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Functional and Aesthetic Outcomes of Surgical Interventions for Post-Burn Deformities: A Prospective Study

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Post-burn contracture, Skin graft, Reconstructive surgery, Burn sequelae, Functional outcome

Abstract:

Background
Post-burn sequelae, including contractures, hypertrophic scars, and non-healing ulcers, continue to pose significant functional and psychosocial challenges in burn survivors, especially in low- and middle-income countries like India. Despite advances in acute burn care, delayed presentation and limited access to reconstructive surgery contribute to a high burden of preventable deformities. This study aimed to evaluate the clinical patterns, surgical management, and functional outcomes of post-burn sequelae in a tertiary care center.

Methods
This prospective observational study included 103 patients presenting with post-burn sequelae over a two-year period. Detailed demographic, etiological, and anatomical data were recorded. Surgical interventions included split-thickness skin grafts (STSG), local flaps, regional flaps, and composite procedures. Functional outcomes were assessed using joint range of motion (ROM) at baseline and six months postoperatively. Complications and patient satisfaction were also documented. Statistical analysis included ANOVA and chi-square/Fisher's exact test with a significance threshold of $p < 0.05$.

Results
The mean age of patients was 24.6 ± 13.1 years, with 56.3% males. Flame burns (67%) were the most common etiology, and contractures were the predominant sequela (86.4%), mainly involving the neck, hand, and elbow. A total of 119 surgical procedures were performed; STSG (n = 67) was the most common technique. Mean take rate was highest for STSG (94.6 ± 7.1%), followed by local flaps (92.3 ± 6.9%). Functional outcomes showed significant improvement in ROM across all joints ($p < 0.001$). Postoperative complications were low, and overall patient satisfaction was high, with 74.8% rating outcomes as good to excellent.

Conclusion
Tailored surgical management of post-burn sequelae, particularly with early intervention and appropriate reconstruction techniques, results in significant functional recovery and high patient satisfaction. The findings underscore the need for integrated burn care systems encompassing acute management, rehabilitation, and long-term reconstructive services to reduce disability from burn injuries in resource-limited settings.

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Introduction

Burn injuries are among the most devastating forms of trauma, often resulting in prolonged hospitalization, extensive rehabilitation, and significant long-term morbidity. Globally, burn injuries account for an estimated 180,000 deaths annually, with non-fatal burns being a leading cause of morbidity, particularly in low- and middle-income countries [1]. India alone reports approximately 6 to 7 million new burn cases each year, of which nearly 1 million require moderate to advanced hospital-based treatment, making it one of the countries with the highest incidence of burns worldwide [2]. Of these, an estimated 10–15% progress to develop moderate to severe post-burn sequelae [3].

Post-burn sequelae are defined as the long-term complications that persist or evolve after the initial wound healing phase. These include hypertrophic scars, keloids, pigmentary disturbances, and—most significantly—post-burn contractures. A multicentric Indian study reported that up to 30–40% of patients with deep dermal or full-thickness burns develop clinically significant contractures requiring surgical intervention [4]. The hands, neck, axilla, elbow, and perioral region are the most commonly affected anatomical sites due to their high functional and aesthetic importance [5]. These sequelae result in not only cosmetic disfigurement but also major functional disabilities, especially in pediatric and working-age populations, leading to loss of livelihood and psychosocial distress.

Management of post-burn sequelae presents significant challenges, especially in resource-constrained healthcare systems where early intervention and rehabilitation services are limited. Surgical management remains the cornerstone of treatment for contractures and includes procedures such as Z-plasties, local flap reconstructions, full-thickness skin grafting, and regional or free flap transfers depending on defect complexity [6]. Split-thickness skin grafting (STSG) is one of the most commonly employed techniques for coverage following contracture release due to its reliability and simplicity; however, it is associated with higher rates of graft contraction and recurrence [7]. On the other hand, flap-based reconstructions provide better contour and durability, especially in mobile or high-stress areas, but demand greater technical expertise and perioperative care [8].

