Percutaneous Aponeurotomy and Lipofilling: A Regenerative Alternative to Flap Reconstruction?

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Background: The application of a new approach is presented, percutaneous aponeurotomy and lipofilling, which is a minimally invasive, incisionless alternative to traditional flap reconstructions.

Methods: The restrictive subdermal cicatrix and/or endogenous aponeurosis is punctured, producing staggered nicks. Expansion of the restriction reconstructs the defect and creates a vascularized scaffold with micro-openings that are seeded with lipografts. Wide subcutaneous cuts that lead to macrocavities and subsequent graft failure are avoided. Postoperatively, a splint to hold open the neomatrix/graft construct in its expansive state is applied until the grafts mature. Thirty-one patients underwent one to three operations (average, two) for defects that normally require flap tissue transfer: wounds where primary closure was not possible ($n = 9$), contour defects of the trunk and breast requiring large-volume fat grafts ($n = 8$), burn contractures ($n = 5$), radiation scars ($n = 6$), and congenital constriction bands ($n = 3$).

Results: The regenerated tissue was similar in texture and consistency to the surrounding tissues. Wider meshed areas had greater tissue gain (range, 20 to 30 percent). There were no significant wound-healing issues, scars, or donor-site morbidities. Advancement tension was relieved without flap undermining or decreased perfusion.

Conclusions: Realizing that, whether scar or endogenous fascia, the subdermal aponeurosis limits tissue stretch and/or its three-dimensional expansion, a minimally invasive procedure that expands this cicatrix into a matrix ideally suited for fat micrografts was developed. Grafting this scaffold applies tissue-engineering principles to generate the needed tissue and represents a regenerative alternative to reconstructive flap surgery. (*Plast. Reconstr. Surg.* 132: 1280, 2013.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, V.

In this report, a new concept that harnesses the regenerative potential of fat grafting[1] as an alternative to flap transfer is explored. There has been a resurgence of interest in fat grafting for volume replacement.[2–10] However, fat grafting is commonly deemed unreliable because of variable resorption; this may be caused by fat deposition in large pools or spaces in the tissue where it is unable to survive acutely by diffusion until neovascularization provides support.[1,2] To overcome this limitation, surgeons have focused mainly on different aspects of the graft itself: harvesting, processing, and enrichment.[11–13] However, successful grafting is also dependent on maximization of the recipient site's capacity to accept and support the graft.

Our experience with fat grafting percutaneously released Dupuytren contractures has shown that a tight cord can be transformed into a fat graft recipient scaffold.[14] The most severe contractures can also be released without flaps. The procedure requires nicking of the cord and the palmar aponeurosis, which can expand in a fashion similar to meshed skin grafts. With the deeper restriction released, the

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overlying palmar skin can freely stretch to obviate the need for flaps. This led to the realization that other contractures and tissue deficiencies might be treated without resorting to flaps if the deeper tissues that restrict advancement are mesh-expanded and the tiny gaps generated are fat-grafted.

In a two-dimensional defect, the limitation to tissue advancement and primary closure is the underlying scar or the subcutaneous fascia, collectively called the subcutaneous aponeurosis. Mesh expansion of the restrictive fibers within the aponeurosis, using percutaneous, staggered nicks in the plane of aponeurosis, increases the surface area, allowing further tissue advancement. This percutaneous aponeurotomy creates small pockets or gaps, interspersed with thin connective bands of the original scar/fascia. The gaps in the resulting matrix are ideally suited for grafting fat. Percutaneous mesh expansion should be contrasted with fasciotomies and relaxing incisions, which generate large gaps where the grafts may collect in large deposits and die (Fig. 1).[14,15]

To correct volume deficits, the restriction is three-dimensional, and increases in surface area are not sufficient to effect an optimal space-filling expansion. For proper three-dimensional release, the nicks must be staggered in multiple planes in multiple directions, wherever restrictive fibers prevent expansion. This technique is named "Rigottomy" after its originator.[16,17] Its application leads to an expansion of the restrictive block of scar tissue to create a larger three-dimensional recipient scaffold for fat grafting. The loosened grafted scar becomes softer and closer to normal tissue. Repeating the process a few months later leads to substantial tissue volume gain and scar reduction. The Rigottomy is useful when grafting fat into scarred tissue to correct a volume deficiency. It transforms a restrictive cicatrix into a regenerative matrix. Our clinical experience with grafting the scarred breast and the Dupuytren hand led us to refine this procedure, the percutaneous aponeurotomy and lipofilling reconstruction, which offers a potentially scarless alternative to flaps.

