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Burn Scar Regeneration with the “SUFA” (Subcision and Fat Grafting) Technique - A Prospective Clinical Study

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Abstract

Background: Treatment of burn scars with traditional surgical techniques is challenging due to recurrent contractures. The use of fat grafting in thermal injury has been previously reported only in small clinical series and results are often biased by simultaneous surgical procedures and lack of scientific methods of validation.

Methods: Our study prospectively evaluates outcomes in 9 patients treated with the “SUFA” technique (Subcision and Fat Grafting) for debilitating contracted burn scars limiting range of motion. Results are evaluated clinically with the Vancouver scale and by range of motion through the affected joints at 1, 3, 6 and 12 months. Scientific validation of the outcomes is performed evaluating dermal thickening and scar remodeling by high definition ultrasound and histology examination with hematoxylin-eosin and monoclonal antibodies staining.

Results: Results show clinical improvement, thickening of dermis and redistribution and reorientation of the collagen fibers within the dermis. Statistical significance ($p < 00.5$) has been obtained for all analyzed data. Fat reabsorption occurred with a mean of 40%.

Conclusion: Our study gives scientific validation of the efficacy of subcision and fat grafting in contracted scar. New surgical and diagnostic techniques are illustrated. Our clinical and diagnostic outcomes suggest dermis regeneration secondary to the new fat grafting technique.

Keywords: Burn scar; Subcision and fat grafting; Regeneration

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Introduction

Reconstruction of burn scars remains one of the most challenging aspects of reconstructive surgery. The debilitating functional problems, cosmetic deformities and frequent lack of autologous tissue to replace “like with like” demand that therapeutic efforts are well planned and executed. Conventional methods of treatment of acute burns include primary excision and grafting of deep second-degree and full-thickness burns [1,2]. Scar contraction can be decreased by early excision and grafting, but it is always present to some degree [3].

Current methods of scar contracture releases include non-surgical and surgical methods. Non-surgical methods use corticosteroids injection, silicone gels, pressure dressing, physiotherapy, and laser therapy [4,5]. Surgical correction can be carried out by excision and local tissue rearrangement such as z-plasties, flaps, tissue expansion and skin grafting [6-8]. With all the above surgical treatments the final result is to substitute a scar with another scar that will inevitably be prone to a new contracture.

Fat grafting in burn clinical studies have been conducted on small subsets of patients and outcomes have been evaluated using functional and aesthetic parameters of assessment that often lack scientific validation [9-18]. The goal of our study is to advocate fat grafting as an alternative method to skin graft or flap transfer in burn reconstruction. We prospectively evaluate outcomes in patients who underwent the “SUFA” technique (Subcision and Fat Grafting) for the treatment of

Table 1: Location and demographics.

Location	Head and neck (n=6)	Upper extremity (n=3)	Lower extremity (n=2)	Perineum (n=1)	Total (n=9)
Sex ratio	Men (n=7)	Women (n=2)			
Age	Mean 46 (28-65)				
Follow up	Mean 11 months (2-19)				

Table 2: Vancouver scale.

Vascularity	Normal	0
	Pink	1
	Red	2
	Purple	3
Pigmentation	Normal	0
	Hypo-pigmentation	1
	Mixed-pigmentation	2
	Hyper-pigmentation	3
Pliability (Elasticity)	Normal	0
	Supple	1
	Firm	2
	Banding	3
	Contracture	4
Height	Flat	0
	<2 mm	1
	2-5 mm	2
	>5 mm	3
Pain	None	0
	Occasional	1
	Requires medication	2
Itchiness	None	0
	Occasional	1
	Requires medication	2

contracted burn scars limiting range of motion. Clinical and scientific validated methods are employed to evaluate the effect of fat grafts on scar remodeling. In particular, a non-invasive and cost-effective method of evaluation of fat graft take and dermal thickness, namely ultrasound, is introduced. Dermal "regeneration" is assessed with the use of monoclonal antibody staining.

Material and Methods

Our IRB approved study prospectively analyzed 9 consecutive patients affected by secondary burns over a period of 24 months. A detailed consent form illustrating the procedure risk and benefits was signed before the surgery. Criteria of inclusion were patients with contracted scar bands in flexion creases such as the face and neck (n=6), upper extremity and axilla (n=3), lower extremities (n=2), perineum (n=1). All analyzed scars limit range of motion of the affected joints. Other patients with burn scars were non-functional impeding areas are not included in the study. Patient demographics showed seven males and two females, mean age 46 years, mean time since primary burn was 6 years (Table 1).

