УДК: 616.5-003.921-089.844-07
DOI: 10.24061/2413-4260.XVI.1.59.2026.18

MULTIMODAL RECONSTRUCTIVE AND PLASTIC SURGERY METHODS FOR POST-BURN SCAR TREATMENT

***L. Kenjayev*[1,2], *Sh. Urakov*[3], *N. Kenjayeva*[3], *Z. Murtazayev*[4]**

Bukhara Branch of the Republican Research Centre for Emergency Medicine[1], International University of Asia[2], Bukhara State Medical Institute named after Abu Ali ibn Sino[3] (Bukhara, Uzbekistan),
Samarkand State Medical University[4] (Samarkand, Uzbekistan)

Summary.

Hypertrophic scars and keloids represent pathological outcomes of impaired skin regeneration, defined by excessive fibroblast proliferation, upregulated collagen synthesis, and sustained inflammatory response. Given that these conditions predominantly arise in the setting of deep thermal burns, trauma, and surgical procedures, they constitute a problem of considerable clinical significance in burn and reconstructive surgery.

Objective. *To evaluate the efficacy of reconstructive plastic surgery techniques in the management of hypertrophic and keloid scars.*

Materials and Methods. *A total of 84 patients with hypertrophic and keloid scars were enrolled. The mean age was 37.8 ± 12.6 years (range 18-62 years); 60.8% of participants were male and 39.2% were female. The minimum interval from scar formation to treatment initiation was 1 year, and the mean interval between scar formation and presentation for specialized care was 14.5 ± 6.3 years. Prior to referral, the predominant management approach had consisted of watchful waiting and conservative home-based treatment. As a consequence, a substantial proportion of patients presented at an advanced stage with scar contractures involving the face, chin, and periorbital region. All procedures were conducted in accordance with the Declaration of Helsinki of the World Medical Association (2000 revision). Statistical analysis was performed using SPSS 26.0. Data are expressed as the arithmetic mean (M) ± standard deviation (SD) or standard error of the mean (m). Between-group differences were assessed using Student's t-test and the Mann–Whitney U-test; a p-value of < 0.05 was considered statistically significant. The study was conducted in accordance with the research plan of Bukhara State Medical Institute, entitled «Early Detection, Diagnosis, and Novel Treatment and Prevention Strategies for Pathological Factors Affecting Population Health in the Bukhara Region During the Post-COVID-19 Pandemic Period (2022-2026).»*

Results. *The study demonstrated that combined surgical and laser treatment of hypertrophic and keloid scars resulted in a statistically significant reduction in scar thickness by a mean of 27-28% ($p < 0.05$), a decrease in vascularisation and erythema index by 22-33%, and an improvement in scar tissue elasticity. Objective assessment methods, including ultrasonography, PeriCam, and photoindexing, together with subjective evaluation using the Vancouver Scar Scale (VSS), revealed substantial reductions in the vascular component, scar height, and scar density, yielding an overall VSS score reduction of 42% for hypertrophic scars and 37.9% for keloid scars. Pigmentation changes were moderate; however, marked improvement was observed in the keloid scar group. Adverse effects were transient, no recurrences or serious complications were recorded during the 6-12-month follow-up period, and patient satisfaction exceeded 85%.*

Conclusions. *The 10,600 nm wavelength laser was shown to substantially reduce the inflammatory response and tissue perfusion, thereby preventing pathological scar formation. Laser therapy resulted in a reduction of scar thickness by approximately 30% and a significant improvement in scar tissue elasticity ($p < 0.05$), demonstrating both tissue softening and the clinical efficacy of the method.*

Keywords: *Hypertrophic Scar; Keloid; Burns; Laser Therapy.*

Introduction

The management of burn scars remains one of the most complex and demanding areas of contemporary reconstructive plastic surgery [1]. Despite considerable advances in specialized care for burn survivors, the incidence of hypertrophic and keloid scars remains high, particularly among children and young adults [2, 3]. These pathological cutaneous changes frequently result not only in significant cosmetic defects but also in functional impairment, restricted range of motion, chronic pain, and diminished quality of life [4, 5].

Current approaches to the correction of scar deformities encompass a broad spectrum of conservative, surgical, and instrumental modalities; however, none of these methods in isolation consistently yields stable and predictable outcomes [6, 7]. Accordingly, the development and implementation of combined techniques based on the rational integration of surgical interventions and laser technologies, directed at the elimination of the key pathogenetic mechanisms underlying pathological scar formation, is of particular interest.

Relevance

Hypertrophic scars and keloids arise as a consequence of dysregulated cutaneous regeneration and are characterized by excessive fibroblast proliferation, increased collagen synthesis, and prolonged persistent inflammation. These pathological changes most commonly develop following deep thermal burns, trauma, and surgical procedures, rendering this problem especially pertinent in the practice of burn and reconstructive surgery [8-10].

The clinical manifestations of hypertrophic and keloid scars extend well beyond purely aesthetic concerns. They are accompanied by pruritus, pain, and a sensation

ISSN 2226-1230 (PRINT) ISSN 2413-4260 (ONLINE)
KEY TITLE: NEONATOLOGÌÂ, HÌRURGÌÂ TA PERINATAL'NA MEDICINA (ONLINE)
ABBREVIATED KEY TITLE: NEONATOL. HÌR. PERINAT. MED. (ONLINE)

of skin tightness, and, when located in the periarticular region, by the formation of contractures and persistent functional limitations. A particularly severe clinical course is observed in children, in whom scar deformities progress in accordance with somatic growth [11, 12].

