre ve doğum yapmamış kadınlarda doğum yapmış kadınlara göre anlamlı olarak daha düşüktü ($p<0.05$). Mamografik olarak yoğun meme yapısına sahip kadınlarda MS anlamlı olarak daha yüksekti ($p<0.05$). Ancak, MS ile diğer değişkenler (yaş, parite, menopozal durum, silikon implantlar) arasında anlamlı bir fark saptanmadı.

**Sonuç:** Subpektoral silikon meme implantları, elastografi ile kantitatif olarak ölçülen meme parankim sertliğini önemli ölçüde artırmaktadır. Bununla birlikte, implantasyon sonrası uzun dönemde elastografik meme sertliği ile mastalji arasında istatistiksel olarak anlamlı bir ilişki bulunmamıştır. Bu nedenle, implant sonrası mastalji olgularında implant dışındaki faktörler göz önünde bulundurulmalıdır.

**Anahtar Kelimeler:** mastalji, meme ağrısı, multiparametrik Shear Wave Elastografisi, silikon implant, fibrokistik hastalık

Breast implants are prosthetic devices filled with silicone gel or saline solution and are widely used for cosmetic augmentation and postmastectomy reconstruction. Although the cosmetic results are generally favourable, some unpleasant symptoms may occur after silicone implantation. Although the individual may be able to tolerate these discomforts, sometimes a second surgical procedure or even removal of the implant may be necessary. According to the American Society of Plastic Surgeons (ASPS), approximately 20,000 silicone implants were removed in the United States in 2010 [1]. However, this does not reduce the number of new implants. The number of implants placed in the same year increased by 40% compared to the 2000s, reaching 300,000 nationally and 1.5 million worldwide [1].

The main complaints and complications associated with breast implants can be divided into two groups: those related to the operation and those related to the implant [2]. Common surgical complications include haematoma and infection in the early stages, and scarring in the later stages. Implant-related complications and complaints include severe pain due to tension, redness of the breast due to hypersensitivity reactions and rash in the early period. In the long term, capsular contracture, rupture and malposition may occur [2].

On the other hand, some patients complain of persistent breast pain after breast implantation, which is new compared to the pre-implantation period. The cause of this pain may be due to the incision and scar tissue from the operation, and the tension and stiffness in the breast tissue after the implant. Considering this possibility, the main aim of this study was to evaluate the effect of the implant on the elastographic stiffness of the breast tissue in cases with silicone implants and whether this is associated with mastalgia.

## Material and methods

*Study population:* Cases that underwent a breast ultrasound examination in our hospital between 2019 and 2021 were included in the study. The cases were divided into two groups based on the presence of silicone implants: group 1 (with silicone implants) and group 2 (control group without silicone implants). All cases included in group 1 had subpectoral silicone implants with at least one year of follow-up since surgery. Cases with intramammary or saline implants were excluded from the study. In addition, cases with silicone-related complications (capsule contraction, external capsule rupture, gel bleeding, inflammation, hematoma) with any imaging modality (breast ultrasound, mammography, breast magnetic resonance imaging (MRI)) were not included in the study. Cases with pathologies that may affect breast stiffness, such as lesions suspicious for malignancy, solid or cystic lesions larger than 2 cm, abscess, fluid collection, mastitis, cases with connective tissue diseases that may affect breast stiffness, and those with a history of radiotherapy to the breast area were excluded from the study. Ethics committee approval was obtained from the institutional review board (2021-07/21).

### *Imaging method*

*Elastographic examination:* All ultrasound and elastography images were performed on a LOGIQ S8 (GE Health Care, XDclear 2.0+ Ultrasound System) by two radiologists with more than 10 years of experience in breast imaging. M6-15 probes were used for greyscale evaluation and 9L probes for elastography. A gel pad was applied during elastography and cases were asked to hold their breath during shear wave elastography (SWE) measurements. A single radiologist performed all SWE assessments under the supervision of the other radiologist for standardization. In all cases in both groups, four parameters (Vmean, Vsd, Vmax, and Vmin) were measured with SWE (m/s) from both right and left breast quadrants (upper outer, upper inner, lower outer, and lower inner quadrants). Two breasts of each patient were considered separately (1 patient- 2 breasts). Standardized measurements were made in each quadrant, excluding subcutaneous fat and pectoral muscle, in the middle of the fibroglandular breast tissue, keeping the ROI constant (0.2 cm2=20 mm2) (Figure 1).