All patients included in the study have been initially treated with skin grafts and then with scar release, skin graft or z-plasties for secondary contractures. The SUFA technique was always performed after the initial stage of skin grafting or z-plasty. Scars have been clinically evaluated with the Vancouver scale and range of motion preoperatively, at 1, 3, 6, and 12 months postoperatively. The Vancouver scale includes scar pigmentation, vascularity, pliability and height preoperative and at follow ups (Table 2).

Fat graft survival and skin remodeling have been evaluated by high frequency 18MHz ultrasound [19] preoperatively, at 1, 3, and 6 months postoperatively. 7.5-13 MHz and 10-20 MHz probes were used. In selected patients, the dermal remodeling and regeneration has been demonstrated by histologic examination of scar tissue biopsies with hematoxylin-eosin and rabbit monoclonal antibodies staining for collagen type I and III before and after treatment.

Figure 1: Preoperative markings.

Antibodies used were RabMab anti-collagen I antibody (Abcam, ab138492) and Rabbit Anti-Collagen III antibody (Abcam, ab7778). Both ultrasound and biopsy have been performed at fixed anatomic landmarks to facilitate comparison and avoid bias. Operation time, tumescent infusion, lipoaspirate and injected fat have been recorded. We have taken pre and postoperative pictures and videos at 1, 3, 6, and 12 months follow up intervals. We used a goniometer to assess range of motion of the affected joints. Statistical of data have been analyzed by Student t-test.

Postoperative protocol included taping of the injected areas for 48 hours, oral antibiotics for three days and sutures removal at 1 week. Stretching exercises were started at postoperative day 5. Between surgical sessions, an interval of 2 to 3 months was respected to allow graft take and remodeling. A maximum of three sessions have been employed in some patients.

Technique

We have evaluated scar contracture and range of motion in the flexion creases preoperatively. We marked the scar bands we planned to be released. All patients were operated on under general anesthesia and positioned on the operative table with the contracted cords under tension to facilitate intra-operative release (Figure1).

The abdomen represented the donor site for fat harvesting in all patients. Tumescent solution was infiltrated with 2.7-mm, 12 hole

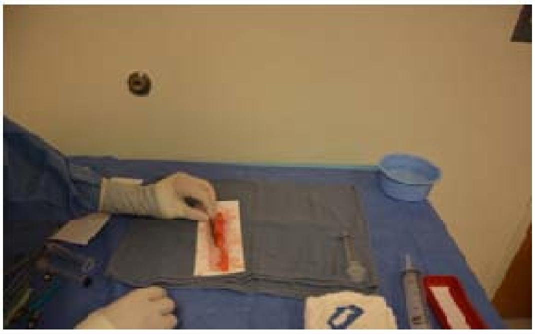

Figure 2: The lipoaspirate is prepared over telfa with atraumatic technique.

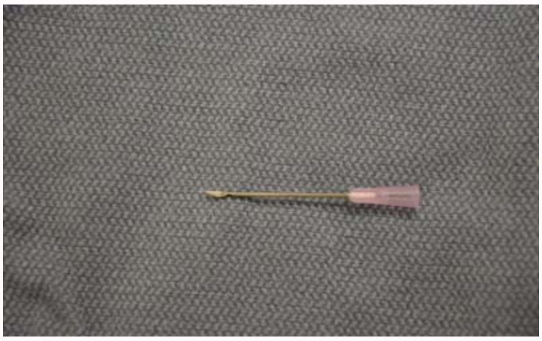

Figure 3: 18-gauze needle with cutting tip.

Figure 4: Technique of injection: 0.3ml of fat is injected at each pass.

cannula, through intra-umbelical incisions to minimize scarring. After 15 minutes of waiting time for the vasoconstrictive effect of the epinephrine, the fat was aspirated with 60 cc syringes under negative pressure. The lipoaspirate was first washed with ringer lactate in a proportion of 1:1 and then processed on telfa (Figure 2). Fat graft was inserted in 10 cc syringe with a traumatic technique: the preparation of the fat was performed on telfa in longitudinal rows facilitated re-insertion into the syringe cylinder while exerting a wiggling motion with the syringe.

