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Case Report

Minimally Invasive Multimodal Treatment of a Traumatic Hypertrophic Scar Using Energy-Based and Regenerative Therapies: A Case Report

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Abstract

Background: Hypertrophic scars are fibroproliferative lesions caused by abnormal wound healing and involve complex vascular and fibrotic processes. Current treatments often yield variable outcomes, supporting interest in multimodal approaches that target different components of scar pathology. *Case Presentation:* A 30-year-old male presented with a traumatic hypertrophic scar on the dorsum of the right hand following a degloving/avulsion injury involving deep dermal and subcutaneous tissue. After immediate surgical debridement, the patient received two months of biweekly polydeoxyribonucleotide (PDRN) injections and regenerative laser therapy without noticeable improvement. After an 8-month treatment free interval, the patient underwent six biweekly sessions combining vascular laser, fractional ablative laser, radiofrequency microneedling, and topical exosome-based therapy, alternating with vascular laser monotherapy. Outcomes were assessed using the Vancouver Scar Scale (VSS) and Global Aesthetic Improvement Scale (GAIS). *Results:* Vascularity, pliability, scar height, and overall appearance improved progressively. The VSS score decreased from 10 at baseline to 4 after six sessions, with a transition from a purple, firm, raised scar to a pink, supple, and flat lesion. GAIS improved from 3 after the second session to 1 after the fifth and sixth sessions. Residual hyperpigmentation persisted. No treatment-related adverse events were observed. ***Conclusion:*** This case highlights the potential of a minimally invasive, multimodal approach to improve vascularity and remodeling in traumatic hypertrophic scars. Further studies are required to validate these findings.

Keywords

Energy-based Therapy, Exosome Therapy, Hypertrophic Scar, Multimodal Treatment, Radiofrequency Microneedling, Regenerative Medicine, Scar Remodeling, Traumatic Scar

1. Introduction

Cutaneous wound healing is a highly coordinated process involving inflammatory, proliferative, and remodeling phases that restore tissue integrity following injury [1]. Disruption of this process may result in pathological scar formation, characterized by excessive collagen deposition and abnormal tissue remodeling [1]. Hypertrophic scars are fibroproliferative lesions that remain confined to the original wound margins, distinguishing them from keloids, which extend beyond the initial injury [2]. Clinically, hypertrophic scars present as raised,

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firm lesions that may cause pruritus, pain, and restricted mobility, resulting in functional impairment and reduced quality of life [3].

Management of hypertrophic scars remains challenging due to the complex and variable nature of wound healing responses [4]. Current treatments, including silicone therapy, pressure therapy, corticosteroid injections, laser therapy, and surgical approaches, provide variable outcomes, reflecting the multifactorial nature of scar pathophysiology [4].

Multimodal energy-based therapies have gained increasing interest in hypertrophic scar management by targeting different aspects of scar pathology. Vascular lasers selectively target oxyhemoglobin, generating thermal injury within dermal blood vessels that result in vessel coagulation and reduced vascularity [5]. Fractional ablative lasers induce fractional photothermolysis by creating microscopic treatment zones, promoting tissue repair, collagen remodeling, and improvements in scar texture and function [6].

Radiofrequency microneedling (RFMN) delivers focused thermal injury to the dermis while sparing the epidermis, enhancing the dermal wound-healing cascade and collagen remodeling [7]. Regenerative biologics, including exosome-based therapies, are being investigated as adjunctive treatments because of their potential to modulate inflammation, stimulate angiogenesis, enhance collagen deposition, and remodel fibrotic tissue, although clinical evidence remains preliminary [8]. These complementary mechanisms provide the rationale for combining therapeutic modalities to address the multifactorial nature of hypertrophic scar pathology.

This case report aims to describe the clinical outcomes of a multimodal treatment approach for a traumatic hypertrophic scar, with a focus on scar remodeling, reduction of vascularity, improvement in pliability, and overall aesthetic appearance.

2. Materials and Methods

2.1. Study Design and Patients

This single-patient case report describes a 30-year-old male with a hypertrophic scar on the dorsum of the right hand following traumatic injury. Ten months prior to treatment, the patient sustained a degloving/avulsion flap injury while repairing a machine radiator, exposing deep dermal and subcutaneous tissue. The patient underwent immediate debridement, followed by two months of biweekly polydeoxyribonucleotide (PDRN) injections and regenerative laser therapy without improvement [9]. No further scar treatment was performed during the subsequent 8-month interval before the current treatment protocol.