During the ultrasound scan, the cases were asked to rate whether they had mastalgia in their daily life. If present, they were asked to rate their pain using the verbal numerical rating scale (0-10). The cases' age, date of birth, and menopausal status were also recorded.

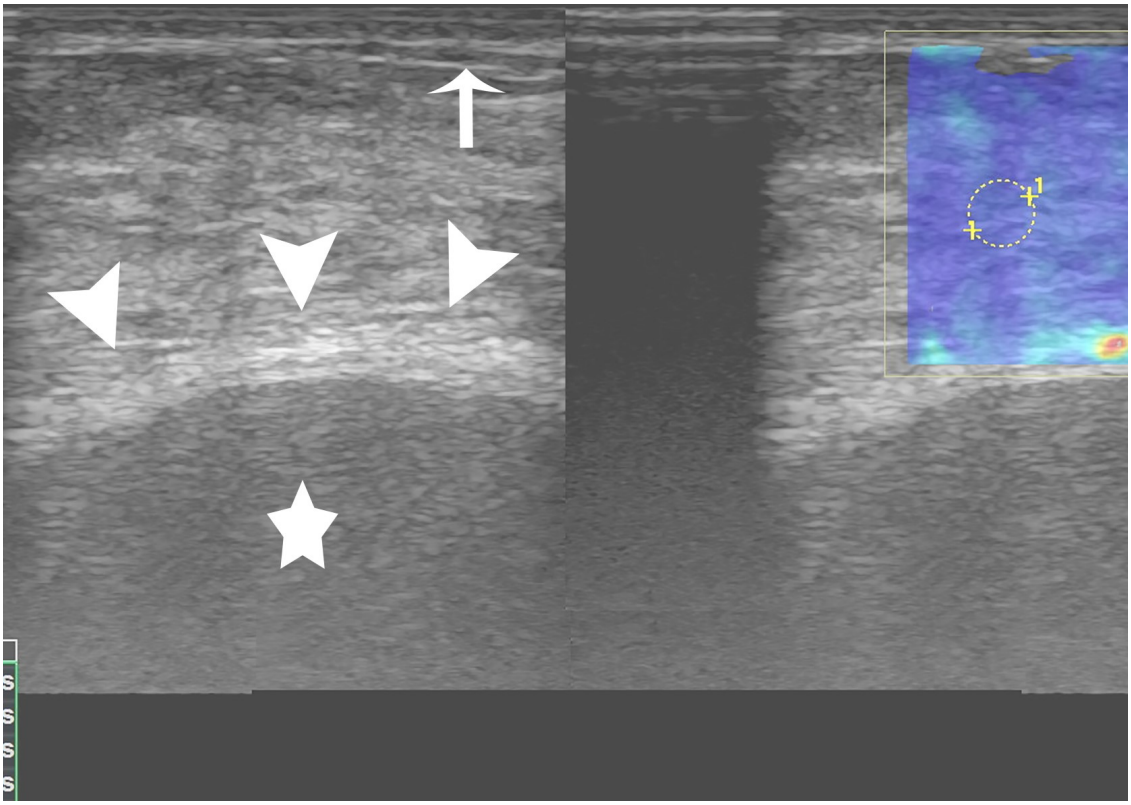

**Figure 1.** Demonstration of breast parenchymal stiffness measurement with SWE in a silicone-implanted breast. (star-subpectoral silicone implant). **a)** In a case with a homogeneous breast structure;

