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REVIEW

Injectable Fillers for Atrophic Acne Scars: A Systematic Review of Mechanisms, Evidence, and Clinical Algorithms

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Background: Acne affects 9.4% of the global population, with the highest prevalence among adolescent males (12–25 years of age). More than 95% of patients develop persistent scarring, predominantly atrophic acne scars (AAS). These scars markedly impair facial aesthetics, psychological well-being, and quality of life, and increase the risk of depression and suicidal ideation. Conventional therapies (eg, Dermabrasion, Subcision and Traditional Ablative Lasers) show limited efficacy for shallow AAS and are associated with procedural pain, delayed onset of improvement, and a need for repeated sessions. Dermal fillers provide a promising alternative by delivering immediate volumetric correction and aesthetic enhancement while also stimulating long-term collagen production with minimal invasiveness and favorable safety profiles. They therefore represent a novel therapeutic approach for AAS.

Aim: This review systematically evaluates the clinical utility of dermal fillers for treating AAS and explores future diagnostic and therapeutic approaches.

Methods: We searched the PubMed and Web of Science databases for studies published in the past 10 years, categorizing and evaluating the efficacy and adverse effects of different dermal fillers for treating AAS.

Results: Twenty-four studies met inclusion criteria, involving collagen-based fillers, hyaluronic acid fillers, collagen stimulator fillers, autologous fat, and decellularized matrix fillers. All filler types demonstrated significant scar improvement. Effects ranged from 3–6 months to >24 months. CaHA, PCL, and autologous fat/SVF demonstrated ≥6-month durability. Transient erythema, edema, and ecchymosis were common. Infrequent events included nodules and hyperpigmentation. No severe complications were reported.

Conclusion: Multiple studies indicate that dermal fillers offer advantages over conventional therapies for atrophic scars. They provide immediate volumetric correction and stimulate long-term collagen production, with less tissue trauma than traditional approaches. Specific formulations also enhance skin hydration and may slow aging processes. Collectively, these benefits demonstrate substantial clinical promise, particularly when incorporated into combination therapies.

Keywords: acne scars, fillers, HA, CaHA, PMMA

Introduction

Acne, a prevalent dermatological condition affecting 9.4% of the global population,[1] primarily emerges during adolescence, with a notable impact on males. It significantly affects functional status, interpersonal relationships, social functioning, and mental health.[2] An estimated 95% of patients with acne develop scars, predominantly atrophic scars, subdivided into rolling, boxcar, and icepick types.[3–6] The uneven texture of these scars significantly impairs facial aesthetics, profoundly affecting patients' psychological well-being.[7] Furthermore, acne scars reduce quality of life and increase the likelihood of depression and suicidal thoughts.[2,8]

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In acne lesions, inflammation primarily occurs in the infundibulum of the hair follicle, leading to scar formation below the skin surface.[9] This depth difference causes surface contraction and a depressed appearance.[10] Studies propose that susceptible individuals in the initial stages of acne exhibit increased transforming growth factor-β1 expression, resulting in enhanced extracellular matrix degradation and reduced keratinocyte proliferation[11] The severity and duration of the inflammatory response are linked to the development of Atrophic Acne Scars (AAS).[12] Prolonged inflammation can lead to breakdown of the sebaceous gland structure, culminating in the formation of AAS.

A range of interventions has been investigated, including surgical procedures, radiofrequency therapy, microneedling, laser treatment, and autologous platelet-rich plasma (PRP) therapy.[13–16] Some AAS with thin bases respond poorly to multiple sessions of fractional laser or radiofrequency treatment (such as radiofrequency microneedling). Injectable filler therapy can rapidly correct tissue defects and stimulate collagen production, opening new possibilities for treating depressed scars. Accordingly, this review systematically evaluates the clinical utility of dermal fillers for treating AAS, synthesizes the latest evidence on mechanisms, safety and efficacy, and explores future diagnostic and therapeutic approaches for this condition.

New Hopes from Filler Applications

The management of AAS remains a significant challenge for plastic surgeons. Although numerous treatment approaches are available, no standardized, most effective treatment protocol has been established (Figure 1). Nevertheless, these approaches have inherent limitations, with outcomes frequently falling short in terms of cost-effectiveness, treatment

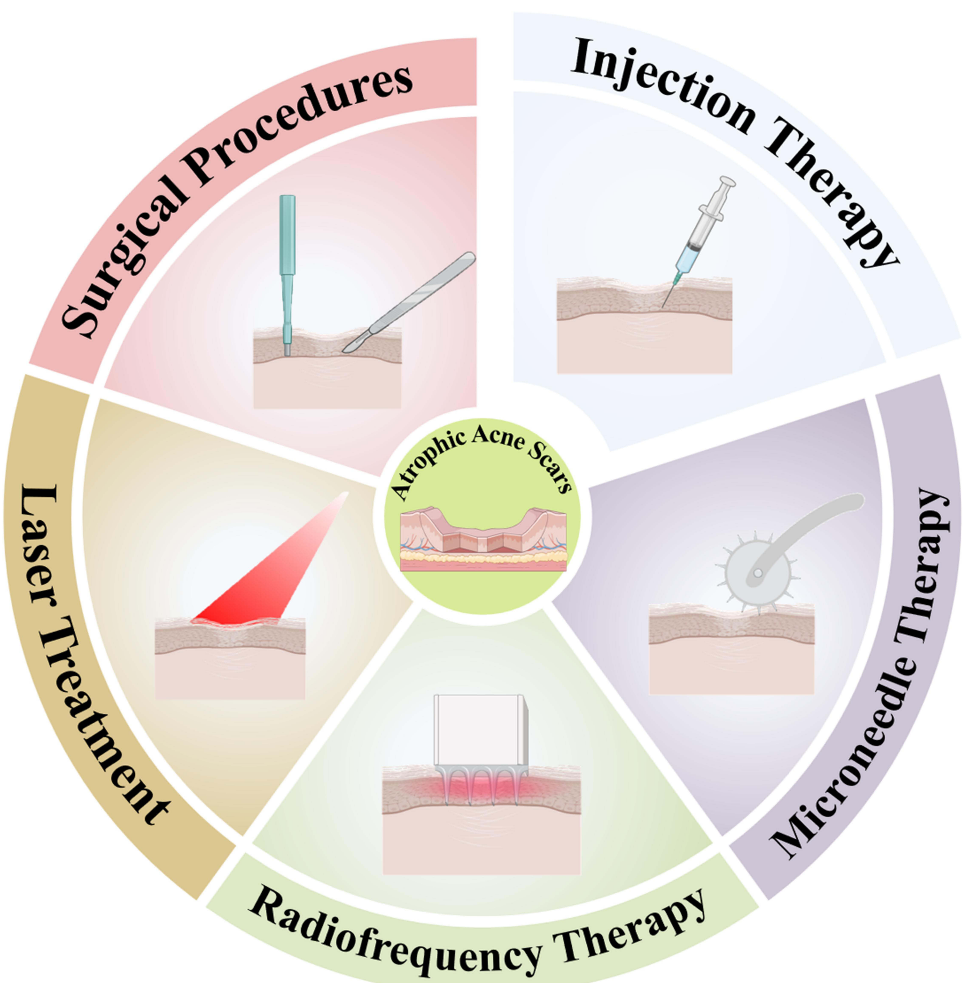

Figure 1 Treatment approaches for AAS.

duration, recurrence rates, and associated complications. For example, laser therapy can induce considerable discomfort, microneedling necessitates multiple sessions, and PRP therapy is characterized by a delayed onset of action and requires repeated injections. Patients often encounter difficulties in achieving noticeable improvements during the initial phases of treatment.

