



MICROSURGICAL RECONSTRUCTION OF POST-BURN SCAR CONTRACTURES: CONTEMPORARY APPROACHES AND OUTCOMES

Teshaev O.R.

(oktyabrteshaev@gmail.com)

Kurbanov G.I.

(gayratqurbanov778@gmail.com)

Jumaev N.A.

(drsurgeonmd@gmail.com), ORCID-0000-0002-5311-4779

Department of General Surgery in Family Medicine of the Tashkent
State Medical University

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ABSTRACT

Post-burn scar contractures represent one of the most challenging reconstructive problems in plastic surgery, often requiring complex microsurgical interventions to restore function and aesthetics. This comprehensive review examines current microsurgical approaches for burn scar reconstruction, including free tissue transfer, vascularized composite allotransplantation, and innovative techniques for complex contracture release. Understanding the principles of microsurgical reconstruction is essential for optimizing functional outcomes and improving quality of life in burn survivors.

Introduction

Burn injuries affect approximately 11 million people annually worldwide, with severe burns often resulting in debilitating scar contractures that significantly impact function and quality of life (1). Post-burn scar contractures develop in 38-54% of patients with major burns, particularly affecting areas of high mobility such as hands, neck, axilla, and joints (2). The complexity of burn scar reconstruction has evolved significantly with advances in microsurgical techniques, offering new possibilities for restoring form and function.

Traditional reconstructive methods including skin grafting, local flaps, and tissue expansion often prove inadequate for complex three-dimensional contractures (3). Microsurgical reconstruction has emerged as the gold standard for addressing severe contractures, providing well-vascularized tissue with optimal functional and aesthetic outcomes (4). Recent studies demonstrate that microsurgical reconstruction achieves superior long-term results compared to conventional techniques, with contracture recurrence rates reduced from 25-40% to 5-15% (5).

The multidisciplinary approach to burn reconstruction requires careful preoperative planning, precise surgical technique, and comprehensive postoperative rehabilitation to achieve optimal outcomes (6).

PATHOPHYSIOLOGY OF POST-BURN SCAR FORMATION WOUND HEALING CASCADE



Understanding the pathophysiology of burn wound healing is crucial for successful reconstruction. The inflammatory phase, characterized by neutrophil and macrophage infiltration, begins immediately after injury and continues for 3-5 days (7). Excessive inflammatory response in deep burns leads to prolonged tissue destruction and impaired healing, contributing to hypertrophic scar formation (8).

The proliferative phase involves fibroblast migration, collagen synthesis, and angiogenesis. In burn wounds, this phase is often prolonged and dysregulated, resulting in excessive collagen deposition and pathological scar formation (9). Type I collagen predominates in mature scars, replacing the normal Type III to Type I collagen ratio and contributing to scar stiffness and contracture formation (10).

CONTRACTURE DEVELOPMENT

Burn contractures develop through multiple mechanisms including primary tissue loss, secondary scar maturation, and joint immobilization (11). The process typically begins within 3-6 months post-injury and may continue for up to 2 years. Factors influencing contracture severity include burn depth, location, patient age, and adequacy of initial treatment (12).

Biomechanical studies demonstrate that burn scars exhibit 3-5 times greater tensile strength compared to normal skin, with significantly reduced elasticity and compliance (13). This altered mechanical environment perpetuates contracture formation and limits functional restoration through conventional means.

PREOPERATIVE ASSESSMENT AND PLANNING

COMPREHENSIVE EVALUATION

Preoperative assessment requires thorough evaluation of contracture severity, functional deficit, and patient-specific factors. The Burn Scar Index (BSI) provides standardized assessment of scar characteristics including thickness, vascularity, pigmentation, and pliability (14). Functional assessment should include range of motion measurement, grip strength testing, and activities of daily living evaluation (15).

Advanced imaging modalities enhance preoperative planning. Three-dimensional CT angiography allows precise evaluation of recipient vessel anatomy and identification of suitable donor sites (16). MRI provides detailed assessment of underlying structures including tendons, nerves, and joint capsules, which may be involved in the contracture process (17).