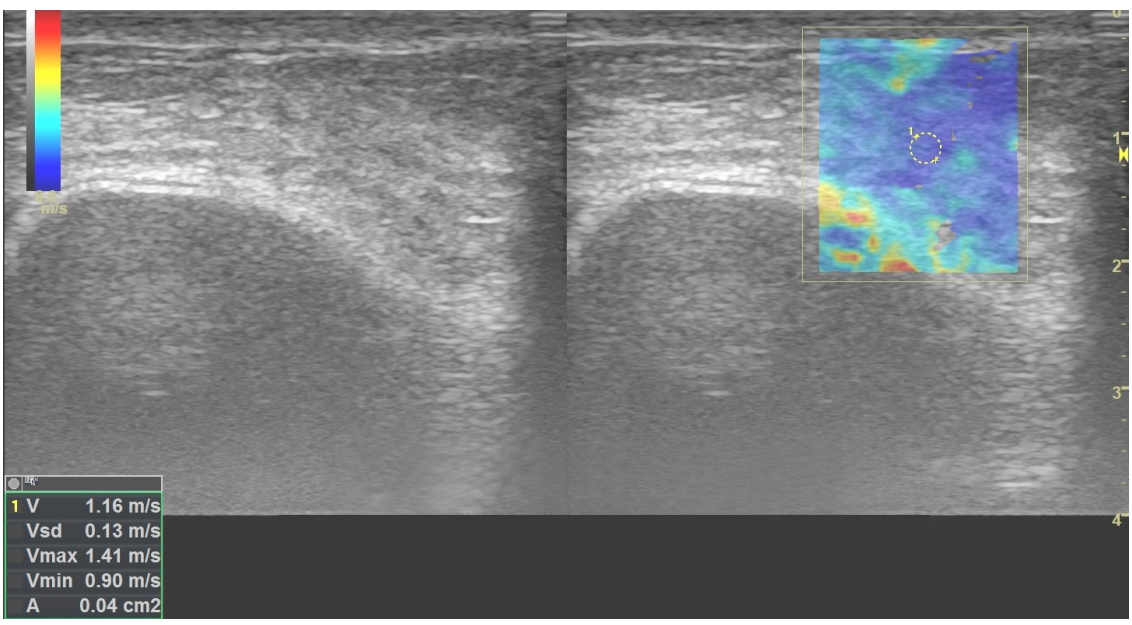


**Figure 1. b)** In a case with a more heterogeneous breast structure, measurements were obtained from the middle portion of the breast tissue between the skin/subcutaneous fat and the pectoral muscle using a standardized ROI area (20 $mm^2$ / 0.2 $cm^2$).

*Mammographic examination:* In cases aged 40 years and older, mammography was performed using the Hologic Selenia, 3Dimensions™ Mammography System device. Standard mediolateral oblique (MLO) and craniocaudal (CC) views were obtained, and tomosynthesis images were routinely obtained in the MLO views. The mammographic densities of the cases were classified according to the American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS) mammography lexicon. This classification included subgroups of type A (almost entirely fatty), B (scattered areas of fibroglandular density), C (heterogeneously dense breasts that may obscure small masses), and D (extremely dense breasts). Mammographic breast density analysis was performed only in patients aged 40 years and older.

*Statistical analysis:* NCSS (NumberCruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, frequency, percentage, minimum, maximum) were used while evaluating the study data. Generalized Linear Mixed Models (GLMM) were performed to examine the effects of age, delivery status, menopause status, mammographic breast density, and mastalgia score (MS) on elastography values. Since both breasts from the same patient were included, intra-patient correlation was accounted for using GLMM. Statistical significance was accepted as $p<0.05$.

## Results

A total of 62 cases and 124 breasts were included in this study. The mean age of all patients was 40.58±7 years (19-54). The mean age of Group 1 cases (n:28) was 41.96±7.43 (19-52) and the mean age of Group 2 cases (n:34) was 39.94±6.65 (29-54). The number of patients over 40 years of age was significantly higher in Group 1 (p= 0.011) (Table 1). 78.5% (n:22) of Group 1 cases and 71% of Group 2 cases (n:24) gave birth. 62% (13/21) of patients over 40 years of age in Group 1 and 72.2% (13/18) of patients over 40 years of age in Group 2 had dense (Type C+D) breast density. Based on the menopause status, 78.5% (n:22) of Group 1 cases and 73.5% (n:25) of Group 2 cases were premenopausal. The MS of Group 1 cases was 3.18±2.03 (0-7), and the MS of Group 2 cases was 3.22±2.72 (0-8). There was no statistically significant difference between the groups regarding birth history, mammographic breast density, menopausal status, and MS (p>0.05) (Table 1).

