Radiol med (2016) 121:521–527
DOI 10.1007/s11547-016-0621-x

ULTRASONOGRAPHY

The utility of the high-resolution ultrasound technique in the evaluation of autologous adipose tissue lipofilling, used for the correction of post-surgical, post-traumatic and post-burn scars

Maria Scotto di Santolo[1] · Marco Sagnelli[1] · Giovanni Tortora[2] · Maria Angela Santoro[3] · Pier Luigi Canta[3] · Guido Molea[3] · Fabrizio Schonauer[3] · Massimo Imbriaco[1]

Received: 29 September 2015 / Accepted: 13 January 2016 / Published online: 4 February 2016

Abstract
Purpose Lipofilling technique is significantly increasing and the need of a non-invasive method to assess the success of the procedure is becoming mandatory. In particular, US can be considered an alternative method to MRI for evaluation of tissue lipofilling due to the simplicity and easy access of the technique and can be also used for monitoring the efficacy of the surgical procedure. The goal of this study was to demonstrate, the utility of the high-resolution ultrasound technique in the evaluation of autologous adipose tissue lipofilling, used for the correction of post-surgical, post-traumatic and post-burn scars.

Materials and methods Twenty-five patients (21 females), aged between 14 and 62 years, underwent surgical correction of scars with ‘‘lipofilling’’ technique. To evaluate the effectiveness of such treatment serial ultrasound examinations were performed at both the region affected from skin dimorphism through the adjacent skin region, using a high frequency transducer. Furthermore, it was assessed the presence of complications ranging from oedema or hematoma to necrosis or adipocyte migration of the graft. Finally, was calculated the average percentage of one-year survival of autologous fat transplant.
Results Quantitative evaluations obtained with time series of ultrasound showed that the greatest benefits of autologous adipose tissue lipofilling, are found at the level of the hypodermis, but that also all the other layers of the skin can benefit from this procedure.
Conclusion The data acquired demonstrate that the eco color Doppler with high resolution can be considered a valid non-invasive tool for the assessment of morphological and quantitative degree of engraftment of autologous adipose tissue transplanted. Lipofilling is an accurate and effective choice for the correction of congenital or acquired skin disorders for its filler effect and consequent benefit for all tissue layers.

Keywords Skin ultrasound · Color-Doppler high-resolution ultrasound · Skin lesions · Lipofilling

✉ Maria Scotto di Santolo
mariellascotto@libero.it

Marco Sagnelli
marcsag@libero.it

Giovanni Tortora
gtor@sirm.org

Maria Angela Santoro
msantoro@libero.it

Pier Luigi Canta
pgcanta@libero.it

Guido Molea
gmolea@unina.it

Fabrizio Schonauer
schonauerf@unina.it

Massimo Imbriaco
mimbriaco@hotmail.com

[1] Department of Advanced Biomedical Sciences, University of Naples Federico II, Via Pansini 5, Naples, Italy

[2] UOC Department Radiology, AOS dei colli Monaldi-Cotugno-CTO, Via L. Bianchi, Naples, Italy

[3] Department of Plastic Surgery, University of Naples Federico II, Via Pansini 5, Naples, Italy

Introduction

Doppler ultrasound examination (ECD) with the use of high-resolution (5–17 MHz) transducers is widely used in the evaluation of normal and pathological skin (Figs. 1, 2). In recent years, diagnostic imaging procedures have

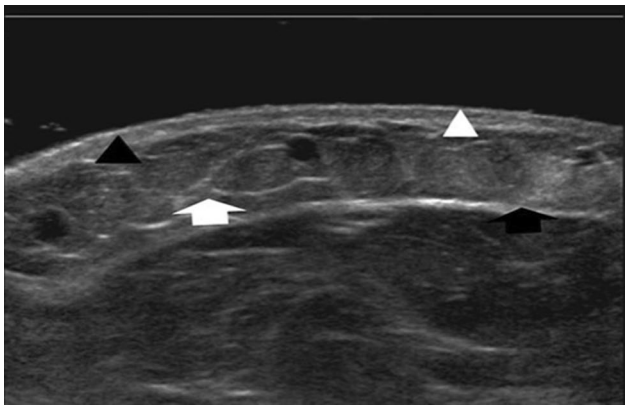

Fig. 1 Ultrasound examination obtained in the transverse view, showing anatomy of young skin, with associated evidence of photoaging. White arrowhead: epidermis, black arrowhead: dermis, black arrow: muscle fascia, white arrow: subcutaneous adipose tissue