Injectable aesthetic treatments are crucial in plastic surgery, with dermal fillers gaining widespread use in cosmetic procedures. Various filler materials have been applied to the treatment of AAS. Filler therapy offers immediate volume restoration, aesthetic enhancement, long-term collagen stimulation, minimal invasiveness, and a favorable safety profile. Advancements in technology and new materials provide promising prospects for patients. This paper presents a detailed review of tissue filler treatments for AAS (Figure 2).

Methods

We conducted a comprehensive literature search using PubMed and Web of Science to identify relevant studies published between January 1, 2015 and January 31, 2025. Search terms combined keywords such as "Acne Scars", "Atrophic Scars", "Collagen", "autologous fat", and "Dermal Fillers" using Boolean operators to ensure thorough coverage. Titles and abstracts of retrieved records underwent initial screening, followed by full-text assessment of potentially eligible studies against predefined inclusion and exclusion criteria. We included studies involving patients of any age or gender with any type of acne scar treated with synthetic dermal fillers (eg autologous fat, calcium hydroxylapatite, collagen, hyaluronic acid, poly-L-lactic acid, polycaprolactone, or polymethylmethacrylate); only studies published in English were included. Eligible studies reported treatment efficacy, adverse events, or safety outcomes. Studies not using injectable fillers as the primary intervention or treating unrelated conditions were excluded. We also excluded studies with very small sample sizes, which was pre-defined as single-arm studies with fewer than 10 participants or comparative studies with fewer than 5 participants per group. During full-text screening, a total of 17 studies were excluded based on this criterion. In total, 24 studies met all criteria and were included in the qualitative synthesis.

Collagen-Based Fillers

Collagen-based fillers are among the earliest biomaterials used for skin repair and are categorized as animal-derived or recombinant humanized collagen. Animal-derived collagen, sourced from bovine, porcine, or fish skin, has a complex composition and can trigger immunogenic responses.[17] Concerns about immunogenicity, hypersensitivity reactions, and prion infection have limited its use.[18,19] Recombinant humanized collagen, produced by inserting human collagen genes into host cells, offers high purity, consistency, absence of animal-derived risks, and enhanced biocompatibility.[20] Clinicians have effectively treated AAS with various collagen preparations, with filling effects lasting approximately 6 months.[21–24]

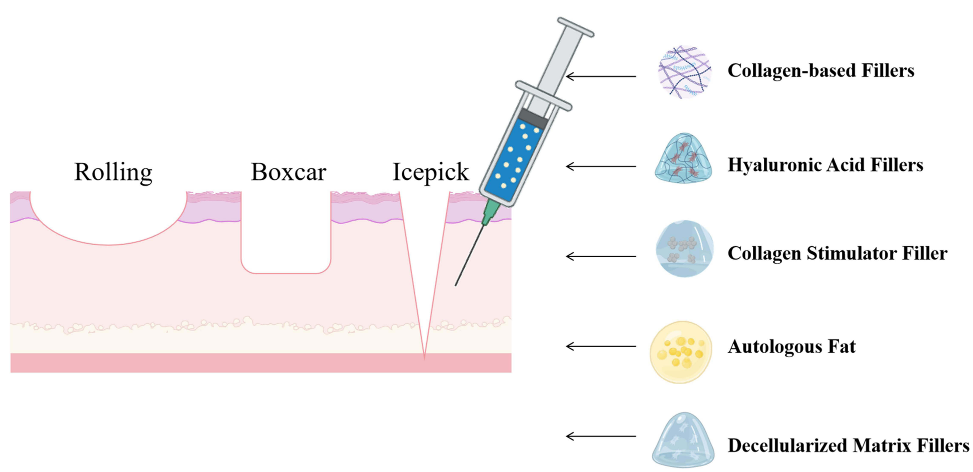

Figure 2 Injection Therapy for AAS.

Hyaluronic Acid Fillers

Hyaluronic acid (HA) is a naturally occurring acidic mucopolysaccharide with consistent composition across species. About half of the HA in the human body resides in the skin.[25] HA is characterized by excellent biocompatibility, lack of immunogenicity, and high water-binding capacity. Upon hydration, it forms a flexible, viscous matrix. When introduced into the dermis, HA promptly enhances skin thickness and moisture content, resulting in immediate aesthetic improvement. It also displays anti-inflammatory properties and promotes collagen production.[3,26] These attributes have led to widespread use of HA in facial aesthetic procedures in recent years. Sipperstein et al[27] conducted a randomized, placebo-controlled trial involving 15 patients with AAS, demonstrating a notable decrease in Global Scar Grading System (QGSGS) scores from baseline in the HA group. A subsequent 2-year follow-up[28] showed sustained efficacy without significant diminution, affirming the enduring reparative benefits of HA injection. Mehrabi et al[29] reported that formulations combining high-molecular-weight HA and low-molecular-weight HA produce more effective long-term outcomes than traditional crosslinked dermal fillers. This increased effectiveness may reflect the capacity of HA complexes of different sizes to interact with multiple cell-surface receptors and regulate cellular functions, thereby decreasing HA degradation and continuously promoting collagen regeneration.[30,31] Sparavigna et al[32] demonstrated notable therapeutic outcomes in individuals with AAS using a high-concentration (4.5%) hybrid cooperative complex of hyaluronans in conjunction with a biplane injection method. Needle-free, spring-loaded jet-injection technology has been used for transdermal delivery of vaccines and insulin for an extended period.[33] Kaminaka et al[34] applied needle-free electronic pneumatic HA injection for facial AAS. The EPIHA method showed substantial effectiveness, with rolling scars improving more than boxcar and icepick scars.

Collagen Stimulator Fillers

To address the limitations of HA fillers, such as short lifespan and restricted capabilities, the aesthetic medicine field has introduced a class of fillers with collagen-stimulating properties. These agents trigger the natural collagen production process of the skin, leading to prolonged tissue rejuvenation and volume enhancement. Commonly used collagen stimulators include polycaprolactone (PCL), poly-L-lactic acid (PLLA), poly-D, L-lactic acid (PDLLA), and calcium hydroxylapatite (CaHA).

CaHA Fillers

Calcium hydroxylapatite (CaHA) is a naturally occurring mineral present in human bones and teeth and can be produced artificially using various deposition methods.[35] Owing to excellent biocompatibility and biodegradability, CaHA has been widely used in non-surgical cosmetic procedures and is the second most commonly used dermal filler, representing 5.9% of all fillers.[36] Facial injections of CaHA have been shown to significantly improve aesthetic outcomes.[37] CaHA formulations typically comprise microspheres 25–45 μm in diameter dispersed in a gel carrier.[38] The gel component offers immediate or short-term volumetric support, whereas the porous structure of the microspheres attracts nearby fibroblasts and promotes continuous collagen production.[39–41] Antonino et al[42] studied women with moderate to severe AAS, assessing outcomes with digital macro photography, Vectra H2, and Antera 3D. The clinical efficacy of CaHA injection was superior to that of placebo, whereas combining CaHA with high-intensity focused ultrasound (HIFU) did not enhance efficacy compared with monotherapy. Goldberg et al[43] treated 10 patients with different AAS types using CaHA fillers, finding substantial improvement in rolling scars and limited effectiveness for icepick scars.

PLLA Fillers

PLLA, a biodegradable synthetic polymer within the polylactic acid (PLA) family, demonstrates exceptional biocompatibility and typically does not elicit significant immune or allergic reactions.[44] PLLA fillers are supplied as microspheres 40–63 μm in diameter, which inhibits phagocytosis by macrophages.[45,46] Soft-tissue enhancement can persist for up to 2 years.[47] Sadick et al[48] reported the use of PLLA injections in a 60-year-old Caucasian female patient with a history of CO2 laser therapy, dermabrasion, and trichloroacetic acid peels for AAS, all of which had yielded unsatisfactory results;

PLLA injection therapy resulted in high patient satisfaction. Several studies[49–51] have shown that PLLA effectively improves AAS, particularly in individuals with thin dermis, with therapeutic benefits lasting as long as 4 years.

