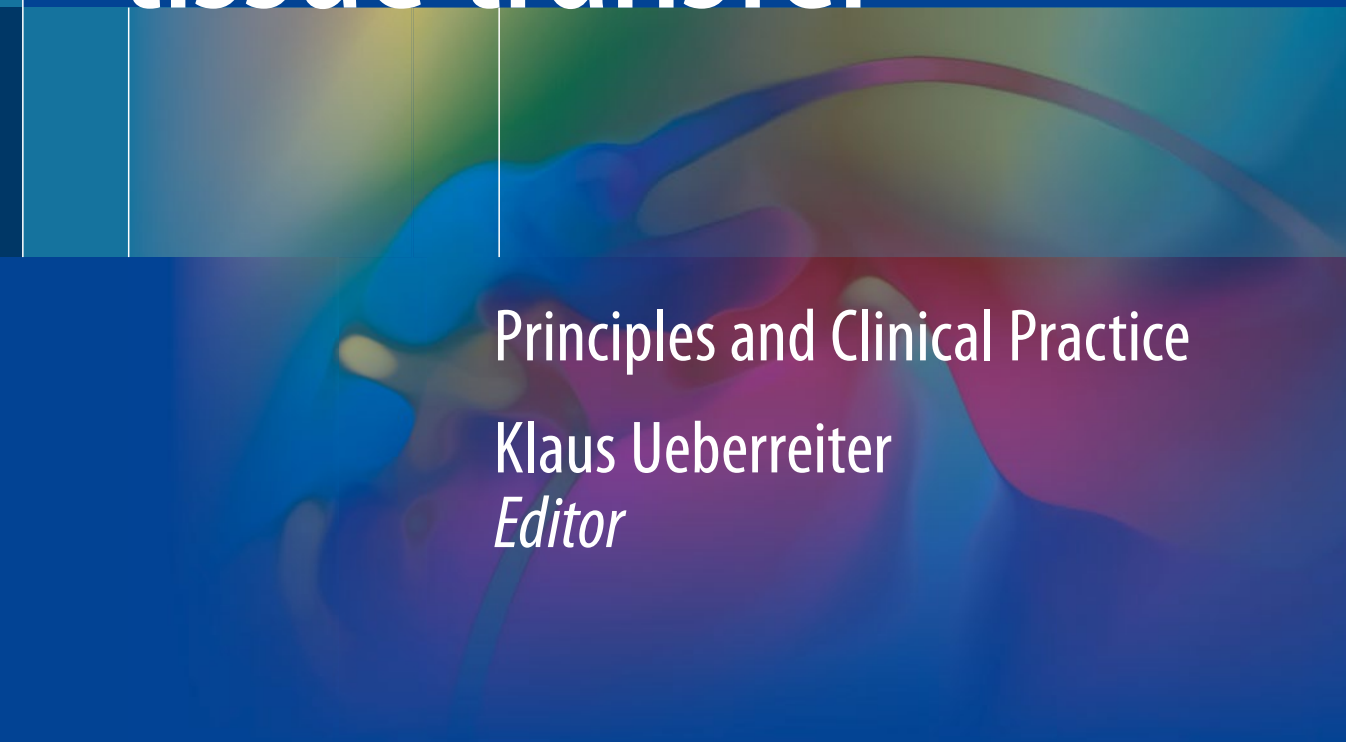
Autologous fat tissue transfer



Principles and Clinical Practice

Klaus Ueberreiter
Editor

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Editor
Klaus Ueberreiter
Fachklinik für Plastische und Ästhetische Chirurgie
Park-Klinik Birkenwerder
Birkenwerder
Germany

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Preface

The transplantation of free adipose tissue had already become an old topic, with the first description, which was already given in the year 1893 (Neuber). It reached its peak in the 1920s and 1930s of the last century. Thereafter, much of the knowledge gained was lost, and, apart from a few pioneers, hardly any work was done using this method. Only after the publication of results for breast augmentation using free autologous fat transplantation by Sidney Coleman in the year 2007, there was an increasing interest in the subject. Since then, this method has found application worldwide in the field of plastic surgery using very reliable techniques.

This book is meant to convey the scientific basis and the required basic knowledge of the technique and thus summarizes the status of practical application and scientific research in this field.

All authors of this book have personally gathered experience in the subject over the years and can rely on a great background of practical knowledge and scientific research as a basis for this book.

Even though new knowledge is continuously being gathered regarding the molecular interrelationships, the fundamentals of a successful transplantation of the free fatty tissue has basically remained unchanged since a period of over 100 years. And precisely this knowledge of the fundamentals is decisive for a successful job in the daily routine, with negative consequences like cysts or calcifications that are extensively avoided.

Birkenwerder, Germany
September 2015

Klaus Ueberreiter

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Contents

Contributors

Jüergen H. Dolderer Department of Plastic Surgery, Bayreuth/Frankfurt/Regensburg, Germany

Plastic and Aesthetic, Hand and Reconstructive Surgery, Bayreuth, Germany

Maximilian Eder Klinikum rechts der Isar, Technische Universität München, Klinik und Poliklinik für Plastische Chirurgie und Handchirurgie, München, Germany

D. Letizia Francia Department of Plastic and Reconstructive Microsurgery/Hand Surgery, Charité University Medicine, Ernst von Bergmann Clinic, Potsdam, Germany

Clinic for Plastic, Aesthetic and Reconstructive Microsurgery, Hand Surgery, Ernst von Bergmann Klinikum Potsdam, Potsdam, Germany

Riccardo Giunta Klinikum der Ludwig-Maximilians Universität München (LMU), Handchirurgie, Plastische Chirurgie und Ästhetische Chirurgie, München, Germany

Marco Conrad Harmsen Department of Pathology and Medical Biology, University Medical Center Groningen, Groningen, The Netherlands

Norbert Heine Clinic for Plastic Surgery, Regensburg, Germany

Caritas Krankenhaus St. Josef, Klinik für Plastische und Ästhetische, Hand- und Wiederherstellungschirurgie, Regensburg, Germany

Christian Herold DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

Sana Klinikum Hameln-Pyrmont, Klinik fur Plastische und Asthetische Chirurgie –Handchirurgie, Hameln, Germany

Plastische Chirurgie und Handchirurgie im Mühlenviertel, Bremen, Germany

Laszlo Kovacs Klinikum rechts der Isar, Technische Universität München, Klinik und Poliklinik für Plastische Chirurgie und Handchirurgie, München, Germany

Hartmut Meyer Praxisklinik, Hamburg, Germany

Norbert Pallua Klinik für Plastische Chirurgie und Ästhetische Chirurgie, Verbrennungschirurgie, RheinMaas Klinikum, AachenWuerselen, Germany

Hans-Oliver Rennekampff Praxisklinik Grünwald Dr. Barbara Kernt, Grünwald, Germany

Uniklinik RWTH Aachen, Klinik fur Plastische Chirurgie, Handund, Verbrennungschirurgie, Aachen, Germany

Klinik für Plastische Chirurgie und Ästhetische Chirurgie, Verbrennungschirurgie, RheinMaas Klinikum, AachenWuerselen, Germany

Aesthetic Elite, Duesseldorf, Germany

Cornelius Dieter Schubert Klinikum der Ludwig-Maximilians Universität München (LMU), Handchirurgie, Plastische Chirurgie und Ästhetische Chirurgie, München, Germany

Maroesjka Spiekman, BSc Department of Pathology and Medical Biology, University Medical Center Groningen, Groningen, The Netherlands

Tilman Stasch Dr. Stasch Clinic, Nairobi, Kenya

Yves Surlemont Chirurgie Plastique Reconstructive et Esthetique, Clinique Saint Antoine, Bois Guillaume, France

Klaus Ueberreiter Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany

Dennis von Heimburg Praxisklinik Kaiserplatz, Frankfurt, Germany

1 Introduction

Klaus Ueberreiter

Until a few years ago, free transplantation of autologous fat had been rejected by many plastic surgery associations, especially for breast enlargement. But in the meantime, a complete change of paradigm has taken place. Nowadays there is hardly a single national or international congress that does not allow a huge time schedule for these discussions.

However, there is an increasing tendency to a false or damaging utilization, and this has increased widely. In general, there is a lack of specialist knowledge regarding the correct procedures with the sensitive substance of adipose tissue.

We want to present a summarizing basis here, in order to convey to the users not only practical instructions but also a solid fundamental basis of knowledge.

Individual fat cells are not basically transplanted but instead small chunks of fat tissue, which are harvested with techniques of liposuction.

- **These small chunks of adipose tissue should ideally possess a diameter of not more of 1.5 mm, in order to guarantee a most complete healing as possible.**

These chunks contain up to 200 adipocytes and blood vessels and the connective tissue. The so-called pericytes are tightly attached to the blood vessels, which are also known as stem cells. With present-day knowledge, it is not possible to detach them from these vessels using mechanical methods.

The adipose tissue also contains numerous factors, which promote and support a wound healing. In this connection, the treatment of chronic wounds and even of certain chronic pain contitions is gaining increasing interest and offers an entirely new perspective about this often very thankless area of knowledge.

The mesenchymal stem cells of the adipose tissue can get diversified after their detachment through enzymatic and physical processes into a number of mesenchymal cells: apart from adipose tissue, mainly cartilage tissue or bone tissue and muscle cells (this is a huge area of interest in the treatment of myocardial infarction), even nerve cells, liver cells, or pancreas cells, can be newly produced from these stem cells.

In spite of the euphoria prevailing on this topic, there is really no proof or indication with a higher evidence level than four or five for applications in the clinical area.

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

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- **The application of free transplantation of adipose tissue has now become an indispensable "workhorse" of plastic surgery and can be considered as reliable and safe, if the method is used with great care and attention.**

A Short History of Transplantation of Autologous Adipose Tissue

2

Klaus Ueberreiter

In the year 1893, Prof. Neubert from Kiel in Germany reported about his experiences with an open transplantation of a lipoma to fill a defect in the breast [1]. Long-term observations were not introduced here about this subject. In the year 1910, Prof. Holländer from Berlin reported on the filling up of a hemifacial atrophy (Romberg's disease) in the face with adipose tissue and in 1912 on the successful correction of a breast defect by means of needle injection with free adipose tissue [2, 3]. This was the actual beginning for such applications in the present day use.

In the 1930s, textbooks on cosmetic surgery have devoted many pages to this subject on the filling up of defects, especially in the facial area using adipose tissue [4]. At this point of time, it was already known that exclusively small particles could completely survive.

The limited problem lay in the early years in the fact that one could recover small aliquots of fat only with great difficulty. In each case, a large block of adipose tissue had to be surgically removed and then cut to smaller pieces using the scalpel.

Even as Miller reported on the needle injections, this method did not become popular [5].

After numerous publications up to and into the 1930s, this method went into oblivion; even Peer [6] could not initiate a renaissance with his pleadings.

It was only with the introduction of liposuction [7] that there was suddenly this possibility to recover large volumes within a reasonable time period.

Mel Bircoll published his results in the year 1987 on breast augmentation using free fat graft [8]. But when he read out his paper before the American Annual Congress for Plastic Surgery, he was the subject of acrimonious criticism. As a consequence, free lipo-transplantation was vetoed by the American specialists. But this happened without any scientific basis or background.

In the subsequent years, only isolated cases of scientists working in this area were published. Also in the so-called cosmetic surgery, unsuitable techniques were frequently used to inject large quantities of fat tissue into the breasts. This resulted in oil cysts and calcification with partly disastrous results which contributed to a large-scale rejection of this method. A development in this period of time can be traced mainly to a few pioneers like Chajchir, Illouz, Ellenbogen, Bircoll and Coleman in the USA [9–11].

In our time, the credit of this rediscovery goes to the plastic surgeon Sidney Coleman of New York. He published the results of breast enlargement using the lipostructure method in March 2007 in the journal *Plastic and Reconstructive Surgery* (PRS)]. This method was originally meant for the face [12–15].

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

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Thereafter, the subject gained increasing interest, and finally, expert committees were appointed in the USA and in Germany. They went through the basic fundamentals once again, and then the ban on the transplantation of fat tissue was finally lifted [16, 17].

Newer methods were subsequently developed, which simplified dealing with the tissue not only during the harvest of fat, but also during the transplantation and made the processes predictable. However, there are a few studies, which deliver a volumetric analysis [18, 19].

Attempts to improve the results of augmentation of breasts by means of enrichment of the transplanted adipose tissue with stem cells have not been able to show any reliable success. An improvement of the healing rate by 20–30% shown by Yoshimura et al. [20] may be interpreted as a less suitable base method for transplantation of adipose tissue. In other studies no difference could be shown [21].

- **In the meantime, fat has been discovered simultaneously as an important reservoir of mesenchymal stem cells [22], and thus a new horizon has been opened up in regenerative medicine.**

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Basic Knowledge

3

Maroesjka Spiekman and Marco Conrad Harmsen

3.1 Introduction

The human body is covered with skin (Fig. 3.1). The skin protects against penetrating disease-causing pathogens and itself nurtures a number of bacteria, which reduce the risk of infection. In addition, the skin carries out a series of functions, which include sensory functions, like differentiating between hot and cold stimuli, of touch, pressure, and injury. This is enabled through a complex network of nerve endings, which widely vary based on their respective function. There is also an extensive microvascular network and the presence of sweat glands, which serve for thermoregulation and also the regulation of fluid management. And it should not be forgotten: the skin forms a barrier against water.

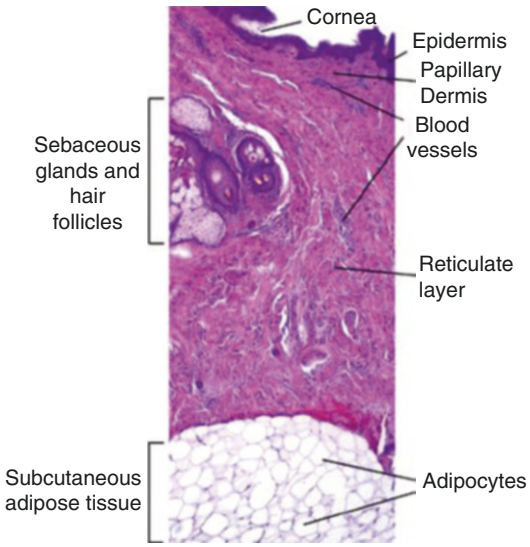

Fig. 3.1 Histology of the skin. Thin section of formalin-fixed, paraffin-embedded human skin embedded and stained with hematoxylin and eosin. The outermost layer of the skin, the cornea, consists of dead cells, which are abraded from the epidermis. The epidermis and the papillary dermis are separated through the basal membrane (not seen here), whereas the reticulate dermis consists of a dense vascularized connective tissue, whose reticulate structures (primarily collagen bundles) are properly visible, and the dermis consists of hair follicles, sweat glands, and sebaceous glands (not seen in the diagram). The latter contain different types of epidermal stem cells. The hypodermis is located below the skin, of which the adipose tissue is an important component and contains its own adipose stem cells, i.e., ASCs (original size 5×)

3.2 Histology of the Human Skin

- **The skin acts dynamically; it gets regenerated in a monthly cycle.**

Skin formation begins with the differentiation of the epidermal stem cells, which lie in the dermis layer next to the sebaceous glands. Either hair roots or epidermis cells could arise from the epidermal stem cells. The dermis consists of a deep, reticulate layer (Fig. 3.1) and consists of collagen and elastic fibers. This layer is responsible for the elasticity and strength.

M. Spiekman · M. C. Harmsen (✉)
Department of Pathology and Medical Biology,
University Medical Center Groningen,
Groningen, The Netherlands
e-mail: m.c.harmsen@umcg.nl

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The papillary dermis is well supplied with blood and is a loosely organized layer directly lying under the epidermis (see Fig. 3.1). The basal membrane lies between the dermis and the epidermis, and it regulates cell migration and the diffusion of molecules. Interestingly, this basal membrane serves as a reservoir for growth factors and other pro-regenerative factors. These are also released after an injury, in order to enable wound healing.

The epidermis is the thinnest, but very dense layer of the skin, which consists of strongly organized epithelial cells, the keratinocytes.

These keratinocytes constantly wander over to the surface and form the horny layer after they die by apoptosis. The horny layer continuously gets peeled off and is then formed once again spontaneously.

Finally, another loose layer lies below the dermis, the hypodermis. Strictly spoken, the hypodermis does not belong to the skin. But it forms a loose connection to the skin and mainly consists of adipose tissue, and in the deeper layer, it consists of muscle fibers.

3.3 Adipose Tissue

Fat deposits are available in the body, mainly subcutaneously, viscerally, and perivascularly. Three types of adipose tissue are differentiated (see the summary), which, respectively, fulfill different functions [1] with their own stem cells [2].

Fat Tissue
- White adipose tissue (WAT)
- Brown adipose tissue (BAT)
- Beige adipose tissue

- **The rest of the chapter will deal with the subcutaneous, white fat (WAT) with focus on its stem cells.**

Seen from a histological viewpoint, a major part of the volume of the adipose tissue consists of adipocytes, (Fig. 3.2), which are embedded in a stroma made up of connective tissue (Fig. 3.2a). The connective tissue contains:

- Fibroblasts
- Pre-adipocytes

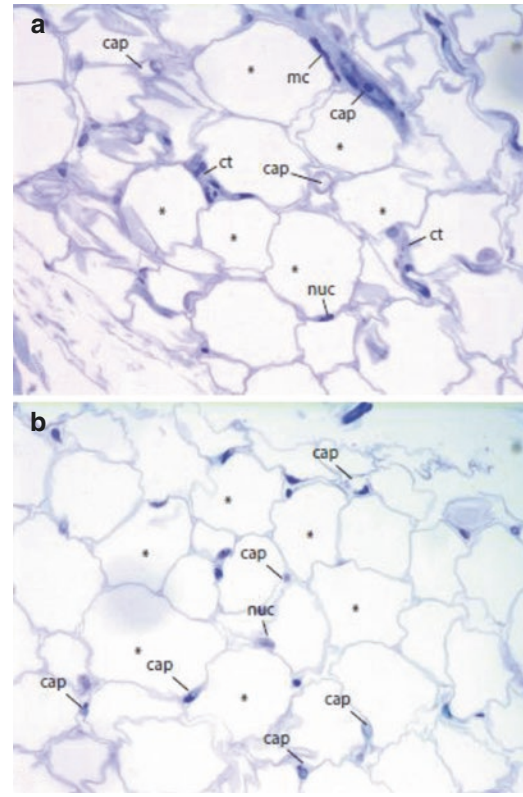

Fig. 3.2 (**a**, **b**) Typical micrograph of a thin layer of subcutaneous adipose tissue fixed in glutaraldehyde and embedded in Technovit 7100 after toluidine staining. Adipocytes (stars) are visible in the form of large, white areas. These cells are among the biggest in the human body. Some of the cell nuclei are cut out in this view (nuc). Adipocytes are supported through fine, connective tissue structures (**a**) and are surrounded by capillaries (cap). The function of the stromal vascular fraction (SVF) is regulated, among others, by mast cells (**a**, mc). The stem cells of the adipose tissue (not visible) reside in the so-called SVF, which designates that part of the adipose tissue, which remains after removal of the adipocytes (original enlargement 20×)

- Microvascular cells:
  - Endothelial cells
  - Smooth muscular cells
  - Pericytes

On the whole, this is designated as the stromal vascular fraction (SVF). Different other, somewhat seldom occurring cells of the immune system like macrophages and mast cells (Fig. 3.2a) regulate not only the vascular functions but also the new formation of the connective tissue, which holds together

the adipose cells. All the non-adipocytic cells far exceed the adipocytes to a large extent numerically.

3.3.1 Adipocytes

The adipocytes are the largest cells in the human body (50–150 µm) and contain a very large lipid-filled vacuole. More importantly, the adipocytes form the energy reservoir of the human body. But the adipose tissue fulfills still other functions, e.g., thermo-insulation and "shock absorption."

Lesser conspicuous but all the more important is the function of the adipose tissue as an endocrine organ, which releases hormones like leptin, estrogen, and resistin into the blood circulation. These hormones regulate the metabolic hemostasis together with other hormones, which control blood sugar levels. An excess of glucose results in the formation of triglycerides in the white adipose tissue (WAT), which serves as the body's energy reservoir.

Excessive quantities of lipids are stored in the WAT in the adipose areas, which again results in an excessive rise of the volume of the individual adipose cells. This is a great burden for the adipose tissue on the whole, and this results in an inflammatory reaction, while its macrophages penetrate massively into the adipose tissue.

Inflamed adipose tissue is an important risk factor for the occurrence of cardiovascular diseases [3–5] caused due to increased chronic secretion of pro-inflammatory cytokines, e.g., TNF-α.

Pre-adipocytes are fibroblast-like precursor cells of the adipocytes. They can thus be differentiated: The fully developed adipocytes have a small underdeveloped fat droplet, and the hypotrophic adipocytes have a typically large fat droplet.

This development process requires a sequence of signal-transmitting transduction routes, on which transcribing factors like PPARγ and RXR have a decisive influence [4–10].

3.3.2 Adipose Tissue-Derived Stem/Stromal Cells (ASC)

Scientists have discovered in recent years that the enzymatic dissection of adipose tissue in combination with centrifugation allows to isolate the stromal vascular fraction (SVF). The SVF contains a fraction of highly plastic-adhesive cells, i.e., ASC. The adhesion occurs within hours after seeding SVF in culture medium on tissue culture petri dishes.

Until today, the fast adhesion to synthetic is the main criterion for the cultivated ASC [11]. ASC have a fibroblast-type spindle form morphology in culture (Fig. 3.3). From a phenotype viewpoint, ASC lack surface expression of certain CD markers such as CD45 (leukocytes) and CD31 (endothelial). ASC express the mesenchymal markers CD44, CD73, CD90, and CD105 [2, 12–14].

Stem cells show two characteristics:

- Firstly: self-renewal, what in vitro translates to virtually unlimited proliferation capacity.
- Secondly: differentiation into mature tissue cells.

- **Of note, ASC are not stem cells, because these lack self-renewal capacity. However, ASC can proliferate significantly in vitro, i.e., to numbers required for regenerative purposes.**

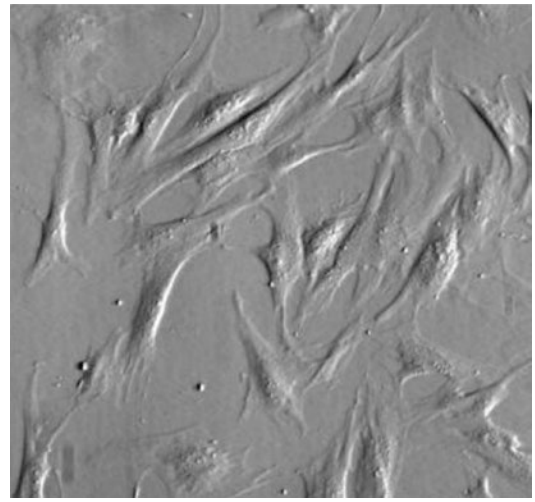

Fig. 3.3 Stem cells/stroma cells from human adipose tissue (ASC) in culture, second passage of the culture. Human ASC have a typical fibroblast type of spindle-shaped morphology. These cells are highly proliferative, which can be seen in the multiplicity in cells arranged in lines. The cell nuclei, visible as rounded structures in the center of the cells, are very active, and this can be seen on the basis of multiple nucleolar organizers (dot-shaped intranuclear structures) (original enlargement 10×, differential interference contrast microscopy)

In spite of this, the ASC can differentiate into different types of cells, e.g.:

- Osteoblasts (bone; Fig. 3.4a)
- Chondrocytes (cartilage)
- Adipocytes (fat; Fig. 3.4b)
- Pericytes
- Smooth muscle cells

The capacity to differentiate into adipose tissue opens up possibilities of "tissue engineering" of adipose tissue within and outside. Adipocyte differentiation was investigated through the Oil-Red-O staining, which detects intracellular adipose deposits (red points). The cell nuclei are counter-stained with hematoxylin (only b) (original magnification 20×) the human body (summaries by [15–17]).

3.3.2.1 ASC as Paracrine Cells

As compared to the adipocytes, which are sensitive to hypoxia, ASC adapt easily to hypoxia and react with a high proliferation rate [18, 19]. The ASC produce and secrete in vitro a large number of growth factors, cytokines, and components of the extracellular matrix [20], which suppress the apoptosis and inflammatory processes and promote mitosis and angiogenesis [21, 22].

In addition, the secreted components suppress the faulty differentiation of the skin fibroblasts [23].

To summarize, ASC and their secreted components are promising to promote regeneration and the repair of damaged tissue [24]. But the underlying mechanism of the pro-regenerative functions of the ASC in vivo remains largely unknown.

3.3.2.2 ASC Increase the Take Rate and the Survival of Adipose Cells After Adipose Tissue Transplantation

In the initial period after transplantation of adipose tissue, the survival of the fat cells depends on the diffusion of the nutrients and the oxygen, because there is no blood supply present as yet. Since the adipocytes are prone to die due to the local ischemia, their death may reduce the take rate of the graft and result in a volume loss of the transplanted fat.

The addition of ASC to fat grafts appears a logical step to improve graft survival. This is because on the one hand, the ASC secrete a number of growth factors, which act anti-apoptotically, and could thus modulate the inflammation, promote the angiogenesis, and, by this, stabilize the newly created blood supply. And on the other hand, the ASC could stabilize the volume of the graft through their differentiation into adipocytes.

3.3.2.3 Cell-Assisted Lipo-Transfer (CAL)

The cell-assisted lipo-transfer (CAL) designates the use of ASC to optimize graft survival.

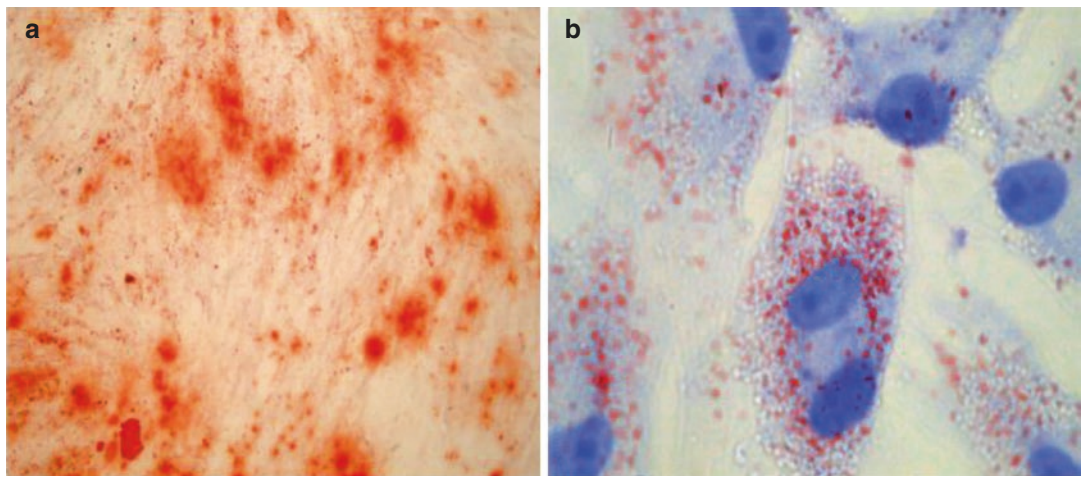

Fig. 3.4 Effective differentiation of the ASC to osteoblasts (**a**) and adipocytes (**b**). The differentiation was induced by a 2-week incubation in a specific differentiation culture medium. The cells were fixed and stained with Alizarin Red to visualize extracellularly deposited calcium phosphate (orangered) which is typical osteoblasts

Different studies in immune-compromised rodents showed that transplanted human fat could be multiplied by the addition of ASC [25–30]. The clinical use of this model, called CAL, was described for the first time by Yoshimura et al. [29, 31, 32].

But even other subsequent studies described the benefit of the addition of ASC cells to the lipoaspirate with regard to the survival of the graft [33–36]. But the results are controversial; on the one hand, a randomized, placebo-controlled experimental study, in which fat was ectopically grafted, showed that the ASC had improved volume retention [37]. On the other hand, another clinical study showed that the ASC do not influence the take rate nor volume of the transplanted fat during the breast enlargement [38]. In both studies, MRI measurements were carried out for the evaluation of the volumetric change. The decisive difference in the study was that, in the study of Kølle et al. [37], cultured stem cells were used, whereas in the other study of Peltoniemi et al. [38], fresh stem cells isolated during the operation were used.

3.3.2.4 Wound Healing

Recent studies have shown that lipografting can improve wound healing with impressive results even in the therapy of chronic ulcers in case of the diabetic foot [39].

3.4 Perspectives

The use of fat grafts is going to become more popular, even beyond the present areas of application of aesthetic surgery. Interestingly already more than a decade ago, ASC had found clinical application in cardiovascular medicine. Clinical and basic researchers will be building a bridge in the coming years through the fact that there will be an increasing understanding for the underlying mechanism of the functioning of a fat graft transplantation. In this process, the advantages of ASC will play a role either as an additive to the aspirate or alone for use by itself.

The execution and organization of double-blind, placebo-controlled studies are a challenge for surgeons dealing with aesthetic surgery. For purposes of therapy of chronic wounds, pain reduction, neuropathic, diabetic ulcers, and arthritis as well as scars, this is going to become easy.

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Fundamentals of Fat Transplantation

4

Jüergen H. Dolderer, Dennis von Heimburg, and Norbert Heine

4.1 Introduction

Jürgen H. Dolderer and Dennis von Heimburg

- Fat is an ideal filling material!

Fat
- Is easily available
- Can be easily harvested
- Is a biocompatible material belonging to the body itself
- Has a long life
- Can be used in multiple procedures

The harvesting can be done from different regions of the body and so also the reinjection. Fat grafting transplantation is used for cosmetic as well as for reconstructive purposes. Transplantation of autologous fat tissue has an established position in aesthetic and reconstructive facial surgery and in breast reconstruction after mastectomy. Even rare indications like HIV-induced facial fat atrophy [1], conspicuous burn scars [2], rhizarthritis [3], or incontinence during sphincter insufficiency [4] are the conditions that can profit from fat grafting.

- **There are only a few standardized procedures available for transplantation of fat tissue**.

The methods of harvesting, processing, and transplantation vary in clinical practice. Several working groups have attempted to arrive at a consensus to propose a generally recognized procedure but without success until today. Many different procedures have been used and are still being used, and due to the varying combinations, hardly any comparisons are possible between the results (tumescence, region, harvesting process, processing steps, transplantation processes, receiving regions, postoperative treatment).

As per the definition in plastic surgery, a fat graft is a so-called composite graft, i.e., it is composed of different tissue bands. Apart from the adipocytes, which have a cell size of up to 120 μm diameter with a narrow cytoplasmic boundary,

J. H. Dolderer (✉)
Department of Plastic and Aesthetic, Hand and Reconstructive Surgery, Bayreuth, Germany
e-mail: juergen.dolderer@klinikum-bayreuth.de

D. von Heimburg
Praxisklinik Kaiserplatz, Frankfurt, Germany
e-mail: dvheimburg@praxisklinik-kaiserplatz.de

N. Heine
Caritas Krankenhaus St. Josef, Klinik für Plastische und Ästhetische, Hand- und Wiederherstellungschirurgie, Regensburg, Germany
e-mail: nheine@caritasstjosef.de

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there are also connective tissue cells, the so-called stromal-vascular fraction (SVF), which again consist of pre-adipocytes, endothelial cells, monocytes, macrophages, granulocytes, lymphocytes, and the stem cells of the fat tissue, and the ADSC (adipose-derived stem cells).

Whereas earlier, fat grafts were harvested through excision [5], nowadays, grafts are almost exclusively harvested using special extraction needles in the present-day modern fat transfer [6].

The size of the fat grafts varies depending on the following factors:

- Perforation diameter of the harvesting needles
- Pressure applied
- Shearing forces

In the process, the inner diameter of the needles appears to be lesser relevant than the importance of the narrowest points of the needles, namely, the perforations at the needle end point.

- **The shearing forces acting on the graft are decisive, which are mainly determined by the flow rate**.

A stronger vacuum can result in a destruction of the graft [7], during which it is not so much the under-pressure but instead the shearing forces multiplied through the enhanced flow through the narrow perforation that have an important influence on the grafts [8]. The following contains a report on the utilization and the applications of different sizes.

4.1.1 Macrofat, Microfat, and Nanofat

Size of the Graft
The ideal size of the graft appears to have a decisive influence on the success of the fat transfer. The radius of a fat particle is indirectly proportional to its surface. This means that if one injects the same volume of fat, and in doing so, we halve the size of the fat particle, and then we can double the area of the contact [6].

Grafts in the magnitude of individual cells may have the potential for a better survival through diffusion. But they do not represent the ideal starting point for the angiogenesis. On the other side, very large grafts are often affected by central necrosis due to the lack of diffusion [9].

Small fat particles are harvested through fine needles with small diameters of the lateral perforations and precisely again transplanted with thin injection needles. There is a proven relationship between the diameter of the fat particles and the diameter of the perforations in the extraction needle [6].

4.1.1.1 Macrofat

Fat is partly harvested and transplanted using relatively large, blunt needles. This classical fatty tissue transplantation ("macrofat") generally has the intention of building up large volumes and is especially of importance in breast reconstruction [10].

4.1.1.2 Microfat

For sensitive areas, mainly in the face, e.g., in case of the eyelids or the lips, we preferably use blunt needles with diameters of 0.7–0.9, and this is the so-called microfat transplantation.

- **In order to achieve a uniform and careful transplantation using fine needles, even the fat particles need to be correspondingly small. Thus a uniform distribution can be ensured, and needle blockages, which can lead to a disuniform lipofilling, can be prevented**.

For the purpose of microfat transplantation, Trepsat used a multiple perforated extraction needle of 2 mm with 1 mm perforations and for the injection 19G needles [11]. Coleman and Mazzola have reported on the use of 22G injection needles [6]. Nguyen et al. [12] used blunt injection needles of 25G for fat grafting in a mouse model and in clinical cases, blunt 21–23G needles.

4.1.1.3 Nanofat

If one wants to work with even thinner needles (up to 27G), then one would require specially processed fat, the so-called nanofat. In order to guarantee a smooth injection, the fat is mechani-

cally processed, in order to obtain a fatty emulsion.

- **A quantity of 1 mL of "nanofat" can be obtained from about 10 mL of lipoaspirate, if one does the processing as described (see below)** [10].

The volume effect of nanofat is limited due to the lack of adipocytes, but it shows a positive effect on the skin rejuvenation and regeneration.

Nanofat transplantation is usually combined with a microfat transplantation. By means of intradermal micrograft transplantation, one achieves a filling effect in the soft tissue, and the intradermal box-shaped nanofat transplantation improves the skin quality. This effect generally becomes evident after a period of 4 weeks up to 3 months and is probably due to an increased collagen and elastin synthesis, which is possibly triggered by the stem cells [10].

Tonnard et al. [10] studied for the first time the differences in view of the adipocyte quality and the stem cell content between macrofat, microfat, and nanofat. A standard 3 mm Mercedes-type needle with large perforations of 2 × 7 mm was used for harvesting the fat in the first group (macrofat). In the second and third group, a multiport 3 mm needle was used with lateral perforations of 1 mm diameter.

In group 3, i.e., the nanofat group, the material harvested was additionally emulsified mechanically after the flushing, and this was done by pushing it back and forth 30 times between 10 cm^3 syringes, which were connected via a female-to-female Luer lock connector. By means of this process, the fat gets converted into an emulsion and becomes liquid. By filtering it once more through a sterile nylon cloth, the fatty liquid is released from the rest of the connective tissue, in order to prevent a blockage inside the needles. The suspension now obtained is called "nanofat."

The following were now studied:

- The survival of the adipocytes
- The number of stem cells contained
- How the stem cells can be cultivated and differentiated

Adipose tissue with an intact histological structure could be identified in the macrofat and the microfat. The adipocytes detected were alive. This was in stark contrast with "nanofat," in which the fatty tissue structure was totally destroyed. In this case, no living adipocytes could be detected.

In the next step, such cells were isolated from the stromal vascular fraction, which stuck to the plastic plates. These cells were cultivated thereafter. The $CD34^+$ subpopulation of the stromal-vascular fraction was isolated and similarly cultivated in a control experiment. Thereafter, the number of living stem cells could be determined by counting the cells, and this was independent of the process selected (macrofat, microfat, or nanofat), and the result obtained was 1.9–3 × 10^6 cells/100 mL of lipoaspirate.

The number of $CD34^+$ cells in the stromal-vascular fraction was 0.1–0.2 × 10^6 cells/100 mL of lipoaspirate. No difference could be determined between macrofat, microfat, and nanofat. Even with regard to cultivation in a standard medium, the stem cells and the $CD34^+$ fraction exhibited the capability to form a monolayer and presented a fibroblastic cell morphology.

Other working groups could not replicate the study results reported by Tonnard et al. [10]. No stem cell enrichment was seen in these studies while using the methods described (van Dongen et al., personal communication). This working group at the University of Groningen was able to achieve stem cell enrichment by using a new mechanical technique (van Dongen et al. submitted/in the Revision of Plastic and Reconstructive Surgery—PRS). The question as to whether or not such an enrichment is meaningful and helpful could not be answered with certainty.

4.1.2 Megavolume

The transplantation of very large quantities of adipose tissue is called "Megavolume autologous fat transfer." This means that large volumes of about 300 mL [13, 14] are transplanted in one single sitting, and this finds application mainly in breast reconstruction and augmentation.

- **The transplantation of very large quantities poses a special challenge, if it has to be carried out in a very compact room around**

the breast or the thoracic wall after mastectomy or even more seriously, in scarred, preoperative, or irradiated regions.

The total possible amount that can be transplanted strongly depends on the physiological preconditions of the receiving area.

The volume-pressure compliance curve plays a decisive role (Fig. 4.1) in the survival of the fatty tissue in this type of a transfer. The compliance of subcutaneous tissue is the greatest, followed by muscular tissue. Scarred and irradiated tissue structures are the least expandable [13, 14].

A positive correlation has resulted between the quantity of the transplanted fat and the tissue expansion using *BRAVA*. Especially during the transplantation of megavolumes, BRAVA offers a noninvasive breast enlargement system, a possibility to prepare the tissue for a forthcoming transplantation.

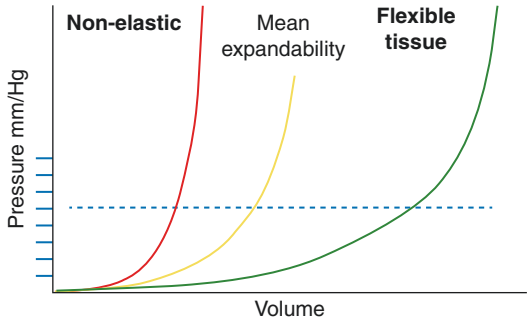

Fig. 4.1 The relationship between the expandability of the tissue, volume, and pressure (adapted from [13, 14])

MRI evaluation of breasts before and after the treatment with BRAVA could demonstrate that there has been a significant enhancement in blood supply and an increasingly expanded fibrovascular framework structure. The ideal preconditions for the growth of grafts are thus created in this manner [15]. But all these studies have been published by Roger Khouri, who has developed the BRAVA System and marketed it. An independent confirmation of the effectiveness is yet to be published.

- **The basic principle of megavolume fat grafting is in the fact that no more volume should be transplanted than the receiving tissue can take up**.

In the two dimensional transplantation, the same amount of skin tissue is transplanted as the size of the wound defect. In the same manner, excess transplantation should not be done in the three-dimensional transplantation (fat) [13, 14].

Large volumes result in critically high rise in interstitial liquid pressure [16]. This hardly supports any graft survival and leads to tissue necrosis. The increased pressure results in a damaging of the capillary blood flow with a reduced oxygen supply. Apart from this, the fat droplets pressed together form a confluence to create larger units with a smaller surface area to receive the graft [13, 14] (Fig. 4.2).

The percentage volume change of the receiver tissue is of decisive importance for the megavol-

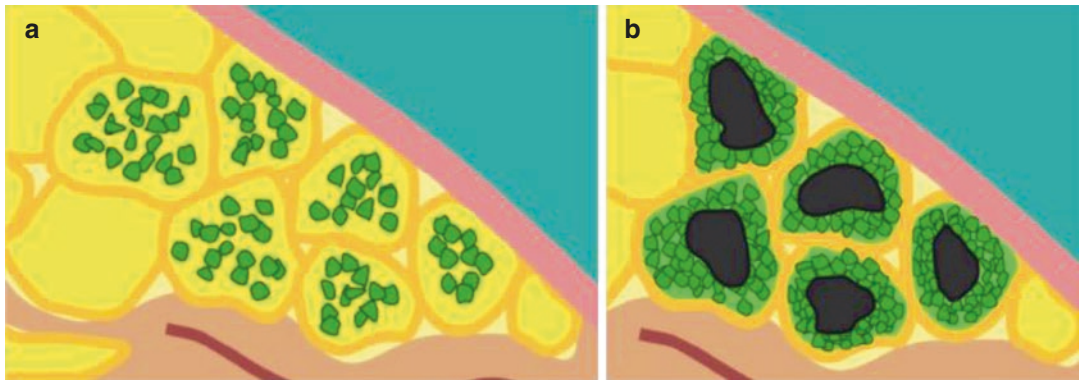

Fig. 4.2 (**a**, **b**) Distribution in the tissue. The accumulation of grafts leads to form necrosis and oily cysts (© Y. Surlemont)

ume grafting. If one transplants 200 mL of fat into a large 2000 mL half of the buttocks, this means a volumetric change of 10% can be well-tolerated by the receiver, without any significant rise in tissue pressure. Most of the fat cells are predictably going to stay alive. If on the other hand, the same quantity of fat (200 mL) is injected into a scarred breast region after mastectomy, then this means an enlargement of 100% with an enormous rise of the tissue pressure. This reduces the perfusion, and even in case of large-scale donated material, necrosis and grafting failure are programmed into such an event [13, 14].

- **The art of a successful megavolume transplantation consists in the fact that one should be able to estimate the compliance of the receiving tissue, and an "overgrafting" should be prevented not only in terms of volume but also with regard to an irregular distribution**.

4.2 The Basic Conditions for a Successful Transplantation

Fat grafting takes place in a three-dimensional space. This poses a challenge for plastic surgeons, who are used to carrying out a two-dimensional transplantation like skin grafting and therefore requires a totally new approach.

The following are two important conditions which guarantee a successful transplantation:

– The graft receiving area and the
– Tissue pressure

Nonvascular grafts can survive if they are injected in small units, not greater than 2 mm [17, 18] in order not to be placed further than 2 mm from the blood vessel supply system of the receiver. The distribution of smaller units increases the graft receiving area and early inosculation and promotes the successful subsequent neovascularization [19]. Within a period of about 2 days, the capillary network should be sufficiently built up in order to give a supply to the graft, which until then, has nourished itself through diffusion and inosculation (mouth-to-mouth anastomosis analogous to the earlier supply of other composite grafts). If this is not successful, then there is the danger of impending central necrosis [9, 20, 21].

Even the careful distribution of graft in the three-dimensional space is of great significance, in order to prevent an overlapping and confluence [13, 14]. But even when a careful dispersion is done along with a uniform distribution of the graft in the receiving parenchyma, there is still a limit to the volume which can be accepted by the receiving tissue. Starting from a certain quantity of injected volume, the compliance of the receiving tissue reduces, and the interstitial pressure rises [22].

- **With a rise in tissue pressure, there is a significant reduction of the capillary circulation with a reduced supply of oxygen and a reduced survival capacity of the graft** ([23–26].

An alternative theory with regard to the physiology in the graft is based on the work done by Hofer et al. [27]. It is assumed in the so-called scaffold or matrix theory (which is based on Peers' "host replacement theory" [28]) that almost all the transplanted adipocytes die and serve to build a scaffolding. This promotes the attraction of macrophages and the stem cell-initiated angiogenesis and adipogenesis [27]. The cytokine-initiated cellular signal transduction between the living and dead and between graft and receiver cells appears to play a decisive role here [29].

Another consideration links several of the theories mentioned. Accordingly, one part of the adipocytes survives through diffusion and angiogenesis. Those that do not survive form a scaffolding and serve as cell carriers for macrophages and the stem cell-initiated induction of angiogenesis and adipogenesis. Diffusion plays a bigger role in smaller grafts. In large-volume grafts, however, the scaffolding effect appears to be of significant importance. This is because fewer cells survive [9].

- **Apparently, the portion of the directly surviving adipocytes strongly depend on the method that has been utilized**.

A revascularization could be detected in the experiment after 2–3 days (J. Sauber, personal communication).

4.2.1 Harvesting Point

The harvesting point is selected based on the individual morphology of the patient, and such areas should be selected if possible, at which no visible harvesting defect can result.

Harvesting Point for Fat Tissue
The main harvesting point is:

– The abdomen
– Followed by the trochanter area

Fat can additionally be harvested at the following local areas [30]:

– In the buttocks region
– At the inner side of the upper thigh
– In the area of the knee

Here, one has to pay attention to the fact that there are different quantities of stem cells present in different regions of the body. Fraser et al. [31] reported that fat tissue in the hip region possesses two to three times more fibroblast forming units and seven times more alkaline phosphatase-positive colony-building units than the abdomen. Sinna et al. [32] refer to the yield of stem cells after centrifuging and noted a content of stem cells lesser by 20% in the stomach region as compared to the buttocks and the trochanter regions.

As to whether or not the harvesting point of the fat tissue has an important influence on the result could not be finally clarified once and for all through scientific studies. The experience of authors, however, shows that, in case of the woman, the fat tissue of the outer upper thigh region and, in case of the man, the fat tissue from the flank region are especially suitable to survive a transplantation [33].

- **However in clinical practice, the donor region is generally selected and specified by the patient herself**.

It is generally pointed out that the individual morphology must be taken into consideration. One should avoid a harvesting defect.

Extraction needles with small perforations (<1.5 mm) are well suited for harvesting the fat grafts. In case of manual extraction (recommended for quantities up to 40 mL), one should withdraw the plunger of a 10 mL syringe only, respectively, 1 mL, in order to prevent a strong underpressure.

The blunt 12G needle can be introduced through a small incision with a scalpel no. 11, and the fat can be harvested by forward and backward movements with a simultaneous backward movement of the syringe plunger.

- **In case of suctioning with a machine, the negative pressure must be essentially reduced to—500 mBar (375 mmHg)**.

The skin should be held with the nondominant hand, and the fat should be harvested with the suction needle over a biggest possible field in the deep layers.

4.2.2 Vascularization

The vascularization of open transplanted grafts, without microsurgical vessel connection, is presently a limiting factor for the reconstruction of large defects.

The nourishment of transplanted adipose tissue bands is based on:

– Inosculation
– Vascularization

Inosculation is the occurrence of random connections between vessel systems of the graft and the capillaries of the receiving area. Vascularization is the growth of capillaries from the receiver bed into the graft [34].

- **Inosculation can be confirmed just within a few hours. It represents the most important**

transport route of nutrients for fat grafts and other so-called composite grafts.

For this reason, the survival of small, open fat grafts in tissue with good perfusion is significantly better than in tissue with bad perfusion [35].

- **Free oil and blood disturb the inosculation that is important for the early phase of the healing process; a removal of these portions before the transplantation is recommended**.

Smahel [36] assumed that it was mainly the diffusion that nourished the graft temporarily. Diffusion as a third mechanism of nourishment of free grafts is, however, only of importance for very thin grafts (e.g., split skin). Folkman and Hochberg already demonstrated in the year 1973 that cells in implants, which are beyond 150–200 µm from the surface of a 1 mm diameter tissue block, can perish [18]. Diffusion is thus meaningless for the center of the fat graft.

The stabilization of the fat graft after a successful inosculation happens through incipient blood vessels of the receiving area. Starting from the seventh day after the transplantation, the vascularization increases [37] and achieves a plateau on the 30th day after the transplantation. Langer et al. [38] could detect new and matured blood vessels in the fat graft after a period of just 12 days, which could be comparable to the blood vessels of healthy fat tissue. The low tolerance as against ischemia is due to the fact that in natural fat tissue, each individual adipocyte is supplied by at least one capillary [38].