Despite the large burden of post-burn deformities in India, there is a paucity of prospective data evaluating the outcomes of various surgical interventions, graft or flap take rates, complication profiles, and long-term functional outcomes [9,10]. Existing studies are often retrospective, limited in scope, or focused on specific anatomical sites [9,10]. Moreover, standardization of outcome assessment, including graft uptake, recurrence rates, patient satisfaction, and improvement in functional range of motion, is often lacking.

Given the significant burden of disease, especially in underserved rural and semi-urban populations, there is an urgent need for systematically collected data to guide evidence-based management. This prospective observational study was undertaken with an aim to analyze the clinical profile of patients presenting with post-burn sequelae at a tertiary care plastic surgery unit, evaluate the types and anatomical distribution of deformities, document the surgical procedures undertaken, and assess outcomes in terms of graft/flap survival, recurrence, complications, and functional recovery.

Material and methods

Study Design and Setting

This prospective observational study was conducted in the Department of Plastic Surgery at Department of Plastic Surgery, ESIC Medical College & Hospital, Faridabad., a tertiary care teaching hospital located in North India. The study was carried out over a period of 24 months, from June 2022 to May 2024. Approval for the study was obtained from the Institutional Ethics Committee prior to initiation, and all patients were enrolled after obtaining written informed consent. The study adhered to ethical guidelines laid out in the Declaration of Helsinki (2013 version) and followed institutional standards for clinical research involving human subjects.

Study Population

The study population comprised patients presenting with clinically diagnosed post-burn sequelae requiring surgical intervention. All patients above the age of five years, irrespective of sex, who presented to the outpatient or inpatient department with functionally or cosmetically significant post-burn deformities were included. Post-burn sequelae were defined as complications arising at least three weeks after complete epithelialization of burn wounds, including hypertrophic scars, keloids, contractures restricting joint motion, and chronic ulceration over scarred areas. Patients with active burn wounds, those within three weeks of injury, and individuals deemed unfit for surgery due to uncontrolled comorbid conditions were excluded. Patients unwilling to consent or unable to comply with follow-up requirements were also excluded.

Data Collection and Clinical Evaluation

At the time of enrollment, each patient underwent a comprehensive clinical assessment. A detailed history was obtained, including the mechanism of burn (flame, scald, electrical, or chemical), total body surface area

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(TBSA) affected during the initial injury (as documented or estimated retrospectively), the time since injury, initial treatment received, and previous surgeries, if any. Socio-demographic variables such as age, gender, occupation, and socioeconomic status (as per modified Kuppuswamy's classification) were recorded. Clinical examination focused on identifying the type, severity, and anatomical site of sequelae. The extent of joint involvement, range of motion restrictions, scar pliability, pigmentation, and presence of trophic changes were assessed. Contractures were classified according to anatomical location and graded by severity using standard clinical criteria.

Surgical Planning and Interventions

Based on clinical findings, each patient was evaluated for the most appropriate surgical intervention. Surgical planning took into account the anatomical site, severity of deformity, availability of adjacent healthy skin, prior surgeries, and patient-specific functional demands. Minor linear contractures and isolated web contractures were managed with techniques such as Z-plasty or multiple local transposition flaps. Moderate to severe linear or circumferential contractures, particularly over joints such as the neck, axilla, elbow, and knee, were treated with complete release followed by coverage with split-thickness skin grafts (STSG). STSGs were harvested from the thigh or gluteal region using a Humby knife or dermatome and meshed where required. In cases with high risk of recurrence or in anatomically mobile regions, local advancement flaps, regional fasciocutaneous flaps (e.g., groin or posterior interosseous flaps), or pedicled muscle flaps were utilized to provide durable and functional soft tissue coverage. Chronic non-healing ulcers were debrided and reconstructed with skin grafts or flaps depending on the depth and size of the defect. All procedures were performed under regional or general anesthesia by experienced plastic surgeons under strict aseptic precautions.

