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REVIEW BREAST SURGERY

Rippling Following Breast Augmentation or Reconstruction: Aetiology, Emerging Treatment Options and a Novel Classification of Severity

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Abstract
Background Implant rippling is a frequent complication following breast augmentation or implant-based reconstruction and results in significant patient dissatisfaction. Traditionally, the treatment has been to replace the implant, often placing it in a subpectoral pocket to reduce the risk of recurrence. Other techniques, such as increasing the implant size or tightening the capsule, can also be used. Recently, however, there has been much interest in alternative treatments, including fat grafting or insertion of an acellular dermal matrix.
Methods We review the evidence base for emerging treatments and propose a classification to grade severity, based on the typical clinical presentation of rippling: Grade 1—MILD—rippling is palpable but not visible: (1a) palpable in the lower outer quadrant, (1b) palpable in the upper inner quadrant (cleavage area); Grade 2—MODERATE—rippling is visible only when the patient bends forward; Grade 3—SEVERE—rippling is visible with the patient upright.
Conclusion Our proposed classification aims to standardise the clinical description of rippling, which will be valuable in determining the efficacy of new treatments and better characterising long-term complications from breast augmentations or reconstructions.
Level of Evidence V This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Implant rippling · Rippling · Breast augmentation · Breast reconstruction · Fat transfer · Acellular dermal matrix

Introduction

Rippling refers to palpable or visible folds on the surface of the breast, transmitted from an underlying breast implant. It is a well-known complication following breast augmentation, occurring in up to 10% of cases [1], and resulting in significant patient dissatisfaction and a high rate of re-operation.

Rippling is typically most apparent in the upper medial or lower lateral portions of the breast. Most commonly, it is only palpable, and the edge of the implant can be felt by running a finger lightly across the breast surface. In more advanced cases, wrinkles or folds become visible.

Aetiology

Changes in the surface of a breast implant will inevitably occur over time. The effect of gravity distorts the implant, causing folds in the outer shell: this can be seen ex vivo when an implant is placed on its side and creases develop on the surface. Typically, these surface changes are relatively minor and are concealed by the overlying breast tissue such that they are not evident. Rippling refers to changes in the implant surface that become *clinically* apparent on the surface of the breast.

There are two main aetiological factors to consider: the quality of the breast tissue covering the implant and the degree of deformation of the implant. Where the breast

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tissue is thin or stretched, folds in the implant surface are not camouflaged and rippling is apparent. Alternatively, certain implant choices or pocket characteristics allow very significant implant surface deformities to develop, increasing the likelihood of them being detectable through the soft tissue coverage.

Risk Factors

The risk factors for rippling can be considered in terms of those affecting soft tissue quality and those affecting the degree of implant deformation (Table 1). Patients with a low BMI are at a far greater risk of rippling due to a paucity of overlying breast tissue. Codner et al. retrospectively reviewed 812 primary breast augmentations over a 15-year period and reported that 11% of underweight patients (BMI < 18.5) developed rippling, whereas no patients with a BMI > 25 were affected [2]. For the underweight patients, the incidence of rippling was highest for those with subglandular implants. Rippling can also occur due to thinning of the breast tissue following weight loss or pregnancy. Breast ptosis can lead to redistribution of glandular tissue over an implant causing rippling at the upper pole.

The choice of pocket is also important. Rippling over the superior pole of the breast is seen less commonly in subpectoral implant placement, as the muscle augments the soft tissue coverage [3]. However, at the inferior pole, rippling is equally likely for subglandular and subpectoral augmentations, as the degree of soft tissue coverage is the same for both techniques [3].

The incidence of rippling is greater for implant-based breast reconstruction and revisional breast surgery than for primary breast augmentation. Handel et al. reported on 1529 patients who received 3495 saline or silicone implants [4]. At an average follow-up of 37.4 months, the incidence of rippling was 5.7% following primary augmentation, 7.7% following breast reconstruction and 11.9% following revisional breast surgery. Again, this likely relates to the overlying soft tissue quality. Mastectomy skin flaps tend to be thin and can be adversely affected by radiotherapy. Patients with partial pectoral denervation may also present with superomedial prominence. Women undergoing revisional breast surgery may have thin, stretched breast tissue as a consequence of previous implants.

Certain implant characteristics also affect the likelihood of rippling, as they determine the degree of deformation that occurs within the breast pocket. In particular, the implant cohesivity and nature of the implant surface are important. Saline implants are associated with the highest risk of rippling, as they are more prone to shape changes. In their series of primary breast augmentations, Codner et al. noted rippling in 9.3% of patients with round smooth saline implants as opposed to 3.9% with round smooth silicone implants, at a mean follow-up of 26 months [2]. Underfilling of saline implants or overgenerous pocket formation, especially when located inferolaterally, also allows excessive movement and folding of the implant.