The survival zones after transplantation are seen in Figs. 4.3 and 4.4.

4.2.3 Influence on the Harvesting of Graft

4.2.3.1 Surface Quality of the Needles

– Diameter
Needles for infiltration, for harvesting, and for transplantation are commercially available made by several manufacturers. The system of Coleman was the trailblazer, and the first standard "Set" for the harvesting and transplantation needles was widely used. Since recently, several manufacturers have offered harvesting and transplantation needles, which are provided with small perforations (Magalon, Tulip, HumanMed, Coleman, etc.). Apart from multi-route systems, single needle systems are also available. Most of the needles can be matched to the conventional Luer lock closure systems.
– Length
The length of the harvesting needles depends on the system used and lies mostly between 15 and 30 cm.

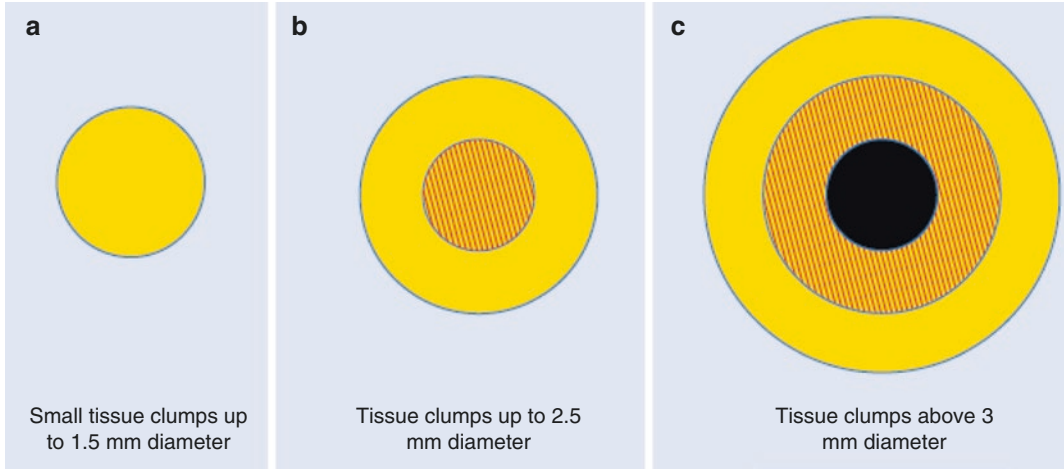

Fig. 4.3 (**a**–**c**) Survival zones of the transplanted adipose tissue (yellow, complete survival; red hashed, necrosis of the adipocytes, survival of the stem cells; black, complete necrosis with resulting oil cysts) (adapted according to [21])

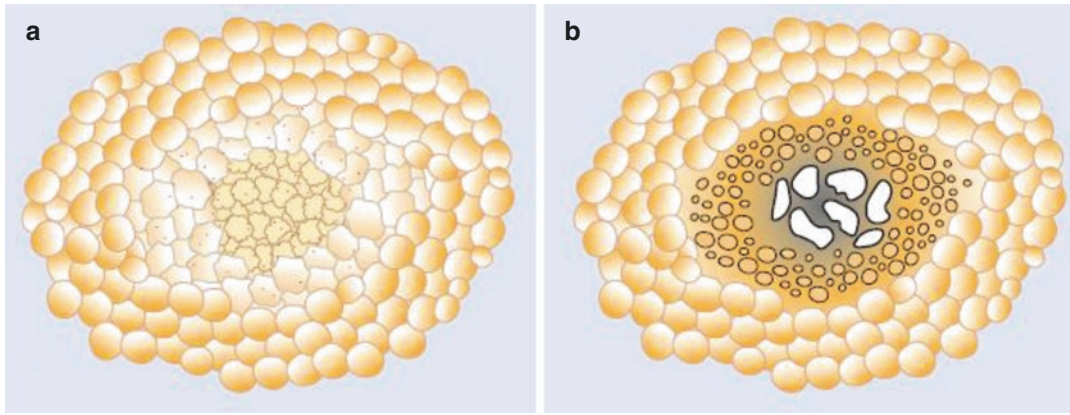

Fig. 4.4 (**a**, **b**) Free phase (**a**: up to 2 weeks). Fat cell chunks of about 5 mm diameter: Outer layer (up to about 0.5 mm): adipocytes survive through diffusion. Transition layer (up to about 1.5 mm): stem cells survive; the adipocytes perish. Deep layer (above 2 mm above the surface); all the cells perish. Splitting phase (**b**; starting from 3 weeks) outer layer (up to about 0.5 mm): adipocytes are supplied by the vascular system. Transition layer (up to about 1.5 mm): new adipocytes are formed from the surviving stem cells. Deep layer (above 2 mm above the surface); all the cells perish. The fat contained flows into the oil system (diagrams as per K. Ueberreiter)

Whereas Coleman preferred to use the blunt extraction [39, 40], a few other authors prefer harvesting using sharp needles [41–43]. Even with regard to needle diameter and vacuum pressures, different publications are available. Yoshimura et al. [44] used 2.5 mm long needles or 18G needles with vacuum pressures of lesser than 700 mmHg or a significant destruction of the adipocytes.

Ozsoy et al. [45] demonstrated a higher number of surviving adipocytes during an extraction with 4 mm needles as compared to 2 or 3 mm needles. Erdmin et al. [46] recommended the use of still bigger needles with 6 mm diameter. Although the number of surviving adipocytes rises, however, the survival rate drops in case of larger cell chunks, so that the use of larger needles is not recommended.

- **Based on the evidence, one cannot say that one method is more superior than the other. But lesser pressure appears to favor the survival of adipocytes**.

4.2.3.2 Pressure

While harvesting fat tissue, the suction point should not be selected too high. A value of 700 mm of Hg significantly destroys the mature fat cells, whereas a reduced suction between 250 and 500 mmHg results in a large number of vital fat cells in the aspirate [47]. A suction pressure of −350 mmHg shows more favorable effect on the harvest of the stromal-vascular fraction than −700 mmHg [7].

Even Shiffman and Mirrafati could demonstrate that more than 10% of cell damage occurs at vacuum pressures of −700 mmHg [48]. The working group with Jackson confirmed in an as yet unpublished study that fat tissue that was harvested with the usual liposuction with a high suction and normal liposuction needles showed up a large part of nonliving cells. Only the extraction of fat tissue with low suction has resulted in the yield of a large number of living cells [49].

Khouri et al. [50] compared a 1-perforation needle with a vacuum pressure of 750 mmHg with a 12-perforation needle with a vacuum pressure of 250 mmHg for fat extraction for the purpose of megavolume transplantation.

- **Lower pressures have proved to be lesser traumatic during tissue extraction**.

4.2.3.3 Tumescence Solution, Influence of Local Anesthesia

Fischer and Fischer [51] carried out liposuction under general anesthesia without preop-

erative infiltration. This became known as the so-called dry technique. This technique is regarded as obsolete today [52]. Illouz [53] further developed the process for the so-called wet technique in which he injected saline solution with epinephrine and hyaluronidase subcutaneously, in order to reduce blood losses through the vasoconstriction effect. It was only through Klein that a breakthrough was made in the year 1987 in the liposuction method through the introduction of tumescence anesthesia. Klein represented the following opinion:

Liposuction Method Through the Introduction of Tumescence Anesthesia

- Tumescence anesthesia is the safest method for liposuction.
- The maximum safe dosage of lidocaine is 50 mg/kg of body weight.
- The maximum dosage of lidocaine without liposuction in combination with adrenaline is 35 mg/kg of the body weight (about 20% of lidocaine is removed through liposuction).
- The max. absorption of lidocaine in subcutaneous fat is achieved after 10–14 h (on the average 12 h) by the administration of 1 g/1000 mL.
- The plasma concentration achieves a value of 0 after approximately 24 h.
- The dosage of lidocaine should be suitably matched whenever such medicines are being administered, which intervene in the CytP450-system [54].

The influence of local anesthesia or tumescence solutions in the area of the extraction point has been differently evaluated [33, 39]. A toxic effect of certain local anesthetics (especially prilocaine) was seen in vitro on the survival rate of stem cells [55, 56], so that at least these specific medicines should be avoided.

No long-lasting negative effect of tumescence anesthesia could be seen on the whole. But one can assume a quantity of admixture in the blood of the portion of live fat cells in the aspirate. Novaes et al. [57] noted as follows:

- **The higher the quantity of blood in the aspirate, the much lesser is the portion of live adipocytes** [57]**. An additive for vasoconstriction should accordingly be present in the infiltration solution**.

Different compositions have been proposed over the passage of time. Generally, the tumescence solution consists of the components listed out in the Summary.

Components of the Tumescence Solution

- It is an anesthetic, mostly of lidocaine
- Epinephrine for the hemostasis
- Bicarbonate as the pH buffer, dissolved in saline or Ringer's lactate solution

Additives like steroids or antibiotics could not yield any benefits as shown in studies [54].

- **Lidocaine has been shown to act most favorably on the survival of the cells contained in fat grafts. A combination with adrenaline is always advised. Otherwise the blood additives would become unnecessarily high. Sodium bicarbonate solution buffers the acidic solution and reduces pains, especially in case of purely local anesthesia**.

Depending on whether the classical tumescence anesthesia or the "superwet technique" is being used, the ratio of infusion solution to the liquid recovered through liposuction varies from 3:1 (in case of classical tumescence anesthesia) to 1:1 (in case of the "superwet technique").

The total volume of tumescence local anesthesia (TLA), which is typically injected into certain regions, varies from 800–2000 mL on the stomach up to 10–200 mL submental [54].

One has to wait for about 30–60 min before starting fat harvesting, so that subsequently, the quantity of fat harvested can be maximized [54]. Some authors wait for only 15 min before they start the fat extraction [58]. In case of other techniques like water jet-assisted liposuction (WAL), far lesser volumes are used for preliminary infiltration; there is also no waiting period.

Kim et al. [59] compared the survival of adipocytes after extraction with different higher epinephrine concentrations and could not find any difference. Even Moore et al. [33] examined the effect of lidocaine and epinephrine on fat cells and could not demonstrate any significant effects on cell morphology, proliferation, or metabolic activity.

For multiple regions and larger quantities, it is advised to provide support through a dosage of analgesics, epidural anesthesia, or general anesthesia.

4.2.3.4 Preparation, Centrifuging

Different attempts were undertaken in the last 10 years to raise the survival rate of transplanted fat tissue cells for clinical applications through special processing methods. These include:

- Concentration of the living cells through decantation after a long-standing period
- Scrubbing process, in order to remove mediators that may cause inflammation [60, 61]
- Filtration through cotton compresses [41, 62]
- Centrifuging the fat [63]
- The adding of different substances like steroid hormones and vitamin E to the graft [64, 65]

But only a few methods among these are suitable for clinical applications and have been demonstrably successful.

The authors of this paper feel that the measures listed in the Summary are of decisive importance to improve transplantation results.

- **Free oil and blood can encumber the inosculation of fat grafts. Mouth-to-mouth anastomosis cannot be formed by this, and the temporary nutrition of the graft remains ineffective**.

Measures for the Improvement of Transplantation Results

The removal of:

- Tumescence solution
- Blood
- Oil
- Cell detritus

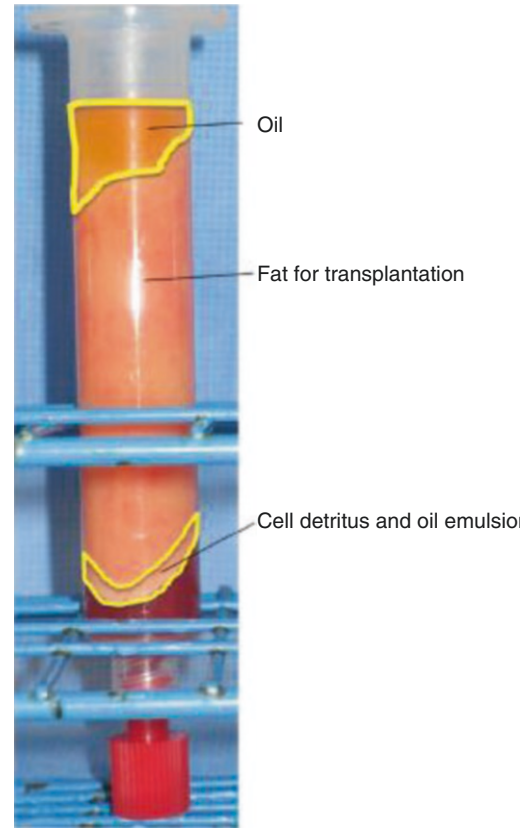

Fig. 4.5 Layer formation after centrifuging (Coleman method)

Suitable measures are filtering (Carraway) as also the method of centrifuging (Coleman). Three layers are exposed macroscopically after centrifuging (Fig. 4.5).

- The uppermost layer consists mainly of oil, which originates from the destroyed adipocytes.

– The central layer mainly consists of fat tissue that can be transplanted (Fig. 4.5).
– The lowermost layer consists of blood, tumescence solution, and cell detritus.

The Luer lock syringe is closed with an end cap and put into the sterile slot of a centrifuge. In doing so, care must be taken that the slots on the opposite side should be equipped with the same filling quantity, so that the centrifuge runs smoothly and is not damaged.

Some authors do not do any centrifuging, and they just put the syringes vertically into a holding device. After leaving them aside for a few minutes, again three layers are similarly formed [66].

There are different versions of the optimum parameters for the centrifuging process. Boschert et al. [67] studied the optimum time duration of the centrifuging at a 50 *g*-force. The samples were centrifuged, respectively, for 2, 4, 6, and 8 min. The studies could show that the centrifuging for 2 min is optimum, in order to obtain a suitable concentration of fat cells that are suitable for transplantation. Neither a prolonged centrifuging nor a high acceleration of centrifuging apparently leads to a rise in concentration of vital adipocytes [67, 68] came to the conclusion that centrifuging at 1200 *g*-force delivers the optimum short-term and long-term results.

The Coleman process has proved to be reliable over the years. But it has significant restrictions in the result. Centrifuging as recommended by Coleman (3000 rpm, 1200 *g*) appears to be traumatizing for the grafts. Other authors could not detect any improvement of the survival rate through centrifuging [69, 70].

Even centrifuging at low rpm (about 2000 rpm) can result in the separation of the upper and lower strata and thus clearly to a lesser trauma of the grafts.

- **Apart from all this, centrifuging takes up a significant extra period of time during large-scale lipotransfer**.

Khouri et al. [13, 14] selected a lower 15 *g* centrifuging for their "megavolume grafts." As compared to compact 1200 *g* centrifuging, the aqueous mixture which results from a 15 *g* centrifuging has the following advantages:

– On the one hand, a 15 *g* centrifuging is lesser traumatic for the tissue, the fat can be more efficiently distributed and less often leads to a blockage of thin needles.
– Individual loose droplets have a large receiving surface for the graft and quickly establish contact with the capillary system.
– Blood platelets, plasma, and growth factors would be lost through strong centrifuging.
– The liquid suspension offers a certain level of protection from "overgrafting"; this is because the liquid part of the graft gets quickly resorbed [13, 14].

In case of the BEAULI method [43], the fat obtained is directly separated and scrubbed in the LipoCollector (see Sect. 6.4).

- **To summarize, one can say that the actual evidence position does not exhibit the superiority of one technique over the other. But it is clearly seen that centrifuging at greater than 3000 rpm (expressed in about 1200 *g*-force) causes large-scale damage to the cells**.

4.2.4 Redistribution and Reinjection

Figure 4.6 shows the special needles as per the st'rim concept of the company PonsaMed.

A number of factors influence the result of the reinjection of fat tissue. On the one hand, one has to take into consideration different strategies and techniques with regard to large or small grafts. On the other, the objectives of a purely cosmetic conservation are expanded by the regenerative aspects, which are brought about by the fat graft.

Today, fat tissue is considered more than a filler. It fulfills the requirements for improvements of the tissue quality and regeneration.

The injection has to be given in such a manner that the survival, stability, and integrity of the fat particle can be guaranteed with the surrounding

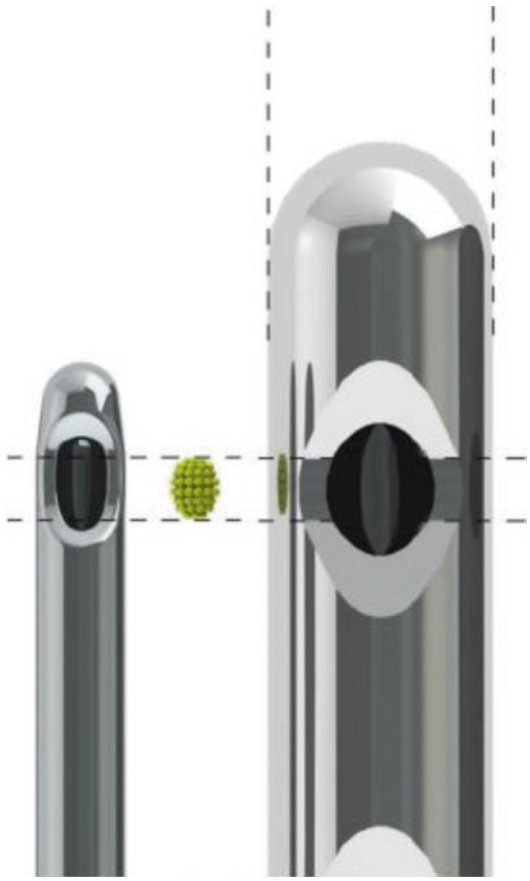

Fig. 4.6 Injection needles as per the st'rim concept (© PonsaMed GmbH, with kind courtesy)

tissue. In the process, a key to success is represented by maximizing the surface contact between the graft and the receiving tissue.

- **Note: the injection of large quantities of fat at the same point leads to a bad supply of nutrients and oxygen and results in resorption or necrosis. Disuniformities in the result are seen as a consequence** [6].

Fat grafting is done below the skin, and so the distribution of the fat particles in the tissue cannot be directly seen. The surgeon must, therefore, proceed systematically, in order to prevent repeated injections in the same area and also to avoid undersupply to other regions with fatty particles [13, 14]. In order to illustrate the difficulties, Khouri et al. [13, 14] injected fat colored with methylene blue into donor breasts and dissected these later for the purpose of analysis.

- **The best distribution was achieved by using a smaller syringe and several exit perforations**.

The computer-aided method of fat injection during breast augmentation carried out by Rigotti is worth mentioning. Entry point and direction of injection are determined by software programs and offer the surgeon an intraoperative aid [71]. An evaluation of the additional use is still pending.

Lack of Oxygen

Matsumoto et al. [72] studied the survival of adipocytes after the first to the fourth hour after harvesting. A rising loss of adipocytes was seen in this case during the time period. The probability of apoptosis and cell death rises with the duration of the extracorporeal lack of oxygen.

The negative aspects of the lack of oxygen could overweigh the advantages of a complex and fundamental technique in the worst case scenario.

- **In case this takes up too much time for processing and procedure** [9]**, grafting should immediately follow sufficient harvesting and processing. Therefore, a quick process is of great advantage**.

4.2.4.1 Injection Technique

Coleman and Mazzola [6] describe the technique of injection as follows:

The needle is introduced at the desired point through the individual incisions, which were used for the injection of local anesthesia. Whereas the skin is stabilized using the other hand, one should softly press the plunger of the syringe while simultaneously gently pulling out the needle. Thus the fat tissue gets deposited along the withdrawing needle.

- **It is important to administer only the smallest quantities of fat during each and individual injection**.

In order to maximize the contact surface, only a max. of 1/10 cm^3 of fat should be injected in the face during each withdrawal of the needle and even much lesser in the periorbital region. The placement should be carried out using a blunt needle because this will cause only the least amount of damage on the individual tissue levels. This favors the embedding of fat particles in the surrounding tissue [6].

4.2.4.2 Needles and Tip Sizes

A large number of different needles is available commercially for the reinjection. This wide variety of diameters, bends, and lengths and number of perforations enable us to select the optimum instrument depending on the region of the body where it has to be used.

- Length
  The length of the needles varies depending on the place of use from 5 to 9 cm in the area of the face to 9–15 cm for the body shape.
- Diameter
  The injection needles are of a smaller thickness than the harvesting needles: the smaller ones have only a single opening at the distal end. The proximal end can attach itself to the Luer lock connectors and thus produces a connection to a syringe. The selection of needles for reinjection ranges from 2 mm to 27G needles depending on the utilization and depending on the region of the body.
- Coleman needles
  Coleman needles are widely used, especially three types of blunt needles and the V-dissector needles. The V-dissector needle is mainly used in case of accretions [6]. In a study, 14, 16, and 20G needles were compared for reinjection. No significant difference could be seen with regard to the survival of adipocytes [73].

Coleman and Mazzola [6] favored the use of blunt needles due to several reasons. On the one hand, injuries to deeply located structures are avoided, and on the other, the fat particles are placed along physiological tissue layers. While withdrawing the needles, the particles are deposited between natural tissue levels; the receiving tissue sinks around them and envelops them.

In case of sharp needles on the other hand, the receiving tissue gets split up, without regard to existing tissue bridges. This causes compartments to form, which favor the flowing together of injected particles and minimize the surface contact with the surrounding tissue. Lower stability and displacement are favored by this. Apart from this, there is the enhanced risk of intra-vasal injection with possibly serious consequences (blinding, hemiparesis) [74].

- **For this reason, exclusively blunt needles should be used for the injections**.

4.2.4.3 Tissue Pressure

The rise in tissue pressure is a limiting factor in fat grafting. The receiving tissue adapts itself to the injected volume to a certain extent by expanding to create some space [13, 14]. But the compliance of the tissue is limited, and during further injection of fat, there is a rise in tissue pressure [22]. A reduction in blood supply is the result, and there are further consequences like reduced oxygen supply, missing neovascularization, necrosis, and cell death [23–26].

- **Despite preoperative estimations like how much fat tissue must be taken out and how much can be transplanted, it is important to guarantee a nearly normal tissue pressure in the receiving region**.

In order to achieve an optimum result and to prevent an increased subdermal tension and a restricted blood supply due to raised tissue pressure, Khouri et al. [13, 14] have tested a process for intraoperative pressure measurement. A catheter equipped with a manometer was intraoperatively introduced into the receiving area. The max. pressure was set to 9 mmHg, i.e., lesser than the 15 mmHg of capillary pressure and minimally higher than the physiological tissue pressure of

6 mmHg [75]. As a result, continuous better results could be achieved.

4.2.4.4 Volume

N. Heine

The loss of volume after fat grafting cannot be exactly predicted and, therefore, is the subject of current scientific and clinical studies. Clinical studies report 20–60% [43, 76–79] of volume loss. The largest part of the volume loss occurs in the first 4–6 months after the intervention [76, 77]. If one still wants to achieve the target volume, then overcorrection has to be done (see the Summary). This is, however, decisively limited by the tissue pressure, because the overcorrection can also be counterproductive.

Overcorrection

- In order to achieve the desired target volume, overcorrection can be done if there is sufficient (!) tissue.
- Delay et al. recommend the 140% rule. For a desired target volume of 100 mL, accordingly, 140 mL of fat should be injected [76].
- Several sittings could become necessary.

It has proved to be successful to carry out fat transfer in several sittings for breast reconstruction, so that the individual tissue components can be matched to the enlarged volume. A summarizing study reports about 1–7 sittings, which were selected for breast enlargement, with a time interval of 221–263 days [30]. The biggest volume transplanted ran into 270 mL per breast [76].

The estimation of volumetric change is frequently based on pre- and postoperative photographs as well as on the evaluation of an experienced surgeon [80]. Different methods of volumetric analysis have been developed. But these do not fulfill the preconditions of reproducibility, impartial investigation, patient compliance, and cost efficiency [81]. These include the methods listed in the Summary:

Methods of Volumetric Analysis of the Breast

- Anthropometric method
- Method of "thermoplastic cast"
- Method of "Archimedes' principle of water displacement"
- 3D laser surface scan
- MRI volumetric measurement

- The anthropometric method, which considers the breast as a semiellipse and calculates the volume using mathematical methods [82].
- The method of "thermoplastic cast" [83], which produces a negative print out of the surface of the body.
- The method of "Archimedes' Principle of water displacement" [84], in which the breast is immersed into a calibrated water basin and the displaced volume of water is measured.
- In order to objectively and exactly be able to measure the quantitative (volumetric content) and the qualitative (fat tissue) success after grafting, 3D laser surface scanning and MRI imaging have turned out to be the most successful [85] tools. 3D laser surface scanning allows us to create a 3D model of the patient, who is in a standing position, without compromising on the breast tissue. It allows the simulation of the postoperative result and thus helps the patient in selecting the postoperative volume [86, 87]. The method is noninvasive and independent of any intervention if the standard protocol is followed [88, 89]. With the help of special breast volume software, the surface, contour, and symmetry can be successfully created [86, 87, 90, 91]. The accuracy could be confirmed as follows: the 3D scans before and after breast enlargement were created with the help of the implant and the change of volume correlated with the size of the implant specified by the manufacturer [92].
- The MRI volumetric measurement enables us to make statements on volumetric changes and also gives us simultaneous diagnostic information on the occurrence of possible compli-

cations after transplantation of autologous adipose tissue [85]. The MRI volumetric method was already used for the evaluation of the volumetric consistency in the vocal fold [93] or after gluteal augmentation [94]. The method was used for the first time in the year 2010 for volumetric measurement after transplantation of autologous adipose tissue [95].

- **The biggest advantage of MRI volumetric measurement lies in the fact that not only the breast surface but also the tissue is analyzed. Even the evaluation of the individual injection levels is possible** [96, 97].

Apart from this, it could be shown that the transplantation of autologous adipose tissue is more consistent in peri-glandular tissue than an injection in the pectoralis muscles with reference to a volumetric yield [98].

4.2.5 Combination with Stem Cells

J. H. Dolderer and D. von Heimburg

In spite of improved injection techniques and latest methods of processing fat, volume loss after fat grafting remains a persistent problem. Especially in the first 3 months after fat grafting, an atrophy of the tissue is seen. The reason for this could be a lack of ASC (adipose-derived stem cells) in the lipoaspirate as compared to the physiological fat tissue. Due to anatomical reasons, it is more difficult to harvest the ASC in the proximity of larger vessels. Even during the preparation, there is a loss of ASC. The lack of ASC is compensated through the addition of further ASC through the method of the so-called stem cell-assisted lipotransfer or CAL.

Yoshimura et al. [44] used the technique for the first time, which is now being called cell-assisted lipotransfer or CAL. As part of this procedure, about half of the lipoaspirate harvested is processed (see below), in order to obtain the stromal-vascular fraction (SVF) in the pellet. This so-called SVF, which contains the ASC, is then added to the other half of the original lipoaspirate, in order to raise the content of ASC per milliliter [68]. One milliliter of the ASC suspension is added with 4–5 mL of fat. This causes a rise in stem cells between 20 and 40% [72].

The effects of this method are considerable and are based largely on the SVF (stromal-vascular fraction) and the stem cells contained therein.

The SVF possesses the potential to suppress local inflammatory processes. Thus there is a reduction in leucocyte infiltration ($CD3^+$) and an increased expression of anti-inflammatory factors like IL-10, prostaglandins, INF-γ, and HGF, as well as a suppression of pro-inflammatory cytokines like TNF-α or IL-6 [99, 100].

Apart from this, a positive effect could be demonstrated on the size of the scars through reduced inflammatory reaction [99]. Even in the treatment of radiation-induced skin irritation like radiodermatitis, ASC-rich lipoaspirates have shown to be successful. Rigotti et al. [101] have reported on the reduction of radiation-induced skin necrosis and the formation of granulation tissue over ulcerations.

The SVF is also attributed with the potential to prevent apoptosis mainly through the secretion of growth factors and direct cell-to-cell interaction. The working groups of Wang et al. and Zhu et al. have shown that the VEGF, HGF, and IGF-1 are secreted by the stromal-vascular fraction ([102, 103].

- **This anti-apoptotic action can protect the SVF tissue grafts from hypoxic conditions and limit any damages to the tissues**.

ASC (adipose-derived stem cells) possess the capacity to differentiate themselves into adipocytes and thus counter the loss of volume. Similarly, they promote angiogenesis [104], and in the process, they differentiate themselves into endothelial cells and favor the distribution of endothelial growth factors [105].

These days, stem cells are implanted without any further qualitative or quantitative characterization. In this case, the precursor cells are of great interest, which are characterized by expansion in culture dishes and through the property of attaching themselves to plastic. They are counted

among the so-called mesenchymal stroma or stem cells ("adipose tissue-derived MSC,", AT-MSC). They are characterized by the following:

- Their high differentiation potential
- Their immunoregulatory properties
- By the secretion of pro-regenerative, anti-apoptotic, and anti-fibrotic factors [106]

The International Society for Cell Therapy (ISCT) defines MSC as expanded cells, which possess certain properties:

- Plastic adherence
- Their differentiation potential in osteoblasts, adipocytes, and chondroblasts in vitro
- A defined immune phenotype (positive (>95%) for CD105, CD73, and CD90 and negative (≤2%) for CD34, CD45, CD14, CD11b, CD79a, CD19, and HLA-DR [107])

Further extensive cultivation and cell splitting are required in order to obtain these, after the isolation of the heterogeneous SVF (see the Summary).

In order to make individual ASC better comparable in quality and quantity, such methods are required, which can record the content and the adipogenic differentiation potential. Thus studies have confirmed that the differentiation potential exhibits a high donor variability. Also, the following factors are important for the quality of the stem cells [109, 110]:

- Anatomic localization
- Harvesting technique
- Storage conditions of the lipoaspirate
- The enzymatic collagen lysis
- The centrifuging
- Age of the patient
- Other sickness complaints of the patient.

Many of these variables can be controlled by the use of automatic equipment, and in this manner, standard production processes are enabled. Different such equipment is commercially available, e.g.:

- Celution System [111]
- Icellator Cell Isolation [112]
- Q-Graft (HumanMed AG 2015)
- **These systems can harvest the SVT automatically from the fat tissue and offer an effective way to generate uniform quantities and homogeneously processed stem cells**.

SVF Isolation

- First of all, the adipose tissue is washed, in order to remove blood cells and other debris.
- In the next step, the enzymatic digestion is done with collagenase. This is because by this process, the cells of the extracellular matrix are freed and are efficiently and gently released from the niches.
- After removal of the adipocytes, the SVF now becomes available.

Latest methods involving enzyme-free SVF-isolation like fat emulsification or the use of ultrasonics have not yet proved to be reliable as against conventional methods [108].

4.2.6 Combination with "Platelet-Rich Plasma" (PRP)

"Platelet-rich plasma" (PRP) can be added to fat, i.e., even to stem cell-enriched tissue before the transplantation, in order to ensure a better survival of the graft [113]. PRP consists of a blood platelet concentrate, which is 3–4 times that much concentrated, as the one in a physiological blood clot. It contains a rich load of growth factors (TGF-β, PDGF-BB, VEGF, EGF, IGF).

The blood is centrifuged for the purpose of production, in order to separate the red blood cells from the plasma. It is designated as platelet-rich after a concentration of about 200,000 platelets per μL [114].

4.2.6.1 Mode of Action

Platelet-rich plasma is believed to promote neoangiogenesis and to induce the formation of a

network of micro-capillaries and also to stimulate the activity of fibroblasts. Apart from this, it causes a rise of ASC (four times higher content in 4 days as compared to a control group). PRP promotes the polymerization of fibrin, which again helps to stabilize the transplanted fat [115, 116].

PRP reduces skin bleeding and edema and simplifies the uniform injection of condensed fat through narrow needles [117]. Studies have shown that PRP positively contributes to the repair of damaged adipocytes and promotes the induction of pluripotent stem cells in adipocytes [118].

4.3 Complications and Risks

4.3.1 Postoperative Complications

4.3.1.1 Swelling

After a correctly carried out fat grafting, a conspicuous swelling is normal. The patient should be explained that the swelling is a normal reaction of the tissue to the transplantation of the numerous fat grafts at different levels.

4.3.1.2 Formation of Hematoma

Small hematoma formation can regularly occur and may occur in groups, if the infiltration of the local anesthesia was carried out with a sharp needle.

4.3.1.3 Survival of the Graft

The survival rate of fat grafts is indicated in the literature as between 40 and 80% and depends on the technique, the surgeon, and several other factors [119]. Thus if very large volumes are transplanted, then this leads to fat necrosis. Experts recommend the injection of smaller volumes in thinner layers, in order to guarantee sufficient perfusion.

4.3.1.4 Cysts and Hardening

Even the formation of oil cysts and calcification could occur especially in the case of large-scale transplantation. Hardening frequently occurs and represents such areas, in which later on, a strong resorption occurs. Dead fat cells, which have a confluence into oil cysts, are suspected here.

- **Under certain circumstances, these hardenings can be palpable and may possibly require a biopsy investigation in case of patients suffering from breast cancer. Oil cysts can, however, generally be properly differentiated either sonographically or radiologically**.

4.3.1.5 Displacement of the Grafts

Shifting the fat grafts is extraordinarily seldom and may be done under circumstances when numerous grafts have been introduced onto large surface areas.

4.3.1.6 Infection

Infections rarely occur. This is because fat grafting is a surgical intervention that requires unrestricted sterility. In spite of this, the patient has to be explained about the danger of a consequential soft tissue infection.

4.3.1.7 Damage to Structures in the Receiving Area

Damage to fascia, nerves, and blood vessels is still possible even when using blunt needles. Especially at the exit points of the trigeminal nerve branches, one has to work very carefully. Fat embolisms should be avoided through intravascular injections. However, these appear very rarely in practice [74, 120]. Demonstrably, damages in transplantation using sharp needles occur very frequently.

4.3.2 Long-Term Complications

4.3.2.1 Tumor Formation

Long-term complications, which were associated in the past with autologous fat injections, concern an enhanced oncological risk through the occurrence of tumors and degeneration. Especially in case of fat tissue transplantation with enriched stem cells, the risks have not yet been thoroughly investigated. There is especially a lack of long-term studies on the basis of which reliable statements can be made.

Mesenchymal stem cells promote factors for angiogenesis, proliferation, and immune response

and can be differentiated into different tissue types. In the year 1987, the American Society of Plastic and Reconstructive Surgeons (ASPRS) rejected breast augmentation with transplantation of autologous adipose tissue. This is because due to the partial resorption of the tissue, findings were seen, which would suggest a possible occurrence of breast cancer [121].

But these fears were dispelled in the following years through numerous studies. The study published by [76] came to the conclusion that oil cysts, calcifications, or other complex cysts as a result of fat necrosis can be easily differentiated from malignant nodes [76]. Pierrefeu-Lagrange et al. [122] could also confirm that lipofilling does not represent a disturbing factor for the radiological follow-up in case of patients with breast cancer. Consequently, based on clinical findings, the ASPS (the American Society of Plastic Surgeons) again recommended autologous fat injection with the following conclusion: based on clinical studies carried out worldwide and the expertise of experienced surgeons, autologous fat transfer is an effective and extensively safe operation method [123].

Apart from eventual radiological faulty diagnosis with reference to breast cancer, a possibility is always pointed out that especially the ASC contained in the adipose tissue could contribute to the occurrence of cancer. The precise mechanisms of the occurrence of cancer are highly complex, and different theories are doing the rounds. Thus the estrogen produced in the adipocytes by means of aromatase could possibly influence the occurrence of cancer [124], precisely like adipokine, i.e., the cytokine that is secreted by adipocytes. Here, adiponectin and leptin appear to play a role [125].

But even messenger substances that are secreted by mesenchymal stem cells as well as their differentiation capacity are subjects of latest studies.

4.3.2.2 Tumor Regression

Another mechanism not yet fully understood is the regulation of the extracellular matrix through matrix metalloproteinases (MMP). The working group of Motrescu recognized the negative effect of MMP-11 on the adipogenesis and the accumulation of fibroblast-like cells, which favor the formation of tumors [126]. Numerous studies which have focused on the regression of breast cancer after fatty tissue transplantation could, however, contradict the fears. Delay et al. [76] conducted a large-scale study and could not identify an enhanced risk of a tumor regression or a tumor reappearance [76]. Even Petit et al. [127] showed in a multicentered study that there is no increased risk of a tumor regression after breast cancer resection and came to the conclusion that there are no explicit contraindications against lipofilling after breast cancer.

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Patient Selection

5

Klaus Ueberreiter

The general precondition for transplantation of large volumes of tissue is that suction-friendly deposits must exist, and these are generally present starting from a body mass index or BMI of above 18–20. However, when more fat tissue is available for use, the execution of this job gets simplified when more fat tissue is available for use.

- **In the ideal case, the patient should have a BMI of between 22 and 30.**

Very favorable preconditions would exist, if, on the one hand, disturbing fat deposits are present on the upper thighs, at the stomach or on the hips, and very small breasts. In these cases, an aesthetic improvement is combined by reduction of unwelcom deposits with an aesthetic improvement of the breasts.

No proof has been produced so far that fat from a particular region of the body is suitable for transplantation. In practice, we recommend to follow the preference indicated by the patients themselves.

But from experience, there is a basis for assumption that the tissue retains the properties of its site of origin, that is to say, especially stubborn fat from the area of the abdomen retains its tendency to increase in the breast area in case of weight gain.

- **Lipedema fat general has a lower take rate and is not recommended for grafting.**
- **Many clinical users are of the unanimous opinion that smoking reduces the rate of healing, even though extensive studies have not been done to support this viewpoint.**

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

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Current Techniques

6

Hans-Oliver Rennekampff, Christian Herold,
Norbert Heine, and Klaus Ueberreiter

6.1 Adipose Tissue Transplantation According to Coleman

Hans Oliver Rennekampff and Christian Herold

Transplantation of autologous adipose tissue as per Coleman involves an open technique, which was introduced in the year 1988 by Coleman [1]. The multistage procedure can be subdivided into three phases [2]. This involves the phases shown in Table 6.1.

Table 6.1 Procedure of transplantation of autologous adipose tissue as per the Coleman technique

Phase	Measure
I	Harvesting of a fat suspension
II	Processing of the fat suspension
III	Return of the pure fat suspension

Fig. 6.1 Coleman harvesting needles

Harvesting of the fat suspension is done using the tumescence technique, during which the quantity of tumescence solution should correspond to the harvested quantity of the fat.

Finally, a blunt 11G needle (about 3 mm) with a double opening (Fig. 6.1), which is attached to a 10 mL syringe, is introduced into the subcutaneous tissue through a prick incision. By gently pulling up the plunger, a negative pressure is produced, through which the fat can be aspirated into the syringe in the smallest portions. Depending upon the plunger rise, an under-pressure of up to 0.52 bar can be generated [3].

- Coleman recommends a lift of 1–2 cm^3 for fat harvesting.

H.-O. Rennekampff
Plastische, Aesthetische und Verbrennungschirurgie, Rhein-Maas Klinikum GmbH, Krankenhaus der Knappschaft und der StädteRegion Aachen, Würselen, Germany
e-mail: hrennekampff@ukaachen.de

C. Herold
DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

N. Heine (✉)
Caritas Krankenhaus St. Josef, Klinik für Plastische und Ästhetische, Hand- und Wiederherstellungschirurgie, Regensburg, Germany
e-mail: nheine@caritasstjosef.de

K. Ueberreiter
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

K. Ueberreiter (ed.), *Autologous fat tissue transfer*, https://doi.org/10.1007/978-3-030-05402-1_6

Fig. 6.2 Hettich centrifuge

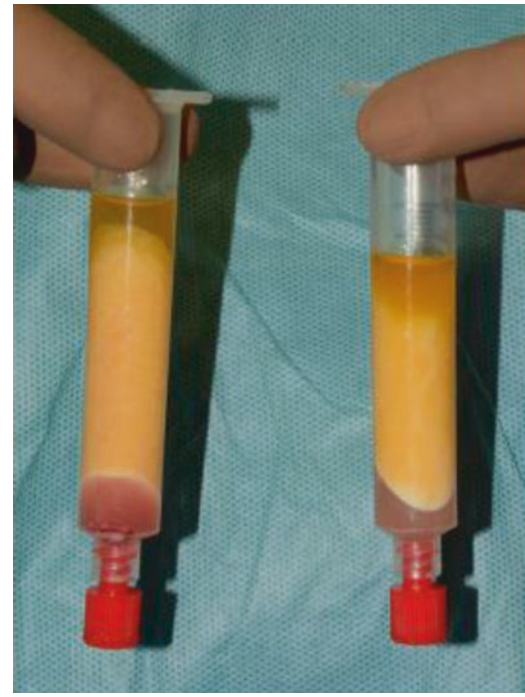

Fig. 6.3 Three-layered cleaning up after centrifuging

As soon as a sufficient quantity of fat suspension has been harvested, the syringes are closed at the cone and are centrifuged in sterile containers in a centrifuge (e.g. Medilite, Mentor, etc.) for 3 min at 3000 rpm (Fig. 6.2). This corresponds to a gravitational force of 920 *g*. Higher gravitational forces are not recommended by Coleman, because the tissue could get damaged [2].

- **During the process of centrifuging, very strict attention has to be paid in maintaining the sterility (open process)**.

Typically, three layers are formed after centrifuging. The uppermost layer consists of free fat from destroyed adipocytes; the lower layer is of blood, lidocaine and Ringer solution as well as detritus (debris), and the central layer contains the fat tissue (Fig. 6.3).

In further steps, the oil layer is pipetted out, and the residue can be removed using the so-called absorbent cotton (Fig. 6.4). The liquid left above the cone is drained out from the bottom of the syringe (Fig. 6.5).

Fig. 6.4 Removal of the oily residue

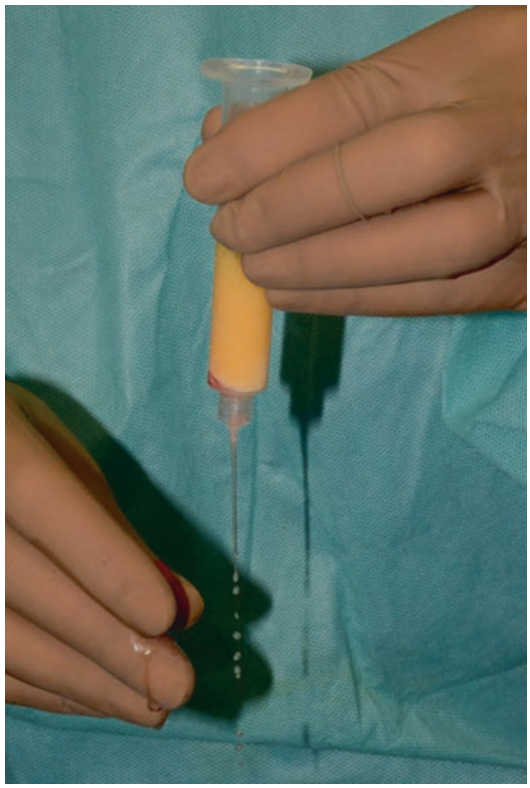

Fig. 6.5 Removal of the aqueous base

Fig. 6.6 Apportioned pure fat

The remaining purified fat can be transferred into a 1 mL syringe with the help of a double luer cone and is now ready for the reinjection (Fig. 6.6).

The transplantation of the fat suspension is done while using the Coleman technique by the Coleman needles I, II or III, which have a diameter of 14 or 16G (Mentor) (Fig. 6.7).

- **The Coleman technique is presently the most widely used technique and is considered a reference standard even in scientific publications**.

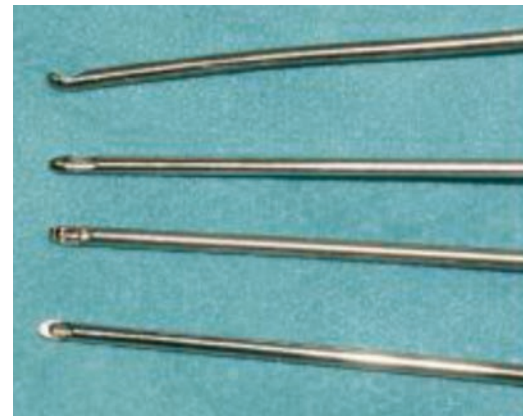

Fig. 6.7 Coleman needles, type I

6.2 Other Alternative Methods of Transplantation of Adipose Tissue

Hans Oliver Rennekampff and Christian Herold

6.2.1 Phase Separation Using Sterile Compresses

The spreading out of lipo aspirates onto sterile compresses is an established and cost-saving technique. This is because no other equipment is required except a suction needle, a drain tube and sterile compresses. Even the infiltration can be done using the suction needle and the drain tube.

The mechanical trauma and the exposure to room air are considered as potential disadvantages.

In an experimental work, a more superior separation of the oil phase, a higher content of stem cells of the fat graft and a more superior survival of the graft in a naked mouse model could be proved as against a filter-based technique and the Coleman technique [4]. But the greater amount of time required was shown as a disadvantage, and therefore, this technique is recommended only for small volume grafts.

In the papers published by Salinas et al. [5], it could similarly be shown that the phase sepa-

ration using sterile compresses represents a possibility to concentrate the harvested fat suspensions to even 90%.

6.2.2 Filter-Based Systems

6.2.2.1 Shippert Process

Shippert System
- Tissu-Trans Filtron
- Shippert Medical Technologies
- Marketingv in Germany through Asclepios Medizintechnik

This harvesting and processing technique of a fat suspension was introduced in the year 2006 by Ron D. Shippert [6]. Harvesting fat as per the Shippert technique is a closed suction and processing processs. The **Shippert System** (Tissu-Trans Filtron, Shippert Medical Technologies) consists of a large lumen suction hose and different large filter receiver flasks (100 mL, 300 mL, 500 mL, 1200 mL, 2000 mL; Fig. 6.8).

Properties of the Tissu-Trans Filtron System
- Large lumen hose system
- Standardized reduced suction
- No centrifuging
- Filter system 800 µm for removal of debris, oil and liquids
- Scrubbing process is possible
- Avoidance of an open fat transfer (as per [6])

A reduced vacuum is used for suctioning in the tumescence technique, typically with up to 3-mm-diameter needles and as against the classical liposuction. R. D. Shippert recommends an under-pressure of about −250 to −500 mmHg.

The receiving flasks have an in-built filter function with a bore diameter of 800 µm (Fig. 6.9). Through the integrated filter, one can separate oil, water and soluble additives like epinephrine. After harvesting of the necessary fat

Fig. 6.8 Different large filter receiver flasks (100 mL, 300 mL, 500 mL, 1200 mL, 2000 mL) with an integrated filter system (© Shippert Medical Technologies Inc. with kind courtesy)

Fig. 6.9 Detailed view of the filter unit with pores 800 µm in diameter

Fig. 6.10 Sterile extraction of the lipo aspirate for further use

suspension, it can be distributed via a transfer connector in a sterile manner into syringes with small volumes (Fig. 6.10).

Shippert points out that based on the design of the hose and filter system, several negative factors were eliminated or improved upon (see Summary). Thus the large lumen hoses further contribute in preventing a damage to the aspirate. The same argument is put forward even for the short hose lengths.

There is absolutely no need of centrifuging, so that, additionally, no personnel is required for manning the centrifuges. Also, there is no need

Fig. 6.11 (**a**, **b**) Aspirate of Tissu-Trans Filtron after 0 min (**a**) and 60 min (**b**). On the average, the original lipo aspirate contains 15% aqueous phase

for a waiting period during centrifuging. There is also no need of further manipulation of the fat tissue through stirring or peeling.

- **Since this is a closed-loop system, any possible contamination through the air or personnel is absolutely ruled out. As compared to other manual suction techniques, the lipo aspirate can be harvested with the help of the Tissu-Trans Filtron System under reproducible and constant under-pressure conditions**.

Thus the Tissu-Trans Filtron method can be used for harvesting the lipo aspirate under standard conditions, e.g. for clinical studies, during which a harvesting of tissue under conditions independent of study is required.

