Original Article

Local Flap Reconstruction of Burn Contractures in Extremities and Neck: A Nine-Year Experience with Long-Term Outcome Evaluation in Southwestern Iran

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ABSTRACT

Background: Treating burn scar contractures remains challenging for reconstructive surgeons; no clear guidelines declare the optimal and most effective technique. We evaluated the efficacy of local flaps in treating patients with post-burn contractures.

Methods: This retrospective study included 243 patients with post-burn contractures referred to Taleghani Hospital (Khuzestan, southwest Iran) for local flap reconstruction from 2011 to 2020. Patients' demographic data, detailed descriptions of scars, surgical procedures, and flap outcomes were assessed. A plastic surgeon conducted all surgical procedures, the goals of which were to release the scar and cover the defect. Joint range of motion (ROM) (according to goniometric measurements), complications, need for second-stage surgery, and patient satisfaction were assessed.

Results: After scar release, 70.4% of joints were covered with a Z-plasty and similar local flaps, 26.1% with a Z-plasty plus skin grafts, and 3.5% with only skin grafts. The outcome after one year revealed a significant improvement in mean ROM (by 45.80% of the normal ROM; $P< 0.001$). The mean functional and aesthetic satisfaction scores were 9.45 and 7.61 out of 10, respectively. The complication rate was 10.82%: re-contracture occurred in 3.82%, flap tip necrosis in 1.27%, and partial flap necrosis in 0.31%.

Conclusion: Simple local flaps such as the Z-plasty are safe and effective in covering the joint following post-burn contracture release. Due to the feasibility, minimal need for facilities, steep learning curve, acceptable functional and aesthetic outcomes, and low complication rate, we strongly recommend the Z-plasty for reconstructing burn contractures, particularly in LMICs.

KEYWORDS
Contracture; Burn; Z-plasty; Flap; Reconstruction

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INTRODUCTION

Post-burn contractures severely worsen the quality of life[1]. Although survival is undoubtedly an immediate concern after an acute burn, the main concern for the victim and the treatment team will soon be the

return to pre-injury functioning[2]. The burn scar may persist, causing various functional and aesthetic problems[3]. Scar contractures[4], the replacement of skin with excessive scar tissue with inadequate extensibility[5], are of particular concern. Scarring is a three-dimensional process that often extends from superficial to deep tissues. The extremities and the neck are the areas most affected by scar contractures[4]. Burn scar contractures limit the joints' range of motion (ROM), significantly impacting patients' abilities and quality of life (QoL)[5]. Even with adequate treatment, contractures remain a global issue, with a prevalence ranging from 38% to 54%[6].

The best treatment option for contracture release is a surgical procedure, typically performed when the scar has matured. The idea is that unless the scar is mature, the local tissues around the inflammatory scar may lead to flap necrosis[6], and interfering with an active scar will lead to more contractures. The principle of contracture release surgery is to release or remove the scar and to replace the defect with the donor tissues that match in texture, color, and pliability[5, 7]. However, balancing scar resurfacing with donor site complications is a challenge[8]. Surgical techniques include scar release combined with skin grafting, Z and V-Y plasties, or various local, regional, and free flaps[3, 7]. It is not yet evident which surgical procedure is the most effective[7, 9], so surgeons have difficulty selecting the most appropriate technique[7]. Although the skin graft is the most economical and technically simple option and provides a moderate color match, it is not ideal for resurfacing[10]; their appearance does not give the best possible color/texture match, skin elasticity, or cosmesis. There is also a tendency for secondary and late contracture recurrence. In addition, they may need recurrent surgeries (to release post-graft contractures), physiotherapy, splinting, pressure garments, and anti-deformity positioning [2, 10-12].

Local flaps often provide better pliability and extensibility than skin grafts, improving joint function[5]. Surgeons have used both local and free flaps to reconstruct burn contractures[13]. Local flaps are much easier to utilize; popular forms include the Z-plasty, continuous Z-plasty, five-flap plasty (combined Z-plasty and Y-V advancement flap)[14], and propeller flaps[15]. If a surgeon intends to release the scar completely and reconstruct it in a single-stage operation, a large defect may remain in the donor site, needing a free flap. An option in difficult or severe contractures (<50% joint range of motion), especially for countries with low income and facilities, is staged Z-plasties, which means repeating the Z-plasty procedure in future operations until reaching a desirable range of motion [16-18].