Fifth-generation silicone implants are associated with a lower rate of rippling than the fourth-generation silicone implants, as the gel filling is more cohesive. Hammond et al. reported that just 2.7% of 572 patients with form-stable anatomical implants developed rippling at 6 years following primary augmentation [5]. Data comparing the varying degrees of cohesivity are sparse, although one study comparing two different cohesities in the same prosthesis model showed a lower rate of rippling in the implant with higher cohesity, as one would expect [6].

The risk of rippling is increased for textured implants, when compared with smooth or polyurethane (PTE)-coated implants. This is through adherence of the textured implant surface to the breast tissues and capsule, resulting in 'traction' rippling. In the Handel series, rippling occurred in 6.9% of patients with smooth implants, 6.7% of PTE-coated implants and 14.2% of textured implants [4].

Treatment Options

Rippling, as with other aesthetic complications of breast augmentation, is a difficult problem to manage. Traditionally, the treatment has been to replace the implant, often placing it in a subpectoral pocket to reduce the risk of recurrence. Other techniques, such as increasing the size of

Table 1 Risk factors for implant rippling

Risk factors for breast rippling	
Factors affecting soft tissue coverage	Factors affecting implant deformation
Low BMI	Saline implants
Poor-quality breast skin	Underfilling of implants
Significant weight loss post-surgery	Lower cohesity of silicone filling
Changes in breast tissue after pregnancy	Textured implants
Subglandular implant placement	Overgenerous pocket formation
Reconstructive/revisional surgery	

Table 2 A summary of case series reporting the use of ADMs to treat implant rippling

Study	Number of cases	ADM	Study follow-up	Results
Duncan 2001 [8]	34 patients	AlloDerm (24), Dermaplant (10)	–	Patient satisfaction of 85% Persistent rippling in most patients
Baxter 2003 [11]	2 patients	AlloDerm	6–24 months	No recurrence
Hartzell 2010 [9]	10 patients (15 breasts)	AlloDerm	21 months	2/10 patients required re-operation for recurrence
Nahabedian & Spear 2011 [12]	5 patients	AlloDerm or Strattice	–	–
Maxwell and Gabriel 2013 [10]	9 patients	6 different ADMs in the study	3.1 years	No recurrences
Spear et al. 2013 [13]	6 breasts	Strattice	17.5 months	No recurrences
Pozner et al. 2013 [14]	6 patients	Strattice	17 months	–

AlloDerm (AlloDerm® Regenerative Tissue Matrix, LifeCell Corp., Branchburg, NJ, USA); Dermaplant (Dermaplant™, Collagenesis Inc, Beverly, MA, USA); Strattice (Strattice™ Reconstructive Tissue Matrix, LifeCell Corp., Branchburg, NJ, USA)

the implant or performing a capsulorrhaphy to tighten the capsule, can also be used as an adjunct.

Recently, however, there has been much interest in alternative treatments. Of these, the two most common methods are fat grafting and insertion of an acellular dermal matrix (ADM) to camouflage the rippling effect. Along a similar principle, other barrier techniques have also been described. We performed a search of PubMed using the term 'implant rippling' to identify all of the published literature relating to each technique.

Acellular Dermal Matrices (ADMs)

For patients with implant rippling, an ADM can be used to supplement and support the soft tissues. There are broadly two surgical strategies, depending on the underlying problem. Where the breast tissue is deficient and an implant contour is apparent immediately beneath the skin, an ADM can be applied as capsular onlay graft to augment the soft tissue thickness. Alternatively, where inadequate lower pole support is the cause of rippling, an ADM can be applied as a hammock to strengthen the inferior pocket.

The safety and efficacy of ADMs in revisional breast surgery is widely reported [7], but there is little published with regard to their specific use for rippling. The largest series to date was reported by Duncan in 2001 [8]. She used AlloDerm (AlloDerm® Regenerative Tissue Matrix, LifeCell Corp., Branchburg, NJ, USA) and Dermaplant (Dermaplant™, Collagenesis Inc, Beverly, MA, USA) to correct rippling in 34 patients following cosmetic augmentation or reconstruction. All patients with implants had them removed and underwent a complete/segmental capsulectomy. In patients with inferolateral defects, a medium-thickness ADM was secured from the inferolateral pectoral muscle edge to the infra-mammary fold. In patients with superomedial pectoral defects, the allograft was secured to the defective region as an onlay graft. An implant was then placed in the subpectoral plane. Whilst the procedure improved the appearance of visible rippling in most patients, it did not eliminate it altogether and most patients had persistent palpable rippling.

Hartzell et al. used ADMs to correct rippling/wrinkling in 10 patients (15 breasts) following cosmetic augmentation [9]. All patients had their implants replaced into a subpectoral pocket and thick/ultrathick AlloDerm was applied within the capsule as an onlay. However, using an ADM is not cheap—the cost of the procedure was greater than $3500 per breast, per operation. Two of these ten patients required a further bilateral cosmetic breast operation before the end of the follow-up period (average of 21 months) due to persistent surface irregularities. In these cases, additional ADM was placed as an onlay within the capsule to correct the problem.