Individual studies [7] for the analysis of phase distribution in free fat (oil), fat suspension and aqueous phase yielded an average fat phase percentage of 85% of the originally suctioned out volume after 1 h (Fig. 6.11). Even after addi-

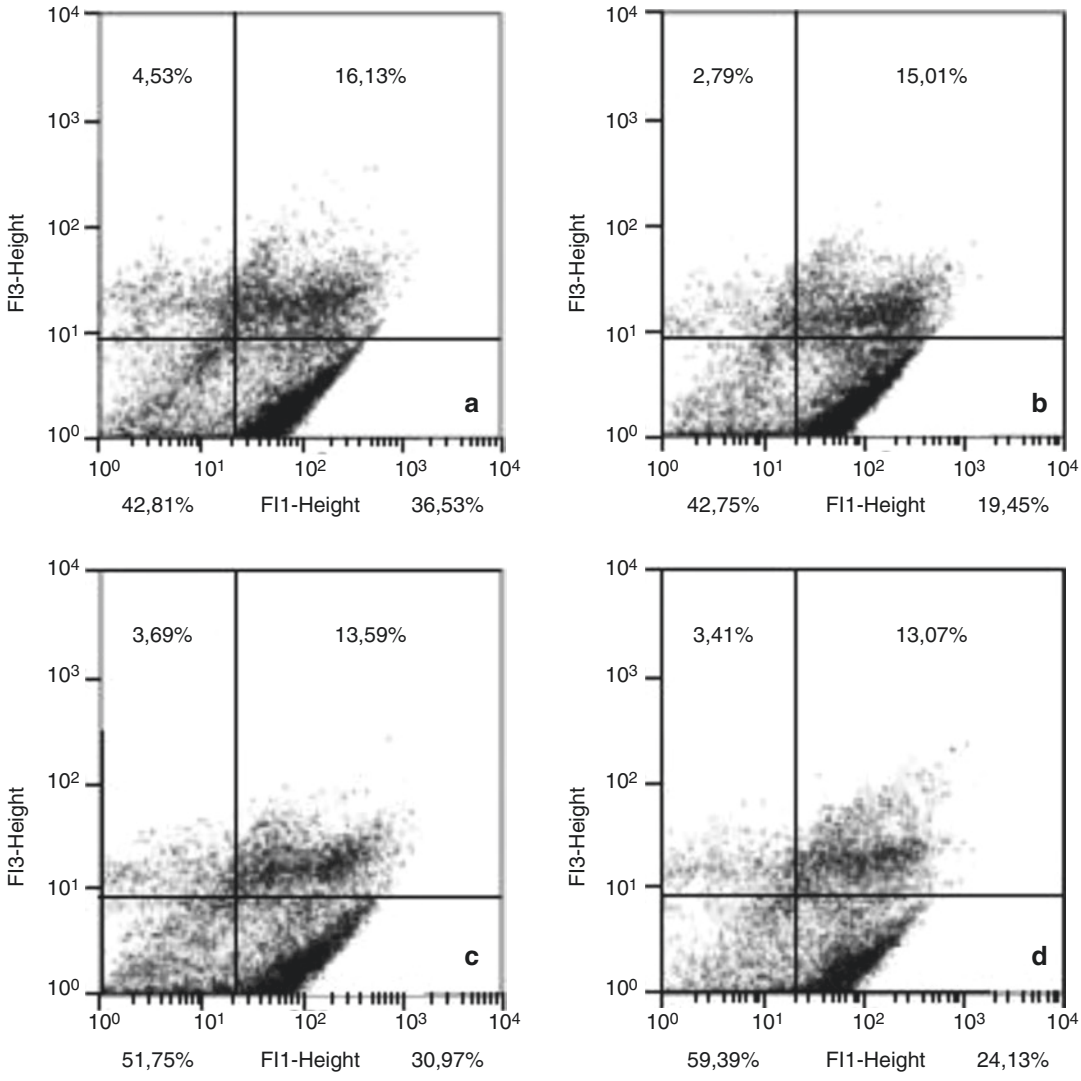

Fig. 6.12 (**a**–**d**) Examples of an evaluation of data of a female patient in the quadrant view, from top left to bottom right: (**a**) Tissu-Trans Filtron, (**b**) Coleman with 920 *g*, (**c**) centrifuging done as per Coleman with 1840 *g* centrifuged, (**d**) native adipose tissue, *x*-axis, Annexin-V FITC; *y*-axis, propidium iodide (PI). There are no significant differences in the number of vital cells (**c**) that are found during the processes adopted

tional experimental centrifuging, the fat phase percentage was recorded at 75–80% (own data). The aqueous fraction contains a high percentage of growth factors and adipocytokines (manuscript submitted). The residual liquid contained in the lipo aspirate should be taken into consideration during the planned autologous fat transplantation and the fat retention values to be achieved at the maximum. No oil phase can be detected after 60 min waiting period in any of the studied samples to a significant extent.

A comparable extremely low value for the residual oil fraction of 1% was recently shown by Fisher et al. [4]. No significant differences as against other extraction techniques could be proved [8] in the vitality test of the lipo aspirate harvested using the Shippert System and also in the lipo aspirate processed in the individual cells (Fig. 6.12).

Fat particles harvested using the Shippert method showed a diameter of 3 mm in the work done by Fisher et al. [4], and in this process, the

mean particle size of the filtered fraction that had to be discarded lay at 300 µm. Whereas hardly any vital cells and mainly debris were found by Fisher et al. in the discarded water-oil fraction after using the Shippert System, it is an open question as to whether the selected filter size of the Shippert System of 800 µm represents the optimum from today's viewpoint. In this area, further investigations are required, because even vital fat particles of around 300 µm were described as optimum in experimental in vivo models [9].

Significance

The advantages of the Tissu-Trans Filtron System lies in the simple handling of a closed-loop system: at the end of the aspiration process, we have a filtered fat suspension with a residual volume of liquid holding a growth factor for the infiltration.

The operator requires only a reduced effort for the harvesting process thanks to the mechanical suctioning as compared to aspiration by hand in the Coleman technique, which becomes a great advantage especially in the recovery of large volumes.

6.2.2.2 LipiVage

The ready-to-use, sterile single-use product (50 mL syringes) is directly connected to a liposuction pump. This is basically a closed-loop system. The oil-water fraction is removed through an integrated filter. With the help of an attached Luer lock transfer connector, sterile apportioning is possible in syringes of smaller volumes for injection [10].

LipiVage
- Genesis Biosystems, Lewisville, USA
- Marketing Germany: Polytech Health & Aesthetics GmbH

6.2.2.3 Pure Graft

This is also a closed double filter system in the form of sachets. At present, three different sizes are available (50 mL, 250 mL, 850 mL).

The fat suspension harvested is transferred into the sterile single-use sachet, is washed two times using Ringer's solution and can then be apportioned into 1 mL syringes for the lipo transfer. When using in the area of the face, one could prove a superior volumetric retention using the 3D surface scan (Vectra) as against fat transplantation, which was harvested using the Coleman technique (41% as against 32% after an average of about 17 months, [11]).

Pure Graft
- Solana Beach, CA, USA
- Marketing Germany: Aromando Medizin Technik

6.2.2.4 Revolve System

Revolve System
- Life Cell Inc. Branchburg, NJ, USA

The Revolve System is basically a closed-loop system, which in many aspects is comparable to the Shippert System. Even in case of this system, the fat suspension is collected in a single plastic container with in-built filter system, in which case the filter has a pore size of 200 µm. Also, there is an equipment for the active mechanical scrubbing and mixing of the fat graft through a propeller that has to be manually activated, which is integrated into the system. In case of the naked mouse model, one could prove a superior volumetric retention as compared to the Coleman technique [12].

6.2.3 Systems for the Enrichment of Stoma and Stem Cells

- **Legal specifications of the law on tissue transfer have to be followed in case of all systems, which include a further processing with the enrichment with stroma and stem cells. An advantage of stem cell enrichment could not be proven [13].**

6.2.3.1 Celution System

Celution System
- Cytori Therapeutics Inc., San Diego, CA, USA

Fat cells without centrifuging are cleaned through several scrubbing steps on the one hand in a closed-loop system, and on the other, stroma and mesenchymal stem cells as well as endothelial progenitor cells ("stroma vascular fraction") are harvested using human collagenase from a lipo aspirate on-site in a processing that takes about 2 h. Finally, the adipose tissue can be mixed with the stroma cell concentrate and injected with 10 mL syringes and applicator using 1 mm Coleman needles.

6.2.3.2 Other Systems

Other commercially available systems, which similarly are based on an enzymatic process, are:

- The **Multistation Minilab** (Multistation P&C International, Korea)
- The **Lipokit GT** (Medikan International Inc., Korea)

In addition, there is the possibility of a mechanical processing with:

- The **Fastem-Corios System** [14].

6.3 Pre-expansion Through the External Under-Pressure Expander (System BRAVA)

Norbert Heine

Even in the 1990s of the previous century, Roger Khouri developed a system for the volumetric augmentation through an external under-pressure expansion device [15]. His original aim was breast enlargement without surgical intervention, only through the intermittent wearing of a device with controlled under-pressure. But the enlargement achieved by this remains within limits; even for continuous success, one had to wear the device repeatedly.

With the emergence of autologous fat grafting into the female breast, two determining factors of this technique became soon evident:

- The quantity of the maximum transferable fat tissue per consultation
- The percentage of the tissue, which permanently survives [16]

In this connection, such questions are of interest as to which criteria determine the survival of the fat cells and the pre-adipocytes and as to how one can influence these.

The quality and the accepting capability of the receiving area are important for the survival of the injected fat tissue. Khouri soon discovered that the BRAVA System not only can be used for the permanent volumetric enlargement of the breast but also for the temporary expansion of the subcutaneous receiving area before the fat transfer. The oedema thus achieved of the subcutaneous area and the assumed neo-angiogenesis not only improve the survival conditions of the fat tissue introduced but also facilitate enhancing the quantity of injected material through volumetric increase of the receiving area [17].

The expansion of the tight and unyielding skin cover achieved over a period of several weeks and the scar attachments that may exist after the preliminary operations represent an advantage as against the sole fat transfer.

- The increasing hardening of the target tissue during the injection, which finally limits the further uptake of tissue, can be further pushed forward through the preliminary expansion.

6.3.1 Technique

The BRAVA System consists of:

- Two cups with semi-adhesive silicone boundary
- One hand pump for quick air expulsion
- An automatic pump (so-called Sport box), which sustains a continuous under-pressure of 15–30 mmHg (Fig. 6.13)

Biometric data are taken in order to select the expansion cups (see Summary).

Recording of Biometric Data Before the Mammary Expansion

- Upper and lower breast width
- Degree of ptosis
- Nipple to clavicle distance
- Bra size
- BMI, etc.

Fig. 6.13 Technology BRAVA System with a Sport box

Apart from these, the indications are recorded (aesthetic augmentation or reconstruction). The optimum size and configuration of the cups should be calculated from these data. This is because a slim, tall lady with small, tight breasts requires different cups as compared to a shorter patient with a slight ptosis.

When putting on the system for the first time, the patient is instructed in handling the system and in skin care. Both cups (during reconstruction, only on one side) are placed without tension on the skin in such a manner that the soft, semi-adhesive silicone boundary is fully in place all around and the entire tissue to be enlarged is left free (Fig. 6.14).

- **Especially in case of faulty structures, the inner boundary of the cup may have to be placed a little lower than the lower boundary of the breast**.

Fig. 6.14 A patient wearing the device of the BRAVA System

The hand pump and the Sports box are connected to the cups via a hose system. It is better to generate the under-pressure required using the hand pump, which will then be sustained by the electric pump. In case of a patient with a narrow thorax, the silicone boundary of the cups which initially are loosely positioned will now get attached automatically after production of the under-pressure.

- **The subsequent skin care and skin observation are of utmost importance. This is because skin irritation is amongst the most frequent complications and occasionally may lead to an interruption or even abandoning the treatment**.

Depending on individual tolerance, preference should be given to the care products delivered as part of the package, because other products could damage the silicone boundary of the set worn.

- **Skin care products other than those delivered as part of the treatment could lead to damage of the material**.

6.3.2 Application

The final outcome depends on how the system has been worn.

6.3.2.1 Preoperatively

One should strive for an uninterrupted wearing duration of about 8–10 h per day as far as possible, which should preferably be done during the nights. Frequent interruptions or lack of sealing could impair the chances of a success.

The required period of time depends on the quality of the tissue that has to be expanded and can be evaluated through inspection directly after taking off the cups. If these were worn correctly, a clear oedema of the tissue becomes visible after just a few days (Fig. 6.15).

- **The enlargement achieved at the end of the expansion should nearly correspond to the increase in volume that is expected postoperatively (Fig. 6.16).**

Fig. 6.15 Expansion underneath the cup

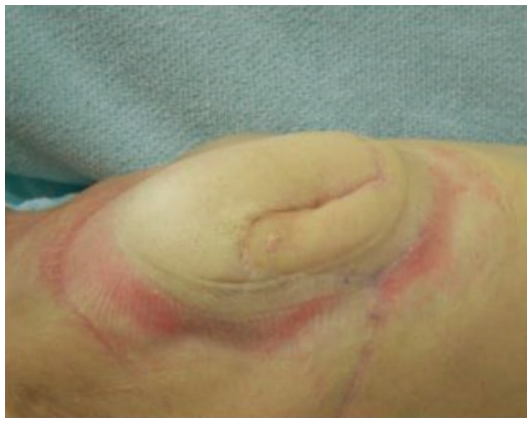

Fig. 6.16 Enlargement and expansion of the scars; the (temporary) expansion volume corresponds to the subsequent (permanent) filling result

On the average, a preoperative wearing duration of about 4–6 weeks is necessary. Thus the daily usage should be intensified while reaching the end of the planned period of wearing, and during the last few days before the planned intervention, no interruptions should take place. Whereas in case of a relatively loose skin cover and aesthetic indication, a period of 4 weeks is sufficient, tighter and smaller breast bulges or scars would require a significantly longer treatment after the mastectomy (Fig. 6.17).

Patients with radiation treatment represent a special group of indications. The irradiated tissue loses its elasticity; the tissue pressure rises disproportionately during the fat injection even after only a slight volume [18]. The total number of fat tissue transfers becomes significantly higher than in case of nonirradiated breasts. In this case, a preoperative preliminary expansion can not only result in a reduction of the individual sittings required but instead occasionally enable a permanent treatment success.

6.3.2.2 Postoperatively

Postoperatively, the system should be applied again after 24 h and should be further worn for a period of about 10–14 days. By this, the fat tissue introduced gets immobilized and gets stabilized as in the case of a skin graft until a revascularization ensures the permanent survival of the cells by means of regeneration of new blood vessels. Also, the postoperative expansion of the skin cover in the critical phase of the healing leads to a reduction of the tissue pressure.

Significance

It can be summarized that an external preexpansion can represent an aid for a significant improvement of the treatment success of an autologous fat transfer at the breasts. A good compliance of the female patient is important, which can be achieved only through a detailed counselling and demonstration before and during the treatment. Unreliable female patients should be identified early in the first consultation itself and critically indexed. Their consequent cooperation is essential if one wants to use the BRAVA method in order for the treatment to become a success (Fig. 6.18).

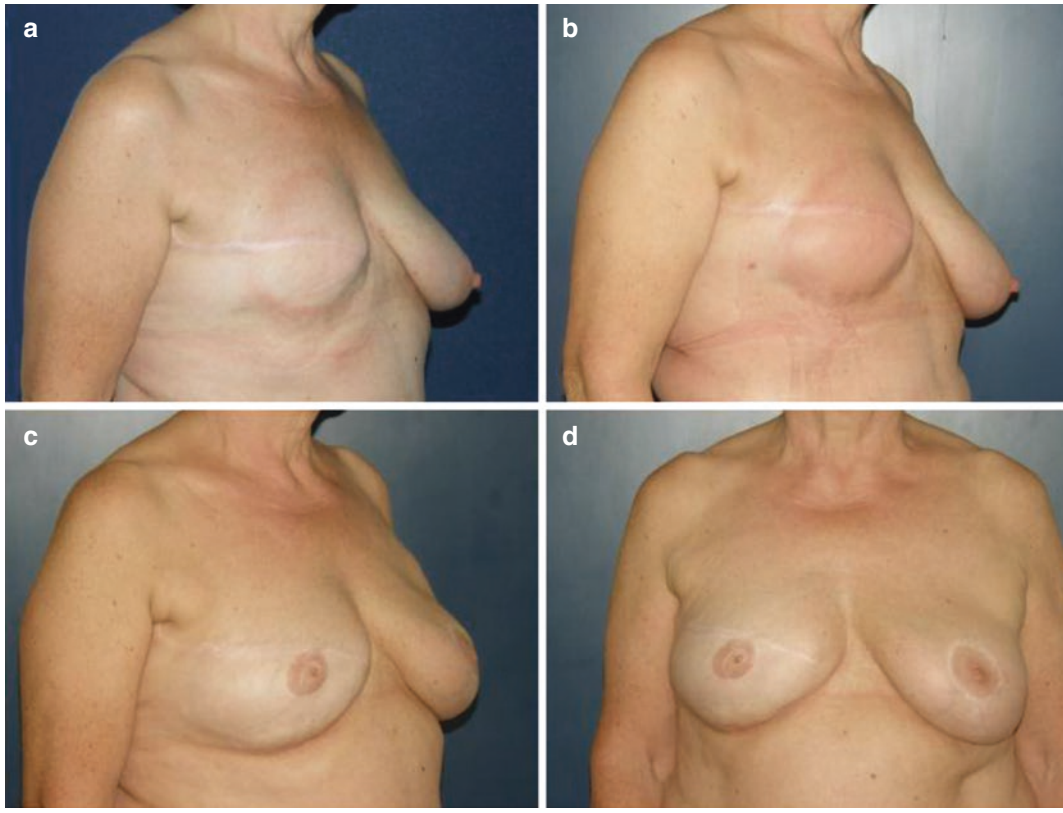

Fig. 6.17 (**a**–**c**) Condition after mastectomy to the right. (**a**) Pre-expansion with BRAVA, (**b**) second consultation: visible oedema and hyperaemia, (**c**, **d**) 4 years after autologous fat reconstruction, to the right, build-up of the nipple to areola complex (MAC build-up) and mastopexy, to the left

Treatment Objectives
- Enlargement of the recipient tissue
- Expansion of the skin cover
- Reduction of the tissue pressure
- Expansion of the scars
- Postoperative immobilization

6.3.3 The Treatment of Faulty Breast Structures Using the External Expansion System (BRAVA-AFT)

Apart from those patients who have the desire to have an aesthetic breast enlargement and breast reconstruction, there are also patients who have birth defects in the form of faulty growth of the mammary glands. These are another indication group that are in great demand for autologous fat injections.

It is precisely in this group of mostly young women that there exist inborn fibrotic structures (tubular breast; Fig. 6.19) or a partial to complete fibrotic transformation of the rudimentarily grown breast glands (Poland syndrome, Amazon syndrome), which can significantly encumber a fat injection as compared to a hypoplastic breast that is normal in growth. In case of the special anatomical situation of tubular breasts with fibrotic constriction of the lower quadrant, deficit skin cover caudal and loose prolapse of the nipple-areola complex, the injected fat often follows the gradient of the tissue pressure to the still sufficiently formed upper quadrant, without sufficiently emphasizing the filling in the area of the

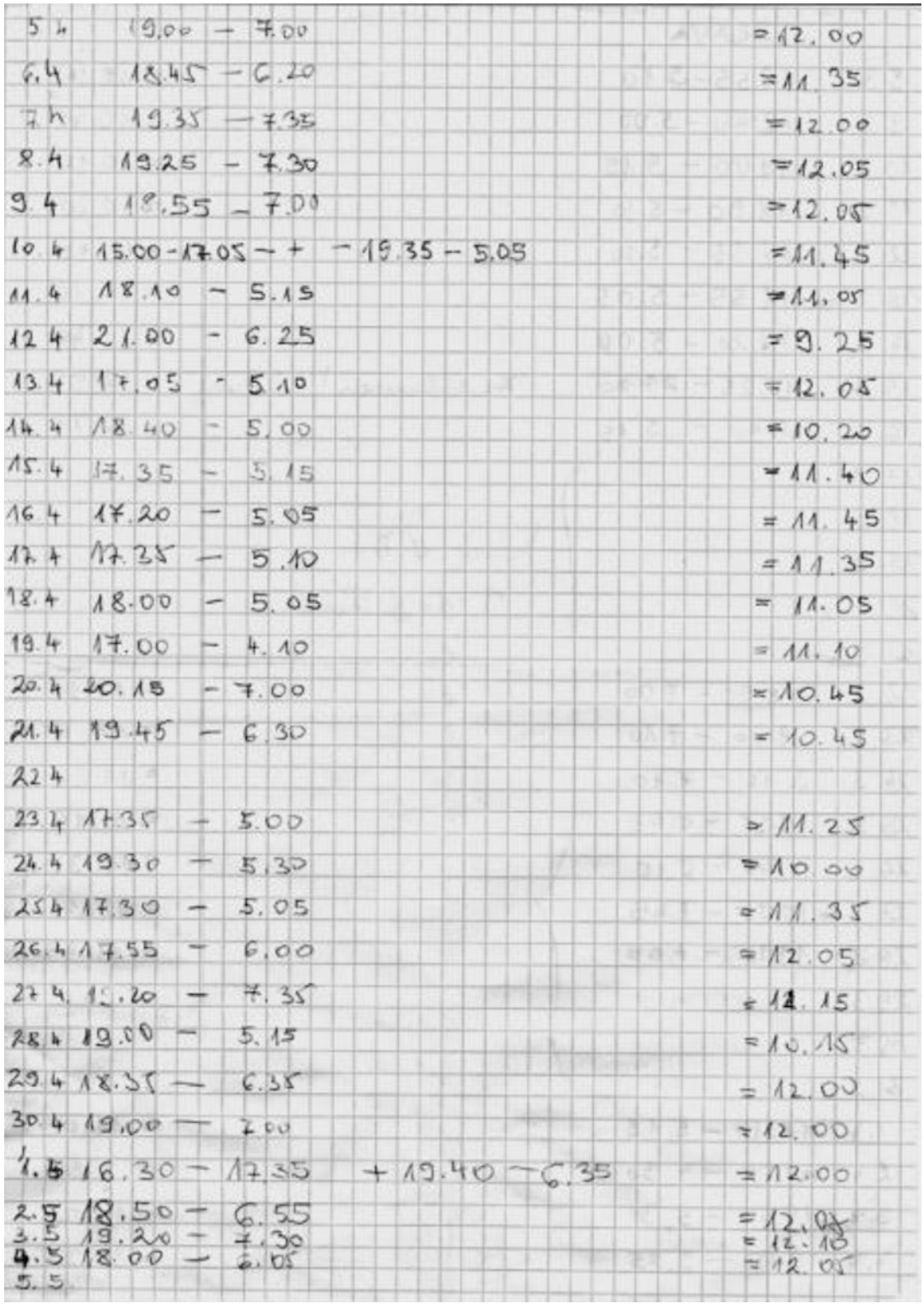

Fig. 6.18 Patient maintains a record of the daily duration of wearing the device

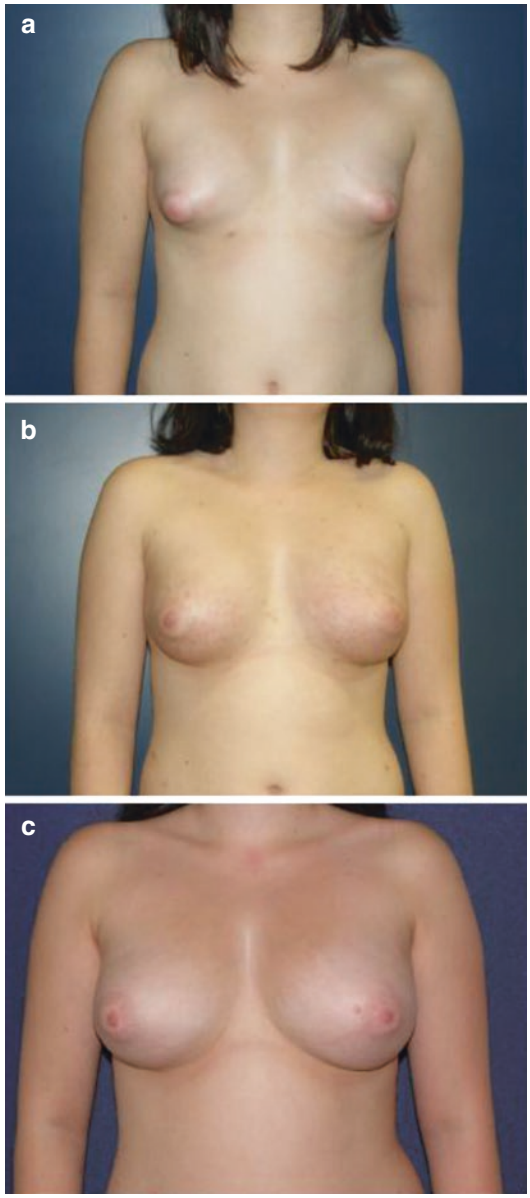

Fig. 6.19 (**a**–**c**) Tubular breasts. (**a**), (**b**) 1 week postoperatively after the pre-expansion, lipo filling and expanded 3D mesh Rigottomy technique; (**c**) 18 months postoperatively, the result is seen to be stable (1 OP)

lower breast, which is required for a natural shape and form.

The consequential external pre-expansion pays for this situation. Here it is important to position the cups at a significantly lower level. This is because as compared to the aesthetic augmentation, the lower breast fold has to be caudalized at a further point.

6.3.3.1 Preoperative

The patient should be painstakingly instructed in the use of the system. The cups should be selected in such a manner that through a relative excess size, the entire planned breast shape gets covered within the silicone cushion of the cups.

- **Note: Any pressure on the cups onto the fat tissue should essentially be avoided ("pressure kills fat")**.

The preoperative expansion phase is monitored by the plastic surgeon or the medically qualified personnel, and the success is checked. A clear sign for correct use is the visible oedema of the areola and of the transition to the boundary of the cups; a simple paling of the expanded skin would be due to the oedema-based thickening of the cutis.

- **At the end of the expansion, a volume and a breast shape should be achieved, which is expected after an operative lipo filling. Thus the injected fat temporarily replaces the temporary oedema that has occurred due to the expansion**.

If a visible effect has been achieved through the BRAVA System, then the patient should be extensively counselled again regarding how to wear the system and about the duration of wear and should be expanded for a further period of 2–3 weeks.

The duration of wear should mostly be individually matched and depends on the:

– Skin quality
– The thickness of the soft tissue cover
– The expansion of the existing scars

Inspections of the expansion result should be planned into the time table.

More important than other indications, the postoperatively expected volume should become visible at the end of the pre-expansion. The minimum duration of wear of 4–6 weeks must, if required, be extended to a further 2–4 weeks [19].

6.3.3.2 Intraoperative

In case of tubular deformities, the fibrous strands of the lower breast must be expanded through multiple, very small incisions in the connective tissue (within the meaning of the 3D mesh Rigottomy technique; Fig. 6.19) intraoperatively. Perforations are done using a 14–16G needle of the entire fibrotic portion of the subcutaneous connective tissue, without creating large hollow spaces in the process, in order to prevent a confluence of the injected fat tissue.

The system should be left to be worn up to in the OP and only removed directly before the operation, in order to sustain the effect of the oedema for the longest possible period of time.

Fat transplantation should be done following the general rules of operation; the fat is distributed with 2–2.5 mm needles three-dimensionally in the form of boxes (while avoiding bolus injections) in the smallest portions into the subcutis as well as in the pectoralis muscles. During the process, the max. quantity should be set to be somewhat higher due to the enlargement of the receiving area as against the conventional methods.

6.3.3.3 Postoperative

Starting from the first postoperative day, the BRAVA System device is worn again. Here one has to pay attention to a good skin care and a thorough cleaning of the silicone boundaries of the cups.

- **Eventually, one has to wait in case there is continuing secretion from the injection pricks until these become sufficiently attached**.

Postoperatively, one waits for the sealing of the secretion from the injection pricks, and thereafter, the device is worn for a further period of 2 weeks, in order to immobilize the tissue in the early phase of the blood vessel regeneration, and then the pressure is reduced through the surrounding soft part covering.

- **Note: Special care must be taken here, especially for the correct positioning of the cups. This will prevent any pressure effect through the push-up bra on the fat tissue injected**.

Special Note to Be Taken
- Lower positioning of the suction cups
- Sufficient formation of oedema
- Intraoperative 3D mesh

6.4 The BEAULI Protocol

Klaus Ueberreiter

In order to be able to harvest large volumes (>100 mL) quickly, reliably and in good quality, Ueberreiter developed the BEAULI protocol after several studies done beforehand in the year 2007 and finally tried out in a prospective, MRI-controlled, multicentral study [20, 21].

The technique is mainly based on a suction with the water jet equipment ("body-jet"; Fig. 6.20) made by the company Human Med AG, Schwerin, Germany.

Fig. 6.20 Body-jet (© with kind courtesy of the company Human Med)

Fig. 6.21 Function of the body-jet needle (© with kind courtesy of the company Human Med)

This equipment uses a double-channelled needle (Fig. 6.21), which carries a tube in the centre, from which the tumescence solution is infiltrated in different pressures and volumes, controlled by a foot pedal not only before but also during the suctioning into the tissue. The following are important points to be considered:

– The conservation of the tissue particles through constant water flow
– The especially small size of the fat chunks to be transplanted of 0.7–1.2 mm [22], which are properly suited for a complete healing [23]

6.4.1 Preconditions for Aesthetic Augmentation

We accept only female non-smoker patients having a BMI of above 18. The most optimum suited are those female patients, who carry heavy fat deposits on the stomach or upper thighs, so that the operation results in a double benefit.

Before the intervention, it is taken into consideration as to from which region which quantity can be approximately suctioned out. Since in the vast majority of cases, at least two grafts have to be done at a space of at least 3 months, it is better to suction out from different regions in the consultations.

- **Suctioning can be done for a maximum of three times from an individual region**.

The following are the typical regions from which suctioning can be done easily:

– Abdominal area and hips/ flanks
– Outer thighs (“saddle bags”), inner thighs and knees
– Buttocks

It is highly recommended to inform the patient beforehand that per transplantation, approximately a half breast size in final volume can be gained. This corresponds to silicone implants of 100–150 mL. These small implants can be given in advance to the patients for inserting into the bra, so that they can get an idea as to what it feels like. If during this consultation it is felt that a much bigger augmentation is desired in a single operation, then one should generally advise against autologous fat augmentation.

- **In order to achieve an entire breast size volume harvesting, two grafts are required. These can be carried out within a space of 3 months. WARNING: Every excessive grafting (more than 250/ 300 ml per breast) will lead to apoptosis of the adipocites, reabsorption and even oily cysts**.

6.4.2 Analgesics and Sedation

The suctioning is carried out while the patient is under sedation with analgesics or even under local anaesthesia. But the job that is done under solely local anaesthesia is significantly slower. This is because one has to wait for the local anaesthesia to take effect.

A full anaesthesia is certainly also possible. But due to the lack of cooperation of the patient, suctioning becomes difficult, especially of the body reverse side. Also, there is an enhanced risk of injury due to a lack of muscular defence.

A good alternative is also the high epidural anaesthesia, which is being used with great advantage since several years in Helsinki. The patient is mobile during the entire operation but is free of pain.

6.4.3 Tumescence Solution

A solution of 500 mg of lidocaine and 1 mL of adrenaline 1:1000 in 1 L of normal saline solution is used for the purpose.

For Example
A solution of 150 mL of lidocaine 1% and 3 mL of adrenaline 1:1000 in 3 L of NaCl solution

In case of operation under local anaesthesia, one should also use sodium bicarbonate 8.4 mVal in a dosage of 12.5 mL per litre of solution to reduce pain during infiltration.

The use of prilocaine should be avoided due to the high toxicity for pre-adipocytes [24]. It is better to use larger containers of 3 or 5 L bags, depending on the experience; 1 to 2 L of solution is consumed for the harvesting of 500 mL of fat for a bilateral breast enlargement.

- **An important part of the protocol is the preheating of the solution to body temperature**.

6.4.4 Preparation

Single use underwear is provided to all the female patients in the ward which can be worn during the entire operation. Skin desinfection is most easily carried out while the patient is standing and then asked to sit back on the steril table. An uncompromised suctioning is thus possible even with the patient turning to the side several times without compromising on sterility.

In our clinic, we use pre-packed complete sets, which contain all the material required for the operation like covering cloth, gown, syringes, plaster, etc.

6.4.5 Operation

6.4.5.1 Suctioning

Small prick incisions are made using a number 11 scalpel at the areas marked out earlier, and finally through these, the respective region to be suctioned is infiltrated. As compared to the classical tumescence technique, only a base infiltration is done with small volumes of 100–200 mL per region. The injection strength is set at the body-jet to level 3–4 and in BodyJet Evo to “Long 4”.

In order to avoid haematoma in the breast region and to enlarge the space available for the uniform fat distribution, we infiltrate tumescence solution into each breast (about 200 mL per breast) not only in the subcutaneous area but also retro-glandular before the suctioning. The fat can be distributed easily in this manner. But this variant requires subsequent evaluation. The introduction of the solution into the breast is done in a sensible manner after infiltration of the expected areas.

Thereafter, the 2.5 mL infiltration needle is replaced by the 3.8 mL rapid harvesting needle.

The LipoCollector (Human Med AG) is interposed in the reverse flow to the suction tank (Fig. 6.22). The fat is retained in this, so that only excess flushing liquid again reaches the suction container.

The negative pressure is reduced to −500 in order to expose the fat to the least possible potentially damaging forces. A still lower under-pressure is, in principal, advantageous; however, the suctioning thus becomes more inefficient and slower. The suctioning is done with a setting of a spray jet strength of 1 on the scale of 1–5 (setting on the body-jet), during which a beginning is done with the region that was infiltrated first. Now care should be taken that the suctioned mixture of fat and tumescence solution will never become dry by means of almost constant use of the infiltration. This is important because fat cells can be more easily destroyed due to shearing forces than by an excess of pressure.

6.4.5.2 Processing the Graft

Liquid and fat are automatically separated in the LipoCollector. The liquid is suctioned into the waste container. About 600 mL of floating fat (scale of the LipoCollector) yields a sufficient quantity of 250–280 mL per side for an aesthetic breast enlargement on both sides after filling up

Fig. 6.22 LipoCollector (© the company Human Med with kind courtesy)

Fig. 6.23 Filling of the syringes

the syringes. With enough fat harvested the bottom valve is connected to the vacuum. This has to be reduced now to -200 mm Hg to avoif damage to the filter mesh. The oily debris which is drained with the waste liquid can vary widely between 10 and 100 ml. It does not contain any vital /stem cells. The filter does not allow for the real fat particles to pass.

The remaining fat is drawn into 50 cm^3 irrigation syringes. The larger syringes help to asses the amount of fat tobe grafted. The 50 cc syringes can be directly fitted to the cone of the 10 cm^3 Luer Lock syringes, which are used for the purpose of reinjection.

The Filling of the syringes is shown in Fig. 6.23.

6.4.5.3 Reinjection

- **A more precise control of the injected volume becomes possible by working with five syringes, respectively, each with 10 cm^3, as has been shown advantageous in practice**.

The harvesting of the smallest possible aliquots of fat cells is essential, as has been described above, for successful grafting. A uniform distribution is required in the tissue with strict avoidance of any accumulation of large quantities at one point, so that these small tissue units have good supply from the surrounding tissue until the first new vessels sprout in. This can most easily be accomplished by using a sufficiently long, blunt needle. We generally use a single pricking point—lateral about 2 cm below the sub mammary fold—per breast, in order to achieve the desired result (Fig. 6.24).

But if the surgeon feels more confident of achieving a uniform distribution through several pricks, then this is also certainly possible. In this case, a prick at the areola boundary can also be done. Just keep in mind that every prick leaves a tiny scar.

Two common procedures are used:

– The needle is moved back and forth with long plunger movements of about 10 cm length, and in doing so, the plunger is depressed, so that with a total of 10–20 piston movements, the content of the 10 cm^3 syringe is distributed in the tissue (Fig. 6.24).

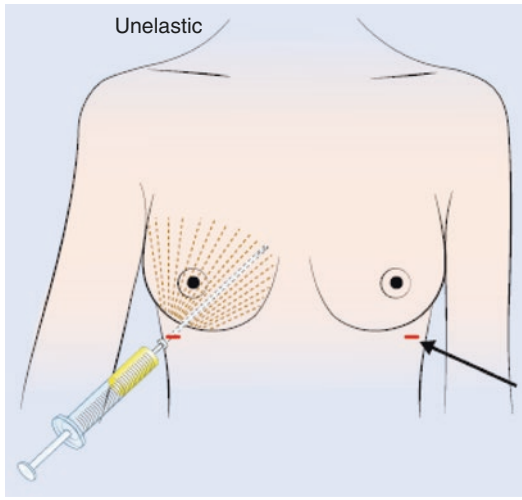

Fig. 6.24 Injection (drawn as per a diagram by K. Ueberreiter)

– The needle is pushed forward until it stops, and finally during withdrawal to a length of at least 10 cm, a volume of about 1 cm^3 is expressed. For the purpose of an exact dosing, a mechanical device can be used, which is placed on the syringe.

Depending on the site and position of the region to be filled up, the fat injection is given, until the area to be filled in bounces elastically, but is not filled up until it is hard.

- **In case of aesthetic augmentation, a volume of 200–300 mL can be transplanted per breast; in the vast majority of cases, it is about 250 mL in our premises**.

We could demonstrate in an MRI-controlled, prospective study that about 80% of the fat tissue harvested does heal. But only the pure fat component after centrifuging was used for the evaluation. This consists of 75% of the retransplanted, floating fat mixture [20, 25]. The rest of the 25% consists of the tumescence solution used from the detachment of the fat.

- **Thus one can assume an assured healing of the transplanted (gross) tissue of 60%. After healing, this corresponds (in case of an average grafted volume of 250 mL) to a volumetric gain of a half of the bra cup size**.

The pricking points should be closed with adhesive strips that have to be left on the skin for a period of about 10 days. Materials like the Omnistrip (R) of the company Hartmann have proven to be reliable and can be in place for the desired period, and even taking a shower is possible having them on. In a similar manner, the pricks after the suctioning are closed. It is recommended to clean the surrounding area of the wound previously with gauze pads dipped in alcohol, so that the plaster can get attached more reliably.

6.4.5.4 Postoperatively

A suitable compression garment is now worn for the compression of the suctioned region. The breast is kept warm through a spool of wide absorbent cotton. Any strong pressure by wearing a bra or excessive movement (through sports, massage) is to be avoided for a period of 4 weeks after the operation.

The patient is pointed out that the visual result corresponds (with the general swelling about 7–10 days postoperatively) to the long-term result after the second intervention. We recommend a "selfie" taken to our patients at this period. The next fat graft can be carried out 3 months later; one or several further transplantations are easily possible.

One example is shown in Fig. 6.25.

Summary for the Practice

The BEAULI (TM) Process described here for transplantation of autologous fat fulfils all the demands that are made for a successful fat tissue transplantation. This method has proved to be reliable, in the past 10 years worldwide in thousands of cases. The big advantages lie in the reliability in achieving the results, the simplicity and quickness in execution and the almost complete lack of any complications. No more than just 60 min are required for the execution of aesthetic mammary augmentation on both sides if one has had some practice. A big harvest can be

reaped with the gain of half a breast size in a single operation.

Other application possibilities include the replacement of silicone implants with one's own fat [26] as well as breast reconstruction after mammary carcinoma [27].

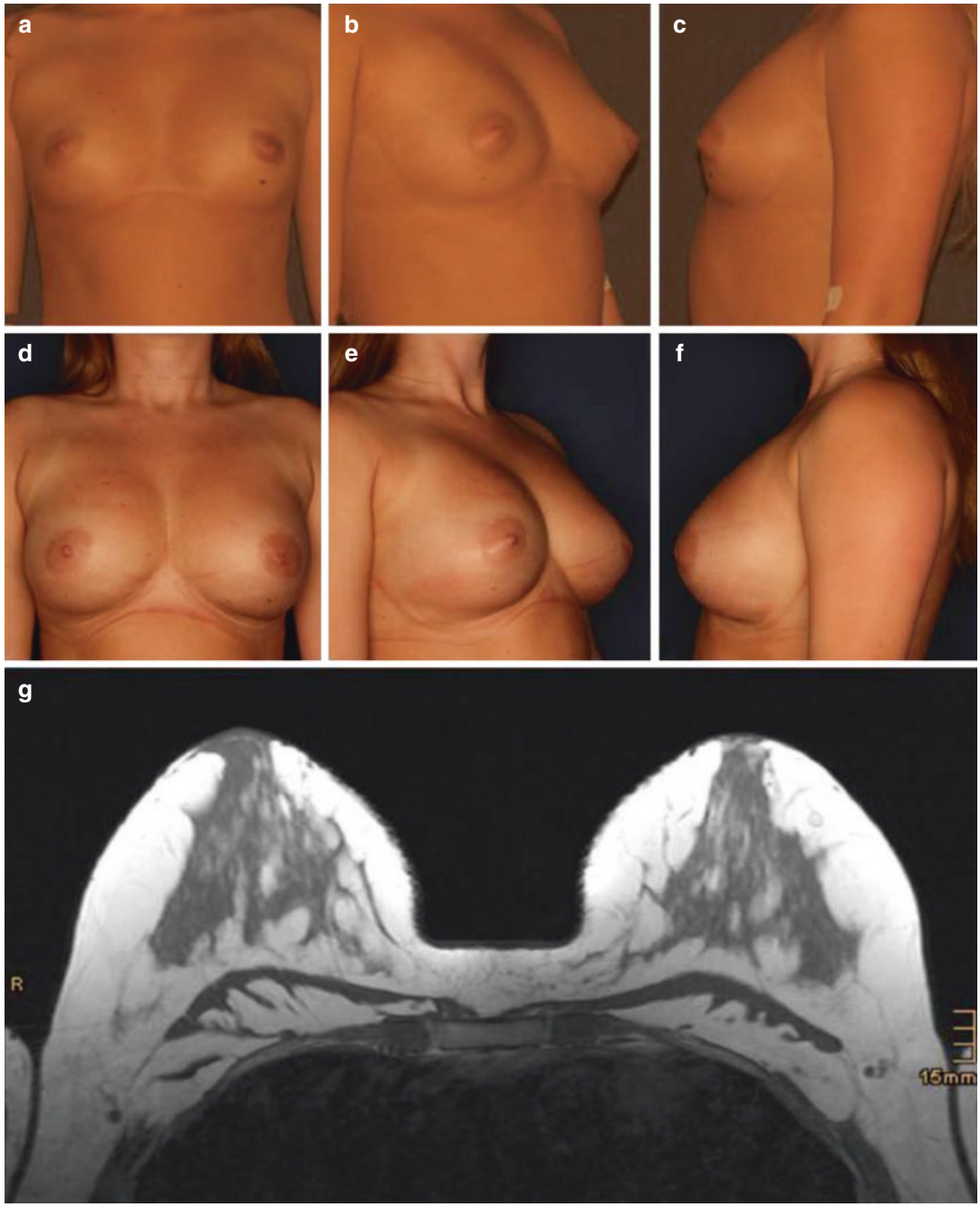

Fig. 6.25 (**a**–**g**) Clinical aspect before (**a**–**c**) and 5 years after treatment two times (**d**–**f**), (**g**) MRI—diagram 5 years postoperatively

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7 Educating the Patient

Klaus Ueberreiter

While advising our patients, it is pointed out to them that volume recovery in a single prosedure is limited in general to half a cup size permanent increase. The most frequent postoperatively discussed side effect is not, however, the breast volume but possible uneven surface at the suctioned areas. For this reason, educating the patient regarding fat suction and the resulting possible consequences gains special importance.

In case of young patients with a tight skin, the risk of an uneven surface can be considered as very low, provided a very careful liposuction has been carried out. But if thick fat cushions are to be found under a less tight skin, then uneven surfaces could result from frequently to very probably depending on the strength of the fat tissue.

- **In case of patients with very thick adipose tissue, we indicate a probability of up to 100% of an uneven surface result.**

There is plenty of information on the Internet about the consequences of transplantation of fat tissue, which discusses the formation of oil cysts, calcification, as well as a disappearance of the tissue over a prolonged period of time. But this is happening only if the fat tissue is transplanted in big chunks and is badly distributed. For this purpose, a safe method to avoid such side effects is to be urgently advised.

One can also point out the fact that small oil cysts and calcifications do occur in about 50% of all operational interventions and such findings can be seen even in non-operated women in the mammography.

In any case, one has to point out that oil cysts and calcifications could possibly occur. But these very rarely occur in practice in the BEAULI (TM) procedure.

- **As a whole, the possible side effects and complications are much lower compared to enlargement of breasts of using silicone implants.**

There is absolutely no proof to be seen whatsoever in the more than 100-year-old history of transplantation of autologous fat tissue that any malignancy could occur after this process. But it should be pointed out that purely from a statistical viewpoint, every tenth woman will *quoad vitam* be affected by breast cancer, and as such, this could also happen after autologous fat augmentation.

One advantage of autologous transplantation lies in the fact that a postoperative diagnostic is easily possible at any time even starting from 6 weeks after the intervention, for example, a mammography.

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

K. Ueberreiter (ed.), *Autologous fat tissue transfer*, https://doi.org/10.1007/978-3-030-05402-1_7

As part of a reconstruction surgery after breast cancer, there is widely varying information to be found in different countries. After a mastectomy and a longer disease-free interval, a reconstruction by fat grafting appears to be secure. In case of breast-conserving therapy, there are contradictory publications on a possible risk of a relapse, so that here a breast reconstruction can be advised only with some reservations.

Documentation and Radiology

8

Christian Herold

8.1 Standard Photography

Pre- and postoperative findings should also be carefully documented by means of photography as in case of other body-modifying interventions in plastic surgery when performing autologous fat tissue transplantation.

Standard Exposures

Face

In General:

- Hair and the face.
- The dress should not come in the way.
- No jewelry, no makeup, and no hearing devices.

Exposures:

- Complete view
- Details
- Right side profile
- Left side profile
- Half profile, right
- Half profile, left

Nose

Exposures:

- Complete view
- Details
- Right side profile
- Left side profile
- Half profile, right
- Half profile, left
- From below with head and neck
- From the top with chin to the breasts

Lids, especially during the treatment of the tear troughs

Exposures:

- Complete view
- Details with open and closed eyes

Breasts

Exposures:

- Frontal (image section of the clavicles and shoulders top to the superior iliac spine below and along with this, the arms near the body)
- Inclined 45°
- Lateral 90°

C. Herold (✉)
DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

Plastische Chirurgie und Handchirurgie im Mühlenviertel, Bremen, Germany
e-mail: c.herold@diako-bremen.de

K. Ueberreiter (ed.), *Autologous fat tissue transfer*, https://doi.org/10.1007/978-3-030-05402-1_8

Hand
Exposures:

- Complete view
- Details
- Palmar and dorsal (pro- and supination) with stretched out fingers and with the fists closed
- Depending on the findings from the ulnar or the radial side with stretched out fingers and with the fists closed

Abdomen
Exposures:

- Frontal (upper limit inframammary, lower limit to the middle of the upper thigh)
- Inclined 45°
- Lateral 90°
- Frontal, with arms raised
- Lateral, upper body bent to 45°
- Using the Valsalva pressure test frontal and lateral (hernia)

Buttocks
Exposures:

- Complete view
- Details
- Right side profile
- Left side profile
- Half profile, right
- Half profile, left

Upper thigh
Exposures:

- Complete view frontal and rear
- Details (e.g., correction of hollow spaces)
- Right side upper thigh:
  Right side profile
  Half profile, right
  Half profile, left
- Left side upper thigh
  Left side profile
  Half profile, right
  Half profile, left

Lower thigh
Exposures:

- Complete view frontal and rear
- Details
- From medial
- From lateral

8.2 3D Photography

A virtual 3D image of body regions can be obtained using 3D scanners using exposures involving multiple cameras. A simulation of expected effects of a mammary augmentation can be simulated. Thus, the possibilities are opened up of showing the patient in advance the expected result of the operation. This can simplify the decision-making on the part of the patient. But then, concrete expectations are raised regarding the operation, which then have to be fulfilled by the surgeon [1].