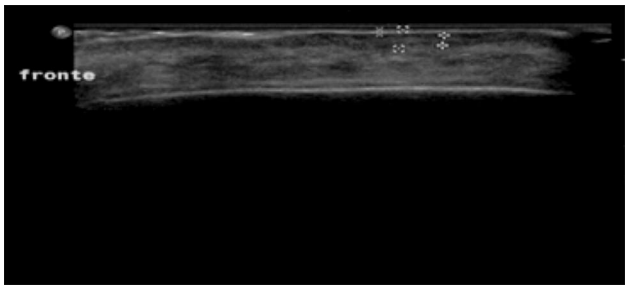

Fig. 2 Ultrasound examination obtained in the transverse view at the level of the skin region affected by dismorphism and at the adjacent region with thickness measurement of the epidermis and dermis

Table 1 Site of injection in patient population

Patient	Site of injection
1	Right arm
2	Right forearm
3	Left arm
4	Glabella
5	Frontal region
6	Left eyebrow
7	Glabella
8	Frontal region
9	Breastbone
10	Left leg
11	Lower lip
12	Left ankle
13	Glabella
14	Right cheekbone
15	Frontal region
16	Right cheekbone
17	Left lower lip
18	Frontal region
19	Left palm hand
20	Right cheekbone
21	Right peri-auricular region
22	Left eyebrow
23	Right neck region
24	Left neck region
25	Frontal region

undergone a profound transformation in parallel with the rapid evolution of technology and computer science [1]. The development of the ultrasound technique in the dermatological field is tied to the availability of high frequency transducers (>15 MHz), the introduction of techniques that reduce the artifacts and optimize the power of resolution and the possibility of studying the vascularization of expansive lesions of the skin and the formation of new vessels with color-Doppler technique [1–9]. Alexander and Miller in 1979 used for the first time ultrasound to study the skin, generating a one-dimensional scanning of the skin with rudimentary equipment and with insufficient spatial resolution [2]. In the study of superficial organs, and in particular in the dermatological field, the depth of the region to be investigated is 1–2 cm and pathology frequently regards lesions with less then 1 mm thickness, it is therefore necessary to use high frequency probes, with high resolution and reduced scan depth [1]. Therefore, the use of these probes, allowing high-resolution imaging, is of paramount importance; nevertheless, currently used 5- to 17-MHz linear arrays probes also allow the visualization of deep layers up to 3.5 cm (depth), with an axial resolution of 0.090 mm, thus permitting to complete the study of superficial tissues [1]. Using variable frequency probes it is possible to cover a depth of scan extended from 3.5 to 7 cm [1]. The high-resolution ECD has also been used for the study of diffuse skin diseases like psoriasis, scleroderma, erythema nodosum, sarcoidosis and lymphedema as well as for the evaluation of local complications due to the application of topical medications and of implantable materials for esthetic use [1–11]. The aim of this study was to demonstrate, the utility of the high-resolution ECD technique in the evaluation of autologous adipose tissue lipofilling, used for the correction of post-surgical, post-traumatic and post-burn scars.

Materials and methods

The study was performed retrospectively on the material and data available in our department and has therefore been performed in accordance with the ethical standards laid down in the declaration of Helsinki in 1964 and its subsequent amendments. Patients were informed and expressed