Maxwell and Gabriel reported their 6-year experience with ADMs in revisional breast surgery [10], which included nine patients with implant rippling. In all cases, implants were exchanged into a new pocket (subglandular to subpectoral; subpectoral to neopectoral). At a mean follow-up of 3.1 years, there were no recurrences of rippling, although one patient developed a post-operative seroma due to double-layering of AlloDerm.

Other groups have reported using ADMs for implant rippling as a subset of a larger study. A summary of case series to date is shown in Table 2.

These series are highly heterogeneous and, whilst most conclude in favour of using ADMs for implant rippling, the

20% re-operation rate in the Hartzell study and Duncan's findings of persistent palpable rippling in most patients, suggest limitations to the technique. Of course, these figures must be taken in the context of a generally high re-operation rate following revisional breast surgery.

The studies suggest that an ADM can provide partial camouflage for visible rippling but may not eradicate palpable rippling. This is unsurprising, since even the ultra-thick AlloDerm has a thickness of only 2.31–3.30 mm, such that it cannot substantially augment the overlying skin flap. One solution proposed has been to layer the ADM for increased thickness, but this impairs revascularisation and can cause seroma formation [9].

Fat Grafting

A recent survey of the American Society of Plastic Surgeons reported that 72% of surgeons employed fat grafting in aesthetic breast surgery to disguise an implant border or improve shape following augmentation [15]. Despite this, as with ADMs, there is a paucity of information in the literature regarding fat transfer in the specific context of implant rippling, with the vast majority of lipomodelling being reported for contour deformities and augmentation.

Kanchwala et al. used fat grafting to correct implant rippling in 12 patients, as part of a larger study [16]. The fat was used to augment the soft tissue coverage, and the implants were not exchanged. They reported that nine patients (66%) noted significant improvement in rippling. Their most common indication was at the medial implant/chest wall interface, the 'cleavage' area, where the overlying tissue was thin. They noted fat grafting to be more effective in areas where the implant was less mobile.

Delay et al. have reported the largest series of breast lipomodelling to date, with 880 procedures performed over 10 years [17]. Whilst they do not provide data specifically for rippling, they comment that their best results are when fat transfer is combined with implant replacement, enabling accurate fat grafting between the skin and capsule once the implant has been removed.

Fat grafting as a treatment for rippling appears to have similar limitations to ADM placement. The Kanchwala group reported improvement in rippling in the majority of their patients, rather than complete resolution. Their observation that fat grafting is most useful in regions where the implant is less mobile suggests that success depends partly on the underlying aetiology of rippling: fat grafts are able to improve soft tissue coverage but not compensate for a significantly deformed/mobile implant. The major advantage of fat grafting over ADMs is that it is a much less invasive procedure and does not necessitate implant replacement or repositioning.

Interestingly, fat grafting is increasingly being utilised as a 'prophylaxis' against future implant rippling. Auclair et al. were the first to report *composite* breast augmentation [18], where breast implants were combined with fat grafting in patients with inadequate soft tissue coverage for their chosen implant size. Fat grafting has also been used to augment mastectomy skin flaps prior to implant-based reconstruction [19].

Alternative Treatments

Alternative barrier techniques have also been proposed to disguise implant rippling. Capsular flaps can be transposed to augment soft tissue cover where it is deficient in the breast. Gargano et al. described using a capsular flap as a treatment for medial breast rippling [20]. The implant is removed and a pocket dissected between the capsule and the underlying pectoral muscle. The implant is then replaced into the subcapsular plane, above the pectoral muscle, and a lateral/superolateral capsule release allows rotation to augment the atrophic medial skin. Massiha reported a similar technique, whereby, following implant removal, the capsule is dissected off the chest wall posteriorly and the breast tissue anteriorly before being folded upon itself to provide two layers of coverage [21].

McGregor and Bahia used a fascia lata patch from the lateral thigh [22] and report that the patch can be placed outside the capsule, without removing the implant. Finally, Collis et al. used a pectoralis major trapdoor flap to disguise rippling on the medial border of the breast [23].

