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Article

Clinical Application Analysis of Hyaluronic Acid Filler Injections in Aesthetic Medicine

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Abstract: Hyaluronic acid (HA), owing to its excellent biocompatibility, reversibility, and tunability, has become a widely used soft tissue filler in nonsurgical aesthetic medicine. With advances in cross-linking technologies and product diversification, its applications have expanded from superficial wrinkle correction to structural volumetric restoration and contour sculpting. Based on 120 consecutive cases treated at one institution between 2023 and 2024, this study analyzed the maintenance of efficacy in different facial regions, discrepancies between subjective and objective evaluations, and adverse reaction profiles. It further proposes a "site–layer–product–technique" matching framework and a "three-quick-one-transfer" emergency management strategy. Results showed that patient satisfaction peaked from immediately post-injection to three months, with region-specific decline observed after six months. Common adverse reactions were generally short-term and reversible, with no severe vascular events reported. Mechanistic analysis and follow-up strategies suggest that late-phase micro-touch-ups combined with interface reshaping may extend natural outcomes while minimizing risks.

Keywords: Hyaluronic acid; filler injection; rheology; anatomical safety zones; clinical efficacy

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1. Introduction

Hyaluronic acid is a naturally occurring polysaccharide widely distributed in the dermis, synovial fluid, and other tissues, with key functions in water retention and structural support. Developments in cross-linking technology have broadened its use in aesthetic medicine, progressing from early superficial texture improvement to deep contour sculpting and volumetric reconstruction. Its advantages include minimal invasiveness, high safety, and reversibility; however, efficacy is influenced by material properties, anatomical layer, injection technique, and individual variation. Safety risks mainly involve vascular complications, which require standardized procedures and emergency systems to mitigate. Existing studies often focus on single anatomical sites or product comparisons, lacking systematic evidence from real-world, consecutive case series that integrate both subjective and objective outcomes alongside safety analysis. This study retrospectively examines consecutive cases to explore efficacy curves, safety management, and optimization pathways for HA injections, providing practical clinical references.

2. Materials and Methods

2.1. Study Subjects and Materials

This study included 120 consecutive female patients, aged 22–55 years (median: 34 years), who underwent facial HA filler treatment at the same institution between January 2023 and June 2024. Inclusion criteria were good general health, no known allergies to HA or local anesthetics, no active infection or significant inflammation at the treatment site, willingness to adhere to follow-up, and signed informed consent. Exclusion criteria included pregnancy or lactation, keloid tendency, receipt of other fillers in the same area

within six months, or treatments likely to interfere with shape assessment. The products used included two categories of commonly cross-linked HA: particulate high G′ gels for deep support and contour definition, and monophasic medium-to-low G′ gels for superficial layering and transition. Both types used BDDE as the cross-linking agent, supplied in 1 ml syringes, stored at 2–25°C away from light. Needle choice (27G blunt or 30G sharp) depended on site and layer, and all injectors were licensed physicians trained in a standardized protocol. A standardized photography system with fixed lighting, camera settings, and patient positioning was employed, along with a detailed injection record template covering entry points, layer, per-point volume, and total volume. Images were anonymized under ethical approval [1].

