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ORIGINAL ARTICLE

Successfully Exploiting Two Opposing Forces: A Rational Explanation for the “Interlocking Suture”

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Abstract

Background Issues of poor circumareolar scars and asymmetry or malposition of the nipple–areola complex (NAC) are frequently associated with those breast reduction or pexy techniques that rely on an ample excision of skin around the areola, either alone or associated with a vertical scar in a circumvertical approach. To prevent such problems, in 2007 Hammond et al. introduced the “interlocking suture.” The objective of this study was to demonstrate the true ability of this suture to reduce the common complications of periareolar surgery simply by managing the existing contrast between NAC centripetal and outer breast tegument centrifugal forces.

Methods By using finite element method (FEM) software, the NAC traditional interrupted stitches were compared with both round-block and interlocking sutures, and the skin strain in all three procedures was qualified.

Results The contribution of circuitous stitches in the interlocking suture leads to a more advantageous distribution of forces. FEM analysis shows that the interlocking suture reduces skin stress on peripheral breast teguments by 14% compared to the round-block suture and by 15% compared to the traditional (radial) suture. When evaluating the areolar edge, the interlocking suture leads to a reduction in skin stress of 9.9% compared with traditional interrupted stitches.

Conclusions The efficient, long-lasting results of the interlocking suture are directly due to its unique design, which effectively reduces the tension between the NAC and breast tegument edges in periareolar surgery, thus improving the quality of the scar.

Keywords Breast suture · Periareolar suture

The plethora of breast-reshaping techniques described in the literature all involve a complex set of variables, including not only shape and symmetry of the breast but also scar quality and position and shape of the nipple–areola complex (NAC) [1]. The increasing demand for elusive and inconspicuous scars, often fueled by unrealistic media and patient expectations, led to the introduction of different periareolar procedures in order to minimize visible stigmata on the breast surface by confining them to the periareolar region. This approach has been described for several clinical situations: ptosis [2] or hypertrophy [3, 4], tuberous breasts [5], gynecomastia [6], and augmentation mastopexy [7, 8].

Because of an inevitable discrepancy between the areola diameter and the outer edge of the wound circumference, the periareolar technique usually entails closure of the defect under tension and with unequal suture bites, even when some of the discrepancy is compensated for by a vertical skin takeout. This often leads to distortion of the areola, scar widening, and hypertrophic scarring [9], and is a well-known setup for litigation with often unfavorable outcomes for the surgeon [10].

In 2007 Hammond et al. [11] described a modified purse-string suture, called the “interlocking suture,” designed to minimize the aforementioned complications of periareolar surgery. The purpose of this article is to demonstrate by use of a physical model the ability of this suture to reduce efficiently the stress between the areola edge and the outer breast tegument circumference, thus reducing

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tension on the suture. This concept is demonstrated by comparing traditional interrupted stitches and round-block sutures to the "interlocking" method.

Methods

The three suture systems were modeled using the finite element method (FEM) software SAP2000 (Computers and Structures, Berkeley, CA, USA) to determine the skin stress in the three procedures and therefore determine which technique would lead to the greatest reduction of tension at the suture margins. Finite element analysis is a technique used in biomechanical physics to investigate the structural integrity of a given material; it recently has been successfully employed in reconstructive microsurgery [12].

The situation was simplified (for both graphical and computational aspects) by converting the three-dimensional geometry into a two-dimensional one (Figs. 1, 2, 3). Also, for the purpose of simplifying this study while maintaining its logic, it was reasonably assumed that material's anisotropy, i.e., the property of being directionally dependent, and nonlinearity would not be taken into consideration for the skin model [13, 14]. (In physics, system nonlinearity entails a nonproportional relationship between two variables, so in this model nonlinearity refers to the skin stress/deformation ratio, which instead are assumed to be directly proportional.)

In all three FEM models, skin was defined as a material with a modulus of elasticity of 2 N/mm^2 and a thickness of 2 mm. The suture thread, identical in the three models, was defined as a one-dimensional element with a diameter of 0.4 mm and a modulus of elasticity of 1,000 N/mm^2; therefore, its stiffness is greater than that of skin. The areolar diameter was set at 3 cm, to be sutured to a 6-cm external diameter of breast, thus with a ratio of 1:2.

