



Treatment of retracted, postsurgical scars and reduction of locoregional edema using a combined three-dimensional approach of liposuction lipofilling, dissecting cannulas, and suspension sutures

P A Will^{1,2,3,4} · J E Berner^{5,6} · Christoph Hirche⁷ · Donna Klevansky^{2,3} · Benjamin Ziegler⁷ · Ulrich Kneser^{2,3} · Emre Gazyakan^{2,3} · Pedro Vidal⁴

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Abstract

Background Post-surgical abdominal and inguinal scars are a frequent challenge in plastic surgery. There are limited non-invasive alternatives to address depressed and retracted scars. The associated retraction and fibrosis might cause lymphatic dysfunction with subsequent regional edema. The authors describe a combined surgical approach of liposuction, the use of dissecting cannulas, lipofilling, and Scarpa's fascia suspension sutures in a prospective case series.

Methods The proposed procedure was performed in 22 consecutive patients between November 2012 and May 2015. Complications were assessed according to the Clavien-Dindo scale. Postoperative psychosocial, edema reduction, and patient satisfaction outcomes were gathered and analyzed based on blinded questionnaires (Rosenberg Self-Esteem scale and a Cosmetic Procedures Screening Questionnaire (COPS)).

Results At 6 months, no major complications and 27.2% minor complications (Clavien-Dindo 1) were recorded. Four patients had superficial infections that settled with oral antibiotics and two patients developed a seroma. A significant improvement in self-esteem, aesthetic satisfaction, and social competence was found postoperatively in all patients. The novel technique reduced regional edema and scar-related self-consciousness. Patient satisfaction was rated very high, and all patients would recommend this surgery for abdominal or inguinal retracted scars.

Conclusions This study shows that the proposed technique is a safe minimally invasive alternative for the treatment of abdominal and inguinal retracted scars. The relatively high rate of minor complications is mainly due to the strict definition of the scale used. The results showed an improvement of local edema and high patient satisfaction.

Level of evidence: Level IV, therapeutic

keywords Cicatrix · Surgery · Plastic · Lipectomy · Abdominoplasty · Mesenchymal stem cell transplantation · Aesthetics

✉ P A Will
pwillmarks@yahoo.de

✉ Pedro Vidal
info@cirugiaplastica.cl

¹ Department of Plastic and Hand Surgery, Faculty of Medicine and University Hospital Carl Gustav Carus, TU Dresden, Dresden, Germany

² Clinic for Hand, Plastic and Reconstructive Surgery, Microsurgery and Severe Burn Injury Centre, BG Unfallklinik Ludwigshafen, Ludwigshafen, Germany

³ Clinic for Plastic Surgery, Ruprecht-Karls-University Heidelberg, Ludwigshafen, Germany

⁴ Department of Aesthetic and Reconstructive Plastic Surgery, Clinica La Parva, Hospital Clinico FACH, Chilean Air Force Teaching Hospital, Santiago de Chile, Chile

⁵ Department of Plastic Surgery, Royal Victoria Infirmary, The Newcastle Upon Tyne Hospitals NHS Foundation Trust, Newcastle, UK

⁶ Kellogg College, University of Oxford, Oxford, UK

⁷ Department of Plastic, Hand and Reconstructive Microsurgery, Hand Trauma and Replantation Centre, BG Unfallklinik Frankfurt Am Main, Academic Teaching Hospital of the Goethe University Frankfurt, Frankfurt am Main, Germany

Introduction

Retracted postoperative scars on the abdomen and inguinal region are a common reason for consulting a plastic surgeon, usually after undergoing a cesarean section or appendectomy. Scar formation is a multifactorial process, which is determined not only by the scar location and the mechanism of origin, but also by endogenous or exogenous factors [1].

The most common pathological scar formations correspond to keloids and hypertrophic scars, which can develop in the first 2 months after injuries to the deep dermis and subcutaneous tissue. Chronic inflammation of the reticular dermis is not infrequently followed by pain, itching, or restricted movement [2]. All these result in a loss of quality of life, mental health, and earning capacity for an estimated 100 million individuals per year in industrialized countries alone [2].

Hypertrophic and keloids scars represent a considerable challenge for the health care system, with recurrence rates of 45 to 100% [3]. In recent years, intensive research has been undertaken looking into conservative and adjuvant therapies for scar management [2, 3]. Exemplary meta-analyses have already demonstrated the prophylactic advantage of compression garments at a low compression level (15–25 mmHg), the use of silicone plasters, liquid silicone, and scar massage [4–6]. New approaches, such as the effect of botulinum toxin A injections and intradermal cytostatic drugs (bleomycin and 5-fluorouracil), have also been demonstrated as advantageous with prospective, double-blind, randomized controlled trials [5, 7].

The regenerative effect of lipofilling and the containing of mesenchymal stem cells (MSCs) for scar treatment were first demonstrated in detail by Rigotti et al. in radiodermatitis [8]. Subsequently, in 2008, Klinger et al. demonstrated the first successes of treating hypertrophic scars with adipogenic MSCs (ADSCs) [9]. Since then, numerous clinical studies in regenerative medicine followed on lipofilling and ADSCs in relation to the treatment of scars and wound healing disorders [5].

In contrast to hypertrophic scars, there are no described conservative measures or evidence of a therapeutic effect of MSCs for retracted scars [10]. Surgical resection of the retracted scar alone is rarely the optimal strategy. Particularly in the case of larger scars, serial excisions or tissue expansion would be necessary.