PDLLA Fillers

PDLLA, a synthetic polymer produced by random copolymerization of D-lactic acid and L-lactic acid monomers, exhibits an amorphous structure that results in accelerated degradation and enhanced flexibility.[52] PDLLA microspheres sized 30–50 µm can induce fibroblast activation via nonspecific inflammatory reactions, thereby facilitating deposition of type I collagen. However, its biostimulatory effect is comparatively short-lived relative to PLLA. Combining PDLLA with fillers such as HA can extend therapeutic effectiveness. Unlike PLLA, the reduced crystallinity of PDLLA lowers the likelihood of post-injection nodules, making it more suitable for superficial scar treatment or combination therapy. A South Korean study included five patients treated with laser-assisted, needle-free microjet injection of poly-D,L-lactic acid. After five treatment sessions, improvements in AAS and skin texture were observed, with high patient satisfaction.[53]

PCL Fillers

PCL is an aliphatic organic polymer recognized for its excellent biocompatibility, biodegradability, and absorbability. It is employed as a collagen stimulator in a novel filler that contains synthetic PCL microspheres (20–50 µm in diameter) suspended in a carboxymethyl cellulose (CMC) gel. The CMC gel serves as a carrier, provides an immediate filling effect, and is gradually absorbed by macrophages over 2–3 months. As the gel resorbs, the PCL microspheres become exposed within the tissue and biologically stimulate type I collagen[54] production, resulting in durable contouring effects. Lotfi et al[15] evaluated PCL combined with radiofrequency-assisted subcutaneous isolation for AAS and observed significant improvement across all AAS appearance categories. Khattab et al[55] treated 24 patients with AAS using either PCL thread engraving or microneedling combined with PRP; both approaches produced marked clinical improvement, although patient satisfaction was higher with PCL thread engraving.

PMMA Fillers

Polymethylmethacrylate (PMMA) is a long-lasting synthetic filler consisting of methyl methacrylate microspheres (30–120 µm in diameter) suspended in a bovine collagen carrier. It is FDA-approved for AAS treatment and is often used in facial rejuvenation procedures targeting regions such as the jawline and temples.[56] PMMA microspheres provide immediate structural support to deep dermal or subcutaneous deficits and induce a controlled inflammatory response that leads to fibroblast encapsulation and collagen deposition, promoting sustained tissue restoration.[57] In 42 patients, Joseph et al[58] reported a ≥1-point improvement in ASAS score at 4 and 7 months after PMMA injection; both clinicians and participants noted significant aesthetic enhancement on the GAIS. Solomon[59] reviewed PMMA use for AAS and found that most patients experienced substantial improvement and exceptionally high satisfaction.

Autologous Fat

Autologous fat serves as an optimal filler due to complete biocompatibility, ample availability in the body, seamless integration into host tissue, favorable plasticity, and potential for long-lasting effects.[60] Although adipocytes were traditionally regarded as inert energy storage units, numerous studies have highlighted their notable capacity for proliferation and regeneration.[61,62] Comprising mature adipocytes and a stromal vascular component (SVF), adipose tissue consists of these two primary constituents.[63] The pivotal characteristic of SVF cells is exceptional reparative capability, facilitated by stem cells that synergize with growth factors to stimulate angiogenesis, collagen remodeling, and skin barrier restoration.[64] Shetty et al[65] evaluated the effectiveness of a single autologous fat graft combined with three PRP injections in patients with AAS. After a three-month follow-up, both groups showed significant improvement in scars, and no statistically significant difference was observed between the two treatment groups. Nilforoushzadeh et al[66] used autologous fat to treat facial AAS in a cohort of 9 adult patients and reported significant improvements in pore size, hyperpigmentation, skin tone, melanin levels, skin elasticity, and transepidermal water loss (TEWL) after a 6-month follow-up. Vingan et al[67] employed microparticle fat aspiration injection for the treatment of AAS. Evaluation at 3 and 6 months revealed enhanced clinical outcomes based on clinician and patient Global Aesthetic Improvement Scale (GAIS) scores. Moreover, an elevated decay coefficient at the 6-month follow-up suggests remodeling and recombination of collagen during the study period.

Decellularized Matrix Fillers

Decellularized matrix is a novel regenerative material derived from the extracellular matrix (ECM). Obtained through a decellularization process, it maintains biologically active components and structure. A key advantage of decellularized matrix is the ability to preserve the natural three-dimensional architecture and bioactive factors of the ECM. This complex organic entity contains signaling molecules that play a crucial role in inducing and facilitating cellular adhesion, proliferation, differentiation, and tissue formation. Particles of decellularized matrix, typically 50–200 μm in diameter, are injected by minimally invasive techniques to address concave scars. The porous structure of these particles enables recruitment of host stem cells and fibroblasts, thereby promoting angiogenesis and tissue regeneration. Park et al[68] used microparticulated decellularized dermal matrix in conjunction with PRP injection to address AAS in a cohort of 16 patients. After 3 months, both study groups showed improvement in AAS. Notably, the combined treatment group exhibited significantly reduced ASAS scores and ECCA weight scores compared with the PRP control group. Table 1 summarizes the main results.

Table 1 Results of Included Studies

Authors	Type of Filler	Combination Treatment	Results	Adverse Effects	Sample Size	LOE Grade
Sage et al[24]	Porcine Collagen Filler	Monotherapy	Scar scores decreased by 24% at 3 months and by 22% at 6 months.	1 case of localized delayed-onset erythema.	20	2b
Sparavigna et al[32]	HA	Monotherapy	Mean scar depth decreased by 20% at 4 months post-treatment (p<0.0001). Goodman & Baron scar grading system scores improved by 31% from baseline to endpoint (p<0.0001).	Erythema, swelling; ecchymosis; induration	15	4
Amer et al[16]	HA	Monotherapy	HA Group: 82.9% of patients achieved "significant improvement" (Goodman qualitative score ≥3). PRP Group: 85.4% of patients achieved "significant improvement" The difference between groups was not statistically significant (p > 0.05).	Transient edema, ecchymosis, and subcutaneous induration.	41	2b
Kaminaka et al[34]	HA	Monotherapy	Treated Side: 48.3% of scars achieved ≥50% volume reduction at 3 months post-final treatment; control side success rate was 0% (p<0.0001). Rolling scars improved most significantly (22% volume reduction), while ice pick and boxcar scars showed limited effects (p<0.05).	Transient stinging sensation in 10% of patients	20	1b
Ebrahim et al[69]	HA PLLA Threads	Subcision	HA Group: 94.1% of patients achieved ≥50% scar volume reduction, significantly better than control (67.3%, p<0.0001). PLLA Thread Group: 82.4% improvement, efficacy intermediate between HA and control. Ice pick scars responded best to HA filler (91% improvement), while rolling scars responded better to PLLA thread support (78% improvement).	Transient pain, edema, hyperpigmentation thread palpability.	34	4

(*Continued*)

Table 1 (Continued).