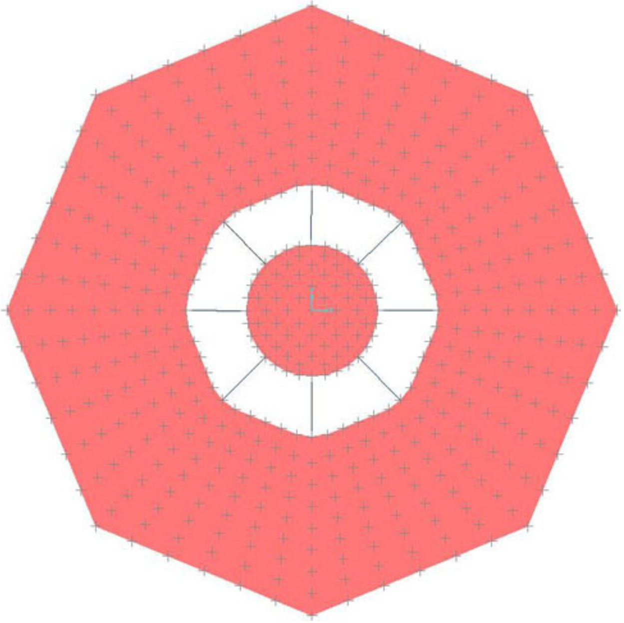
Fig. 1 Interrupted stitches suture bidimensional model

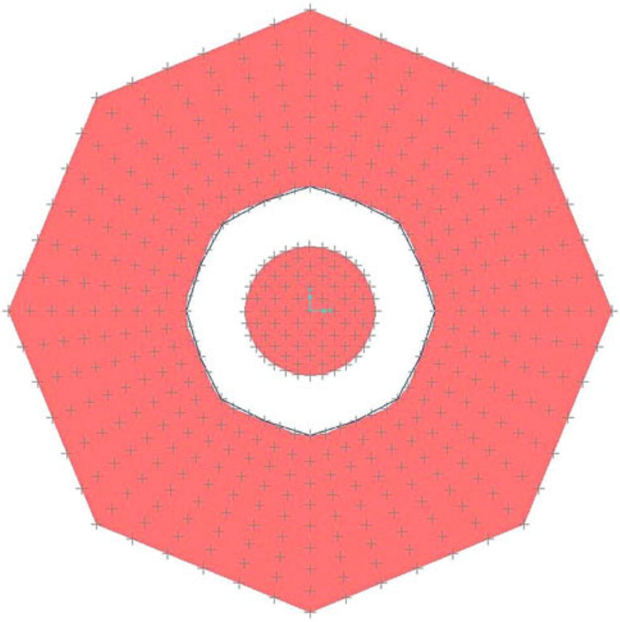
Fig. 2 The round-block suture model

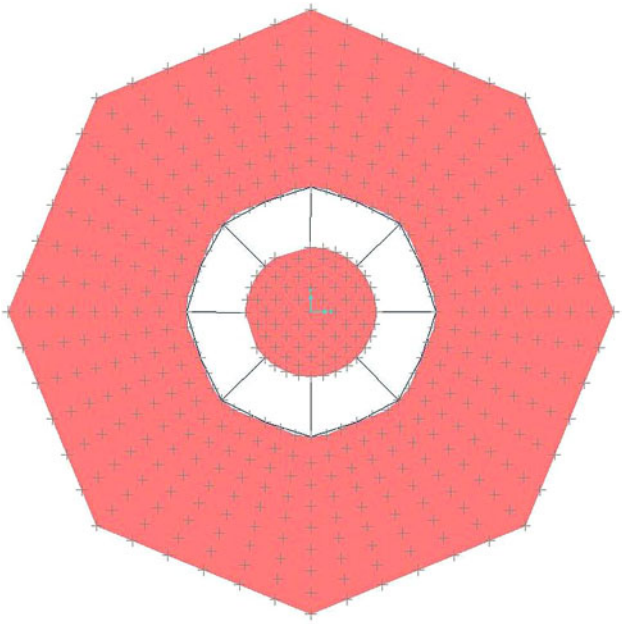
Fig. 3 The interlocking suture bidimensional diagram

The stresses on the threads were different in the three procedures. (1) In the interrupted stitches model, a 100% stress was assigned to the suture (to close up the areolar edge to the external skin). (2) In the round-block suture model, a 55% stress was assigned to the suture (to reduce the external circumference to the dimension of the internal one). (3) In the interlocking suture model, the two previous stress measurements were combined. Stress is a measure of the average amount of force exerted per unit area of the surface on which internal forces act within a deformable body: its model unit is equivalent to one newton (force) per square millimeter (unit area).