Despite the availability of numerous treatment modalities – including pharmacological therapy, injection-based methods, compression therapy, and physiotherapy – their overall efficacy remains limited [13]. The high density of fibrotic tissue and the reduced permeability of scar tissue substantially diminish the effectiveness of topical and injectable treatments, frequently necessitating multiple procedures with suboptimal outcomes [14-16].

Surgical treatment, although capable of removing a substantial volume of scar tissue, is associated with a high risk of recurrence, particularly in the case of keloid scars. According to published data, the recurrence rate following isolated surgical excision may reach 50-80%, which underscores the need to identify novel and more effective therapeutic approaches for this patient population [17, 18].

In recent years, laser technologies have assumed increasing importance in the management of pathological scars owing to their capacity to selectively target the vascular component, stimulate collagen remodeling, and attenuate inflammatory activity. Laser monotherapy does not consistently yield a durable clinical effect, particularly in cases of severe and long-standing scar changes [19], underscoring the significance of combined surgical and laser approaches directed at stepwise intervention across the various stages of scar pathogenesis. Such an integrated approach reduces the volume and severity of scar tissue, diminishes the risk of recurrence, and improves both functional and cosmetic treatment outcomes, conferring considerable clinical and practical relevance upon the present study.

Study Objective. To evaluate the efficacy of reconstructive plastic surgery techniques in the management of hypertrophic and keloid scars.

Materials and Methods

Priority is generally accorded to non-surgical treatment modalities. However, when such approaches fail to produce adequate outcomes, surgical intervention is considered the preferred treatment method.

Although minimally invasive techniques have demonstrated favourable results for soft and thin scars, their application presents considerable challenges in the management of firmer and thicker scar tissue. The capacity of topically applied agents to penetrate deeply into the skin is severely limited, and the injection of therapeutic substances is frequently impeded by the presence of densified fibrotic tissue, necessitating repeated procedures of limited efficacy. The present study is based on our prior positive clinical experience with the CO_2 laser in the treatment of hypertrophic scars. The combined use of laser technologies in the surgical management of hypertrophic scars is examined. Through the generation of precisely directed local thermal effects delivered via the fibre-optic system of a CO_2 laser operating at a wavelength of 10,600nm, rapid vaporisation of fibrotic scar tissue is achieved, inducing cellular lysis, necrosis, and coagulation, thereby producing tissue ablation and attenuating inflammatory activity.

A total of 84 patients with hypertrophic and keloid scars were enrolled in the study. The mean patient age was 37.8 ± 12.6 years (range: 18-62 years). The minimum interval between scar formation and the initiation of treatment was 1 year. The mean duration of scar persistence prior to presentation for specialised care was 14.5 ± 6.3 years. In clinical practice, watchful waiting and home-based conservative management – including the topical application of goose fat – were the most frequently observed prior treatment approaches. As a consequence, a substantial proportion of patients presented at an advanced stage with scar contractures involving the face, chin, and periorbital region. The mean scar area was 207.19 cm² (range: 18.00-1,063.50 cm²). The majority of patients presented with scars resulting from burns (55.8%), surgical procedures (20.8%), trauma (13.3%), and inflammatory skin conditions (10.0%), respectively. Of particular note, a history of watchful waiting was documented in 28.3% of cases, indicating that medical care had not been provided for an extended period following the initial injury.

All patients were stratified by the nature of the causative agent, type of injury, age, and sex, in accordance with current published data. Based on survey data from the study group, the predominant patient categories were those with burn scars (55.8%), followed by post-surgical scars (20.8%), post-traumatic scars (13.3%), and scars attributable to inflammatory skin conditions (10.0%). Suppurative inflammatory conditions – including furuncle and furunculosis – were classified as inflammatory skin diseases. Among patients who had sustained burn injuries, scalding with boiling water or hot oil was the most frequently reported mechanism in the clinical history.

The mean number of procedures performed per patient was 1.38 (range: 1-3). The mean energy delivered per procedure was 4,486.76 J (range: 388-17,536 J), and the mean power per procedure was 4 W (range: 3-6 W). The mean follow-up duration was 7.2 months (range: 6-12 months).

All procedures were conducted in accordance with the Declaration of Helsinki of the World Medical Association (2000 amendment).

Statistical analysis was performed using SPSS version 26.0. Data are presented as the arithmetic mean (M) ± standard deviation (SD) or standard error of the mean (m). Between-group differences were assessed using Student's t-test and the Mann–Whitney U test. A p-value of less than 0.05 was considered statistically significant.

The study was conducted in accordance with the research plan of Bukhara State Medical Institute under the topic: «Early Detection, Diagnosis, and Novel Treatment and Prevention Strategies for Pathological Factors Affecting Population Health in the Bukhara Region During the Post-COVID-19 Pandemic Period (2022-2026).»

Results

Scar thickness was assessed at each follow-up visit, and Doppler ultrasonography demonstrated a reduction of 0.308 ± 0.138 cm at 6 months ($p < 0.05$), representing

a significant decrease relative to baseline (0.633 ± 0.306 cm versus 0.942 ± 0.377 cm). This reduction amounted to 27.7% in hypertrophic scars and 28.2% in keloid scars.

Scar elasticity was evaluated at each visit using stiffness parameters R and Q, which are inversely proportional to their numerical values, demonstrating changes of 0.023 ± 0.008 ($p = 0.007$) and 2.616 ± 1.169 units ($p = 0.029$), respectively, with improvement observed across both subgroups (R: 1.82 ± 0.056 units, Q: 365.7 ± 13.113 units and R: 1.9 ± 0.06 units, Q: 368.3 ± 12.5 units). This corresponded to an improvement of 1.2% in hypertrophic scars ($p < 0.05$) and 0.4% in keloid scars ($p = 0.26$), the latter not reaching statistical significance.