PERCUTANEOUS APONEUROTOMY AND LIPOFILLING PRINCIPLE AND TECHNIQUE

The procedure begins with tumescent syringe liposuction, using a 2.7-mm, 12-hole cannula (Marina Medical, Sunrise, Fla.), from wherever the patient has excess fat. The aspirated fat is allowed to sediment for a few minutes, or if centrifuged, the *g*-force is much less than that described by Coleman,[3,4] typically approximately 15 to 20 *g*. The dilute lipoaspirate slurry is injected meticulously into the recipient scaffold, using a fine cannula and a small syringe. The most even distribution of graft is achieved by injecting through multiple needle holes all around the defect, and through each entry site, performing multiple radial passes in multiple planes, never injecting more than a few microliters at a time. The injection continues until the recipient tissue become tight and blanches from the epinephrine still present in the graft solution. This technique is termed lipotumescence. At this stage, the interstitial fluid pressure is above physiologic range because the added volume from the graft swells the site beyond what the compliance of the scarred tissue would allow.[18] Increased interstitial fluid pressure aids the next step by putting the restrictive tissue fibers under tension, making them susceptible to nicking by a sharp needle tip.

An 18-gauge hypodermic needle is used for the Rigottomies,[16,17] or for more practical and effective release, a brush-like device is used to inflict a predetermined pattern of staggered nicks that transforms the scar/fascia into the neomatrix scaffold. Tension is the key to the differential cutting ability of the needle tips. For the nicks to be more directional, a skin hook is often used to exert additional tension in the third dimension of expansion (Fig. 2). The needles are inserted multiple times in an ordered and staggered series of punctures, typically at a density of four or five nicks per square centimeter. At each puncture, a 45- to 60-degree oscillatory motion of the needlepoint generates short slits in the fascia, which results in loosening and expansion. Each time a nick is made, it is readily felt by the surgeon retracting as a tiny release advancement, and can often be heard as a soft click, provided that there is sufficient tension on the scar/fascia. These nicks open the tissue, creating a honeycomb pattern into which the graft moves, expanding the space and reducing interstitial fluid pressure to physiologic levels. To maximize expansion and volume of graft placement within a given scar/fascia bed, occasionally the best option is to alternate between graft injection and aponeurotomy/nick creation.

The deep tissue release is performed through many 2-mm puncture wounds that regenerate individually, rarely resulting in new scar formation. Open scoring of the restrictive fascia or incisions that cause a broader relaxation must be avoided. These create cavities where fat may