Results

Results, listed in Table 1, can be easily read in the stress maps of Figs. 4, 5, 6, where "stress states" in the principal stress direction are illustrated.

The color scale scheme shown in Fig. 7 helps one to interpret the analysis. Results of the analysis documented that the round-block suture produces the greatest stress on the peripheral skin edge (as is intuitively apparent), while stress values were similar for the traditional interrupted stitches suture and the interlocking suture. However, the contribution of circumferential stitches in this latter technique (the passes of the straight needle that generously and evenly engage the peripheral dermis shelf in eight segments in Hammond's description) leads to a more advantageous, better balanced distribution of forces and therefore to a decrease of stress on the skin of the breast (Fig. 8).

Table 1 Areolar suture techniques: a comparison

Type of suture system	Max skin stress (areolar edge) (N/mm^2)	Max skin stress (breast teguments edge) (N/mm^2)
Traditional interrupted stitches	1.22	0.80
Round-block	0.00	0.79
Interlocking	1.10	0.68

The FEM analysis thus proved that the interlocking suture is the best choice. In fact, this suture reduces skin stress on skin breast teguments by 14% compared with round-block suture (0.68 vs. 0.79) and by 15% compared with the traditional (interrupted radial) suture (0.68 vs. 0.80).At the areolar edge, the interlocking suture reduces skin stress by 9.9% compared with traditional interrupted stitches (1.10 vs. 1.22).

Discussion

The periareolar approach results in the shortest possible scar pattern, with incision designs that can be a concentric [15, 16] or an eccentric pattern; the latter was first reported by Puckett [9] to combine mastopexy with augmentation. Rohrich et al. [17] also described the periareolar technique to perform mastopexy in patients with mild ptosis who did not desire implant replacement after removal. Even if it so obviously versatile, the periareolar approach has the major drawback of scar widening and hypertrophy, with areola spreading and shape distortion. This unfortunate complication, which is even more so when volume is added by an