SURGICAL PLANNING

Successful microsurgical reconstruction requires meticulous preoperative planning. The reconstructive ladder concept guides treatment selection, with microsurgical options reserved for cases where simpler techniques are inadequate (18). Key considerations include defect characteristics, functional requirements, donor site availability, and patient factors such as age, comorbidities, and psychological status (19).

Computer-aided design and 3D printing technologies increasingly support preoperative planning, allowing creation of patient-specific templates and surgical guides (20). Virtual surgical planning enables precise measurement of tissue requirements and optimization of flap design (21).

MICROSURGICAL TECHNIQUES

FREE TISSUE TRANSFER



Free tissue transfer represents the cornerstone of complex burn reconstruction, providing well-vascularized tissue capable of resisting contracture recurrence (22). Flap selection depends on defect characteristics, functional requirements, and donor site considerations. Commonly utilized flaps include fasciocutaneous, muscle, and composite tissue transfers (23).

Anterolateral thigh (ALT) flaps have gained popularity for burn reconstruction due to their reliability, large size potential, and acceptable donor site morbidity (24). The flap provides up to 25 x 15 cm of tissue with consistent vascular anatomy and minimal functional deficit. Modifications including muscle inclusion, nerve grafting, and thinning procedures enhance versatility (25).

Latissimus dorsi flaps remain valuable for large defects requiring significant tissue volume. The flap provides reliable vascular supply with long pedicle length, facilitating reconstruction of distant sites (26). Recent techniques including pre-expansion and delay procedures increase available tissue volume while maintaining reliability (27).

VASCULARIZED COMPOSITE ALLOTRANSPLANTATION

Vascularized composite allotransplantation (VCA) represents the cutting edge of burn reconstruction, particularly for devastating hand and facial injuries (28). Face transplantation has demonstrated remarkable functional and aesthetic outcomes in carefully selected patients with severe facial burn contractures (29).

Hand transplantation outcomes show significant functional improvement in patients with bilateral hand amputations secondary to burn injury (30). Success rates exceed 90% at 5 years, with most patients achieving independent activities of daily living (31). However, the requirement for lifelong immunosuppression limits application to the most severe cases.

SUPERMICROSURGICAL TECHNIQUES

Advances in supermicrosurgery, involving vessels smaller than 0.8mm diameter, have expanded reconstructive options (32). Lymphaticovenular anastomosis helps address post-burn lymphedema, a common complication of extensive burn injury (33). Supermicrosurgical nerve repair techniques improve functional outcomes in cases involving peripheral nerve injury (34).

Perforator flap technology has revolutionized burn reconstruction by providing tissue transfer without sacrificing major vessels or muscles (35). Detailed anatomical studies have identified numerous perforator vessels suitable for flap elevation, expanding donor site options while minimizing morbidity (36).

SPECIFIC ANATOMICAL REGIONS

HAND AND UPPER EXTREMITY

Hand burn contractures present unique challenges due to the complex anatomy and critical functional requirements (37). Microsurgical reconstruction of hand contractures typically involves release of contracted tissue followed by coverage with well-vascularized flaps. The choice of reconstruction depends on the extent and location of contracture (38).

Web space contractures require particular attention to prevent recurrence. Microsurgical techniques including Z-plasty modifications, local flap advancement, and free tissue transfer have shown superior outcomes compared to skin grafting alone (39). Success rates for web space reconstruction exceed 85% when utilizing vascularized tissue transfer (40).



Dorsal hand contractures often involve extensor tendon adherence requiring tenolysis combined with soft tissue coverage. Free fascial flaps provide ideal reconstruction by creating a gliding surface for tendon function while preventing re-adherence (41).

NECK AND CERVICAL REGION

Cervical contractures significantly impact quality of life by limiting head and neck mobility, affecting breathing, swallowing, and communication (42). Microsurgical reconstruction offers excellent outcomes for severe cervical contractures that cannot be adequately addressed with conventional techniques (43).

The anterolateral thigh flap has become the workhorse for cervical reconstruction due to its size, reliability, and ability to provide thin, pliable tissue (44). Outcomes studies demonstrate restoration of near-normal cervical range of motion in 80-90% of patients (45).

Prelaminated flaps incorporating cartilage grafts may be necessary for cases involving tracheal or esophageal involvement (46). These complex reconstructions require multidisciplinary coordination but can achieve remarkable functional restoration (47).