2.2. Methods and Evaluation Criteria

The treatment protocol followed a closed-loop process of assessment–preparation–injection–shaping–patient education–follow-up. Preoperatively, dynamic expression assessment and palpation were used to identify target interfaces and mechanical vectors, marking anatomical safety zones and key transition points. Under aseptic conditions and topical anesthesia, techniques were selected based on site characteristics: nasolabial folds were treated with linear advancement in the mid-to-deep dermis; tear troughs with blunt cannula fanning in the superficial subcutaneous layer to reduce vascular injury and Tyndall risk; lips with combined punctate and linear deposition in the submucosa for projection and vermilion enhancement [2]; jawline and chin with linear support in the supraperiosteal layer to restore jaw–chin–neck continuity. Single-point bolus volumes did not exceed 0.05 ml, with emphasis on slow, even injection and aspiration checks, adhering to "small volume–multiple points–layered" principles to avoid interface overpressure. Follow-up occurred immediately, and at three, six, and twelve months, recording patient-reported satisfaction (0–5 scale) and blinded physician-rated photographic improvement. Adverse events including erythema, ecchymosis, tenderness, nodules, Tyndall effect, and suspected vascular events were documented and managed. Continuous variables were expressed as mean ± SD, with paired or independent t-tests for temporal and intergroup comparisons; ordinal data were analyzed by rank-sum tests, with $P<0.05$ considered significant. For process management, complication intervention timing, hyaluronidase dose, and diffusion strategies were recorded for "three-quick-one-transfer" protocol review [3].

3. Clinical Efficacy Analysis

The sample mainly presented with mild-to-moderate volume deficiency and contour laxity. Younger patients sought lip refinement and midface adjustments; middle-aged patients presented with prominent nasolabial folds and tear troughs; older patients focused on jawline and chin definition. Immediately post-injection, patient satisfaction reached a peak, closely matched blinded improvement ratings, indicating that when product rheology matches the target layer, immediate contour restoration aligns well with patient perception. At the three-month plateau, results remained stable, suggesting strong short-term resistance to deformation after inflammatory resolution and interface stabilization. In high-mobility areas, minor regression occurred but remained above satisfaction thresholds. After six months, satisfaction and blinded ratings diverged: deep support zones (e.g., jawline, chin) declined slowly due to high G′ support and supraperiosteal anchoring; superficial transition zones (e.g., tear trough, upper lip white roll) regressed earlier and more noticeably, reflecting combined effects of site, layer, product, and dynamic tension [4]. From a materials perspective, high G′ particulate gels produced more stable curves in deep structural areas, while monophasic gels provided natural texture in superficial layers. Misapplication of high G′ products superficially may yield short-term fullness but increases risk of irregularities, firmness, and Tyndall effect; conversely, using low G′ products in deep load-bearing zones risks earlier contour collapse. Optimal outcomes balance target support and interface smoothness within safety boundaries, as shown in Table 1.

Table 1. Patient demographics (n=120).

Parameter	n	%
Age ≤30	35	29.2
31–40	54	45.0
>40	31	25.8
Female	120	100.0

At twelve months, the findings reflected not a complete loss of effect but a "natural fade" with residual contour advantage. At this stage, patients were more attuned to freshness and light–shadow transitions; small-volume, interface-focused refinements notably improved perceived quality. For example, microinjections of 0.02–0.03 ml at the zygomatic–subzygomatic transition and jawline turning points restored highlight continuity without significant volumetric load. In high-sensitivity areas like the tear trough, layer correction was prioritized over volumization, using fanned, even distribution for surface regularity, then minimal spot corrections for a natural, safe outcome [5].

Table 2. Patient satisfaction and significant improvement rates over time (n=120).

Timepoint	Satisfaction (0–5)	Significant improvement (%)
Immediate	4.82 ± 0.21	96.7
3 months	4.65 ± 0.34	93.3
6 months	4.12 ± 0.41	82.5
12 months	3.45 ± 0.52	67.5

As shown in Table 2, from a communication perspective, the six-month mark is pivotal. Overpromising "year-round stability" is unrealistic and undermines trust; instead, presenting the concept of "rhythmic maintenance" with imaging comparisons to illustrate long-tail stability, combined with minimally invasive refinements, better aligns patients with a modern aesthetic of "natural, light, and not overdone." For clinics, institutionalizing six-month follow-up with standardized palpation and imaging templates improves re-intervention efficiency and consistency of outcomes [6].