No significant improvement in scar pigmentation was observed across the combined subgroups. The melanin index prior to treatment was 251.413 ± 157.716 units, and at 6 months it was 234.349 ± 90.708 units, yielding a difference of 17.063 ± 131.33 units ($p = 0.308$). In the keloid subgroup, however, scar pigmentation improved by 21.3% ($p < 0.01$).

Scar vascularisation was measured using a PeriCam device and Doppler ultrasonography, which demonstrated a reduction in scar vessel count of 33.645 ± 15.667 units, as well as a reduction in the erythema index of 17.349 ± 9 units as assessed by photo-indexing. These findings indicate that laser treatment significantly reduces scar blood supply (Cam PSI: 118.4 ± 44.593 versus 85.3 ± 34.4; $p < 0.05$; erythema index: 438.8 ± 97.8 versus 421.4 ± 97.5; $p < 0.05$). In both subgroups assessed independently, a significant reduction in blood perfusion of 29.6% and in the erythema index of 4% was observed in hypertrophic scars, and a reduction in perfusion of 22.7% and in the erythema index of 3.1% was recorded in keloid scars (Figure 1).

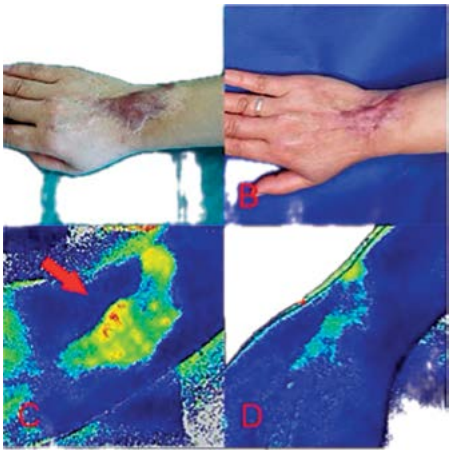

Figure 1. A 30-year-old female patient with a post-traumatic hypertrophic scar of 2 years' duration prior to treatment (A); at 6 months following combined surgical and laser treatment (B); scar blood supply was markedly reduced: preoperatively – 105.3 units (C), postoperatively – by 28.5% (D); scar thickness preoperatively – 0.73 cm (E), reduction postoperatively – 43.84% (F).

Subjective Assessment: Scar pigmentation, height, vascularity, and pliability were evaluated throughout the treatment course using the Vancouver Scar Scale (VSS). The study findings demonstrated that, in the context of laser surgical therapy, the vascular component of scars was significantly reduced, scar thickness was decreased, and scar pliability was improved. Specifically, the overall VSS score improved by 42% in the hypertrophic scar (HS) subgroup and by 37.9% in the keloid scar subgroup (Table 1).

Table 1

Changes in scar characteristics before and after laser therapy as assessed by the Vancouver Scar Scale (VSS)

Parameter	Parameter	Parameter	Parameter	P
Scar thickness (cm)	0.95 ± 0.4	0.52 ± 0.4	0.29 ± 0.14	< 0.001
Scar elasticity				
R0 (units)	1.7 ± 0.045	1.85 ± 0.06	–0.024 ± 0.008	0.006
Q0 (units)	356.7 ± 13.2	370.3 ± 12.55	–2.7 ± 1.17	0.025
Scar pigmentation (units)				
Melanin index	Melanin index	Melanin index	Melanin index	0.31
Scar vascularisation				
Blood perfusion (units)	116.79 ± 43.66	83.322 ± 32.331	32.675 ± 14.554	< 0.001
Erythema index (units)	436.654 ± 93.664	421.441 ± 95.432	16.234 ± 8.12	< 0.001
VSS scores				
Pigmentation	2.543 ± 0.78	2.423 ± 0.7	0.154 ± 0.41	0.073
Height	3.800 ± 0.000	2.200 ± 0.567	2.000 ± 0.643	< 0.001
Vascularity	2.342 ± 0.433	1.432 ± 0.521	1.345 ± 0.543	< 0.001
Pliability	3.643 ± 0.532	2.000± 0.665	1.532 ± 0.722	< 0.001

ISSN 2226-1230 (PRINT) ISSN 2413-4260 (ONLINE)
KEY TITLE: NEONATOLOGÌÂ, HÌRURGÌÂ TA PERINATAL'NA MEDICINA (ONLINE)
ABBREVIATED KEY TITLE: NEONATOL. HÌR. PERINAT. MED. (ONLINE)

Figure 2. A 15-year-old patient with a keloid scar on the surface of the left leg of 1 year's duration following trauma (A); after surgical intervention and two sessions of laser treatment (B).

The rate of postoperative pain was 85.71%, with a mean duration of 2.23 ± 0.8 days and a mean pain score of 1.2 ± 1.33 units. Local oedema was observed in 100% of patients, with a mean duration of 7.00 ± 1.2 days. Tissue necrosis was identified in 29.6% of cases, with a mean healing time of 25.23 ± 12.3 days. During the follow-up period of 6 to 12 months, no recurrence of hypertrophic scarring was recorded in any patient following laser therapy. No cases of persistent hyperpigmentation, hypopigmentation, or cutaneous infection lasting more than 3 months were observed. No cases of persistent hyperpigmentation, hypopigmentation, or cutaneous infection lasting more than 3 months were observed.