The patient provided written informed consent for publication of this case report, including the use of clinical images and medical data.

2.2. Treatment Protocol

The patient received six biweekly sessions using the multimodal scar protocol. Sessions alternated between (A) combined Tri-Beam laser, Cellec V, Edge One fractional laser, POTENZA RFMN, and topical ExoBM application, and (B) Tri-Beam laser monotherapy.

2.3. Outcome Assessment

Clinical outcomes were assessed at baseline and at each visit, with the final assessment performed at the sixth session. Scar severity was rated using the Vancouver Scar Scale (VSS) for vascularity, pliability, height, and pigmentation, along with the Global Aesthetic Improvement Scale (GAIS). All assessments were performed by the treating physician, who was not blinded.

Clinical photographs documented scar changes, and the study monitored treatment tolerability and adverse events throughout the study period. All the clinical photos were corrected for white balance using Python (Python Software Foundation, Wilmington, DE) and OpenCV (Intel, Santa Clara, CA).

3. Results

3.1. Baseline Clinical Characteristics

At baseline, the patient presented with a well-demarcated, raised erythematous-to-violaceous hypertrophic scar on the dorsum of the right hand with a firm surface. The VSS score was 10, reflecting marked vascularity, firmness, mild elevation (<2 mm), and mixed pigmentation. Table 1 summarizes the treatment parameters for the six-session multimodal scar protocol.

Table 1. *Six-session scar treatment parameters.*

Treatment Session	Treatment Protocol	Tri-Beam (Mode; Shots; Energy; Spot size)	Edge One Fractional Laser (Power; Pulse energy; Depth; Density; Passes)	POTENZA RFMN (Mode; Shots; Level; Needle depth)	Cellec V (Pulse type; Pulse width; Energy)	ExoBM (Volume)
First	Combined multimodal	Collimate HP; 1000; 1.9 J; 7 mm	30 W; 20 mJ; 120 μm; 1.1%; 1	LPOR N25; ~20; Level 5;	Double Peak (4 ms + 4 ms); 40	2-3 mL

Treatment Session	Treatment Protocol	Tri-Beam (Mode; Shots; Energy; Spot size)	Edge One Fractional Laser (Power; Pulse energy; Depth; Density; Passes)	POTENZA RFMN (Mode; Shots; Level; Needle depth)	Cellec V (Pulse type; Pulse width; Energy)	ExoBM (Volume)
	therapy			0.5 mm	ms; 21 J	
Second	Monotherapy	Collimate HP; 1000; 1.9 J; 7 mm;	-	-	-	-
Third	Combined multimodal therapy	Collimate HP; 1000; 1.9 J; 7 mm	30 W; 20 mJ; 120 µm; 1.9%; 1	LPOR N25; ~50; Level 5; 0.75 mm	Double Peak (4 ms + 4 ms); 40 ms; 22 J	2-3 mL
Fourth	Monotherapy	Collimate HP; 1000; 1.9 J; 7 mm	-	-	-	-
Fifth	Combined multimodal therapy	Collimate HP; 1000; 1.9 J; 7 mm	30 W; 20 mJ; 120 µm; 1.9%; 1	LPOR N25; ~50; Level 5; 0.75 mm	Double Peak (4 ms + 4 ms); 40 ms; 22 J	2-3 mL
Sixth	Monotherapy	Collimate HP; 1000; 1.9 J; 7 mm	-	-	-	-

3.2. Clinical Outcomes

Serial clinical evaluation demonstrated progressive improvement in scar characteristics following the current multimodal treatment protocol. The most notable changes included reduction in vascularity, improved pliability, flattening of scar elevation, and overall improvement in scar appearance [Figure 1 (a-g)]. Table 2 summarizes changes in VSS and GAIS scores over the treatment course**.** Overall, the VSS score decreased from 10 at baseline to 4 after the sixth treatment session, while GAIS scores improved from 3 after the second treatment session to 1 after the fifth and sixth treatment sessions. Residual hyperpigmentation persisted at the final assessment.