The recipient areas were infiltrated with lidocaine 1% with epinephrine 1:100.000 and vasoconstriction was allowed waiting for 15 minutes. The subcision of the scar cords was performed with18G Admix needle with cutting tip while the cord is under maximum tension (BD Nokor™) (Figure 3).

The subcision technique included parallel repetitive longitudinal passes of the cutting needle through the cords. At the end the remaining scar adherences were released with 45 to 60-degree oscillatory motion of the needle blade. The release generates short slit in the scar, which results in loosing and expansion (Video 1). In this way a tridimensional donor site scaffold was created. Fat was injected with 2.5 mm lipofilling cannulas in a three dimensional pattern with 0.3 ml of fat injected at each pass (Figure 4). The total amount of fat was estimated during the preoperative planning and recorded for each anatomic subunit. When the face was the area to be treated, fat was injected mainly at the jaw line to minimize postoperative disfiguration in case of weight gain. The treatment of burn hands took into consideration the location of structures to be preserved. Webspaces were released and fat grafted. The dorsum of the hands was subcised between dermis and extensor tendons and then fat grafted in the released space. V-shape cannulas were at times used to cut more tenacious bands.

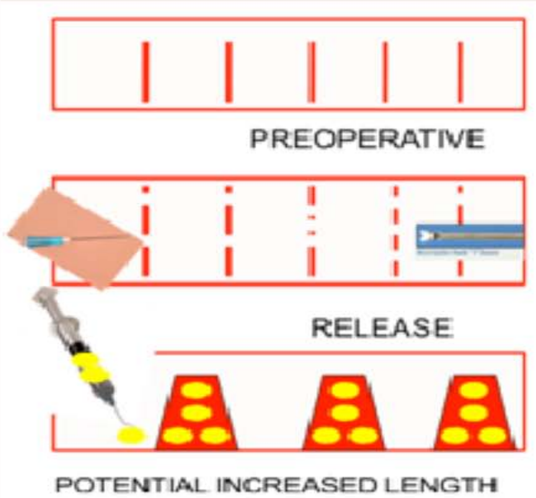

Figure 5: Diagram showing potential scar lengthening with the "SUFA" technique.

Table 3: Intraoperative data for fat grafting technique.

Surgical data	Operative time	Tumescence	Lipo-aspirate	Injected fat
	70'(45'-180')	100cc	100cc	45cc(30-75)

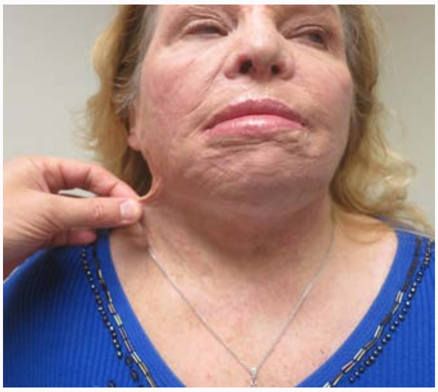

Figure 6: Postoperative results at 12 months follow up. Pinch test shows improved skin elasticity.

The SUFA technique allowed release and expansion of the scar tissues with multiple micro-fractures in the offending scar bands that were filled by fat injection in a three dimensional scaffold. This elongated the scar of almost 20% at each session (Figure 5).

Results

Mean operative time was 70 minutes (range 45 to 180 minutes), mean tumescent fluid infiltrated and fat aspirated was 100cc and mean injected fat grafts 45 cc (range 30cc to 75cc) (Table 3).

All patients showed statistically significant improvements in scar contractures in the Vancouver scale and for range of motion of the head, neck, hands, lower extremities, and perineum at 3 and 6 months follow ups ($P < 0.005$) (Table 4, Figure 6 and Videos 2-5).

High frequency ultrasound showed mean fat reabsorption of approximately 40% and increased dermal thickness at three and six month's controls (Table 5 and Figure 7). Anatomical bias was eliminated performing the high frequency ultrasound and biopsies at fixed anatomic landmarks. Only one radiologist performed the ultrasounds and one surgeon performed the biopsies.

Table 4: Statistically significant improvements in range of motion and Vancouver scale.