Table 2

Hypertrophic scar (HS) and keloid subgroups: changes before and after laser treatment expressed as percentages

Parameter	Thickness	Thickness			Elasticity		Elasticity	
	HS	Keloid			HS		Keloid	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Mean ± SD	0.9 ± 0.3	0.56 ± 0.10	1.2 ± 0.55	0.82 ± 0.55	354.7 ± 13.5	383 ± 15.4	364.43 ± 9.2	364.88 ± 6.0
Min; Max	0.43; 0.23	0.40; 1.20	0.42; 1.00	0.18; 1.75	333; 425	350; 430	340; 378	355; 378
Difference	–0.2	–0.28			4.2		1.3	
Improvement (%)	–26.8	–27.2			1.3		0.4	
Paired t-test (p)	< 0.001	< 0.001			< 0.05		0.26	
	Blood Perfusion	Blood Perfusion			Erythema Index		Erythema Index	
	HS	Keloid			HS		Keloid	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	d Pre	Follow-up
Mean ± SD	90.2 ± 25.6	71.3 ± 24	132.3 ± 51.1	102.3 ± 42.1	422.7 ± 106.1	402.3 ± 105.1	444.4 ± 85	433.5 ± 92.1
Min; Max	30; 143	21; 104	31; 225	21; 178	241; 630	221; 618	166; 570	142; 649
Difference	–28.6	–28.8			–16.0		–12.8	
Improvement (%)	–29.3	–22.5			–4.2		–3.2	
Paired t-test (p)	< 0.001	< 0.001			< 0.001		< 0.05	
	Pigmentation	Pigmentation			Total VSS Score		Total VSS Score	
	HS	Keloid			HS		Keloid	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Mean ± SD	202.3 ± 105.1	244.6 ± 102.2	278.6 ± 160	225.2 ± 83.4	12.5 ± 0.8	7.3 ± 1.5	12.0 ± 0.6	8.2 ± 2.3
Min; Max	81; 481	81; 469	81; 623	81; 322	11; 12	5; 9	11; 13	6; 12
Difference	42.1	–61.4			–5.2		–4.9	
Improvement (%)	21.1	–22.1			–41.0		–36.7	
Paired t-test (p)	0.03	< 0.01			< 0.001		< 0.001	

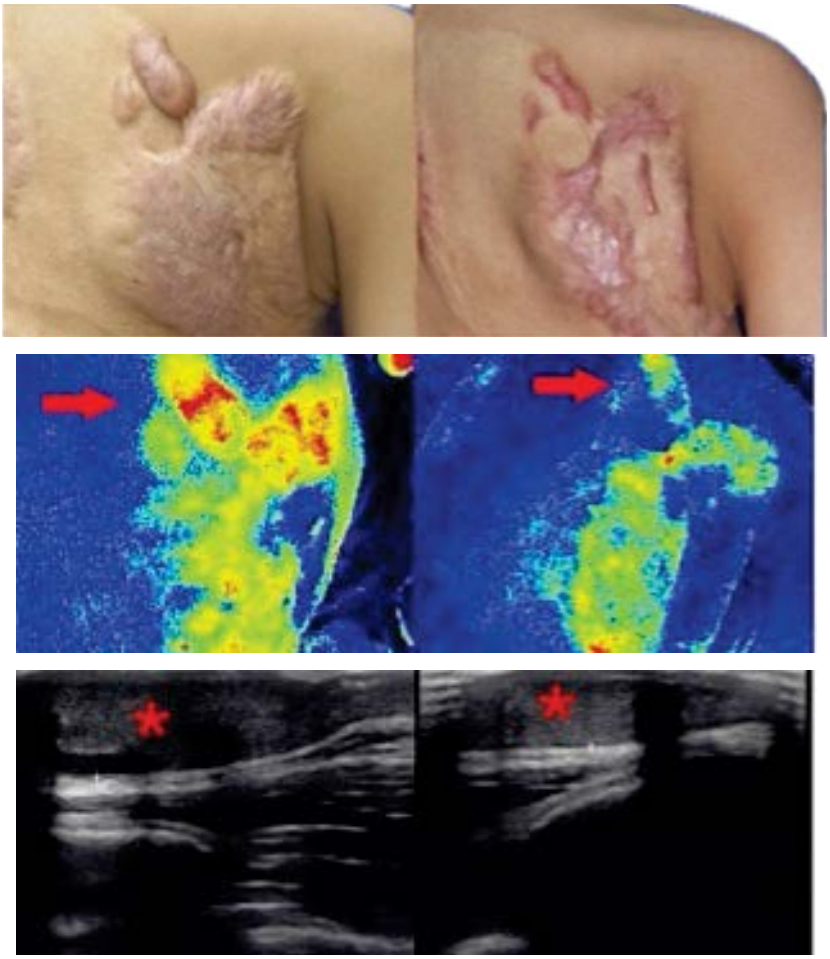

Figure 3. A 23-year-old male patient with a hypertrophic scar in the lumbar region prior to treatment (A); following surgical intervention and laser therapy (B); pretreatment scar blood flow was 141.7 units (C), with a reduction of 33.5% recorded after laser treatment (D); mean scar thickness prior to surgery was 1.02 cm (E); scar thickness decreased by 62.3% following laser treatment (F)..

Table 3

Adverse events following treatment. SD – standard deviation; VAS – visual analogue scale.

Adverse Event	Mean ± SD	Duration
Pain	86.21%	2.2 ± 0.73 days
Total VSS score	4.2 ± 1.3	—
Oedema	100%	7.00 ± 1.2 days
Partial scar necrosis	28.30%	14.83 ± 3.05 days
Hyperpigmentation > 3 months	0	0
Hypopigmentation	0	0
Cutaneous infection	0	0
Worsening of keloid or hypertrophic scar	0	0

Figure 4. A 46-year-old male patient with a keloid scar on the chest and arm of 2 years' duration following a burn injury (A); at 6 months of follow-up after three laser sessions, the patient achieved marked cosmetic and functional improvement (B).