Table 2. *VSS and GAIS scores during treatment.*

Assessment Time Point	Vascularity	Pliability	Height	Pigmentation	Total VSS Score	GAIS Score
Baseline (pre-treatment)	3 (Purple)	3 (Firm)	1 (<2 mm)	3 (Mixed pigmentation)	10	NA
After first treatment	3 (Purple)	2 (Yielding)	1 (<2 mm)	2 (Hyperpigmentation)	8	NA
After second treatment	3 (Purple)	2 (Yielding)	1 (<2 mm)	2 (Hyperpigmentation)	8	3
After third treatment	2 (Red)	2 (Yielding)	1 (<2 mm)	2 (Hyperpigmentation)	7	2
After fourth treatment	1 (Pink)	2 (Yielding)	1 (<2 mm)	2 (Hyperpigmentation)	6	2
After fifth treatment	1 (Pink)	1 (Supple)	0 (Flat)	2 (Hyperpigmentation)	4	1
After sixth treatment	1 (Pink)	1 (Supple)	0 (Flat)	2 (Hyperpigmentation)	4	1

Footnote: The VSS evaluates scar characteristics across four domains: vascularity (0-3: normal to purple), pliability (0-4: normal to banding), height (0-3: flat to > 4mm), and pigmentation (0-3: normal to mixed pigmentation), with higher scores indicating greater scar severity. GAIS was assessed using a 5-point scale: 1, very much improved; 2, much improved; 3, improved; 4, no change; and 5, worse.