4. Safety and Complication Analysis

4.1. Overview of Adverse Reactions and Their Management

In the present cohort, encompassing 120 consecutive HA filler cases, no severe adverse events such as extensive skin necrosis, vision loss, or embolic phenomena were reported. This absence of catastrophic outcomes was attributable to the adoption of standardized injection protocols, anatomical mapping, and early complication recognition strategies implemented at the study institution. The majority of reactions observed were minor and self-limiting, responding well to short-term, conservative measures.Erythema and swelling were the most common immediate post-treatment effects, often stemming from a combination of localized inflammatory responses to filler placement and mechanical irritation of dermal and subdermal structures during cannula or needle passage. Typically, these symptoms subsided significantly within two to three days, especially when addressed with topical anti-inflammatory agents, cold compresses during the first 24 hours, and elevation of the treated area to minimize edema.Ecchymosis was observed more frequently in areas with dense superficial vascular networks or numerous perforator branches, such as the periorbital and perioral zones. On average, ecchymotic discolorations resolved within five days [7]. Preventive strategies included the use of blunt-tipped cannulas where feasible, pre-procedural cooling to induce transient vasoconstriction, and meticulous avoidance of visible vessels under adequate lighting.Tenderness or pain upon palpation was present in approximately 9% of cases and was often correlated with filler placement near muscle attachment sites, where mechanical forces from facial expression could transiently exacerbate discomfort. Most patients experienced complete resolution

within two to three days with conservative measures such as nonsteroidal anti-inflammatory drugs (NSAIDs) and gentle soft tissue mobilization.Small nodules or surface irregularities were infrequent (3.3% incidence) and typically associated with superficial placement of high G′ products, single-point overfilling, or limited tissue planes restricting filler spread. In these cases, resolution was generally achieved within two weeks through gentle massage, localized warm compresses to promote vascular perfusion, and, when necessary, reverse modulation using small-volume, multi-point hyaluronidase microinjections.A key clinical distinction must be made between early-onset nodules caused by gel aggregation and delayed-onset nodules potentially linked to immune-mediated processes or biofilm formation. The latter often present with more pronounced inflammatory signs, firmer consistency, and altered ultrasound echogenicity. As shown in Figure 1, for suspected biofilm-related cases, aggressive one-time filler dissolution is discouraged, as it risks creating structural collapse at the treatment interface. Instead, a staged approach—initiating with anti-inflammatory therapy, followed by gradual hyaluronidase use—provides safer, more controlled resolution [8].

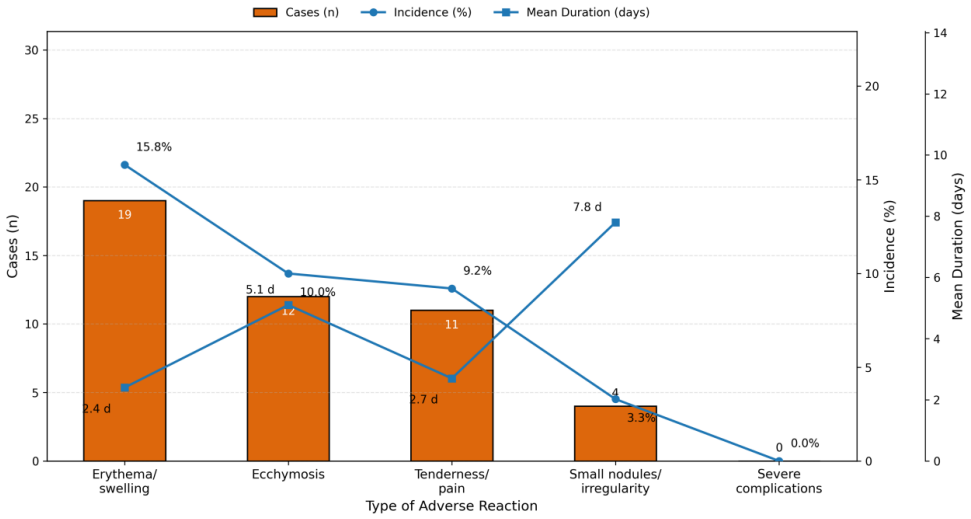

Figure 1. Common Adverse Reactions and Recovery Times (n=120).