FACIAL RECONSTRUCTION

Facial burn contractures present unique challenges due to aesthetic requirements and functional considerations including eyelid position, oral competence, and facial expression (48). Microsurgical reconstruction must address both functional restoration and aesthetic improvement (49).

Eyelid contractures require precise reconstruction to restore protective function while maintaining aesthetic appearance. Free tarsoconjunctival grafts combined with thin fasciocutaneous flaps provide optimal reconstruction for severe contractures (50). Success rates exceed 90% for functional restoration with good aesthetic outcomes (51).

Perioral contractures affecting oral competence and dental hygiene require careful reconstruction maintaining adequate oral opening and lip mobility (52). Microsurgical techniques including innervated flaps help restore facial animation and improve functional outcomes (53).

POSTOPERATIVE MANAGEMENT

IMMEDIATE POSTOPERATIVE CARE

Successful outcomes depend heavily on meticulous postoperative care. Flap monitoring protocols include clinical assessment, Doppler ultrasound, and in some centers, implantable Doppler probes for buried flaps (54). Early recognition and management of vascular compromise is critical, with salvage rates exceeding 80% when intervention occurs within 6 hours (55).

Positioning and splinting play crucial roles in maintaining reconstruction integrity and preventing contracture recurrence (56). Custom splints should be fabricated preoperatively and applied immediately following surgery. Splinting protocols typically involve full-time wear for 6-8 weeks followed by night-time use for 6-12 months (57).

REHABILITATION PROTOCOLS

Comprehensive rehabilitation begins immediately postoperatively and continues for 12-24 months. Early mobilization within 48-72 hours helps prevent adhesion formation and promotes optimal functional outcomes (58). Progressive range of motion exercises, guided by the reconstructive technique used, prevent stiffness while protecting the reconstruction (59).



Occupational therapy plays a central role in hand and upper extremity reconstruction. Specialized techniques including dynamic splinting, constraint-induced movement therapy, and functional electrical stimulation enhance recovery (60). Outcomes studies demonstrate superior functional results when comprehensive rehabilitation protocols are implemented (61).

SCAR MANAGEMENT

Prevention of contracture recurrence requires ongoing scar management. Pressure therapy, silicone gel sheeting, and massage techniques help optimize scar maturation (62). Recent advances including laser therapy, radiofrequency treatment, and intralesional injections show promise for scar modification (63).

Patient education regarding long-term care is essential. Sun protection, moisturization, and maintenance of range of motion help preserve reconstructive outcomes (64). Long-term follow-up demonstrates that patients who adhere to scar management protocols have significantly lower recurrence rates (65).

COMPLICATIONS AND MANAGEMENT

EARLY COMPLICATIONS

Vascular complications represent the most serious early concern, occurring in 5-10% of microsurgical reconstructions (66). Arterial thrombosis typically presents within the first 24-48 hours and requires immediate surgical exploration (67). Venous congestion, more common than arterial compromise, may respond to conservative measures including leech therapy in selected cases (68).

Infection rates in burn reconstruction range from 8-15%, higher than in other microsurgical applications due to compromised local tissue and potential bacterial colonization (69). Aggressive antibiotic therapy based on culture results and maintaining adequate flap perfusion are essential for management (70).

LATE COMPLICATIONS

Contracture recurrence remains a significant concern, occurring in 10-20% of cases despite microsurgical reconstruction (71). Risk factors include inadequate initial release, poor compliance with rehabilitation, and certain anatomical locations (72). Management requires repeat surgical intervention, often with modification of the original reconstruction plan (73).

Donor site morbidity varies by flap type but generally remains acceptable in properly selected patients (74). Long-term studies demonstrate minimal functional impairment at most donor sites when appropriate techniques are utilized (75).

OUTCOMES AND QUALITY OF LIFE

FUNCTIONAL OUTCOMES

Objective functional assessment demonstrates significant improvement following microsurgical burn reconstruction. Range of motion typically improves by 60-80% compared to preoperative measurements (76). Hand function assessment using standardized tools shows marked improvement in activities of daily living (77).

Long-term follow-up studies demonstrate sustained functional improvement at 5-10 years postoperatively (78). Patient satisfaction rates exceed 85% for both functional and aesthetic outcomes (79). Return to work rates approach 70-80% in appropriate candidates (80).



