

Effective improvement methods for *striae distensae*: A novel approach utilizing laser-induced micro-jet injectors with poly-d,L-lactic acid

Suk Bae Seo MD¹ | Soo-Bin Kim PhD² | Kyu-Ho Yi MD, PhD²

¹SeoAhSong Dermatologic Clinic, Seoul, Korea

²Department of Oral Biology, Division in Anatomy and Developmental Biology, Human Identification Research Institute, BK21 FOUR Project, Yonsei University College of Dentistry, Seoul, Korea

Correspondence

Kyu-Ho Yi and Soo-Bin Kim, Department of Oral Biology, Division in Anatomy & Developmental Biology, Yonsei University College of Dentistry, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea.
 Email: kyuho90@daum.net and tnqls1128@yuhs.ac

Abstract

Introduction: *Striae distensae* (SD), or stretch marks, result from rapid stretching of the skin due to various factors. Conventional treatments often yield unsatisfactory results, leading to the exploration of alternative methods. Laser-induced microjet technology offers a promising approach for drug delivery to target areas. This study investigates the efficacy of using a microjet injector with poly-d,L-lactic acid for treating SD.

Methods: Four female participants with SD were treated with poly-d,L-lactic acid solution using a microjet injector over five sessions. Patients were assessed based on severity scales before and after treatment. Topical anesthetics were applied to minimize discomfort. Injection techniques were optimized to reduce side effects such as bleeding and pain.

Results: All patients showed significant improvement in SD appearance after 5–7 treatments. Assessment scales indicated positive outcomes both immediately after treatment and at the 32-week follow-up. Minimal side effects, primarily petechiae, were observed.

Discussion: Laser-induced microjet technology offers several advantages, including rapid drug delivery and mechanotransduction effects, promoting skin regeneration. Poly-d,L-lactic acid injections demonstrated effectiveness in treating SD, particularly when delivered via microjet injectors. Patients expressed high satisfaction due to the procedure's minimal invasiveness and quick recovery.

Conclusion: Utilizing a needleless microjet injector with poly-d,L-lactic acid shows promise as a treatment for SD, typically requiring 5–7 sessions for optimal results. Mild petechiae may occur as a common side effect. This approach offers an effective and minimally invasive alternative for addressing this common cosmetic concern.

KEY WORDS

laser technology, microjet injector, PDLLA, skin regeneration, *striae distensae*

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1 | INTRODUCTION

Striae distensae (SD), a form of skin scarring that occurs when the skin stretches rapidly, can result from various causes such as pregnancy, rapid weight gain, growth spurts, certain medical conditions, or prolonged use of potent topical steroids.¹ Histologically, the epidermis becomes thinner, and there is pronounced damage to the fibrous tissue of the dermis.² Particularly, severe damage to elastic fibers occurs along with collagen fibers. There is minimal regeneration of elastic fibers, posing considerable challenges for existing treatments aimed at regenerating these fibers and patients seek treatment for cosmetic reasons. Methods explored in the literature for improving SD are included in **Table 1**.

Drug delivery through the skin is a significant concern in dermatological procedures.^{3,4} Recently, advancements in technology have led to the development of laser induced microjet device that utilize laser energy to deliver a sufficient amount of medication to the desired depth of the skin rapidly and evenly without causing significant damage.⁵⁻⁷ This technology operates with high-speed jet pressure, generating strong vibrations and shocks within the dermis at a frequency of 30–40Hz, which can provide physical signals of mechanotransduction to the cells.⁷ Repetitive tapping and micro-tearing can serve as important signals for skin regeneration. Among various needleless injection devices developed recently, laser induced microjet device stands out for its ability to achieve the highest speed of 40Hz.

This study has utilized laser-induced micro-jet injectors with poly-D,L-lactic acid (PDLLA) as an approach for treating patients with SD.

2 | METHODS

Four female participants with SD were included in this investigation. The treatment involved the precise administration of PDLLA (Juvelook, VAIM Global, South Korea) solution using the microjet injection system (Mirajet, JSK Inc., South Korea), conducted either once or twice monthly for a total of five sessions. Minimal post-procedural side effects were observed, mainly transient bleeding.