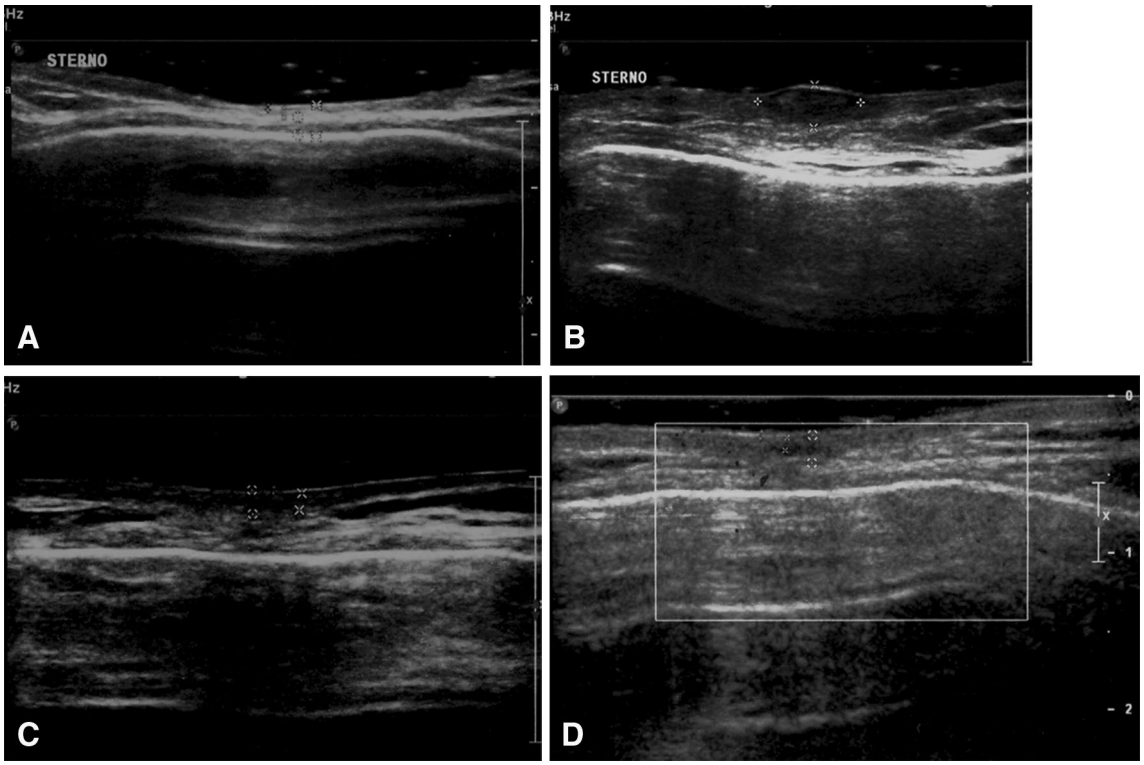

Fig. 3 **a–d** Serial ultrasound examinations in the transverse views, performed both at the level of the skin region affected by dismorphism and at the adjacent region, (Time 0, 1 week, 1 month and 1 year after the surgical procedure)

their consent for the use of such material for cumulative and statistical studies. Twenty-five patients (21 females), aged between 14 and 62 years, underwent surgical correction of scars with ''lipofilling'' technique [10–16] (Table 1). Each patient underwent a general clinical and dermatological examination, by a plastic surgeon who then performed the ''lipofilling'' surgical procedure. Inclusion criteria were: good cardiovascular condition with blood examination and blood pressure within normal limits and sufficient availability of body fat tissue. Exclusion criteria were: pregnancy or breast-feeding, general contraindication to surgical or anhestetical procedures and patients with psychological problems.

Deriving from the greek ''lipos'' = fat and English ''to fill'' = infiltrate, the term lipofilling means the grafting of autologous adipose tissue, a surgical technique that can correct the volumetric defects of the soft tissues caused by trauma, resection of cancer, congenital defects and aging [10–16].

In our study a "lipofilling or lipostructure by Coleman" [10–14] was performed in all patients. In particular, this procedure is based on several standardized surgical steps: (1) withdrawal from the donor region (2) centrifugal and sedimentation (3) transfer to the subcutaneous receiving site (4) infiltration with small cannulas within the subcutaneous fat tissue, such as to maximize the contact surface between the graft and the recipient tissue [10–14].

To evaluate the effectiveness of such treatment and in particular the survival or viability of autologous fat grafts, serial high-resolution ECD examinations were performed by the same operator (MSdS) with more than 10 years experience in ultrasound procedures, both at the level of the skin region affected by dismorphism in the site of maximum thickness and at the adjacent region using high frequency (5-17 MHz) transducer and a Philips iU22 ultrasound device (Best, The Netherlands); such evaluation was performed preoperatively, at 1 week, 1, 6 and 12 months after the surgical procedure (Fig. 3a–d). Figure 4 shows ultrasound examination at the level of skin region affected by dismorphism and at the adjacent region, with measurement of autologous fat implant.