**Table 1.** Patient-based demographic and clinical characteristics and mastalgia scores

| | Group 1 (n:28) (Silicone implant) | Group 2 (n:34) (Control) | p |
|---|---|---|---|
| | n (%) | n (%) | |
| **Age** | | | [a]**0.011*** |
| <40 | 7 (25) | 16 (47.1) | |
| ≥40 | 21 (75) | 18 (52.9) | |
| **Parity** | | | [a]0.236 |
| No | 6 (21.4) | 11 (32.4) | |
| Yes | 22 (78.6) | 23 (67.6) | |
| **Mammographic breast density** (patients ≥40 years, **n:39)** | | | [a]0.217 |
| A+B | 8 (38) | 5 (27.8) | |
| C+D | 13 (62) | 13 (72.2) | |
| **Menopausal status** | | | [a]0.405 |
| Pre-menopausal | 22 (78.6) | 25 (73.5) | |
| Post-menopausal | 6 (21.4) | 9 (26.5) | |
| Mastalgia score**, Mean±SD** | 3.18±2.03 | 3.22±2.72 | [b]0.924 |

*[a] Pearson chi-square test, [b] Independent groups t-test, * p <0.05*

In the elastographic evaluation performed separately according to Vmean, Vmin, Vmax, and Vsd values, all values in the upper outer quadrant were lower than the other quadrants. All values were lower in cases under 40 years of age compared to cases aged 40 years and over, in those who had not given birth compared to those who had, in Type A breasts according to mammography compared to other types, in post-menopausal cases compared to pre-menopausal cases. All values were higher in Group 1 (with silicone) than in Group 2 (Table 2).

Statistical analysis revealed significant differences in mpSWE values according to quadrant, age, birth history and presence of silicone implant (Table 3). Vmean values were significantly lower in the upper outer quadrant compared to other quadrants (p:0.028). In patients under 40 years of age, Vmean (p:0.005), Vsd (p<0.001) and Vmax (p:0.002) values were significantly lower than in patients aged 40 years and over. However, no significant difference was found in Vmin value (p:0.092). Vmean (p:0.040) and Vmin (p:0.034) values were significantly lower in patients who had not given birth compared to those who had given birth. No significant difference was found in mpSWE values according to mammographic breast density and menopausal status (p>0.05). All mpSWE values were significantly higher in Group 1 than in Group 2 (p<0.05). No significant correlation was found between MSs and mpSWE values (p>0.05) (Table 3).

**Table 2.** Multiparametric Shear Wave Elastography values according to variables

| | Vmean | VSD | Vmax | Vmin |
|---|---|---|---|---|
| | Mean±SD | Mean±SD | Mean±SD | Mean±SD |
| **Quadrant** | | | | |
| UOQ | 1.36±0.30 | 0.17±0.07 | 1.80±0.40 | 1.05±0.25 |
| UIQ | 1.41±0.32 | 0.18±0.07 | 1.91±0.52 | 1.09±0.28 |
| LOQ | 1.45±0.27 | 0.19±0.07 | 1.92±0.38 | 1.09±0.26 |
| LIQ | 1.45±0.33 | 0.19±0.07 | 1.90±0.38 | 1.09±0.29 |
| **Age** | | | | |
| <40 | 1.34±0.28 | 0.17±0.06 | 1.78±0.40 | 1.03±0.25 |
| ≥40 | 1.46±0.32 | 0.19±0.07 | 1.94±0.42 | 1.11±0.28 |
| **Birth history** | | | | |
| No | 1.35±0.29 | 0.18±0.06 | 1.81±0.38 | 1.02±0.25 |
| Yes | 1.44±0.31 | 0.19±0.07 | 1.91±0.44 | 1.10±0.28 |
| **Mammographic breast density (≥40 years old)** | | | | |
| A | 1.42±0.25 | 0.19±0.05 | 1.88±0.32 | 1.09±0.23 |
| B | 1.49±0.34 | 0.19±0.06 | 1.94±0.38 | 1.14±0.30 |
| C | 1.47±0.33 | 0.21±0.08 | 1.98±0.47 | 1.09±0.28 |
| D | 1.43±0.28 | 0.19±0.06 | 1.90±0.41 | 1.10±0.27 |
| **Menopausal status** | | | | |
| Pre-menopausal | 1.49±0.33 | 0.20±0.08 | 1.95±0.44 | 1.13±0.29 |
| Post-menopausal | 1.42±0.29 | 0.19±0.07 | 1.93±0.40 | 1.06±0.26 |
| **Group** | | | | |
| Group 1 (with silicone implant) | 1.53±0.33 | 0.20±0.07 | 1.97±0.42 | 1.21±0.27 |
| Group 2 (without silicone implant) | 1.32±0.25 | 0.17±0.06 | 1.81±0.41 | 0.97±0.22 |