Authors	Type of Filler	Combination Treatment	Results	Adverse Effects	Sample Size	LOE Grade
Mehrabi et al[29]	HA	Monotherapy	Low MW HA Group: Significant scar volume reduction at 1 month (p<0.001), but limited improvement in elasticity and distensibility. High MW HA Group: No significant change at 1 month, but scar volume reduction exceeded the Low group at 6 months (p<0.01), with 18% improvement in skin elasticity.	Erythema, ecchymosis, nodules.	30	2b
Akerman et al[70]	HA	1540nm Non-Ablative Erbium Glass Laser	GAS scores indicated 25–50% scar volume reduction. Improvement rate for ice pick scars was significantly higher than for boxcar scars (p<0.05).	Swelling, erythema.	20	4
Artzi et al[3]	HA	Monotherapy	Scar Depth Improvement: Treated side QGSGS score decreased by 7.2 points (p=0.003), significantly better than the 2.1-point decrease on the control side	Erythema, ecchymosis, nodules	20	4
Siperstein et al[27]	HA	Monotherapy	Treated side QGSGS score decreased by 6.6 points from baseline (p=0.008), significantly better than the 1.7-point decrease on the placebo side.	No serious adverse events reported in the study	15	1b
Koren et al[71]	CaHA	FACL or NAFL	Taged treatment with FACL followed by CaHA yielded the highest scores on the Global Assessment Scale (GAS). Both patient and physician assessments showed a significantly higher proportion achieving ≥50% scar volume reduction compared to other protocols (p<0.001). Ice pick scars responded best to FACL+CaHA (68% improvement), while boxcar scars responded better to NAFL+CaHA (52% improvement).	Erythema lasting 7–10 days, edema for 2–3 days, transient hyperpigmentation in 22% (resolved within 6 months). Localized ecchymosis in 15% (resolved within 1 week), mild induration in 3% (resolved with massage).	45	1b
Antonino et al[42]	CaHA	HIFU	CaHA monotherapy significantly improved wrinkles, skin texture, and AAS at 1 month (p<0.05). Combining CaHA with HIFU therapy did not demonstrate significantly greater benefit compared to HIFU monotherapy.	Transient stinging, hyperpigmentation.	60	1b
Sapra et al[50]	PLLA	Monotherapy	Mean PSIS and BESIS scores progressively improved, decreasing from the 2nd treatment (3.4–3.9 and 3.7–3.9) to follow-up (2.4–2.9 and 2.2–2.5). Patients assessed with the VISIA-CR system achieved the highest rates of PSIS ≤2 (63.6%) and BESIS ≤2 (68.2%) at follow-up. SASIS scores also decreased progressively from the 2nd treatment (3.4 and 1.4) to follow-up (2.4 and 2.5). Patients imaged with VISIA-CR achieved the highest rates of SASIS ≤2 and STSS ≥3 at follow-up (45.5% and 54.5%, respectively).	Erythema, ecchymosis, nodules	22	4

(*Continued*)

Table 1 (Continued).

Authors	Type of Filler	Combination Treatment	Results	Adverse Effects	Sample Size	LOE Grade
Beer et al[51]	PLLA	Monotherapy	Scar severity significantly decreased after 7 treatments, with a maximum reduction of 46.4% at treatment 7. While cumulative reduction increased with continued treatment, changes were not significant after reducing injection volumes over the next 6 treatments. Subject ratings showed significant reduction in scar severity after 7 treatments; satisfaction scores showed an upward trend but were not significant.	Erythema, ecchymosis, nodules	26	4
Lotfi et al[15]	PCL	RF-Microneedling	Ice pick scars: 47% reduction in number ($p=0.002$); Rolling scars: 53% reduction ($p<0.001$); Boxcar scars: 38% reduction ($p=0.023$). Total Scar Burden: Goodman & Baron score improved by 41% from baseline to endpoint ($p<0.001$).	Transient edema; ecchymosis; subcutaneous induration; hyperpigmentation. No long-term complications, vascular compromise, infection, or granuloma formation occurred.	15	4
Lotfi et al[15]	PCL	RF-Assisted Subcision	At 3 months post-final treatment: Ice pick scar number decreased by 47% ($p=0.002$), rolling scars by 52% ($p<0.001$), boxcar scars by 31% ($p=0.023$). Scar volume and surface area decreased by 47% and 43%, respectively. The VISIA-CR system showed a significant reduction in skin roughness.	Swelling, erythema, transient nodules, ecchymosis.	15	4
Khattab et al[55]	PCL	Monotherapy	PCL Thread Group: 95.8% of patients achieved "significant improvement" (≥50% scar depth reduction) at 6-month follow-up, significantly superior to the Microneedling + PRP group (83.3%, $p<0.0001$). Rolling scars showed the most significant improvement (22% volume reduction), while ice pick scars showed limited effect ($p<0.05$).	Localized pain, bruising, swelling, and acne.	24	2b
Joseph et al[58]	PMMA	Monotherapy	ASAS scores improved by ≥1 point at both 4 and 7 months post-initial treatment. Both physicians and subjects on GAIS observed significant aesthetic improvement. QOLIS scores showed that 30% of subjects had ≥1 point improvement post-treatment.	Bruising and ecchymosis	42	4
Hevia et al[56]	PMMA	Monotherapy	Jawline scores significantly decreased from baseline to 24 months ($p<0.01$), with a mean improvement of 1.8 points (from baseline 3.1 to 1.3). PGAIS showed 90% of patients achieved "Improved" or "Much Improved" at 24 months.	Erythema, ecchymosis, nodules	30	4
Solomon et al[21]	PMMA	Monotherapy	99% of patients reported improvement and satisfaction	Nodules, edema	38	4

(*Continued*)

Table 1 (Continued).

Authors	Type of Filler	Combination Treatment	Results	Adverse Effects	Sample Size	LOE Grade
Behrangi et al[64]	Autologous Fat	SVF	At 1 month post-treatment, the intervention group showed significantly greater improvement in scar volume, area, and depth compared to the control group (p<0.05). Rolling scars showed the most significant improvement (22% volume reduction), while ice pick scars showed limited improvement.	Transient edema; bruising; subcutaneous induration;	40	1b
Nilforoushzadeh et al[66]	Autologous Fat	PRP + SVF + Fat	At 6-month follow-up, 66.6% of patients achieved "good to excellent" improvement assessed by VISIA-CR, with ≥50% scar volume reduction. Skin elasticity (Cutometer) increased by 22%, and TEWL decreased by 18%.	Edema; bruising	45	4
Vingan et al[67]	Micronized Lipoaspirate	Monotherapy	At 6-month follow-up, both Clinician Global Aesthetic Improvement Scale (CGAIS) and Subject Global Assessment Scale (SGAIS) showed significant improvement (p<0.05). Scar volume was reduced by ≥50%. Skin elasticity (Cutometer) increased by 22%.	Only 1 case of transient milia.	14	4
Shetty et al[65]	Autologous Fat	Monotherapy	Autologous Fat Group: Scar score improvement rate was 61.23%±9.48% (p<0.001). Rolling scars showed the most significant improvement. PRP Group: Improvement rate was 44.16%±7.28% (p<0.001), with better efficacy for boxcar scars. Inter-group comparison: Difference between groups was not statistically significant (p=0.23).	Erythema, ecchymosis, Induration.	60	1b
Gronovich et al[72]	Autologous Fat	Laser	All patients showed scar improvement at 6-month follow-up; 73% achieved ≥50% scar volume reduction, with 43% achieving ≥75% improvement. Traumatic scars (especially new scars treated within 30 days post-injury) responded more significantly. Acne scars showed marked improvement in flattening and pigmentation irregularity.	Transient milia. Erythema. Swelling.	32	4

Notes: LOE Grade Definition (Oxford Centre for Evidence-Based Medicine 2011) 1b: High-quality prospective randomized controlled trial (RCT), randomized comparative trial. 2b: Prospective cohort study, split-face controlled study, comparative study. 4: Prospective single-arm study, case series (sample size ≥10 cases), pilot study.
Abbreviations: PLLA, Poly-L-lactic acid; HA, Hyaluronic Acid; CaHA, Calcium Hydroxylapatite; PCL, Polycaprolactone; PMMA, Polymethylmethacrylate; mADM, Micronized Acellular Dermal Matrix; SVF, Stromal Vascular Fraction; PRP, Platelet-Rich Plasma; FACL, Fractional Ablative Carbon Dioxide Laser; NAFL, Non-Ablative Fractional Laser; HIFU, High-Intensity Focused Ultrasound; RF, Radiofrequency; MW, Molecular Weight; LOE, Level of Evidence.