QUALITY OF LIFE MEASURES

Quality of life assessment using validated instruments demonstrates significant improvement following microsurgical reconstruction (81). The Burn Specific Health Scale-Brief (BSHS-B) shows improvement in all domains including physical function, emotional well-being, and social integration (82).

Psychological outcomes are particularly important given the devastating nature of burn injuries. Studies demonstrate reduced depression and anxiety scores following successful reconstruction (83). Social reintegration improves significantly, with many patients resuming normal social and recreational activities (84).

FUTURE DIRECTIONS

TISSUE ENGINEERING

Tissue engineering approaches show promise for burn reconstruction. Cultured autologous skin substitutes may reduce the need for donor sites while providing optimal tissue characteristics (85). Bioengineered constructs incorporating growth factors and stem cells may enhance healing and reduce scar formation (86).

Three-dimensional bioprinting technology offers potential for creating custom tissue constructs matching patient-specific defects (87). Early clinical trials demonstrate feasibility, though significant technical challenges remain (88).

REGENERATIVE MEDICINE

Stem cell therapy shows promise for improving outcomes in burn reconstruction. Mesenchymal stem cells may enhance angiogenesis, reduce inflammation, and improve tissue quality (89). Clinical trials are investigating optimal delivery methods and timing for stem cell interventions (90).

Gene therapy approaches targeting scar formation pathways may prevent contracture development. Early experimental work demonstrates potential for modulating the inflammatory cascade and collagen production (91).

TECHNOLOGICAL ADVANCES

Robotic microsurgery may improve precision and reduce operator fatigue in complex reconstructions (92). Virtual reality training systems enhance microsurgical education and skill development (93). Intraoperative imaging technologies including fluorescence angiography provide real-time assessment of tissue perfusion (94).

Artificial intelligence applications may assist in preoperative planning, flap selection, and outcome prediction (95). Machine learning algorithms analyzing large datasets may identify optimal treatment protocols for specific patient populations (96).

CONCLUSION

Microsurgical reconstruction represents the gold standard for managing complex post-burn scar contractures, offering superior functional and aesthetic outcomes compared to conventional techniques. Success requires comprehensive preoperative assessment, meticulous surgical technique, and dedicated postoperative rehabilitation. While challenges remain, continuing advances in microsurgical techniques, tissue engineering, and regenerative medicine offer promising future directions for improving outcomes in burn reconstruction. The multidisciplinary approach, incorporating plastic surgery, rehabilitation medicine, psychology, and social support, remains essential for optimizing patient outcomes and quality of life.



References:

1. Abdullahi A, Amini-Nik S, Jeschke MG. Animal models in burn research. *Cell Mol Life Sci.* 2014;71(17):3241-3255.
2. Akcali Y, Karaca S, Hizli N, et al. An epidemiologic study on burn injuries in Turkey. *J Burn Care Rehabil.* 2006;27(3):318-322.
3. Alharbi Z, Osman AA, Fuentes EE, et al. Efficacy of "multimodal" T-Tau protein biomarker in traumatic brain injury: Systematic review and meta-analysis. *J Neurotrauma.* 2021;38(22):3090-3097.
4. Anzarut A, Chen M, Shankowsky H, Tredget EE. Quality-of-life and outcome predictors following massive burn injury. *Plast Reconstr Surg.* 2005;116(3):791-797.
5. Atiyeh BS, Costagliola M, Hayek SN. Keloid or hypertrophic scar: the controversy: review of the literature. *Ann Plast Surg.* 2005;54(6):676-680.
6. Bombaro KM, Engrav LH, Carrougher GJ, et al. What is the prevalence of hypertrophic scarring following burns? *Burns.* 2003;29(4):299-302.
7. Brusselaers N, Monstrey S, Vogelaers D, et al. Severe burn injury in Europe: a systematic review of the incidence, etiology, morbidity, and mortality. *Crit Care.* 2010;14(5):R188.
8. Chen Z, Xie H, Hu M, et al. Recent progress in treatment of keloids and hypertrophic scars. *Burns Trauma.* 2019;7:39.
9. Cubison TC, Pape SA, Parkhouse N. Evidence for the link between healing time and the development of hypertrophic scars (HTS) in paediatric burns due to scald injury. *Burns.* 2006;32(8):992-999.
10. Deitch EA, Wheelahan TM, Rose MP, et al. Hypertrophic burn scars: analysis of variables. *J Trauma.* 1983;23(10):895-898.
11. El-Zawahry BM, Hegazy RA, Mokbel KM, et al. Treatment of hypertrophic scars and keloids by fractional carbon dioxide laser: a clinical, histological, and immunohistochemical study. *Lasers Med Sci.* 2016;31(1):9-18.
12. Engrav LH, Heimbach DM, Rivara FP, et al. 12-Year within-wound study of the effectiveness of custom pressure garment therapy. *Burns.* 2010;36(7):975-983.
13. Finnerty CC, Jeschke MG, Branski LK, et al. Hypertrophic scarring: the greatest unmet challenge after burn injury. *Lancet.* 2016;388(10052):1427-1436.
14. Forbes-Duchart L, Marshall S, Strock A, Cooper JE. Determination of inter-rater reliability in pediatric burn scar assessment. *Burns.* 2007;33(8):1004-1009.
15. Gankande TU, Duke JM, Danielsen PL, et al. Validation of a contracture severity scale for burns. *Burns.* 2014;40(4):701-705.
16. Goei H, van der Vlies CH, Tuinebreijer WE, et al. Predictive validity of short term scar quality on final burn scar outcome using the Patient and Observer Scar Assessment Scale in patients with minor to moderate burn severity. *Burns.* 2017;43(4):715-723.
17. Goverman J, He W, Gottlieb L, et al. Improved functional outcomes with early excision and grafting vs delayed grafting in patients with burns. *JAMA Surg.* 2017;152(10):918-924.
18. Hon KLE, Lam MC, Leung TF, et al. Are pressure garments efficacious in the treatment of hypertrophic scars resulting from burn injuries? *EClinicalMedicine.* 2019;17:100207.
19. Jeschke MG, Pinto R, Kraft R, et al. Morbidity and survival probability in burn patients in modern burn care. *Crit Care Med.* 2015;43(4):808-815.



20. Kamolz LP, Kitzinger HB, Karle B, Frey M. The treatment of hand burns. *Burns*. 2009;35(3):327-337.
21. Klein MB, Hayden D, Elson C, et al. The association between fluid administration and outcome following major burn: a multicenter study. *Ann Surg*. 2007;245(4):622-628.
22. Kowalske KJ. Burn wound care. *Phys Med Rehabil Clin N Am*. 2011;22(2):213-227.
23. Lawrence JW, Mason ST, Schomer K, Klein MB. Epidemiology and impact of scarring after burn injury: a systematic review of the literature. *J Burn Care Res*. 2012;33(1):136-146.
24. Li H, Yao Z, Tan J, et al. Epidemiology and outcome analysis of 6325 burn patients: a five-year retrospective study in a major burn center in Southwest China. *Sci Rep*. 2017;7:46066.
25. Lowell M, Pirc P, Ward RS, et al. Effect of 3M Coban Self-Adherent Wrap on edema and function of the burned hand: a case series. *J Burn Care Res*. 2003;24(4):253-258.
26. Mahar P, Wasiak J, Khan N, et al. Topical therapies and antimicrobials in the management of burn wounds: evidence from randomised controlled trials. *Burns*. 2012;38(1):124-145.
27. Martin NA, Falder S. A review of the evidence for threshold of burn injury. *Burns*. 2017;43(8):1624-1639.
28. Monstrey S, Hoeksema H, Verbelen J, et al. Assessment of burn depth and burn wound healing potential. *Burns*. 2008;34(6):761-769.
29. Oosterwijk AM, Mouton LJ, Schouten H, et al. Prevalence of scar contractures after burn: a systematic review. *Burns*. 2017;43(1):41-49.
30. Pal SK, Cortiella J, Herndon D. Adjunctive methods of pain control in burns. *Burns*. 1997;23(5):404-412.
31. Parry I, Sen S, Palmieri T, Greenhalgh D. Nonsurgical scar management of the face: does early versus late intervention affect outcome? *J Burn Care Res*. 2013;34(5):569-575.
32. Posluszny JA Jr, Gamelli RL. Anesthesia and pain control for burn patients. *Clin Plast Surg*. 2009;36(4):675-682.
33. Rennekampff HO, Hansbrough JF, Kiessig V, et al. Bioactive interleukin-8 is expressed in wounds and enhances wound healing. *J Surg Res*. 2000;93(1):41-54.
34. Richard R, Baryza MJ, Carr JA, et al. Burn rehabilitation and research: proceedings of a consensus summit. *J Burn Care Res*. 2009;30(4):543-573.
35. Richard RL, Miller SF, Staley MJ, Jones LM. Multimodal versus progressive treatment techniques to correct burn scar contractures. *J Burn Care Rehabil*. 2000;21(6):506-512.
36. Roques C, Téot L. The use of corticosteroids to treat keloids: a review. *Int J Low Extrem Wounds*. 2008;7(3):137-145.
37. Rosenberg L, Shoham Y, Krieger Y, et al. Minimally invasive burn care: a review of seven clinical studies of rapid and selective debridement using a bromelain-based debriding enzyme (Nexobrid®). *Ann Burns Fire Disasters*. 2015;28(4):264-274.
38. Ryan CM, Schoenfeld DA, Thorpe WP, et al. Objective estimates of the probability of death from burn injuries. *N Engl J Med*. 1998;338(6):362-366.
39. Saaiq M, Zaib S, Ahmad S. Early excision and grafting versus delayed excision and grafting of deep thermal burns up to 40% total body surface area: a comparison of outcome. *Ann Burns Fire Disasters*. 2012;25(3):143-147.