*UOQ: Upper outer quadrant; UIQ: Upper inner quadrant; LOQ: Lower outer quadrant; LIQ: Lower inner quadrant*
***Note:*** *Mammographic breast density is only valid for patients over 40 years of age.*

**Table 3.** Evaluation of the relationship between mpSWE according to variables

| | Vmean | VSD | Vmax | Vmin |
|---|---|---|---|---|
| **Quadrant** | 0.028* | 0.069 | 0.075 | 0.330 |
| **Age** | 0.005* | <0.001* | 0.002* | 0.092 |
| **Birth history** | 0.040* | 0.192 | 0.100 | 0.034* |
| **Mammographic breast density** | 0.801 | 0.140 | 0.659 | 0.899 |
| **Menopausal status** | 0.236 | 0.192 | 0.712 | 0.136 |
| **Group** | <0.001* | 0.002* | 0.002* | <0.001* |
| **Mastalgia score** | 0.848 | 0.488 | 0.359 | 0.855 |

**p<0.05*

When the variables associated with MS were evaluated, only mammographic breast density was found to be significantly associated with mastalgia (p<0.001) (Table 4). MS was significantly higher in patients with dense breast structure (MS: 4.30±1.85) than in patients with fatty breast structure (MS: 1.44±1.83). No significant difference was found in MS according to age, birth history, menopausal status and presence of silicone (Table 4).

**Table 4.** Evaluations regarding the mastalgia score

| | Mastalgia score (MS) Mean±SD | p |
|---|---|---|
| **Age** | | 0.275 |
| <40 | 2.89±2.66 | |
| ≥40 | 3.38±2.27 | |
| **Parity** | | 0.825 |
| No | 3.12±2.58 | |
| Yes | 3.23±2.38 | |
| **Mammographic breast density** (patients ≥40 years, n=39) | | <0.001* |
| A+B | 1.44±1.83 | |
| C+D | 4.30±1.85 | |
| **Menopausal status** | | 0.686 |
| Pre-menopausal | 3.15±2.51 | |
| Post-menopausal | 3.35±2.17 | |
| **Group** | | |
| 1 | 3.18±2.03 | 0.932 |
| 2 | 3.22±2.72 | |

*Independent groups t-test *p<0.05*

## Discussion

The results of this study showed that although higher breast parenchymal stiffness values were observed in the long term after silicone implantation, this was not significantly associated with mastalgia. Although age distribution differed between groups, multivariate GLMM analysis confirmed that the presence of silicone implants remained an independent predictor of increased stiffness. Therefore, subpectoral silicone implants do not appear to be a major determinant of mastalgia.

This finding may be explained by the fact that elastographic stiffness primarily reflects stromal and mechanical properties of breast tissue, whereas mastalgia is more closely related to neural, inflammatory, and hormonal mechanisms. In cases with silicone implants, increased stiffness may be predominantly related to periprosthetic capsule formation or stromal alterations, which may not directly stimulate nociceptive pathways. Accordingly, a mismatch between stromal stiffness and neural pain perception may explain the lack of association between elastographic findings and mastalgia.

Mastalgia can be clinically classified into three main subtypes: cyclic, non-cyclic and extramammary. The most common subtype is cyclic mastalgia, which is caused by hormonal fluctuations during the menstrual cycle. It is most common in fibrocystic and dense breasts and is most severe before menstruation and resolves spontaneously within a few days after menstruation. It is usually bilateral and is associated with generalised breast fullness, firmness and tenderness [3,4]. Non-cyclic mastalgia is not associated with hormonal changes or menstruation. It can be described as a unilateral, sharp, localised pain that is most common after cystic disease, infection and surgery [3,4]. Extramammary mastalgia is used to describe pain that originates from outside the breast. It can come from the lungs, heart, oesophagus or chest wall. For example, pain is usually felt at trigger points outside the breast region, such as in Tietze's disease, which is caused by inflammation in the cartilage junction of the ribs. In extramammary mastalgia, pathologies related to vital organs such as the heart and pulmonary aorta must be excluded [4].