In this manner, form changing interventions can be planned and documented noninvasively [2–5].

High costs of equipment and hardware have prevented a large-scale popularity. But cost-saving alternatives are increasingly being evaluated, e.g., the use of deep sensor cameras of the Microsoft Kinect Multimedia systems. Even web-based software solutions are being increasingly offered and enable the bypassing of high hardware costs. In this process, patient photo taken by digital cameras is sent online to firms for a 3D reconstruction.

Another alternative is the cost-free App 123d Catch, with which photos taken on mobile devices of the firm Apple are uploaded automatically via the Internet to external computer centers. The user then gets a finished 3D model in return. Initial evaluations of this technique appeared to be promising. A comparison with a fixed system showed a comparable accuracy of the measurements. Finally, it has to be ensured that data is protected in case of actual patient photographs [6].

- **Finally, it can be said that 3D systems can be used as a supporting feature, in order to gain valuable information regarding the surface, contour, and symmetry of the body region being treated.**

8.3 Mammography and Ultrasound

Mammographically, transplanted fat appears to be normally round and radiolucent. Frequently, no specific findings are indicated, especially in case of peri-glandular injection in the fat-rich breasts [7].

Fat necrosis appears as a central radiolucent areola with a calcified seam. Cystic fat necrosis shows a liquid-like central areola. Scattered micro fat can be mistaken for carcinoma-based microcalcification, but these calcified deposits can generally be well differentiated through their morphology.

The worry that an autologous fat transplantation in the breast can encumber the diagnostics or early identification of breast cancer cannot be supported by recent studies.

Mammographic changes after autologous fat transplantation and reduction mammaplasty were compared in a study by Rubin et al. [8]. This study yielded the data shown in Table 8.1.

- **Normal changes after autologous fat transplantation can be best confirmed using ultrasound. Here, we can find oval hypoechogenous smooth-walled changes, which mean these are oil cysts.**

Table 8.1 Mammographic changes after autologous fat transplantation (according to [8])

Mammographic change	Fat tissue transplantation (%)	Reduction mammaplasty (%)
Oil cysts	25.5	31.5
Intramammary scar	17.6	85.6
Calcification	17.1	27.2
Calcification that required a biopsy	4.6	1.6
Unclear space demand that required a biopsy	2.8	13.6

These benign changes can be best demonstrated using sonography due to high resolution (0.8–0.35 mm). In addition, transplanted fat particle can be differentiated properly from the surrounding tissue through ultrasound.

Using sonography, Fiaschetti et al. [9] could detect typical oil cysts with up to 10 mm diameter in 67% of the breasts after transplantation of autologous fat tissue 3 months after transplantation of fat tissue and only in 46% of the breasts 12 months after injection. During MRI studies conducted simultaneously, these changes, which were typical for fat tissue transplantation, could be detected only in 8% after 3 months and in 4% after 12 months. This could be attributed to the lower resolution of the MRI. Large fat necrosis of >20 mm in diameter could be detected to the same extent in ultrasound and in MRI.

- **Space demands with no clear limitation and vascular blood flow signal are to be considered as highly suspicious, and a carcinoma can be positively predicted with a 100% certainty** [10] **and, therefore, have to be followed up accordingly.**

8.4 MRI

In nuclear magnetic resonance imaging, which has a resolution of 1.8–2 mm, round, hypointensive findings in the fat-suppressed STIR sequence are to be considered as normal.

MRI is the most sensitive technology that can be used to identify fat necrosis and to be able to clearly differentiate it from oil cysts or a malignancy. In nuclear magnetic resonance imaging, fat necrosis appears as heterogeneous hyperintensive areolas in T2-weighted images. This is because they contain central colliquations and internal bleeding [7].

Using fat-suppressing techniques, the signal of oil cysts can be suppressed, because despite liquefaction, these are basically fat tissues. Due to their smaller size, oil cysts cannot be displayed properly in the surrounding fat tissue. This explains why oil cysts could not be detected

using MRI diagnostics in some of the published papers [11].

MRI has a special function in the detection of clinically predicted tumor relapse. This is because this technology possesses an excellent sensitivity and speciality (>90%). Only in case of purely intraductal processes the sensitivity is reduced (60% and 85%). The specificity in breast imaging can be further enhanced [9] through dynamic investigations using contrasting agents, fat saturation, and subtraction techniques.

See Chap. 17 for an evaluation and measurement of the results.

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The Face

9

Yves Surlemont

9.1 The Treatment of Wrinkles

9.1.1 The Harvesting of Micro and Nano Fat

The terms "mini," "micro," and "nano" refer to the size of the fat particles. Due to the influence of the diameter of the transplanted fat particles on the result of the transplantation [1, 2] secondarily as a result, the diameter of the instruments used in transplantation is of decisive importance for the aesthetic result of the operation.

A set of cannulas standardized equipment for the Coleman technique, was introduced during the end of the 1990s for the purpose of facial surgery [3]. During those days, the outer diameter of the grafting cannulas used to be 1.5 mm (17G).

These cannulas were really not suitable for use in specific areas of the face, e.g., the lids and lips [4]. This resulted in the fact that new types of cannulas were developed for the harvesting and the grafting of smaller fat particles. These grafting cannulas were called the "minis" [5]. The author of this paper has been using cannulas of the size 16G, 19G, and 22G (Fig. 9.1) since the mid-2000s. Needles of up to 25G are used for the skin grafting into the skin.

Fig. 9.1 Coleman little needles (micro needles)

It is not possible to graft in very hard tissue like scars or the dermis using blunt, round tip cannulas; in such cases, sharp injection needles are used [5].

The transplantation of small fat particles using blunt cannulas of a small diameter was later called "microfat grafting" [6], or SNIF ("sharp needle intradermal fat grafting")—depending on the application [7] Fig. 9.2).

Tonnard et al. introduced the term nano fat ("nanofat") in the year 2010 (see Sect. 4.1.1) and published a paper in the year 2013. The so-called nano fat enables us to transplant fat into the dermis using a 27G needle. For this purpose, the aspirate is emulsified mechanically. This is done by injecting it back and forth from one Luer Lock syringe into another via an inclined three-way valve connected between them (Fig. 9.3), and then the filtration is done. After the emulsification the so called Nano fat does not contain intact adipocytes anymore.

Y. Surlemont (✉)
Clinique Saint Antoine, Bois Guillaume, France
e-mail: dr.surlemont@mce-rouen.fr

K. Ueberreiter (ed.), *Autologous fat tissue transfer*, https://doi.org/10.1007/978-3-030-05402-1_9

Fig. 9.2 (**a–e**) A 48-year-old female patient: a stage of autologous fat tissue transplantation of the upper lip (3 mL) and the lower lip (4 mm) with mini cannulas and 25G needle (2 mL) combined with cervicofacial facelift and the removal of a nevus of the left commissure (**a**). Preoperative marking (**b**). Postoperative day 7 (**c**). Postoperative day 15 (**d**, **e**). The same patient (**d**). Preoperative (**e**). After 4 years

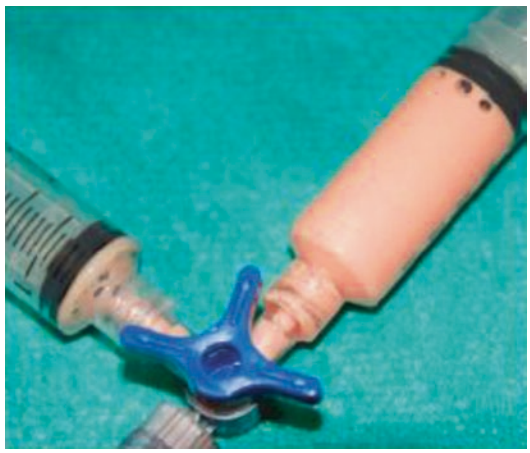

Fig. 9.3 Three-way valve

- **The nano fat grafting is generally carried out in connection with a microfat grafting of the layer lying above it.**

While using this technique, a yellow coloring of the upper skin layer could occur temporarily, which vanishes after some time.

Sometimes a small fat bubble is also seen, which spontaneously gets resorbed after a couple of days (Fig. 9.4).

The nano fat can improve the skin quality and thus the skin appearance when it is injected into the skin (Fig. 9.5).

The improvement of the skin quality by fat transplantation has been known for a long time and has been proven in many studies [8, 9]. The mechanism of effect of the nano fat has in these cases not been clearly defined. Tonnard et al. [10] have reported that the positive effect mainly comes into effect through the transplanted stem cells. This is because the adipocytes do not survive the process of emulsification.

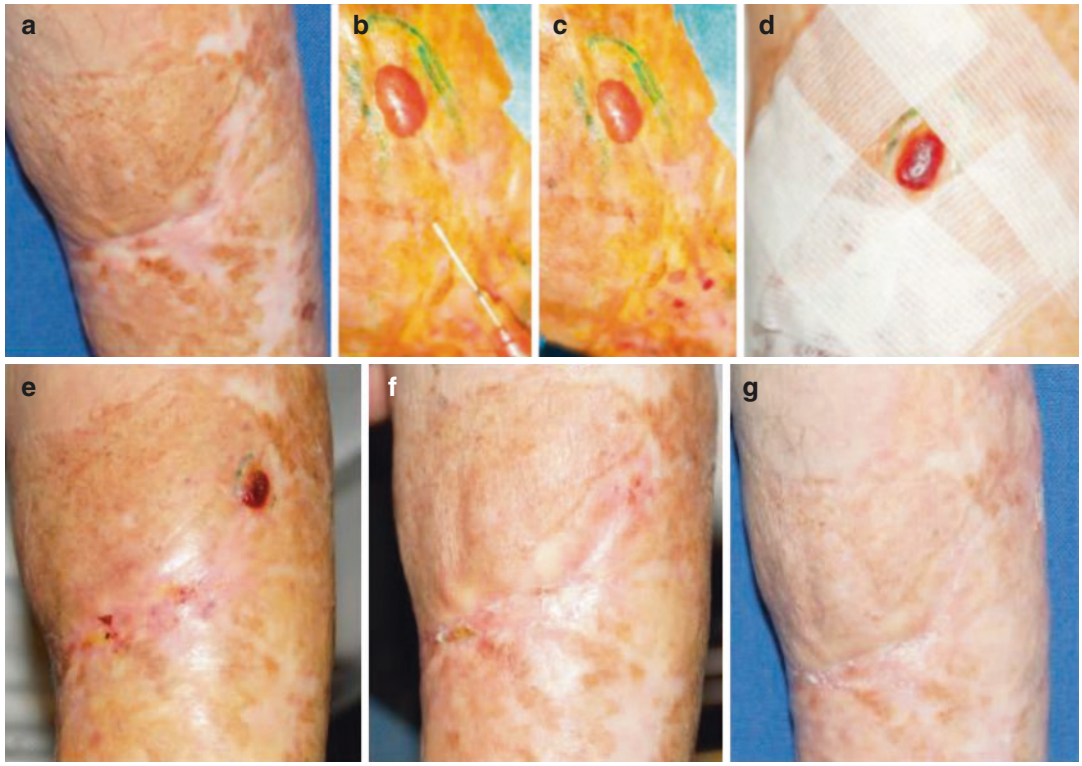

Fig. 9.4 (**a–g**) Nano fat grafting below a 30-year-old burn scar of the lower arm. (**a**) Preoperative. (**b**, **c**) Perioperative formation of a fatty bubble during the injection using a 25G needle. (**d–g**) Postoperative view on day 1 (**d**), day 9 (**e**), and day 16 (**f**) and after a period of 6 months (**g**)

Fig. 9.5 (**a–g**) Nano fat grafting on the face. (**a**) Female patient of 18 years of age. (**b**, **c**) Preoperative view, photographed without (**b**) and with (**c**) a flashgun. At that time, the patient of 46 years of age, weighed 50 kg. (**d**) Marking of the planned nano fat injections. (**e**) Clinical view after the procedure. (**f**, **g**) Result after a period of 18 months photographed without (**f**) and with (**g**) a flashgun. At that time, the patient weighed 53 kg

Fig. 9.5 (continued)

9.2 Autologous Fat in the Face

Since the introduction of the lipostructure technique for the transplantation of autologous tissue by Sidney Coleman in 1998 in France [3, 11], this process has found application not only in reconstructive surgery but also in aesthetic surgery.

- **In the hands of an experienced surgeon, there are very few to absolutely no complications to be experienced at all.**

Numerous modifications were introduced in the years thereafter [4–6, 12], which can now make the result of fat grafting predictable and now result in a much briefer recovery period.

In the following, the experience of the author of this paper since the introduction of mini cannulas in the year 2007 has been described.

9.2.1 Fat Harvesting

There is a basic difference compared to ready-made fillers: Using 1–2 mL of hyaluronic acid, a significantly larger volumetric effect is achieved than with the same quantity of autologous fat. One's own fat is permanent and has very few side effects. The volumes used lie here between 5 and 50 mL.

If a volume of lesser than 15–20 mL is required, then one can do a manual liposuction. For this purpose, we use cannulas of 2 or 1.6 mm external diameter depending on where the harvested fat is going to be grafted.

Initially, the donating area is infiltrated with 40–80 mL of tumescence solution. A waiting period of 10 min should be maintained, before one can start the suctioning. In no case shall one use Prilocaine, because it can result in cell toxicity [13].

For the purpose of suctioning, the cannulas are, respectively, placed on a 10 mL Luer Lock syringe.

- **Only a slight withdrawal at the syringe is important (2 mL, respectively), in order to avoid an unnecessary damage to the tissue.**

For each 10 mL syringe, about 5 mL of transplantable fat can be harvested. A brief centrifuging is possible (e.g., hand centrifuge), but it is not compulsory. Time can be saved, if one is familiar with the method.

If more than 20 or 30 mL is required, then a harvesting is recommended using the water-jet process (WAL) using needles of 3.5 or (even better) 3.0 mm outer diameter and, finally, decanting the aspirate.

- **It is recommended to cover the suctioned area with an adhesive plaster bandage for a few days, so that postoperative swellings can be extensively avoided. It is not necessary to wear compression clothing.**

9.2.2 Transplantation

The transplantation is carried out using mini, micro or nano technologies [7]. Cannulas of an outer diameter of 1 and 0.7 mm; the needles measure 22 and 25G (Sect. 4.2.4). Even if, basically, sharp needles can be used, today, there is a great variety of blunt needles available, which should be given preference due to safety reasons (fat embolism).

An overcorrection is not required, because it does not bring about any better results, and permanent heavy swelling of the face, which is usually seen in the lipostructure method, is avoided.

- **It may be recommended, in each case, to plan a second session right from the beginning, because this procedure always yields better results.**

Before the operation, the areas to be injected should be marked out with the cooperation of the patient using a mirror. In this process, one can also estimate as to which areas, what volumes, and what layer the transplantation has to be done.

The example (Fig. 9.6) shows the anatomical units of the face, which are relevant for the transplantation to be carried out.

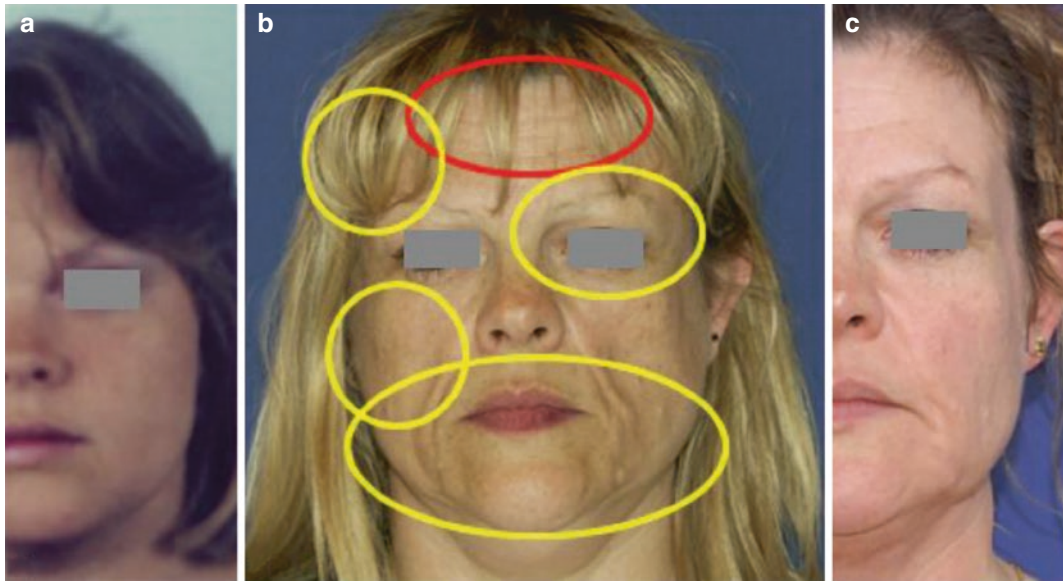

Fig. 9.6 (**a–c**) A 45-year-old woman, condition after an HIV infection through blood transfusion. (**a**) At the age of 24 years. (**b**) Transplanted areas. (**c**) Result after injection given two times (37 and 33 mL) after 1 year. The harvesting was done using Body-jet. The weight of the patient is stable at 74 kg

The pricking points are set using an 18G needle and these later become invisible. For this reason, it is not so decisive, as to where these pricking areas should be located.

- **It is important for planning that at least two entry points must be planned per receiving area, because the graft tunnels may intersect.**

The estimated recovery period has now become reduced (Fig. 9.7) since the transplantation technique has become refined and has changed for the better. In general, the patients become normal after just 3 days and nothing can be noticed. But the final healing result is reached after 4 weeks.

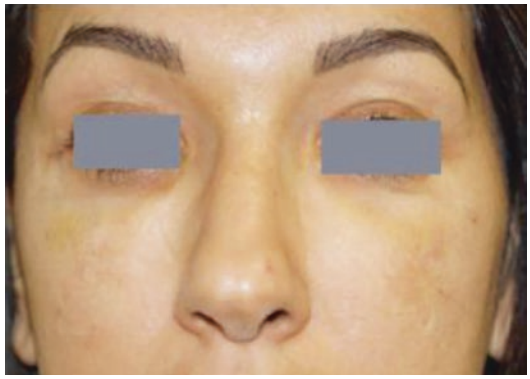

Fig. 9.7 A 38-year-old woman seen 3 days after the intervention, without makeup

9.2.3 Areas of the Face Where Transplantation Has to Be Carried Out

With regard to the areas of the face to be transplanted, all the regions can be taken into consideration for the fat tissue transplantation. But some local differences will be present.

The following gives a summary of the possible regions.

9.2.3.1 Forehead

A special situation is seen in the area of the forehead. In this area, exclusively nano fat should be used (Sect. 4.1.1), in order to avoid a visible bulge formation.

9.2.3.2 The Region of the Eyebrows and the Temples

Depressed temples are a typical sign of aging. In this area, a strong rejuvenating effect can be achieved through a large-scale autologous fat infiltration (about 10 mL per side). The injection is done subcutaneously with 16–18G cannulas—absolutely blunt—in order to avoid injury to the temple blood vessels.

Frequently lateral brows are mostly also sunken in, and even here, one can simultaneously achieve a level-raising effect (volumes 2–5 mL per side, cannulas 16–18G).

The examples are shown in Figs. 9.8 and 9.9.

Fig. 9.8 (**a**, **b**) The entry points, which are generally used, (**a**) preoperatively, (**b**) result after 2 days and 2.6 mL of fat grafting

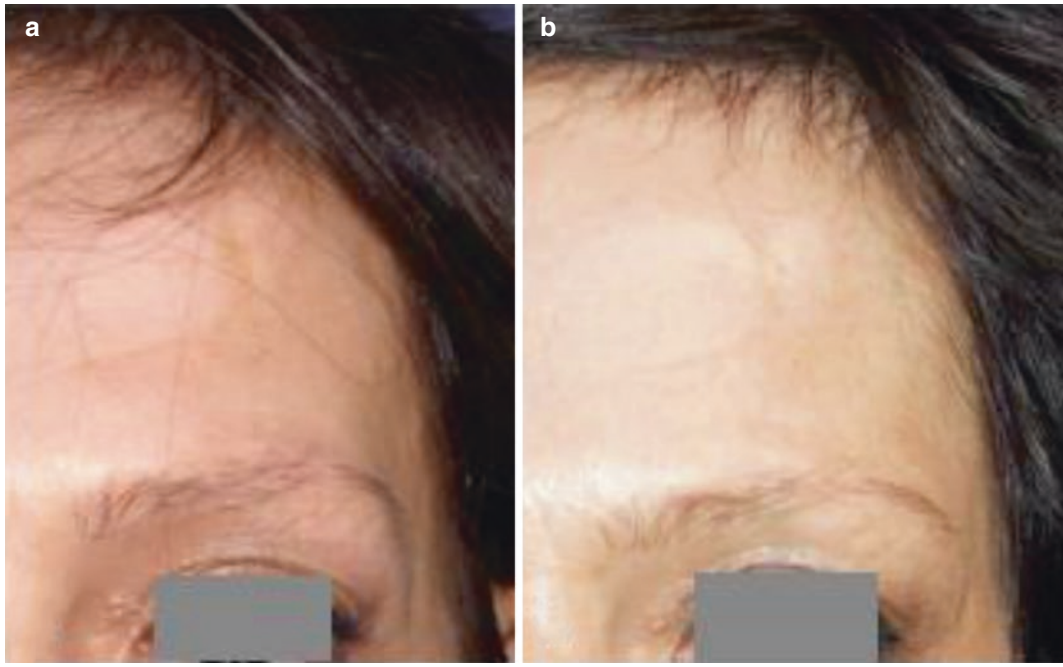

Fig. 9.9 (**a**, **b**) Before treatment at the age of 42 years (BMI 20), (**b**) 4 years later (BMI 20.66) with 2.6 mL mini fat grafting

9.2.3.3 Periorbital Region

A treatment of the periorbital region is technically more difficult. This is because the receiving region is not thick and the skin covering is also very thin. But it is precisely in such a place that impresive results can be achieved. This is because an increase in volume and an improvement of skin quality are achieved despite the operation being technically difficult to carry out.

A sign of aging includes the increasing loss of fatty tissue in the upper lid area, which results in the appearance of sunken eyes. About 0.5–1 mL of microfat above the septum orbitale especially in the medial area results in very positive changes.

Figure 9.10 shows an example. A skin resection would be a wrong option for treatment. This is because it will result in "hollow eyes deformity."

Wrinkles on the sides ("smile wrinkles") can similarly be treated and reduced in appearance. This is achieved by introducing a small quantity (about 0.2–0.5 mL per side) of fat **vertical** to the wrinkles in connection with a temporal filling and brow injection inside the skin.

9.2.3.4 Lower Eyelid

The skin of the lower eyelid should be filled up only with cell debris ("Nano fat"). Otherwise, visible lipomas could easily form here. Microfat can also be carefully transplanted infra orbicularly in case of strongly sunken eyes. The most visible tear trough can be improved through a deep, epi-periostealic injection of 1–2 mL of macro fat below the tear troughs.

With regard to the lower eyelid, treatment can be given for darkening and the eye ring operation indications (Figs. 9.11, 9.12, and 9.13). The fat is largely placed below the orbicular muscles and, to a small part, even directly under the skin.

9.2.3.5 Middle Part of the Face

No special technique is required for the middle part of the face. The entry points for the needles are selected in such a manner as they are required.

Fig. 9.10 (**a**, **d**) A young woman of the age of 21 (**a**) and 57 years (**b**) preoperative (**c**). The fat graft was placed in direct contact with the bone. 1.3 mL were applied in the upper lid and 1.5 mL in the temporal region using the mini technique. (**d**) Result after 6 years

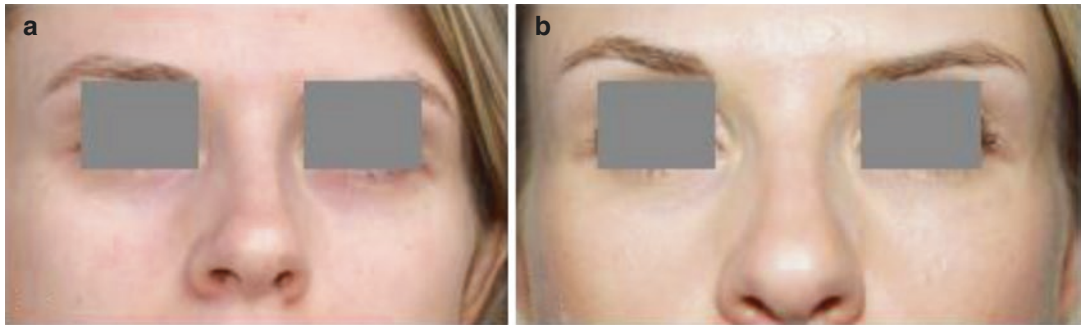

Fig. 9.11 (**a–d**) A 28-year-old woman at the time of the first treatment with dark eye rings (**a**) and 5 years later (**b**). A mini procedure had been carried out with 1 mL of transplantation during one consultation and "touch up" of 0.7 mL 1 year later. The same patient photographed without a flashgun (**c**) preoperatively, (**d**) 5 years later

Fig. 9.11 (continued)

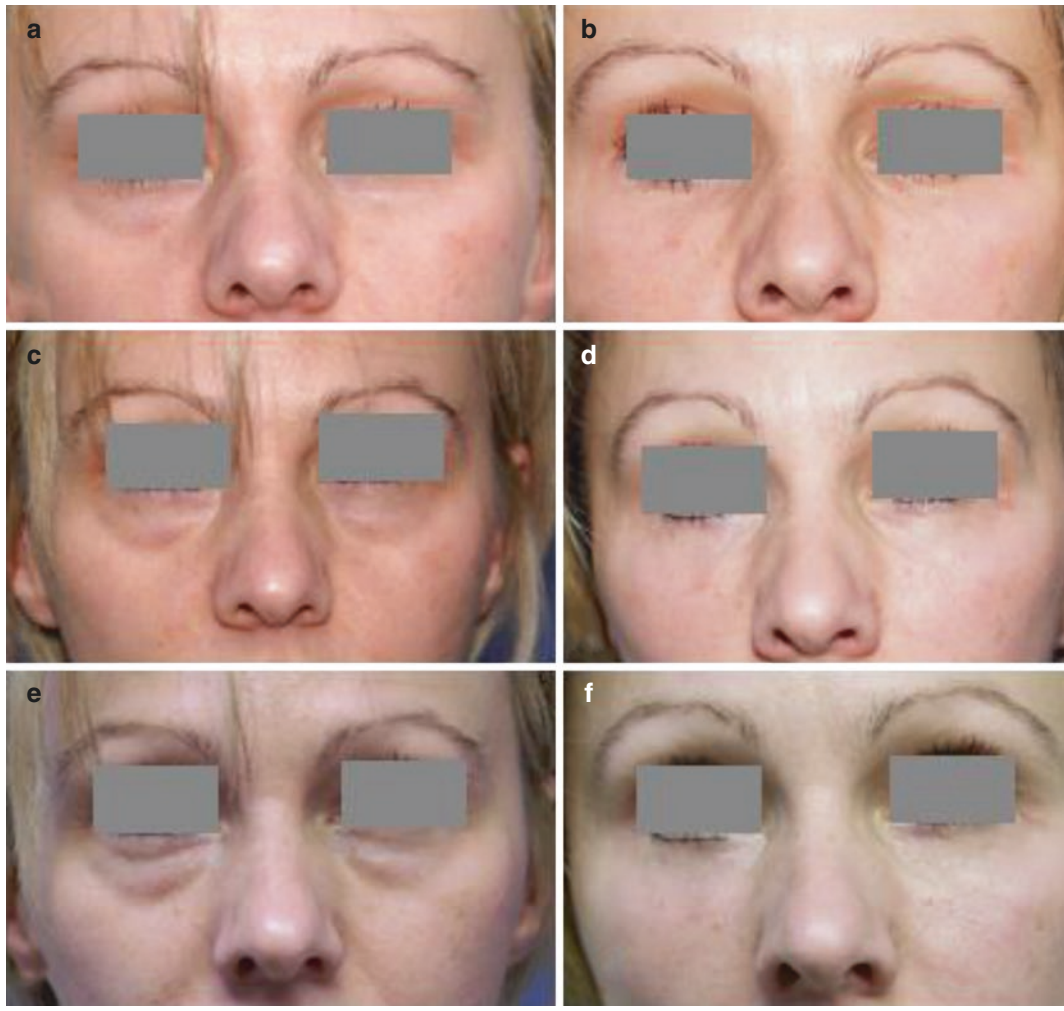

Fig. 9.12 (**a–f**) Frontal view (**a**, **b**) looking straight in the front. (**a**) A 38-year-old woman with a fat cushion at the lower eyelid and hollow orbital rims. (**b**) 2 years after the lower eyelid plastic surgery, removal of the fat cushion without a skin resection. In addition, autologous fat transplantation into the tear troughs (2.5 mL to the right and 2 mL to the left). (**c, d**) The same patient with her view directed upward (**c** preoperatively, (**d**) after the plastic surgery). (**e**, **f**) The same patient photographed without using a flashgun ((**e**) preoperatively, (**f**) after the lower eyelid plastic surgery)

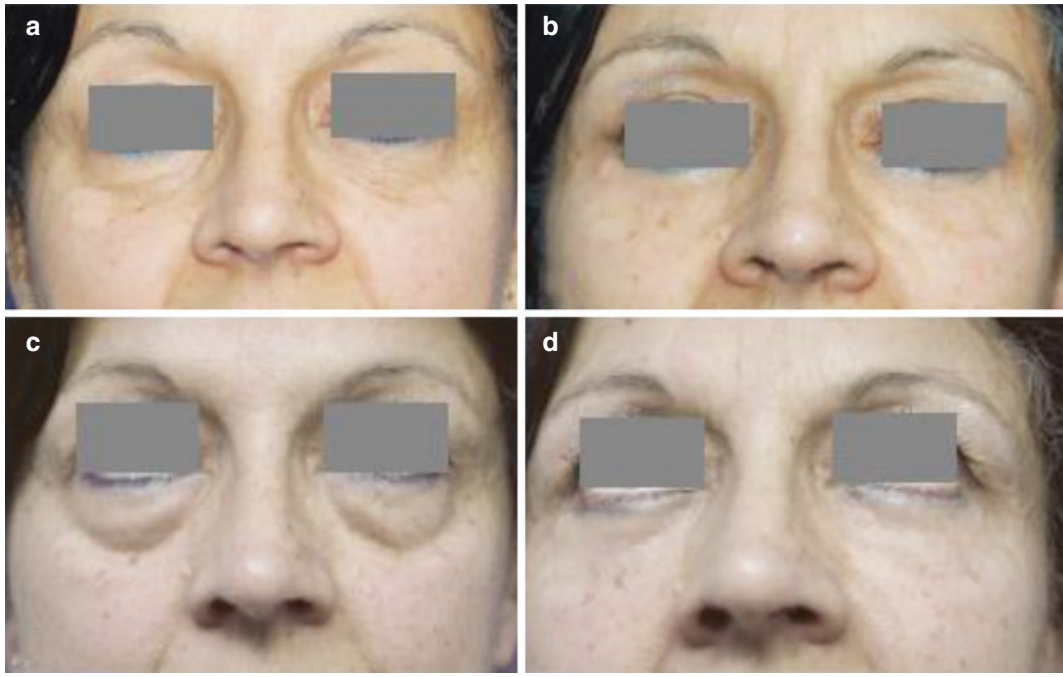

Fig. 9.13 (**a–d**) Frontal view while looking straight in the front. (**a**) A 60-year-old woman with fat cushions at the lower eyelid and hollow orbital rims. (**b**) Result 1 year postoperatively after the lower eyelid plastic surgery with fat removal, skin resection, and autologous fat tissue transplantation into the tear troughs (2 mL to the right and 2 mL to the left). (**c**, **d**) The same patient pre- (**c**) and postoperatively (**d**) photographed without using a flashgun with her view directed upward

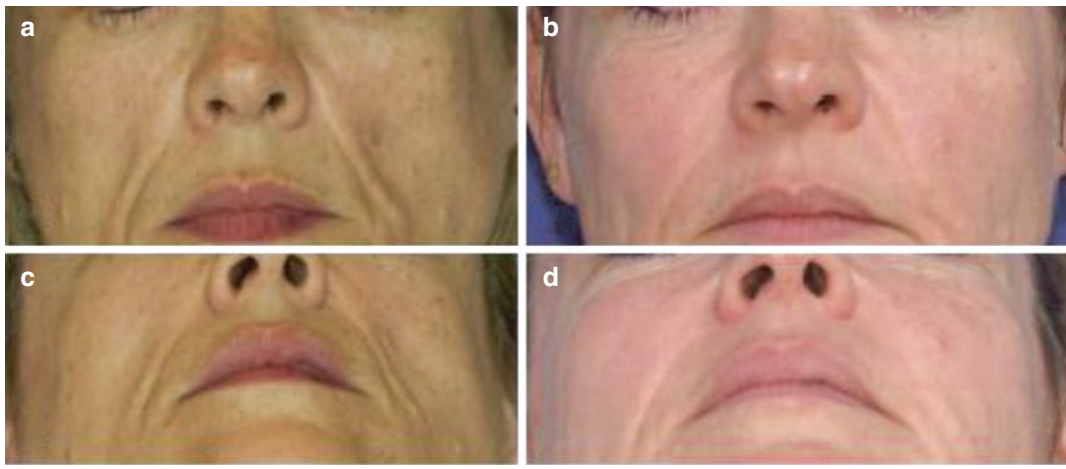

Fig. 9.14 (**a–f**) Female patients 41 years old (from left) and 46 years old after two fat graft were carried out using autologous fat transplantation (37 and 33 mL, respectively, to the right). The fat was harvested using the WAL technology. The patients had a stable body weight of 74 kg. (**a**, **b**) Frontal view while looking straight in the front. (**c**, **d**) Patient with the face directed upward. (**e**, **f**) Patient with the face looking downward

Fig. 9.14 (continued)

During the process, it is important to ensure that these points become invisible in the future.

Up to 40 mL of fat per side is distributed per side subcutaneously and, if required, also intramuscularly up to epi-periostealically. In this case, one can use cannulas of 16G.

One can clearly recognize the expected result in the series of photographs in Fig. 9.14 after fat grafting in the middle part of the face.

9.2.3.6 Lower Third Part of the Face, Lips, and Perioral Region

It is very difficult to achieve natural results after transplantation of fat in the perioral region. The taking rate in the area of the lips is not so great as in the other regions of the face. This is because this is an area that keeps moving and which cannot be adequately immobilized for any period of time. On the other hand, an enlargement of the lips should be preferred using autologous fat rather than other fillers. This is because with the proper procedure, there is no danger of hardening or swelling occurring.

- **However, it should be clearly explained to the patient right at the very beginning (as in the case of any fat transplantation) that in case they put on more weight (more than 5 kg), the transplanted areas will also exhibit a visible enlargement.**

On the one hand, the fat is applied below the mucosa in the lip region, in order to achieve a eversion of the lip, and on the other hand inside the muscle, in order to achieve a good projection. A direct subcutaneous injection of the upper lip skin should be done with greatest care and that, too, using micro or nano techniques [6].

The results are shown as examples in Fig. 9.15.

Fig. 9.15 (**a–m**) A 34-year-old woman (**a–d**), before autologous fat transplantation (left with makeup, right without makeup, respectively, with closed and open mouth). (**e**, **h**, **k**) Preoperatively in different positions of the mouth, (**f**, **i**, **l**) 2 years after autologous fat transplantation of 4 mL into the upper lip and 5 mL into the lower lip. (**g**, **j**, **m**) The same patient after 5 years postoperatively

Fig. 9.16 (**a–i**) A 39-year-old man at the time of the transplantation (5 mL in classical technique using 1.5 mm needle; **a**, **d**, **g**) and the result seen after a period of 3 years (**b**, **e**, **h**) and after 10 years (**c**, **f**, **i**); in addition, "touch up lateral" chin in the frontal view, in the right and left profile view

9.2.3.7 The Chin

The chin can easily be enlarged through fat transplantation without osteotomy (Fig. 9.16).

9.2.3.8 Jawline

The jawline can similarly be modeled through autologous fat injection. Interventions in this area are frequently combined with liposuction (Fig. 9.17).

The indication in this technique was limited due to the increasing ptosis and the reduced quality of the skin in the aging face. But the combination of this technique with other operations yields natural results, as is being shown in the case study examples in Figs. 9.18 and 9.19.

Fig. 9.17 (**a–f**) A 62-year-old woman (**a**), who rejected a facelift (**b**). The area marked in violet was treated with a liposuction; the area marked in green was treated with autologous fat tissue transplantation (4.5 mL in mini technique). (**c**, **e**) preoperative and (**d**, **f**) after 2.5 years frontal and lateral

Fig. 9.18 (**a–j**) A 54-year-old woman with skin excess and ptosis of the cervicofacial tissue (**a**, **b** preoperative). (**c**, **d**) Planning of the intervention: suction of the fat (marked in violet), autologous fat transplantation (marked in green), and facelift (personally modified technique), (**e**, **g**, **i**) preoperative and 1 year postoperative (**f**, **h**, **j**). In case of the face looking upward (result after 1 year), the effect is especially properly visible by the redistribution and harmonization of the volume (**i**, **j**)

Fig. 9.18 (continued)

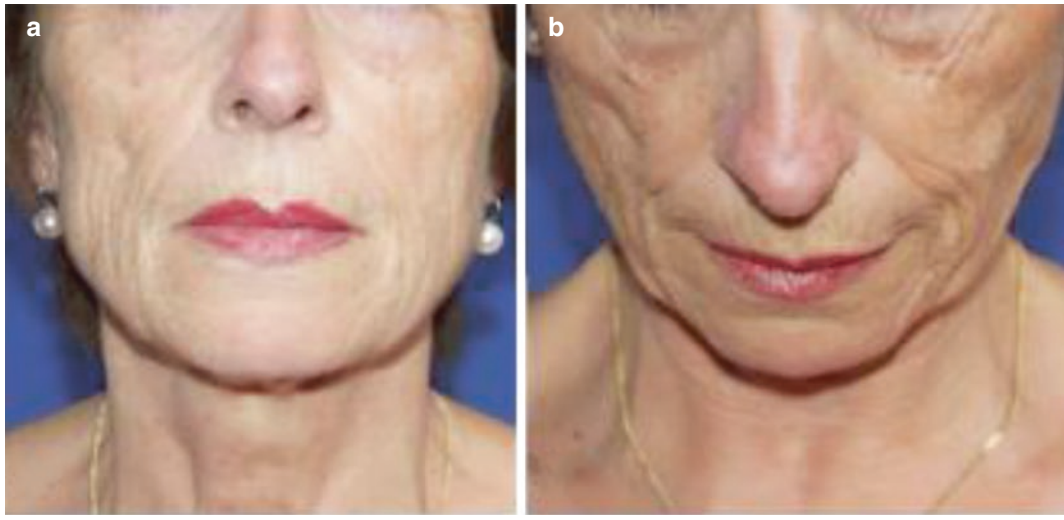

Fig. 9.19 (**a–h**) A 62-year-old woman with sunburned skin in combination with volumetric loss of the face (**a**, **b**, **e** and **g** preoperative aspect **b** pending position). (**d**) Planning of the intervention, autologous fat tissue transplantation in mini and micro technique (marked in green), and facelift (personally modified technique) and plastic surgery for the lower eyelids (**d**, **f**, **h**). The result is seen after 1 year (frontal and half profile view)

Fig. 9.19 (continued)

Fig. 9.19 (continued)

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Fat grafting to the Breast

10

Klaus Ueberreiter, Hartmut Meyer,
Yves Surlemont, Norbert Heine,
and Delia Letizia Francia

10.1 Aesthetic Indications

Klaus Ueberreiter

10.1.1 Aesthetic Breast Enlargement

There are certain preconditions to be followed during the process of breast enlargement using only just fat augmentation.

One important fact that is to be noted is that the patients should be non-smokers. Even though there are studies that do not indicate any differences in the healing of fat in case of both smokers and non-smokers, a clear difference can be observed in practice, either due to the reduced oxygen supply in the subcutaneous area or caused by the breakdown products of nicotine (cotinine).

- **In any case, if there are patients who desire a transplantation of adipose tissue urgently, but also do not want to give up smoking, they have to be warned about a possible reduced rate of healing.**

For beginners in fat grafting those patients are ideal, who do not want a very large enlargement of the breast and simultaneously can profit from a liposuction at the so-called problem zones. It is a little more difficult to handle such patients who do not have any special preference for regions for fat suctioning and (or) have a low body weight.

- **A BMI of 18 has proven to be the lower limit in our practice.**

But it is general possible that especially slim patients can put on about 2–3 kg of weight by increasing their calorie intake between individual interventions. Even if they manage to reduce

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

H. Meyer
Praxisklinik, Hamburg, Germany
e-mail: post@praxisklinik-brahmsallee.de

Y. Surlemont
Chirurgie Plastique Reconstructive et Esthetique, Clinique Saint Antoine, Bois Guillaume, France
e-mail: yves.surlemont@wanadoo.fr

N. Heine
Clinic for Plastic Surgery, Regensburg, Germany

Caritas Krankenhaus St. Josef, Klinik für Plastische und Ästhetische, Hand- und Wiederherstellungschirurgie, Regensburg, Germany
e-mail: nheine@caritasstjosef.de

D. L. Francia
Clinic for Plastic, Aesthetic and Reconstructive Microsurgery, Hand Surgery, Ernst von Bergmann Klinikum Potsdam, Potsdam, Germany
e-mail: dr.deliahoppe@gmx.de

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weight again after the procedure, still the increase in volume in the breasts remains.

It is advisable to counsel the patients beforehand, that per transplantation, about half a cup size volume can be gained. This corresponds to silicone implants of 100–150 mL. One can hand over these implants to the patients to be worn inside the bra beforehand, so that they can get an idea of what it's going to feel like. If it is noticed during this consultation that a much greater augmentation is desired just in one sitting, then one should generally advise them against autologous fat transplantation. In order to gain an entire bra size volume, two transplantations are required. These can be carried out after a gap of 3 months.

10.1.1.1 Execution

In order to prevent a hematoma in the breast region and to enlarge the space available for uniform fat distribution, tumescence solution (about 100 mL per breast) is infiltrated beforehand into each breast not only in the subcutaneous area but also in the retro-glandular area. The fat can be distributed more easily in this manner and post operative bruising is reduced. But this variant has not yet been evaluated as to whether with this procedure there is the possibility of transplanting larger volumes or if the healing rates are high because of the skin pre-expansion connected with the procedure. But there were no side effects observed.

Reinjection is done using a long, blunt, and not a very thick cannula. We have had a good experience with the 16 cm long BEAULI single-use cannula.

In order to leave behind the least number of visible pricking points, we use routinely just one point per breast, small pricks placed laterally below the sub-mammary fold. Any other pricking points can also be used but preferably at the areola boundary.

- **Note: It is very important to ensure that the future sub-mammary fold will be lowered in some cases up to 5 cm below the existing ones, especially in tuberous breast deformity. The newly planned sub-mammary fold should in each case be marked out beforehand using a marker pen.**

The needle is first inserted into the subcutaneous area in the direction of the jugulum. The fat distribution is begun in the upper inner pole of the breast. It is important that the 10 cm^3 content of each syringe (larger syringes produce more pressure and are not recommended), is emptied with a total of 10 or better, even 20 long strokes in both directions, in order to prevent fat accumulation in any case. In the process, the needles must be pulled back to at least 10 cm and again reintroduced, in order to ensure that a new subcutaneous channel is created.

The subcutaneous fat tissue above the Cooper ligament is loose and does not offer any noticeable resistance to the needles as compared to the glandular tissue. The needle can be seen below the skin (Fig. 10.1).

After filling up the upper inner quadrants with about 50–60 mL of fat, the upper outer, the lower inner, and finally the lower outer quadrants are filled up in a similar manner. Then one has to fill the subglandular area in and above the M. pectoralis major. Another 100 cm^3 or more is distributed here intramuscular/subglandular. This numerical data should be taken as a basis for an average aesthetic breast enlargement. In cases if skin laxity it is recommended to graft more volume retroglandurar than subcutaneaous. In case of very small, tight breasts in women who have never borne a child, only 200–220 cm^3 should be introduced in the first sitting.

- **The correct end point is reached, when the breast bounces elastically, and still one is able to compress it.**

One alternative consists in the intraoperative pressure measurement in the tissue, which according to Khouri, should not exceed 8 mm of Hg, but that is recommended more for scientific evaluation than for daily routine.

In case of a very thick dermis, the sub-mammary fold can often be raised up only slightly during the operation. An additional release by multiple needle insicions (rigottotomy) is not essential. This is because the tissue will yield in the weeks after the infiltration. But the patient is to be instructed that she has to wait for at least 4–6 weeks after the OP for the result.

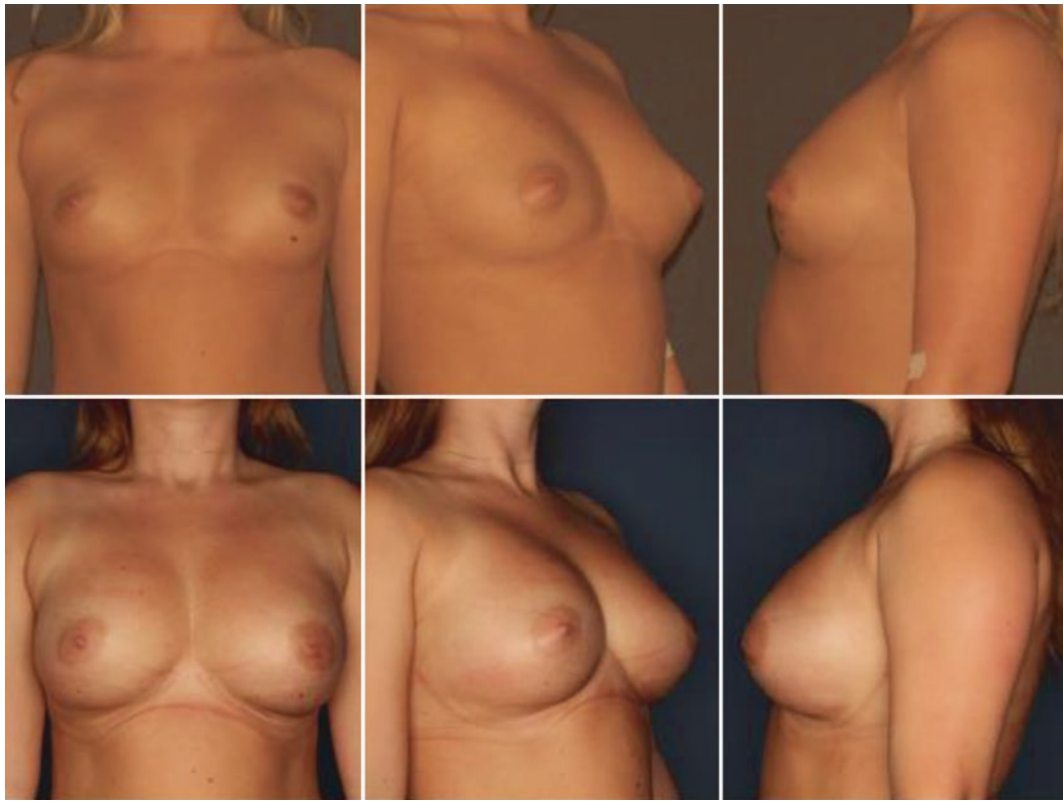

Fig. 10.1 A 22-year-old patient preoperative and 5 years after the second fatty tissue transplantation after the BEAULI protocol (of 240 Ml per OP)

After the procedure the breast is protected with a bandage made of cotton wool (8 cm) wrapped to ensure warmth and for the comfort of the patient (Chap. 18).