In retracted abdominal scars, the deformity is determined by adhesions to the deeper soft tissue and abdominal wall fascia, and furrows form parallel to the scar, which are visually enhanced by the accumulation of fatty tissue around the retracted scar [11]. The accompanying, sometimes extensive scarring of the subcutaneous tissue,

can lead to further restrictions in locoregional lymphatic drainage [12]. Taken together, these scars can then pose a significant functional and aesthetic problem for the patient, requiring three-dimensional analysis and multimodal therapy.

The present study aimed to develop and evaluate a surgical strategy to improve retracted and lymphatic congestion scars on the abdomen and groin in a single surgical procedure without excisions and with a combination of liposuction, subcutaneous scar release with Toledo dissection cannulas, lipofilling, and suspension sutures.

Patients, material, and methods

Patients

After receiving ethical approval (No. 3416) and signed consents for the surgery and the study, 22 patients were included in the monocentric prospective study described here between November 2012 and May 2015. All patients were treated in a private clinic with the combined concept of three-dimensional scar contracture by liposuction, scar release with sharp dissection cannulas, lipofilling, and suspension sutures (Figs. 1 and 2). Patients with abdominal and inguinal retracted post-surgical scars and local abdominal wall edema were included according to the pre-defined inclusion criteria (Tables 1 and 2). In addition to the standard surgical informed consent, all patients agreed to participate in the study and to the storage and use of data.

Method

Surgical technique

A standardized pre-operative photograph for all patients at six image angles (0, 360, and left and right at 45 and 90 degrees). All patients underwent preoperative sonography of the abdomen to rule out herniation of the scar area.

Marking of the disturbing scar areas and the anamnestic edematous regions was done with the patients standing. The liposuction sites on the abdomen and flanks were also marked. All operations were performed under general anesthesia in the supine position. To ensure standardization, all operations were performed by the same three surgeons (PAW, JEB, and PV). Intraoperative prophylactic antibiotics were not used. The concept of three-dimensional scar correction in combination with the therapy of local edema is based on four foundations or surgical steps (Figs. 1 and 2).

Step 1: liposuction scar environment In an area of the groin or abdomen easily concealed by the underwear and located 10 to 15 cm from the scar, a 3-mm incision was made using

Fig. 1 Overview of the surgical technique. **A** Exemplary illustration of the technique to correct a retracted scar of the abdomen or inguinal area. **B** Liposuction with different cannulas in the underlying and surrounding fat is shown as the first foundation of the three-dimensional technique. As a second foundation (**C**), deep strands are loosened with the Toledo dissection cannula to free the scar plate from adhesions and contracted collagen fibers. Lipofilling of washed and centrifuged fat and AMSCs follows as the third step of the technique. Here, a generous overcorrection under the scar is important (**D**). If all steps have been performed correctly, the previously retracted scar ideally exceeds the skin level of the surrounding area (**D**)

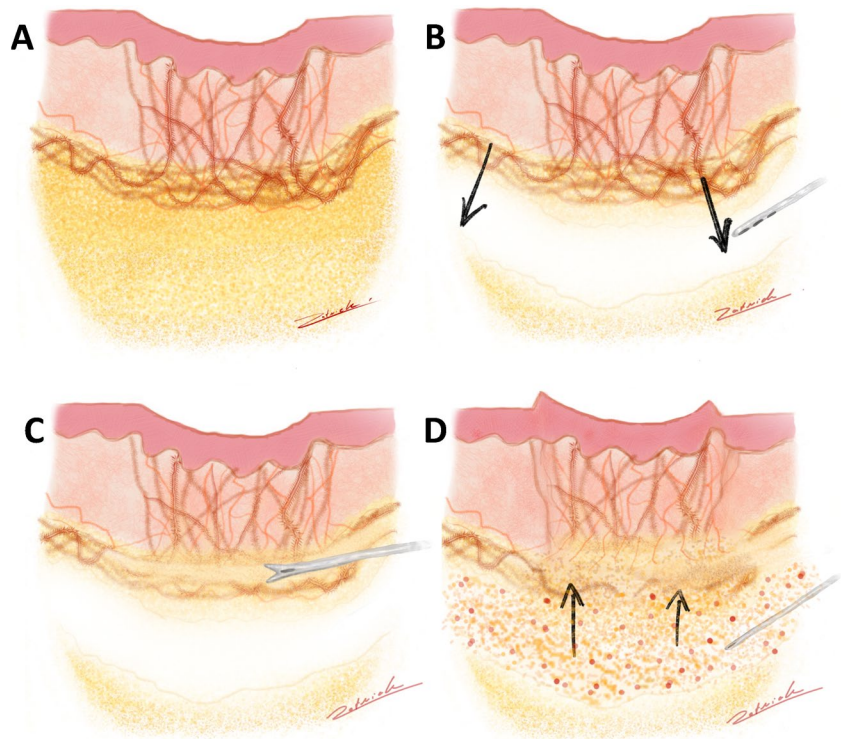


Fig. 2 Schematic illustration of the suture technique for suspension and fixation of the Scarpa fascia as the fourth foundation. The non-absorbable suture is used to stitch perpendicular to the skin in depth (**A**). The maximum length of the needle is used here. The piercing of the scar is done as deep as possible to grasp the Scarpa fascia or scarred strands of the previously loosened, retracted scar (**B**). These provide the counter support for the suspension. Then, knotting is done under slight tension so that the transplanted fat is fixed in depth from below like a corset and cannot migrate. The skin level can remain inverted during fixation (**C**). After loss of part of the fat and suture removal, the skin levels out again