Postoperative Management and Rehabilitation

Postoperative care protocols were standardized across all patients. Graft dressings were opened on the fifth to seventh postoperative day to assess graft take, which was calculated as a percentage of surface area uptake. Flap viability was assessed clinically by monitoring flap color, capillary refill, and edge bleeding. Patients were started on physiotherapy from postoperative day 3–5 depending on the site and extent of surgery, initially focusing on passive mobilization, followed by active range-of-motion exercises. Physiotherapy was continued on an outpatient basis for at least 12 weeks. Pressure garments and silicone gel sheets were provided as indicated, particularly for hypertrophic scar prevention or recurrence risk reduction. Follow-up visits were scheduled at 1 month, 3 months, and 6 months postoperatively to assess long-term outcomes.

Outcome Measures

Primary outcome measures included graft or flap take rate (defined as percentage of surface area survival on day 7), improvement in functional range of motion measured with a goniometer pre- and postoperatively, recurrence of contracture (defined as return of restriction requiring intervention within six months), and patient satisfaction. Satisfaction was assessed using a 5-point Likert scale evaluating appearance, mobility, and overall improvement. Secondary outcomes included occurrence of postoperative complications such as wound infection, partial graft loss, hypertrophic scarring, and need for revision surgery. Digital photographs were taken at each stage to objectively document progress.

Statistical Analysis

All collected data were entered into Microsoft Excel and analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY). Continuous variables such as age, duration since burn, and graft take percentage were expressed as mean ± standard deviation (SD). Categorical variables such as gender distribution, contracture site, and type of surgical procedure were summarized as frequencies and percentages. Preoperative and postoperative range-of-motion measurements were compared using paired t-tests or Wilcoxon signed-rank tests based on data normality. Associations between type of surgery and complication rates were analyzed using Chi-square or Fisher's exact test. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

The study included 103 patients with a mean age of 24.6 ± 13.1 years. Males comprised 56.3% of the study population. A majority (64.1%) belonged to the lower socioeconomic class, and 31.1% were students. The most common burn etiology was flame burns (67.0%), followed by scalds (20.4%) and electrical burns (9.7%). The mean TBSA involved

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during the acute burn was 22.8 ± 9.3%. The median time since burn injury at presentation was 14 months (IQR: 10–22), and over half of the patients (56.3%) had initially received treatment at a secondary or tertiary care hospital (Table 1).

Table 1: Demographic and Burn Injury Profile of the Study Population (N = 103).

Variables	Frequency (%)/Mean ± SD/Median (IQR)
Age (in years)	24.6 ± 13.1
Gender	
Male	58 (56.3%)
Female	45 (43.7%)
Socioeconomic status	
Lower	66 (64.1%)
Middle	33 (32.0%)
Upper	4 (3.9%)
Occupation	
Students	32 (31.1%)
Laborers	29 (28.2%)
Homemakers	21 (20.4%)
Others	21 (20.4%)
Burn Etiology	
Flame	69 (67.0%)
Scald	21 (20.4%)
Electrical	10 (9.7%)
Chemical	3 (2.9%)
TBSA involved (%)	22.8 ± 9.3
Time since Burn Injury (months)	14 (IQR: 10–22)
Initial treatment provided at	
Home	16 (15.5%)
Primary Health Center	29 (28.2%)
Secondary/Tertiary Hospital	58 (56.3%)

Contractures were the most prevalent sequelae, observed in 86.4% of patients. The most commonly involved sites were the neck (23.3%), hand (21.4%), and elbow (16.5%). Severity grading among contracture cases revealed 21.3% as mild, 50.6% moderate, and 28.1% severe. Hypertrophic scars were noted in 20.4%, most commonly on the face (8.7%) and trunk (6.8%). Keloids were observed in 4.9% of patients, while 10.7% had non-healing ulcers. Multiple sequelae affecting more than one region were identified in 27.2% of cases (Table 1).