10.1.1.2 Postoperative Care

The swelling of the breast achieved in the operation continuously reduces in the oncoming days and weeks. As per our observation, a certain volume is reached after approximately 10 days, which can be achieved permanently after a second fat tissue transplantation. This is already explained to our patients well in advance and we recommend to take photos of the breast at this time ("Selfie"). It is very important to explain to the patients about the loss of volume occurring during the first six to eight weeks after the procedure, in order to prevent any disappointments.

Very slight changes in volume are seen after a period exceeding 6 weeks, so that if necessary, a second operation can be planned. This should be done after 3 months at the earliest.

10.1.1.3 Results

Using MRI evatiation, we have calculated an average rate of healing (take rate) of the grafted net fat tissue of 76 ± 11% (after distraction of the tumescence liquid) in a controlled prospective clinical study [1]. We found that the percentage of fat lies at about 75% in case of the mixture of fat cell chunks and tumescence liquid introduced, then one can expect an increase in breast volume to an extent of about 50–60% of the gross transplanted volume. This represents a permanent enlargement of 130–150 mL per breast for 250 cm^3 and thus approximately a half a bra cup size.

10.1.2 Combination with Silicone Implants

There is the possibility to improve the outer silhouette of the breast through additional autologous fat in case of silicone implants. This can either be done simultaneously with the augmentation or secondarily after the implant is already in place.

Silicone Implant Combined with Autologous Fat

The combination is preferably used in such cases, where there is less autologous fat available and, on the other hand, an enlargement is desired by a full cup size or more in a single sitting. Even in case of ptosis of the first grade, especially an implant with a high projection can achieve a better breast alignment than this would be possible using only autologous fat. In case of a thin tissue cover, implants frequently leave behind a broad, flat intermediate space above the sternum. Also very frequently, one can feel the edges of the implant at the outer sides of the breast. In these cases, one can use smaller quantities of fat tissue (100–200 mL) to achieve a good contour shaping and compensation to create a natural form.

It is not important whether the implant is introduced in a sub-glandular manner, completely subpectoral, or the dual-plane process.

- **As compared to a sole autologous fat augmentation, it is recommended in this case to carry out the transplantation from small pricks in the areola boundary. By this, the danger of a perforation of the implant can thus be avoided.**

A good form, shape, and compensation are possible in case of moderate implant sizes. Compression must be avoided in the posttreatment process. Redon drainages are recommended in the implant area (Fig. 10.2 and 10.3).

If after a silicone implantation the décolleté and the upper poles have not yet shaped out sufficiently, then form compensation can be carried out using fat tissue in the manner described above.

10.1.3 Execution of the Job Under Local Anesthesia

H. Meyer

- **During a liposuction, the patient herself is the best "warning system" for the prevention of accidental injuries.**

Due to the reduced sensibility of the fat tissue as compared to other structures, there is no urgent necessity of a general anesthesia or a deep sedation from a physiological viewpoint. After introduction of tumescence techniques, even large quantities of fat tissue can painlessly be removed.

- **Since, however, during the technically correct execution of the job, only the fat tissue is subjected to analgesia, any wrong entry of the needle will directly result in the patient crying out in pain. As all the movements of harvest and filling are to be performed in reduced speed, the entires process will take about double time as compared to anaesthesia assisted procedures.**

Due to this, serious injuries of nearby structures are prevented right from the start. Even the unavoidable trauma of the procedure and consecutive bleeding are reduced to a minimum. Apart from this, liposuction and lipo-transfer under local anesthesia enable an optimum mobility of the patient. Thus, better conditions are created for both the operating steps.

Thus, optimum attention can be paid to individual regions in different body positions. This increases precision and correct evaluation at the end of the procedure. A constant attention with regard to the type of needle entry and the optimum positioning of the patient are the preconditions for this.

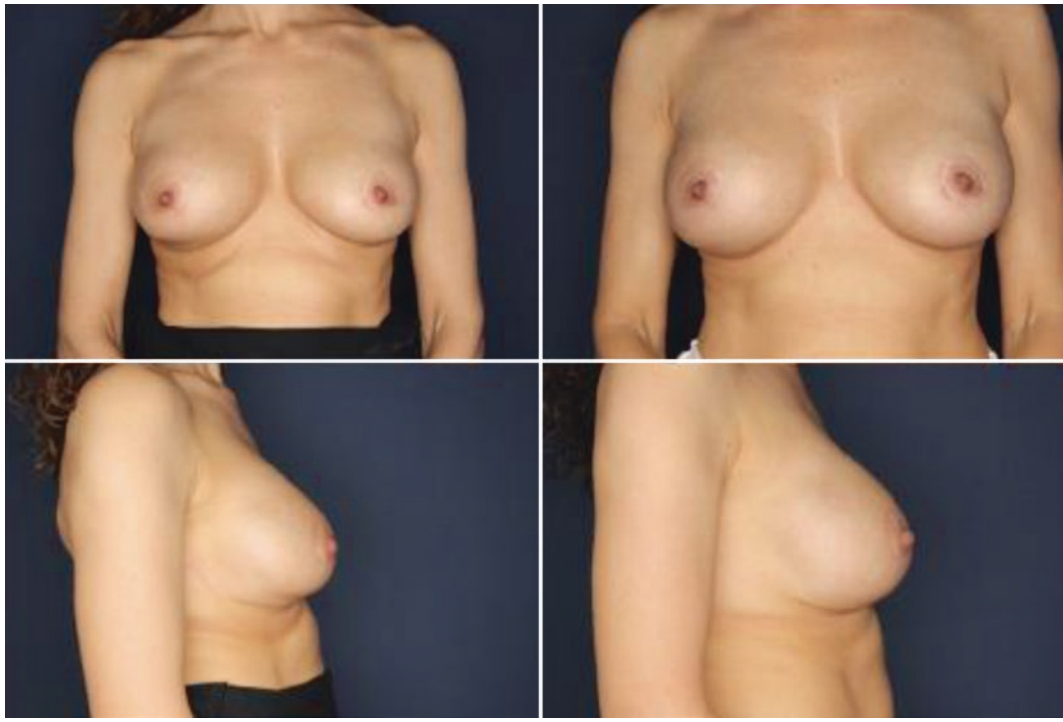

Fig. 10.2 A 30-year-old patient after silicone augmentation. (Left) preoperative and (right) 1 year postoperative after additional contour compensation using autologous fat. 150 mL caudal to the right and 80 mL to the left

Sedation

- A simple sedation at the beginning of the infiltration, e.g., with 5 mg of midazolam i.v. has proven to be effective. A perceptible relaxation of the patient who is fully ready to cooperate can be easily achieved by this in the shortest possible time.
- The effectivity of only just 15–25 min is definitely a bit less, but it eliminates the initial fear factor and feelings of uncertainty.
- Even a so-called verbal anesthesia which means a constant communication with the patient greatly contributes to a painless treatment.

The incisions marked beforehand using a color marker pen for the needles are injected with 1% local anesthesia after the usual skin disinfection. The length of the incision should be a max. of 5 mm.

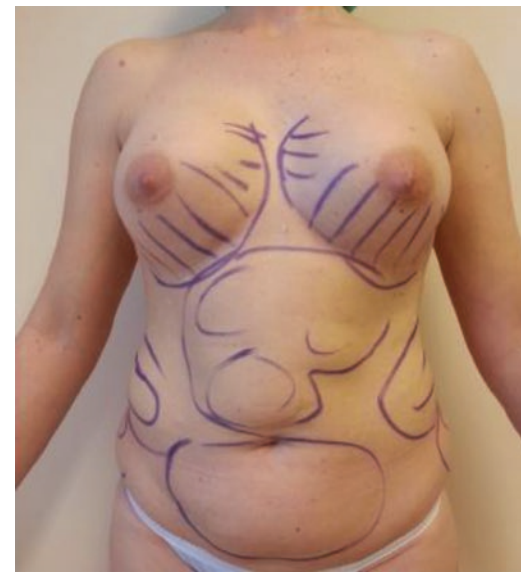

Fig. 10.3 Planning of an autologous fat injection in case of a flat implant

In order to achieve the most uniform suction results, one should use the "crisscross" technique. A suitable number of incisions must be applied depending on the number of regions to be suctioned.

Table 10.1 Infiltration solution

Substance	mg/mL	mL/1 L	mL/3 L
NaCl 0.9%		1000	3000
Lidocaine 1%	10	50	150
Epinephrin	1	1	3
$NaHCO_3$ 8.4%	84	20	60

Table 10.2 Flushing solution

Substance	mg/mL	mL/1 L	mL/3 L
NaCl 0.9%		1000	3000
Lidocaine 1%	10	25	75
Epinephrin	1	1	3
$NaHCO_3$ 8.4%	84	20	60

When using the water-jet assisted liposuction (WAL) technique, the liquid used is not supposed to act as a tumescence solution but is still supposed to achieve a prolonged analgesic effect and vasoconstriction. Therefore, an infiltration with a high concentration of local anesthesia is carried out, in order to keep the medicine concentration as low as possible and thus to avoid not only undesirable systemic side effects but also toxic influences on the organism. Just half the quantity of local anesthetic is enough for the actual suctioning.

The infiltration solution (Table 10.1) or the flushing solution (Table 10.2) as follows has proved to be effective:

10.1.3.1 Infiltration

In order to break the tissue resistance very gently and without causing pain, the needle is rolled slightly between the fingers (turning the handpiece) while continuously injecting the liquid. In the process, a rolling of about 30° each side is sufficient. The feed is carried out at a rate of about 1 cm/s with a simultaneous soft pressure.

During the process, one can mentally count like 21, 22, 23, etc., and the needle can be further pushed inside, respectively, for 1 cm, and this has proved to be effective in practice.

A preselected quantity of about 120 mL/min is sufficient for the infiltration when using the water-jet assisted liposuction technique (WAL). This corresponds to a quantity of about 2 mL per cm^3 of volume in case of the abovementioned procedure.

In this manner, one should create a continuous channel, which extends up to the boundary of the area to be processed or it extends up to the needle length. On the way back, liquid should be continuously injected at the same rate. Since a distribution zone of about 1–2 cm occurs around the tip of the needle, the next channel is suitably selected at about 1–2 cm distance. Thus the entire work area which can be reached through the incision is gradually infiltrated in the form of boxes.

- **The effective concentration achieved in the process in the tissue is reliably sufficient for an adequate analgesic effect and also for a sufficient vasoconstriction. Despite this, the low volume causes only a slight swelling. But one always has the choice of evaluating the suction region.**

If it should be seen during the subsequent suctioning that there are still painful areas left in the work area, then one can always achieve a further pain reduction at any time. For this purpose, the suctioning is temporarily interrupted. Then infiltration is done once again in the painful region with a slow feeding process. By this method, an intensified analgesic effect can be achieved at any time. The concerned region can further be suctioned after a few minutes given for an effective action to take place.

Typical infiltration quantities are given in Table 10.3 based on the volume to be filtered.

10.1.3.2 Suctioning

A change to the suction needles is done after complete infiltration. As to which thickness and perforation arrangement are selected depends on the position of the area and on the existing fat

Table 10.3 Volume of infiltration

Region	Less	Medium	Much
Face/neck	50	80	100
Upper arm	100	200	300
Upper thigh outer/back/inner	300	500	700
Calf	100	200	300
Upper stomach	300	400	500
Lower stomach	300	400	500

volume. Generally it is recommended to use the thinnest possible needles, in order to be able to work as less traumatically as possible.

Thin channels can be created by the back and forth movements of the needles, and in the surrounding environment, more connective tissue structures remain intact with the blood vessels and nerves. One can also tell by the color of the aspirate. The thicker the suction needle is selected, the more blood is visible on the aspirate.

If greater volumes can be suctioned out in a time-efficient manner, then one can achieve a quicker yield even with needles of 3.8 mm diameter. Diameters of greater than about 4 mm are not recommended, because the fat tissue particles obtained also become too large through the bigger perforation diameter and thus they cannot offer suitable preconditions for an optimum healing rate. Apart from this, pain and collateral damage could increase with increasing thickness of the needles.

- **At the beginning of the suction, one should use the thinnest possible needles. These are generally 3.5 mm needles. By this, one can tell for sure as to whether the suctioning can be done free of pain.**

Even though the infiltration solution applied in a small quantity has an analgesic effect, the subsequent liposuction would be painful at least in phases due to the low concentration of the effective medium used. For this reason, a continuous supply of flushing solution with a small concentration of the local anesthetic is necessary. By this, a sufficient concentration is always achieved at the actual suction point.

Basically, it should always be considered that during the water-jet assisted liposuction (WAL) technique, the liquid jet does the main part of the work. It loosens the fat cells from the tissue attachment. The manually introduced suction needle is solely meant to transport out the mixture made up of flushing liquid and fat tissue that is created. There should be no forcible and thus traumatic mechanical separation of the fat particles through the needles!

From a natural viewpoint, tissue resistance is especially high in the beginning and starts reducing with an increasing number of passages in the same tunnel. About three to five passes are normally required in the normal case. Thereafter, a uniformly low resistance becomes noticeable, which allows us to move the needles using just two fingers without any use of force. At this point of time, the next bigger size of needles can also be used if required.

10.1.3.3 Lipofilling

In order to achieve the highest possible healing rate, one should minimize the quantity of local anesthetic used in the receiving area. If there appears to be a reduced sensitivity for painful stimulus during the liposuction, e.g., in the boundary areas of the boundary regions, then one can attempt to carry out the lipo-transfer without infiltration of the receiving area. This is true for more than half of all the treatments in case of native tissue conditions. One only just needs to use a skin template for the prick incisions.

During a careful subcutaneous introduction of the thinnest possible needles for lipo-transfer while simultaneously rolling the area between the fingers, it can directly be seen as to whether or not a sufficient painless filling is possible. If this is not the case, then initially a small quantity of flushing liquid can be infiltrated. In this case, approximately half the normal infiltration quantity is sufficient for the liposuction.

The combination of a low concentration and low volume contributes to a minimum damage of the vitality of the transferred cells if there is sufficient analgesic action. A waiting period of a few minutes contributes lesser to the initiation of effective action but more to the diffusion of the liquid into the neighboring tissue and thus contributes to the further reduction of toxic influences on the lipo graft.

- **The correct subcutaneous application level is achieved, if the resistance while injecting is low.**

The Cooper ligaments in the subcutaneous level offer very less resistance that can easily and

painlessly be eliminated. The same is true for filling up of the sub-glandular space. Even here, the graft can be placed frequently without local anesthesia in the boundary layer to the pectoralis fascia that can be penetrated easily. In order to reach this layer, needle guidance controlled by ultrasonic means is helpful while dispensing with local anesthesia.

10.2 Treatment of Capsular Contracture

Klaus Ueberreiter

In case of at least 10% of all silicone implants, capsular fibrosis may occur within a period of 10 years [2]. There are big differences in data according to the observed postoperative period in the available publications.

The standard techniques of replacing the implants are not part of this book. The indications for at least a temporary removal of the implant become evident no later than the second but certainly after the third relapse of the capsule formation within a period of a few years.

10.2.1 Autologous Fat Injection Around the Capsule

As it could be confirmed in numerous publications that autologous fat has the possibility of improving the scar tissue, this possibility is also available in case of capsular fibrosis. But no statements have been made as to in which percentage of the cases one can expect an improvement. In such cases, one should undertake a study in which the patients reject a removal of the implant.

Autologous fat tissue transplantation leads to a distinct improvement even in case of so-called rippling which occurs after a few years after subcutaneous implantation.

During the OP counseling, one should point out the possibility of an implant damage. If the implant gets accidentally damaged, then it has to be removed in any case. Therefore, it is very important to fine-tune the precise OP steps beforehand, which could consequently have to be taken. Since in some cases of a capsular fibrosis there is already a ruptured implant existing, a careful perioperative diagnostics, mainly with ultrasonic methods, is to be advised. But there is no sufficient specific diagnosis technique, which can exclude an implant leakage with 100% security.

- **In view of the increasing number of ALCL cases (ALCL = anaplastic large-cell lymphoma), a sample of tissue liquid and capsule should be studied expressly on a CD30 marker.**

Even in this case, the fat tissue should be introduced through several injection points from the areola boundary laterally around the capsule, which can be generally well identified with the injection needle while carefully pushing forward and injecting exclusively during withdrawal (Fig. 10.3). In order to get to the surface of the capsule, additionally, a lateral prick is required.

When the job is carried out carefully, there is only a slight danger of an injury to the implant. The quantity of tissue, which is utilized here, is lesser than in case of the complete aesthetic augmentation and generally lies at about 100 mL per breast.

The postoperative therapy consists even in this case in the avoidance of any compression for a period of 4 weeks.

10.2.2 Removing the Implant and Replacing the Volume Through Autologous Fat

- **Once a capsular fibrosis is detected, there is a high chance of a relapse. Therefore, we recommend to our patients right from the beginning to remove the implant and to use only autologous fat.**

In the process one certainly has to follow the usual preconditions for aesthetic fat graft (nonsmoker, BMI above 18).

In case of smaller implants (up to 250 mL), frequently an almost complete volumetric replacement is possible in an operation. The breasts generally take up more tissue and show a very good healing rate. In our experience with more than 100 female patients, there was generally a very high degree of satisfaction, and only among 10% of patients, there was the desire to carry out another transplantation [3]. An example is shown in Fig. 10.4.

10.2.2.1 Procedure

The quantity of fat to be transplanted should correspond roughly to the implant sizes in case of implants up to 350 mL of volume. The patient should be instructed that the breast will assume a natural and more ptotic form compared to implant augmentation. The exaggerated fullness in the cranial breast area, which regularly occurs in case of capsular fibrosis, disappears postoperatively (Fig. 10.4).

- **Note: A breast lift cannot be achieved by the fat alone**!

The postoperative development is similar to the process in the purely autologous fat tissue transplantation: the max. swelling appears around the fifth day, and then the volume starts to reduce over a period of 6 weeks.

After an adequate quantity of fat has been harvested, the removal of the implant is done most conveniently through the sub-mammary fold as also from the peri-areolar areas (less popular, but still possible) while carrying out an excision of any scar that may be present here. An operation via axillaryaccess is not recommended.

The lower boundary of the capsule is exposed and opened up, and the implant is extracted out from here (Fig. 10.5). Then a basic cleaning of the capsule is carried out by repeated flushing and wiping, until an optical impression is obtained of a completely clean inner capsule surface (Fig. 10.5 and 10.6). If one is dealing with a defective implant, then a cleaning process is to be carried out for so long, until no more silicone residue can be observed.

- **During the process, the gloves should be changed several times.**

Operative Strategy

It is important to leave the capsule completely in situ. The reasons are:

- Due to a very good blood supply on its surface, a good healing of the transplanted tissue is enabled in this manner.
- On the other hand, one can fill the retroglandular space to get a good projection and avoid the collection of fat tissue in a large open wound cavity.
- We recommend to send a small patch for pathological examination.

If there is still a muscular layer available between the capsule and the ribs, then even here, some fat graft can be injected. Since one can keep the needles in view or follow their progress even by the use of an endoscope, the injection can be carried out without any complications.

- **Note: A perforation in the capsule should be carefully avoided, but if it still happens, then the fat that may enter into the empty capsule should be drained (Redon drain 12–14 Ch 24 hours) at the end of the operation.**

In order to achieve a safe and even distribution of the ventral side of the capsule with fat graft, it is recommended to draw the frontal margin of the capsule with a sharp clamp. In this manner, one can carefully push forward the needle under digital control and inject the fat while withdrawing it (Fig. 10.6).

Since mostly a strong central projection exists through the implant and, on the other hand, the tissue is somewhat thinned out in the direction of the areolas, the injection creates a renewed satisfactory projection, especially in the central area. In this case, one should introduce here a minimum of 150 mL of fat.

The subcutaneous injection (Fig. 10.7) is given in the same manner as described in case of

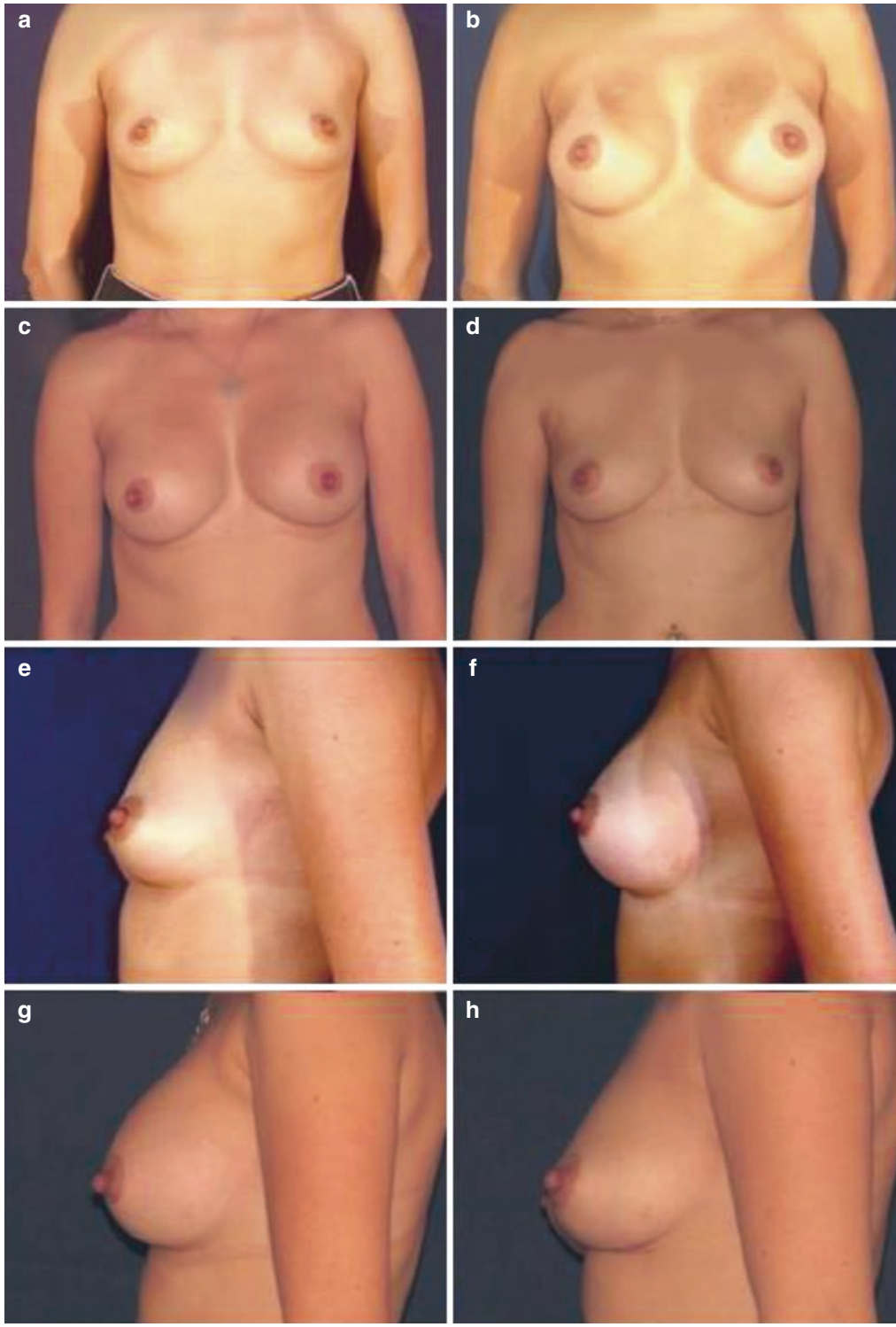

Fig. 10.4 (**a–h**) A patient before (**a**, **e**) and after (**b**, **f**) mammary augmentation with silicone implants, (**c**, **g**) 8 years later with capsular fibrosis B III with implants still in place, (**d**, **h**) status after the removal of the implants and volumetric replacement through autologous fat

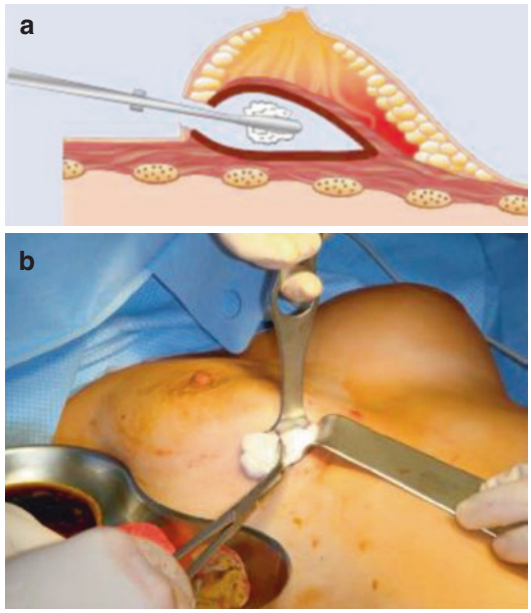

Fig. 10.5 (**a**) Curette operation of the capsule (**b**) cleaning of the wound cavity (prepared as per a drawing by K. Ueberreiter)

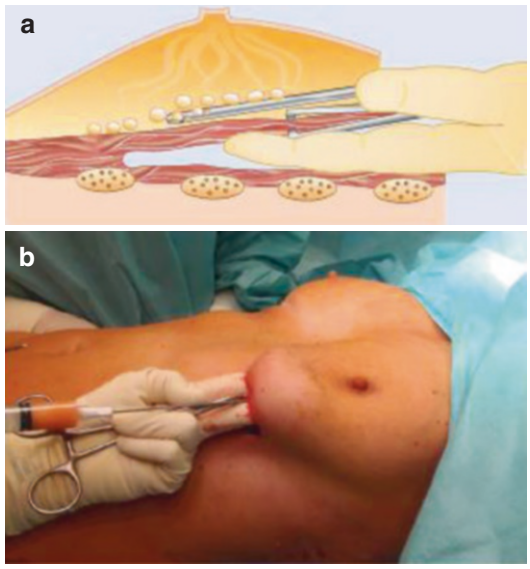

Fig. 10.6 (**a**) Injection around the capsule under digital control (**b**) Injection around the capsule (prepared as per a drawing by K. Ueberreiter)

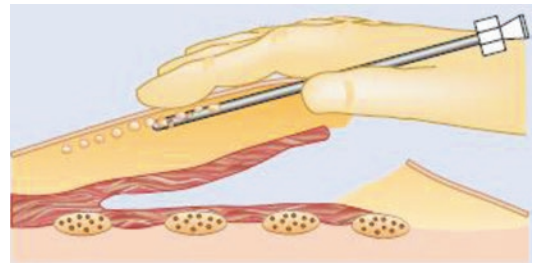

Fig. 10.7 Subcutaneous injection (prepared as per a drawing by K. Ueberreiter)

the aesthetic augmentation (Sect. 10.1.1). Separate pricks are not required; the needles can in this case be inserted from the operation wound.

Finally, it is recommended to resect a strip about 2 cm long from the boundary area of the capsule, in order to enable drainage of a possible seroma into the subcutaneous tissue. We observed after closure of the capsule in the beginning seromas present in our patient population in two cases. Also it is recommended with BIA-ALCL discussion going on to send a specimen of intracapsular seroma as well as the excised patch for pathological analysis. A drainage is not paramount but recommended. Without drainage the operation can also be carried out in an outpatient treatment.

- **If seromas occur in rare cases, then they should be drained by needle aspiration, and the hollows should be injected with cortisone.**

Exclusively the subcutaneous tissue and the skin are closed during wound closure. The area directly above the wound can then be filled up with fat through a separate prick incision in the skin. Postoperatively a loose cotton bandage is applied without any compression.

Three case studies are shown in Figs. 10.8, 10.9, and 10.10.

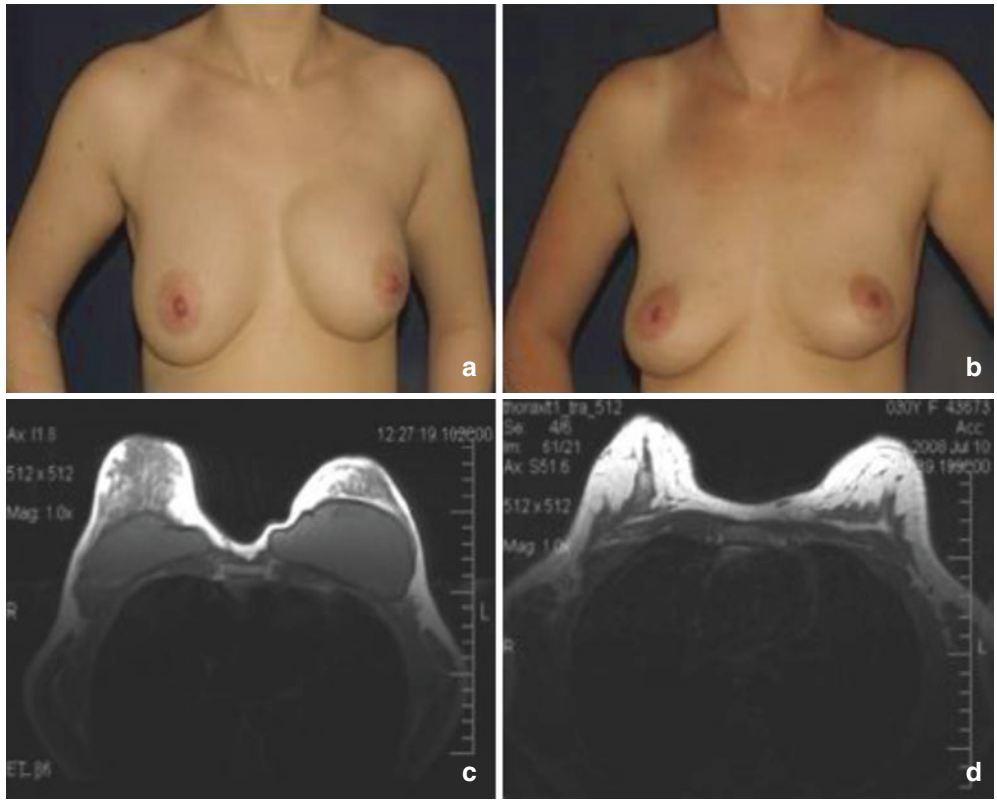

Fig. 10.8 (**a**–**d**) Capsular fibrosis (left) after mammary augmentation through the insertion of silicone implants (**a**, **c**) and 6 months after the BEAULI procedure (**b**, **d**), respectively, in the clinical aspect and in the MRI

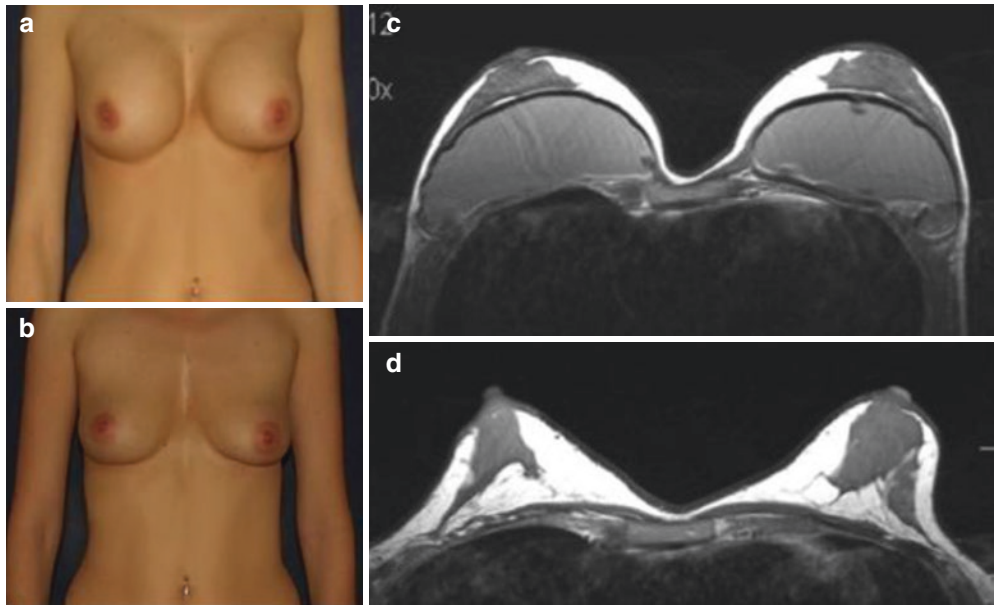

Fig. 10.9 (**a**–**d**) Capsular fibrosis (left) after mammary augmentation through the insertion of silicone implants (right, 305 g; left, 265 g) (**a**, **c**). Two operations are carried out due to the capsular contracture, (**b**, **d**) condition after an autologous fat injection (right 180 mL, left 160 mL), respectively, in the clinical aspect and in the MRI

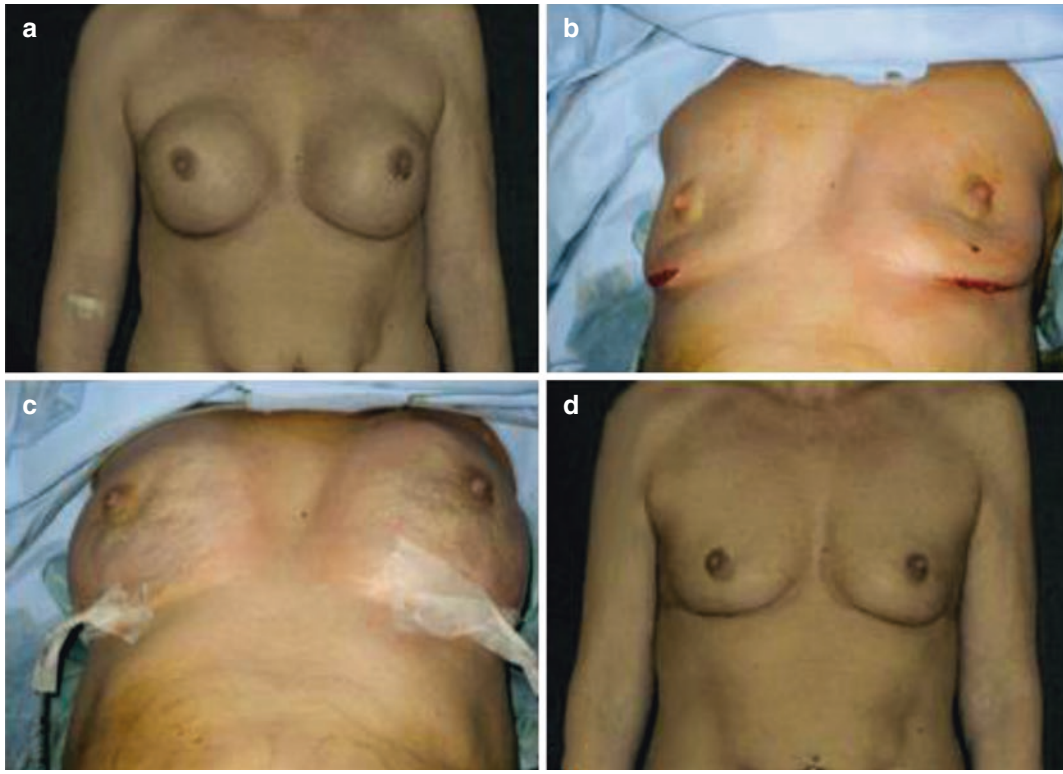

Fig. 10.10 (**a**–**d**) Capsular fibrosis on both sides after mammary augmentation through the insertion of silicone implants, (**a**) preoperative, (**b**, **c**) intraoperative, (**d**) 1 year postoperatively

10.3 Tuberous (Tubular) Breasts

The special characteristic of the tubular breast consists in a very tight dermis, which does not allow sufficient expansion of the skin if the breast grow. This frequently results, on the one hand, in an asymmetric micromastia and, on the other, in a very large, flaccid, and prolapsed nipple area.

In case 2, the fat has different functions:

- On the one hand, it brings up the volume, which could not materialize during the growth.
- On the other, it results in a loosening of the dermis, and thus it results in the desired occurrence of a natural breast shape.

The buildup is done in an analogous manner to the aesthetic breast enlargement in two to three steps (see Sect. 10.1.1). A sub-mammary fold is filled in the first stage directly injecting the fat below the old sub-mammary fold. At first, the new sub-mammary fold is marked out as per the desired and targeted breast size 8–10 cm caudal to the nipple, and thereafter the fat is injected subcutaneously above this marking (Fig. 10.11). Now in this process, one cannot expect the old and often very rigid fold to immediately disappear. But within a period of just 6 weeks, one can see it starting to disappear almost without exception; the skin fully expands itself at this point. No other maneuvers are required.

A correction of the nipple area is done in a second sitting after 3 months. For this purpose, the areola is marked reduced to the desired size. Then the excess strip of the pigmented skin is de-epithelized, and the dermis is completely separated through at the outer periphery. Then a tobacco pouch suture is applied at the outer area toward the nipple skin (Fig. 10.12).

Fig. 10.11 (**a**–**d**) Tuberous breast. (**a**) Marking of the new sub-mammary fold and of the extraction area. (**b**) Condition after an injection of 290 mL (right) and 300 mL (left), 17 days postoperative, (**c**, **d**) 6 months and 9 months postoperatively

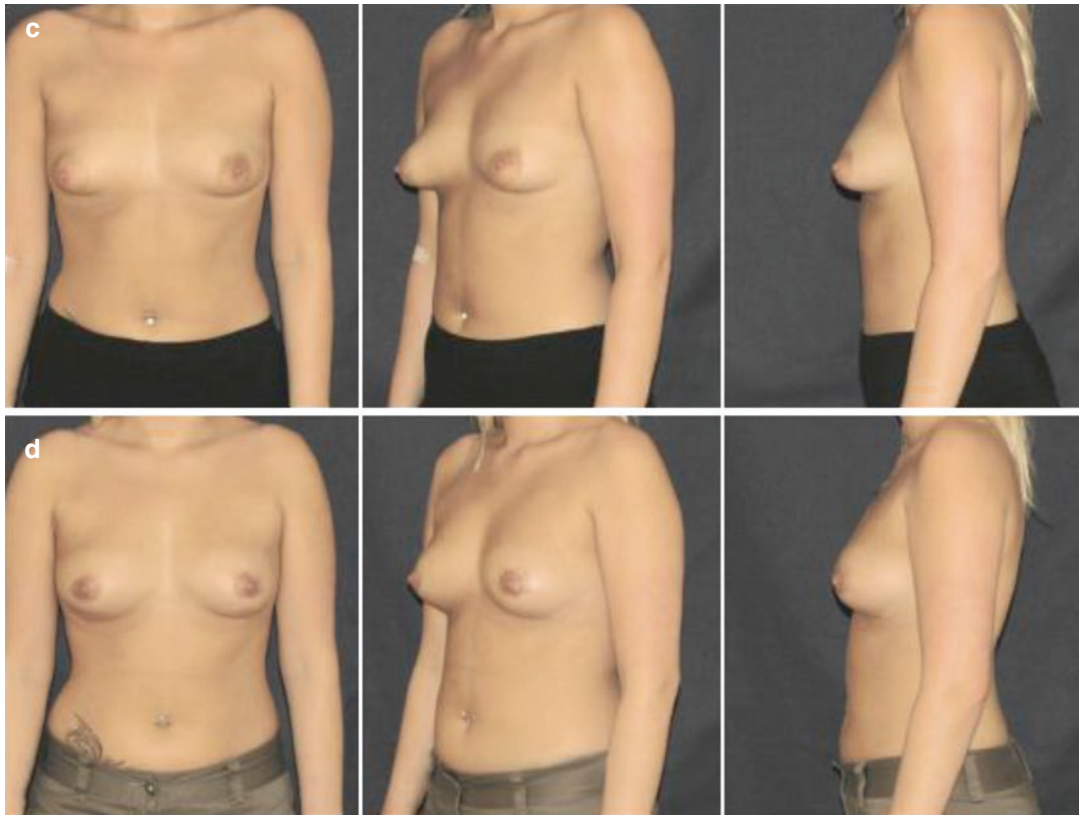

Fig. 10.11 (continued)

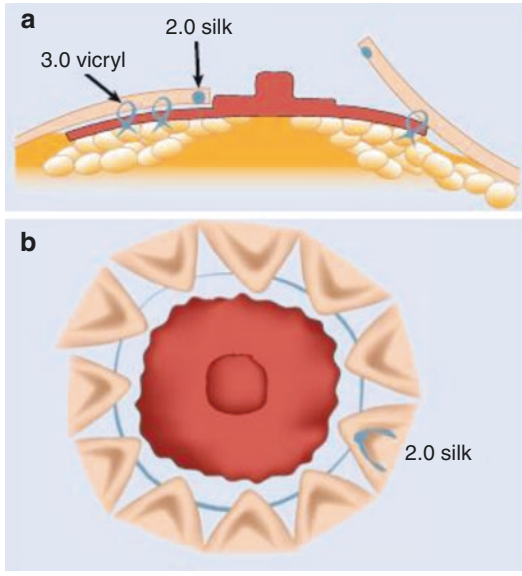

Fig. 10.12 (**a**, **b**) Diagram of the areola reduction (**a**) tobacco pouch suture with 2-0 silk (**b**) (prepared as per a drawing by K. Ueberreiter)

- **Since there is a strong tendency toward a renewed enlargement of the areola complex, one should select a long-term sustainable thread. For the last 5 years we have been using silk of the grade 2–0 after we faced the problem of removing Goretex threads frequently in the postoperative months and also the very slowly resorbable PDS threads did not yield the desired long-term sustainability.**

The renewed fat graft is finally carried out through the same type of distribution analogous to the aesthetic primary breast enlargement subcutaneously and in a retro-glandular manner.

10.3.1 Significance

Autologous fat tissue transplantation is generally superior in the correction of tuberous breast

deformity as compared to silicone implants based on extension of the skin, the disappearance of the constrictions and high sub-mammary folds, as well as the individual possibility of modeling. Apart from this, it is a fact that in general patients of a very young age are being operated and implants will oblige them to have several subsequent operations *quoad vitam.*

Treatment with the BRAVA System offers a good alternative, which is described in Sect. 6.3.

10.4 Asymmetries

Breasts of different sizes are quite common. But as soon the difference exceeds half a breast size or more, it becomes optically noticeable and can result in static pains due to one-sided extra load on the vertebral column.

Since the variety of breast forms are wide, Autologous fat tissue transplantation is an ideal solution here for the compensatory correction of size and contour and is greatly superior to silicone implants.

It is an individual decision as to whether or not an operative reduction on the other side should be performed.

Since half a breast size can be compensated per sitting, the number of necessary sittings and volume should be precisely planned. If both breasts have to be increased on size, then one has to start with the smaller size. In this case, volumes of 150–250 mL (un-centrifuged) are realistic. Only a slight quantity, if at all, should be introduced into the bigger-sized breast.

A sub-mammary fold located at a higher level, which is frequently the case on one side, can be lowered by direct injection (Fig. 10.13).

Even thoracic deformities (see Sect. 10.5) and general asymmetries like outwardly pointing nipples can be properly corrected (Fig. 10.14).

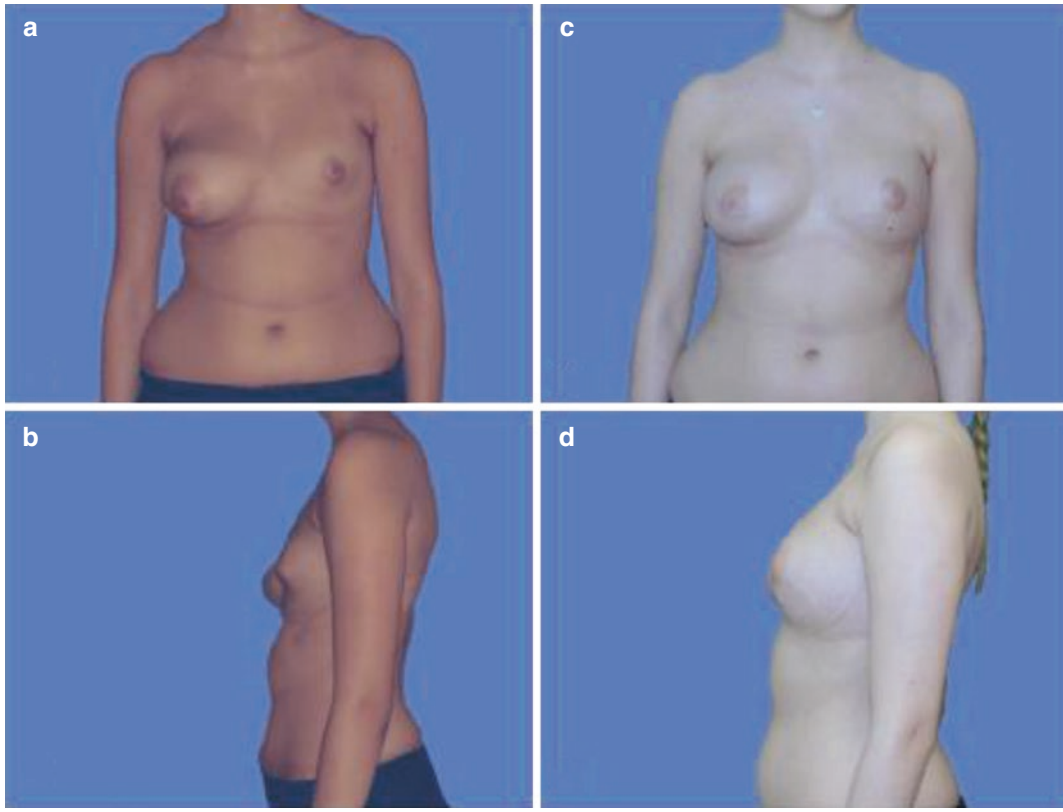

Fig. 10.13 (**a**–**d**) Asymmetry (**a**, **b**). The same patient after three sittings left and reduction mammoplasty right (**c**, **d**)

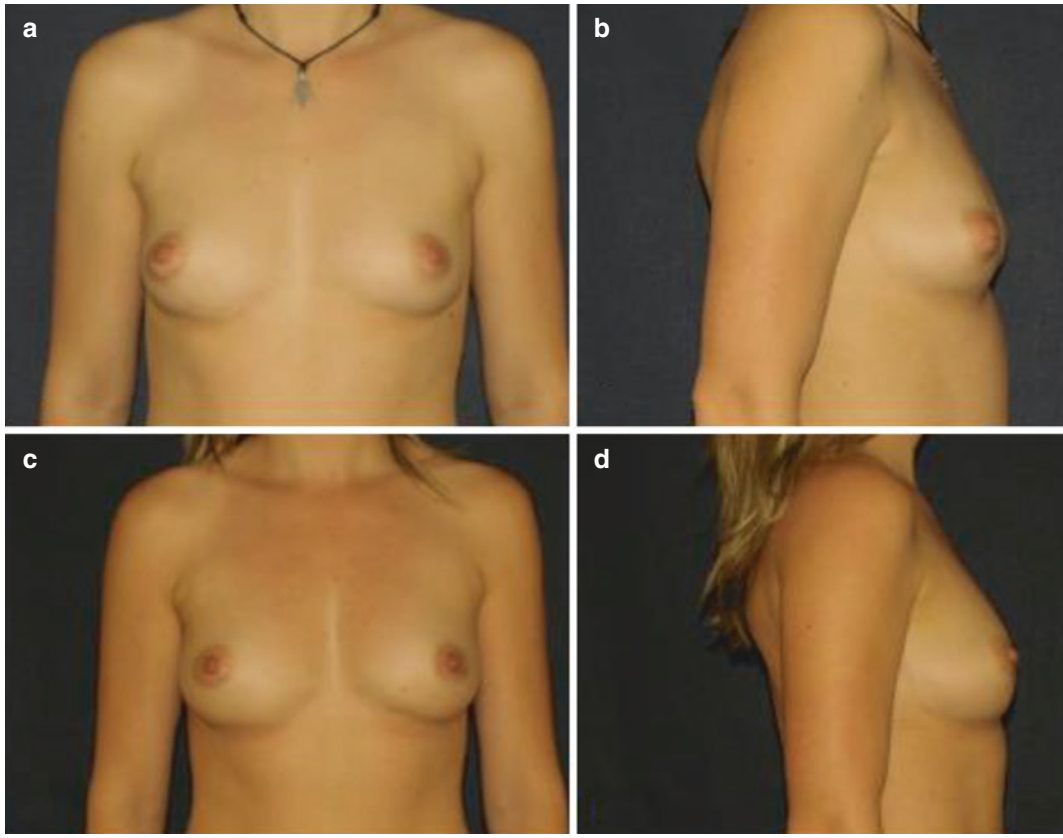

Fig. 10.14 The correction of missing lateral volume

10.5 Poland Syndrome and Pectus Excavatum

Yves Surlemont

10.5.1 Pectus Excavatum

The sunken chest (pectus excavatum) is the most frequent thoracic anomaly with an estimated incidence of between 1/300 and 1/1000. Partly, this deformity is related to a Marfan syndrome.