Although the Z-plasty technique (in all its variations) represents one of the most effective methods for post-burn scar contractures[4], all included studies have methodological and statistical shortcomings, meaning that studies with clear outcome assessments and precise statistical analysis are needed globally[9].

Here, we report the first study from southwestern Iran evaluating the functional improvement and complications following local flap reconstruction of post-burn contractures in the neck and extremities. Our series is one of the largest ever reported on this topic.

PATIENTS AND METHODS

Study design

We conducted a retrospective review study of 243 patients with burn scar contractures referred to Taleghani Hospital—a burn center in Khuzestan Province, southwestern Iran. The Ahvaz Jundishapur University of Medical Sciences Ethics Committee approved the study protocol (IR.AJUMS, HGOLESTAN.REC.1400.151). Patients provided written informed consent for inclusion in this study, and we ensured the confidentiality of their data.

Data collection

We collected data on the patients' age, sex, city of residence, distance to the hospital, burn incident (date, cause, etc.), resulting scars, contracture location, surgical procedures, method of operation, number of operations, pre- and post-op range of motion, infection, dehiscence, necrosis, contracture recurrence, and need for staged Z-plasty. This information was gathered from the charts of patients who were operated in this hospital from September 2011 to March 2020. All procedures and post-up evaluations were done by a plastic surgeon.

Surgical procedure

This study's main surgical method was using a local flap to cover all contractures and reconstruct the

Figure 1: Creation of a multi-Z surgery technique

burn scar. Our procedure featured an unprecedented technique that is innovative compared with traditional approaches. The flap has a triangular shape (Figure 1). This procedure was sometimes impossible, so we used staged z-plasty, skin grafts, or a combination of z-plasty and skin grafts instead.

Study definitions

In burns victims, joint ROM can be assessed accurately with a goniometer[19]. We retrieved normal values from the "American Academy of Orthopedic Surgeons" and "Norkin and White protocol" for large joints[5] and from Richard et al. [20] for fingers (Table 1). ROM data were indexed to percentages of the normal values instead of absolute ROM values to control for different normal ROM values of the various joints.

Outcomes

Adverse events included post-surgery infection, flap necrosis, wound dehiscence, and re-contracture. We defined re-contracture as a bundle-like scar with a reduced range of motion compared with the day of discharge, with partial or total recurrence of the preoperative problem.

A one to ten rating scale was used for each patient regarding functional and aesthetic improvements compared to the preoperative period, where 1 = completely dissatisfied and 10 = completely satisfied.

Statistical analysis

Statistical analysis was done using SPSS v.22 software (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation, with nominal variables depicted as numbers and percentages. The Kolmogorov–Smirnov test assessed the conformity of parameters to a normal distribution. A paired-sample *t*-test was used to compare the mean pre- and post-operative ROM. One-way ANOVA was used to compare several continuous variables. Nominal variables were analyzed using the chi-squared test and Fisher's exact test. Statistical significance was determined at $P \leq 0.05$.

RESULTS

A total of 243 patients (with 314 affected joints), both children and adults, underwent contracture release surgery between September 2011 and March 2020. Among the 314 affected joints, 148 (47.1%) were in males, and 166 (52.9%) were in females. Ages ranged from 1 to 65 years.

The types of initial burn insults comprised flame burns in 38.1% of cases, scalds in 28.4%, gas explosion (blasts) in 16.4%, electrical burns in 9.7%, contact burns in 4.5%, and acid burns in 3.0%. The total burn surface area (TBSA) ranged from 1 to 70%. The smallest TBSA was found in cases of isolated burns of the hands or digits secondary to electrical or flame burns, while the largest TBSA was

Table 1: Normal range of motion (ROM) values considered in the present study.

Extremity	Joints	POM	Normal ROM
	Neck	Extension	45
		Flexion	45
		Rotation	60
		Lateral flexion	45
Upper extremity			
	Shoulder	Extension	60
		Flexion	180
		Abduction	180
		Adduction*	40
	Elbow	Extension	0
		Flexion	150
	Wrist	Extension	70
		Flexion	80
Lower extremity			
	Hip	Extension	20
		Flexion	120
		Abduction	40
		Adduction	20
	Knee	Extension	0
		Flexion	135
	Ankle	Plantarflexion	50
		Dorsiflexion	20
		Extension	70
	Toe MTP	Extension	70
		Flexion	45
Hand			
Thumb	CMC*	Palmar abduction	60
	CMC*	Radial abduction	60
	MCP	Flexion	50
	IP	Flexion	80
		Extension	0
Digits II-V	MCP***	Flexion	80
		Extension	0
	PIP	Flexion	90
		Extension	0
	DIP	Flexion	65
		Extension	0