Table 2: Distribution and Characteristics of Post-burn Sequelae (N = 103).

Sequela Type	Anatomical Site(s) Involved	Frequency (%)
Contracture*		89 (86.4%)
	Neck	24 (23.3%)
	Hand	22 (21.4%)
	Elbow	17 (16.5%)
	Axilla	11 (10.7%)
	Knee	8 (7.8%)
	Ankle	7 (6.8%)
Hypertrophic Scar		21 (20.4%)
	Face	9 (8.7%)
	Trunk	7 (6.8%)
	Upper limb	5 (4.9%)
Keloid		5 (4.9%)

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	Earlobe	2 (1.9%)
	Shoulder	2 (1.9%)
	Upper limb	1 (1.0%)
Non-healing Ulcer		11 (10.7%)
	Leg	6 (5.8%)
	Dorsum of foot	3 (2.9%)
	Ankle	2 (1.9%)
Multiple Sequelae Involving >1 Region	—	28 (27.2%)

Among the 89 patients with post-burn contractures, 19 (21.3%) had mild, 45 (50.6%) had moderate, and 25 (28.1%) had severe contractures based on clinical assessment of functional limitation and joint involvement.

A total of 119 procedures were performed across 103 patients. The neck (23.3%), hand (21.4%), and elbow (16.5%) were the most commonly operated sites. STSG was the most frequently employed technique, particularly after contracture release. Z-plasties and local flaps were preferred for axillary and neck contractures. Regional flaps such as the reverse sural and gastrocnemius flaps were used in 11.7% of patients with deeper or complex defects. Some patients required multiple procedures or composite reconstructions depending on deformity complexity (Table 3).

Table 3: Surgical Procedures Performed by Anatomical Site (N = 103).

Anatomical Site	Type of Procedure	Frequency (%)
Neck		24 (23.3%)
	Z-plasty	6 (5.8%)
	STSG	12 (11.7%)
	Platysma flap	6 (5.8%)
Hand		22 (21.4%)
	STSG after release	16 (15.5%)
	Cross-finger flap	3 (2.9%)
	Full-thickness skin graft	3 (2.9%)
Elbow		17 (16.5%)
	STSG	10 (9.7%)
	Local flap	6 (5.8%)
	Posterior arm flap	1 (1.0%)
Axilla		11 (10.7%)
	Z-plasty	5 (4.9%)
	STSG	4 (3.9%)
	Regional flap	2 (1.9%)
Knee		8 (7.8%)
	STSG	6 (5.9%)
	Gastrocnemius flap	2 (1.9%)
Ankle/Foot		7 (6.8%)
	STSG	5 (4.9%)
	Reverse sural flap	2 (1.9%)
Non-healing Ulcers		11 (10.7%)
	STSG	7 (6.7%)
	Local flap	2 (1.9%)
	Debridement only	2 (1.9%)

Functional outcomes showed significant improvement in joint mobility at six months postoperatively. Neck mobility improved from a mean of 42.6° to 71.3° ($p < 0.001$), elbow flexion from 60.5° to 103.7° ($p < 0.001$), and shoulder abduction from 58.7° to 95.1° ($p < 0.001$). Similar gains were observed at the knee (40.3° mean improvement) and ankle (23.8° improvement), all statistically significant ($p < 0.001$), indicating substantial restoration of range of motion following surgery and rehabilitation (Table 4).

Table 4: Functional Outcomes Before and After Surgery (N = 83 patients with joint involvement).

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Joint	Preoperati	Postope	Improv	p-
	ROM (Mean ± SD)			
Neck	42.6 ± 9.4	71.3 ±	28.7 ±	<0.0
Elbow	60.5 ± 12.1	103.7 ±	43.2 ±	<0.0
Shoulder	58.7 ± 10.4	95.1 ±	36.4 ±	<0.0
Knee (n=8)	72.3 ± 13.2	112.6 ±	40.3 ±	<0.0
Ankle	22.1 ± 5.8	45.9 ±	23.8 ±	<0.0

ROM: Range of motion, assessed with goniometer.