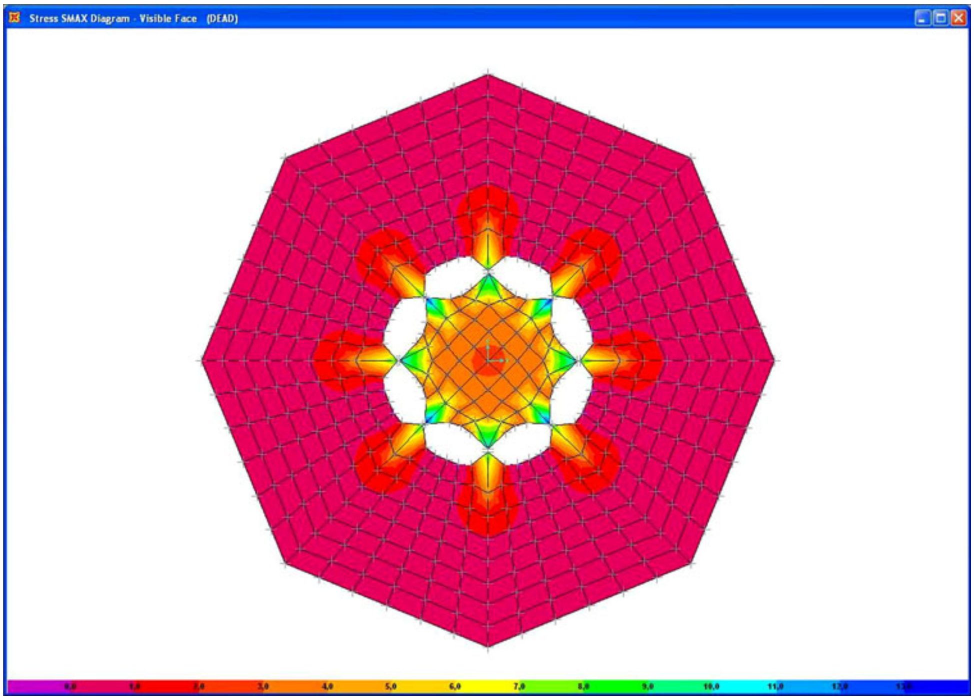

Fig. 4 Interrupted stitches suture stress map

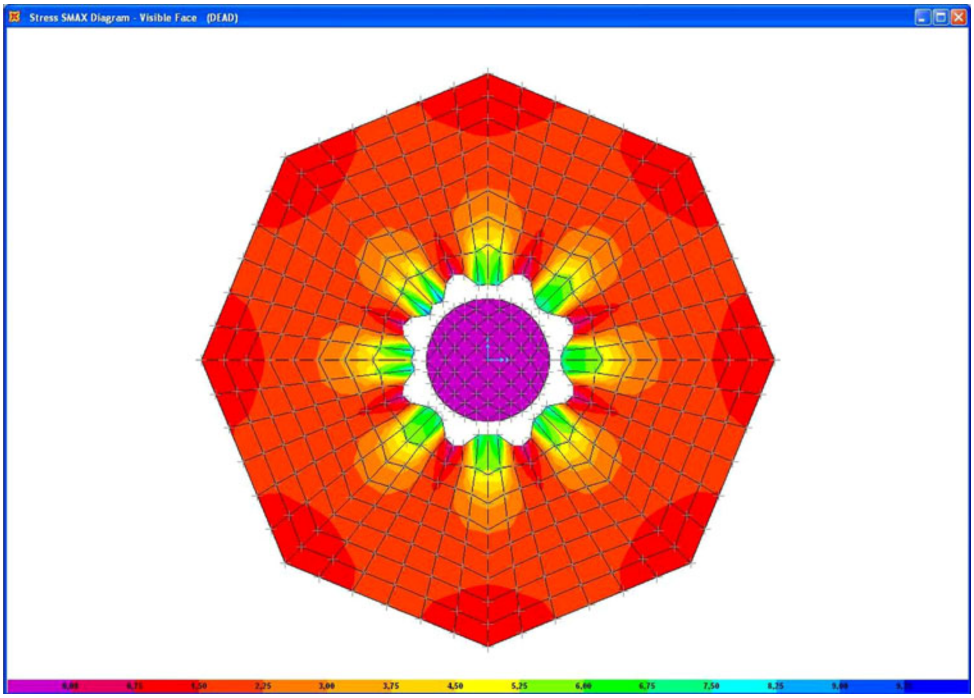

Fig. 5 Round-block suture stress map

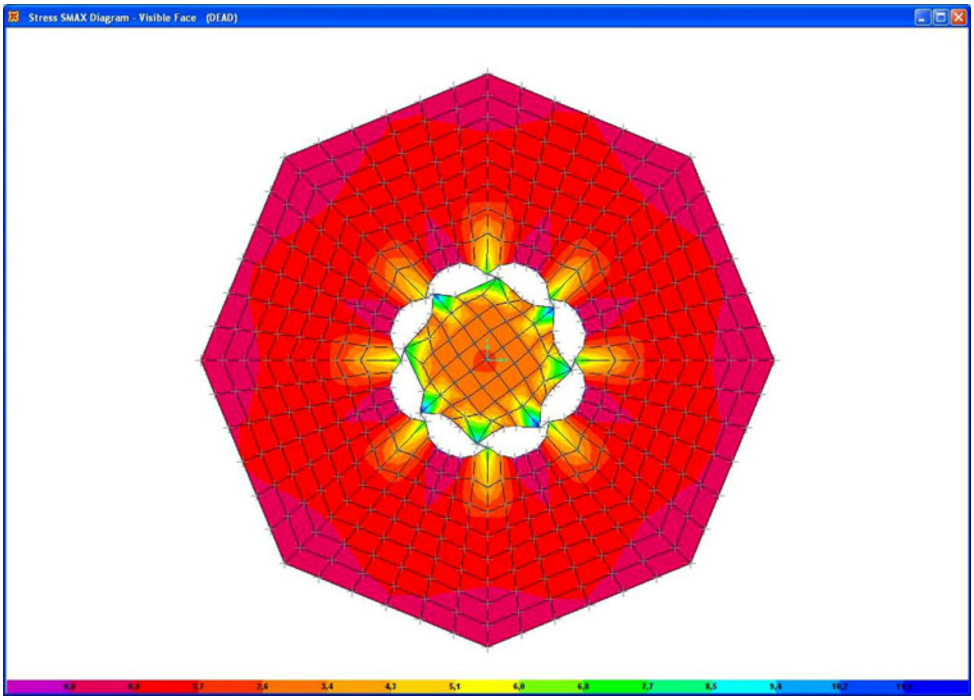

Fig. 6 Interlocking suture stress map

Fig. 7 The color scale scheme. Skin stress unit measurement is N/mm^2

implant and thus increasing tension on the suture, often leads to litigation in court [10].

Certainly, tension on the suture line is the main factor responsible for these common complications. The periareolar technique necessarily entails a "final synthesis" between the inner wound edge and an outer wound edge with a much larger diameter and circumference. Obviously, the more this discrepancy increases, the more stress or

Fig. 8 Interlocking suture in progress

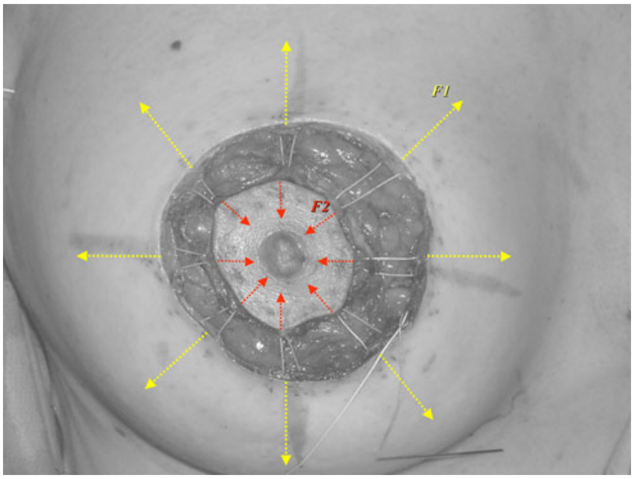

Fig. 9 The interlocking Gore-Tex suture and the two opposing forces (*F1*, *F2*): *centrifugal* (*yellow arrows*) represents the tendency of the breast teguments to widen and *centripetal* (*red arrows*) represents the tendency of the areola to contract

strain will be inflicted on breast teguments. To this effect, Spear et al. [18] stated that to reduce tension and wrinkling, the size of the outer diameter should indeed be limited to no more than three times that of the inner diameter.

Thus, reducing tension on the suture is a main objective of the surgeon who performs periareolar surgery. The introduction of the purse-string technique with nonabsorbable suture as described by Benelli [2, 3] indeed was aimed at reduction of areolar spreading. Also, using a similar principle, Goés [19] introduced a mesh support to stabilize the reshaped parenchyma and thus also prevent the scar from spreading, although this method did not gain widespread acceptance because of imaging concerns in follow-up. Other authors, instead, placed emphasis on camouflaging the periareolar scar. For instance, Gryskiewicz and Hatfield [20] employed an irregular wavy-line incision as one way to produce a less obvious scar around the areola, without simultaneously trying to reduce the tension on the wound edges. However, they still reported a 14% rate of hypertrophic scarring following mastopexy and a 5% rate of partial dehiscence after breast reduction.

Finally, in 2007, Hammond et al. [11] described the interlocking suture, using a Gore-Tex suture (W.L. Gore & Associates, Flagstaff, AZ, USA) as initially reported by Spear et al. [18], on a CV-3 needle.