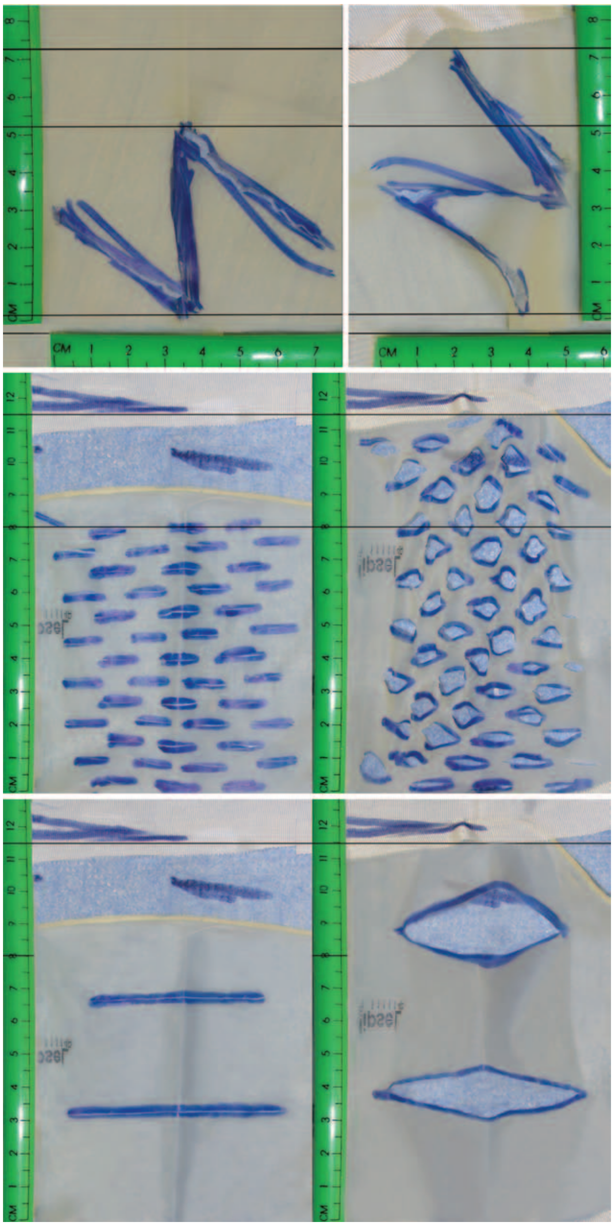

Fig. 1. Flap versus percutaneous aponeurotomy and lipofilling versus relaxing incisions. Z-plasty flap transposition (*above*) is compared with the percutaneous aponeurotomy and lipofilling procedure (*center*) and with the fasciotomy/relaxing incisions (*below*) simulated on a surgical glove, with incisions outlined with a blue marker. In the classic Z-plasty flap transposition, a 5-cm vertical tightness (*above*, *left*) is expanded to 7 cm at the expense of a horizontal tightness (*above*, *right*). "Borrowing from Peter to pay Paul" resulted in no overall tissue gain. In contrast, scars were left behind and flap necrosis and wound healing issues were risked. The percutaneous aponeurotomy and lipofilling procedure (*center*, *left*) uses a series of small percutaneous nicks to mesh the deeper tissues that restrict advancement. Mesh expansion (*center*, *right*) of the restrictive subcutaneous tissue enlarges the flap from 8 to 11 cm while leaving behind a network of small gaps where the fat grafts can survive. A net 3-cm tissue gain (30 percent) was generated without new scars.

Fig. 2. Placement of an 18-gauge needle mounted onto a needle holder is shown (*right*), with an oscillatory movement to make the many small nicks/cuts (Rigottomies) in the scar/fascia. The two Gillies hooks place the scar/fascia under tension to allow the needle tip to preferentially release the fibers that restrict expansion.

collect and die from insufficient proximity to a recipient capillary network. For this reason, only small gaps are created. For two-dimensional defects, the process is akin to skin graft mesh expansion. For three-dimensional defects, a solid block of scar tissue is mesh-expanded in the third dimension, creating a honeycomb structure with micro-openings into which grafts can migrate and survive. The most important component of a successful percutaneous aponeurotomy and lipofilling is the transformation of a restrictive cicatrix into a regenerative matrix that expands a tight scar or constriction into a loose, three-dimensional recipient scaffold that is receptive to fat grafts. Performed solely through needle pricks, the procedure is usually scarless.

The key to success is knowing when to stop the release and the grafting. Too many cuts or Rigottomies in the tissue leads to structural loss of the fibrous network, the merging of adjacent small nicks/cuts into larger slits, and the formation of cavities where fat grafts may pool and fail. Whenever possible, preprocedural Brava (Brava, LLC, Miami, Fla.) expansion is included, which loosens restrictive fibers and increases capillary density,[19]

Fig. 1. (*Continued*) In the fasciotomies or relaxing incisions (*below*, *left*), instead of meshing the tissue with multiple tiny nicks, two large cuts are made. Advancement of the tissue is not as even and the cuts expand into large open spaces (*below*, *right*), where the fat grafts will pool with poor interface with the recipient, leading to fat necrosis, fibrosis, and likely loss of the expansion from scar contraction.

allowing more Rigottomies to be performed without significant vascular compromise.[20–26]

A gain of approximately 20 percent of the total meshed area can be accomplished at each stage. This two-dimensional increase translates to a larger three-dimensional volume expansion. An interval of at least 2 to 3 months is used between sessions to allow inflammation to subside and the grafts to mature. After each release and grafting procedure, the construct is splinted in outward extension. Although standard splints function well for two-dimensional defects, for three-dimensional volume correction, our current preferred splinting method is the Brava external negative-pressure device,[27] which is capable of exerting a gentle three-dimensional outward expansive force in the early postoperative period. The increased vascularity from Brava enhances graft survival.[19,23,24] Keeping the meshed fibrous construct in an open-expanded shape is akin to having many tiny growth chambers where spontaneous adipogenesis may occur.[28,29]

Clinical Experience

Thirty-one patients were treated for various body area defects: trunk (n = 3), breasts (n = 12), extremities (n = 13), face (n = 2), and scalp (n = 1). Percutaneous aponeurotomy and

Fig. 3. Palmar scar contracture before (*above*) and 1 year after (*below*) a single percutaneous aponeurotomy and lipofilling release. Note the severe blanching before the percutaneous aponeurotomy and lipofilling in the thumb/fifth finger line with the patient's effort to open the hand, which was eliminated, with excellent mobility after the procedure.