STSGs demonstrated the highest mean take rate (94.6 ± 7.1%), followed by local (92.3 ± 6.9%) and regional flaps (89.7 ± 8.6%). Composite procedures had a take rate of 91.5 ± 4.3%. Partial graft loss was observed in 14.9% of STSGs and 25% of regional flaps. Infection rates ranged from 5.3% (local flap) to 16.7% (regional flap). Hypertrophic scars occurred most frequently after STSG (19.4%), while recurrence of contracture was lowest in composite repairs (0%) and highest in regional flaps (16.7%). Take rate differences were statistically significant (p = 0.041) (Table 5).

Table 5: Graft/Flap Take Rates and Postoperative Complications by Procedure Type.

Procedure	STSG	Loca	Regio	Comp	p-
	Frequency (%)/Mean ± SD				
Take Rate	94.6 ±	92.3	89.7	91.5 ±	0.041
Partial	10	2	3	0 (0%)	0.366
Infection	6	1	2	0 (0%)	0.532
Hypertrop	13	3	1	0 (0%)	0.284
Recurrence	7	1	2	0 (0%)	0.446

Take rate = area of viable graft/flap on day 7. Recurrence = contracture requiring re-intervention at 6 months.

Patient satisfaction at six months was high, with 39.8% rating their overall outcome as excellent and 35.0% as good. Functional improvement received the highest satisfaction, with 46.6% reporting excellent recovery. Aesthetic outcomes were also favorable, with 33.0% reporting excellent and 36.9% good results. Only 2.9% reported poor satisfaction in any category, indicating favorable long-term outcomes from surgical management (Table 6).

Table 6: Patient-Reported Satisfaction Scores at 6 Months Post-op (N = 103).

Outcome	Excelle	Good	Moder	Fair	Poor
	Frequency (%)				
Overall	41	36	17	6	3
Aesthetic	34	38	18	9	4
Functiona	48	34	13	5	3

Discussion

Burn injuries represent a major public health concern in developing countries, with India contributing to over 1 million annual burn cases, many of which progress to disabling sequelae due to delayed or suboptimal acute management [11,12]. Our prospective observational study of 103 patients aimed to evaluate the patterns, surgical management, and functional outcomes of post-burn sequelae in a tertiary care setting.

In our study, the mean age of the population was 24.6 years, with a male predominance (56.3%). This demographic profile aligns with existing Indian studies by Salam et al., and Trakroo et al., where burns predominantly affect young, economically active individuals, often due to high-risk domestic or occupational exposures [13,14]. A large proportion of patients (64.1%) were from lower socioeconomic strata, reinforcing the strong correlation between poverty, unsafe cooking environments, overcrowded housing, and lack of access to early burn care [15]. The etiological spectrum was dominated by flame burns (67.0%), consistent with prior studies by Nair et al., and Mumtazudin et al., where flame-related incidents accounted for over 60–70% of thermal injuries [16,17]. Scalds and electrical burns constituted 20.4% and 9.7% respectively, with a minority sustaining chemical burns.

Contractures were the most common post-burn sequelae, present in 86.4% of patients. The neck, hand, and elbow emerged as the most frequently affected sites, similar to findings by Mehta et al. and Srinivas et al., who reported contractures in the cervical and upper limb regions as particularly disabling due to their impact on essential functions like eating, grooming, and working [18,19]. Severity grading revealed that over three-fourths of contractures were moderate to severe, reflecting the late presentation and lack of sustained physiotherapy or splinting. Our study found hypertrophic scars in 20.4% and keloids in 4.9% of patients, figures comparable to those reported by Amini-Nik et al., and Goverman et al., who documented scar hypertrophy in up to 25% of post-burn survivors, especially in younger individuals with darker skin phenotypes prone to exuberant collagen deposition [20,21].