Discussion

Acne scarring remains a persistent challenge for plastic surgeons, particularly affecting adolescents physically and psychologically. Although various treatments have been developed, many are time-consuming, traumatic, and require multiple sessions for noticeable improvement. Conventional methods often fail to address deep or wide scars effectively. In contrast, filler treatments can provide prompt and substantial improvement in scar depression with a single injection. The minimally invasive nature of this approach is well received by patients, and the reversibility of most fillers allows adjustment through enzymatic degradation. For more profound scars, therapeutic benefit can be achieved with filling injections. Fillers are broadly categorized into two types: volume fillers, such as HA, injected directly into scars to enhance the skin, and biostimulatory fillers PLLA, PMMA, CaHA, and PCL, which increase volume immediately and stimulate natural collagen production.[73]

In addition to the dermal fillers and autologous cell- and tissue-based regenerative therapies discussed above, autologous platelet concentrates (APCs) have emerged as a promising minimally invasive treatment option for AAS. Their key advantages include an autologous origin, easy accessibility, low immunogenicity, and multitarget regenerative properties.[74] The current international classification system divides APCs into four main types: pure platelet-rich plasma (P-PRP), leukocyte-rich platelet-rich plasma (L-PRP), pure platelet-rich fibrin (P-PRF), and leukocyte-rich platelet-rich fibrin (L-PRF).[75] A growing body of evidence suggests that APCs significantly promote wound healing and tissue regeneration, improve graft survival, and reduce the risk of adverse events Notably, they have shown favorable clinical outcomes in the management of skin defects. Therefore, APCs hold promise as a valuable therapeutic approach for the future treatment of refractory AAS.[76–78]

In cases with significant dermal loss in deep scars, conventional treatments such as laser therapy and chemical peels may not effectively promote rapid collagen regeneration. Biostimulatory fillers present a more favorable option because they provide immediate filling effects and stimulate collagen regeneration for long-term therapeutic benefit.

Comprehensive Therapy

The management of acne scars frequently presents challenges when relying on a single therapeutic approach. A prevailing treatment paradigm integrates multiple modalities to enhance efficacy.[79] Koren et al[71] conducted a comparative analysis of EBD alone, CaHA alone, and a combined approach, concluding that CaHA with EBD outperforms either treatment alone. Ebrahim et al[69] assessed subcutaneous isolation in conjunction with crosslinked HA or PLLA for scarring resulting from AAS. Following surgical intervention alone, 67.3% of patients demonstrated notable clinical enhancement, whereas combination therapy yielded significant clinical improvement in 94.1% and 82.4% of patients, respectively. Abdelwahab et al[80] compared subcutaneous separation combined with either dotmatrix CO2 laser or crosslinked HA against subcutaneous separation alone and reached a consistent conclusion. Gronovich et al[72] demonstrated that combining autologous fat grafting with a 154-nanometer, non-stripping erbium laser dot matrix can safely and effectively treat AAS, improving scar appearance and texture.

Future research should explore combination approaches, such as integrating fillers with dot-matrix CO_2 laser therapy to enhance scar edge smoothness and using botulinum toxin to relax local muscle tension for the prevention and treatment of depressed scars.[81]

Adverse Reactions and Complications

Complications related to filler therapy are influenced by filler type, injection technique, and individual patient characteristics. These events range from mild injection-site reactions to more severe outcomes such as granulomas and allergic reactions.[82,83] Commonly reported complications include petechiae, edema, pain, and bleeding at the injection site; most patients recover quickly. Superficial placement can cause skin discoloration and the Tyndall effect.[84] Rare but serious complications, such as skin necrosis, vision loss, and paresthesia, are associated with the complex vascular and neural anatomy of the face.[85]

HA demonstrates a favorable safety profile with transient and localized side effects,[86] which is reversibility and low immunogenicity. Most studies report mild adverse events, including pain, edema, and ecchymosis, rather than severe complications.[27,70] In contrast, other fillers such as CaHA and PLLA may result in small nodules or scars due to microsphere properties.[87] PMMA, which contains bovine collagen microspheres, is associated with a higher risk of pruritus, allergy, and granuloma formation.[88] PCL, evaluated by Lin et al[87] in a retrospective study of 1111 patients, showed minimal complications over 3 years, with few cases of edema, bruising, and lumps. Notably, there were no reports of intravascular injection, nodules, granulomas, or infection. Autologous fat grafting may cause pain during both harvesting and injection, as well as erythema, congestion, edema, and pigmentation at the donor site.[89]

In addition to local injection site reactions, lymphadenopathy from dermal fillers are an underrecognized safety issue.[90] Lymphadenitis is among the most commonly reported events.[91] Clinical observations indicate that facial filler injections frequently result in regional lymphadenopathy. Microparticles from both biodegradable and non-biodegradable fillers can migrate via lymphatics to cervical and facial nodes, inducing a foreign-body inflammatory response. However, due to the lack of routine lymphatic imaging or histological examination in follow-up, these complications remain unconfirmed by large-scale prospective studies. Another underrecognized complication is non-odontogenic abscess, which can be life-threatening depending on the extent of purulent involvement.[92]

These abscesses typically occur in the head and neck region—areas that closely overlap with common dermal filler injection sites. Iatrogenic factors, including facial injections and implant procedures, are important triggers. Moreover, infections in this region can progress rapidly and carry high morbidity.[93] Therefore, timely diagnosis and intervention—including drainage and anti-infective therapy—are critical to improving clinical outcomes.

The Limitations

This review has several limitations that should be considered when interpreting its findings and clinical recommendations. First, as a narrative review, it did not involve original clinical trials or experimental research. Consequently, it cannot offer causal conclusions derived from primary data and instead aims to synthesize and analyze published clinical evidence on injectable fillers for atrophic acne scars. Second, the literature search was restricted to a 10-year period, which may have excluded seminal early studies and long-term follow-up data, thereby providing an incomplete perspective on the field's development. Third, only 24 references were included, a limited number that may not fully capture the breadth of relevant clinical evidence, technical advances, or real-world practice data. Fourth, the review included only English-language publications, potentially overlooking high-quality studies, technical reports, and clinical insights reported in other languages—introducing a degree of language selection bias.

In addition, heterogeneity among the included studies limits the generalizability of the findings. Variability in sample sizes, endpoint definitions, and imaging modalities contributed to this issue. There may also be a risk of publication bias, as studies with favorable outcomes are more likely to be published.

To strengthen the evidence base, future research should adopt standardized core outcome measures. These should include validated clinician-reported tools, such as the Quantitative Global Scarring Grading System (QGSGS) and the Global Aesthetic Improvement Scale (GAIS), alongside patient-reported outcome measures (e g PROMIS). Implementing consistent imaging protocols and predefined follow-up durations will also be essential to enhance cross-study comparability.

Conclusion and Future Perspective

The use of fillers for treating AAS offers immediate therapeutic benefit with minimal invasiveness and shows promising potential. Nonetheless, single-filler therapy encounters obstacles, including the need for repeated injections and limited efficacy for deep scars. Furthermore, concurrent use of different filler types may enhance both immediate filling and long-term regenerative effects, thereby extending therapeutic duration. These combined approaches are expected to address limitations of conventional treatments, such as high recurrence rates and prolonged recovery. However, refinement of injection methodologies and dosage ratios is essential to establish uniform clinical application.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Tan JK, Bhate K. A global perspective on the epidemiology of acne. *Br J Dermatol*. 2015;172 Suppl 1:3–12. doi:10.1111/bjd.13462
2. Layton AM, Thiboutot D, Tan J. Reviewing the global burden of acne: how could we improve care to reduce the burden? *Br J Dermatol*. 2021;184 (2):219–225. doi:10.1111/bjd.19477
3. Artzi O, Cohen S, Koren A, Niv R, Friedman O. Dual-plane hyaluronic acid treatment for atrophic acne scars. *J Cosmet Dermatol*. 2020;19 (1):69–74. doi:10.1111/jocd.12991
4. Nilforoushzadeh MA, Heidari-Kharaji M, Alavi S, et al. Acne scar treatment using combination therapy: subcision and human autologous fibroblast injection. *J Cosmet Dermatol*. 2022;21(10):4677–4683. doi:10.1111/jocd.14988
5. Fabbrocini G, Cacciapuoti S. Evaluation, prevention, and management of acne scars: issues, strategies, and enhanced outcomes. *J Drugs Dermatol*. 2018;17(12):s44–s48.
6. Fife D. Practical evaluation and management of atrophic acne scars: tips for the general dermatologist. *J Clin Aesthet Dermatol*. 2011;4(8):50–57.