In this study, we used an anatomical model with an areolar diameter of 3 cm to be sutured to a 6-cm external diameter, thus remaining within the Spear et al. indications of an acceptable ratio [18]. The aim of the study was to demonstrate the true ability of the "interlocking" method to reduce the common complication of periareolar surgery simply by balancing the existing contrast between NAC centripetal force and outer breast tegument centrifugal force. Although the concept can be intuitively grasped to some degree, there is a paucity of information in the current literature on this topic. To our knowledge this article is the first to report on the physical investigation of tension on wound edges generated by three different suture techniques frequently used in periareolar closure.

The *traditional suture* (with single, radially placed, interrupted stitches) and the *round-block suture* produce a great stress on the suture and thus on the skin. In Fig. 9, $F1$ is the centrifugal force (distributed on the external circumference) directed toward the outside generated by the breast teguments, while $F2$ is the centripetal force (spread on the areolar circumference) generated by the NAC's inner contraction. It is obvious that when using the traditional suture, radial stitches oppose both forces with the traction force $T2 = F1 + F2$. On the other hand, the round-block suture system acts by opposing the $F1$ force through the circuitous stitches which produce a traction $T1 = F1 \times r$, where r is the radius of the external circumference. In this case, $F2$ is nil. With the simplified hypothesis of linear elastic skin behavior, the traction on both types of suture increases as the skin strain increases. Therefore, it is evident that if the two suture systems are combined into interlocking suture (instead of using one of them), the stresses are spread out in the two systems and both of them have to endure a reduced traction. Thus, because of its unique design, the interlocking suture has a final force, resulting from two opposing forces, that is always less than the single $F1$ centrifugal force or the single $F2$ centripetal force.

In clinical practice, the interlocking suture rigidly locks an internal system (the NAC), which tends to contract, to an outer system (breast teguments), which tends to move externally. Hammond’s technique is thus able to contrast an expanding external system by fixing it to an inner unit that is prone to collapse. The above-described physical analysis performed by the FEM software serves to confirm and clarify the principle of the interlocking suture as a method that exploits antagonist forces to an advantage. It is also interesting to note that these data suggest that the true effectiveness of the interlocking suture derives from its original pinwheel pattern design. It is thus likely that the nature of the suture material plays a limited role, although the use of nonabsorbable suture is advocated by many surgeons [2, 3, 11, 18].

As suggested by Hammond et al. [11], we have used CV-3 Gore-Tex suture for the interlocking suture until it became unavailable. The interlocking suture is now performed with Prolene 3-0 KS (Ethicon, Somerville, NJ, USA) on a straight cutting needle. The ease of slide and the cinching effect of the two suture materials are similar, except that the resulting final knot has to be carefully buried under the skin because Prolene is somewhat stiff.

Potential drawbacks of the interlocking suture are those associated with a nonabsorbable suture: thread palpability and/or extrusion. So far, some degree of palpability has been a rather frequent finding, although in general is has not caused concern to any of our patients. Extrusion has occurred in one patient, necessitating removal of the suture with subsequent areolar spreading (Fig. 10). Since this episode, we have adopted the practice of both dipping the knot into povidone-iodine and carefully burying it under adequate soft tissue, held in position with a single overlying small caliber resorbable suture.

A final problem can be the occasional long-term persistence of periareolar wrinkles, which may occur when the discrepancy between the inner and outer circumferences is excessive. To avoid this, one should try to limit the size of the outer diameter to no more than three times that of the inner diameter, as suggested by Spear et al. [18].

Fig. 10 The interlocking nonabsorbable suture extrusion

Fig. 11 The interlocking suture at 1 year postoperatively (*frontal view*)

Fig. 12 The interlocking suture in the same patient 1 year postoperatively (*lateral view*)

Conclusions

The long-lasting results of the interlocking suture are due to its unique design, which effectively decreases skin tension between the areola edge and the breast tegument edges in periareolar surgery (Figs. 11, 12). This modified purse-string suture allows the surgeon ideal control over tension distribution at the suture edges compared with traditional interrupted stitches and round-block sutures. Thus, the common complications of periareolar surgery are minimized and patient satisfaction is enhanced. So far, we, as many others, have enthusiastically adopted Hammond's "interlocking suture" in a wide spectrum of breast procedures due to the outstanding clinical results and to some degree of intuition in understanding its merit. It is now our hope that a physical model will scientifically elucidate its advantageous dynamics.

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Conflict of interest None.

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