Fig. 4. Preoperative and postoperative abduction. A single-stage percutaneous aponeurotomy and lipofilling procedure was performed on a trunk burn patient (*left*), after which a 45-degree abduction gain was achieved (*right*). The restrictive subcutaneous scar was meshed from the abdomen to the antecubital fossa.

Fig. 5. (*Left*) Preprocedural view of postirradiation axillary contracture and threatened implant erosion; (*center*) periprocedural view showing mesh release of the contracture and immediate filling of the grafted fat into the expanded scaffold, including fat grafting in the thin space between the skin and the implant capsule; and (*right*) 1-month postprocedural view with nearly full arm elevation and improved breast contour and implant padding.

Fig. 6. Computed tomographic scan of the patient in case 4, showing severe scoliosis with a fixed contour defect on the right. A thin subcutaneous layer of tissue is evident in the defect, adherent to fascia, which is the target site for treatment.

lipofilling was used as an alternative to a flap for the following indications: wound defects that could not be closed primarily (n = 9), contour defects that required megavolume fat grafts (n = 8), burn contractures (n = 5), radiation scars (n = 6), and congenital constriction bands (n = 3). All patients had their defects regenerated with tissues similar in texture and consistency to the surrounding tissues without additional scars or donor-site morbidity. Because the maximal permitted tissue gain is 20 to 30 percent per percutaneous aponeurotomy and lipofilling session, most cases required two procedures (range, one to three) performed 2 months apart. There were no significant complications or wound healing issues. The tension of the scarred site was always relieved without flap undermining or noticeably decreased perfusion. The regenerated tissue had nearly normal texture and often with considerable preservation of sensation.

CASE REPORTS

The versatility of the technique is illustrated in several clinical cases shown below.

Case 1: Palmar Scar

A 21-year-old man sustained a short-range gunshot blast injury to the palm of the hand that was débrided and allowed to heal by secondary intention. He presented with a stellate contracted midpalmar scar and tendon adhesions that restricted digital extension. He had already failed treatment with splinting alone. The deficiency was treated with a percutaneous aponeurotomy and lipofilling similar to a Dupuytren contracture release.[30] With the contracture under tension, the restrictive scar was mesh-expanded through multiple punctures and the resultant loosened structure was grafted with 30 ml of dilute lipoaspirate, diffusely injected into the palm. The hand was splinted in extension for 1 week and then with night splints for 3 months (Fig. 3).

Case 2: Burn Scar Contracture

A 42-year-old man with second- and third-degree burns to the trunk, axilla, and left upper extremity presented 1 year after skin grafting and wound healing with a severe axillary contracture. He failed scar management therapy and extension splints. After tumescent lipofilling of the burn scar with 150 ml of dilute lipoaspirate, and with the contracture under tension, a percutaneous aponeurotomy of the restrictive scar was performed through hundreds of skin nicks over a wide area. To preserve the integrity of the scar and its ability to support fat grafts, the concentration of nicks in the axilla was limited. Tissue length needed for arm elevation was gained by performing the percutaneous aponeurotomy and lipofilling over a wide surface area, extending from