7. Tan J, Beissert S, Cook-Bolden F, et al. Impact of facial atrophic acne scars on quality of life: a multi-country population-based survey. *Am J Clin Dermatol*. 2022;23(1):115–123. doi:10.1007/s40257-021-00628-1
8. Tan J, Beissert S, Cook-Bolden F, et al. Evaluation of psychological well-being and social impact of atrophic acne scarring: a multinational, mixed-methods study. *JAAD Int*. 2021;6:43–50. doi:10.1016/j.jdin.2021.11.006
9. Knutson DD. Ultrastructural observations in acne vulgaris: the normal sebaceous follicle and acne lesions. *J Invest Dermatol*. 1974;62(3):288–307. doi:10.1111/1523-1747.ep12676804
10. Jennings T, Duffy R, McLarney M, et al. Acne scarring-pathophysiology, diagnosis, prevention and education: part I. *J Am Acad Dermatol*. 2024;90 (6):1123–1134. doi:10.1016/j.jaad.2022.04.021
11. Moon J, Yoon JY, Yang JH, Kwon HH, Min S, Suh DH. Atrophic acne scar: a process from altered metabolism of elastic fibres and collagen fibres based on transforming growth factor-β1 signalling. *Br J Dermatol*. 2019;181(6):1226–1237. doi:10.1111/bjd.17851
12. Carlavan I, Bertino B, Rivier M, et al. Atrophic scar formation in patients with acne involves long-acting immune responses with plasma cells and alteration of sebaceous glands. *Br J Dermatol*. 2018;179(4):906–917. doi:10.1111/bjd.16680
13. Al-Dhalimi MA, Dahham Z. Split-face clinical comparative study of fractional Er:YAG (2940nm) laser versus long pulsed Nd:YAG (1064nm) laser in treatment of atrophic acne scar. *J Cosmet Laser Ther*. 2021;23(1–2):35–40. doi:10.1080/14764172.2021.1967996
14. Ebrahimi Z, Alimohamadi Y, Janani M, Hejazi P, Kamali M, Goodarzi A. Platelet-rich plasma in the treatment of scars, to suggest or not to suggest? A systematic review and meta-analysis. *J Tissue Eng Regen Med*. 2022;16(10):875–899. doi:10.1002/term.3338
15. Lotfi E, Shafie'ei M, Ahramiyanpour N. Radiofrequency-assisted subcision combined with polycaprolactone-based dermal fillers in the management of atrophic facial acne scars: a pilot investigative study. *Skin Res Technol*. 2022;28(6):865–871. doi:10.1111/srt.13228
16. Amer A, Elhariry S, Al-Balat W. Combined autologous platelet-rich plasma with microneedling versus microneedling with non-cross-linked hyaluronic acid in the treatment of atrophic acne scars: split-face study. *Dermatol Ther*. 2021;34(1):e14457. doi:10.1111/dth.14457
17. Avila Rodríguez MI, Rodríguez Barroso LG, Sánchez ML. Collagen: a review on its sources and potential cosmetic applications. *J Cosmet Dermatol*. 2018;17(1):20–26. doi:10.1111/jocd.12450
18. Kontis TC, Rivkin A. The history of injectable facial fillers. *Facial Plast Surg*. 2009;25(2):67–72. doi:10.1055/s-0029-1220645
19. Salvatore L, Natali ML, Brunetti C, Sannino A, Gallo N. An update on the clinical efficacy and safety of collagen injectables for aesthetic and regenerative medicine applications. *Polymers*. 2023;15(4):1020. doi:10.3390/polym15041020
20. Yang C, Hillas PJ, Báez JA, et al. The application of recombinant human collagen in tissue engineering. *BioDrugs*. 2004;18(2):103–119. doi:10.2165/00063030-200418020-00004
21. Solomon P, Sklar M, Zener R. Facial soft tissue augmentation with Artecoll(®): a review of eight years of clinical experience in 153 patients. *Can J Plast Surg*. 2012;20(1):28–32. doi:10.1177/229255031202000110
22. Elson ML. Clinical assessment of Zyplast Implant: a year of experience for soft tissue contour correction. *J Am Acad Dermatol*. 1988;18(4 Pt 1):707–713. doi:10.1016/s0190-9622(88)70094-8
23. Varnavides CK, Forster RA, Cunliffe WJ. The role of bovine collagen in the treatment of acne scars. *Br J Dermatol*. 1987;116(2):199–206. doi:10.1111/j.1365-2133.1987.tb05812.x
24. Sage RJ, Lopiccolo MC, Liu A, Mahmoud BH, Tierney EP, Kouba DJ. Subcuticular incision versus naturally sourced porcine collagen filler for acne scars: a randomized split-face comparison. *Dermatol Surg*. 2011;37(4):426–431. doi:10.1111/j.1524-4725.2011.01918.x
25. Laurent TC, Laurent UB, Fraser JR. Functions of hyaluronan. *Ann Rheum Dis*. 1995;54(5):429–432. doi:10.1136/ard.54.5.429
26. Marinho A, Nunes C, Reis S. Hyaluronic acid: a key ingredient in the therapy of inflammation. *Biomolecules*. 2021;11(10):1518. doi:10.3390/biom11101518
27. Siperstein R, Nestor E, Meran S, Grunebaum L. A split-face, blind, randomized placebo-controlled clinical trial investigating the efficacy and safety of hyaluronic acid filler for the correction of atrophic facial scars. *J Cosmet Dermatol*. 2022;21(9):3768–3778. doi:10.1111/jocd.15153
28. Siperstein R, Nestor E, Meran S. Prospective clinical trial demonstrating the efficacy of hyaluronic acid filler for the improvement of atrophic facial scars up to 2 years. *Dermatol Surg*. 2024;50(12):1143–1148. doi:10.1097/DSS.0000000000004315
29. Mehrabi J, Shehadeh W, Gallo ES, Artzi O, Horovitz T. Comparison of 2 hyaluronic acid-based fillers for the treatment of acne scars: structural lifting versus biostimulatory effect. *Dermatol Surg*. 2023;49(6):581–586. doi:10.1097/DSS.0000000000003789
30. Stellavato A, Corsuto L, D'Agostino A, et al. Hyaluronan hybrid cooperative complexes as a novel frontier for cellular bioprocesses re-activation. *PLoS One*. 2016;11(10):e0163510. doi:10.1371/journal.pone.0163510
31. Stellavato A, La Noce M, Corsuto L, et al. Hybrid complexes of high and low molecular weight hyaluronans highly enhance HASCs differentiation: implication for facial bioremodelling. *Cell Physiol Biochem*. 2017;44(3):1078–1092. doi:10.1159/000485414
32. Sparavigna A, Grimolizzi F, Cigni C, Lualdi R, Bellia G. Dual-plane treatment with highly concentrated hybrid cooperative complexes of hyaluronans for facial atrophic acne scars. *Dermatol Surg*. 2025;51(2):152–156. doi:10.1097/DSS.0000000000004387
33. Mitragotri S. Current status and future prospects of needle-free liquid jet injectors. *Nat Rev Drug Discov*. 2006;5(7):543–548. doi:10.1038/nrd2076
34. Kaminaka C, Sakata M, Nishiguchi M, et al. Clinical evaluation of needle-free electronic pneumatic hyaluronic acid injection treatment for facial atrophic acne scars: a prospective, randomized comparative trial. *J Dermatol*. 2023;50(8):971–981. doi:10.1111/1346-8138.16830
35. Loghem JV, Yutskovskaya YA, Philip Werschler W. Calcium hydroxylapatite: over a decade of clinical experience. *J Clin Aesthet Dermatol*. 2015;8 (1):38–49.
36. Zhang Q, Wang W, Schmelzer E, Gerlach J, Liu C, Nettleship I. The degradation behavior of calcium-rich hydroxyapatite foams in vitro. *J Biomed Mater Res A*. 2021;109(6):859–868. doi:10.1002/jbm.a.37077
37. American Society of Plastic Surgeons (ASPS). 2020 plastic surgery statistics report. 2020. Available from: https://www.plasticsurgery.org. Accessed March 26, 2026.
38. Amiri M, Meçani R, Llanaj E, et al. Calcium hydroxylapatite (CaHA) and aesthetic outcomes: a systematic review of controlled clinical trials. *J Clin Med*. 2024;13(6):1686. doi:10.3390/jcm13061686
39. McCarthy AD, Hartmann C, Durkin A, Shahriar S, Khalifian S, Xie J. A morphological analysis of calcium hydroxylapatite and poly-l-lactic acid biostimulator particles. *Skin Res Technol*. 2024;30(6):e13764. doi:10.1111/srt.13764
40. Lorenc ZP, Bass LM, Fitzgerald R, Goldberg DJ, Graivier MH. Composite facial volumization with calcium hydroxylapatite (CaHA) for the treatment of aging. *Aesthet Surg J*. 2018;38(suppl_1):S18–S23. doi:10.1093/asj/sjy026