The vascular signal has been evaluated at the same site of the injection using the color- and power-Doppler parameters that have been set for the study at low speed blood flow (color-Doppler: PRF 500 Hz, wall filter 27 Hz, gain 75 %, persistent media; power Doppler: PRF 350 Hz, wall filter 45 Hz, gain 85 %, low optimization) [1]. The vascularity of the graft region was assessed in all cases by means of flow qualitative analysis, in addition to the measurements of the peak systolic velocity. Possible complications,

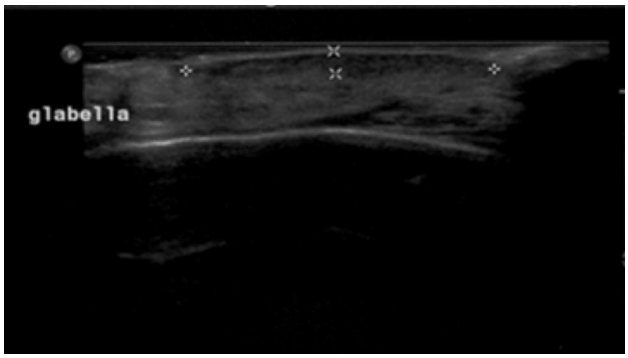

Fig. 4 Ultrasound examination obtained in the transverse view at the level of skin region affected by dismorphism and at the adjacent region, showing measurement of the autologous fat implant

ranging from edema or hematoma to necrosis or adipocyte graft migration, were evaluated. Finally, we calculated the average percentage of 1-year survival of autologous fat graft through a mathematical formula. This formula, the so-called fat graft survival (FGS) (%), expresses the ratio between the hypodermal thickness (in cm) detected at high-resolution ECD 1 year from lipofilling and the hypodermal thickness (in cm) detected at US 1 week from lipofilling × 100.

ECD criteria to assess the efficacy and the survival of the autologous implanted fat, included the following: (1). Measurement of the progressive increased thickness of the different cutaneous layers, especially dermis and epidermis. (2) Verification and monitoring of the correct positioning and changing in echogenicity and morpho-volumetry of the autologous fat implant over time. (3) Assessment by means of ECD of changing in vascularity in the peri or intra-implantation area, as expression of complications such as inflammatory phenomenon or granulomas.

Results

The high-resolution ultrasonography of the skin performed before the surgical procedure, showed mild echogenic disorganization, with evidence of a slight thickening reduction of all dermal regions, in addition, there was poor differentiation between the superficial and deep layers of the dermis, with associated extensive hypo echogenicity. Conversely, immediately after the surgical procedure and in the successive controls, it was observed the presence of an area of hyper echogenicity corresponding to the implanted adipose tissue, with regular margins, that became progressively smaller in the following controls at 1 and 6 months, due to natural phenomena of reabsorption, disappearing completely at 1 year. It was also associated a gradual increased thickening of the dermal, hypodermal and epidermal regions, more pronounced within the first month, allowing sometime to distinguish the superficial and deep dermal layers. The estimated increase in the volume of the implant and its percentage of viability-reabsorption, evaluated with clinical, qualitative and quantitative assessments with serial ultrasound exams, showed significant benefits for both the skin texture and the scars appearance, resulting in modest attenuation of the margins.

Table 2 US-detected serially evaluated hypodermal thickness

Thickness of hypodermis (cm)					
Patient	Time 0	1 week	1 month	6 months	1 year
1	0.5	0.8	1.1	1.0	1.0
2	0.2	0.5	0.4	0.3	0.3
3	0.6	1.0	1.0	1.2	0.8
4	0.1	0.7	0.5	0.4	0.2
5	0.2	1.7	1.5	1.8	1.7
6	0.1	1.5	1.2	1.2	1.5
7	0.2	0.4	0.3	0.4	0.2
8	0.7	1.7	1.5	1.4	1.3
9	0.6	0.6	0.6	0.5	0.5
10	0.3	0.7	0.7	0.6	0.3
11	0.1	0.6	0.3	0.3	0.3
12	0.5	0.8	1.0	1.0	1.0
13	0.2	0.6	0.3	0.3	0.3
14	0.7	1.0	1.1	1.2	0.8
15	0.1	0.7	0.5	0.4	0.2
16	0.1	1.4	1.3	1.2	1.5
17	0.2	1.7	1.5	1.8	1.7
18	0.1	0.6	0.3	0.3	0.3
19	0.2	0.7	0.8	0.5	0.4
20	0.5	0.6	0.6	0.5	0.5
21	0.6	1.7	1.5	1.4	1.3
22	0.2	0.5	0.3	0.4	0.2
23	0.4	0.9	1.1	1.2	1.0
24	0.5	1.0	1.1	1.2	0.8
25	0.2	1.7	1.5	1.8	1.7