If the Marfan syndrome has been ruled out, then the rate of functional pulmonary and cardiac consequences gives rise to controversies and varies as per the existing references. Published papers show that they occur in combination with serious deformities. A majority of authors has observed that the main indication for operation happens to be psychological, aesthetic, and social ([4]).

Due to the high rate of complications of an invasive operation technique of 8% [5], the very low rate of complications and low postoperative morbidity of an operational correction using autologous fat transplantation appear to be of great interest.

- **Generally, between two and three transplants of an average of 100 mL of fat appear to be sufficient.**

A case study is shown in Fig. 10.15.

10.5.2 Poland Syndrome

The Poland syndrome (first described in the year 1841 by Sir Alfred Poland in England) is a congenital complex malformation and occurs with an incidence of 1/30,000 [6]. The complete

Fig. 10.15 (**a**–**h**) A 25-year-old patient (BMI 20.20) with pectus excavatum before (**a**, **d**, **g**) and after the first sitting with autologous fat graft (305 cm^3) (**b**, **e**, **h**). Result after a second sitting of autologous fat graft (410 cm^3) and 5 years postoperatively (after 2 pregnancies have taken place, BMI 23) (**c**, **f**, **i**)

syndrome includes the findings summarized below.

The Complete Poland Syndrome
- Thoracic deformity
- Hypoplasia of the M. pectoralis major
- Malformation of the ipsilateral hand

But in daily clinical practice, a wide variation of the expression of the syndrome was seen. In case of women, mamma asymmetry is frequently seen as a hypoplasia of the breast and of the nipple areola complex with eventually default of the pectoralis major.

In the earlier days, treatment of this deformity was not easy and often showed a high morbidity rate. Conventional procedures included the insertion of the M. latissimus dorsi, generally connected with silicone implants. This meant extra scars on the breast and on the back and somewhat significant lifting defects and seldom a satisfying symmetry.

The correction of the less difficult expression of the Poland syndrome is similar to the therapy of the pectus excavatum. This is because the transplantation of autologous fat tissue exhibits a very low postoperative morbidity and similarly, a very reduced rate of complications, compared with the other methods [7].

A complex form of the Poland syndrome with aplasia of the M. pectoralis major or of the M. latissimus dorsi, however, requires enhanced operative measures. Depending on the volume of the normally developed breast on the opposite side, the possibility of harvesting fat, and the desire of the patient, the reconstruction is either exclusively carried out through a fatty tissue transplantation [8] or by the additional use of an implant.

If, a large volume is missing, a buildup is possible only through a series of three to six fat grafts.

The big advantage as against other procedures lies in the expansion of the skin cover with a gradual shift of the areola caudally.

- **A contralateral reduction is frequently to be taken into consideration, in order to limit the volume to be built up.**

From the viewpoint of technology, there is no basic difference between an aesthetic or reconstructive breast enlargement.

The correction of a complex Poland syndrome is shown in a case study (Fig. 10.16).

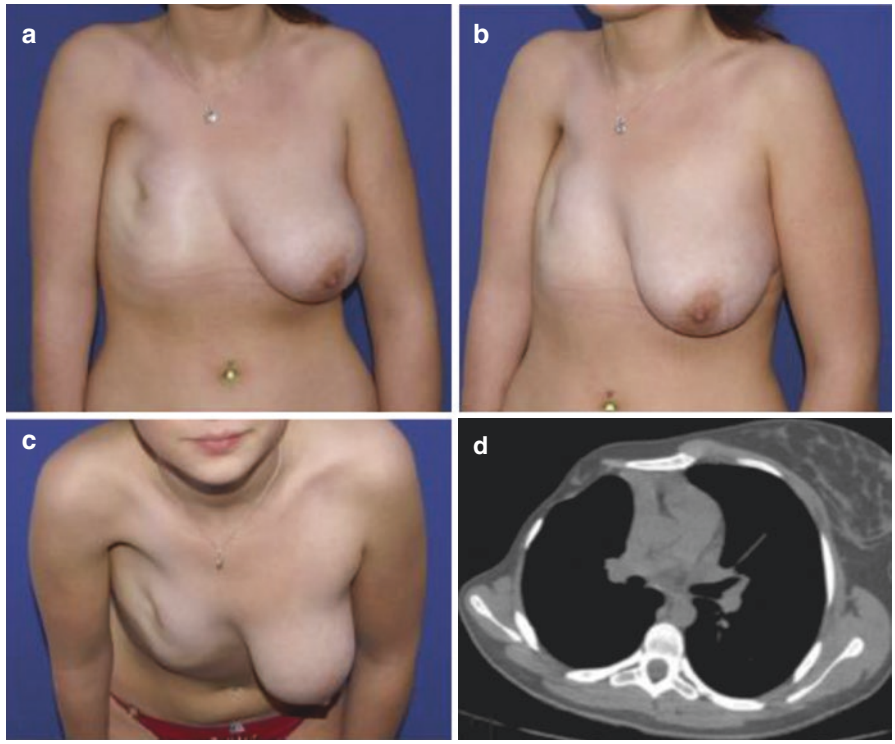

Fig. 10.16 (**a**–**c**) A 16-year-old girl (BMI 23) before the first operation for the correction of a complete Poland syndrome. The missing M. pectoralis major and the M. latissimus dorsi can be seen clearly on the MRI image (**d**). Only the skin is covering the atrophied right side breast wall. Result after 10 months and four sittings with autologous fat tissue transplantation (150, 210, 220, and 345 cm^3) and mastopexy of the right breast with a complete retention of the right side areola for future reconstruction of the right side areola (**e**, **f**, **g**, **h**). Result at the age of 22 years: 10 months after the last operation, round-shaped implant of the size 300 cm^3 filled with hydrogel in combination with an abdominal advancement flap. (Before this operation, an expander implantation was done with the objective of the formation of scarred fibrotic structure as an anchor for the advancement flap)

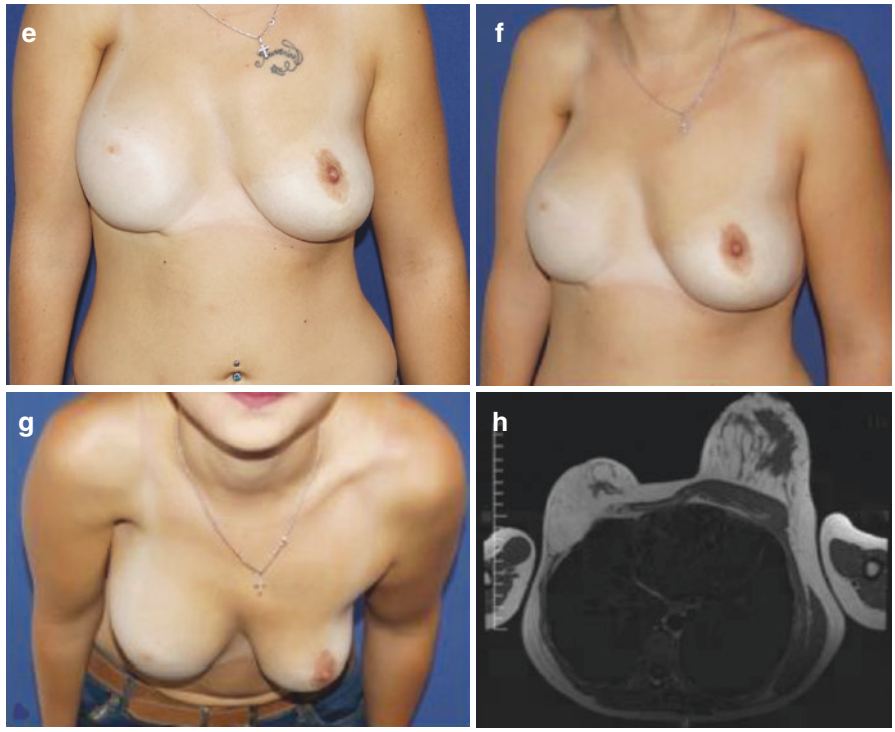

Fig. 10.16 (continued)

10.5.2.1 Significance

To summarize, one can say that the therapy modalities of thoracic deformities have undergone a change due to the multiple uses of transplantation of autologous fat tissue with natural and long-lasting results together with only a slight formation of scars and hardly any complications. Transplantation of autologous fat tissue is going to be the number one choice among different treatments in the future.

10.6 Autologous Fat and Lifting

Klaus Ueberreiter

Basically, any type of breast lift can be combined with autologous fat tissue transplantation.

- **Note: While combining both these methods, strict attention should be paid to the fact that the fat to be grafted is introduced only into the area within some distance of the wounds.**

A cranial shafting is suitable the best with a central folding of the dermis in the caudal area without separating the glandular body. A fat deposit can be inserted even sub-facial and intrapectoral; this then serves for a better projection (Fig. 10.17).

About 100–150 mL per side should be introduced mostly in the upper quadrants of the breast in connection with a breast lift.

Even here, one should be careful not to apply any strong compression postoperatively because this will adversely affect fat healing. But with a total lack of compression, there is an enhanced risk of hematoma formation during the breast lift. For this reason, a compression bra or an elastic bandage is worn, which does not exert any pressure in the area above the areola.

- **Note: While combining these methods, strict attention should be paid to the fact that the fat to be grafted is introduced only into the area, which is not perforated with wounds.**

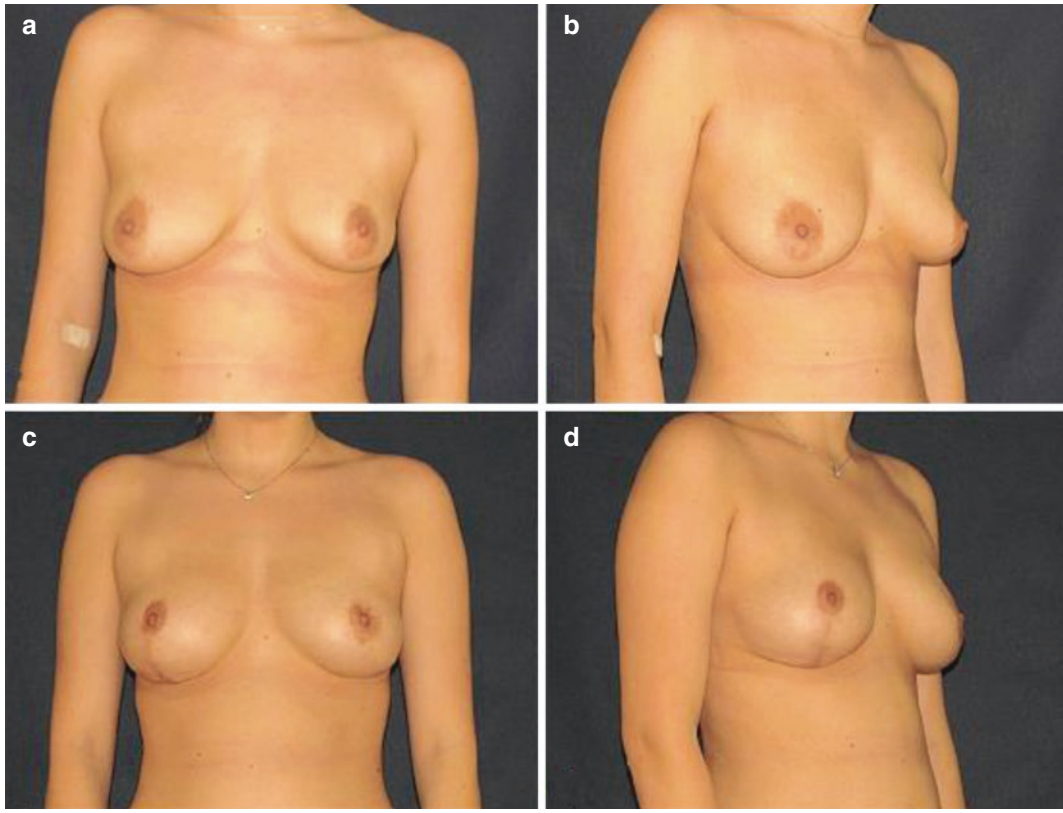

Fig. 10.17 (**a**, **b**) Preoperative, (**c**, **d**) 1 year after breast lift with a simultaneous autologous fat tissue transplantation of 200 mL per side

A cranial pedicle is suitable the best with a central folding of the dermis in the caudal area without separating the glandular body. A fat deposit can be inserted even sub-facial and intrapectoral; this then serves for a better projection.

10.7 Reconstruction of the Breast

Klaus Ueberreiter, Norbert Heine, and Delia Letizia Hoppe

10.7.1 Introduction

Nowadays, autologous fat tissue transplantation is considered as a low risk and simple to use method in reconstructive breast surgery ([9–11] and by others) as a routine method for two-stage interventions or partial reconstruction. In the meantime, it could be shown that even a complete breast reconstruction is feasible even after a total mastectomy and can be used as an alternative to open flap plastic surgery in clinical applications.

- **An S2A guideline has been issued on the subject of lipofilling under leadership of the German Societiy of Plastic and Reconstructive Surgery.**

We would like to refer to our experience in the complete reconstruction using water-jet assisted liposuction (WAL) and the BEAULI protocol.

10.7.2 Personal Approach

The preconditions for the reconstruction are as follows:

– Concluded treatment including 6 months of concluded postoperative treatment (irradiation/chemotherapy).
– A detailed explanation of all other available alternative processes, especially microvascular pedicled flap plastic surgery. Our female patients, who were treated, were suitably informed in advance, and they indicated that they reject any other method of reconstruction for themselves.
– The existence of sufficient fat deposits for a series of four to eight suctions with autologous fat tissue transplantation.

All the concerned patients must be aware of the fact that the treatment can thus last for more than 2 years or even longer. Parallel to fat tissue transplantation, an appropriate reduction plastic surgery on the opposite side, an ipsilateral abdominal advancement flap, and a buildup of the nipple-areola complex can be performed.

- **In any case, it is recommended to take a look into the results of histology, because in some cases only small safety distances exist during the tumor resection and thus naturally an enhanced risk of relapse exists.**

It is also important to point out that as per the latest information that exists today, there is no predictable enhanced risk of a relapse caused by autologous fat tissue transplantation. Nevertheless an individual risk of relapse always exists independent of the therapy.

Due to the somewhat varying procedures, we would like to describe the process involved after breast ablation as well as after the previously undergone irradiation in different chapters.

10.7.3 After Ablation

If there is only a very thin layer of soft tissue available or even a missing of the M. pectoralis, a very less amount of fat can be grafted, respectively, in the first few steps (50–100 mL). Since the subcutaneous fat tissue grows with every step, a somewhat increased volume can be introduced with every intervention. After those steps a skin expander can be implanted (10.7.3.1)

If an expander is already in place, then this is released, respectively, for each step in order to lower the tension with the ongoing fat injection. Initially one should distribute about 50–100 mL subcutaneously, until a clear tension of the skin is achieved. Then one can again reduce this strong stress through a relief of the expander by about 50–100 mL volume. The great advantage of the expander for the patient lies in the fact that a noteworthy breast volume is gained and one does not need to wear an epithesis which should be avoided postoperatively in order to reduce the negative impact of additional pressure. In case of silocone implants the exchange for an expander is recommended.

10.7.3.1 Subcutaneous Expander

Once a sufficiently thick subcutaneous fat layer has been achieved (above 1 cm), in the next step, one has the opportunity of applying an expander. We utilize simple, round expanders with an external valve (!), in order to facilitate a future removal through the smallest possible incision. In case there is a small breast on the other side, then the expander alone is sufficient. If a bigger breast has to be reconstructed, then simultaneously abdominal advancemet flap can be undertaken.

- **In any case, one has to give preference to placing the expander subcutaneously. A muscle position would later always result in unfavorable movements of the breast during muscular tension.**

10.7.3.2 Abdominal Advancement with Expander Insertion

In order to harvest extra skin or subcutaneous fat tissue for the buildup of the breast, the stomach skin can be shifted up to a limit of 5 cm on the affected side. We proceed as follows.

The position of the sub-mammary fold is marked while the patient is standing, on the healthy side, and the lower expansion is clearly indicated on the sternum, in order to get a marking for the necessary lifting up at a later stage. On the ablation side, the new sub-mammary fold newly planned is marked out about 5 cm more caudally than on the healthy side.

The ablation scar is excised (don't forget the histology!). A subcutaneous, epimuscular preparation is carried out up to the level of this planned newly formed fold. Then the muscle fascia is separated through the entire length of the future sub-mammary fold, and from here, a further 5 cm is prepared towards caudal - dorsal below the fascia (in the muscular area). Then the fascias are again separated at this level in order to prepare a fascial patch adherent to the subcutaneous tissue. The preparation is carried out from here further ventral (epifascial) between the fascia and the subcutaneous fat tissue.

A mostly blunt detachment must be carried out up to far caudally (level of the navel). In doing so, a careful hemostasis must be carried out especially of the perforators. Support through light retractors or endoscopes is highly recommended.

The insertion of a Redon drainage into the wound hollow is also recommended. It is possible to carry out even a double suture row for attachment to the muscle fascia lying beneath it through the approximately 5 cm wide fascia layer. Thus one has reached a very reliable and permanent formation of the new sub-mammary fold (Fig. 10.18).

The fatty tissue under the newly created submammary fold can later be thinned out and modeled by suctioning.

A further advantage in raising that advancemet flap lies in the fact that one can now generally and very easily introduce a tissue expander of about 300 mL (up to 500 mL) (Fig. 10.19). The valve should best be placed laterally on a rib, in order to guarantee a simple puncture at a later stage. We always use the smallest valve.

The further procedure has been described above (see Sect. 10.1.1).

The evaluation of patient data as part of a pan-European multicenter study [12] after conclusion of treatment and at least 6 months (average 2.6 years) of time having passed has yielded the following result: at an average, four to six fat tissue transplantations with, respectively, 159 mL (±61 mL) over a period of 21 months (9 months up to a max. of 2.5 years), in order to achieve an end volume of 1020 mL (±515 mL) for a complete breast buildup. In this study, the patients exhibited a significant higher intervention rate and volume demand after adjuvant radiation therapy ($p < 0.041$).

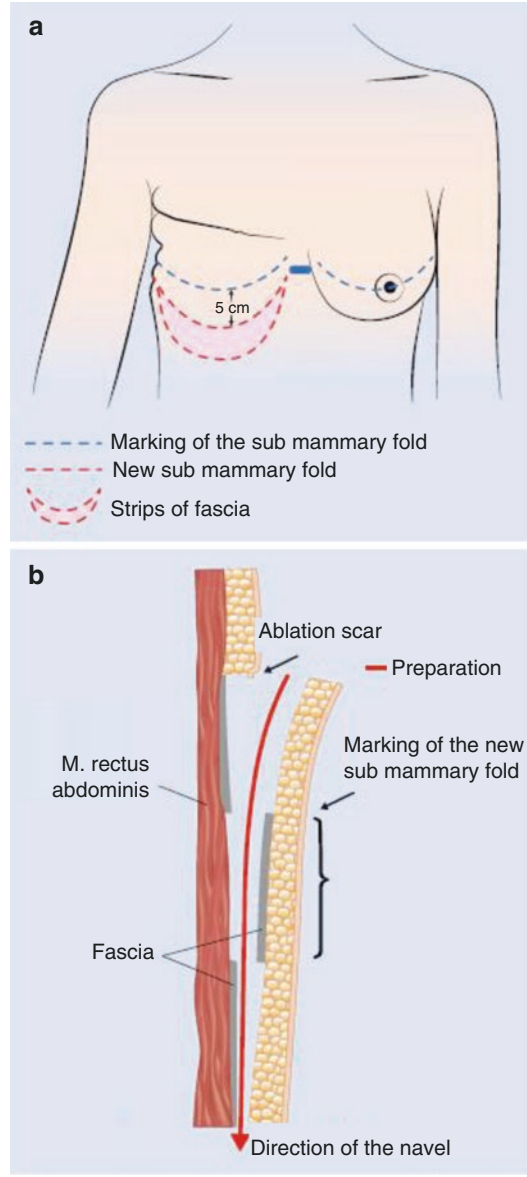

Fig. 10.18 (**a**, **b**) Tummy tuck (**a**) from the front (**b**) lateral (schematic diagram) (prepared as per a drawing by K. Ueberreiter)

The following were seen as postoperative complications:

- Local infection (0.74%)
- Granuloma (0.74%)
- Fat necrosis (2.59%)

All of these complications did not exhibit any clinical relevance. A high degree of patient satisfaction could be registered (95.42%) with

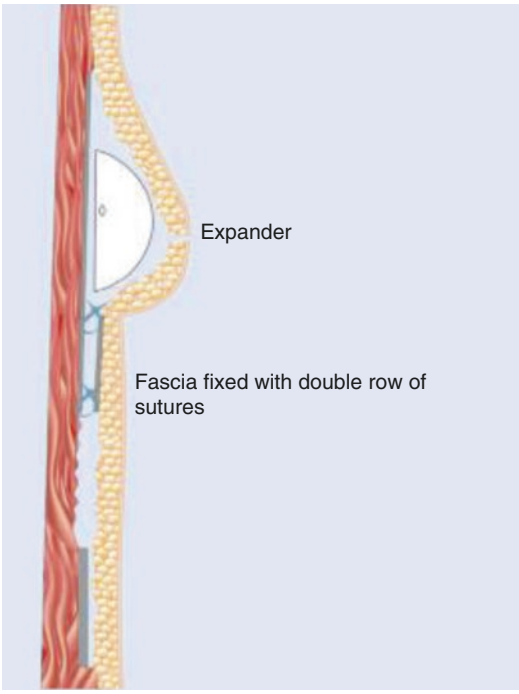

Fig. 10.19 Expander (prepared as per a drawing by K. Ueberreiter)

good to very good aesthetic results (67.68%) (Fig. 10.20).

10.7.3.3 Significance

To summarize, one can conclude that the autologous fat tissue transplantation is basically suitable for a complete breast reconstruction after breast ablation in the case of which an average of four to six lipo-transfers is required within a time frame of about 2 years. This is best suitable for moderate Breast sizes (cup A–B).

10.7.4 After Breast Conserving Therapy

Concerning the reconstruction by lipofilling after breast conservation therapy, there was a temporary uncertainty after the publication of Petit et al. [13] due to the question of an increased risk of relapse [13, 14]. In this study, younger female patients with an enhanced gene expression of KIR were increasingly affected by a relapse.

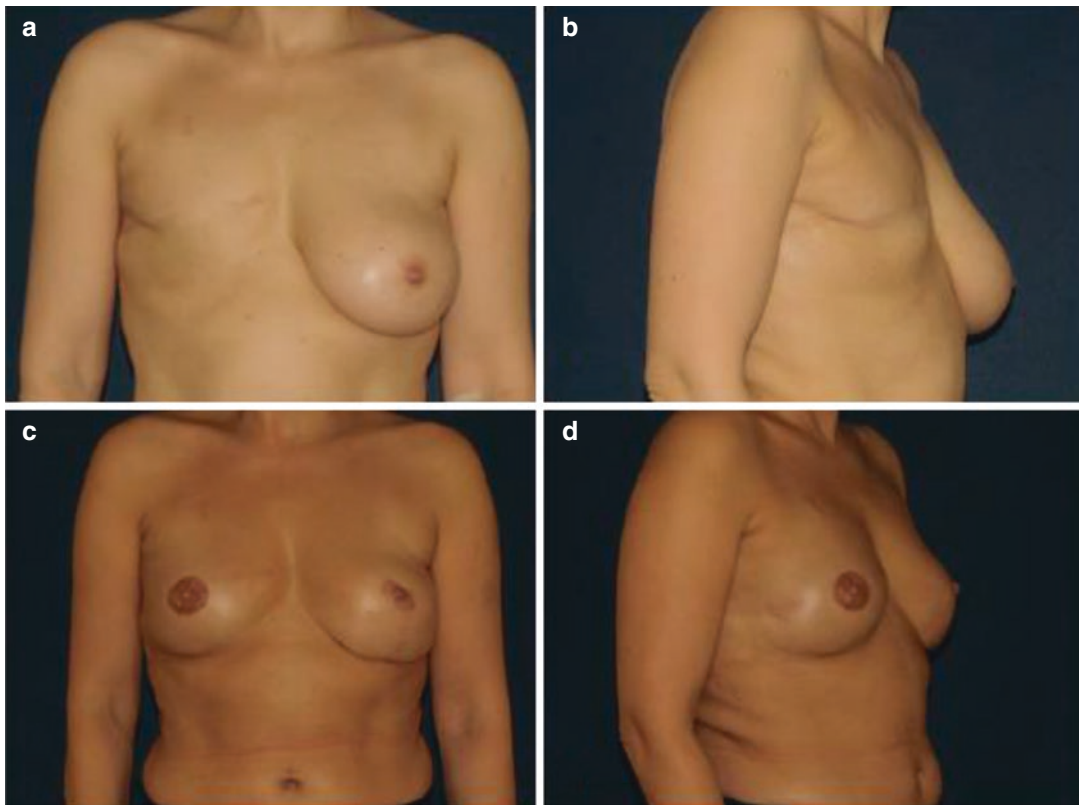

Fig. 10.20 (**a**–**d**) Before (**a**, **b**) and after a successful reconstruction (**c**, **d**)

Even though this could not be proved through subsequent studies [9–11], even in such cases, one has to counsel the affected patients without unnecessarily creating a panic in their minds about the occurrence of a relapse.

It is even recommended here to very carefully record the medical history, especially the histological result.

- **In case of very narrow resection margins, we are very cautious regarding a reconstruction for the higher rist of reoccurrence might be blamed to the fat graft. Breast conservation therapy is generally connected with a subsequent radiation therapy; the procedure after radiation therapy has to be followed (see Sect. 10.7.5).**

One can reliably and better achieve the objective, if one starts grafting smaller volumes (e.g. 60–100 mL) for the first three to four procedures. (see chapter 10.7.5)

10.7.4.1 Significance

Basically, transplantation of autologous fat tissue can be considered as comparable or even superior for form and volume compensation in breast conservation therapy as compared to all the other therapies like, e.g., M. latissimus dorsi flaps, silicone implants, or free-flaps. Therefore, it should be considered as a clinical option.

10.7.5 After Radiation Therapy

After adjuvant radiotherapy, about four additional sittings will become necessary to cure the radio damage. Thus the whole process will be streched over a period of up to 3 years for final breast reconstruction. This observation is confirmed with the same experience of other surgeons (Rogder Khouri, personal communication). The reason is apparently in various causes:

– Radiation causes a noticeable fibrosis in the subcutaneous tissue, which hinders a smooth expansion of the tissue when the volume increases.
– Due to the reduced mitotic capability of the cells, even the neovascularization gets reduced. Thus possibly the healing rate of the grafted tissue is also consequently reduced. The causes are individually discussed in Chap. 15.

- **It is important to explain to the concerned female patients right at the beginning of the therapy about these basics and to point out that the first three to four fatty tissue transplantations are not going to bring about any increase in volume, but these exclusively serve to improve the quality of the irradiated skin.**

It is also totally meaningless to attempt a quick noticeable volume buildup. We normally infiltrate only small quantities of 50–70 mL in the area of the breast skin. Generally, the structure and expansion capability of the skin are seen to improve after four or even after three of these treatments. Thus, a gradual increase in volume can be transplanted. Once a subcutaneous fat layer of about 2 cm has been achieved, one can now apply an expander with or without a tummy tuck (see Sect. 10.7.3).

10.7.6 Reconstruction After Mastectomy with the External Expansion System (BRAVA–AFT)

N. Heine

Transplantation of autologous fat tissue is utilized in most of the cases for the correction of contour deformities after a mammary carcinoma. Frequent indications are:

– Remaining pit formation after flap plastic surgery
– Volume deficit in case of insufficient flap volume
– Volume loss due to muscle atrophy, e.g., after a TMG or TRAM reconstruction

Mostly in this case, only limited volumes are injected; a pre-expansion, which includes

the entire tissue due to system requirements, is required here only in exceptional cases.

The situation is quite different in case of a very thin skin cover over an implant or expander reconstruction. If a fat augmentation is being planned here due to visible implant contours or rippling, then this generally becomes a difficult job due to the very thin soft tissue cover. The external pre-expansion with sufficiently large cups enlarges the subcutaneous space, loosens it with edema, and not only creates more places in the receiver matrix but also reduces the iatrogenic risk of an injury for the implant.

The prophylactic BRAVA–AFT treatment is similarly suitable for the thin soft tissue cover if an expander reconstruction is being planned. A stable soft tissue layer can be generated through one or two sittings with pre-expansion and subsequent autologous fat injection. This enables an implant reconstruction even in case of initially very thin soft tissue covers.

Reconstruction after mastectomy presently represents one more domain of flap plastic surgery or implants. Only a few publications have appeared to date about a successful complete buildup of the breast after complete mastectomy [12, 15].

The autologous tissue transfer through fat injection has a few system-based disadvantages in this indication (see the Summary).

Disadvantages of Breast Reconstruction with free Fat Graft

- Basically, several at least 4 procedures in Breast sizes until B are necessary.
- The harvesting possibilities are often limited.
- The risk of occurrence of oil cysts and fat necrosis increases.
- The time duration of the entire treatment requires a high degree of compliance from the patients.
- The result cannot be reliably predicted. But that is the case in any method of reconstruction.

For this reason and due to the oncological risk that cannot be evaluated with certainty, the female patients should be selected after strict tests, and they should be fully informed and told about all other alternative possibilities. The following patients are well suited:

- Non irradiated breasts
- Having a BMI of 25–30
- With “problem zones” on the stomach and the legs that are amenable to liposuction
- With a high level of compliance
- A max. planned reconstruction of a B–C cup
- Who, even after listening to advice, reject a reconstruction with a (high-risk) flap plastic surgery as also a reconstruction using a foreign object

The use of an external pre-expansion with the BRAVA System has significant advantages here: after a mastectomy, not only is the breast volume missing but subcutaneous and pre-muscular coarse and adherent scars also develop, which act against a sole fat injection. After the lipofilling, there often results a transverse withdrawal through the mastectomy scar; a forced scar treatment is always connected with the risk of bigger hollow spaces, in which a confluence of the introduced fat tissue results in necrosis and oil cysts.

Due to the multi-week pre-expansion, a continuous tension is exerted before the actual operation on these scar structures, which expands the adherences apart from the enlargement and expansion of the receiving area already described, removes the skin from the musculature, and thus optimizes the acceptance readiness of the tissue for the fat transfer. A clinical example is shown in Fig. 6.11.

10.7.7 After Subcutaneous Mastectomy

Subcutaneous mastectomy, which is frequently done for DCIS (ductal carcinoma in situ) and gene carriers (BRCA 1 and other conditions), represents a special case. If the operation is being carried out correctly and thoroughly, there is only a very thin layer of subcutaneous fat left. If in the subsequent procedure, a submuscular implant,

which could be reinforced by a plastic net or heterologous tissue, is introduced into the caudal area, then the new construction becomes very difficult using autologous fat.

Since in these cases, capsular fibrosis frequently occurs, the implant cannot be substituted by fat in a single sitting. This is because the existing tissue layer is not sufficient to replace the volume. As a consequence, a marked fibrotic shrinkage of the skin occurs with a formation of lymphedema, which has to be corrected through several individual small volume grafts. To some extent, the tissue is so hard that the fat tissue can only be introduced through a sharp needle. Therefore never try to place an implant ind those cases in one setting! Better exchange the implant for an expander and deflate stepwise in every procedure.

For this reason, we recommend a completely different procedure for such cases:

- **Since in the case of prophylactic subcutaneous mastectomy carried out due to reasons of an enhanced genetic risk, there is no urgent need for an emergency intervention; in such cases, the subcutaneous tissue layer can be significantly enlarged by carrying out an autologous fat tissue transplantation two or three times preceding the intervention.**

If a subcutaneous mastectomy is carried out after a reinforcement of the subcutaneous tissue, a sufficiently strong tissue layer is now present for covering an epimuscular implant that has now to be introduced.

If the patient desires to have a complete autologous fat reconstruction, an expander is introduced instead of the implant and later removed after proper volumetric filling up of the fat tissue. This procedure has been described in Sect. 10.7.3.

A vertical incision from the lower boundary of the areola to the sub-mammary fold has proven to be a favorable access during subcutaneous mastectomy. It guarantees an optimum access and a good overview in all areas, and later on, it is almost invisible as compared to the long and horizontally carried out incision in the sub-mammary fold as is the standard practice. A peri-areolar access is possible, but this frequently results in disturbances in perfusion in the caudal nipple-areola complex.

This procedure is good for smaller breast sizes (up to Cup C). If a reduction is simultaneously being carried out, then despite this, a previously carried out increase of the subcutaneous fatty tissue is recommended (in the later nonreduced area). The subsequent subcutaneous mastectomy can then be conveniently carried out using only a vertical suture or an L-shaped suture with a cranial pedicle formation.

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Gluteal Augmentation

11

Klaus Ueberreiter

11.1 Introduction

Enlargement of the hips and bottom has only a small demand in German-speaking countries. But there is a very great demand for this type of intervention in Latin American countries, in North America and in the Arab countries. One can say that there is a greater demand for augmentation of the bottom than for breast enlargement. And the number of demands is increasing constantly.

But one has to note the great width of variation in ideal concepts in different ethnical countries [1]. A form that emphasizes the enlargement of the cranial area (or the "Brazilian butt") is mainly in demand in the American countries, in southern Europe or in African countries. The Arab countries seem to prefer a general enlargement and expansion, whereas in North America, a compensation in the central region is in demand after a heavy weight loss has occurred.

- **It is commonly seen in all cultures that the ideal ratio of waist to hip lies at 1:1.4** [2]**.**

11.2 Indication

The indication for gluteal augmentation is:

- After heavy weight reduction
- If one is not satisfied with the shape provided by nature
- In case of acquired or iatrogenic defects
- Capsular fibrosis after previous silicone implantation [3]

Even the so-called banana fold deformation or a fat bulge below the gluteal fold caused by excessive fat suctioning can be corrected using one's own individual fat ([4]; photographic example for this is seen at the end of the chapter).

There are general form descriptions, which are taken as a basis (square-shaped, V-form, pear shaped; [5]), and from these, procedures are derived during the filling process.

The volumes of 200–1300 mL for each side have been described [6]. No reliable data is available until today about the resorption rate; the surviving fat tissue was detected in individual MRI control studies [6]. Recently gluteal fat graft has been rated as the most hazardous procedure in Plastc Surgery. That is entirely based on exaggerated and anatomically incorrect performed procedures. If one observes basic rules of volume limit and placement, it is as save as any other procedure.

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

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11.3 Methods

The following methods are applied:

- Vibration aspiration ("power-assisted liposuction") for suctioning as well as reinjecting the fat [7]
- The lipo-structure method according to Coleman [8]
- Undefined methods partly under PRP ("platelet-enriched plasma"; [9])

The chapter author utilizes the BEAULI-Protocol [10] with WAL (Water assitsted Liposuction).

11.4 Planning and Preparation

Since the individual concept of the ideal result can very strongly vary in the opinions between the surgeon and the patients, a most precise discussion with the concerned patient is absolutely necessary when planning the intervention. And this is most conveniently done using photographic simulation or plotting a drawing of the desired silhouette into a photograph. One can also request the patients to bring along with them photographs of what they ideally desire as an end result (e.g. downloaded from the internet). Thus one can prevent misunderstandings about the form to be achieved and even unrealistic expectations. But it should essentially be pointed out that the end result cannot be achieved solely through a single intervention; a repeat job may be required after 3 months.

During the preparations, the areas to be suctioned and to be enlarged should be drawn in differing colours as far as possible. Markings should also be carried out on the buttocks, especially the superior gluteal artery and veins. One should proceed very carefully while injecting the musculature as an additional enhancement in this region (Fig. 11.1).

While selecting the anaesthesia, it should be noted that the injection should be done in general in prone position. It can be done in the side position only in the case of mainly lateral augmentation.

Fig. 11.1 Markings

It is recommended to give a single shot antibiotic prophylaxis with, e.g. cephalosporin. In case of an enhanced tendency to thrombosis, heparin can be administered for 7 days.

11.5 Performance of the Procedure

Initially about 600–1000 mL of fat should be collected for reinjection.

- **It is strongly recommended to perform a thorough liposuction in a diamond-shaped area over the cranial sacrum. By this, the rounding of the buttocks gets additionally enhanced (Fig. 11.2).**

Basically there is no significant difference in the procedure of gluteal augmentation as compared to breast enlargement using the person's individual fat. However, in general, a significantly greater quantity of fat can be introduced in the buttocks area.

Fig. 11.2 Suctioning out in the sacral region

- **In order to achieve visible results, 300–500 mL should be injected into the subcutaneous layer as well as carefully and superficially the gluteal musculature on each side. Larger volumes would result in a higher absorption rate with possible scar-affected changes.**

Careless procedures can result in injuries of the large gluteal vessels followed by enhanced risk of pulmonary embolism. Generally, gluteal augmentation is considered to be a safe and reliable procedure with far lesser side effects than in the case of silicone implants [11, 12].

The volume is mainly introduced into the outer upper and central quadrants as well as, if required, in an epi-trochanteric fashion. The prick incisions can be selected in such a manner that the entire region can be injected in cris-cross technique from at least two sides (Fig. 11.3). The end point is reached, if the tissue is well expanded but still elastic.

11.6 Post-operative Treatment

It is recommended to place a diamond-shaped cut-out foam piece of about 3–5 cm thickness for a good contouring of the sacral region ("sacral diamond"), which should be worn for a period of at least 2 weeks (Fig. 11.4).

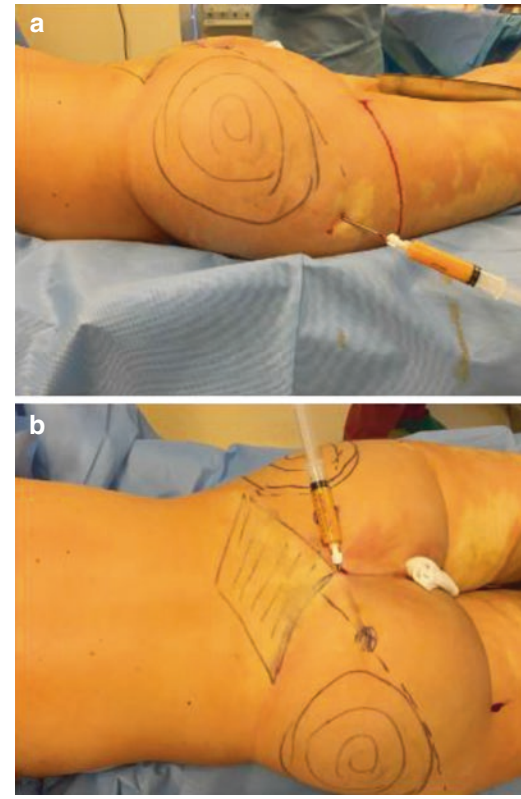

Fig. 11.3 (**a, b**) Injection process

Fig. 11.4 Wearing a sponge piece for contouring the sacral region

Compression garments must contain suitable cut-out portions for the transplanted areas (Fig. 11.5). Nowadays these are available for sale

Fig. 11.5 Compression trousers

by different manufacturers. The duration of recommended treatment is shown in the summary.

It should be pointed out during post-operative treatment that one should avoid as far as possible sleeping on the back and on the sides. But sitting is allowed in case of the upper augmentation. Only if infra-gluteal augmentation has been done ("banana fold"), then even sitting is not allowed.

11.7 Risks and Complications

Gluteal fat augmentation is a reliable method for increasing volume in case of correct ratio of fat transfer done to the area concerned in this region. This means, in the case of smaller buttocks, one shall not exceed 200 mL per side. In case of very large starting volumes, quantities up to 500 mL per side are possible. Even though there are reports of significantly higher quantities published [6], one would advise against such procedures for want of reliable published data.

Uneven levels (in the infiltrated regions) are more or less an exception.

When correcting scar defects, a desired correction is sometimes achieved only after several repetitions.

Injuries to the nerves or pulmonary embolisms were even with deadly outcomes were reported recently. All in connection with very large quantities of fat and often unqualified surgeons. Infections are very rare and should not occur in sterile procedures.

11.8 Patient Case Studies

Figure 11.6 shows a female patient, who constantly suffered from pain while sitting due to a defect while standing up after an SGAP-extraction (SGAP = "superior gluteal artery perforator"). After 290 mL of her own fat, the patient became fully cured of her pains. Apart from this, there was a visible optical improvement of the scar.

A transgender patient is shown in Fig. 11.7, who used to feel disturbed because of the male outline of her hip and buttock area. Figure 11.7 shows the condition before and half a year after a total of two transplantations of her own fat tissue of 300 mL during every procedure per side.

Compression Treatment

On the whole, the compression treatment for the suctioned areas should be carried out for a period of 4 weeks:

- 2 weeks over a 24 h/day
- Another 2 weeks for 12 h/day

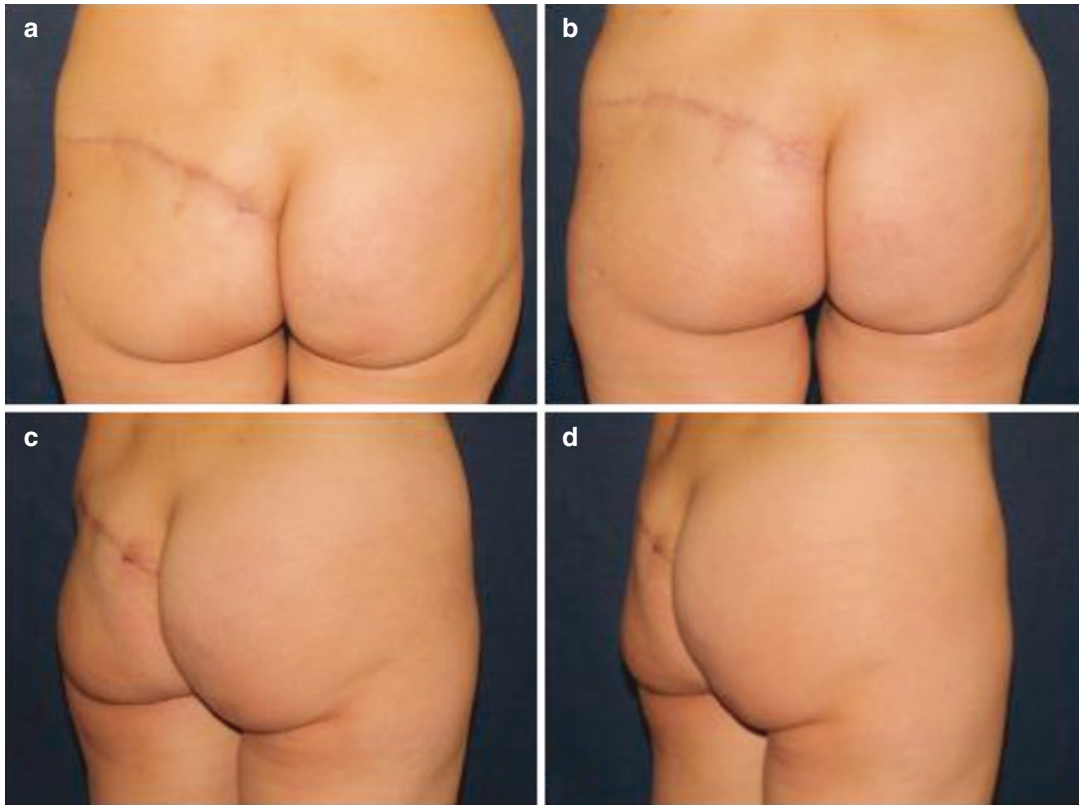

Fig. 11.6 (**a–d**) Patient with status after an SGAP-flap (SGAP = "superior gluteal artery perforator"). She constantly suffered from pain while sitting due to a defect while standing up. After 290 mL of her own fat, the patient became fully cured of her pains. Apart from this, there was a visible optical improvement of the scar

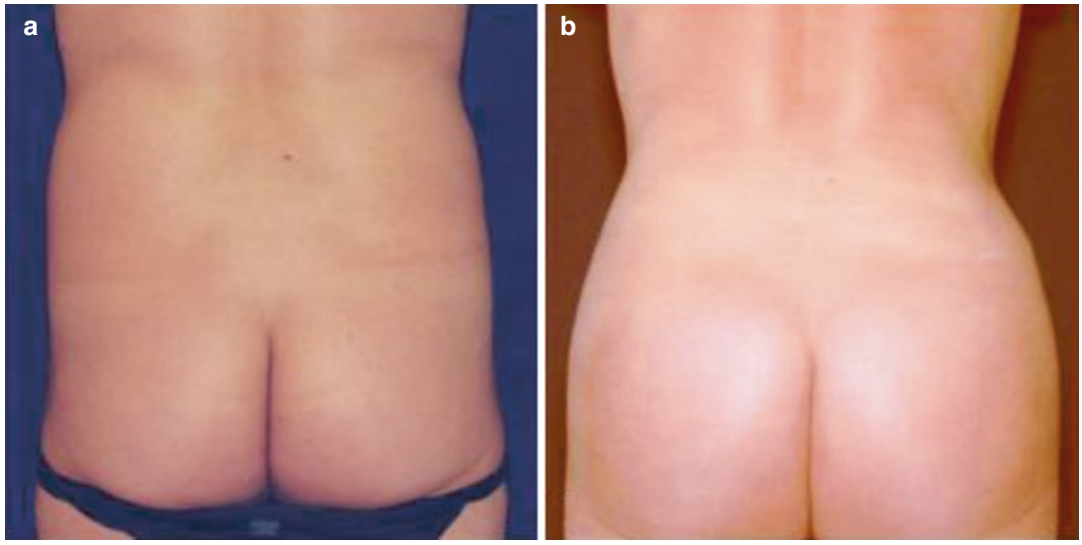

Fig. 11.7 (**a, b**) Transgender patient condition before and 6 months after gluteal augmentation through two transplantations of her own fat tissue of 300 mL, respectively, per side

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Lipofilling of the Hand

12

Cornelius Dieter Schubert, Maximilian Eder,
Laszlo Kovacs, and Riccardo Giunta

12.1 Introduction

A self-critical body consciousness and the desire for a fresh and, if necessary, a rejuvenated appearance are hot topics in our society today. Due to a continuous presence in daily life, plastic-aesthetic interventions are gaining increased popularity for changing the appearance of individuals and for reducing the appearance of ageing and fatigue. Apart from the face, the back of the hand is constantly exposed and visible to all, and this part is subjected, as in the case of other body parts, to a natural ageing process (Fig. 12.1).

In contrast to the facial region, hardly any preventive measures are taken consciously due to exposure to sunlight by using sun lotions or creams. In addition, in the area of the hand, further influencing factors include mechanical stress in everyday life and in work and daily contact with hazardous substances. The ageing process results in the back of the hand undergoing objective changes as described in the summary (Fig. 12.2; [1]).