The most common cause of mastalgia is cyclical mastalgia, which develops due to hormonal factors and is more common in the premenstrual period [5]. It is most common in the 30-50 year age group, and fibrocystic and mammographically dense breasts are a potential risk group for mastalgia [5]. Cyclic mastalgia occurs mainly during periods of hormonal irregularity, such as puberty, premenopause, and the first months of pregnancy or lactation [6]. Mastalgia is less common after the menopause due to changes in the architectural structure, a decrease in hormonal action in the breast tissue and the disappearance of cyclic hormonal fluctuations. In the chronic period after childbirth and lactation, the fibroglandular breast tissue undergoes structural changes due to hormonal factors and lactation, and cyclic mastalgia rates decrease compared to the prenatal period.

Mammographic breast density is known to increase in fibrocystic breasts and other benign breast diseases [7,8]. Some hormonal factors also affect breast density [9]. The study by Boyd et al [10] showed that childbirth decreases mammographic breast density. Although mammographic breast density decreases with the decline in endogenous sex hormone levels in postmenopausal women, some speculative studies show that breast density is affected in women taking hormone replacement therapy [9]. Mammographic breast density decreases with age, particularly with menopause [11]. Another study by Boyd et al [11] showed that elastographic breast parenchymal stiffness correlates with mammographic breast density. From this study it can be concluded that factors such as age, menopausal status and parity that influence mammographic breast density may also influence elastographic breast parenchymal stiffness [10]. Breast tissue has several components. It consists of breast parenchyma (acinus+lobule+ductus), adipose tissue and stromal connective tissue. Pregnancy history, breastfeeding history, hormone use and family breast structure are some of the factors that influence these components. Although breast parenchymal density can be assessed by mammography, information on connective tissue is difficult to obtain. Elastography evaluates the average of everything. Therefore, even if the breast is lipomatous (type A-B), if there is an excess of fibrotic stromal connective tissue, it may appear hard on elastography. The opposite is also true. Even if the breast is very dense, if there is less fibrotic stromal connective tissue, it may appear softer elastographically. This is mainly due to the histological structure of the breast. Tabar has several studies on this topic. There are differences between the ACR and Tabar classifications in terms of breast density [12]. The fact that mammographic breast density did not correlate with elastographic breast stiffness in our study group can be explained by the fact that the structure of the breast parenchyma and the ratios of these components are different in each patient. In the studies by Rzymski et al [13], the main parameters influencing breast elasticity in SWE are age and lactation. It has been shown that glandular tissue elasticity correlates with age, adipose tissue elasticity correlates with lactation duration, and mastalgia is associated with elastographic heterogeneity [13]. The relationship between elastographic breast stiffness and mastalgia has also been the subject of other studies [14]. Mastalgia is more common in elastographically stiff breasts. This relationship is associated with fibrocystic breast disease. Breast parenchymal stiffness increases in fibrocystic breasts and therefore mastalgia was observed at a higher rate [14]. In our study, it was also evaluated the effects of factors that affect breast structure and may be associated with mastalgia, such as age, parity, menopausal status, and mammographic breast density, on elastographic breast stiffness, and some interesting results were obtained. A statistically significant correlation was found only between mammographically dense breast structure and mastalgia score, in agreement with the literature ($p<0.001$).

There are also studies in the literature that use elastography to assess the increase in stiffness of breast tissue after silicone implantation. The study by Rzymski et al [13], performed on 19 cases of breast augmentation with silicone implants, showed that the highest values of SWE measurements before and after surgery was found on the 7th postoperative day and decreased significantly on the 14th postoperative day. According to the same study, glandular tissue elasticity and pain were not correlated in the lower quadrants, but there was a significant correlation between the 6th and 10th days in the upper quadrants. Although there was a correlation between implant volume and breast pain in the early postoperative period, it was not correlated with any sonoelastographic parameter. During the postoperative period from day 4 to day 10, when mastalgia was strongly associated with periprosthetic stiffness, the results suggest that mastalgia and parenchymal stiffness result from inflammatory reactions. After silicone implantation, 53% of cases complained of pain and 20% required analgesics [13]. Although postoperative pain resolves within months, it may persist in some cases. Pain that persists after 3 months is considered chronic pain, and the cause of this pain is not yet known [15]. Although it

has been suggested that it may be related to the duration of surgery, focal nerve damage is more likely to cause chronic pain [16]. Inflammation and capsule reactions due to foreign body reactions are also important causes of long-term postoperative pain [16]. It has been shown that the capsule formation in submuscular implants is exposed to more pressure and causes nerve ischaemia in the brachial plexus, resulting in more pain [16]. In contrast to these early postoperative findings, our results suggest that silicone implants do not appear to be a major determinant of mastalgia in the chronic period.