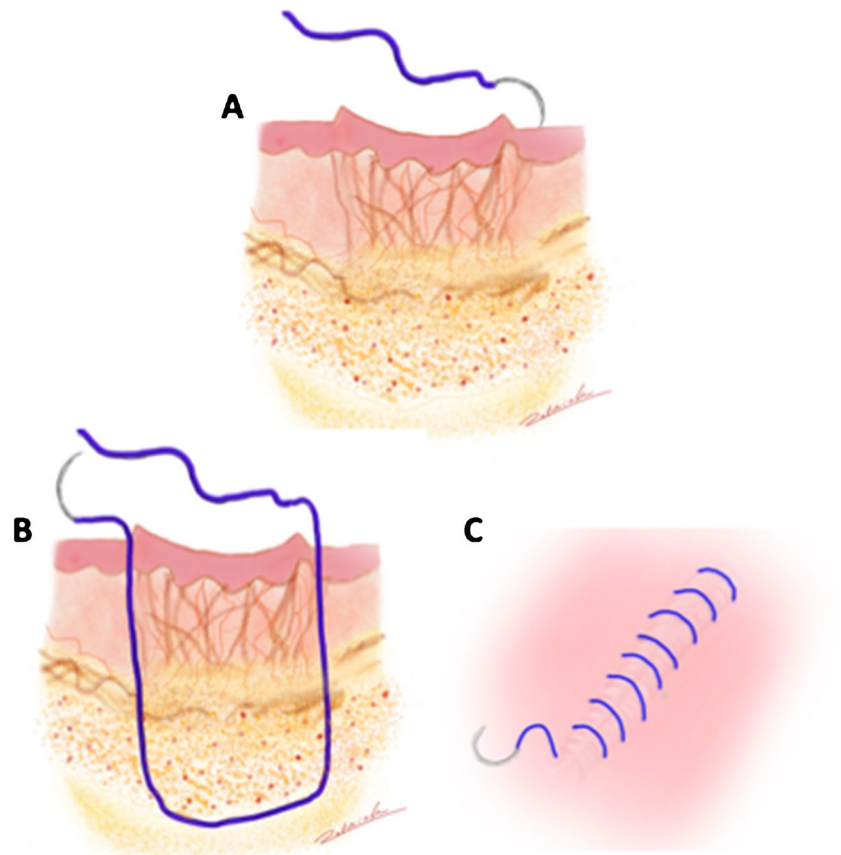


Table 1 Inclusion and exclusion criteria of the study

Inclusion criteria	Exclusion criteria
Patients older than 18 years and willing to sign an informed consent	Minors or Patients not able to give consent
Consulting patients for liposuction of the abdominal area	Mentally unstable patients or patients with suspected body dysmorphic disorder
Retracted and adherend postoperative scar in the inguinal area or the abdomen	Diagnosed lymphedema on the abdomen or extremity
Edema or clinical lymphatic clearance deficit on the region of the scar	Patients not fulfilling the inclusion criteria
	Patient loss during follow-up period
	Scar hernia

Table 2 Patient data and characteristics

Nr	Age	BMI pre- and postoperative	ASA classification	Etiology of the retracted scar	Timepoint of clinically evident edema	Additional surgery performed
1	19	26.3 25.7	ASA 1	Appendectomy	Perimenstrual	
2	20	23.8 21.2	ASA 1	Laparotomy inferior midline	Perimenstrual	
3	22	19.4 20.4	ASA 1	Appendectomy	Perimenstrual	Rhinoplasty
4	22	22.4 22.2	ASA 1	Appendectomy	Perimenstrual	Breast augmentation
5	24	25.3 24.8	ASA 2	Cesarean section	Perimenstrual	
6	27	19.8 20.2	ASA 1	Appendectomy	Perimenstrual	
7	28	22.6 23.2	ASA 1	Cesarean section	Perimenstrual	Rhinoplasty
8	28	32.3 30.6	ASA 2	Cesarean section	Perimenstrual	
9	30	23.7 21.4	ASA 1	Cesarean section	Perimenstrual	
10	31	21.3 20.8	ASA 1	Explorative laparoscopy	Perimenstrual	
11	32	22.6 21.5	ASA 2	Appendectomy	Perimenstrual	
12	33	27.8 27.6	ASA 1	Cesarean section	Pregnancy and perimenstrual	
13	35	23.7 22.6	ASA 2	Inguinal exploration	Pregnancy and perimenstrual	
14	35	24.6 25.3	ASA 2	Explorative laparoscopy	Perimenstrual	Breast augmentation
15	38	31.2 27.6	ASA 2	Laparotomy superior midline	Pregnancy and perimenstrual	
16	39	30.8 27.4	ASA 1	Appendectomy	Perimenstrual	
17	39	20.7 20.2	ASA 1	Cesarean section	Pregnancy and perimenstrual	
18	39	29.6 26.8	ASA 1	Cesarean section	Pregnancy and perimenstrual	
19	41	24.2 25.8	ASA 1	Appendectomy	Perimenstrual	Blepharoplasty
20	42	22.8 23	ASA 1	Laparotomy inferior midline	Pregnancy and perimenstrual	
21	44	26.7 24.4	ASA 2	Cesarean section	Perimenstrual and menopause	Rhinoplasty
22	45	27.3 27.6	ASA 2	Cesarean section	Perimenstrual, pregnancy and menopause	Mastopexy

a 15-blade scalpel down to the subcutis. This was done on at least two separate regions.