ISSN 2226-1230 (PRINT) ISSN 2413-4260 (ONLINE)
KEY TITLE: NEONATOLOGÌÂ, HÌRURGÌÂ TA PERINATAL'NA MEDICINA (ONLINE)
ABBREVIATED KEY TITLE: NEONATOL. HÌR. PERINAT. MED. (ONLINE)

The evolution of laser and surgical techniques has demonstrated a broad spectrum of clinical and cosmetic applications. On the basis of these innovative technologies, a novel method of combined surgical treatment for hypertrophic scars was developed. The method consists of laser removal of the scar zone with preservation of the boundary between scar tissue and adjacent healthy skin, preceded by excision of the superficial layer of scar tissue to a depth of up to 1 mm, including its epithelial covering. The scar is subsequently eliminated with a reduction of the affected area by 2-3 mm relative to the surrounding healthy skin. A focused continuous-wave laser mode is employed at a wavelength of 10.05 μm and a power of 20 W (Fotona CO_2 Fraxel). The wound surface is thereafter treated with yellow laser irradiation (Denave Optiscan, 585 nm, power 5 W, 30 J/cm²) in scanning mode.

The previously excised scar segment is affixed to the wound surface following processing and thinning of the dermal layer, and is secured at the periphery using biological adhesive. Upon complete or partial engraftment of the transposed tissue segment, photodynamic therapy is performed using a 20% photosensitiser ointment containing 5-aminolevulinic acid (5-ALA) and red light irradiation (PDT laser Deka) in the 600-660 nm range for 5 minutes at a power of 1 W per 1 cm² of surface area. Following wound epithelialisation, laser irradiation is applied (Deka Fraxel CO_2) at a power of 1 W, a wavelength of 1.06 μm, and a frequency of 50 Hz for 1 minute per 1 cm², with the beam directed along the wound perimeter and over the centre of the lesion. Treatment is administered every 14 days with a gradual reduction in irradiation power to 500 mW and an exposure time of 30 seconds. An elastic compression dressing with tissue tension of up to 100 kPa is subsequently applied for 1 month.

Discussion

The results obtained confirm the high clinical efficacy of combined surgical and laser treatment for hypertrophic and keloid scars. Analysis of objective parameters demonstrated a comprehensive effect of laser techniques on the key pathogenetic mechanisms of scar formation, including reduction of hypertrophy, normalisation of vascularisation, attenuation of excessive collagen synthesis, and improvement of tissue elasticity [20, 21].

The substantial reduction in scar thickness across both groups (mean 27-28%) indicates a pronounced remodelling effect of laser ablation combined with subsequent photodynamic therapy, which is consistent with published data on the regenerative potential of the CO_2 laser. The improvement in elasticity parameters reflects restoration of the mechanical properties of the tissue; a more pronounced effect was observed in hypertrophic scars, which may be attributable to less severe structural disruption compared with keloids [22, 23].

Assessment of vascularisation revealed a statistically significant reduction in perfusion and the erythema index (22-33%), indicative of the formation of a more mature scar tissue phenotype and a decrease in factors associated with keloid progression. Changes in pigmentation in the overall study group were limited in magnitude; however, a positive trend was observed in patients with keloid scars, suggesting the potential efficacy of combined modalities in this subgroup [24, 25].

Subjective assessment using the VSS demonstrated marked improvement across all parameters, with a reduction in the total score of 42% in hypertrophic scars and 37.9% in keloid scars. Adverse events were transient in nature and did not affect the final outcome, and the absence of recurrence and serious complications during the 6-12-month follow-up period confirms the safety and clinical promise of the proposed laser-surgical technique [26, 27].

Conclusions

The findings of the present study indicate that the application of a laser at a wavelength of 10,600 nm contributes to the attenuation of the inflammatory response and a reduction in tissue perfusion, which together impede the formation of pathological scar changes. The use of this method resulted in a significant reduction in scar thickness (by approximately 30%) and in the degree of inflammation within the keloid scar zone ($p < 0.05$). According to the data obtained, the elasticity index of scar tissue decreased significantly following laser therapy, indicating tissue softening and improvement of elastic properties ($p < 0.05$). A statistically significant improvement of 1.2% was recorded in the overall study group.

Future Research Directions

A promising avenue for further investigation is the conduct of randomised controlled trials with larger patient samples and extended follow-up periods to evaluate long-term outcomes and recurrence rates. Of particular interest is the study of the molecular and cellular mechanisms of scar tissue remodelling under the influence of combined laser-surgical therapy, including analysis of type I and type III collagen expression, angiogenic factors, and pro-inflammatory cytokines.

The development of personalised algorithms for the selection of laser parameters based on scar type, chronicity, thickness, and location is also warranted. Additional research may be directed towards evaluating the combination of laser technologies with biological dressings, cell-based therapies, and regenerative approaches to enhance treatment efficacy and prevent recurrence.

Author Contributions: L. Kenjayev – study concept development, performance of surgical interventions, clinical data analysis, manuscript preparation and editing; Sh. Urakov – scientific supervision, methodological support, critical review, and final approval of the manuscript; N. Kenjayeva – clinical data collection, data processing, and participation in statistical analysis; Z. Murtazayev – scientific consulting, interpretation of results, scientific editing, and coordination of publication preparation.

All authors have read the final version of the manuscript and consented to its publication.

Conflict of Interest. The authors declare no conflict of interest.

Funding. The study was conducted as part of the research activities of the authors' institutions. No additional external funding was received.

Acknowledgements. The authors express their gratitude to the medical staff of the surgical departments of the Bukhara Branch of the Republican Research Centre for Emergency Medicine and to the specialists of the diagnostic units for their assistance in patient examination and technical support throughout the study.