In implantations made for cosmetic purposes, the incision site is usually made along the lower edge of the areola or in the axillary or inframammary folds. Those made for reconstruction after cancer surgery are usually placed in the breast from the surgical incision site [17]. Although the effect of operation or incision site on mastalgia is not clear, it has been suggested that pectoral and intercostal nerve damage in the incision area may be associated with chronic pain [15]. Loss of sensation in the nipple has been reported in cases with subareolar incisions [18]. In the augmentation procedures performed for reconstruction due to breast cancer, the breast tissue may be more prone to pain since the breast tissue loses its normal anatomical architecture. The type of implant may also be significant in terms of mastalgia. Capsule reactions are less commonly developed in saline implants. Therefore, pain due to capsular contracture is less likely to be observed. It can be concluded that the probability of rupture is higher and the possibility of causing pain secondary to the rupture is more likely to occur [19]. A relationship has been shown between the outer surface structure of the implant and the formation of the capsule [20,21]. A textured shell of implants compared to smooth ones decreases fibroblast proliferation and increases the inflammatory response, resulting in delay of collagen deposition [20,21]. In this study, we did not evaluate the relationship between these factors and mastalgia since we were working with the same case population regarding indications, techniques, and materials.

*Limitations:* The major limitation of our single-center study was the small number of patients, although it is relatively larger compared to other studies. In this study, higher breast parenchymal stiffness values were observed in cases with silicone implants; however, no significant association was found between stiffness and mastalgia. Another limitation of the study is that the cases included in the study were not evaluated according to the menstrual cycle. Mastalgia was assessed using a single-time self-reported scale without differentiation between cyclic and non-cyclic pain, which may have introduced measurement bias. One of the important limitations is that we could not assess the relationship between implant volume and breast stiffness since most cases did not remember their implant volumes. Perhaps, in patients with small breast tissue, the insertion of high-volume silicone can be an important factor causing breast pain by affecting breast elasticity due to tension stress. Since the surface feature of the material used is unknown in most cases and cannot be understood by imaging modalities, it was not included in the evaluation criteria. In our study, the incision localization was not taken into account, assuming that it would not affect breast elasticity. Therefore, the relationship between the incision site and mastalgia has not been evaluated. The interval between augmentation operation and mastalgia onset was not questioned in cases with silicone implants, which was another important limitation of the study.

## Conclusion

Subpectoral silicone breast implants are associated with increased breast stiffness. However, according to the results of this study, no direct relationship was found between the increase in breast stiffness and mastalgia. Moreover, no significant relationship was found between elastographic breast stiffness and menopausal status, mammographic breast density, and parity. For this reason, dense breast structure should be considered as a primary cause of breast pain experienced in the long-term period in cases with silicone implants, as in other women without silicone.

## Declarations

### *Ethics approval*

Ethics committee approval was obtained from the institutional review board (2021-07/21).

### *Conflict of Interest*

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

### *Animal and human rights statement*

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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### *Scientific Responsibility Statement*