Since the aesthetic perception of a contracted and retracted scar must be considered in the context of the overall image of the abdomen, special attention was paid to the relation of the contracture to the surrounding soft tissues (Fig. 1A). Perilesional fat accumulation in the subcutaneous tissue visually enhances the retracted scar appearance. In addition to the aim of obtaining fat tissue for lipofilling, liposuction of the area surrounding the scar was performed to enable harmonious balancing of the contour of the abdomen.

Using a thin 1.5-mm 10-hole infiltration cannula (Richter, Sao Paulo, Brazil), a tumescent solution consisting of Ringer's lactate solution with adrenaline (dilution 1:1000 or 0.001 mg/ml) with > 3 ml infiltration solution per ml expected lipoaspirate was infiltrated evenly in a fan-shaped fashion into the subcutaneous tissue under the scar plate and into the perilesional abdominal and flank regions. The addition of bicarbonate or local anesthetic was omitted to avoid potential cytotoxicity to the harvested preadipocytes, adipocytes, and adipose-derived mesenchymal stem cells (ADSC) [13, 14]. After 10 min of exposure time for maximal

adrenaline-mediated vasoconstriction, the surrounding adipose tissue was removed with suction cannulas. For this purpose, cannulas of sizes 2, 2.5, 3, 3.5, and 4 mm with lengths of 15, 20, and 30 cm, and Sorensen Harvester, Mercedes, Double Mercedes, Kotzur, and Candy cane shapes (Richter, Sao Paulo, Brazil) were used, depending on the patient profile. The suction-assisted liposuction was regulated to 15 mmHg (15 torr).

The three-dimensional adjustment of fat excess deposited at the scar edges on the abdomen and flanks is particularly important to correct the retracted visual effect of the scar (Fig. 1B).

Step 2: releasing the scar with a V-shaped dissection cannula Without suction, to avoid further accidental scar deepening or unnecessary blood loss, a pointed 15-cm Toledo dissection cannula (Richter, Sao Paulo, Brazil) was used to epifascially release the scar adhesions extending from the scar into the surrounding tissue (Fig. 1C). After releasing the surroundings of the scar, the V-shaped Toledo cannula was moved in all directions in the superficial subcutaneous layer directly beneath the scar plate dissecting hereby the strands and fibrotic attachment of the scars causing the retraction. The scar dissection was completed when the cannula could slide smoothly under the scar and surrounding area without resistance.

Step 3: lipofilling to volumize the scar The adipose tissue obtained by liposuction was collected sterily in a collector, washed, and then centrifuged for 3 min and 3000 rpm.

To avoid new adhesions forming under the scar, 10–40 ml of autologous fat with ADSC was injected below the scar and homogeneously distributed with an exploded-tip cannula (Fig. 1D). To have finer control of the lipofilling, 0.7- and 1.0-mm Luer lock injection cannulas (Richter, Sao Paulo, Brazil) were used for the lipofilling. An overcorrection of 30% of the skin contour was aimed to compensate for the expected loss of transplanted fat tissue. The incisions through which cannulas were passed were closed with non-absorbable suture material of strength 5–0 (Ethilon, Ethicon Inc., Sao Paulo, Brazil) in single button sutures.

Step 4: Scarpa fascia suspension sutures Next, cross-stitches were made parallel and on both sides of the scar with Nylon 4–0 (Ethilon, Ethicon Inc., Sao Paulo, Brazil) to create a kind of suture corset in the deep subcutaneous tissue with fixation to the Scarpa fascia (Fig. 2). This is to suspend the scar and lipofilling in such a way as to prevent the formation of new adhesions and retracted scarring. Furthermore, the knotting created a controlled tension from the depth that slightly inverted the wound and prevented migration of the autologous fat (Fig. 2). In addition, it is postulated that the reduction of subcutaneous dead space in the first week could

lead to a higher survival rate of ADSC and adipocytes fed by diffusion. The correct placement of the suture and lipofilling was confirmed by intraoperative sonography.

The postoperative procedure was also standardized. Patients were admitted to the hospital and the discharge was planned for 1 day postoperatively (POD). In case of ecchymosis and swelling, arnica ointment (ArnicaDerm, Farmacias Knop, topical for 14 days) and compression pants were prescribed from the 1 POD for 30 days. Follow-up and dressing changes were done at 1, 7, 14, 30, and 90 POD and finally at 6 postoperative months. Sutures were removed at 7 POD.

Recording of outcomes

Patient- and procedure-related outcomes, such as scar dimensions (pre- and postoperative), number of incisions required, average volume of aspirated adipose tissue, average amount of transferred adipose tissue (lipofilling) required, actual hospitalization time, number of revision procedures, and surgical complications, were pseudonymously documented and evaluated in an Excel file. The pseudonymized data and written consents for the study and publication of images were stored in encrypted form on a clinic server in accordance with the ethical approval.