The major benefits of high-resolution ECD detectable lipofilling were found at the hypodermis (Table 2); however, all the other skin layers showed benefit as well, probably due to the biological effects that determine a slight volumetric increase (Fig. 3). An example of patient's scar tissue of the sternal region, before and after lipofilling correction, is shown in Fig. 5.

Given the possibility to have quantitative data at ultrasound examination representing the various skin and subcutaneous layers in serial evaluations after surgery (Table 2), it was possible to calculate the average percentage of one-year survival of autologous implanted fat. This formula expresses the FGS. The average percentage of 1-year

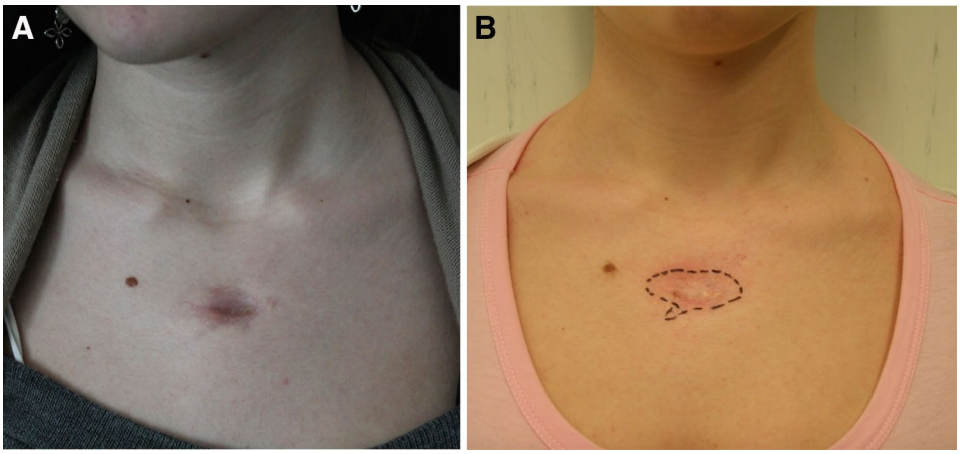

Fig. 5 An example of patient's scar tissue in the frontal view of the sternal region, in a 42-year-old woman, before (**a**) and after lipofilling correction (**b**)

survival of autologous implanted fat in our study was identified at approximately 72 %. In particular, it was found to be satisfactory in 13 patients (50 vs 87 %), good in 7 patients (vs 100 %) and poor in 5 patients (vs 23 and 46 %) (Table 3). No significant complications were detected.

The beneficial and regenerative effects of adipose implanted tissue were detected not only at physical examination of the patients, but also at quantitative high-resolution ECD analysis, which showed an increase both in the thickness not only of the subcutaneous adipose tissue, but also of the dermis and epidermis (Tables 4, 5).

Using color- and power-Doppler, a slight increase in the vascular signal in the region of the implant of adipose homologous tissue and in the surrounding skin region was found. No complications such as oil cyst were observed, after the lipofilling correction.

Table 3 Average percentage of lipoaspirate fat graft survival (%)

Patient	Fat graft survival rate (%)
1	100
2	81
3	81
4	23
5	100
6	100
7	50
8	77
9	87
10	46
11	53
12	100
13	81
14	81
15	23
16	100
17	100
18	50
19	77
20	87
21	46
22	53
23	100
24	81
25	23
Mean value	72

Discussion

Deriving from the greek "lipos" = fat and English "to fill" = infiltrate, the term lipofilling means the grafting of autologous adipose tissue, a surgical technique that can correct the volumetric defects of the soft tissues caused by trauma, resection of cancer, congenital defects and aging [10–16].