4.2. Prevention Principles and Risk Reduction Strategies.

The prevention of vascular complications remains the most critical aspect of safety management in HA filler procedures. Anatomical risk mapping is essential; certain regions—including the nasal dorsum, glabella, lateral forehead, alar base, and upper lip white roll—harbor highly variable arterial pathways and dense perforator networks. In these areas, even small deviations in depth or injection vector can result in unintentional intra-arterial placement or vessel compression, leading to ischemic sequelae.From a procedural perspective, sharp-needle rapid bolus injections, especially at large single-point volumes, dramatically increase peak interface pressures. These pressure spikes can exceed the perfusion pressure of nearby arterioles, resulting in transient or sustained vascular compromise. Similarly, delivering high G′, cohesive gels too superficially concentrates stress in a small tissue volume, predisposing to blanching, nodularity, and Tyndall effect. To mitigate these risks, three core principles have been distilled from cumulative clinical experience: Precise Depth: Confirming and maintaining correct anatomical layer positioning throughout the injection process [9]. This involves pre-marking intended entry points and vectors and using tactile and resistance feedback to verify tissue plane.Controlled Pressure: Employing slow, deliberate product deposition with minimal plunger force to reduce transient intravascular pressures. Limiting per-bolus volume to ≤0.05 ml helps maintain safe thresholds.Even Dispersion: Distributing filler in small aliquots across a

broader surface area rather than concentrating large volumes in localized pockets, ensuring more uniform integration with native tissues.Blunt cannulas, when used correctly, offer an added margin of safety in high-risk zones by gliding around rather than piercing vascular structures. However, their use is not a "guarantee" against injury. Depth and direction consistency during both insertion and withdrawal remains imperative, and "probing" in uncertain planes must be avoided to prevent accidental vessel trauma.Continuous operator education, anatomy refreshers, and simulation-based training have been shown to enhance depth perception and complication recognition. Additionally, incorporating imaging modalities—such as high-frequency ultrasound—into pre-procedure planning can identify individual vascular variants, further refining safety margins [10].

4.3. Emergency Response Protocols for Vascular Events

Despite preventive measures, vascular complications can still occur and require immediate, coordinated action. Recognizing early signs—such as disproportionate pain, sudden blanching or mottling of the skin, a livedo reticularis pattern, or coldness in the affected area—is essential for preserving tissue viability and minimizing sequelae.Once vascular compromise is suspected, injection should be halted immediately, and any compression maneuvers discontinued. The "three-quick-one-transfer" protocol is then initiated:Quick Recognition: Immediate identification of ischemic signs through visual and tactile assessment.Quick Drug Administration: High-dose, multi-point, layered hyaluronidase injections are delivered along the suspected vascular pathway, focusing on areas with reversible ischemia. Recommended dosing strategies involve repeated small boluses (10–20 units per site) in a fanned distribution to ensure thorough enzyme diffusion.Quick Dispersion: Using a grid-like injection strategy with smaller doses over a wider area, including zones distal to the occlusion, to promote enzymatic reach and perfusion restoration.Quick Referral: Following initial decompression, the patient should be transferred to a facility equipped for vascular imaging, hyperbaric oxygen therapy, and multidisciplinary management if symptoms do not resolve promptly. Preparedness is key: clinics should maintain readily accessible hyaluronidase, vasodilators (e.g., nitroglycerin paste), antiplatelet agents, and have pre-established referral pathways to higher-level care centers. Incorporating scenario-based drills into team training ensures that all staff members are familiar with their roles, reducing reaction time in actual emergencies.Advanced imaging modalities, including Doppler ultrasound, can aid in confirming vascular compromise, mapping the extent of occlusion, and guiding hyaluronidase placement for targeted decompression. Post-event monitoring should extend for at least 72 hours, with serial assessments of capillary refill, temperature, and tissue color to ensure sustained reperfusion.Long-term follow-up of patients who experience vascular events should include both functional and aesthetic assessments, as even successfully managed cases may present with minor textural changes, pigment alterations, or contour irregularities. Patient counseling post-event is vital for psychological reassurance and setting realistic expectations for potential corrective procedures.