Fig. 12.1 Ageing process of the hand (from left to right): 5-year-old girl, 40-year-old woman and 90-year-old lady with full expression of atrophy of the subcutaneous fat tissue, exposure of the veins and tendons, wrinkle formation and pigment spots. Another complaint present here is the ulna plus situation with the condition of a distal radius fracture

Changes at the Back of the Hand as Part of the Ageing Processes

- Formation of pigment spots
- Visible vein enlargements ("vein prominence")
- Visible tendon enlargements ("tendon show")
- Skin atony with wrinkle formation

C. D. Schubert · R. Giunta
Klinikum der Ludwig-Maximilians Universität München (LMU), Handchirurgie, Plastische Chirurgie und Ästhetische Chirurgie, München, Germany

M. Eder · L. Kovacs (✉)
Klinikum rechts der Isar, Technische Universität München, Klinik und Poliklinik für Plastische Chirurgie, und Handchirurgie, München, Germany
e-mail: l.kovacs@lrz.tum.de

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Pigment spots occur about starting from the 40th birthday and can be effectively reduced by means of:

- Laser therapy [3, 4]
- Intense pulsed light flashbulb therapy (IPS = intense pulsed light; [5])
- Peeling treatment

In order to reduce subcutaneous atrophy, autologous fat graft transplantation was carried out [3, 6–8]. But this initially resulted in frequent fat necrosis and nodule formation [9]. Only the technique of structural fat grafting introduced by Coleman in the final parts of the 1990s [10, 11] enables higher survival rates of the grafts with few complications. In this process, fat tissue that has been earlier processed by means of centrifuging is injected into numerous injection canals by means of fine cannulas in the form of boxes.

Dermal filler substances like calcium hydroxylapatite (Radiesse; [12, 13]), hyaluronic acid [14] or others [1, 15, 16] are often subjected to a breakdown process and must therefore be utilized multiple times. Substances alien to the body can also result in undesirable foreign body granulomas [17]. The transplantation of autologous fat tissue offers, on the other hand, possibly even the simultaneous autologous transplantation of mesenchymal stem cells of the fat tissue ("adipose derived stem cells", ASC; [18, 19]), a very promising opportunity for the rejuvenation of the hand.

The operational technique for lip fillings are demonstrated for the back of the hand in this paper.

12.2 Operating Technique

The injection of autologous fat is already an established therapy process for the treatment of e.g. deep skin furrows in the naso labial, forehead or lower eyelid areas. This technique can also be successfully used at the back of the hand [9]:

Fat is suctioned out from the area of the lower stomach (Fig. 12.3a) under sterile conditions through a prick insertion in the navel area. For this purpose any of the described harvesting methots can be used.

The sterile centrifuging of the injection syringes is done thereafter at 3000 rpm for just

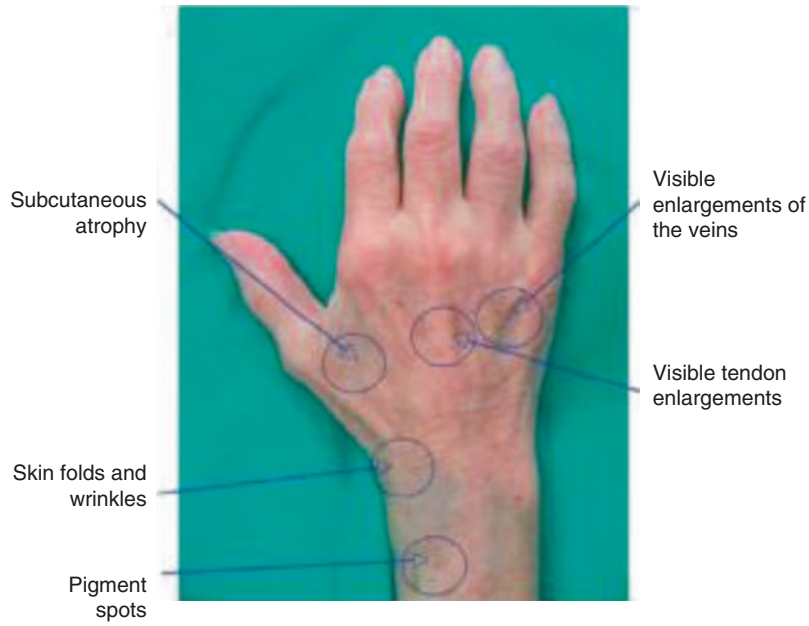

Fig. 12.2 Changes on the hand as part of ageing process (from [2] with kind courtesy)

3 min (Fig. 12.3b). The residue is discarded and the piston is introduced from the reverse side. Alternatively to this Colen protocol a short centrifugation with a simple hand centrifuge (e.g. Hettich 153) shows very good effects.

For the purpose of fat injection, special blunt injection needles are required. Injection needles are, depending on the manufacturer, commercially available in different diameters and lengths. As per our experience, the injection needles as

Fig. 12.3 Steps during the operation [2, 17]: (**a**) Liposuction in the area of the lower stomach. (**b**) Injection syringes after sterile centrifuging. (**c**) Prick incision in the area of the proximal back of the hand with a marking of the affected areas. (**d**) Box-shaped blunt preparation of access routes. (**e**) Autologous fat injection using advance prepared access routes. (**f**) Schematic diagram of the box-shaped fat injection. (From [2] with kind courtesy; the authors would like to thank Johannes Schmal, artist of the Klinikum to the right of the river Isar for the diagram of (**f**))

per Coleman (e.g. the company Byron) are suitable for the back of the hand.

- **Mostly, the volumetric defects correspond to the interosseous spaces. Usually 20 cc per hand are sufficient.**

Before the operation, the concerned volumetric defects are marked at the back of the hand (Fig. 12.3c). Thereafter, the local anesthesia of the back of the hand is carried out, e.g. with lidocaine through a dorsal handblock of the Ramus superficialis of the N. radialis and the space dorsalis of the N. ulnaris.

Now box-shaped access routes are created (Fig. 12.3d) in the especially visible atrophied areas between the tendons and the metacarpal bones. The fat tissue extracted from the lower stomach was processed in the meantime (see the top) and can now be introduced using a blunt infiltration needle (Fig. 12.3e, f). This is done in the form of boxes in fine canals.

- **The injection of the fat tissue shall be done only after drawing back the needles in the sense of a filling up of the canals thus created by the needles.**

In order to keep the contact areas as large as possible and thus to enable a quick incorporation, only very thin layers of fat tissue cells are introduced. The healing rate is improved by adopting this technique.

Principles

– An external compression of the fat tissue should be avoided as far as possible.
– Only blunt instruments shall be used; this prevents injuries of the sensitive skin nerves and vessels.

In this manner, the skin is under-cushioned. By augmentation of the subcutaneous fat tissue, the veins and tendons become less visible. By this, optically, a primary rejuvenation effect results [17]. Other rejuvenating effects, e.g. by an increase of the collagen production with a subsequent increase of the dermis thickness, are being actively researched [20–22].

Finally, the prick incisions are closed using 5.0 non-absorbable monofile suture material (e.g. 5.0 Ethilon; of the company Ethicon), and a sterile ointment gauze wound bandage is applied.

12.2.1 Post-operative Treatment

The hand joint is immobilized post-operatively for a period of 5 days in an underarm splint. But the fingers are not immobilized.

- **Thus both hands can be operated upon easily within a single sitting.**

12.2.2 Case Study with Example

A 72-year-old patient consulted us in our clinic, with a desire to rejuvenate the back of both of her hands. She had very few pigmentation spots on these areas. But she felt especially disturbed by the subcutaneous atrophy with a strongly visible set of veins and tendons as well as an increasing formation of wrinkles and folds (Fig. 12.4a).

Chances and risks of transplantation of autologous fat graft were discussed with the patient before the operation on two different dates of consultation.

Initially, 40 mL of fat tissue from the area of the frontal stomach wall were suctioned out using liposuction under local anesthesia and processed based on Coleman's procedures (2008). About 3–4 cm^3 of the centrifuged fat tissue was injected in the form of boxes into each interosseous space. A total of 14 cm^3 of fat tissue was grafted overall for each back of the hand.

The post-operative healing process turned out to be without any complications. The stitches were removed on the 7th day after the operation. In the inspection after a period of 6 months, the desired filler effect was seen with veins and the

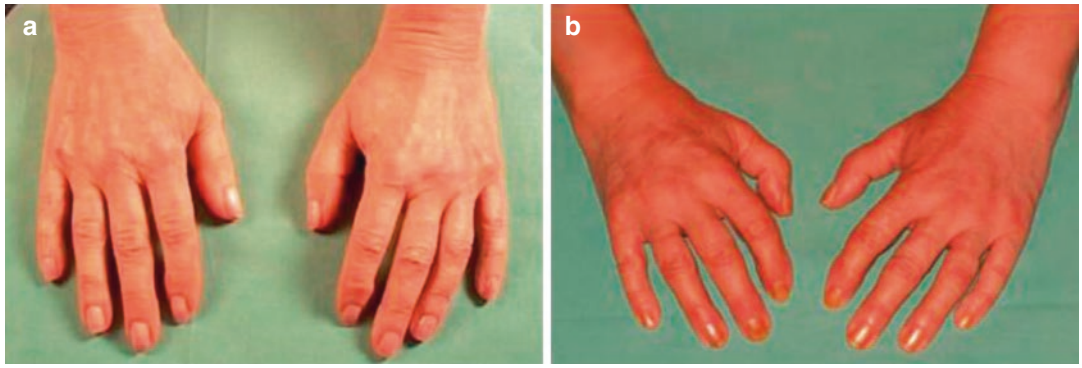

Fig. 12.4 (**a**, **b**) Case study example: transplantation of autologous fat tissue at the back of the hand in case of a 72-year-old female patient. (**a**) Pre-operative complaint with typical stigmas involving ageing of the hand: among other things, atrophy of the subcutaneous fatty tissue, clearly visible veins and tendons as well as loosening of the skin with wrinkles being formed. (**b**) Post-operative appearance 6 months after transplantation of autologous fat graft with a clearly filled-up subcutaneous fat as well as reduced visibility of veins and tendons (from [2] with kind courtesy)

tendons reduced in visibility in the area at the back of the hand (Fig. 12.4).

12.3 3D Mapping of the Body Surface

The 3D mapping of both hands of the patient is carried out in this example by means of a linear laser scanner, Type Minolta Vivid 910 (made by the company Konica Minolta Co. Ltd. Osaka, Japan). The patient's hands are mapped three-dimensionally at different points of time in this process based on standard scanning procedures fixed already for other body regions [19]:

- Pre-operatively:
  - Pre-OP
- Post-operatively:
  - Post-OP I—first day post-operatively
  - Post-OP II—first month post-operatively
  - Post-OP III—6 months post-operatively

The hands of the patient are scanned and evaluated as virtual 3D models using a special software package (Raindrop Geomagic Studio 10 and Geomagic Qualify 9, of the company Raindrop Geomagic Inc., NC, USA). The virtual 3D models of both the hands are studied with regard to the following at each point of time based on a standardized analysis protocol [23]:

- Changes in surface contours (Fig. 12.5a–d)
- Changes in the volume (Fig. 12.5e)

Changes in surface contour of the virtual 3D hand models are visualized and analysed with the help of the software called Geomagic Qualify 9. The pre-operative 3D hand model (reference model) is superposed on the respective post-operative 3D hand model (test model), and the mean deviation is displayed of the model surfaces compared to one another in a colour-coded histogram (mm) in a so-called 3D comparison or by point-based annotations (deviations in mm) (Fig. 12.5 a, c).

The contour changes can be visualized and quantified along a standardized and positioned sectional plane in the area of the back of the hand at different post-operative periods of time in comparison to the pre-operative starting status with the help of a 2D deviation (mm) (Fig. 12.5b, d). A clear change in contour can be seen with the passing of time from the instant of post-OP I (Fig. 12.5a, b) until the instant of post-OP III (Fig. 12.5c, d).

Using the software Geomagic Studio 10, the post-operative volumetric change can be quantified apart from this (Fig. 12.5e). One day after the

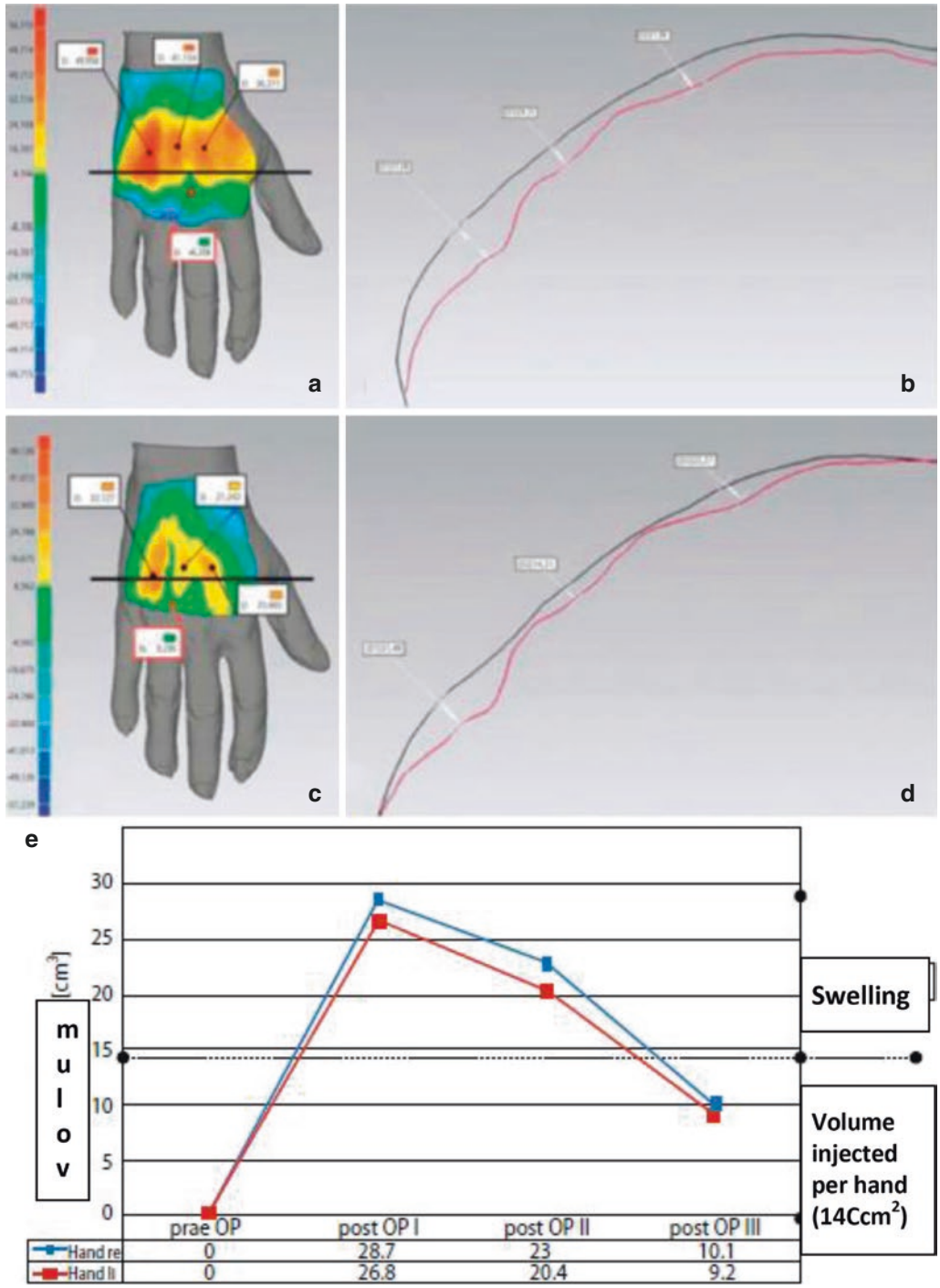

Fig. 12.5 (**a**–**e**) 3D quantification of surface changes using the example of the right hand. (**a**) Colour-coded pre-operative status at the outset (pre-OP). (**b**) 2D deviation between pre-operative starting status (pre-OP) and post-operative result (post-OP I—first day post-operative). Deviations in mm. (**c**) Colour-coded post-operative result (post-OP III—6 months post-operative). (**d**) 2D deviation between pre-operative starting status (pre-OP) and post-operative result (post-OP III—6 months post-operative). Deviations in mm. (**e**) Quantification of post-operative volumetric change including the tendency for swelling of both the hands as time progresses (pre-OP, post-OP I (first post-operative day), post-OP II (one month post-operative), post-OP III (6 months post-operative)) with the help of 3D body surface scanning in cu cm (from [2] with kind courtesy)

operation (post-OP I), the mean post-operative volumetric change shows the highest value for both the hands (27.8 cm^3), i.e. the injected volume of the fatty tissue and, in addition, the post-operative swelling. In the further course of post-operative events, the volumetric difference decreases to pre-operative, then through post-OP II (21.7 cm^3) to post-OP III (9.65 cm^3) corresponding to the post-operative reduction in swelling. Six months after the operation (post-OP III), thus, in the present case, an average of 68.9% of the injected volume is retained.

12.4 Discussion

12.4.1 3D Surface Scan

Different mechanisms cause the ageing process at the back of the hand. But it is possible to suitably reduce and to attenuate the ageing of the back of the hand by using different processes and treatments. Depending on the circumstances, one can also use a combination of different procedures as part of a single operation or even a two-stage procedure could be desirable.

But in each case, the precondition for each treatment is the individual and detailed consultation about the chances and risks associated with the individual plastic-aesthetic procedure.

The operation should be carried out only by experienced hand surgeons. This is because the intervention requires experience with the special surgical requirements of the hand and the post-operative treatments of hand surgery interventions. Until recently, reports have been published about a post-operative infection at the back of the hand with atypical mycobacteria after autologous fatty injection at the back of the hand [18] as per our understanding.

The operating technique introduced here is simple to execute and can be safely carried out by surgeons experienced in hand surgery and plastic surgery.

- **During injection of the fat tissue, the occurrence of bigger fat tissue nodules should be avoided (-→ primarily homogeneous distribution). This is because otherwise this could give rise to fat tissue necrosis. The subsequent distribution as well as modelling of the fat tissue through outer compression should be avoided as far as possible.**

The method introduced here of the objective 3D body surface scanning allows a reliable volumetric calculation and surface contour analysis even for the hand as time progresses. Investigative costs have not yet been assessed. This is because the costs would include the costs for the procurement of the equipment in the area of sonography. As compared to alternative procedures like e.g. magnetic resonance tomography (MRT), this investigation is significantly economically viable [24].

Characteristics of the method introduce:

- Patient-friendly
- Quick
- Contactless (no deformation of the soft tissues)
- Non-invasive

As compared to some radiological processes like computer tomography (CT), there is no radiation load [25, 26].

However, there seems to be an important disadvantage in this: As compared to nuclear magnetic resonance imaging (MRI), there is no possibility of checking the vitality diagnostics of the transplanted tissue.

Significance
Laser scanning is thus suitable as an objective volumetric process for the evaluation of transplantation of autologous fat tissue. As compared to the conventional 2D photography, it enables an objective analysis of the operating results in the progress of time in the sense of a post-operative quality assurance ([23, 26]).

Recent methods include 3D photogrammetry, which in our experience, represents a valid instru-

ment of volumetric recording in the plastic surgery of the face and the breasts.

- **Preliminary results show that during structural fat grafting at the back of the hand, about 69 % of the injected volume remains in place permanently.**

This would approximately correspond to the resorption rate after transplantation of autologous fat tissue in the breasts. This volume appears to mainly correspond to the surviving grafted fat tissue. This itself shows that the tissue is clinically soft and free of scars. Laser scanning allows no vitality diagnostics, however, in comparison to MRI, but instead is restricted to solely the volumetric measurement possibility.

12.4.2 Transplantation of Autologous Fat Tissue at the Back of the Hand

The characteristics of subcutaneous atrophy and its consequences like the prominent appearance of veins and tendons can be attenuated as per our experience, with structural fat grafting. In contrast to destructive procedures (like the destruction of veins of the back of the hand through endoluminal laser ablation; [23]), structural grafting appears to be best suited as a regenerative solution in our opinion as per today's technology.

Especially in contrast to the usual filler substances [12, 14, 15] like e.g. hyaluronic acid, the body's own tissue is utilized for the healing. This achieves a rejuvenation in the sense of a regeneration through the patient's own fat tissue.

An especially enhanced healing potential can be achieved based on transplanted stem cells of the fatty tissue (ASC) during structural fat grafting [20, 25, 27–30], probably due to the influence of the factors initiated by the ASC like e.g. bFGF, IGF, VEGF or PDGF [22]. The precise mechanism of effectivity is the subject of ongoing research [10, 20–22], which will identify the actual effect of the ASC and the corresponding initiating factors.

12.5 Summary

- The technique of transplantation of autologous fat tissue for the purpose of rejuvenation is in the experience of the hand surgeon, a reliable process for the attenuation of symptoms of subcutaneous atrophy at the back of the hand.
- The objective study of long-term success shows a permanent volumetric effect of about 70% of the injected volume.
- Lipo-filling at the back of the hand is a method of regenerative medicine, which is secondary to the concept of an actual regeneration through the body's own tissue as compared to the presently practiced alternative process.

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Contour Deformities of the Trunk and Extremities

13

D. L. Francia

13.1 Introduction

Free autologous fat cell transplantation is suitable not only for the aesthetic correction of degenerative changes of the facial skin or as a volumetric filler in breast surgery. Since the past few years, it is also being used for the restoration of the integument, in this case, especially of the subcutaneous fat tissue, at the stem and acra [1]. The wide range of applications of transplantation processes that can be used is indicative here.

- **Basically, in the case of expanded secondary volume defects and strong scar contractures, the local stemmed, free fold plastic surgery or the dissolving Z-plastic surgery represents the primary treatment in general plastic surgery.**

In case of smaller contour defects, for example, a hypotrophic scar on the finger, front part of the foot, hand, or ankle, the volume that is to be transplanted (up to 50 cm^3) can be harvested and inserted the quickest using the method as per Coleman or with the single stage systems (e.g., strim) for the so-called microfat graft using local anesthesia [2]. In case of several larger areas like at the stem, gluteal, or upper thigh region, one may require several interventions and a closed sterile system, with which intraoperatively, volumes up to 300 cm^3 can be harvested and transplanted economically. In this case, the BEAULI method is used.

Most of the peripheral contour irregularities are caused posttraumatically or iatrogenically and are seldom inherited (M. Romberg, Sclerodomy, HIV). These occur during wound healing through subcutaneous atrophy of the fat tissue or the fibrotic transformation of the dermal collagen (Type I and Type II).

The resulting volumetric defect could occur due to different patho-mechanisms, which decisively influence the type and the duration of the correction treatment. The most frequent causes are due to burn injuries or decollement injuries, operative interventions (tumor resection, external fixatives), acid or caustic injuries, or injection therapies.

A detailed case history and documentation of the areas as well as, if required, a radiological study using MRI are essentially to be done before the operation, and these will help in a precise operation planning. When in contact with the patient, a differential indication study should be done for the purpose of reconstruction of the local subcutaneous fatty tissue in case of clinical pains or for an aesthetic contour correction in case of otherwise freedom from pains.

D. L. Francia (✉)
Department of Plastic and Reconstructive Microsurgery/Hand Surgery, Charité University Medicine, Ernst von Bergmann Clinic, Potsdam, Germany

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It is important to pin down the important skin complaints and the objective of the therapy jointly with the patient in the very first consultation itself. This enables, on the one hand, an objective and detailed understanding of the patient's requirements and, on the other, simplifies the precise planning of the operation. In the process, it is important to take into consideration the expectations of the patient and also what is done in the other areas of application of autologous fat graft transplantation.

13.2 The Procedure

Peripheral Volumetric Defects
During the identification and the treatment of peripheral volumetric defects, certain parameters have to be taken into consideration:

- The cause
- The spread
- Localization
- Sympathetic pains

Due to isolated traumatic compression, local fat tissue necrosis seldom occurs with remaining intact skin over it, so that exclusively a filling up is required of the empty subcutaneous tissue spaces. Mostly, one has to carry out a combined treatment of the scar and defects for the restoration of the subcutaneous structure as an important protective and sliding layer and thus eliminate the contour unevenness.

For example, in the burns and soft tissue surgery, one can see that large areas of the wound are covered with a meshed split skin, even beyond the articulated joint (Fig. 13.1). This can exhibit

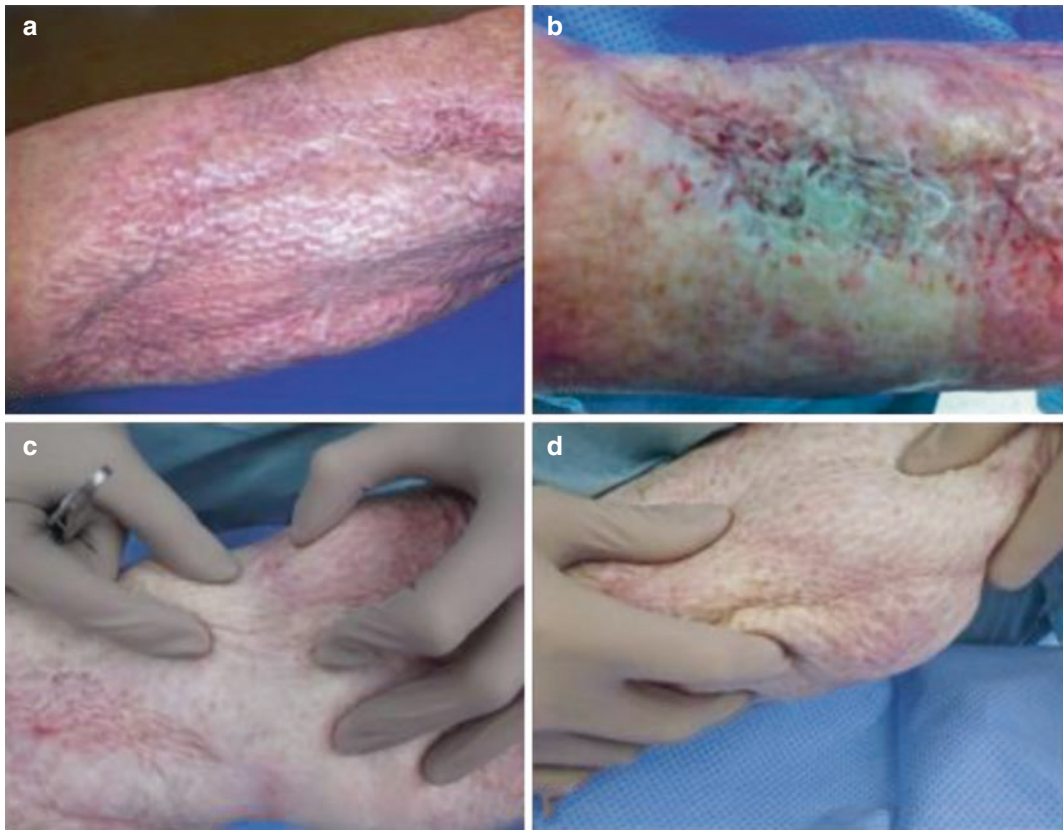

Fig. 13.1 (**a**–**d**) Volumetric defect after injury to the peeling and split skin grafting at the lower part of the thigh. (**a**) Adhesive and hardened surface scar preoperative. (**b**) After adhesiolysis and re-injection of the fat tissues. (**c**) Subcutaneous fat tissue serves as a sliding mechanism. (**d**) Postoperative result after a period of 3 months

dermal and epidermal consolidation on the muscle fascia and, in the course of time, result in painful contractures.

The new "substitute skin" lacks elasticity and tension due to the collagen scar formation. The subcutaneous fat tissue is only partly or as in case of injury to the peeling, totally destroyed. Postoperatively adherent and hypotrophic scar regions result in a local sinking of the skin, and thus the volumetric deficit is clearly visible.

The fibrotically changed, mostly stigmatized skin and soft tissue areas must be examined most precisely for deep and surface-based scar formation preoperatively and this must be recorded. In a similar manner, the following must be included in a precise multimodal documentation:

- A precise dimensioning of the depth, width, and length
- The consistency and sliding capability of the local skin
- The skin complexion
- The presence of pains pain
- Restrictions in movement

In case of complaints beyond the articulated joints, the scope of movement of the extremity should be recorded using the neutral-0 method and saved in photographs.

A preoperative MRI is recommended for a precise demonstration of the skin and soft tissue conditions in case of expanded volumetric deficiency. Thus even in case of externally inconspicuous skin faults, internal scars can be demonstrated (Fig. 13.2).

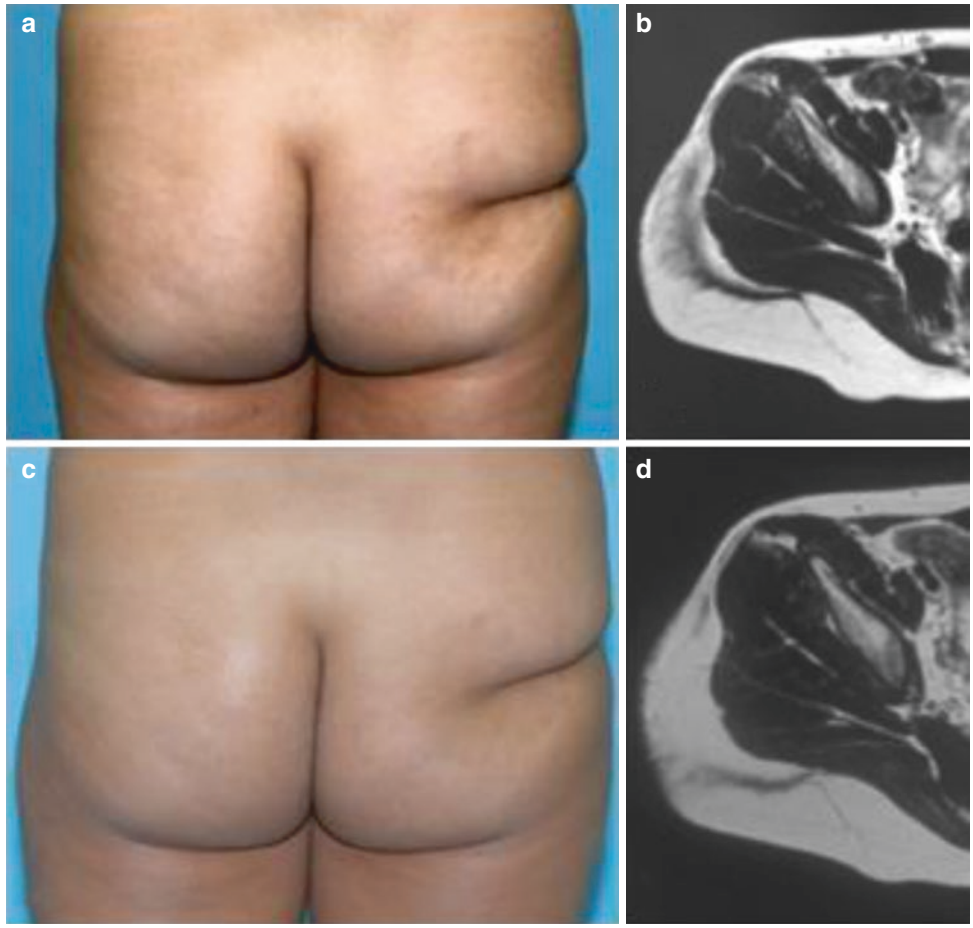

Fig. 13.2 (**a**–**d**) Gluteal withdrawal without cutaneous lesion as an example of subdermal scar formation after a hematoma of the soft tissue. The MRI proves the beginning of the scar dissolution after the first procedure

13.3 Technique

- **The primary objective of treatment is mainly the restoration of the subcutaneous fat tissue layer and the soft tissue contour.**

The same technical guidelines are valid for transplantation of autologous fat graft analogous to the application in facial or breast surgery in case of peripheral volumetric deficiency. But the procedure has to be carried out based on the volume, in which the graft is re-injected into the receiving area radially and in a multi-planar fashion (Chap. 4).

In case of a fully intact epidermal and dermal skin layer, the autologous fat is best suitable as a biocompatible filler for a low-risk correction of the contour irregularities. The autologous fat is introduced through the injection point into the subcutaneous region without any perceptible resistance. Even here, the volume introduced should solely serve for a propagated stress of the local skin. Overcorrection should be avoided among other things, because of the pressure-based oil cysts formation.

But if there is a multilayer scar formation, then the operative and postoperative settings get modified.

Initially, sufficient space has to be created at the receiving point by dissolution of the scar for the purpose of the grafting [3]. During the process, numerous point-shaped pricks could occur or hollow spaces due to rigottomy, into which the small fat particles are finally placed.

- **Cave. In order to reduce the danger of an infection or perfusion disturbance, the mostly scar-affected and thus fragile skin must be damaged to the least possible extent.**

A local hyperemia of the skin can be exhibited even up to 4 days postoperatively.

In general, multiple sittings are required for planar dermal adhesions, like in case of volumetric defects associated with split skin (Fig. 13.3). Even after the first use, the resistance during the re-injection of the graft gets perceptibly reduced.

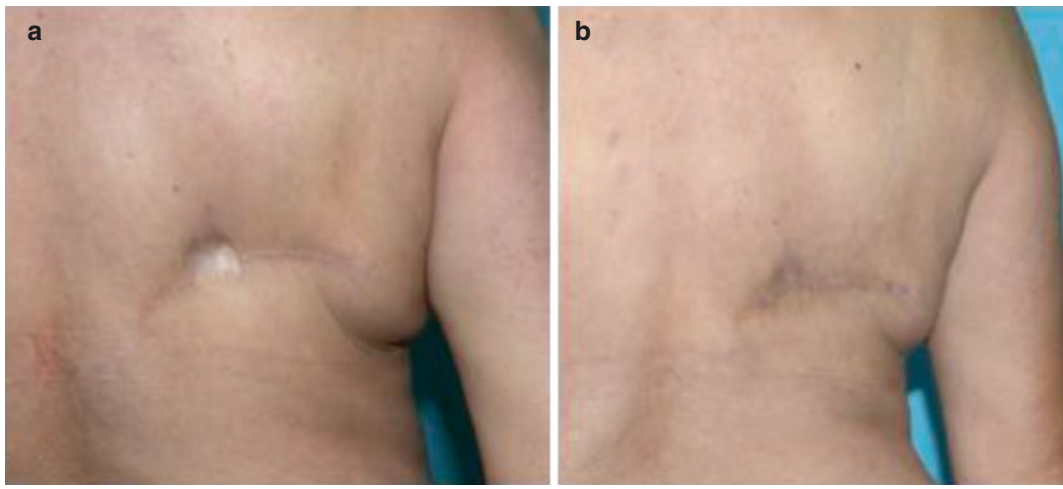

Fig. 13.3 Adherent and painful scars after Latissimus-dorsi-fold plastic surgery (**a**). Restoration of the contour defect (**b**) and freedom from pain after two procedures

13.4 Postoperative Treatment and Results

13.4.1 Postoperative Dressing

The patient should be provided intraoperatively with a low-compression sterile compression and cotton bandage, if required, with a splint for immobilization, depending on the localization and elongation of the receiving region. This should be left up to the first postoperative day, and the body portion shall be kept warm.

The extraction points should be supplied with or without compression dressing corresponding to the transplantation process used.

13.4.2 Complications

The most frequent postoperative complications of the donor regions are as follows:

- Hematoma associated with liposuction
- Pain due to movement and pressure
- Infection of the insertion points
- Temporary reduction in sensitivity

The following complaints of pain could occur at the receiving point:

- Unpleasant feeling of tension
- Touch sensitivity
- Pulling movement pains
- Cutaneous infection with wound healing disturbances
- Skin necrosis

Similarly there could be a partial or complete failure of the transplantation, for example, in the pre-irradiated skin regions after tumor resecting.

13.4.3 Immobilization

A consequential immobilization of the concerned extremity can be supported by splints for a maximum period of 7 days. Thereafter, a weightless arrangement must be made for daily activities for at least a further period of 4 weeks. The wearing of low-compression dresses and strict abstinence from sports shall be maintained by the patient for a total of 6 weeks.

A subsequent operation can be carried out starting from the third postoperative month after proper procedures.

13.5 Summary

Transplantation of autologous fat graft serves for the restoration of the subcutaneous tissue and results in an increase of the dermal mobility and skin elasticity. In case of complaints beyond the articulated joint, an improvement in the freedom of movement can be achieved (Fig. 13.4). Apart from this, the consistence and complexion of the scar area undergo a change, and the patients report a significant improvement in pain relief due to pressure and movement.

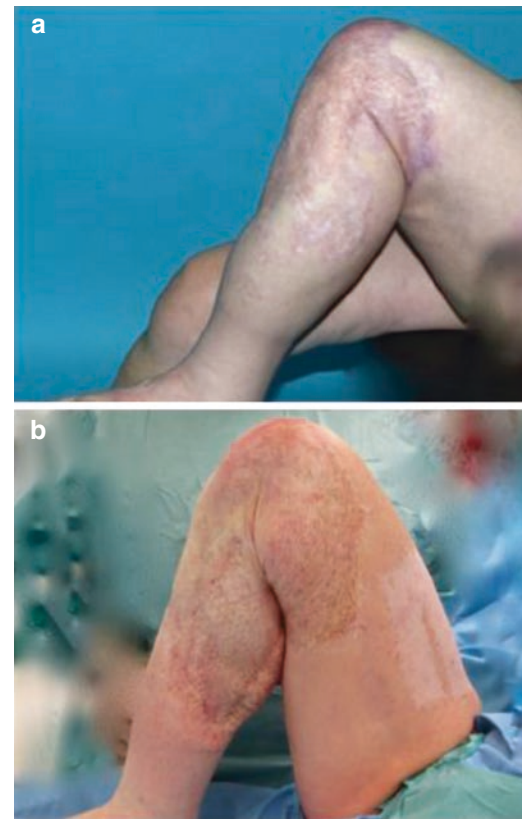

Fig. 13.4 (**a**, **b**) Increase of dermal mobility and thus freedom of movement after two procedures at the ventral knee region in case of contractures associated with split skin

The regenerative properties of the fat graft are presently the subject of updated experimental and clinical studies.

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Chronic Wounds

14

Tilman Stasch

14.1 DEALT Method

- **The DEALT Method ("debridement and autologous lipotransfer") describes a technique of wound debridement and transplantation of autologous adipose tissue for the purpose of supporting the wound healing in cases of chronic ulceration of the lower extremities.**

Chronic wounds of the lower extremities generally pose a huge challenge not only in plastic surgery but also in general surgical practice. Existing ailments like diabetes mellitus or vascular disease often delay adequate wound healing using conservative therapy. Especially chronic wounds, which have already been treated without success for prolonged periods of time using surgical debridement, negative pressure wound therapy (NPWT), or split skin grafting, generally have to be dealt with by radical surgical measures like amputations.

The positive influence of fatgrafting onto the skin [1], scar tissue [2], and burn scars [3] as well as a positive influence during the healing of chronic wounds [4, 5] and decubitus ulcers in the early stages [6] was mainly reported in individual cases.

T. Stasch (✉)
Dr. Stasch Clinic, Nairobi, Kenya

14.1.1 In-House Study Results

In the present study [7], a simple technique is described for the treatment of therapy-refractory wounds of the lower extremities in case of diabetic foot syndrome and chronic perfusion disturbances. Malignancy was excluded preoperatively in all cases.

Twenty-six patients (17 men and 9 women) with an age of between 25 and 85 years (average 60 years) were included in the prospective cohort study. The average BMI was at 26.9; all the patients suffered from diabetes mellitus, half of them suffered from peripheral vascular disease. Inclusion criteria were therapy-resistant (progressing for more than 2 months) ulcers of the lower extremity of above 2 cm^2 size. Therapy-resistant meant that the patients did not show any tendency to a reduction of the wounds despite conservative care by specially trained wound- therapy personnel and also after surgical therapy through debridement, vascular intervention as well as plastic surgery therapy.

The main investigative criterion was the time period for complete wound closure, and another measurement criterion was the period of time for a reduction of the wound surface by 50%.

Results: Eighty-eight percent of all the patients showed very good healing results in the abovementioned study. After unsuccessful previous therapy for an average of 17 months (2–72 months), a complete wound closure was seen after an average of 2 months. A reduction of the

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wound base by an average of 50% was achieved after a period of just 4 weeks. All the wounds were followed up - for at least 3 months and healed tissues were observed to be stable. No complications were observed due to this treatment.

In case of very large wounds of above 10 cm^2, a healthy granulating wound base can be achieved through the DEALT Method, which better accepts a conventional split thickness skin graft for the final coverage. In case of stagnating wounds, the described therapy can be repeated after a period of 3–4 weeks.

- **The objective is to transform chronic wounds into acute wounds.**

Even in cases of exposed bone, complete wound healing was achieved.

In order to successfully perform the DEALT method of healing chronic wounds, it is important to closely follow the described steps 1 to 10, below. In case of complete lack of compliance by the concerned patient, however, this method is generally doomed to failure.

No complications were observed due to this treatment.

- **The average operating time of the method described in the following is about 30 min.**

Examples are shown in Figs. 14.1, 14.2, 14.3, 14.4, and 14.5.

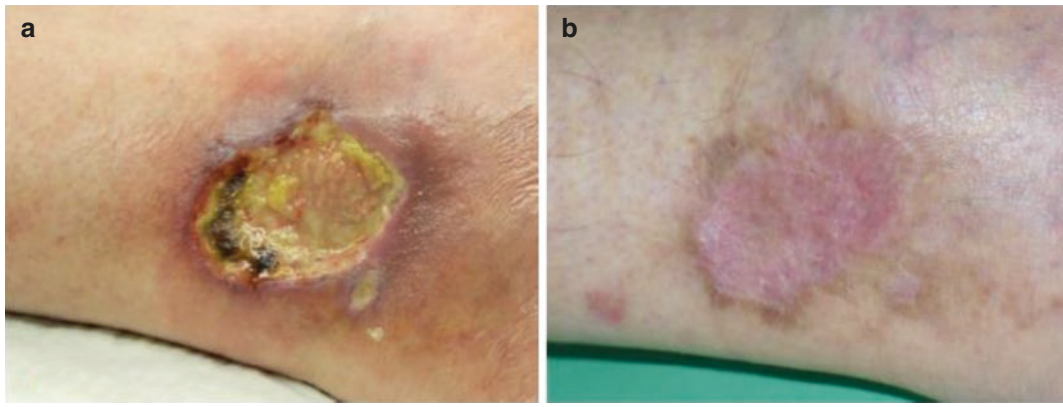

Fig. 14.1 (**a**, **b**) (12 months old) completely heals after a treatment with the DEALT Method and split thickness skin grafting (Courtesy: Stasch et al. [7], with kind permission)

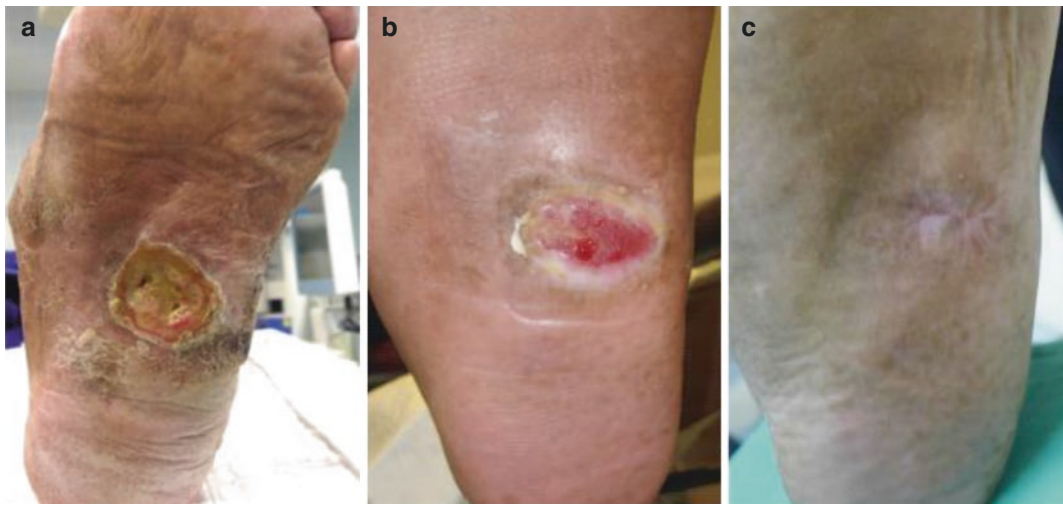

Fig. 14.2 (**a**–**c**) Diabetic foot in case of a 74-year-old patient with chronic renal failure and right-side below knee amputation: the Mal perforans ulcer (**a**) was treated with debridement and autologous lipotransfer and showed a complete wound healing (**c**) (from Stasch et al. [7], with kind permission)

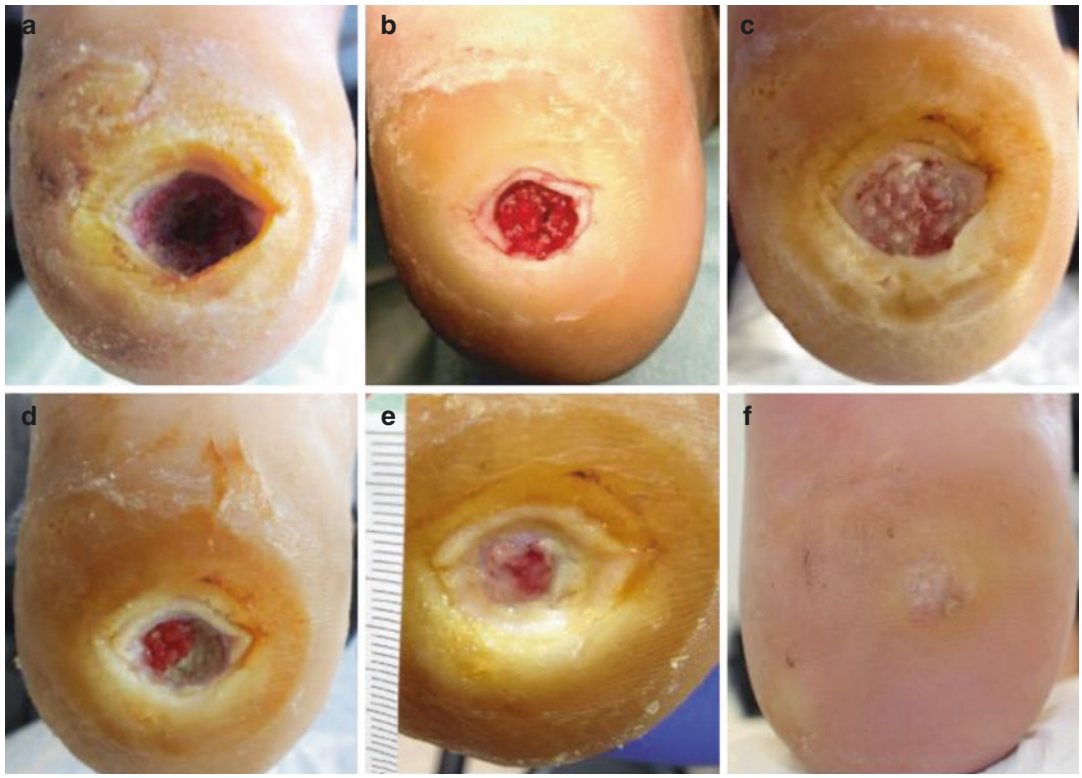

Fig. 14.3 (**a**–**f**) Wound in case of a 46-year-old patient (existing for 1 year): (**a**) After debridement, (**b**) after lipotransfer, (**c**) 6 days (**d**) Showing granulation tissue and (**e**) 21 days postoperative with granulation tissue and complete wound healing (**f**) (from Stasch et al. [7], with kind permission)

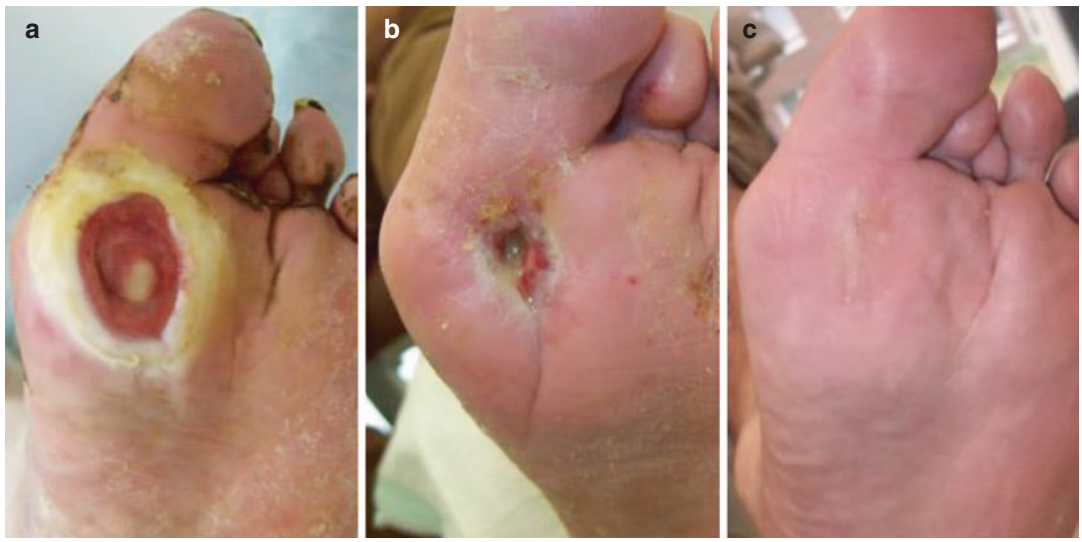

Fig. 14.4 Diabetic pressure ulcer, refractory for 19 months (**a**) showed a good healing tendency after 8 mL of lipotransfer (7 weeks; **b**) and complete wound healing after a period of 10 weeks (**c**) (from Stasch et al. [7], with kind permission)

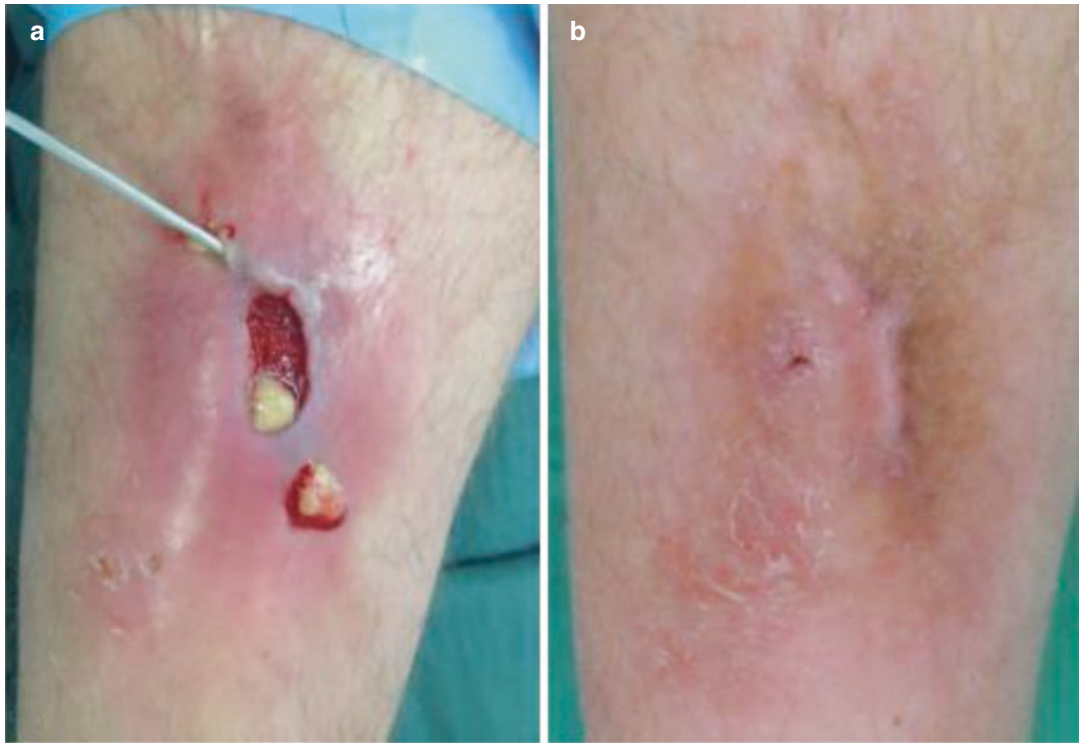

Fig. 14.5 Lipotransfer by means of the DEALT Method in case of a pretibial ulcer (5 months old; **a**) and postoperative photo with stable tissues (**b**) (from Stasch et al. [7], with kind permission)

14.1.2 Surgical Procedure Involving the DEALT Method

A wound swab should be taken a few days preoperatively, in order to be able to objectively provide treatment using appropriate antibiotics both preoperatively and postoperatively. The intervention is done under the usual surgically sterile conditions.