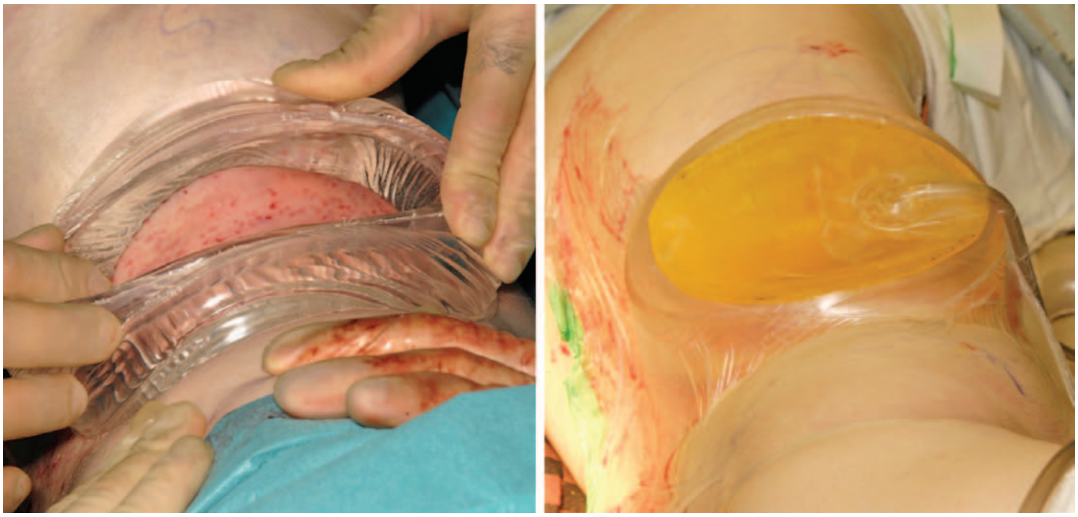

Fig. 7. Modification of Brava for three-dimensional splinting in the patient in case 4.

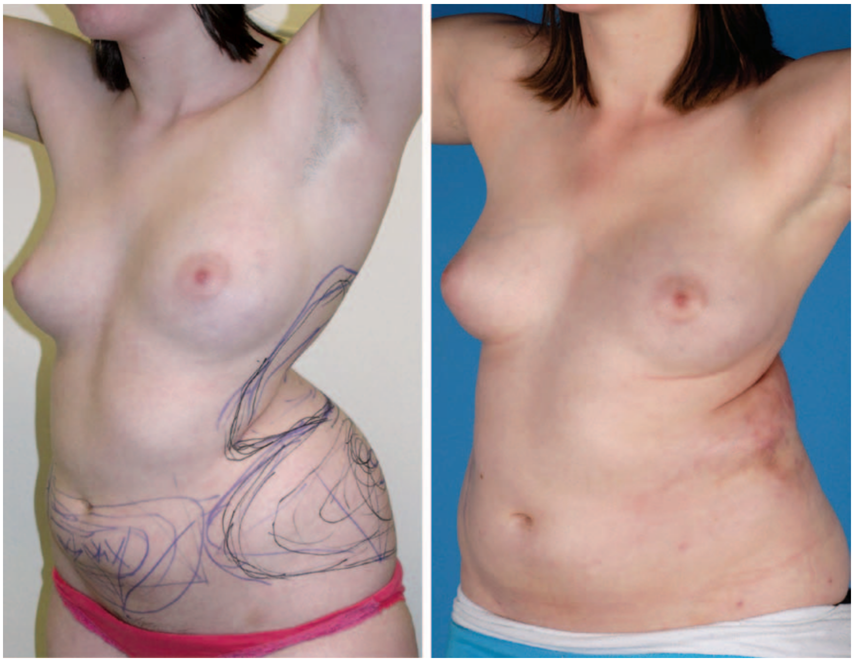

Fig. 8. Views of the left flank obtained preoperatively (*left*) and 5 months postoperatively (*right*). To improve her contour, more than 300 ml of fat survived, and her trunk circumference at the depth of the cleft increased from 65 cm to 78 cm.

the antecubital fossa to the abdomen. The patient had a shoulder extension splint applied (which he poorly tolerated) and underwent physiotherapy for 2 months after percutaneous aponeurotomy and lipofilling. Three months after the first-stage percutaneous aponeurotomy and lipofilling, a 45-degree abduction gain was achieved and the scar was significantly softened (Fig. 4).

Case 3: Irradiated Axillary Scar Contracture

A 65-year-old woman 23 years following mastectomy and irradiation to the axilla presented with progressive inability to raise her left arm and an indurated contracture of the pectoralis and latissimus muscles (along with threatened erosion of the breast implant). There was no available local flap that could be used to perform a classic release of the contracture. The underlying scar-irradiated tissues were tumesced with 100 ml of dilute lipoaspirate. Then, with the contracture under tension from lipotumescence and arm elevation, hundreds of Rigottomy nicks/cuts were made into the pectoralis and the latissimus dorsi muscle. This subcutaneous tissue release was performed in multiple staggered planes and on multiple levels, which allowed nearly full arm elevation to be achieved during the procedure (Fig. 5). This gain in motion was maintained postprocedurally, and as the fat grafts matured, the tissue gradually improved in consistency and texture. To pad the breast implant, the plane between the capsule and skin was also fat grafted during the same setting.