In analogy with the Clavien-Dindo classification [15], all complications (wound dehiscence, wound infections, post-operative bleeding, seromas, fat necrosis, etc.) which resulted in a revision operation or hospitalization were classified as major complications (Clavien-Dindo grades 2 to 4). All possible complications that required some form of therapeutic modification of the intended and expected postoperative course were classified as minor complications (Clavien-Dindo grade 1). Postoperative ecchymosis, imperceptible seromas, swelling, and postoperative pain that could be treated on an outpatient basis were not considered complications, because they correspond to the normal healing process. Unscheduled reconsulting of the patients for dressing changes or wound controls, with no underlying surgical or medical complications, were equally assessed as a normal course.

Self-esteem and self-confidence Before surgery and after 6 months, a validated version of the Rosenberg Self-Esteem Scale was used as an anonymous self-report questionnaire [16]. In psychology, this test is considered the “gold standard” for self-esteem [17]. In this test, 10 questions were asked and the answers were scored from 1 to 4 points (maximum 40, minimum 10 points) [17]. In the evaluation, a score of less than 25 is classified as low self-esteem, while 25–35

Fig. 3 Rosenberg Self-Esteem Scale (RSE) in the original English version. In the version validated in Spanish, the respective questions were rated anonymously by the patients with a number from 1 to 4

Please record the appropriate answer for each item, depending on whether you Strongly agree, agree, disagree, or strongly disagree with it.

1 = Strongly agree
2 = Agree
3 = Disagree
4 = Strongly disagree

- _____ 1. On the whole, I am satisfied with myself.
- _____ 2. At times I think I am no good at all.
- _____ 3. I feel that I have a number of good qualities.
- _____ 4. I am able to do things as well as most other people.
- _____ 5. I feel I do not have much to be proud of.
- _____ 6. I certainly feel useless at times.
- _____ 7. I feel that I'm a person of worth.
- _____ 8. I wish I could have more respect for myself.
- _____ 9. All in all, I am inclined to think that I am a failure.
- _____ 10. I take a positive attitude toward myself.

points correspond to the normal range [17, 18]. The English questionnaire is shown as an example in Fig. 3.

Aesthetic perception and psychological distress Based on the instrument developed by King's College of London to assess dysmorphophobia and psychological distress of individual aesthetically disturbing body segments during cosmetic procedures (Cosmetic Procedures Screening Questionnaire, COPS) [19], three selected questions were applied before as well as 6 months after surgery in a second self-report questionnaire (Fig. 4).

Change in local lymphoedema The above-mentioned preoperative questionnaire was supplemented with a fourth and a fifth question during postoperative data collection (Fig. 4). The first question aimed to evaluate the changes in the recurrent locoregional lymphoedema of the abdomen and groin. In the second question, patients anonymously rated their satisfaction with the aesthetic result after 6 months: very dissatisfied (0 points) to absolutely satisfied (8 points). For a stringent query, all questions of this self-report questionnaire were used in the same format and with a visual 8-point scale (analogous to the questions taken from the COPS test) (Fig. 4).

General satisfaction At the final interview 6 months after surgery, and considering the therapeutic alternatives, the patients were asked to answer anonymously whether they

would choose the same procedure again or rather a resection of the scar (binary question: scar correction/resection). In addition, the same anonymous questionnaire asked the patients whether they would recommend this operation to a friend or relative with the same aesthetic and functional scar problem (binary question: yes/no).