	Preoperative	postoperative	P value T test
Vancouver Scale	10 (9-12)	4 (3-7)	0.0025
Range of motion neck (rotation)	82 (50-100)	123.8 (90-160) [41.8]	0.0166
Range of motion neck (flex / ext)	36.3 (20-45)	61.2 (45-70) [24.9]	0.0451

Table 5: High frequency ultrasound showed mean fat reabsorption of approximately 40% and increased dermal thickness at three and six months controls.

	Preoperative	postoperative	P value T test
18 MHz US Dermal thickness	0.2 mm	0.35 mm	0.0006
Fat resorption		40% (25-60)	
Complications		1 minor not requiring surgery	

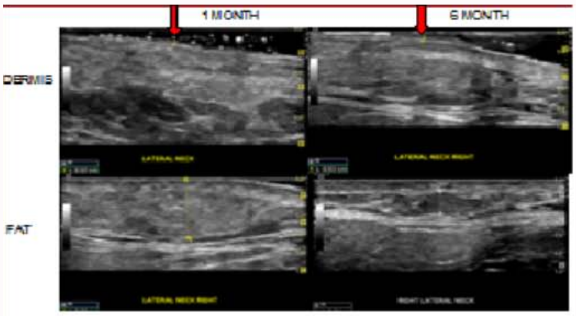

Figure 7: High frequency ultrasound shows fat reabsorption of approximately 40% and increased dermal thickness.

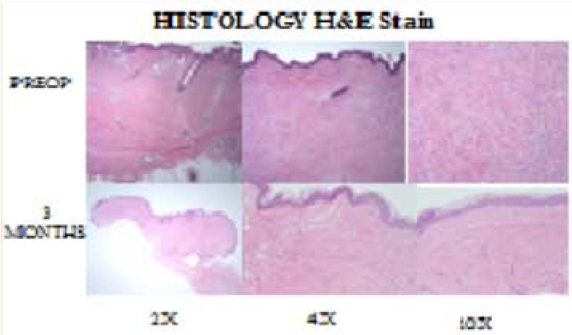

Figure 8: Hematoxilin eosin staining. Preoperative: The lowest power (2x) illustrates dermal thickening and fibrosis, with disruption of hair follicles. On higher power (4x) you can appreciate the fibroblastic proliferation and fibrosis, with focal keloidal collagen bundles (which are highlighted in the 10x picture). Postoperative: 2x and 10x shows scar formation without hypertrophic scar and keloid formation. Collagen fibers have a horizontal orientation wo bundle formation, decreased fibroblasts.

The histology staining with rabbit monoclonal antibodies for collagen type I and III showed increased deposition of the collagen III after the fat grafting and remodeling of the collagen type III fibers with regular orientation as in mature healing dermis (Figure 8 and 9).

One patient had skin breakdown resulting in uneventful healing (Figure 10). No donor site morbidity was noticed. All patients were followed up to assess range of motion and functional improvements were achieved (Figure 11 and 12).

Discussion

Principles of burn reconstruction include understanding of wound healing and contracture processes. The effect of time on the maturation of scars is of pivotal importance and requires expertise on choosing the correct time for surgery. Multiple operations are the rule

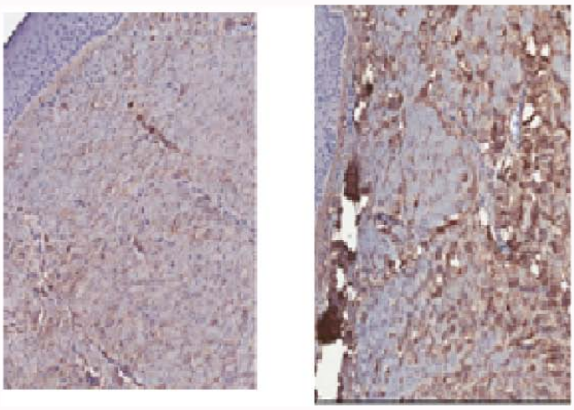

Figure 9: Staining with monoclonal antibody shows increased deposition of the collagen III after the fat grafting. RabMab anti-collagen I antibody (Rabbit monoclonal to Collagen I), Abcam, ab138492. Rabbit Anti-Collagen III antibody (Rabbit polyclonal to Collagen III), Abcam, ab7778.