Case 4: Flank Defect

An 18-year-old female patient presented with a large, fixed, three-dimensional contour defect of the left flank 5 years after a thoracolumbotomy and a dorsal thoracolumbar spondylodesis for an extreme progressive congenital idiopathic scoliosis. Percutaneous aponeurotomy and lipofilling simultaneously addressed three problems: a cutaneous surface topography deficiency of the trunk circumference at the depth of the cleft, a soft-tissue volume deficiency, and scar adhesion bands tethering the skin deep in the cleft (Fig. 6).

After harvesting fat from the hip, buttock, and abdominal area, and subsequent low-gravity centrifugation, the defect was tightly lipotumesced with 250 ml of lipoaspirate through multiple needle puncture entry sites. The graft was delivered in a sprinkler-like fashion from each site through numerous passes of the cannula at multiple angles and multiple levels, delivering less than 2 ml per pass. The Rigottomy, consisting of percutaneous needle releases of the constricted area, relieved the lipotumescent tension and opened the defect. Achieving the necessary gain in cutaneous circumference at the level of the cleft required meshing the subcutaneous tissues past the midline both anteriorly and posteriorly. The cycle of lipotumescent grafting and meshing was repeated until 375 ml of fat was diffusely grafted in the matrix. Because the correction required the application of a three-dimensional splint postoperatively, the silicone gel rim of Brava was used in combination with a custom-made hard-top and a transparent polyurethane membrane (OpSite; Smith & Nephew, London, United Kingdom) to preserve a low-vacuum seal (Fig. 7).

Superficial blisters under the gel rim led to short interruptions of the 2-month postgrafting vacuum splint treatment. With conservative treatment, all wounds healed without scars. There were no clinical signs of infection, fat necrosis, or fat resorption, and the resulting flank correction remained stable throughout the first 5 postoperative months (Fig. 8).

Case 5: Breast Agenesis

A 15-year-old girl with left breast agenesis from tumor resection during infancy presented with a rudimentary nipple-areola complex tethered to the chest, minimal breast volume restricted to the upper outer quadrant, and a contour defect of the chest wall. The Brava device was applied for 4 weeks before grafting. Her abnormal chest contour precluded her from achieving a normal vacuum seal and regular Brava use. She had to apply the Brava domes while lying down. With a hand pump, she brought the vacuum pressure to 80

Fig. 9. Progression of Brava expansion and serial percutaneous aponeurotomy and lipofilling sessions that generated the lower pole of the right breast. (*Above*, *left*) Original defect. (*Above*, *second from left*) Pre–percutaneous aponeurotomy and lipofilling Brava expansion increased breast volume and separated the nipple-areola complex from the chest. (*Above*, *center*) Completion of the first percutaneous aponeurotomy and lipofilling; note the tissue gain and the multiple needle holes necessary for the percutaneous aponeurotomy. (*Above*, *second from right*) Extent of additional Brava expansion 8 weeks after the first percutaneous aponeurotomy and lipofilling, at the time of the second percutaneous aponeurotomy and lipofilling. (*Above*, *right*) Normal application of Brava. (*Below*, *left*) Early outcome after second percutaneous aponeurotomy and lipofilling. (*Below*, *second from left*) Further volume and nipple-to-intramammary length gained after 8 additional weeks of Brava expansion at the time of the third percutaneous aponeurotomy and lipofilling. (*Below*, *center*) Immediately after the third percutaneous aponeurotomy and lipofilling. Note again the multiple needle punctures required to three-dimensionally expand the restriction into a receptive scaffold for fat grafts. (*Below*, *second from right*) Early result. (*Below*, *right*) Final outcome at 18 months showing regeneration of the lower pole of the breast and sustained volume and shape.

mmHg for 30 minutes, followed by 30 to 60 seconds of deflation, repeating the cycle four or five times in a row, twice daily. This loosened the tissues, induced a hyperemia indicative of increased vascularity, and separated the nipple-areola complex from the chest wall by 2 to 3 cm (Fig. 9, *above*, *left* and *second from left*). The first percutaneous aponeurotomy and lipofilling procedure increased the separation of the nipple-areola complex from the inframammary fold by 1 to 2 cm, generated tissue in the lower pole, and partially corrected the volume and contour defect (Fig. 9, *above*, *center*). Thirty-six hours after the procedure, she resumed Brava wear to maintain the release and support graft survival. Over the next 8 weeks, Brava expansion augmented tissue matrix, breast volume, and cutaneous envelope (Fig. 9, *above*, *second from right*). The improved chest wall contour allowed her to transition to normal Brava wear at 20-mmHg vacuum (Fig. 9, *above*, *right*).