We retrieved the values from the American Academy of Orthopedic Surgeons (AAOS) and Norkin and White protocol for large joints[5] and Richard et al. [20] for fingers. * Shoulder adduction values were not available from AAOS and were therefore added. ** Thumb CMC abduction values were not available from AAOS and were added. *** We used the median composite ROM data of the right fingers; for clarity, we displayed the median ROMs of the right index finger. Abbreviations: Range of Motion (ROM), Plane of Motion (POM), Carpometacarpal joint (CMC), Interpharyngeal Joint (IP), Metacarpophalangeal (MCP), Proximal Interphalangeal (PIP), Distal Interphalangeal (DIP).

in patients with a history of flame or explosion burns. The mean time between the initial burn injury and operation was 546.1 ± 493.1 days (Table 2).

The etiology and location of contractures are listed in Table 3. The most affected burn sites were the hand (144 cases), elbow (51 cases), neck (50 cases), axilla (35 cases), lower extremity (30 cases), and eyelid (4 cases). Seventy-one patients had more than one contracture; the predominant combination of contractures was neck and hand (7 cases), followed by elbow and hand (6 cases), axilla and hand (2 cases), and neck and axilla (2 cases).

There were 4 cases with lower eyelid scars, for which full-thickness skin grafting was used following ectropion release. After treatment, lacrimation decreased, and conjunctivitis resolved. Other

Table 2: Patient characteristics

Total patients	243
Men	106 (43.6%)
Women	137 (56.4%)
Age	
Mean ± SD	19.2 ± 13.8
Median (years)	20
≤ 18	110 (45.27%)
> 18	133 (54.73%)
Time between injury and operation (mean ± SD)	546.1±493.1
Distance to hospital (kilometer) (mean ± SD)	76.3±80.2
Total burn surface area	
1-9 (%)	22.6%
10-19 (%)	21.5%
20-29 (%)	11.8%
30-39 (%)	18.3%
40-49 (%)	14.0%
50-59 (%)	6.5%
60-69 (%)	5.4%

Table 3: Scar characteristics and complications

Variable	**(%)**
Etiology	
Fire	38.1
Scald	28.4
Blast	16.4
Electrical	9.7
Chemical	3.0
Contact	4.5
Joints, n (%)	314 (100)
Location:	
1- Neck	50 (15.9)
2- Upper extremity	
Axilla	35 (11.1)
Elbow	51 (16.2)
Finger & Wrist	144 (45.9)
3- Lower extremity	30 (9.6)
4- Eyelid	4 (1.3)
Complications, n (%)	
Flap failure	
Tip necrosis (>80%)	4 (2.2)
Partial necrosis (30%-80%)	1 (1.3)
Complete necrosis (<30%)	0 (0.3)
Surgical site infection	14 (7.3)
Wound dehiscence	3 (1.0)
Re-contracture	12 (3.8)
Need for 2nd stage operation	13 (5.4)

areas of contractures (neck, axilla, elbow, or hand) accompanied all four eyelid burn contractures.

After contracture release, 221 (70.4%) out of 314 joints were managed using a Z-plasty and other similar local flaps, 82 joints (26.1%) were reconstructed with Z-plasty and local flaps plus skin grafts, and 11 joints (3.5%) were released and subsequently covered only with skin grafts. Our preference in skin graft coverage was full-thickness grafts whenever the size of the defects and donor availability permitted. Most contractures were released with the application of a Z-plasty (Table 4).

The mean preoperative ROM of all motions pooled was 47.2 ± 28.7% of the normal value. Twelve months after surgery, the mean ROM was 93.0 ± 10.0% of the normal ROM, and the mean improvement was 45.80% (P<0.001). There was no significant difference in ROM improvement between different joints.

Overall, complications occurred in 10.82% of patients (34 joints). Flap tip necrosis (<20% of flap) occurred in 4 out of 314 joints, while partial flap necrosis (20% to 70%) occurred in 1 out of 314 joints (0.31%), where the contracture was on the thigh (released and covered with Z-plasty) and the partial necrosis of flap involved 30% of its surface area during early follow-up. Meticulous debridement and wound care were performed, and the wound healed secondarily; subsequently, skin graft coverage for the raw area was done. We observed no complete flap necrosis (>70%) in our patients (Table 5).