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

## References

1. Chao AH, Garza R 3rd, Povoski SP (2016) A review of the use of silicone implants in breast surgery. Expert Rev Med Devices. 13(2):143-156. https://doi.org/10.1586/17434440.2016.1134310.
2. Nava MB, Rancati A, Angrigiani C, Catanuto G, Rocco N (2017) How to prevent complications in breast augmentation. Gland Surg. 6(2):210-217. https://doi.org/10.21037/gs.2017.04.02
3. Morrow M. The evaluation of common breast problems (2000) Am Fam Physician. 61(8):2371-8
4. Eren T, Aslan A, Ozemir IA, Baysal H, Sagiroglu J, Ekinci O, et al (2016) Factors Effecting Mastalgia. Breast Care (Basel). 11(3):188-193. https://doi.org/10.1159/000444359
5. Bolat H, Aşcı Ö, Kocaöz S, Kocaöz S (2022) Noncyclical and cyclical mastalgia in Turkish women: Prevalence, risk factors, health-care seeking and quality of life. Health Care Women Int. 43(1-3):160-175. https://doi.org/10.1080/07399332.2021.1887194.
6. Rosolowich V, Saettler E, Szuck B (2006) Breast Dısease Commıttee. Mastalgia. J Obstet Gynaecol Can. 28(1):49-57. https://doi.org/10.1016/S1701-2163(16)32027-8
7. Han H, Cha YM, Yang JH, Song EH, Hwang HY, Chung HS, et al (1993) Fibrocystic disease of breast: variable mammographic and sonography appearance. J Korean Soc Med Ultrasound. 12:216-222.
8. Román M, Louro J, Posso M, Alcántara R, Peñalva L, Sala M, et al (2021) Breast density, benign breast disease, and risk of breast cancer over time. Eur Radiol. 31(7):4839–4847. https://doi.org/10.1007/s00330-020-07490-5.
9. Warren R, Skinner J, Sala E, Denton E, Dowsett M, Folkerd E, et al (2006) Associations among mammographic density, circulating sex hormones, and polymorphisms in sex hormone metabolism genes in postmenopausal women. Cancer Epidemiol Biomarkers Prev. 15(8):1502-1508. https://doi.org/10.1158/1055-9965.EPI-05-0828.
10. Boyd NF, Li Q, Melnichouk O, Huszti E, Martin LJ, Gunasekara A, et al (2014) Evidence that breast tissue stiffness is associated with risk of breast cancer. PLoS One. 9(7):e100937. https://doi.org/10.1371/journal.pone.0100937
11. Boyd NF, Li Q, Melnichouk O, Huszti E, Martin LJ, Gunasekara A, et al (2002) A longitudinal study of the effects of menopause on mammographic features. Cancer Epidemiol Biomarkers Prev. 11:1048-1053
12. Gram IT, Funkhouser E, Tabár L (1997) The Tabár classification of mammographic parenchymal patterns. Eur J Radiol. 24(2):131-136. https://doi.org/10.1016/s0720-048x(96)01138-2.
13. Rzymski P, Kubasik M, Gaca M, Opala T (2011) Is the shear wave sonographic elastography correlated with pain after breast augmentation with silicone implants an indication of inflammatory activity? A preliminary report. Wideochir Inne Tech Maloinwazyjne. 6(4):217-225. https://doi.org/10.5114/wiitm.2011.26255.
14. Dzoic Dominkovic M, Ivanac G, Bojanic K, Kralik K, Smolic M, Divjak E, et al (2020) Exploring Association of Breast Pain, Pregnancy, and Body Mass Index with Breast Tissue Elasticity in Healthy Women: Glandular and Fat Differences. Diagnostics (Basel). 10(10):393. https://doi.org/10.3390/diagnostics10060393.
15. Urits I, Lavin C, Patel M, Maganty N, Jacobson X, Ngo AL, et al (2020) Chronic Pain Following Cosmetic Breast Surgery: A Comprehensive Review. Pain Ther. 9(1):71-82. https://doi.org/10.1007/s40122-020-00150-y
16. Wallace MS, Wallace AM, Lee J, Dobke MK (1996) Pain after breast surgery: a survey of 282 women. Pain. 66(2-3):195-205. https://doi.org/10.1016/0304-3959(96)03064-3.
17. Gabriel A, Maxwell GP (2019) Implant selection in the setting of prepectoral breast reconstruction. Gland Surg. 8(1):36-42. https://doi.org/10.21037/gs.2018.11.09
18. Bae JY, Shin HY, Song SY, Lee DW (2021) Risk and protective factors affecting sensory recovery after breast reconstruction. Arch Plast Surg. 48(1):26-32. https://doi.org/10.5999/aps.2020.01151.
19. Patel BC, Wong CS, Wright T, Schaffner AD (2021) Breast Implants. In: StatPearls (Internet). Treasure Island (FL): StatPearls Publishing.
20. Wyatt LE, Sinow JD, Wollman JS, Sami DA, Miller TA (1998) The influence of time on human breast capsule histology: smooth and textured silicone-surfaced implants. Plast Reconstr Surg. 102(6):1922-1931. https://doi.org/10.1097/00006534-199811000-00017.
21. Luke JL, Kalasinsky VF, Turnicky RP, Centeno JA, Johnson FB, Mullick FG (1997) Pathological and biophysical findings associated with silicone breast implants: a study of capsular tissues from 86 cases. Plast Reconstr Surg. 100(6):1558-1565.