During the second percutaneous aponeurotomy and lipofilling, additional volume and lower pole tissue were gained (Fig. 9, *below*, *left* and *second from left*), after which she resumed Brava wear for 8 weeks in preparation for a third and final grafting session (Fig. 9, *below*, *center* and *second from right*). At 18-month follow-up, she has a breast that is soft and sensate and appears like the normal contralateral breast (Fig. 10). This regenerated a breast mound without any scar, incision, flap transfer, or insertion of alloplastic implants.

DISCUSSION

Percutaneous aponeurotomy and lipofilling is a new concept that adheres to basic plastic surgery principles: release of the contracture, meticulous grafting of the created defect, and splinting of the graft in extension.[31–33] However, instead of treating the large wound defect by classic incision-release, contracture release is achieved through a series of percutaneous nicks and staggered slits that mesh expand the scar/fascia and transform it

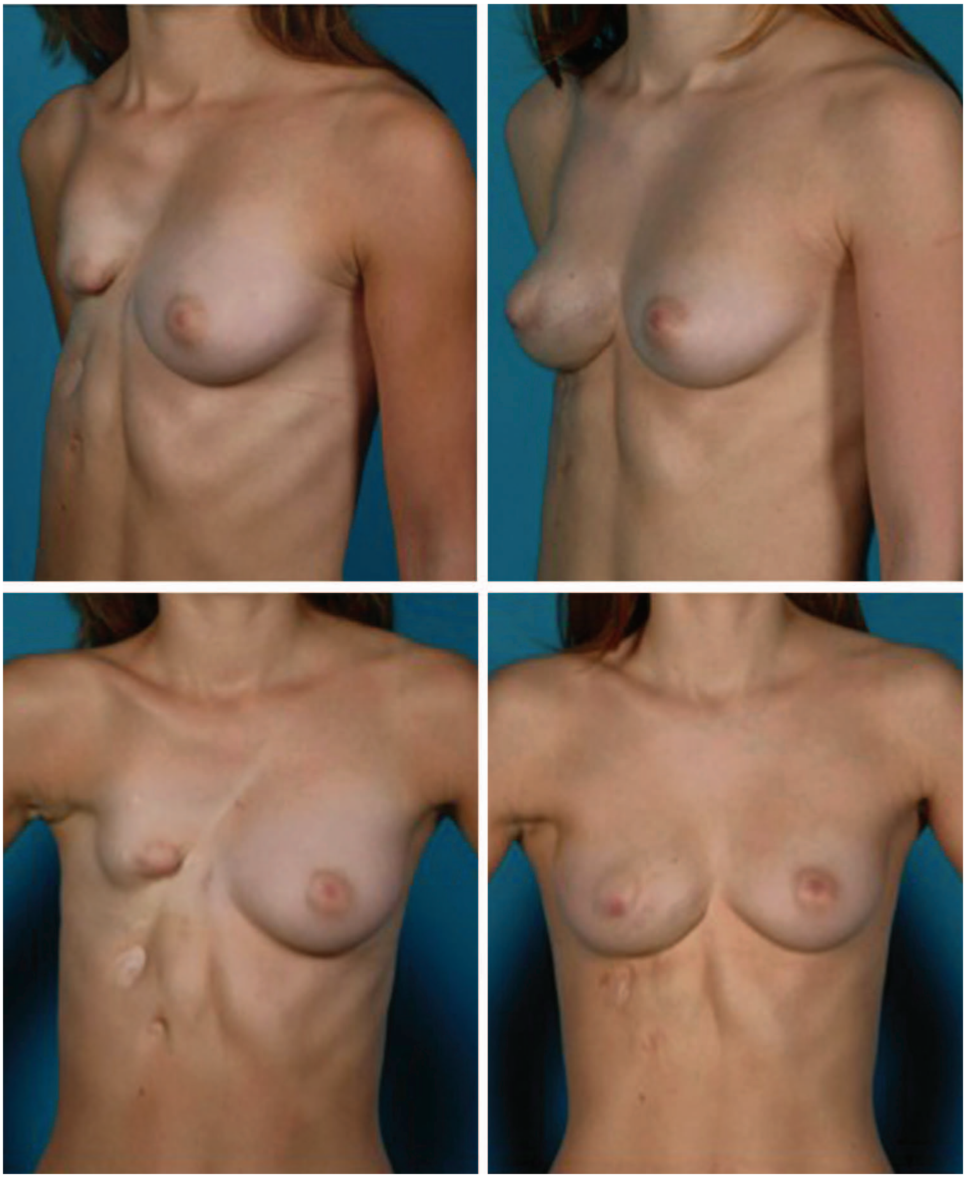

Fig. 10. Oblique (*above*) and anteroposterior (*below*) views of the original defect (*left*) and views at 18-month follow-up (*right*) of the patient in case 5 after three percutaneous aponeurotomy and lipofilling sessions and Brava expansion over a 20-week treatment span. The procedures corrected the chest wall deformity and generated a symmetrical C-cup breast with symmetry of the nipple-areola complex without using an implant, flap, or incision.

into a recipient scaffold with small holes or gaps that are receptive to filling with grafted fat. For the two-dimensional defects, to maintain the gain in surface area, a simple extension splint can be used. However, to maintain the volume gain for the three-dimensional defects, more elaborate splinting is required. Whenever applicable, a negative-pressure device, such as Brava, can achieve this efficiently. In addition, preoperative external expansion of three-dimensional defects with Brava increases not only the size of the recipient site but also capillary density,[19] thus preserving perfusion of the meshed construct, allowing for more extensive meshing.

When a meshed skin graft is applied, the advancing epithelial ridge that fills the gaps is considered regeneration. The converse is true for the percutaneous aponeurotomy and lipofilling, where it is the defect and its surroundings that are meshed instead, and it is the micrografted fat that fills up the gaps to regenerate "like" tissue.