In terms of long-term adverse events, 12 patients (3.82%) developed a re-contracture (8 on the hands, 2 elbows, 1 axilla, and 1 on the neck).

We recorded no cases of in-hospital mortality. The mean functional satisfaction score was 9.45 ± 1.50 out of 10, and the mean aesthetic satisfaction score was 7.61 ± 2.06 out of 10. This technique can open burns without skin grafting (Figure 2).

DISCUSSION

Despite immense progress in burn treatment technology, burn scars have not decreased[14]. Approximately 4 million new burn scars occur annually in developed countries, with 11 million globally[5, 21]. Scar contractures often result from burns at joints, leading to functional and aesthetic issues in patients.

Appropriate wound care, early escharotomy, skin grafting, and early physical rehabilitation can theoretically reduce the occurrence of joint burn scar contracture[22]. However, a previous study revealed that even with early joint extension rehabilitation, scar contracture could not be completely avoided[21]. So, reconstruction of post-burn contractures is still an issue.

Table 4: Frequency of each surgical technique according to the location of the burn contracture

Method / Location	Total	Z-plasty & local flaps	Z-plasty & local flaps + graft	Only graft
Axilla	35	27	8	0
Elbow	51	39	11	1
Hand	144	99	37	2
Neck	50	32	15	3
Lower extremity	30	19	10	1
Eyelid	4	0	0	4

Table 5: Relationship between the location of contractures and complications

Complication / Location	Infection	Dehiscence	Tip necrosis	Partial necrosis	Complete necrosis	Re-contracture
Axilla	4 (1.27%)	1 (0.32%)	1 (0.32%)	0	0	1 (0.32%)
Elbow	3 (0.96%)	0	1 (0.32%)	0	0	2 (0.64%)
Hand	5 (1.59%)	1 (0.32%)	2 (0.64%)	0	0	8 (2.55%)
Neck	0	0	0	0	0	1 (0.32%)
Lower extremity	2 (0.64%)	1 (0.32%)	0	1 (0.32%)	0	0

Figure 2: a, b, and c: Contracture of the finger and need for staged Z-plasty. d, e, and f: Release of contracture of 2nd to 5th fingers: 5th and 2nd fingers released and reconstructed with Z-plasty in staged fashion (more than 1 operation) and 3rd & 4th fingers with administration of skin graft. Note the differences between appearance and quality of skin. Also the staged Z-plasty results in more functional fingers and joints.

The strengths of this study are its evaluation of surgery in LMIC (low and medium-income countries) conditions and its large sample size, offering a better understanding of contracture release surgery compared with previous studies[23, 24]. The context of this study is relevant because most severe burns occur in LMICs, and better access to effective treatment can have a significant impact[6, 8, 16, 17, 25]. In our study, most patients were relatively young, indicating the socioeconomic implications of burns on victims in the age range of economic productivity. Several studies corroborate the frequent involvement of younger people[10].

In our series, burn contractures were more prevalent in female patients (56.4%). However, some studies have reported more contractures in males[10, 26-28]. Botman et al.[5], in their series of 44 patients, reported 24 females and 20 males; similar findings were reported by Paul et al.[29].

In this study, we routinely operated on contractures that developed over at least a year, except in cases that necessitated earlier intervention (such as debilitating neck contractions with the inability to look forward, severe microstomia interfering with adequate nutrition and oral hygiene, crippling hand contractures, bilateral knee contractures, and ectropion carrying the risk of corneal desiccation). As a general rule, we do not perform scar release surgery on post-burn contractures in the active phase of wound healing because the immature scar is immensely vascular and at high risk for subsequent re-contracture. A thorough examination determines the maturity of a scar; if it is no longer congested but is rather soft and supple, it is considered mature. A scar usually matures in one year[10].

In our study, the average ROM improved significantly. Multiple previous studies also assessed the patients' improvement with the same method, i.e., measurement of ROM in comparison to normal ROM values[21].

We used Z-plasty based on triangular pointed flaps and similar techniques like multiple modifications and combinations of Z-plasty and Y-V plasty as our routine method of contracture release. We used a skin graft to complement the local flap only when it was essential, and only a few cases forced us to use skin grafting as the main method. We emphasize the use of local flaps because of their better long-term results than the more popular method of skin grafting. Local flaps provide remarkable outcomes due to providing "like for like" tissues and effectively covering vital tissues such as vessels, nerves, and tendons. Compared with skin grafts, they offer a lower risk of re-contracture and tissue loss, do not have donor site morbidity, and provide a better quality of skin[30]. Indeed, if adjacent tissue is available, local flaps are recommended[5, 7, 22, 24]. However, skin grafting remains popular among surgeons,

especially in developing countries, perhaps due to its easier design and use[2, 10-12].