Step 1: The procedure can be selectively carried out under general anesthesia, spinal anesthesia, or local anesthesia. In the process, tumescence solution (10 ml of 2% Lidocaine and 1 ml of adrenaline per liter) is used to infiltrate the adipose tissue donor area - usually the anterior upper thigh or lower abdomen.

Step 2: The wound base is debrided using a sharp scraper and the wound margin is cut out using a scalpel. Exposed bones are sparingly resected using a Luer tongs. If required, biopsies can be taken for the purpose of an histological investigation.

Step 3: The preferred areas for an extraction of the lipoaspirate are the lower abdomen as well as the upper thigh. During liposuction of the lipoaspirate, one should observe the general safety guidelines for successful tissue grafting (Chap. 4).

- **About 2 mL of fat tissue per square cm of the base are required.**

Step 4: The decanted and non-centrifuged fat is transferred in 1 or 2 mL syringes with a Luer lock adapter.

Step 5: Sharp needles of 16–18 G are suitable for an injection into the wound surroundings and the wound base. During infiltration of the fat, it should be ensured that the direction is from the healthy tissue toward the wound (Figs. 14.6). High pressure infiltration causing blanching of the skin, should be avoided. This is because this could lead to further necrosis formation of the surrounding tissue. The remaining fat can subsequently be filled up in the wound crater.

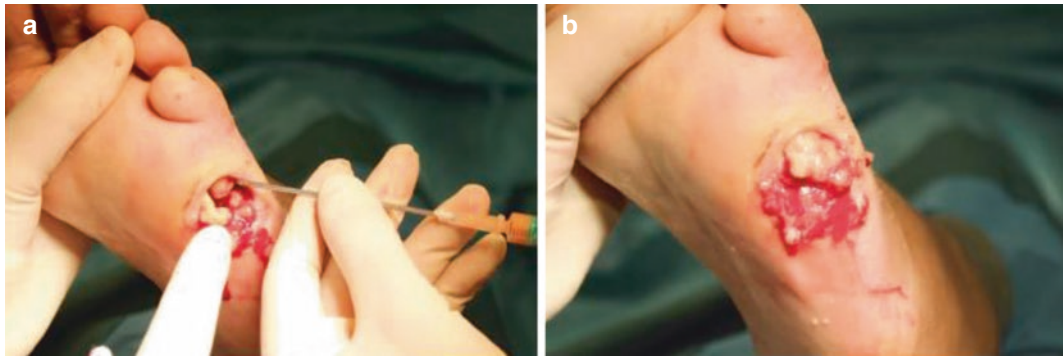

Fig. 14.6 (**a**, **b**) The DEALT Method: After debridement of the wound, lipotransfer is performed into the wound periphery and the wound base using a 16-G needle (from Stasch et al. [7], with kind permission)

Smaller wounds can now directly be covered with a nonadhesive silicon gauze.

Step 6: Wounds of above 2 cm^2 surface do heal significantly quicker, if in the same sitting Reverdin grafting is carried out (see the summary). Any area with skin excess is suitable as the donor site for the skin (e.g. grain). The donor site can then be closed primarily with running absorbable intradermal sutures. The Reverdin grafts are then loosely placed onto the transplanted fat which covers the wound base.

Step 7: The entire wound can then be covered with paraffin gauze, although preference should be given to non-adhesive fenestrated silicone sheet if available. The primary wound dressing should be left for 4–5 days, in order not to disturb the initial healing phase (just like in the case of a full thickness skin transplantation). For the next layer of dressing, preference is given to a transparent, adhesive film dressing which is manually fenestrated, in order to keep the wound moist yet allow exudate to seek through. The exudate is absorbed by sterile compression gauze which can be changed daily.

Alternately, a vacuum dressing (NPWT) can be applied. It is especially suitable for better immobilization of very active patients.

Step 8: Perioperative and postoperative antibiotic therapy is very important based on the swab results.

Step 9: Strict immobilization of the limb for a period of at least 5 days is required. In case of inconspicuous local findings, the bandage can remain closed for this period of 5 days. Subsequent to this, the usual conservative wound therapy with regular dressing changes has to be carried out until complete closure is achieved.

Step 10: Non-weight bearing mobilization can be commenced after 5 days. Partial load bearing shall not commence before 2 weeks. Fitting an orthopaedic shoe to reduce pressure on the affected part of the foot is also important.

Reverdin Graft

Reverdin grafts were described for the first time by a Swiss surgeon of the same name in the year 1869 [8]. These are basically small skin graft particles, measuring 2–4 mm, containing the complete epidermis and dermis in the central portion, thinning out toward the edges. After infiltrating the donor site with local anesthesia, the skin is lifted up using a hooked needle and removed tangentially with a scalpel blade, to create several small skin graft islands. The grafts thus obtained can either be temporarily stored on a moist gauze or directly transferred to the wound base.

14.2 Discussion

Based on the results of this study, and clinical observation, introduction of autologous fat tissue to chronic wounds can thus lead to transformation into acute and thus more active wounds with a higher potential for healing. This development can be limb saving, especially when preceding therapy attempts have proven to be ineffective. This is especially true, if the preceding therapy has proven to be of no success. The mechanism of this transformation has, however, not been actively researched until today.

The regenerative effect of fat tissue could be demonstrated in a few experimental and in some clinical studies [1, 9, 10]. The positive influence was attributed partly to the stem cells contained in high numbers within the fat tissue (ADSC, adipose-derived stem cells), which exhibit numerous wound-healing factors and showed a direct, positive influence on the healing [9]. Other studies showed that better wound healing occured [10] due to adipokine and leptin [11] and adiponectin [12] during topical use on full surface wounds in animal experimental studies, which were carried out on diabetic mice.

The positive results observed after autologous fat transfer are in line with the results for the treatment of cutaneous fibrosis [1, 2]. The results could also be explained by the effect of growth factors contained in the fat tissue and peptides that are known to promote wound healing [13–15]. Apart from this, stem cells further exhibit vascular and other growth factors (VEGF, pFGF).

It is presently not known whether the adipose tissues as a whole or the stem cells alone are mostly responsible for the positive effects on wound healing. But studies like the present one gives good insights that complicated isolation of stem cells might not be necessary, in order to achieve a healing effect. The addition of PRP (platelet-enriched plasma) to the fat tissue, as demonstrated in a study by Cervelli et al. [16], led to good but not superior results as compared to fat grafting alone.

14.2.1 Significance

In summary, one can say that the treatment of chronic wounds with autologous fat tissue is a very promising new therapy. The basic underlying effective mechanism has not yet been fully understood. Since the DEALT method of debridement and autologous fat transfer is a safe and cost effective procedure, which reduces morbidity and can save patients more extensive surgery or amputations, it should be included as a standard method in plastic and reconstructive surgery.

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Scars

15

Hans-Oliver Rennekampff and Norbert Pallua

15.1 Introduction

The scar can be described through parameters like height, elasticity, texture, vascularity and pigmentation. The therapeutic influence of the scar can be achieved through conservative and/or invasive measures. The operative measures include the sub-lesional injection of autologous adipose tissue as a suspension. In this case, the suspension is applied in small deposits as pearly cords, sub-lesionally. This procedure can be combined with a subdermal procedures (adhesiolysis, subcision, Rigottotomy).

Clinical studies with an evidence level of III have shown that by means of an autologous fat grafting, the texture and elasticity of the scar can be improved. Variable results have been obtained with regard to pigmentation, magnitude and accompanying itch, while vascularity of the scar was not changed. Experimental work also supports these results. At present, clinical investigation results are not available on the application of purely adipocytic or adipose-derived stem cell (ASC) transplantations.

The integrity and the consequently resulting optimum functional capacity of the skin are attributed a special importance. Disturbances in the regular build-up of the skin inevitably lead to functional disturbances and could also result in psychic disturbances. Injuries to the skin, especially of the reticular dermis, result in a reparative process, which ends in a visible scar. The scar represents the result of the wound healing process with macroscopic, microscopic and biochemical modification of the normal structure and function of the skin architecture. These changes can be objectively and clinically measured, e.g. by using the scar volume, elasticity, contour and relief, the vascularity and pigmentation of the skin and other parameters (Table 15.1) [1, 2].

Experimentally, one can detect numerous differences in the cell and protein expression of the scar in comparison with healthy skin. In addition, changes in the diagnostic picture of the skin can be described by the patient and/or the doctor subjectively. For this purpose, one can use different scar scores like POSAS [3] or other such scores.

While scar formation was initially attributed to exclusive changes in the dermis, recently published papers show that there is an additional interaction between the subcutaneous tissue [4, 5] and mesenchymal stem cells [6]. These

H.-O. Rennekampff (✉)
Klinik für Plastische Chirurgie und Ästhetische Chirurgie, Verbrennungschirurgie, RheinMaas Klinikum, AachenWuerselen, Germany

Aesthetic Elite, Duesseldorf, Germany
e-mail: hans-oliver.rennekampff@rheinmaasklinikum.de

N. Pallua
Klinik für Plastische Chirurgie und Ästhetische Chirurgie, Verbrennungschirurgie, RheinMaas Klinikum, AachenWuerselen, Germany

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Table 15.1 Possibilities of the evaluation of skin properties by using non-invasive, objective equipment and scaled, subjective expert opinion; VSS, Vancouver Scar Scale; POSAS, Patient and Observer Scar Assessment Scale; *in italics*, *trade names*

Property	Equipment	Scale
Colour	Tristimulus colour systems	VSS subparameter
	Minolta Chroma Meter	POSAS subparameter
	LabScan XE	Beausang Score
	Mircocolor	
	Narrow-band spectrophotometric colour analysis	
	Mexameter	
	DermaSpectrometer	
Vascularity	Laser Doppler Imaging (LDI)	VSS subparameter
	O2C LDI	
	Moor LDI	
	Perimed LDI	
	Tristimulus colour systems	
	Minolta Chroma Meter	
	LabScan XE	
	Mircocolor	
	Narrow-band spectrophotometric colour analysis	
	Mexameter	
	DermaSpectrometer	
Thickness	Ultrasonography	VSS subparameter
	DermaScan C	
	Tissue Ultrasound Palpation System	
	Calliper	
Volume	Drain	
Relief/texture	Phase-shift measurement	VSS subparameter
	PRIMOS	Beausang Score
	Profilometry	Hamilton Score
	Visioline	Smith Score
	D Imaging	
	Vivid900 3D Digitizer	
Elasticity	Tonometry	VSS subparameter
	Pneumatometer	POSAS subparameter
	Durometer	
	Tonometer	
	Underpressure measurement	
	Cutometer	
	Torsion measurement	
	Dermal Torque Meter	
	Dermaflex	
	DermaLab	
Area	Planimetry	
	Photography	
Collagen	Light interference	
	SIA scape	
	Confocal Laser Scanning Microscopy	
	VivaScope	
	Impedance measurement	
	Reviscometer	
Function	Goniometry	SODA
		DASH

reports suggest that autologous fat transplantation, which contains adipocytes and adipose-derived stem cells (ASC), could have therapeutic effects on the scar.

15.2 Technique of Autologous Fat Grafting for Scar Treatment

Scar treatment by autologous fat grafting is usually performed in two steps:

- In the first step, subdermal scar strands are dissected (Rigottotomy, subcision; [7]).
- In the second step, the actual fat injection is done in the subdermal layer.

Step 1: The scar is disected by using a large-lumen 14 G needle, which is used as a stiletto (Fig. 15.1), or the Toledo V-dissector (Fig. 15.2). The scar can be adhesiolysed via multiple small incisions. Experiments carried out on animals showed that the mechanical stimulus on the dermis is not responsible for the positive effect observed.

Fig. 15.1 14 G needle for adhesiolysis of the scars

Step 2: The subsequent fat infiltration is carried out in the subdermal layer. This is done using a 1.2 mm (Coleman) or 0.8 mm (Magalon) needle and 1 mL syringes (Fig. 15.3). The fat can be recovered and processed using different techniques, in which case, the technique as per Coleman is preferred. During the infiltration, box-type entry or several small incisions are used, as is otherwise normal in lipofilling. Smallest deposits of the fat suspension are applied in the form of pearly strings while withdrawing the needle. Post-operatively, a protective bandage is applied with e.g. Mepilex.

A clinical example is shown in Fig. 15.4.

Fig. 15.2 Toledo dissector

Fig. 15.3 Infiltration using Magalon needles in the area of the forehead

Fig. 15.4 Hypertrophicy scar on the forehead; before (**a**) and after (**b**) subcision and fat grafting

15.3 Clinical Studies

Few cohort studies are available for the improvement of scars using autologous fat tissue transplantation.

One of the first descriptions of post-operative scar treatment was the study of de Benito in the year 1999 [8]. In a case series of 30 patients, scars were treated after previous operation using adhesiolysis and fat injection. A very good result was reported for 27 patients without going into further parameters.

Covarrubias et al. [9] carried out histological studies on changes in healthy skin after the injection of fat. The authors described an increase of the thickness of the dermis while the thickness of the epidermis remained the same. Also, an increase of dermal vessels was noticed.

Similar results were shown in the histological work by Klinger et al. [10]. The authors report that autologous fat grafting of cutaneous scars results in an almost normal skin architecture along with the formation of hair follicles just three months after treatment. The filling up effect of a fat injection below the scar is pointed out in the critically discussed publication.

Own investigations [11] on the treatment of scars with fat injection showed a significant improvement in the pigmentation, texture and elasticity of the scars in the patient and physician evaluation itch and thickness of the scars and their vascularity were not significantly changed.

Comparative results were published by Sardesai and Moore [12], which exhibit a significant improvement of scar thickness, scar texture and scar elasticity. Change in vascularity, pigmentation and itch were not significantly different. The objective study with the Cutometer and Mexameter showed a significant improvement only in the elasticity measurement, whereas the melanin index did not change perceptibly.

15.4 Experimental Fundamentals

15.4.1 Epidermis and Fat

Only a few papers have been published on the influence of fat on the regeneration of the epidermis. In these papers, cocultures of keratinocytes with pre-adipocytes and fat stroma cells were studied. Thus, it was shown that keratinocytes and adipocytes can be co-cultivated.

Sugihara et al. [13] and Campbell et al. [14] studied the mitogenic effect of fat cells on keratinocytes. In both papers, the enhanced proliferation of keratinocytes could be demonstrated. Thus, it could be seen that this mitogenic effect was exhibited to the same or stronger extent than in the case of classical fibroblast-feeder layer technique.

Aoki et al. [15] studied the in vitro effect of adipocytes and mesenchymal stem cells of bone marrow and fibroblasts on keratinocytes in a skin culture model. Whereas the proliferative effect of the cells of mesenchymal origin like fibroblasts, pre-adipocytes and mesenchymal bone marrow stem cells (MSC) on keratinocytes was comparable, morphological differences were seen, e.g. the formation of a rete structure only in case of MSC-containing skin construction.

15.4.2 Pigmentation and Fat

Hyper- and hypopigmentation of re-epithelialiszed wounds, skin grafts or scars are an often observed phenomena, their cause and thus prevention and therapy have been studied to a much lesser extent [16]. Dressler et al. [17] reported that the number of melanocytes is high in the post-operative hypopigmented scar, and only with time, the normal ratio is reached. In contrast to these findings, other authors have reported that neither the number of melanocytes nor the content of melanin was changed in the hypopigmented scar in contrast to normal skin, and thus no explanation could be given for the brighter skin colour [18].

- **Even the content of melanocytes in the skin of people of different Fitzpatrick Groups is nearly identical.**

This research work clearly shows that not only the absolute number of melanocytes but also the activity of melanin production, the melanosome transport and transfer play an important role in the finally observed pigmentation.

The activation of melanocytes through the corresponding receptors suggests the possibility of a paracrinous influence. A paracrinous effect on the pigmentation could be possible not only by the spatial proximity of the subcutaneous fat to the hair follicles with melanocytes (precursor cells) but also intradermal adipocytes. Hormones (MSH α), growth factors (bFGF, SCF, HGF, GM-CSF) and other proteins (“agouti”) could result in the proliferation of melanocytes, morphological changes or the production of melanin [19, 20].

The inflammation reaction on the skin can result in a significant change of pigmentation through pro-inflammatory cytokines, e.g. IL-1, IL-6, TNF-α, prostaglandin and leukotriene. But not all pro-inflammatory cytokines lead to hyperpigmentation [21]. For IL-1, IL-6 and TNF-α, a suppression of the pigmentation through inhibition of the melanocytic proliferation and melanin synthesis was documented.

- **A number of the above-mentioned factors are initiated through adipocytes and/or ASC [22, 23], through which a therapeutic influence of a fat graft on pigmentation becomes clear.**

15.4.3 Dermis and Fat

The dermis does not represent a homogeneous and uniform structure. The dermis can be subdivided into two compartments with regard to the matrix and the cellular parts, namely, the papillary dermis and the reticulate dermis. From a viewpoint of development, the hypodermis (subcutaneous fat tissue) can be assigned to the reticular dermis [24]. An

injury of the reticulate dermis, especially with open fat cones, will result in the formation of a visible scar [4, 5]. Fibroblasts from the papillary dermis can be clearly differentiated from fibroblasts, isolated from the reticulate compartment [25–27].

It was shown that mesenchymal stem cells from the subcutaneous tissue (ASC) promote scar formation, by an increased collagen deposition [6] and by differentiation of intradermal adipocytes to myofibroblasts [28]. Apart from these negative effects on scar formation, other experimental studies point to an anti-fibrotic influence of MSC from bone marrow on scars [29]. Studies on the influence of adipocytes on the function of fibroblasts showed that lipid-rich adipocytes inhibit not only proliferation but also the collagen-1 synthesis of fibroblasts [30]. These effects were attributed to released fatty acids, palmitic acid and oleic acid.

Studies on adiponectin, an adipokine from adipocytes, point to a possible favourable effect of adipocytes on scar formation. Adiponectin suppresses the collagen-1 expression in fibroblasts and reduces the effect of TGF-β_1 [31]. Adiponectin results in an anti-fibrotic tissue remodelling, e.g. by means of a reduced proliferation and activity of the peri-sinusoidal liver cells (Ito cells) with reduction of a liver cirrhosis or cardiac fibrosis. In systemic scleroderma the adiponectin level is inversely correlated with severity of disease [32].

Other authors could not confirm these anti-fibrotic effects of adiponectin [33, 34]. We were able to show that adiponectin is present in a biological relevant quantity not only in the cellular fraction of a fat suspension (1 μg/g) but also in the supernatant of the fat suspension (1.5 μg/mL) (our own unpublished data).

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Burn Scars

16

D. L. Francia

16.1 Introduction

Most high-degree burn injuries can be reliably covered and treated by means of meshed split skin transplantation. Covering the defect is done in this case, after debridement and frequently multistage vacuum therapy.

Subcutaneous fat tissue, muscle fascia, or tendon parts as well as vessels or nerve structures could get exposed on the concerned wound base. The reconstruction of multilayer inner and upper skin has been successful in the past few years especially in case of deep burn injuries by the temporary use of xenogeneic and acellular biomaterials (mostly produced on a collagen basis; [1, 2, 3]).

After the completion of a phase-based wound healing, even after a good treatment result, the split skin can be optically recognizable through its characteristically network-like pattern in the transplantation area. The patient can consider this to be a sign of stigmatization, and this can be treated only to a limited extent among other things, through a compression therapy in the postoperative stages. Depending on the quantity of the subcutaneous fat tissue of the surrounding skin, the split skin region appears as a sunken contour scar at the affected body region (volumetric defects Chap. 13). In the ideal case, the discreetly visible pattern remains in place without a level difference to the surrounding skin or damaging of functionality.

However, burn scars or previous split skin areas become conspicuous because of scar growth at the previous wound base. These surface skin adhesions can, for example, cause pain during movement or dysesthesia. If a pathologically modified scar formation occurs, then even isolated scar trails or joint covering contractures could occur. Autologous fat tissue transfer has been utilized in these indications in the last few years with good results in individual cases in clinical trials (scar therapy Chap. 15).

16.2 Procedure and Technique

16.2.1 Preparation of the Patient

During the preoperative preparations, a detailed discussion is essential to be conducted with the patient using a differential analysis with reference to the pain and the expected success of the therapy. As part of this, one should always demonstrate the standard procedure like the Z-plastic surgery, scar excision, or local flap surgery and should be taken in for serious consideration. Similarly in case of hypertrophic scar formation, even ablative laser process or dermal needling

D. L. Francia (✉)
Department of Plastic and Reconstructive Microsurgery/Hand Surgery, Charité University Medicine, Ernst von Bergmann Clinic, Potsdam, Germany
e-mail: delialetizia.francia@klinikumevb.de

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should without doubt be integrated as a complementary measure in the treatment plan.

A hypertrophic scar proliferation after split skin grafting can lead to a spreading confluence of the typical pattern (Fig. 16.1). In this case, we recommend the stemming of the scar proliferation even just in the early symptomatic phase, using, among other remedies, a peri-lesion cortisone injection. Due to the anti-inflammatory effect, a quicker scar healing occurs and leads to an alleviation of the typical pains like itching or unpleasant feelings of tension.

Fig. 16.1 Hypertrophic scar after split skin grafting in case of a patient with severe burn injuries. Typical network pattern (partly highlighted)

- **Based on data collected during our experience, one should wait for a period of 6 months after the split skin cover-up until the introduction of autologous fat tissue transplantation. In this period, we recommend that the scar formation should be stringently treated with the help of multimodal conservative therapy measures (among other remedies, compression using silicon inserts, massages, physiotherapy, and occupational therapy).**

16.2.2 Technique

The treatment of split skin area after burn injuries covers at least two procedures in our institution. This is because a conversion of the skin architecture takes place in steps and this could be proved histologically (Fig. 16.2).

Starting from up to three insertion points, insertion is done subdermally and in stages, section-wise, and in a multi-planar fashion through up to three different needle sizes (16–22 G). In doing so, it is important to immediately create a receiver area with wide-lumen dissectors.

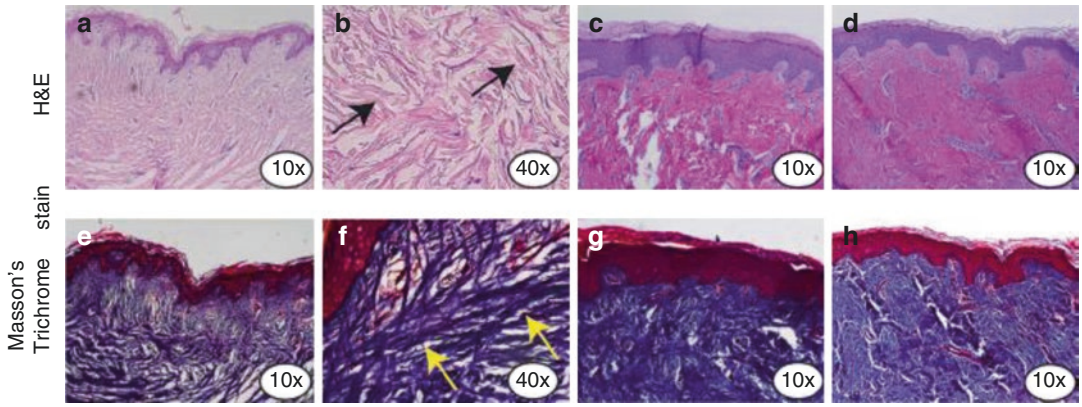

Fig. 16.2 Biopsy exposures of a split skin scar in H&E (**a**–**d**) and a Masson's trichrome stain (**e**–**h**); from left to right: preoperative, after the first and second procedure. After two procedures, an improved skin architecture can be seen, especially in the stratum spinosum and stratum granulosum and the dermal extracellular matrix

- **Note: Aggressive adhesiolysis can result in an increased danger of bleeding with a reduced growth rate or to skin necrosis.**

In a study carried out by us, we developed the concept of the "inner scaffold"—a three-dimensionally built-up subdermal framework made up of fine fibrotic strands. This minimally invasive process achieves a healing by loosening up and by a surface enlargement of the receiver area. The transplanted adipose cell cluster can be entrapped and embedded in this fibrous network (Fig. 16.3a).

The selection of the suitable process for graft recovery and processing was now opened up, during which we could gather the most experience

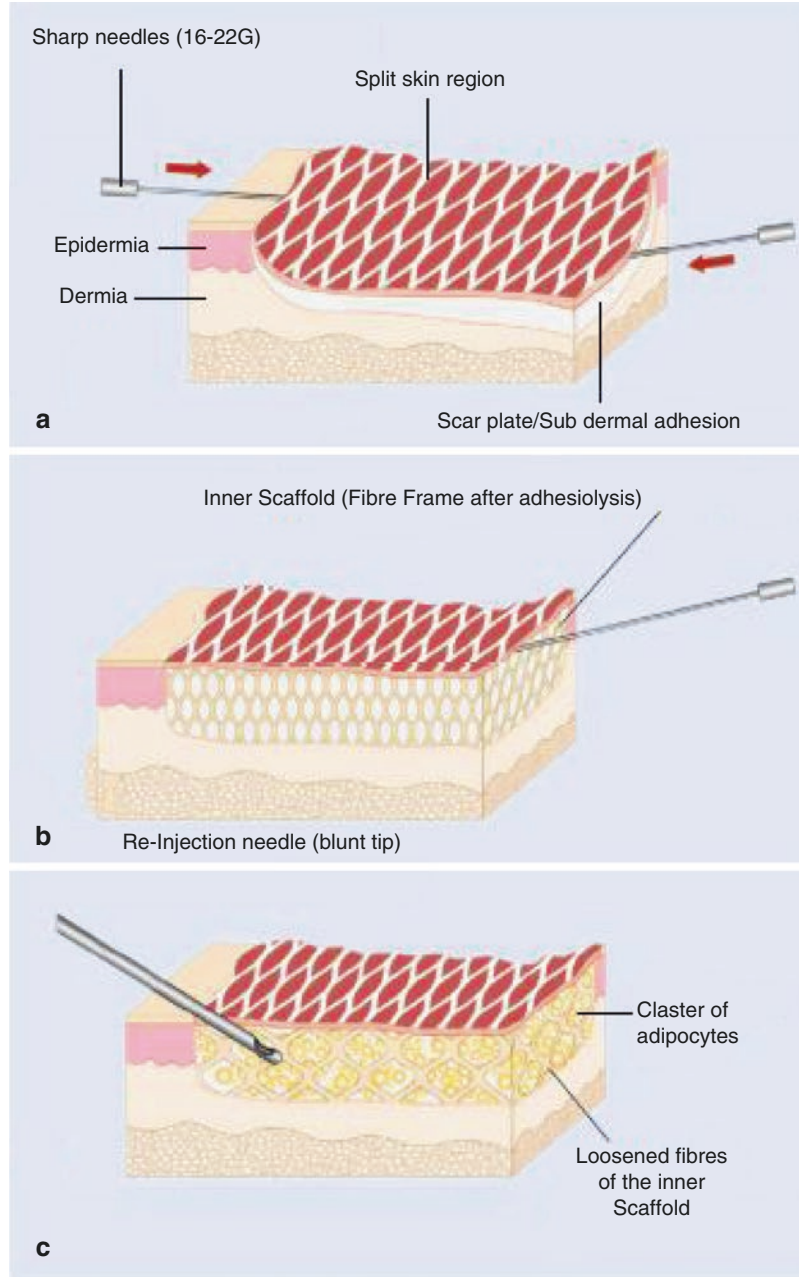

Fig. 16.3 Concept of the "inner scaffold": (**a**) Minimal invasive scar solution with sharp needles in multi-planar and box-shaped direction. (**b**) A three-dimensional fiber framework is obtained. (**c**) In case of careful reinjection, the adipocytes enter into the strand network and can get settled down there (Created as per a template by D. L. Hoppe)

in case of these patients with the water jet-assisted process (LipoCollector; [4]).

Blunt hypodermic needles with a single perforation with a lumen of −1.4 mm should be used for reinjection, for example, the BEAULI needles (human med) or filling needles (PonsaMed). In the process, the graft is introduced in a similar manner in the form of boxes and in a multi-planar fashion with 3 or 10 cm^3 Luer Lock injections after the processing (Fig. 16.3c).

After the reinjection, the insertion points can be closed using a plaster or a fine suture.

16.2.3 Postoperative Treatment

The concerned body region should be immobilized absolutely without movement for a period of 5 days, for example, by using a plaster splint. The set of bandage shall not exert any compression for a period of at least 2 weeks on the transplanted region. An external compression by means of dress, massage, etc. can only be allowed starting from the fourth postoperative week. Depending on the quantity of the grafting, a compression of the donating region for a period of 3–6 weeks should be taken into consideration.

We recommend that postoperative inspections should be carried out after 1 and 4 weeks and after 3 months, in order to record the grafting effect in the healing process and to further plan other procedures with the patient. An average of 2–5 applications have been carried out up to closure of therapy so far in our group of patients.

Other extra processes like scar plastering or silicone-containing gel applications should be carried out only starting from the sixth postoperative week. This is also true for the muscular stress in the affected body region.

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Osteoarthritis

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Christian Herold

The injection of hyaluronic acid as an option for at least temporary pain reduction has already been described for carpometacarpal joint osteoarthritis of the thumb [1]. Seen purely from a mechanical viewpoint, autologous fat graft can offer a relative sliding effect in the joint gap. The high content of SVF cells in the fat tissue has been proved and also the possibility of the included stem cells to differentiate in the most different tissues, including the bone [2, 3].

Apart from this, several studies have not only confirmed an anti-inflammatory and chondroprotective effect of adipose-derived stem cells [4], but also a cartilage regenerative effect was described [5]. It could be shown that chondrocytes could excite a differentiation of adipose-derived stem cells [5]. Based on this background, the injection of fat stem cells into an abraded joint appears to be useful in principle.

Unpublished data until today from the research group Michalek from the Czech Republic covers results of over 1000 patients treated successfully with fat stem cells.

The use of modified fat tissue grafts or even stem cell suspensions, which were produced from fat tissue, is rather restricted in Germany. The production and use of cell-therapeutic preparatives are strictly regulated in Germany through the ATMP (advanced therapy medicinal products).

- **Fat tissue stem cells are classified as "Medicines for new types of therapy." A manufacturing permit as per Article 13 of the ATMP is necessary to produce such items in Germany.**

Even classical fat grafts contain fat stem cells [6].

- **If these lipo-aspirates are used without any industrial production process while maintaining established production steps and without any substantial processing as grafts, then they are considered as classical tissue preparatives, and their use does not require any licensing** [7]. **But even this is under discussion recently in Germany and even normal fat grafts may be classified as ATMP if they will have a different function f.e. regeneration of cartilage in a joint after injection.**

Since the suctioned-out fat tissue exhibits viscous-supplementary properties analogous to hyaluronic acid, its use not only appears to be more meaningful as against fat stem cells under the

C. Herold (✉)
DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

Plastische Chirurgie und Handchirurgie im Mühlenviertel, Bremen, Germany
e-mail: c.herold@diako-bremen.de

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prevalent legal frameworks but also because a sliding function can be exerted inside the abraded joint.

17.1 Carpometacarpal Joint Osteoarthritis of the Thumb

Carpometacarpal joint osteoarthritis of the thumb is a frequent malady that affects up to 25% of the postmenopausal women. Since trapeziectomy presently represents the surgical standard therapy, we started with an injection into the carpometacarpal joint. This is because in case of a therapy failure or in the worst-case scenario of damage to the joint due to the injection, a removal of the concerned joint under normal conditions would already have to be done and thus can still be done, without this compelling an escalation of the therapy as compared to standard therapy.

Since the summer of the year 2013, we have started the treatment of injection of autologous fat into the carpometacarpal joint of the thumb. In the first year itself, more than 40 patients were given this treatment. And until now, we treated more than 500 patients.

The operation can be carried out under local anesthesia with Klein's solution for suction at the abdomen or lateral upper thigh and in the main block of the ramus superficialis. The quantity of 1.5 mL is the volume of fat tissue, which can be injected without any pressure into the carpometacarpal joint (Fig. 17.1). If one attempts to inject a greater quantity, a clearly perceptible resistance can be experienced at the pressure point of the syringe plunger. In such a case, the thumb should be held under axial tension, in order to expand the joint gap (Fig. 17.2).

Fig. 17.1 The fat graft, which was processed using the Coleman technique, is injected with a 10 mL Luer Lock needle and an 18 G needle into the carpometacarpal joint. 1–1.5 mL of fat tissue is injected

Fig. 17.2 The needle is introduced into the carpometacarpal joint under illumination. During the puncture and the injection, an axial traction is brought about onto the thumb, in order to minimize a trauma to the joint

It is recommended to use an 18 G single-use needle for the injection. The skin closure can be done via a single head suture and/or a Steri-Strip bandage.

17.1.1 Study Results

Results first published certify that the technique has a good effectivity; the average preoperative pain of 7.4 on the visual analog scale (VAS) during load and 3.8 at rest could be reduced to an average of 2.4 and 0.8 after a period of 3 months. The pain reduction was statistically significant.

Even the force could be improved. Thus the power of the rough grip of 78% and the pinch

grip of 74% increased compared to the healthy side preoperatively to 93% and 89%, respectively, 3 months postoperatively. No complications occurred.

Evaluation using the DASH graph (DASH = disabilities of the arm, shoulder and hand) confirmed these results. The DASH value was at an average of 58 preoperatively and postoperatively after 3 months at 33. Thus one could see a significant improvement of the estimation of the hand function in the patients [8–10].

17.1.2 Significance

Considering the reduced invasiveness and the significant improvement in pain reduction, autologous fat tissue transplantation presents an interesting alternative for the carpometacarpal joint of the thumb. A special advantage exists in the fact that in case of a therapy failure, the classical hand surgery techniques are always available for use. But this cannot be said with certainty in the case of an implantation prosthesis or a trapeziectomy that has already been performed.

Now it remains to be seen as to whether after the investigation of a large number of patients over a prolonged period of time the technique introduced here will find its place among standard intervention techniques. Or if governmental dicisions will limit its use.

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Postoperative Treatment

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Christian Herold

For all solid matter transplantations, there is one common point to be implemented in the postoperative treatment:

- **Pressure has to be avoided in any case.**

Due to the introduction of the tissue, the tissue pressure is already increased, and by an extra pressure from the outside, the perfusion could get compromised. This would lead to a lower healing rate of the transplanted tissue. We have to make the observation here that during the reconstruction of the breasts, in such cases, where the patients have undergone an epithesis subsequently, a significantly lesser amount of healing was seen in the region of the strongest pressure.

Since the perfusion and thus the healing are also promoted by heat, we apply an absorbent cotton bandage to our patients. For this purpose, we require only 1–2 packs of broad cushioning absorbent cotton, as they are used in plaster cast bandages. This absorbent cotton bandage has to be worn for the first 24–48 h (Fig. 18.1).

Fig. 18.1 Postoperative bandage

In case of an autologous fat tissue transplantation in the breast area, we recommend that no bra shall be worn for a period of 4 weeks. Alternately, a bikini upper part can be worn loosely.

In case of transplantations for correcting deformities at other places, in such cases, where in the same region, a compression dress is required, because a suctioning has been carried out in addition, the area of fat injection should be cut out from the compression dress.

- **For this purpose, in general, one can cut out a suitable hole simply using the scissors in the compression dress.**

Especially in case of gluteal enlargements, compression clothing is being sold with the corresponding areas already cut out.

C. Herold (✉)
DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

Plastische Chirurgie und Handchirurgie im Mühlenviertel, Bremen, Germany
e-mail: c.herold@diako-bremen.de

K. Ueberreiter (ed.), *Autologous fat tissue transfer*, https://doi.org/10.1007/978-3-030-05402-1_18

Avoiding too much movement in the tissue is a very important point to be kept in mind. Considering the fact that approximately 1 mm large tissue chunk has to find connectivity with the blood vessel system within a period of just 2–3 days, it is self-evident that in such cases, too much movement can have a damaging effect. In case of split skin supply, generally, even the tissue is made to rest using a plaster splint, which in such cases is naturally not possible.

There is no objection to the patient carrying out normal tasks of everyday life. But activities like sprinting or jogging or more intensive sports activities in any case have to be strictly avoided. Even in this case, we recommend a preventive period of 4 weeks.

- **One has to essentially stress on the fact that any kind of direct mechanical load on the surface areas of the fat tissue should be strictly avoided.**

Unfortunately, there is a lot of rubbish in the Internet with recommendations on massage, regular cream application with particular commercial creams, or similar counterproductive measures.

Since under the influence of insulin the growth of fat cells and the differentiation from stem cells are positively impacted, we recommend the concerned patients to regularly eat small meals that are rich in carbohydrates. Thus, the insulin levels can be maintained to the required levels. However, there are no scientific studies that have been carried out to substantiate this suggestion.

- **Most of the resorption takes place within the first 4 weeks. After a period of 6 weeks, the final healing result is reached. Starting from 3 months after the intervention, this can then be repeated.**

Volumetric Documentation

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Christian Herold

19.1 Introduction

During the efficiency inspection after an autologous fat tissue transplantation, the following two aspects are of prime importance:

- The highest possible recovery of volume of the transplanted fat tissue (quantitative procedure inspection)
- The least possible complications (qualitative procedure inspection)

In reality, the following two techniques are especially suitable, in order to carry out volumetric process inspections:

- 3D surface analysis
- MRI volumetry

19.2 3D Surface Analysis

The exposure time is rapid (2 s to 2 min [1, 2]); only the picture analysis and interpretation take a period of 11–45 min [1, 3].

A 3D volumetric analysis was carried out in a study on patients before and after a mastectomy, and the difference with the mastectomy preparatives, whose volumes were calculated using water displacement, was compared [4, 5]. A volumetric deviation of only 2% in this case confirmed the exact precision. Another study was used to compare the 3D volumetric analysis before and after augmentations of the mammary glands and showed a deviation in the implantation volume of only just 1.9% [6]. A few examples for actual commercially available systems are Axis3, 3dMD, and Vectra von Canfield (Fig. 19.1).

Fig. 19.1 3D scanning (Vectra, Fa. Canfield)

C. Herold (✉)
DIAKO Bremen, Plastische und Ästhetische Chirurgie, Bremen, Germany

Plastische Chirurgie und Handchirurgie im Mühlenviertel, Bremen, Germany
e-mail: c.herold@diako-bremen.de

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Table 19.1 MRI volumetry for the documentation of the volumetric retention after autologous fat tissue transplantation in the breasts

Literature	Volumetric retention (%)	Patients	Technique used
Herold et al. [13]	72 ± 11	10	WAL
Ueberreiter et al. [12]	76 ± 11	36	WAL
Alexander Del Vechio and Bucky [14]	64 ± 13	25	Coleman + BRAVA
Khoury et al. [15]	82 ± 18	81	Khouri-Technik + BRAVA
Peltoniemi et al. [16]	79 ± 13	8	WAL + Celution
Fiaschetti et al. [17]	85 ± 2	15	Coleman + PRP

Creasman and colleagues introduced the precision light system, with the possibility of automatic and thus no more examiner-dependent determination of measured points. The deviation of the measured values from the actual volumes in this case was found to be 9%. But there exists an extremely high reproducibility of the measured results of 99.6% [7].

Using 3D surface analysis, Yoshimura could prove a volumetric recovery of stem cell-enriched fat grafts of 40–80% after implant conversions in case of capsule fibrosis [8].

Choi and colleagues used the Canfield system for volumetric rechecks after autologous fat tissue transplantation in the breasts. They divided their patients into three groups based on injection volumes. The group with the largest injection volume (111–216 mL, average 151 mL) exhibited a volumetric retention of 86.9% after 7 days, 81.1% after 16 days, 57.5% after 49 days, and 52.3% after 160 days. It could further be shown in this study that a radiation does not have any negative influence on the volumetric retention of the fat graft.

After a fat tissue transplantation for the rejuvenation of the hand, a volumetric retention of 69% could be proved using 3D volumetry [9].

19.3 MRI Volumetry

Even though the first application of MRI volumetry for rechecking after autologous fat tissue transplantation in the breasts is already 25 years old [10] and lipofilling was described in the year 2006 for the augmentation of the buttocks [11], it was only in the year 2010 that the authors first described volumetric retention in autologous fat tissue transplantation for breast enlargement using the BEAULI technique based on MRI volumetry [12]. Over the years, even other authors used MRI volumetry for the purpose of quantitative analysis after autologous fat tissue transplantation in the breasts (Table 19.1).

Since MRI studies are carried out in the prone position, the patient is provided with a special breast support, in order to prevent compression of the breasts. Layer thicknesses between 3 and 4 mm are used. An investigation takes about 20 min, and the imaging is stored in the DICOM (Digital Imaging and Communications in Medicine) format.

The volumetry per se is based on a technique, which calculates the area and then adds the volumes over the respective layer thickness; this is called **segmentation** (see the Summary).

Area of Interest in MRI Volumetry

As an area of interest, we always analyze the area between the uppermost and the lowermost pole of the breast with the center of the sternum as the middle point and the lateral thoracic artery and the skin as the surface limit. This region is measured before the operation and at a defined point of time after the operation and can then be compared with the injection volume.

Nowadays, a variety of software packages are available for segmentation. We have carried out studies with the open-source software OsiriX, the

professional radiology program called Medisan, and the Brainlab Neuronavigation Software (actually, this is a system meant for neuronavigation).

A high precision of the technology could be confirmed using MRI volumetry of mammary implants in situ [12]. Measured values calculated volumetrically using MRI deviated from the Brainlab Neuronavigation Software only by $2.2 \pm 1.7\%$ from the real volumes of the implants as indicated in the implant passes.

Even the other software options were similarly well-suited and showed a deviation of lesser than 3% [13, 18].

An interesting effect is that different injection levels can be separately analyzed for the volume retention.

- **It could be shown that an injection in the peri-glandular fat tissue results in a higher volume retention than when injection is being done into the breast muscles** [19].

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Possible Future Developments

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Klaus Ueberreiter

It is always speculative to throw a glance into the future. In the area of autologous fat, it has been seen that many application possibilities, which are today being "newly" discovered, had already been tried out in the 1920s and the 1930s of the previous century. The really new area of interest is dealing with stem cells from fat tissue. Embryonic stem cells were earlier the focus of intensive research. Then, for example, stem cells were obtained from the bone marrow for the treatment of osteoarthritis. But in recent years, fat tissue has been discovered to contain a virtually inexhaustible source of mesenchymal stem cells. Now the focus has shifted to which type of cells can be developed from this with suitable research projects being conducted and clinical applications being carried out worldwide.

Another broad field is the marking of stem cells with tissue markers, in order to be able to use them finally in an objective manner in the treatment of cancer.

One really cannot predict as to which of these therapies will be successful in hospitals and can be integrated into daily routine. But it is difficult to imagine that the mesenchymal stem cells would not turn out to be useful in hospitals in the long term.

One idea that is presently being considered is that fat tissue can at some time be prophylactically suctioned and the stem cells contained in it can be cryo-conserved. This way, in case of a therapeutic emergency (e.g., acute myocardial infarction), exactly these cells will be available for use. The bankink of embryonic stem cells is being actively propagated in the USA by certain firms, which have specialized in the preservation of tissue in banks, while pointing out possible legal consequence in case of failure of this procedure. Since there are until now no clinical applications for this, promoting this type of conservation appears to be mainly commercially based.

The simple transplantation of fat cells into other body regions has already become daily practice and is being increasingly entrusted to the surgeon, be it for modeling; for the procurement of new sliding tissues, for example, in tendon surgery; for the alleviation of pain in osteoarthritis; in the treatment of chronic fistula and fissures; and in many other indications.

K. Ueberreiter (✉)
Park-Klinik Birkenwerder, Fachklinik für Plastische und Ästhetische Chirurgie, Birkenwerder, Germany
e-mail: dr@ueberreiter.com

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