References:

1. Abarca-Pineda YA, Alaniz IC, Ibraheam A, Bhasin I, Alasaadi S, García ML, et al. Conventional and Emerging Surgical and Non-surgical Approaches to the Management of Skin Burn Scars: A Comprehensive Review. Cureus. 2025;17(8): e90982. DOI: http://doi.org/10.7759/cureus.90982 PMID: 41018317; PMCID: PMC12460041.

2. Jain R, Bhatti D, Hever P, Pandya WCA. Across borders, over time: epidemiology of post-burn injury patterns and late sequelae presenting to surgical outreach camps across three geographical regions. Med Confl Surviv. 2026;42(1):61-76. DOI: http://doi.org/10.1080/13623699.2026.2613455 PMID: 41693647.

3. Teshaev OR, Kurbanov GI, Jumaev NA. Microsurgical reconstruction of post-burn scar contractures: contemporary approaches and outcomes. Eurasian Journal of Medical and Natural Sciences. 2025;5(5-2):36-44. DOI: https://doi.org/10.5281/zenodo.15600307

4. van den Bosch AS, Verwilligen RAF, Pijpe A, Jansen LB, van der Vlies CH, van Eck ME, et al. Indications for the use of dermal substitutes in patients with acute burns and in reconstructive surgery after burns: A systematic review. Wound Repair Regen. 2025;33(1): e13248. DOI: http://doi.org/10.1111/wrr.13248 PMID: 39727218; PMCID: PMC11672668.

5. Al-Najjar FG. Outcomes of Z-Plasty vs W-Plasty in Scar Revision for Post-Burn Contractures Among Iraqi Patients: A Prospective Comparative Clinical Study. Journal of Clinical Practice and Medical Research. 2025;1(1):45-52. DOI: https://doi.org/10.59324/jcpmr.2025.1(1).08

6. Klimeczek-Chrapusta M, Chrapusta A. From Scar to Function: Plastic Surgery in the Management of an Extreme Hand Contracture in a Child. Cureus. 2025;17(9): e92121. DOI: http://doi.org/10.7759/cureus.92121 PMID: 40949073; PMCID: PMC12427595.

7. Anastasova V, Kiskinov P, Georgiev A, Ivanova K, Krasteva E, Atliev K et al. Z-plasty–Basic Surgical Technique for Post-Burn Patients. Acta Medica Bulgarica. 2025;52(1):21-8. DOI: http://doi.org/10.2478/AMB-2025-0004

8. Kalinova K, Raycheva R, Petrova N, Uchikov P. Acute Management of Deep Periorbital Burns: A 10-Year Review of Experience. Ann Burns Fire Disasters. 2024;37(1):53-63. PMID: 38680840; PMCID: PMC11041892.

9. Umarkhodjaev AM, Gulyamov SS, Umarkhodjaeva GM. To Develop An Algorithm And Tactics For The Treatment Of Post-Burn Scars, Depending On The Nature Of The Tissue. Stanford Database Library of International Journal of Medical Sciences And Clinical Research. 2025;5(12):145-50. DOI: https://doi.org/10.37547/ijmscr/Volume05Issue12-32

10. Sing QY, Borg T-M, Shahid S, Abbassi O. Breast Burns Scar Reconstruction: A Systematic Review of Management Considerations and Recommendations. Ann Burns Fire Disasters. 2025;38(2):166-71. PMCID: PMC12186187, PMID: 40589709

11. Zhernov OA, Osadcha OI, Zhernov AO, Sochienkova LS, Kozinets GP. The use of methods of conservative therapy in children with post-burn scarring and their impact on connective tissue metabolism. Modern Pediatrics. Ukraine. 2022;4(124):48-53. DOI: http://doi.org/10.15574/SP.2022.124.48

12. Bekkers VZ, Bik L, van Huijstee JC, Wolkerstorfer A, Prens EP, van Doorn MBA. Efficacy and safety of needle-free jet injector-assisted intralesional treatments in dermatology-a systematic review. Drug Deliv Transl Res. 2023;13(6):1584-99. DOI: http://doi.org/10.1007/s13346-023-01295-x PMID: 36884194; PMCID: PMC10126042.

13. Yang X, Li R, Mao X, Gong S, Fan Y, Xu C, et al. Non-surgical treatments for post-burn scars: A network meta-analysis. PLoS One. 2025;20(8): e0330428. DOI: http://doi.org/10.1371/journal.pone.0330428 PMID: 40839603; PMCID: PMC12370048.

14. Blome-Eberwein SA, Cartotto R. Preoperative planning: A holistic approach to burn reconstruction. In: Herndon DN, editor. Total Burn Care. 6th ed. London: Elsevier; 2026. p. 513-20. DOI: http://doi.org/10.1016/B978-0-323-88389-4.00055-5

15. Villalba GK, Ibáñez FX, Carbajal AY, Muñoz SD, Carranza AJ, Rodriguez JD, et al. Advanced reconstructive techniques for surgical management of extensive skin defects due to post-burn scarring: a systematic review. Arandu UTIC. 2024;11(2):2281-94. DOI: https://doi.org/10.69639/arandu.v11i2.419

16. Mc Kittrick A, Hammond L, Brown J. Interventions for Functional and Cosmetic Outcomes Post Burn for Eyelid Ectropion-A Scoping Review. Eur Burn J. 2025;6(3):46. DOI: http://doi.org/10.3390/ebj6030046 PMID: 40843806; PMCID: PMC12372075.

17. van den Bosch AS, Verwilligen RAF, Pijpe A, Bosma E, van der Vlies CH, Lucas Y, et al. Outcomes of dermal substitutes in burns and burn scar reconstruction: A systematic review and meta-analysis. Wound Repair Regen. 2024;32(6):960-78. DOI: http://doi.org/10.1111/wrr.13226 PMID: 39435560; PMCID: PMC11584356.