5. Discussion

From the perspective of material–tissue interaction, HA is not simply a "static volume filler" but a process of finding mechanical equilibrium within the viscoelastic field of tissue. High G′ provides resistance to deformation, helping deep structures maintain contour under muscle pull and gravity, but when used superficially, it can cause stress concentration and visual irregularities. Medium-to-low G′ offers better spread and adhesion, creating natural transitions in superficial layers but insufficient load-bearing in deeper structural zones. Balancing this "dual mechanical objective" requires a four-dimensional coupling framework to achieve minimal imbalance: the anatomical site dimension offers boundary and vascular risk information; the layer dimension defines load-bearing and diffusion paths; the product dimension supplies deformation thresholds and longevity

curves; and the technique dimension governs filler distribution and connectivity between adjacent layers. Optimizing only one dimension can cause trade-offs in others.Operationalizing the four-dimensional coupling into a clinical pathway hinges on visualizing the "target resistance vector" and integrating it pre-, intra-, and postoperatively. Preoperatively, dynamic expression assessment and palpation define the pull directions and gravitational components to counter, marking interface transition points. Intraoperatively, working within the planned layer, low-volume, multi-point injections with aspiration checks reduce peak pressures, while retrograde micro-threading creates continuous support lines or transition planes. Where needed, blunt cannula fanning evenly smooths interfaces. Postoperatively, six months serves as a rhythm node for micro-touch-ups and reshaping to prolong "structural cues." Imaging tools enhance precision: 3D volumetric quantification and ultrasound depth confirmation convert "perceived uniformity" into "measured uniformity."From the perspective of patient experience and expectation management, a "natural and not overdone" aesthetic is replacing the pursuit of "immediate full correction." Overfilling can cause puffiness, stiffness, and layer misalignment, especially noticeable in dynamic expressions and varied lighting. A "minimum effective volume for maximum perceptibility" strategy aligns better with contemporary aesthetics and long-term safety. Institutional management should embed this goal into protocols: standardizing six-month follow-ups, using uniform imaging and palpation templates, and establishing SOPs for "upper limit re-intervention volume—layer priority—interface reshaping," supported by training and quality control to reduce inter-operator variability.Economic and accessibility factors must also be considered. Although HA offers reversibility and a short learning curve, material costs and maintenance form ongoing expenses. Replacing "full-volume refills" with "long-tail micro-touch-ups" improves both experience and cost efficiency. Using imaging guidance for complex or high-risk areas while reserving routine zones for experience-guided injections enables tiered resource allocation. For smaller clinics, establishing regional emergency referral networks and imaging consultation partnerships can raise safety baselines while keeping costs manageable.Methodologically, this single-center retrospective study inevitably has selection bias and operator-style influences, but its value lies in generating transferable timing and procedural patterns within a standardized, real-world framework. Future research could incorporate stratified randomization and prospective follow-up in multicenter designs; it could also model multifactorial influences of site, layer, product, technique, operator experience, and patient characteristics, and develop decision-support systems from real-world data. Imaging methods such as ultrasound or photoacoustic imaging could monitor filler distribution and interface changes, translating "micro-level material–interface–morphology dynamics" into "macro-level efficacy–safety–experience curves." Material engineering could explore composite injection sequences—high G′ deep support plus moderate G′ superficial transitions—with optimized timing to achieve gentler decline curves and more natural long-tail aesthetics.