Lipofilling represents an ideal "Filler" due both to its filling and regenerative effect, being the adipose tissue an unlimited source of stable, biocompatible and inexpensive material [10–13]. Many experimental clinical and radiological studies have demonstrated the survival of adipocytes in the receiving site [10–13]; both in humans and animals, histological evidence of surviving transplanted fat grafts has been collected [3, 12–17]. Human studies have been performed both for experimental purposes and in the context of follow-up of patients undergoing autologous fat transplant procedures [16] through the histological analysis of tissue biopsies. Among the radiological techniques useful for verifying the level of engraftment of autologous transplanted adipose tissue, particular interest has risen in the ultrasound techniques and magnetic resonance imaging (MRI) [12, 13, 15, 16]. Some authors [12–17] have conducted experimental studies using ultrasound as a means to document the post-operative results and, above all, to

Table 4 US-detected thickness in the dermis at serial assessments

Thickness of dermis (cm)					
Patient	Time 0	1 week	1 month	6 months	1 year
1	0.2	0.5	0.3	0.3	0.2
2	0.2	0.2	0.2	0.2	0.2
3	0.1	0.6	0.6	0.7	0.1
4	0.1	0.1	0.3	0.2	0.1
5	0.2	0.3	0.2	0.2	0.3
6	0.2	0.2	0.2	0.2	0.3
7	0.1	0.4	0.3	0.3	0.1
8	0.1	0.2	0.2	0.2	0.2
9	0.1	0.4	0.3	0.6	0.1
10	0.1	0.2	0.3	0.3	0.11
11	0.2	0.2	0.2	0.2	0.2
12	0.2	0.5	0.3	0.3	0.3
13	0.2	0.2	0.2	0.2	0.2
14	0.1	0.5	0.7	0.7	0.1
15	0.1	0.1	0.3	0.2	0.1
16	0.1	1.5	1.3	1.2	1.5
17	0.2	1.7	1.5	1.8	1.7
18	0.1	0.6	0.3	0.3	0.3
19	0.2	0.7	0.8	0.6	0.4
20	0.5	0.6	0.6	0.5	0.5
21	0.6	1.7	1.5	1.4	1.3
22	0.2	0.5	0.3	0.4	0.2
23	0.4	0.9	1.0	1.0	1.0
24	0.5	1.1	1.1	1.2	0.8
25	0.2	1.7	1.5	1.8	1.7

Table 5 US-detected thickness in the epidermis at serial assessments

Thickness of epidermis (cm)					
Patient	Time 0	1 week	1 month	6 months	1 year
1	0.0	0.1	0.1	0.1	0.0
2	0.1	0.1	0.1	0.1	0.1
3	0.0	0.1	0.1	0.1	0.0
4	0.0	0.0	0.0	0.1	0.0
5	0.0	0.0	0.1	0.1	0.0
6	0.0	0.1	0.1	0.1	0.0
7	0.1	0.1	0.1	0.1	0.0
8	0.0	0.1	0.1	0.1	0.05
9	0.1	0.1	0.1	0.1	0.05
10	0.1	0.1	0.1	0.1	0.1
11	0.1	0.1	0.1	0.1	0.1
12	0.0	0.1	0.1	0.1	0.0
13	0.1	0.0	0.1	0.1	0.1
14	0.0	0.1	0.0	0.1	0.0
15	0.0	0.0	0.0	0.1	0.0
16	0.0	0.1	0.1	0.1	0.0
17	0.0	0.0	0.1	0.1	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.1	0.1	0.1	0.0
20	0.0	0.1	0.1	0.1	0.0
21	0.1	0.1	0.1	0.1	0.1
22	0.0	0.1	0.1	0.1	0.1
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.1	0.0
25	0.0	0.1	0.1	0.1	0.0

detect possible complications. The ultrasound exam makes it possible to study with a non-invasive, fast and low-cost technique the subcutaneous tissue, to achieve a preoperative planning and to confirm the effectiveness of the surgical technique used, documenting the increase in volume [12, 13, 15, 16].