This retrospective case series included women aged 32, 37, 53, and 28, enrolled between February 2023 and June 2023. These adult patients sought treatment for SD on their buttocks, thighs, and abdomen, all classified as Fitzpatrick Skin Types IV. Inclusion criteria required mild-to-moderate visibility of SD, while exclusion criteria encompassed recent procedures such as energy-based devices within the past 6 months. They were measured in the Striae Distensae Severity Scale (SDSS) with categories of mild, moderate, severe, and extremely severe.⁸

To alleviate discomfort, a topical anesthetic cream containing lidocaine and prilocaine was applied to the treatment area 30min prior to the procedure. For SD treatment, a mixture of lidocaine and epinephrine was added to the drug to minimize bleeding and pain, administered at low energy levels before the main treatment. The procedure involved overlapping injections

TABLE 1 Methods explored in the literature for improving striae distensae.

Method	Description
Topical treatments	Creams containing tretinoin (a retinoid) can restore collagen and make stretch marks less noticeable, though tretinoin should not be used during pregnancy. Topical hyaluronic acid can increase skin elasticity and reduce the visibility of stretch marks. Applying moisturizers to affected areas regularly can make stretch marks less noticeable
Microdermabrasion	A procedure to remove dead skin cells, improving the appearance and texture of the skin
Microneedling radiofrequency	Stimulates collagen production by creating tiny holes in the skin's surface and using heat energy from radiofrequency to help improve the appearance of stretch marks
Laser therapy	Effective for both red and white stretch marks. Pulsed dye laser therapy can be effective for early red striae. Fractional non-ablative laser can aid in the regeneration of older white striae
Ultrasound	High-intensity focused ultrasound can stimulate collagen production to improve the appearance of stretch marks
Platelet-rich plasma (PRP)	Used in conjunction with microneedling, PRP involves injecting a small amount of the patient's blood processed and injected into stretch marks
Chemical peels	Application of chemical substances to the skin can promote exfoliation, improving the appearance of stretch marks
Poly-D,L-lactic acid (PDLLA)	Recently introduced and used in South Korea, these treatments show promising results in quickly regenerating not only challenging stretch marks but also wider areas affected by them

rather than dropping the nozzle, which proved advantageous in reducing pain and facilitating micro-incision (Video S1). In cases of injecting strong energy with rounded particles such as PDLLA, minor bleeding was observed, necessitating immediate pressure treatment as the procedure progressed through the treatment area. Effective pressure treatment post-procedure can reduce the duration of residual bruising. During the procedure, minor bleeding was managed by wiping the area with gauze soaked in a 10% dilution of hydrogen peroxide and epinephrine, aiding in hemostasis and visibility.

Patient improvement was assessed before the procedure and at 32 weeks using the Global Aesthetic Improvement Scale (GAIS) by two physicians, who assigned scores ranging from -1 to 3. Patient satisfaction with aesthetic outcomes was self-evaluated on a scale of 0 to 3 at the conclusion of the procedure and again at 32 weeks, with higher scores indicating greater satisfaction levels.

3 | RESULTS

All assessments from both the GAIS and the patient satisfaction scale indicated positive results during the 32-week follow-up. See Table 2 for a summary of all results.

3.1 | Case 1

A 32-year-old woman underwent the buttock SD treatment, receiving a total of five treatments. She reported an 8-year history of stretch marks, which developed during rapid weight gain in her mid-20s. Initially, both physicians assigned a score of severe on the SDSS. After 32 weeks, improvements were noted, with the severity grading reducing to mild. The GAIS scores from both physicians indicated significant improvement (score 2) compared to the initial assessment. The patient herself expressed satisfaction, rating her outcome as 1 on a 4-point questionnaire. Side effects included petechiae lasting for 4 days.