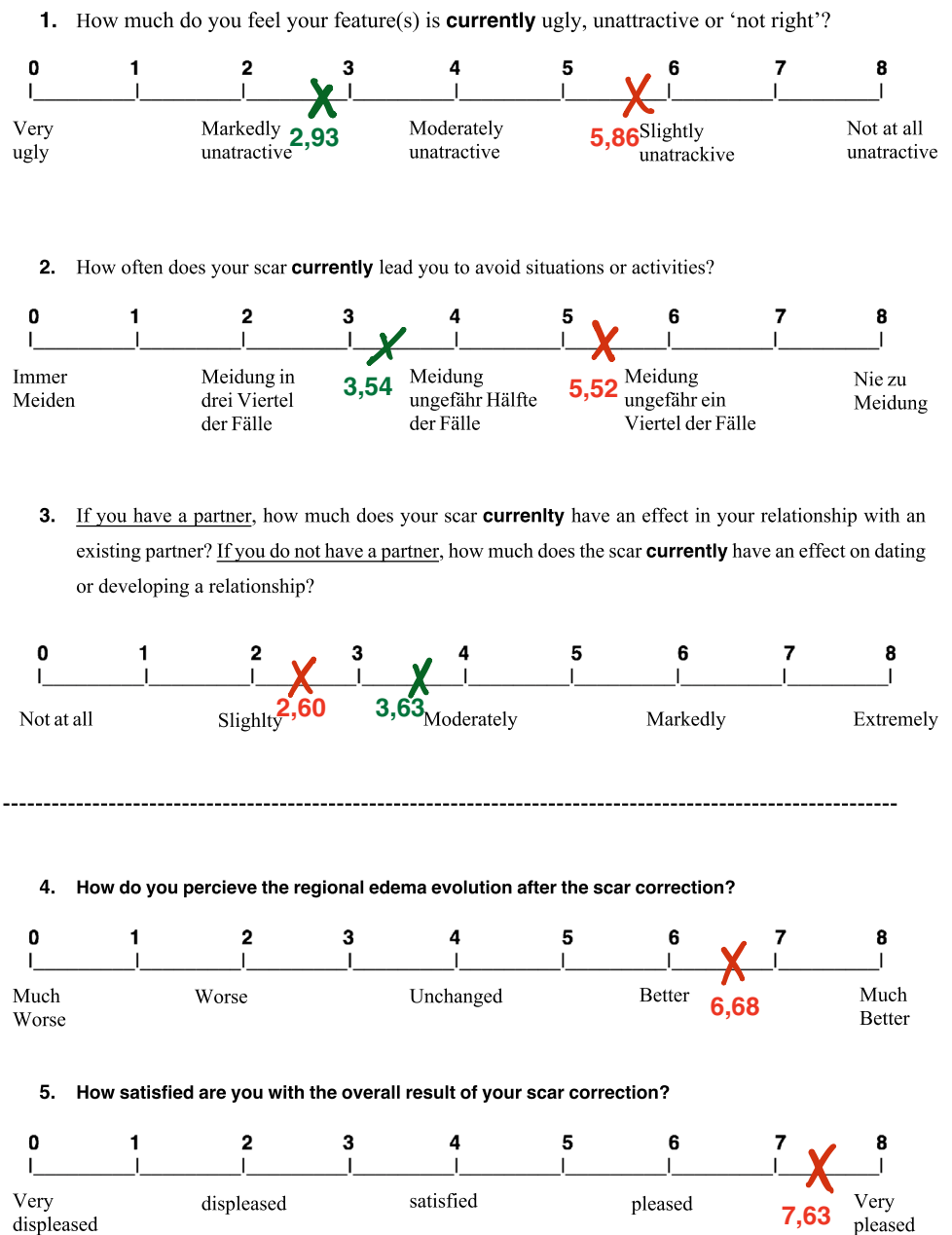
Statistical evaluation

Scoring instruments were used to quantify treatment outcomes (aesthetic and functional) as well as the effect on locoregional lymphoedema, psychological impact, and overall patient satisfaction. All data collected were tested for normal distribution using Shapiro–Wilk test ($p < 0.05$) in GraphPad Prism 8.0. Statistical significance ($p < 0.05$) was then tested using Wilcoxon matched pairs test (for non-parametric datasets) or t -test (for parametric datasets).

Results

In this study, 22 patients underwent surgery using three-dimensional multimodal scar therapy. All patients were female and aged between 19 and 45 years (32.40 ± 7.96 years). In seven patients, the retracted scar resulted from appendectomy; in nine patients, the scar resulted from cesarean section; in five patients, the scar

Fig. 4 Pre- and postoperative evaluations of a self-report questionnaire with an 8-point scale (based on the COPS questionnaire). The average score on the day before surgery is shown in green and the average postoperative score is shown in red. The respective average scores recorded for the corresponding questions pre- and postoperatively are shown on the right



resulted from laparoscopic or open laparotomy; and in one patient, the retracted scar resulted from surgical exploration of the inguinal area (Table 2).

The retracted abdominal scars were measured before and after the surgical procedure. The scar lengths were heterogeneous, depending on the original causative surgery. There was no difference in pre- and postoperative scar lengths (13.47 ± 5.63 cm and 13.15 ± 5.42 cm). Liposuction and lipofilling required an average of 2.59 ± 0.73 incisions, 1.13 ± 0.24 l aspirated, and 30.77 ± 7.34 ml autologous fat transplanted (Table 3). No patient required an overnight stay beyond that planned (Table 3). No patient had an emergency, revision, or re-hospitalization.

Accordingly, no major complication (Clavien-Dindo grade 2 to 4) was recorded in this study (Table 3). Overall, six out of 22 patients experienced a minor complication (Clavien-Dindo grade 1) (Table 3). While prophylactic antibiotics were prescribed in 3 cases for persistent local redness, another patient required the administration of an oral antibiotic for clinically confirmed postoperative infection. In two cases, there was a small, clinically noticeable seroma that required prolonged compression treatment by custom-made compression garments (Table 3). No seroma required puncture. The patient group experienced considerable weight loss in the postoperative period, from an

Table 3 Summary of clinical results

Clinic parameter	Arithmetic mean and standard deviation
Scar length pre- and postoperative	13.47 ± 5.63 cm/13.15 ± 5.42 cm
Incisions for liposuction/lipofilling	2.59 ± 0.73
Fat removed by liposuction	1.13 ± 0.24 l
Lipofilling volume	30.77 ± 7.34 ml
Hospital stays (in days)	1 ± 0.0
Revision surgery/rehospitalization	0
Major complications (Clavien-Dindo 2–4)	0/22 (0%)
Minor complications (Clavien-Dindo 1)	6/22 (27.2%) <ul style="list-style-type: none"> • 3/6 (50%) additional oral antibiotics (prophylactic because of local redness) • 1/6 (16.7%) additional oral antibiotics (therapeutic because of local infection) • 2/6 (33.3%) new compression garment because of seroma