41. Nowag B, Casabona G, Kippenberger S, Zöller N, Hengl T. Calcium hydroxylapatite microspheres activate fibroblasts through direct contact to stimulate neocollagenesis. *J Cosmet Dermatol*. 2023;22(2):426–432. doi:10.1111/jocd.15521
42. Antonino A, Francesco A. Prospective and randomized comparative study of calcium hydroxylapatite vs calcium hydroxylapatite plus HIFU in treatment of moderate-to-severe acne scars. *J Cosmet Dermatol*. 2021;20(1):53–61. doi:10.1111/jocd.13472
43. Goldberg DJ, Amin S, Hussain M. Acne scar correction using calcium hydroxylapatite in a carrier-based gel. *J Cosmet Laser Ther*. 2006;8 (3):134–136. doi:10.1080/14764170600891632
44. Yoon SD, Kwon YS, Lee KS. Biodegradation and biocompatibility of poly L-lactic acid implantable mesh. *Int Neurourol J*. 2017;21(Suppl 1):S48–S54. doi:10.5213/inj.1734882.441
45. Fitzgerald R, Bass LM, Goldberg DJ, Graivier MH, Lorenc ZP. Physiochemical characteristics of Poly-L-lactic acid (PLLA). *Aesthet Surg J*. 2018;38(suppl_1):S13–S17. doi:10.1093/asj/sjy012
46. Christen MO. Collagen stimulators in body applications: a review focused on Poly-L-lactic acid (PLLA). *Clin Cosmet Invest Dermatol*. 2022;15:997–1019. doi:10.2147/CCID.S359813
47. De Boulle K, Heydenrych I. Patient factors influencing dermal filler complications: prevention, assessment, and treatment. *Clin Cosmet Invest Dermatol*. 2015;8:205–214. doi:10.2147/CCID.S80446
48. Sadick NS, Palmisano L. Case study involving use of injectable poly-L-lactic acid (PLLA) for acne scars. *J DermatolTreat*. 2009;20(5):302–307. doi:10.1080/09546630902817879
49. Sadove R. Injectable poly-L: -lactic acid: a novel sculpting agent for the treatment of dermal fat atrophy after severe acne. *Aesthetic Plast Surg*. 2009;33(1):113–116. doi:10.1007/s00266-008-9242-7
50. Sapra S, Stewart JA, Mraud K, Schupp R. A Canadian study of the use of poly-L-lactic acid dermal implant for the treatment of hill and valley acne scarring. *Dermatol Surg*. 2015;41(5):587–594. doi:10.1097/DSS.0000000000000366
51. Beer K. A single-center, open-label study on the use of injectable poly-L-lactic acid for the treatment of moderate to severe scarring from acne or varicella. *Dermatol Surg*. 2007;33 Suppl 2:S159–S167. doi:10.1111/j.1524-4725.2007.33356.x
52. Lee KWA, Chan LKW, Lee AWK, Lee CH, Wong STH, Yi KH. Poly-d,l-lactic acid (PDLLA) application in dermatology: a literature review. *Polymers*. 2024;16(18):2583. doi:10.3390/polym16182583
53. Seo SB, Wan J, Chan LKW, Lee KWA, Kim SB, Yi KH. Poly-d,l-lactic acid-enhanced atrophic scar treatment via transdermal microjet drug delivery in Asians. *Skin Res Technol*. 2024;30(6):e13762. doi:10.1111/srt.13762
54. Christen MO, Vercesi F. Polycaprolactone: how a well-known and futuristic polymer has become an innovative collagen-stimulator in esthetics. *Clin Cosmet Invest Dermatol*. 2020;13:31–48. doi:10.2147/CCID.S229054
55. Khattab FM, Samir MA, El Khouly SS, Atwa EM. Efficacy of polycaprolactone threads in treating atrophic acne scars: a split-face comparative study. *J Clin Aesthet Dermatol*. 2023;16(9):33–37.
56. Hevia O. Safety and efficacy of polymethylmethacrylate-collagen gel filler for correction of the pre-jowl sulcus: a 24-month prospective study. *Aesthet Surg J Open Forum*. 2022;4:ojac030. doi:10.1093/asjof/ojac030
57. Ng QX, Koh SSH, Shin D, De Deyn MLZQ, Ho CYX. Use of polymethylmethacrylate (PMMA) microspheres collagen to treat atrophic acne scars. *Med Hypotheses*. 2017;108:115–116. doi:10.1016/j.mehy.2017.08.016
58. Joseph JH, Shamban A, Eaton L, et al. Polymethylmethacrylate collagen gel-injectable dermal filler for full face atrophic acne scar correction. *Dermatol Surg*. 2019;45(12):1558–1566. doi:10.1097/DSS.0000000000001863
59. Solomon P, Ng CL, Kerzner J, Rival R. Facial soft tissue augmentation with bellafill: a review of 4 years of clinical experience in 212 patients. *Plast Surg*. 2021;29(2):98–102. doi:10.1177/2292550320933675
60. Coleman SR. Structural fat grafting: more than a permanent filler. *Plast Reconstr Surg*. 2006;118(3 Suppl):108S–120S. doi:10.1097/01.prs.0000234610.81672.e7
61. Abu-Ghname A, Perdanasari AT, Reece EM. Principles and applications of fat grafting in plastic surgery. *Semin Plast Surg*. 2019;33(3):147–154. doi:10.1055/s-0039-1693438
62. Byun KA, Kim HM, Oh S, et al. High-intensity focused ultrasound increases facial adipogenesis in a swine model via modulation of adipose-derived stem cell cilia. *Int J Mol Sci*. 2024;25(14):7648. doi:10.3390/ijms25147648
63. Liu W, Shi K, Zhu X, et al. Adipose tissue-derived stem cells in plastic and reconstructive surgery: a bibliometric study. *Aesthetic Plast Surg*. 2021;45(2):679–689. doi:10.1007/s00266-020-01615-3
64. Behrangi E, Moradi S, Ghassemi M, et al. The investigation of the efficacy and safety of stromal vascular fraction in the treatment of nanofat-treated acne scar: a randomized blinded controlled clinical trial. *Stem Cell Res Ther*. 2022;13(1):298. doi:10.1186/s13287-022-02957-2
65. Shetty VH, Bhandary SN, Bhandary R, Suvarna C. A comparative study of efficacy and safety of autologous fat grafting versus Platelet-rich plasma in the treatment of post-acne scars. *J Cosmet Dermatol*. 2021;20(11):3454–3461. doi:10.1111/jocd.14503
66. Nilforoushzadeh MA, Heidari-Kharaji M, Alavi S, et al. Transplantation of autologous fat, stromal vascular fraction (SVF) cell, and platelet-rich plasma (PRP) for cell therapy of atrophic acne scars: clinical evaluation and biometric assessment. *J Cosmet Dermatol*. 2022;21(5):2089–2098. doi:10.1111/jocd.14333
67. Vingan NR, Wamsley CE, Panton JA, et al. Investigating the efficacy of modified lipoaspirate grafting to improve the appearance of atrophic acne scars: a pilot study. *Aesthet Surg J*. 2023;43(8):NP613–NP630. doi:10.1093/asj/sjad102
68. Park S, Huang L, Ao X, et al. Micronized acellular dermal matrix combined with platelet rich plasma in the treatment of atrophic acne scars: a self-controlled split face study. *J Cosmet Dermatol*. 2024;23(7):2386–2391. doi:10.1111/jocd.16293
69. Ebrahim HM, Nassar A, ElKashishy K, Artima AYM, Morsi HM. A combined approach of subcision with either cross-linked hyaluronic acid or threads in the treatment of atrophic acne scars. *J Cosmet Dermatol*. 2022;21(8):3334–3342. doi:10.1111/jocd.14675
70. Akerman L, Mimouni D, Nosrati A, Hilewitz D, Solomon-Cohen E. A combination of non-ablative laser and hyaluronic acid injectable for postacne scars: a novel treatment protocol. *J Clin Aesthet Dermatol*. 2022;15(3):53–56.
71. Koren A, Isman G, Cohen S, et al. Efficacy of a combination of diluted calcium hydroxylapatite-based filler and an energy-based device for the treatment of facial atrophic acne scars. *Clin Exp Dermatol*. 2019;44(5):e171–e176. doi:10.1111/ced.13952
72. Gronovich Y, Maisel Lotan A. Treatment of scars with autologous fat grafting and 1540 nm non-ablative erbium laser. *J Cosmet Laser Ther*. 2022;24(6–8):80–83. doi:10.1080/14764172.2022.2055078