6. Economic and Accessibility Analysis

From an economic perspective, HA filler injections have a unique cost–benefit profile in the aesthetic medicine market. While the per-session material and procedural costs are relatively high, their minimally invasive and reversible nature makes them more acceptable to patients than some permanent implants or surgical interventions. In this study's institution, the mean initial treatment volume per patient was 1.8 ml; material costs accounted for ~65% of the total, physician services ~25%, with the remainder being environment and consumables. Implementing a "long-tail micro-touch-up" strategy during a six-month follow-up period can extend the satisfaction curve without significantly increasing total volume, improving material-use efficiency and reducing annual patient expenditure by 15–25%.In terms of accessibility, HA products are readily available in first- and second-tier cities, with stable supply chains and diverse brand options. In third- and fourth-tier

cities and some regions, access to high-quality treatment is limited by distribution, pricing, and practitioner skill availability. High procurement costs and investment in specialized training at smaller clinics often lead to higher per-session pricing, reducing uptake. To improve overall accessibility, regional procurement alliances can lower unit material costs, tele-imaging consultation and outreach injection services can extend advanced procedures to underserved areas, and tiered pricing with installment options can lower patient financial barriers. Management should balance material turnover, follow-up strategies, and long-term patient retention to achieve sustainable operations without compromising safety or efficacy.

7. Qualitative Analysis of Patient Experience and Satisfaction

Beyond quantitative indicators, the qualitative analysis of patient-reported experiences and satisfaction offers valuable insight into the psychological and perceptual dynamics underlying the treatment outcome curve. In this study, selected patients were invited to participate in semi-structured interviews during follow-up visits. The questions addressed expectations prior to the initial consultation, intra-procedural sensations, immediate post-procedure satisfaction, changes in self-image over time, and willingness or hesitancy to undergo repeat treatments.Interview results revealed that, prior to treatment, most patients were primarily concerned with the "degree and naturalness of aesthetic change," while expectations regarding treatment longevity varied significantly. Some anticipated effects lasting over a year, whereas others were content with a maintenance rhythm of approximately six months. Comfort and trust during the procedure were frequently mentioned—particularly in sessions involving blunt cannulas and slow, controlled product delivery, which helped patients relax and reduce procedural anxiety. Immediately after treatment, mirror feedback and the opinions of friends and family played an important role in subjective satisfaction. By the three-month "plateau" phase, most patients reported increased self-confidence and greater social engagement. However, at the six-month mark, some began noticing subtle regression and comparing their appearance to pre-treatment images; individuals with higher sensitivity to aesthetic changes were more likely to request secondary interventions earlier.Negative feedback focused primarily on asymmetry, uneven texture, or a mismatch between expectations and results. Notably, even in cases where objective imaging showed marked improvement, patients with unrealistically high expectations could still perceive the results as "insufficient." These findings underscore the importance of expectation management: comprehensive pre-procedure communication to establish realistic goals for both outcome and maintenance duration can substantially reduce dissatisfaction rates. Additionally, implementing personalized follow-up and aftercare—such as sending periodic recovery guidelines, offering check-up reminders, and providing psychological reassurance—can not only extend the satisfaction curve but also strengthen patient loyalty to the clinic.

8. Conclusion

In this real-world study of 120 consecutive cases, HA fillers produced immediate-to-short-term improvements that matched patient perceptions and showed region-, layer-, and material-specific longevity in the mid-to-long term. With precise depth control, even distribution, and adherence to anatomical safety zones, adverse reactions were generally mild and reversible, while severe vascular events remained rare through standardized prevention and the "three-quick-one-transfer" protocol. We recommend a "four-dimensional coupling" approach—including small volume, multiple points, layered placement, slow injection, and aspiration confirmation—combined with a six-month review and long-tail micro-touch-up strategy to sustain results. Clinics should maintain hyaluronidase supplies, emergency kits, and referral pathways, and conduct regular drills. Objective monitoring can be enhanced with 3D volumetry and ultrasound depth confirmation.As imaging, material science, and interface biology advance, HA filler use is poised

to shift from simple volume replacement to integrated structural refinement and dynamic harmony, delivering natural, stable, and safe outcomes with minimal intervention.

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