Implant Rippling: A New Classification of Severity

Given that new treatment modalities are emerging, we feel that it would be beneficial to have a more objective method of classifying rippling. In studies thus far, observation of rippling is typically 'binary'—noted to be either present or absent. In reality, there is a spectrum of clinical presentations. We propose a simple classification to grade severity, based on the typical clinical presentation of rippling (Figs. 1, 2, 3):

- Grade 1—MILD: rippling is palpable but not visible
  - 1a: palpable in the lower outer quadrant
  - 1b: palpable in the upper inner quadrant (cleavage area)
- Grade 2—MODERATE: rippling is visible only when the patient bends forward
- Grade 3—SEVERE: rippling is visible with the patient upright

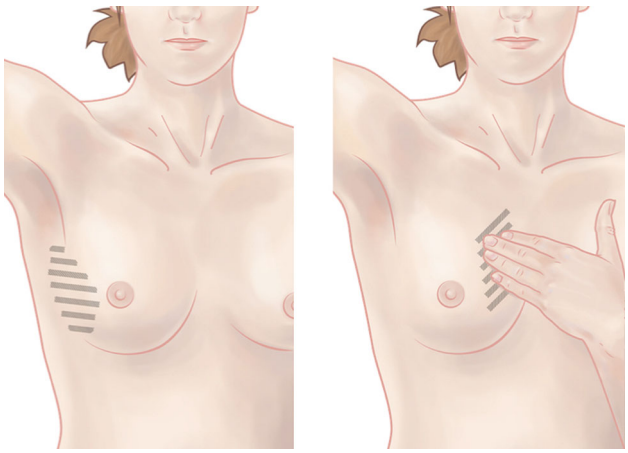

Fig. 1 Grade 1: rippling that is palpable but not visible. Left—Grade 1a: palpable rippling in the lower outer quadrant. Right—Grade 1b: palpable rippling in the cleavage area

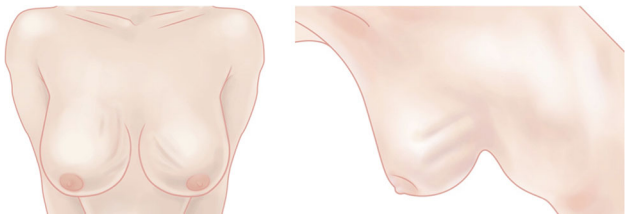

Fig. 2 Grade 2: rippling is visible only when the patient bends forward

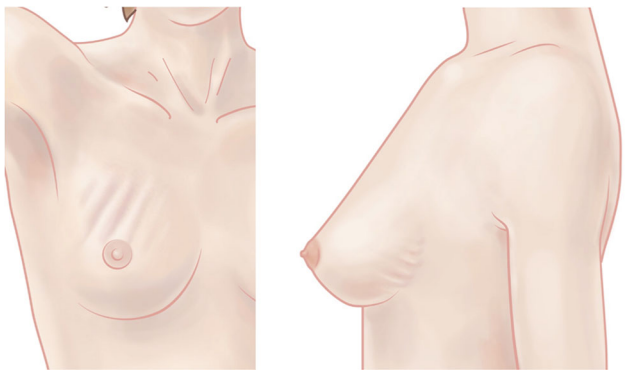

Fig. 3 Grade 3: rippling is visible with the patient upright

This classification system is designed to reflect the severity of the condition from the patient's perspective. Grade 1 rippling is not visible and is typically only apparent when running a finger lightly over the breast skin. This is the most common form and may not bother the patient, particularly in the lower outer quadrant, where the palpable region is often contained within a bra. We have subdivided Grade 1 into two categories, as their typical aetiology is different. Rippling in the upper inner quadrant is more suggestive of inadequate breast tissue cover in subglandular augmentation. Rippling in the lower outer quadrant is more reflective of changes in the shape of the implant in a dependent position.

Grades 2 and 3 represent more advanced rippling and tend to present later after surgery. Visible rippling gives a very poor cosmetic outcome, with high rates of patient dissatisfaction. Upon bending forwards, rippling tends to become more apparent, possibly as the implant shifts closer to skin and the forces on the soft tissues change, resulting in greater traction (Grade 2). In the most severe situation, rippling is visible with the patient even in an upright position (Grade 3).

Our proposed classification, in a similar manner to the Baker classification for capsular contracture, aims to standardise the clinical description of the severity of rippling. This will be particularly valuable in determining the efficacy of new treatments for rippling and enabling patients to be properly counselled regarding treatment options and their limitations. The published studies discussed suggest that ADMs and fat grafting can be used to improve rippling but may not eradicate it altogether. However, patients may accept persistence of palpable rippling if visible rippling has been corrected: the average degree of satisfaction in Duncan's series using ADMs was 85% despite most patients still having persistent palpable rippling [8]. Having a system to classify the severity of rippling will enable better characterisation of the degree of improvement that each treatment can offer and allow comparison with the traditional techniques. It will also be important in determining whether any improvement is long lasting, as the severity can be recorded during the follow-up period.

Conclusion

Implant rippling is a significant complication following breast augmentation or implant-based reconstruction. We propose a classification based on the typical clinical presentation to standardise the description and enable a more accurate comparison between treatment methods.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflicts of interests.

Human and Animal Rights This article does not contain any studies with human participants or animals performed by any of the authors.

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