18. Alharbi ZI, Moshref LH, Badr RE, Zahran OA, Almaghrabi MT, Khamis SF. Post-Burn and Surgical Scar Reconstruction with Tissue Expanders: Review of the Literature and Our Local Experience. Reports (MDPI). 2023;7(1):1. DOI: http://doi.org/10.3390/reports7010001 PMID: 40729250; PMCID: PMC12225367.

19. Gus E, Zhu J, Brooks SG. Postburn breast reconstruction: a scoping review. Scars Burn Heal. 2023;9:20595131231202100. DOI: http://doi.org/10.1177/20595131231202100 PMID: 37743873; PMCID: PMC10512695.

20. Fouad S, Rizk A, Mosbah E, Nabeeh MM, Awadin W, Elmezayyen AS, et al. Platelet-rich fibrin and silver nano-particles loaded chitosan treatment for post-laminectomy epidural scar adhesions: in vivo rats study model. BMC Neurosci. 2025;26(1):10. DOI: http://doi.org/10.1186/s12868-025-00929-9 PMID: 39910448; PMCID: PMC11796154.

21. Lei Y, Zhang N, Liu Y, Du X. A prediction nomogram for residual after negative pressure aspiration for endogenic cesarean scar ectopic pregnancy: a retrospective study. BMC Pregnancy Childbirth. 2025;25(1):107. DOI: http://doi.org/10.1186/s12884-025-07255-2 PMID: 39901095; PMCID: PMC11789346.

22. Sulaymonovich DS, Fayzullaev N, Nazirova R, Ishankulov A, Omidi M, Al-Nuaimi BN, et al. Single-atom silver-borophene hybrid hydrogels for electrically stimulated wound healing: a multifunctional antibacterial platform. Biomater Sci. 2025;13(15):4180-98. DOI: http://doi.org/10.1039/d5bm00609k PMID: 40540010.

23. Leszczynski R, da Silva CA, Pinto ACPN, Kuczynski U, da Silva EM. Laser therapy for treating hypertrophic and keloid scars. Cochrane Database Syst Rev. 2022;9(9): CD011642. DOI: http://doi.org/10.1002/14651858.CD011642.pub2 PMID: 36161591; PMCID: PMC9511989.

24. Morasiewicz P, Urbański W, Kulej M, Dragan SŁ, Dragan SF, Pawik Ł. Balance and lower limb loads distribution after Ilizarov corticotomy. Injury. 2018;49(4):860-5. DOI: http://doi.org/10.1016/j.injury.2018.03.016 PMID: 29571564.

25. Davlatov S, Qurbonov N, Yunusova A, Tursunova N, Narbekova R, Abdumaruf A, et al. Secure and privacy preserving predictive framework for iot based health cloud system using cryptographic modfels. Health Leadership and Quality of Life. 2024;3:8. DOI: https://doi.org/10.56294/hl2024.177

26. Tsuge T, Aoki M, Akaishi S, Dohi T, Yamamoto H, Ogawa R. Geometric modeling and a retrospective cohort study on the usefulness of fascial tensile reductions in severe keloid surgery. Surgery. 2020;167(2):504-9. DOI: http://doi.org/10.1016/j.surg.2019.07.028 PMID: 31561991.

27. Zahorec P, Sarkozyova N, Ferancikova N, Bukovcan P, Danisovic L, Bohac M, et al. Autologous mesenchymal stem cells application in post-burn scars treatment: a preliminary study. Cell Tissue Bank. 2021;22(1):39-46. DOI: http://doi.org/10.1007/s10561-020-09862-z PMID: 32862394.

НЕОНАТОЛОГІЯ, ХІРУРГІЯ ТА ПЕРИНАТАЛЬНА МЕДИЦИНА
NEONATOLOGY, SURGERY AND PERINATAL MEDICINE
т. XVI, №1(59), 2026
VOL. XVI, №1(59), 2026
ISSN 2226-1230 (PRINT) ISSN 2413-4260 (ONLINE)
KEY TITLE: NEONATOLOGÌÂ, HÌRURGÌÂ TA PERINATAL'NA MEDICINA (ONLINE)
ABBREVIATED KEY TITLE: NEONATOL. HÌR. PERINAT. MED. (ONLINE)

МУЛЬТИМОДАЛЬНІ МЕТОДИ РЕКОНСТРУКЦІЙНОЇ ТА ПЛАСТИЧНОЇ ХІРУРГІЇ ДЛЯ ЛІКУВАННЯ РУБЦІВ ПІСЛЯ ОПІКІВ

Л. Р. Кенджаєв[1,2], *Ш. Т. Ураков*[3], *Н. А. Кенджаєва*[3], *З. І. Муртазаєв*[4]

Бухарський філіал Республіканського науково-дослідного центру екстреної медицини[1],
Міжнародний університет Азії[2],
Бухарський державний медичний інститут імені Абу Алі ібн Сіно[3]
(м. Бухара, Узбекистан),
Самаркандський державний медичний університет[4]
(м. Самарканд, Узбекистан)

Резюме.

Гіпертрофічні рубці та келоїди є патологічними наслідками порушення регенерації шкіри, що характеризуються надмірною проліферацією фібробластів, підвищеним синтезом колагену та тривалою запальною реакцією. З огляду на те, що ці стани переважно виникають на тлі глибоких термічних опіків, травм та хірургічних втручань, вони становлять проблему значного клінічного значення в опіковій та реконструктивній хірургії.

Мета. Оцінити ефективність методів реконструктивної пластичної хірургії в лікуванні гіпертрофічних та келоїдних рубців.