TABLE 2 An overview of the assessment scores used in the study. The Striae Distensae Severity Scale (SDSS) scores, ranging from mild to extremely severe, were determined independently by two physicians before and 32 weeks after treatment. These scores indicate the severity of the striae distensae present on the patients' bodies. Additionally, the Global Aesthetic Improvement Scale (GAIS) scores were evaluated by both physicians after 32 weeks of treatment, reflecting the overall improvement in aesthetic appearance. Furthermore, patient satisfaction scores, obtained through self-reporting using a 4-point questionnaire, indicate the level of satisfaction with the treatment outcome.

Patient	Physician 1			Physician 2			Patient satisfaction score
	SDSS pre-treatment	SDSS post-Treatment	GAIS	SDSS pre-treatment	SDSS post-Treatment	GAIS	
1	Severe	Mild	2	Extremely severe	Mild	2	1
2	Extremely severe	Moderate	2	Extremely severe	Moderate	2	1
3	Severe	Mild	1	Severe	Moderate	1	2
4	Extremely severe	Severe	2	Extremely severe	Moderate	2	2

3.2 | Case 2

A 37-year-old woman underwent abdominal SD treatment, undergoing a total of seven treatments. She had a history of abdominal stretch marks for 2 years following the birth of her first child. Initially, both physicians assigned a score of extremely severe on the SDSS. After 32 weeks improvements were observed, with the severity grading decreasing to moderate (Figure 1). The GAIS scores from both physicians indicated significant improvement (score 2) compared to the initial assessment. The patient herself expressed satisfaction, rating her outcome as 1 on a 4-point questionnaire. Side effects include bumpiness of 4 days and petechiae lasting for 9 days.

3.3 | Case 3

A 53-year-old woman underwent the thigh SD treatment, receiving a total of six treatments. She reported having thigh stretch marks for around 10 years due to rapid weight gain. Initially, both physicians assessed her condition as severe on the SDSS scale. After 32 weeks, improvements were noted, with the severity grading reducing to mild and moderate. The GAIS scores from both physicians indicated significant improvement (score 1) compared to the initial assessment. The patient herself expressed satisfaction, rating her outcome as 2 on a 4-point questionnaire. Side effects included petechiae lasting for 4 days.

3.4 | Case 4

A 28-year-old woman underwent the buttock SD treatment, undergoing a total of five treatments. She reported having buttock stretch marks since her early 20s due to rapid weight gain. Initially, both physicians assessed her condition as extremely severe on the SDSS scale. After 32 weeks, improvements were observed, with the severity grading decreasing to severe and moderate. The GAIS scores from both physicians indicated significant improvement (score 2)

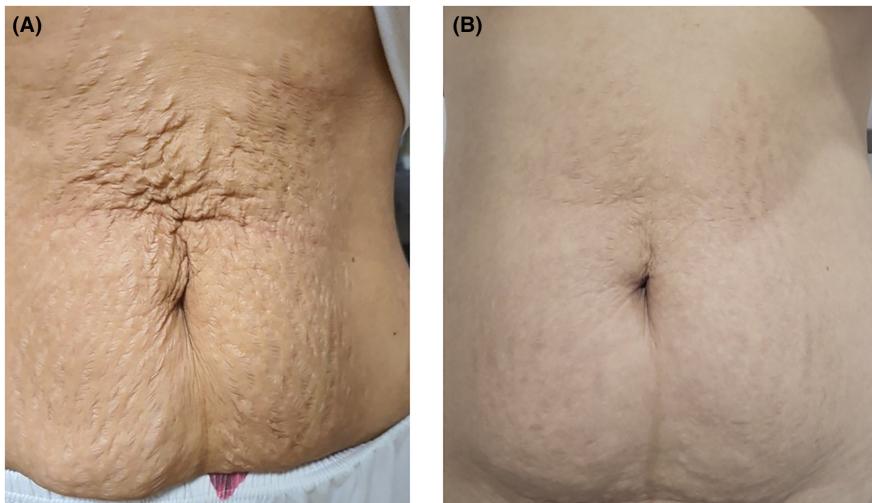


FIGURE 1 Treatment progression in a 37-year-old woman with abdominal striae distensae. The patient underwent a total of seven sessions. Initially, severity was rated as extremely severe on the SDSS (A), but after 32 weeks (B), it improved to moderate levels. The patient reported satisfaction with the outcome, scoring 1 on a 4-point questionnaire. However, she experienced side effects, including 4 days of bumpiness and 9 days of petechiae.

compared to the initial assessment. The patient herself expressed satisfaction, rating her outcome as 2 on a 4-point questionnaire. Side effects included petechiae lasting for 1 week.