Figure 10: Delayed healing occurred in only one patient and did not require further procedures.

and frequently take place over a long period of time. Over the past 50 years, primary excision and grafting of deep second-degree and full-thickness burns has become the standard of care in the United States and in most developed countries [1,2]. All burns of the second and third degree result in open wounds and heal by contraction and epithelialization. Contraction is dependent from degree of burn and time elapsed between injury and surgical intervention. Therefore contracture can be decreased by early excision and grafting, but it is always present to some degrees [3]. Contraction leads to tension, and tension is one of the principal causes of hypertrophic and contracted scars. Understanding the role of tension and lack of healthy tissues in

Figure 11: Improved range of motion.

Figure 12: Improved range of motion.

the evolution of post-burn deformities is essential to their successful treatment. Burn reconstruction is fundamentally about the release of contractures and the correction of contour deformities. It should not be focused on the excision of burn scars because a scar can only be traded for another scar of a different variety. In burns the fundamental problem is the inadequate skin and soft tissues and further excision of scars, skin graft or Z plasties can easily add to the clinical problem of worsening contraction. Non-surgical methods of scar release such as pressure therapy, physical therapy, cortisone injection and laser therapy are often disappointing. Surgical corrections of contracted scars can be carried out by excision and reconstruction with local tissue rearrangement such as Z-plasties, flaps, tissue expansion, skin grafting. All the above mentioned surgical methods carry the potential of lack of tissue, "borrowing from Peter to give Paul" and the event of a new contracture. For the aforementioned reasons, we think that subcision and fat grafting represents a worthy approach with remodeling of the scar form inside minimizing the risk of a new contracture.

The regenerative role of fat grafting in burns has been validated by in vitro studies. Revascularization decreased scarring and fibrosis, increased dermis thickening with rearrangement of the collagen fibers within the dermis has been proven in murine models [20-23]. Despite the in vitro models positive outcomes, the clinical series reported in the literature lack of scientific validation or are biased by concurrent therapies [9-18,24,25-27]. Published data suggest that degree of fat resorption ranges between 30 and 40% and our data overlaps these findings [14]. Khouri et al. [25] recently published their technique of percutaneous aponeurotomy and fat grafting. We describe in detail the technique learned initially from Dr. Gino Robotti and then refined by Dr. Khouri R [25]. I personally learned the same technique from Dr. Khouri [25] and then modified it in some technical details. We use 18 G needle with sharp pointy blade at its tip because we think this has more control during the subcision of the scars. Our choice for the "wash out" fat preparation technique is due to the more long lasting survival achievable with this technique [26]. Another difference from previous publications is also that our clinical outcomes have been evaluated with objective data and measurements with statistically significant improvement for range of motion. Scientific validation of the "regenerative effect" of fat grafting has been demonstrated by high definition ultrasound and histology changes within the dermis. Our study is the first to validate clinically what has been previously demonstrated only by in vitro studies [11,17,21,23]. In fact, ultrasound evaluation with thickening of the dermis at three and six months and histology findings of rearrangement of the collagen type III fibers within the dermis confirm what has been previously demonstrated in the murine models [21].

Lack of soft tissue and burn scar contracture after Z plasties suggest that we should aim for an "internal remodeling" of the scar without jeopardizing the already scant and altered skin envelopes [25]. Our clinical experience suggest that the "SUFA" technique maintain and improve the range of motion over time when compared to traditional "external remodeling" techniques.

Our results show that the effects of subcision and fat grafting is probably a combined and synergic effect of mechanical expansion (subcision of scar) and fat grafting (dermal regeneration) and certainly the prevention of scar contracture is due to the fat that could act as a "spacer" or stem cell induction for regeneration.

The "SUFA technique" cannot be considered effective at 100% in all cases, especially when the scars are thick and extremely limiting range of motion. In these instances we use the technique for a maximum of three times at three months intervals and then release the tenacious contraction with a "prefabricated Z-plasty" flap. The prefabrication of the flaps with fat injection softens the scars, gives adequate padding and limits the scar contracture of the transposed flaps. The prefabrication of the Z-plasty with fat graft also allows better viability, lengthening and reduction of contractures.

Our study will aim in the future to include patients in the very early stages of burns to try to modify the natural history of the retracting scars.

Conclusion

The "SUFA" technique represents a new promising approach in the era of "regeneration" of the connective tissues. In our study, improvements in clinical outcomes are supported by validating scientific methods such as high definition ultrasounds and histology with monoclonal antibody staining for collagen type I and III. Collagen III regeneration and reorientation is probably promoted by adipose tissue-derived stem cells.

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