Surgical intervention was tailored to site, severity, and functional impairment. A total of 119 procedures were performed in 103 patients. Split-thickness skin grafting (STSG) remained the mainstay (performed in 67 cases), owing to its versatility, rapidity, and relatively high take rate, especially in linear contractures or areas with preserved bed vascularity. Local and regional flaps were utilized in 31 cases (25 flap procedures), especially for recurrent, circumferential, or deep contractures involving critical functional areas. These choices are in line with standard reconstructive ladders and supported by studies such as those by Nuli et al. and Lakhani et al., who

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advocate flap-based reconstructions in challenging anatomical zones like the neck and axilla [22,23].

Functional outcomes post-surgery were encouraging. Statistically significant improvements in joint range of motion (ROM) were observed at all major sites. Elbow flexion improved by a mean of 43.2° ($p < 0.001$), while shoulder abduction and neck extension improved by 36.4° and 28.7°, respectively ($p < 0.001$ for all). These findings are comparable to those reported by Hayashida et al., and Zuccaro et al., who observed post-surgical gains of 30–50° in joint ROM when surgery was combined with structured physiotherapy and splinting [24,25]. Our study underscores the critical importance of postoperative rehabilitation, which was uniformly emphasized in patient care protocols.

In terms of take rates and complications, STSGs had the highest mean graft take (94.6 ± 7.1%), with low rates of partial graft loss (14.9%) and infection (9.0%). Local flaps showed slightly lower take rates (92.3 ± 6.9%) but fewer complications, whereas regional flaps, although useful in large and complex defects, demonstrated higher rates of partial loss (25.0%) and infection (16.7%). These outcomes echo findings by Sadhu et al. and Rajan et al., who highlighted that while regional flaps offer durable coverage, they demand meticulous planning and vascular preservation [26,27]. The rate of hypertrophic scar formation was highest with STSG (19.4%)—a known limitation of grafted skin, especially in mobile areas, unless pressure garments and scar modulators like silicone gel are consistently applied [28].

Recurrence of contractures was observed in 10.4% of STSG patients, 5.3% of local flap patients, and 16.7% of regional flap recipients, while no recurrence was seen among composite reconstructions. These results support by Ahuja et al., advocating for tension-free closure, stable vascular coverage, and rigorous follow-up as essential determinants of long-term success [29].

Patient-reported outcomes were encouraging, with 74.8% rating their overall satisfaction as good to excellent. Functional satisfaction (79.6% good/excellent) surpassed cosmetic satisfaction (69.9%), indicating that restoration of movement and independence is often prioritized over appearance, particularly in male and working-age populations. Studies by McAleavey et al., and Jawad et al. similarly found that functional restoration is a key determinant of psychosocial recovery in post-burn patients [30,31].

Taken together, this study demonstrates that a multidisciplinary approach—combining early identification of deformities, site-specific surgical reconstruction, consistent physiotherapy, and patient education—can significantly enhance long-term outcomes in post-burn sequelae. However, the persistent prevalence of severe contractures and hypertrophic scarring reflects systemic challenges, including delayed referrals, socioeconomic constraints, and inconsistent rehabilitation services in India's public healthcare system. Future strategies must focus on preventive education, strengthening acute burn care at the primary level, and integrating long-term rehabilitation, including psychosocial support, into standard burn protocols. The inclusion of community-based burn rehabilitation and subsidized reconstructive services under schemes like the Ayushman Bharat program may improve access and reduce disability-adjusted life years (DALYs) attributed to burn injuries.

Conclusion

Overall, the study demonstrates that individualized surgical management, guided by anatomical location, severity grading, and available reconstructive options, yields satisfactory functional and aesthetic outcomes in post-burn sequelae. However, the findings also highlight the persistent gaps in early burn care, patient education, and rehabilitation access in resource-limited settings, which contribute to the burden of preventable deformities. Long-term follow-up and integration of physiotherapy, occupational therapy, and psychosocial support into burn care protocols are essential for sustained functional recovery and patient well-being.

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