73. Guo J, Fang W, Wang F. Injectable fillers: current status, physicochemical properties, function mechanism, and perspectives. *RSC Adv*. 2023;13(34):23841–23858. doi:10.1039/d3ra04321e
74. Gerova-Vatsova T. Investigating the efficacy of regenerative therapy with autogenous platelet-rich plasma in vertical bone defects. *Cureus*. 2024;16(10):e72686. doi:10.7759/cureus.72686
75. Yung YL, Fu SC, Cheuk YC, et al. Optimisation of platelet concentrates therapy: composition, localisation, and duration of action. *Asia Pac J Sports Med Arthrosc Rehabil Technol*. 2017;7:27–36. doi:10.1016/j.asmart.2016.11.003
76. Du X, Zhao J, Ren Q, et al. Clinical application of platelet rich plasma to promote healing of open hand injury with skin defect. *Regen Ther*. 2024;26:308–314. doi:10.1016/j.reth.2024.06.003
77. Chen J, Wan Y, Lin Y, Jiang H. The application of platelet-rich plasma for skin graft enrichment: a meta-analysis. *Int Wound J*. 2020;17(6):1650–1658. doi:10.1111/iwj.13445
78. Liu X, Li Y, Shen L, Yan M. Leukocyte and platelet-rich plasma (L-PRP) in tendon models: a systematic review and meta-analysis of in vivo/in vitro studies. *Evid Based Complement Alternat Med*. 2022;2022:5289145. doi:10.1155/2022/5289145
79. Albargawi S. Synthetic dermal fillers in treating acne scars: a comparative systematic review. *J Cosmet Dermatol*. 2025;24(1):e16752. doi:10.1111/jocd.16752
80. Abdelwahab AA, Omar GAB, Hamdino M. A combined subcision approach with either fractional CO2 laser (10,600 nm) or cross-linked hyaluronic acid versus subcision alone in atrophic post-acne scar treatment. *Lasers Med Sci*. 2022;38(1):20. doi:10.1007/s10103-022-03677-y
81. Behrangi E, Dehghani A, Sheikhzadeh F, Goodarzi A, Roohaninasab M. Evaluation and comparison of the efficacy and safety of cross-linked and non-cross-linked hyaluronic acid in combination with botulinum toxin type A in the treatment of atrophic acne scars: a double-blind randomized clinical trial. *Skin Res Technol*. 2024;30(1):e13541. doi:10.1111/srt.13541
82. Galadari H, Krompouzos G, Kassir M, et al. Complication of soft tissue fillers: prevention and management review. *J Drugs Dermatol*. 2020;19(9):829–832. doi:10.36849/JDD.2020.10.36849/JDD.2020.5084
83. Machado RA, Oliveira LQ, Martelli-Júnior H, et al. Adverse reactions to the injection of face and neck aesthetic filling materials: a systematic review. *Med Oral Patol Oral Cir Bucal*. 2023;28(3):e278–e284. doi:10.4317/medoral.25713
84. Clark NW, Pan DR, Barrett DM. Facial fillers: relevant anatomy, injection techniques, and complications. *World J Otorhinolaryngol Head Neck Surg*. 2023;9(03):227–235. doi:10.1002/wjo2.126
85. Oranges CM, Brucato D, Schaefer DJ, Kalbermatten DF, Harder Y. Complications of nonpermanent facial fillers: a systematic review. *Plast Reconstr Surg Glob Open*. 2021;9(10):e3851. doi:10.1097/GOX.0000000000003851
86. Kyriazidis I, Spyropoulou GA, Zambacos G, et al. Adverse events associated with hyaluronic acid filler injection for non-surgical facial aesthetics: a systematic review of high level of evidence studies. *Aesthetic Plast Surg*. 2024;48(4):719–741. doi:10.1007/s00266-023-03465-1
87. Lin SL, Christen MO. Polycaprolactone-based dermal filler complications: a retrospective study of 1111 treatments. *J Cosmet Dermatol*. 2020;19(8):1907–1914. doi:10.1111/jocd.13518
88. Roohaninasab M, Khodadad F, Sadeghzadeh-Bazargan A, et al. Efficacy of fractional CO2 laser in combination with stromal vascular fraction (SVF) compared with fractional CO2 laser alone in the treatment of burn scars: a randomized controlled clinical trial. *Stem Cell Res Ther*. 2023;14(1):269. doi:10.1186/s13287-023-03480-8
89. Rageh MA, Ibrahim SMA, Abdallah N, Tawfik AA. Autologous nanofat injection combined with fractional CO2 laser in the treatment of atrophic acne scars. *Clin Cosmet Invest Dermatol*. 2024;17:697–705. doi:10.2147/CCID.S454514
90. Gaddey HL, Riegel AM. Unexplained lymphadenopathy: evaluation and differential diagnosis. *Am Fam Physician*. 2016;94(11):896–903.
91. Richner S, Laifer G. Peripheral lymphadenopathy in immunocompetent adults. *Swiss Med Wkly*. 2010;140(7–8):98–104. doi:10.4414/smw.2010.12892
92. Böttger S, Zechel-Gran S, Schmermund D, et al. Clinical relevance of the microbiome in odontogenic abscesses. *Biology*. 2021;10(9):916. doi:10.3390/biology10090916
93. Gossen IM, McSween Z, Kamel S, Garlapati AR, Lazarescu R. A rare case of parapharyngeal abscess in a healthy adult: importance of timely diagnosis and intervention. *Cureus*. 2025;17(6):e86158. doi:10.7759/cureus.86158