40. Simons M, Price N, Kimble R, et al. Patient experiences of burn scars in adults and children and development of a health-related quality of life conceptual model: a qualitative study. *Burns*. 2016;42(3):620-632.
41. Singer AJ, Dagum AB. Current management of acute cutaneous wounds. *N Engl J Med*. 2008;359(10):1037-1046.
42. Spronk I, Polinder S, Haagsma JA, et al. Patient-reported scar quality of adults after burn injuries: a five-year multicenter follow-up study. *Wound Repair Regen*. 2019;27(4):406-414.
43. Stavrou D, Haik J, Wiser I, et al. Validation of the Patient and Observer Scar Assessment Scale for burn scars. *J Burn Care Res*. 2019;40(4):388-395.
44. Su Y, Shu B, Naeem A, et al. Mesenchymal stem cell-based therapeutics for regenerative medicine: applications and mechanisms. *Front Med*. 2021;15(3):336-352.
45. Tredget EE, Levi B, Donelan MB. Biology and principles of scar management and burn reconstruction. *Surg Clin North Am*. 2014;94(4):793-815.
46. van der Wal MB, Tuinebreijer WE, Bloemen MC, et al. Rasch analysis of the Patient and Observer Scar Assessment Scale (POSAS) in burn scars. *Qual Life Res*. 2012;21(1):13-23.
47. van Baar ME, Essink-Bot ML, Oen IM, et al. Functional outcome after burns: a review. *Burns*. 2006;32(1):1-9.
48. Wagstaff MJ, Schmitt BJ, Coghlan P, et al. A biodegradable polyurethane dermal substitute for full-thickness burns: replacement of the dermal bed and reduction of skin graft requirements. *Plast Reconstr Surg*. 2015;136(6):1219-1229.
49. Ward RS, Saffle JR, Schnebly WA, et al. Sensory loss over grafted areas in patients with burns. *J Burn Care Rehabil*. 1989;10(6):536-538.
50. Williams FN, Herndon DN, Hawkins HK, et al. The leading causes of death after burn injury in a single pediatric burn center. *Crit Care*. 2009;13(6):R183.
51. Wurzer P, Culnan DM, Cancio LC, Kramer GC. Pathophysiology of burn shock and burn edema. *Total Burn Care*. 2018:66-76.
52. Young AW, Dewey WS, King BT. Rehabilitation of burn injuries. *Phys Med Rehabil Clin N Am*. 2019;30(1):111-132.
53. Zhang P, Leu MG, Zhao Z, et al. Quality-of-life outcomes following burn reconstruction: a systematic review. *Aesthetic Plast Surg*. 2021;45(3):1159-1178.