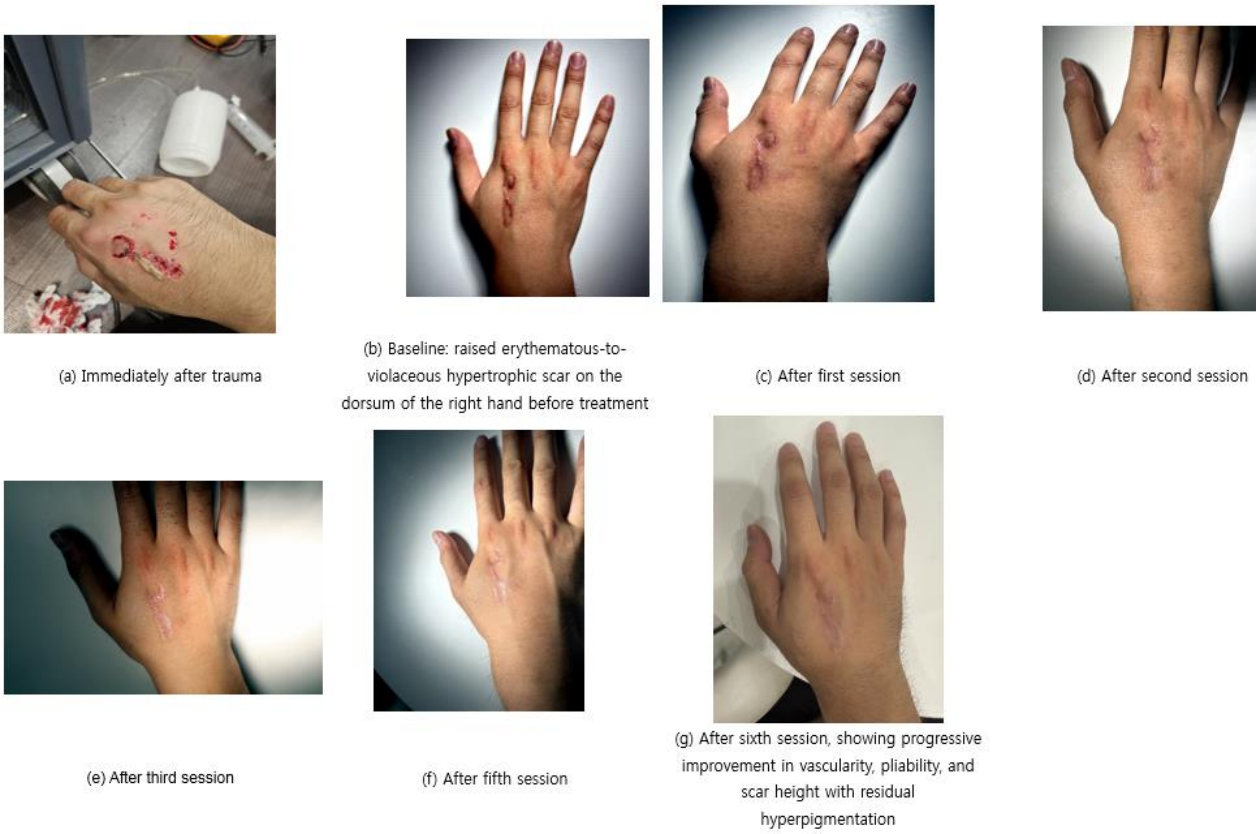


Figure 1. *Clinical evolution of traumatic hypertrophic scar during multimodal treatment. (a) Immediately after trauma (b) Baseline (c) After first session (d) After second session (e) After third session (f) After fifth session (g) After sixth session, showing progressive improvement in vascularity pliability and scar height with residual hyperpigmentation.*

3.3. Safety and Tolerability

The treatment protocol was well tolerated, with no treatment-related adverse events or treatment interruptions.

3.4. Follow-Up

At the final assessment, clinical improvement was maintained, with no delayed adverse events.

4. Discussion

This case describes the management of a traumatic hypertrophic scar following deep dermal injury using energy-based and regenerative therapies targeting distinct components of scar pathology. The baseline scar characteristics, including marked vascularity, firmness, and elevation, reflected the complex biology of hypertrophic scar formation and the involvement of both vascular and fibrotic processes.

The clinical improvement observed was consistent with the mechanisms of the applied therapies. The reduction in vascularity from purple to pink may reflect the selective photothermal effects of vascular-targeting laser treatment on abnormal dermal vasculature [10]. Improvements in pliability and height may reflect fractional ablative laser and RFMN-induced dermal remodeling and collagen reorganization [6, 7]. Topical exosome-based therapy was used as an adjunctive regenerative approach to enhance wound healing through angiogenesis, collagen deposition, and tissue remodeling [11, 12]. However, because the exosome-based therapy was used only in combination with energy-based modalities, its independent contribution cannot be determined and further clinical studies must be done to confirm its role in scar management [13, 14].

Clinical assessment showed progressive improvement, with the VSS score decreasing from 10 at baseline to 4 after six sessions. The scar changed from a purple, firm, raised lesion to a pink, supple, and flat appearance, with the greatest improvements in vascularity, pliability, and height. Persistent hyperpigmentation highlights the variable response of scar components and the need for targeted pigmentary management.

Current hypertrophic scar treatments often have variable outcomes as individual modalities address specific biological pathways. This case supports combining therapies targeting vascularity, dermal remodeling, and tissue regeneration.

The treatment protocol was well tolerated, with no treatment-related adverse events observed. This favorable safety profile is relevant in scar management, where treatment-induced injury may influence inflammatory responses and pigmentary changes [15].

This case is limited by its single-patient design and inability to determine the contribution of individual treatment components. Furthermore, all assessments were performed by the treating physician without blinding [15]. And while the patient did not notice improvements with previous treatments, natural scar maturation and the prior PDRN and laser treatment may have contributed to the observed improvement [9, 10]. Larger controlled studies with objective outcome measures are needed to evaluate the efficacy and durability of combined scar therapies.

Overall, this case suggests that a targeted, minimally invasive approach may improve vascularity and scar remodeling in traumatic hypertrophic scars.

5. Conclusion

This case highlights the potential of a minimally invasive approach combining vascular and dermal remodeling strategies for traumatic hypertrophic scars. Although favorable improvements in scar vascularity, pliability, and height were observed, further clinical studies are needed to confirm these findings.

Abbreviations

GAIS	Global Aesthetic Improvement Scale
J	Joules
LPOR	Large Pores
mJ	Millijoules
ms	Milliseconds
NA	Not Assessed
PDRN	Polydeoxyribonucleotide
RFMN	Radiofrequency Microneedling
μm	Micrometers
VSS	Vancouver Scar Scale

Author Contributions

Minsung Bock: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflicts of interest.

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