Матеріали та методи. У дослідження було включено 84 пацієнти з гіпертрофічними та келоїдними рубцями. Середній вік становив 37,8 ± 12,6 років (діапазон 18-62 роки); 60,8% учасників були чоловіками, а 39,2% – жінками. Мінімальний інтервал від утворення рубця до початку лікування становив 1 рік, а середній інтервал між утворенням рубця та зверненням за спеціалізованою допомогою – 14,5 ± 6,3 років. До направлення до нас основним підходом до лікування було пильне спостереження та консервативне лікування в домашніх умовах. Як наслідок, значна частина пацієнтів звернулася на пізній стадії з рубцевими контрактурами, що охоплювали обличчя, підборіддя та періорбітальну ділянку. Усі процедури проводилися відповідно до Гельсінської декларації Всесвітньої медичної асоціації (редакція 2000 року). Статистичний аналіз проводили за допомогою SPSS 26.0. Дані виражено у вигляді середнього арифметичного (M) ± стандартне відхилення (SD) або стандартна похибка середнього (m). Міжгрупові відмінності оцінювали за допомогою t-критерію Стьюдента та U-критерію Манна–Уітні; значення $p < 0,05$ вважали статистично значущим. Дослідження проводилося відповідно до плану наукових досліджень Бухарського державного медичного інституту під назвою «Раннє виявлення, діагностика та нові стратегії лікування і профілактики патологічних факторів, що впливають на здоров'я населення Бухарської області в післяпандемічний період COVID-19 (2022-2026 рр.)».

Результати. Дослідження продемонструвало, що комбіноване хірургічне та лазерне лікування гіпертрофічних та келоїдних рубців призвело до статистично значущого зменшення товщини рубців у середньому на 27-28% ($p < 0,05$), зниження індексу васкуляризації та еритеми на 22-33% та поліпшення еластичності рубцевої тканини. Методи об'єктивної оцінки, включаючи ультрасонографію, PeriCam та фотоіндексацію, разом із суб'єктивною оцінкою за допомогою Ванкуверської шкали рубців (VSS), виявили суттєве зменшення судинного компонента, висоти та щільності рубців, що дало загальне зниження балу за VSS на 42% для гіпертрофічних рубців та на 37,9% для келоїдних рубців. Зміни пігментації були помірними; проте у групі з келоїдними рубцями було відмічено значне поліпшення. Побічні ефекти були тимчасовими, рецидивів або серйозних ускладнень протягом 6-12-місячного періоду спостереження не зафіксовано, а рівень задоволеності пацієнтів перевищив 85%.

Висновки. Було показано, що лазер з довжиною хвилі 10600 нм суттєво зменшує запальну реакцію та перфузію тканин, тим самим запобігаючи утворенню патологічних рубців. Лазерна терапія призвела до зменшення товщини рубців приблизно на 30% та значного поліпшення еластичності рубцевої тканини ($p < 0,05$), що свідчить як про розм'якшення тканин, так і про клінічну ефективність методу.

Ключові слова: гіпертрофічний рубець; келоїд; опіки; лазерна терапія.

Contact information:
Laziz Kenjayev – Candidate of Medical Sciences (PhD), Head of the Research Department, Bukhara Branch of the Republican Research Centre for Emergency Medicine (Bukhara, Uzbekistan)
e-mail: laziz_kenjayev@gmail.com
ORCID ID: https://orcid.org/0000-0003-2781-9617

Shuhrat Urakov – Doctor of Medical Sciences, Professor, Head of the Department of Surgical Diseases in Family Medicine, Bukhara State Medical Institute named after Abu Ali ibn Sino (Bukhara, Uzbekistan)
e-mail: Shuhrat.urakov1962@gmail.com
ORCID ID: https://orcid.org/0000-0003-3549-0954

Nozima Kenjayeva – Assistant of the Department of Phthisiology and Pulmonology, Bukhara State Medical Institute named after Abu Ali ibn Sino (Bukhara, Uzbekistan)
e-mail: nozimakenjayeva88@gmail.com
ORCID ID: https://orcid.org/0009-0002-7658-9125

Zafar Murtazayev – PhD, Associate Professor, Department of General Surgery, Samarkand State Medical University (Samarkand, Uzbekistan)
e-mail: murtazayev.zafar1959@gmail.com
ORCID ID: https://orcid.org/0000-0002-6342-5212

Контактна інформація:
Кенджаєв Лазіз Раззокович – кандидат медичних наук, завідувач науково-дослідного відділу Бухарського філіалу Республіканського науково-дослідного центру екстреної медицини (м. Бухара, Узбекистан)
електронна пошта: laziz_kenjayev@gmail.com
ORCID ID: https://orcid.org/0000-0003-2781-9617

Ураков Шухрат Тухтайевич – доктор медичних наук, професор, завідувач кафедри хірургічних захворювань у сімейній медицині Бухарського державного медичного інституту імені Абу Алі ібн Сіно (м. Бухара, Узбекистан)
e-mail: Shuhrat.urakov1962@gmail.com
ORCID ID: https://orcid.org/0000-0003-3549-0954

Кенджаєва Нозіма Ахтамовна – асистент кафедри фтизіології та пульмонології Бухарського державного медичного інституту імені Абу Алі ібн Сіно (м. Бухара, Узбекистан)
e-mail: nozimakenjayeva88@gmail.com
ORCID ID: https://orcid.org/0009-0002-7658-9125

Муртазаєв Зафар Ісрофулович – кандидат медичних наук, доцент кафедри загальної хірургії Самаркандського державного медичного університету (м. Самарканд, Узбекистан)
e-mail: murtazayev.zafar1959@gmail.com
ORCID ID: https://orcid.org/0000-0002-6342-5212

Received by the editorial office: 14 January 2026.
Approved for publication: 23 February 2026.
Published: 27 March 2026.