In recent years, with the widespread of the lipofilling techniques, MRI has been considered the reference imaging method for evaluation of adipose tissue. This technique has proven to be a very reliable technique for the follow-up of these patients, especially as a preoperative study in cases with complex multi-tissue involvement and in the evaluation of complications. However, its use is limited by the high cost of the technique [16]. Conversely, due to its lower cost and its wider availability, the ultrasound examination has mainly shown the possibility of a qualitative visual assessment of the affected area treated with this surgical procedure; nevertheless, in our study we have drawn up the possibility of a quantitative assessment using standardized measurements of certain dermal areas and of the transplant itself at established times, thus obtaining a numerical value (%) expressing the survival rate of adipose implanted tissue. Ultrasound performed with high resolution and multi-frequency transducers (5–17 MHz) is cost effective and allows widespread examination, answering the fundamental question that surgeons arise when performing this type of surgery, that is how much adipose tissue has taken root. A potential limitation of the study is the limited number of patients recruited and the slight difference in terms of thickness between dermis and epidermis, that might be a potential source of error.

Conclusions

Lipofilling represents a slightly invasive, but effective technique for the correction of congenital or acquired defects of the skin, due to its filler effect and consequent tissue growth benefit despite the majority of patients seem to have lost a percentage of the injected fat over time [10–13]. High-resolution Doppler ECD is a valuable non-invasive tool for the quantitative and morphological evaluation of the degree of

engraftment of the transplanted autologous adipose tissue, for the evaluation of its clinical-esthetic benefits and for the assessment of its complications [12, 13, 15, 16].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest related to the publication of this article.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Scotto di Santolo M, Sagnelli M, Mancini M, Scalvenzi M et al (2015) High-resolution color-Doppler ultrasound for the study of skin growths. Arch Dermatol Res 307(7):559–567. doi:10.1007/s00403-1557-z
2. Alexander H, Miller DL (1979) Determining skin thickness with pulsed ultrasound. J Invest Dermatol 72(1):17–19
3. Kleinerman R, Whang TB, Bard RL, Marmur ES (2012) Review ultrasound in dermatology: principles and applications. J Am Acad Dermatol 67(3):478–487. doi:10.1016/j.Jaad.2011.12.016
4. Pupelli G, Longo C (2013) Small diameter melanocytic lesions: morphological analysis by means of in vivo confocal microscopy. Br J Dermatol 168(5):1027–1033. doi:10.1111/bjd.12212
5. Rallan D, Harland CC (2003) Ultrasound in dermatology-basic principles and applications. Clin Exp Dermatol 28:632–663
6. Schmid-Wendtner MH, Burgdorf W (2005) Ultrasound scanning in dermatology. Arch Dermatol 141(2):217–224
7. Srivastava A, Woodcock JP, Mansel RE et al (2012) Doppler ultrasound flowmetry predicts 15 year outcome in patients with skin melanoma. Indian J Surg 74(4):278–283. doi:10.1007/s12262-011-0398-z
8. Wortsman X, Wortsman J (2010) Clinical usefulness of variable frequency ultrasound in localized lesions of the skin. J Am Acad Dermatol 62:247–256. doi:10.1016/j.jaad.2009.06.016
9. Wortsman X (2012) Common applications of dermatologic sonography. J Ultrasound Med 31(1):97–111
10. Coleman SR (2002) Hand rejuvenation with structural fat grafting. Plast Reconstr Surg 110(7):1731–1744
11. Coleman SR (1995) Long term survival of fat transplants: controlled demonstrations. Aesthetic Plast Surg 19:421–425
12. Costantini M, Cipriani A, Belli P et al (2013) Radiological findings in mammary autologous fat injections: a multitechnique evaluation. Clin Radiol 68(1):27–33. doi:10.1016/j.crad.2012.05.009
13. Costantino A, Fioramonti P, Ciotti M, Onesti MG (2012) Lipofilling in skin affected by radiodermatitis: clinical and ultrasound aspects. Case report. G Chir 33(5):186–190
14. Jauffret JL, Champsaur P, Robaglia-Schlupp A et al (2001) Arguments in favor of adipocyte grafts with the S.R Coleman technique. Ann Chir Plast Esthét 1:31–38
15. Bilgen IG, Ustun EE, Memis A (2001) Fat necrosis of the breast: clinical, mammographic and sonographic features. Eur J Radiol 39(2):92–99
16. Fernandes Chala L, De Barros N, De Camargo Moraes P et al (2004) Mammographic, sonographic, computed tomography, and magnetic resonance imaging findings. Curr Probl Diagn Radiol 33(3):106–126
17. Marques A, Brenda E, Saldiva PH et al (1994) Autologous fat grafts: a quantitative and morphometric study in rabbits. Scand J Plast Reconstr Surg Hand Surg 28(4):241–243