All patients in this study had significant improvement in the appearance of their SD after a total of 5–7 treatments. Patient satisfaction of the procedure was also extremely high, due to the short nature of the treatment, quick recovery time and preclusion of needles or anesthesia.

4 | DISCUSSION

Patients have a strong preference for choosing non-invasive aesthetic procedures. The popularity of energy-based devices in recent years has been met with caution due to potential side effects that can occur such as erythema, blistering, infection and pigmentary changes.⁹ SD is a common skin condition that affects males and females, often appearing in areas such as the abdomen, breasts, thighs and buttocks, causing significant cosmetic concerns. Despite the array of treatment modalities available, including topical medications, energy-based devices, and surgical procedures, satisfactory results in treating this prevalent condition remain elusive. Here, we present the success of a laser-based, needleless microjet transdermal drug delivery system for the treating condition.⁷

Using lasers as a power source, the fundamental principle of creating a strong output is by concentrating energy on a medium that absorbs the laser and inducing the medium's rupture to generate micro-jets. Selecting the appropriate laser wavelength, pulse width, effective medium for laser absorption, and robust sealed chamber are necessary. A special liquid medium that absorbs the laser and a sub-chamber for storing the drug are separated by an elastic membrane. When the medium ruptures due to the laser, the elastic membrane rapidly expands, exerting strong pressure on the drug. This causes it to be ejected through small nozzles at speeds ranging from as low as 150 m/s to over 800 m/s, with an average of approximately 350 m/s.^{10–12} This speed is sufficient to penetrate the skin with liquid

substances. Research combining laser wavelengths and media has shown that Er-YAG Laser and moisture are an appropriate combination in terms of sustainability, reproducibility, and durability. Various efforts and expertise have been combined to maximize medium absorption and expansion, resulting in excellent efficiency of 10–40 Hz. The shape of the sub-chamber, like the upper chamber, has been designed over years of research to contain an appropriate volume of the drug while providing the best jet pressure discharge. Nozzle sizes ranging from 150 to 250 µm are achievable. The volume of drug that can be delivered at once is less than 1–5 µL/shot, and delivery depth can reach approximately 100–1500 µm.¹² Additionally, overlapping shots on the same area allow for the delivery of a large amount of drug into deeper layers. Shooting obliquely at the same area induces exfoliation of the upper epidermis along with the drug, aiding in scar regeneration and preventing re-adhesion. Plans for development include attaching injection needles or multi-needles to the nozzle and eliminating intermediate barriers to simplify the structure, increase durability, and adjust temperature for use or artificially cooling for injection. These methods are expected to expand the scope of application, overcoming the drawbacks of slow-speed needle-type automatic injectors.^{3,8,9}

It has been confirmed that the powerful rupture phenomenon and heat generation in the upper chamber, which absorbs the laser in such systems, do not cause physical damage to sensitive drugs such as cytokines emitted from the lower chamber, even when ejected at high speeds for extended periods. It has been observed that the temperature in the lower chamber does not exceed 40–45°C even after prolonged high-speed ejection.

Clinically, drugs with viscosities similar to non-cross-linked hyaluronic acid can be delivered to the dermis, and it is important to ensure uniform distribution of particles with different properties when mixed.¹³ The space where the drug is injected and dispersed is equipped with a reflux prevention valve system in the nozzle and drug injection port to ensure that the liquid drug progresses in one direction without backflow. Failure of these valves can significantly affect efficiency. It is essential to set the energy intensity stronger than the typical injection energy and speed to facilitate the

formation of initial jet pressure at around 10Hz. This preparation for generating jet pressure can be considered the most crucial step in the procedure. When the jet pressure is well established, the drug is observed to be ejected rapidly with a high-pitched sound, and the practitioner must be able to distinguish whether the high-speed jet pressure is being maintained to perform the procedure effectively. Laser settings are generally more favorable with shorter pulse durations, and selecting shorter pulses is advantageous for prolonged use. Operating with short pulse times is preferable as prolonged use can heat the medium and cause bubbles to form, leading to decreased efficiency.