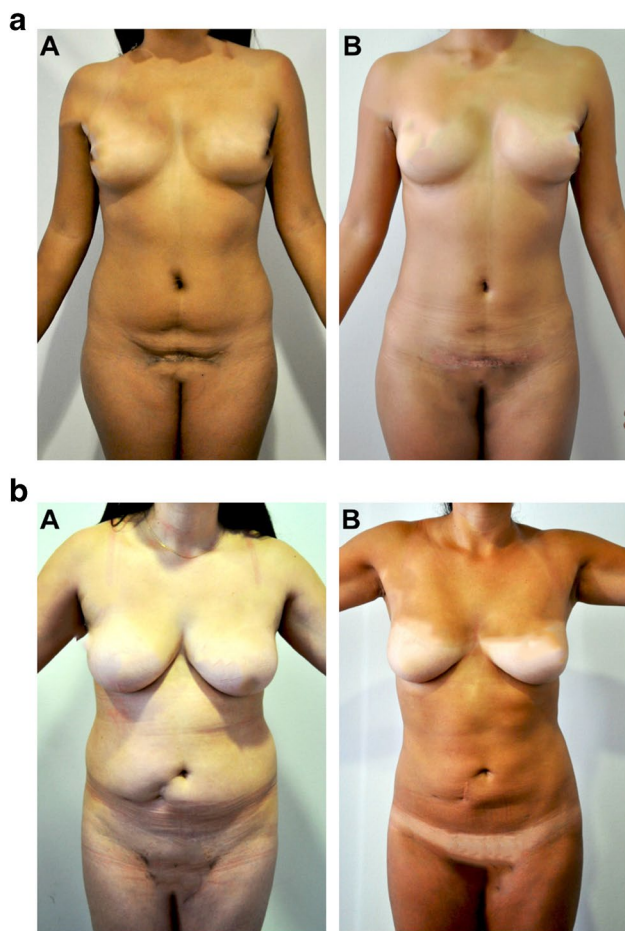


Fig. 5 Pre- and postoperative results of the technique using two examples. (Top) 24-year-old female patient with retracted cesarean scar. (Bottom) 39-year-old female patient with retracted appendiceal scar. In each case in **A** the preoperative findings and in **B** the 6-month postoperative result. The breasts and the pubic area were pixelated. Both patients lost weight in the postoperative 6 months but patient **B** lost significantly more (nearly 8 kg)

average BMI preoperative of 24.95 ± 3.67 to a postoperative BMI of 24.15 ± 3.06 (Table 2).

There was a significant ($p < 0.05$) difference between pre- and postoperative self-assessment regarding scar aesthetics and social well-being (Fig. 5). While in the COPS-derived questions, the preoperative scar was rated significantly unaesthetic (clearly unattractive, score 2.93 ± 1.35), the aesthetic perception improved significantly postoperatively among patients (slightly unattractive, score 5.86 ± 1.14) (Fig. 5). Whereas before surgery the patients avoided half of certain activities or social contacts because of the unaesthetic scar, postoperatively, the patients reported that they would only avoid a quarter of such activities or social participation (Fig. 5). The average scores of social avoidance improved significantly from 5.52 ± 1.46 , preoperatively, to 3.54 ± 2.09 after the intervention (Fig. 5). Although a clear statistical trend could be identified, the scar correction did not cause a significant improvement in the partner relationship (Fig. 5). The unaesthetic abdominal scar was considered a rather moderate burden on the romantic relationship preoperatively (score 3.63 ± 2.28), while this strain was reported as minimal after scar correction (score 2.60 ± 1.98) (Fig. 5).

In addition to the aesthetic perception, a positive effect was noted with regard to edema. The recurrent locoregional edema associated with hormonal fluctuations was reported to be less frequent and significantly milder after treatment (score 6.68 ± 1.06 on a scale of 0 to 8) (Fig. 5).

All patients stated that they would recommend this multimodal three-dimensional surgical technique to an acquaintance or relative with retracted scars in the abdomen or groin. Twenty-one out of 22 patients (95.45%) indicated retrospectively that they would prefer this type of scar correction again before any resection. The overall high patient satisfaction was found with an average score of 7.63 ± 0.58 points (scale from 0 to 8 points).

Discussion

Retracted scars on the abdomen or groin are often too large and adherent to different layers for pure excision and primary suturing. Sometimes, the external scar may be fine and barely visible, with the retraction making them unsightly. On the other hand, the potential risks and costs of a horizontal abdominoplasty are usually disproportionate to the expected aesthetic benefits [20]. Excision of the scar and resuture may provide a temporary benefit, at the cost of having a fresh scar that then has to go through its maturing process, plus the risk of recurrence of the retraction. If patients also have edema in the region of the retracted abdominal scar, this indicates dysfunction of the lymphatic drainage likely because of deep scarring. Although these edemas are only described as transitory by patients and not included in the traditional definition of lymphoedema, they are subject to impaired lymphatic clearance [21].

The three-dimensional and multimodal therapeutic concept for the treatment of retracted post-surgical scars investigated in this study could be evaluated as effective and safe. Liposuction of the surrounding fat tissue visually compensated for the deepening of the scar. The combination of dissection and lipoaspiration was able to even out the perilesional area and volumize the scar, thereby resolving the lymphatic drainage disturbance. Subsequent lipofilling allowed unevenness to be evened out and the potentially beneficial pleiotropic effects of antifibrotic, immunomodulatory, and prolymphangiogenic ADSCs and adipocytes to be utilized [22–24]. Temporary suspension sutures were used to minimize the potential subcutaneous “dead space” after liposuction. This would have the advantage that the autologous fat would not lose site integrity and the risk of seroma formation would be minimized. In addition, potential paracrine mutual interference of fat cells and ADSCs would be favored with a smaller distance. The molecular foundations of the effect of our technique are not part of this clinical study.