Gillies and Millard, over 50 years ago, recognized that plastic surgery was the art of "replacing like with like" and "borrowing from Peter to pay Paul (only if Peter can afford it)."[34] Whereas conventional reconstruction requires the surgical transfer of tissue flaps, percutaneous aponeurotomy and lipofilling facilitates tissue regeneration in situ, inducing the growth of the "like" tissue needed to correct the defect, by turning a restrictive cicatrix into a regenerative matrix. This is achieved by loosening the scar/fascia that restricts advancement with multiple nicks/cuts, turning it into a mesh pattern that expands into a honeycomb-like matrix suited for fat graft survival. Thus, the need to borrow from Peter can be bypassed and, instead, Paul can be given the ability to regenerate and correct the defect. The procedure rarely creates skin scars and leaves no donor-site defect.

These cases are a selection of many patients that were treated with percutaneous aponeurotomy and lipofilling when the conventional alternative required a flap reconstruction. They show that a broad range of reconstructive problems can be addressed adequately with percutaneous aponeurotomy and lipofilling, often performed under regional anesthesia on an outpatient basis. Although this approach of mesh expansion with postoperative splinting (including negative-pressure therapy) allows for larger volumes of lipofilling, the expansion tissue gained is limited to 20 to 30 percent of the meshed area. One has to be cautious to not overmesh lest the nicks and cuts merge to create large cavities where the injected fat graft will die. Similarly, the amount of lipofilling should be moderated, to prevent overinjection and resulting excess interstitial pressure. Optimal correction of extensive defects often requires more than one percutaneous aponeurotomy and lipofilling session.

CONCLUSIONS

In summary, percutaneous aponeurotomy and lipofilling is a novel procedure in which, with little chance of leaving a visible scar, an array of tiny percutaneous needle sticks create a mesh pattern in deeper tissues under tension and expand them to transform the restrictive cicatrix into a regenerative matrix scaffold suitable for fat grafting. Whether or not it is combined with preoperative and postoperative external expansion, the percutaneous aponeurotomy and lipofilling procedure is an effective, simple, permanent, natural, autologous, usually nonscarring, and patient-friendly regenerative alternative to flap reconstructions.

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