The laser-induced microjet technique facilitates the delivery of various drugs, allowing for the injection of all liquid medications approved for medical use. These agents can also be delivered by manually or using other injection devices, underscoring the need for more potent and specific drugs to enhance efficacy. To optimize the effects of laser-induced microjet, it is essential to employ a suitable formulation capable of rapid injection with solid components. This approach maximizes the physical mechanotransduction effects on the dermis while ensuring a prolonged and safe duration of action. Clinically, excellent results have been observed using PDLLA agents featuring a rounded shape and mesh-like internal structure, characteristics unattainable with manual or traditional drug delivery methods. While PDLLA has traditionally served as a filler for volume restoration in depressed scars, leveraging laser-induced microjet for rapid and precise injection yields superior results.

Poly-L-lactic acid (PLLA) and PDLLA, both classified as biodegradable collagen stimulators, have become increasingly popular in aesthetic medicine.¹⁴⁻¹⁸ PLLA with smaller particles demonstrates favorable effects on dermal regeneration, addressing concerns such as wrinkles, skin regeneration, whitening, erythema, improvement of photoaging, and freckles. Conversely, PDLLA with larger particles is typically used for dermal volumization. A study by Seo et al.¹⁶ investigated the efficacy and safety of injectable dermal PDLLA for skin rejuvenation. Their findings indicated statistically significant improvements in signs of aging skin post-treatment, including fine wrinkles, skin texture, irregular pigmentation, telangiectasia, and facial erythema post-treatment. Moreover, diluting PDLLA slightly and administering it into the dermis in small amounts via the laser-induced microjet system can produce excellent results, particularly in treating challenging depressed scars.¹⁹ This method allows for simultaneous delivery of the drug and mechanotransduction effects, especially beneficial in severe cases of SD characterized by extensive loss of elastic fibers, leading to positive clinical outcomes.

Furthermore, the separation of PDLLA particles within the dermis enhances the area surrounded by the extracellular matrix, promoting skin regeneration. The potential risk of foreign body reactions is offset by the minimal amount of PDLLA injected in a single shot, ensuring safety.

The rapid onset of action and mechanotransduction effects achieved with laser-induced microjet, which are not attainable with

manual injection methods, are likely to drive its widespread adoption among dermatologists in the future.

5 | CONCLUSION

In conclusion, utilizing a needleless microjet injector with PDLLA presents a viable therapeutic option for treating SD. Typically, achieving satisfactory outcomes entails an average of 5–7 treatment sessions. Mild petechiae may commonly occur as a side effect.

AUTHOR CONTRIBUTIONS

All authors have reviewed and approved the article for submission. Conceptualization: Suk Bae Seo, Kyu-Ho Yi, Soo-Bin Kim. Writing—Original Draft Preparation: Suk Bae Seo, Kyu-Ho Yi, Soo-Bin Kim. Writing—Review & Editing: Suk Bae Seo, Kyu-Ho Yi, Soo-Bin Kim. Visualization: Suk Bae Seo, Kyu-Ho Yi, Soo-Bin Kim. Supervision: Suk Bae Seo, Kyu-Ho Yi, Soo-Bin Kim.

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There is no financial disclosure to report.

CONFLICT OF INTEREST STATEMENT

I acknowledge that I have considered the conflict of interest statement included in the "Author Guidelines." I hereby certify that to the best of my knowledge, no aspect of my current personal or professional situation might reasonably be expected to significantly affect my views on the subject I am presenting.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was performed in accordance with the principles of the Declaration of Helsinki.

CONSENT

Consent was received from the patients.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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