The most controverted aspect of the proposed technique might be the need for suspension sutures. In a pilot group, we observed, with the use of sonography, that the lipotransferred fat grafts did not migrate after incorporating this technical refinement additionally to the other principles of the technique. Since the suspension sutures do not increase the risks, operation time, or cost considerably, we included them as a fourth pillar of our scar release technique. Nonetheless, to prove that the addition of the suspension sutures improves the clinical outcomes a case–control study is required. To demonstrate that it avoids fat graft migration, also a patient case–control comparison with MRI or ultrasonography or an equivalent preclinical model must be pursued.

A limitation of the technique is the unclear and uncontrollable fat resorption rate as well as the insufficient

prevention of a possible migration of the lipofilling. Although, in the development of our technique, the suspension sutures and lipofilling were performed with intraoperative sonography and there were no changes in the first postoperative days, a long-term retention of the transplanted fat in the scar region was not investigated in detail. These intrinsic limitations of autologous adipose tissue transplantation are well-known and have been discussed extensively in peer-reviewed journals [4–6]. Technical recommendations from the literature have been considered to minimize fat resorption [25–27]. Whether postoperative compression prevents or even promotes the migration of fat tissue remains unclear and should consequently be assessed individually.

There are also limitations of the study, for example, the subjective assessment of the regional edema. Even though the locoregional edema was preoperatively identified by sonography and MRI, and thereby differentiated from fat maldistribution, the objectification of edema by volumetric analysis would have been additionally beneficial. Since conventional clinical measurements of edema in a region of the abdomen are not meaningful, modern methods such as infrared perometry or 3D laser scanners would have been useful for volumetric quantification pre- and postoperatively. However, these were not available and approved as medical devices in South America at the time of the study. The correction of locoregional edema was not followed up for more than 6 months in the collective. A few individual patients presented again > 2 years later for other reasons and did not report a recurrence of any edema around the scar. Consequently, we assume a long-term reduction of edema by correction of the lymphatic drainage. If the improvement is due to a correction of transluminal lymphatic drainage, an improvement of intrinsic matrix quality or neolymphangiogenesis are questions that should be investigated with molecular studies or lymphangiographic techniques in the future. Analogous to the diagnosis and microsurgical therapy of lymphoedema, our study could have benefited from preoperative imaging or intraoperative visualization of lymphatic drainage with indocyanine green near-infrared lymphography, Tc-99 lymphoscintigraphy, or lymphatic MRI [28]. Unfortunately, the technical conditions were not available for the study.

After the evaluation of the self-report questionnaires, there was a clear increase in self-esteem and patient satisfaction. At first glance, there is a dichotomy between a relatively high rate of minor complications (27.2%) and a high level of patient satisfaction as well as an objectified improvement in the functional, aesthetic, and psychosocial treatment outcome. This can be explained, among other things, by the fact that minor complications were defined extremely broadly in this study. Any change in the intended therapy was considered a minor complication. Retrospectively,

customized compression garments (instead of using prefabricated compression) would probably have resulted in even fewer postoperative seromas. In 18.2% of patients with postoperative reddening of the scar in the first days, an incipient infection could not be distinguished certainly from a liposuction-related irritation or inflammatory perfusion change of the skin. To these patients, antibiotics were prescribed prophylactically. As postoperative prophylactic antibiotics were not provided, these cases were considered minor complications (Clavien-Dindo 1). Retrospectively, it is unclear whether patients would have benefited from postoperative antibiotics as prophylaxis with this technique. Although in our series > 80% of cases apparently did not require antibiotics postoperatively, we currently prescribe prophylactic antibiotics using cefuroxime for the first two postoperative weeks in this type of scar correction. Even when applying the strict Clavien-Dindo criteria for complications, the presented three-dimensional technique for scar correction proved to be safe with only minor complications. Individual patients lost considerable weight after the performed scar correction, and the average weight loss in the postoperative period was 0.8 points in the BMI. The postoperative weight loss might have indirectly influenced the quality-of-life questionnaires to a more positive perception of the surgical technique. Mood changes might have an influence on the postoperative survey during the vacation season in summer in contrast to the cold winter of the preoperative surveying. The discussed weight changes of most of our patients could also be interpreted encouragingly. If our patients gain confidence, change their lifestyle, perform more sports, and thereby lose weight after the surgery, the positive feedback from the survey might not necessarily lose validity but gain real-life empirical legitimacy.

Conclusions

Retracted abdominal scars represent an aesthetically and functionally relevant impairment for many patients after oncological or general surgical procedures. For many plastic surgeons and patients, the resection of a larger retracted scar on the abdomen and groin in the sense of an abdominoplasty is not in proportion to the risks and the effort involved. In this study, we were able to show that the multimodal, three-dimensional combination of liposuction, scar release with the Toledo dissection cannula, lipofilling, and specifically placed Scarpa fascia suspension sutures consistently improved the results. In addition, there was a subjective reduction in locoregional edema postoperatively. All this significantly improved the self-esteem, aesthetic self-perception, and social competence of the 22 patients and led to a high level of satisfaction. A larger number of patients and a longer follow-up are necessary to validate the study

results. In addition, the underlying molecular mechanisms should also be investigated in a further experimental study.

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Declarations

Ethical approval The study was approved by the local Ethics Committee (Project No. 3416). All procedures performed in studies involving human participants 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.

Consent to participate All patients included in this study completed and signed a standardized preoperative informed consent form for the surgery, study protocol, and data storage/data publication. All patient data were de-identified.

Consent for publication The authors affirm that human research participants provided informed consent for publication of the images in Fig. 5 A and B.

Competing interests The authors declare no competing interests.

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