Using many cases, we demonstrated that local flaps (i.e., Z-plasty, multiple Z-plasty, and double opposing Z-plasty) are safe, relatively simple, and effective for treating post-burn contractures, significantly improving ROM with few complications. Another option for difficult or severe contractures (<50% joint ROM), especially for countries with minimal facilities [16-18], is staged Z-plasties, which means repeating the Z-plasty procedure until reaching a desirable ROM.

To determine whether surgery was effective, we chose an improvement of 50% of ROM or reaching 100% of the normal ROM value in all planes of motion in a single joint. The threshold of 50% was chosen because this seemed feasible and provided a remarkable clinical improvement. We only found one study in the literature that set a distinct figure as a threshold[3]; a 25% improvement in ROM indicated an effective surgery in that study.

Another issue with scar contractures is the limitations in daily activities and the aesthetic problems. The high satisfaction rate of our patients shows that the treatment has improved their functional ability and appearance. Especially regarding functional improvement, the satisfaction rate was remarkable (9.45 out of 10).

The complication rate was 10.82%; the majority were minor and were treated conservatively. This rate is similar to some other studies, with reported complications between 0% and 14.8%[27]. Other reports of higher complication rates (between 15% and 56%) also exist [31, 32]. The low recurrence rate is the most important outcome of our selected operation technique.

A new concept in our study is that Z-plasty was done on both scarred and non-scarred tissue. In these circumstances, the emphasis was on an incomplete release of flaps, especially on scarred tissues. Indeed, the dissection was limited to the incision line and some surrounding tissues. We found that despite conservative dissection, the flaps reached each other with moderate counter-traction, and subsequently, interdigitation occurred. Obviously, we did not apply excess tension on the flaps and planned for a staged Z-plasty when necessary. Also, we used the Z-plasty technique for both severe (<50% of ROM) and non-severe (>50% of ROM) cases of contracture.

Another point is that it is not always mandatory to reach 100% ROM motion because, in some cases, even less contracture release provides a good quality of life and satisfaction for the patients. However, future studies with large cohorts can help confirm the best technique for treating post-burn contractures. An adequate duration of follow-up would be at least 6 to 12 months, given that almost all complications and major improvements occur in this period.

This study had limitations. The threshold of 50% improvement in ROM is debatable. However, no criteria exist to show when an operation is considered effective. The few other studies that evaluated the effectiveness of contracture release surgery used various outcome measures, making comparing outcomes difficult[3]. We used standard lateral goniometry to measure the ROM of the joints. However, Parry et al. recently mentioned that this method is debatable in burn survivors[20, 33] and recommended a revised protocol based on cutaneous functional units and functional positions of joints[6, 20, 33]. The shortcoming of standard goniometry is that it fails to consider the influence of adjacent joint positions and skin pliability when measuring motions. Future studies should consider using the method proposed by Parry et al.[5, 33]

Our study of a large number of cases of post-burn contracture shows that Z-plasty can be used safely and effectively as the main method of contracture release surgery. Indeed, the best option for burn scar reconstruction is to use adjacent skin flaps to minimize differences in skin characteristics. Most complications were minor; re-contracture occurred in less than 4% of operated patients. Joint flexibility improved significantly, and surgery was effective in most patients. Due to the feasibility, minimal need for facilities, steep learning curve, acceptable functional and aesthetic outcomes, and low complication rate, we strongly recommend the Z-plasty for reconstructing burn contractures, particularly in LMICs.

CONCLUSION

Appropriate wound care, early escharotomy, skin grafting, and early physical rehabilitation can theoretically reduce the incidence of joint burn scar contraction. In this study, we used surgery in LMIC conditions and a large sample size to better understand contraction release surgery compared to previous studies. We demonstrated that local

flaps are safe, relatively simple, and effective for the treatment of post-burn contractures, significantly improving ROM with few complications. Also, the high level of satisfaction of our patients shows that the treatment has improved their functional ability and appearance. Therefore, we emphasize the use of local flaps because of their better long-term results than the more popular method of skin grafting.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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