Clinical, Cosmetic and Investigational Dermatology

Dovepress
Taylor & Francis Group

Open Access Full Text Article

EXPERT OPINION

Expert Perspectives: Evidence-Based Applications of Polynucleotides (PNs) in Aesthetic Medicine and Dermatology

Nark-Kyoung Rho[1], Suneel Chilukuri[2,3], Gavin Chan[4], Michael James Kim[5], Jihye Shin[5], Atchima Suwanchinda[6,7]

[1]Leaders Dermatology Clinic, Seoul, Republic of Korea; [2]Refresh Dermatology, Houston, Texas, USA; [3]Department of Dermatology, Baylor College of Medicine, Houston, Texas, USA; [4]Victorian Cosmetic Institute, Melbourne, VIC, Australia; [5]Medical Strategy Division, PharmaResearch Co., Ltd, Seongnam, South Korea; [6]Department of Dermatology, Chulabhorn International Collage of Medicine, Thammasat University, Bangkok, Thailand; [7]Division of Dermatology, Department of Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Correspondence: Atchima Suwanchinda, Cooperative Learning Center, Piyachart 2, 99 Moo 18, Phahonyothin Road, Klong Luang, Rangsit, Pathum Thani, 12120, Thailand, Tel +66813753000, Email dr.atchima@gmail.com

Abstract: Polynucleotides (PNs) are increasingly used in aesthetic dermatology, supported by emerging clinical evidence and growing interest in restorative approaches to skin treatment aiming to improve skin conditions. This expert opinion article brings perspectives from an international panel of dermatologists and aesthetic physicians on the use of PNs (Rejuran®, PharmaResearch, South Korea) across dermatological indications. The proposed mechanism of action of PNs involves the formation of a hydrophilic, scaffold-like matrix that may support tissue remodeling and hydration. This article highlights the clinical applications of PNs across four indications: skin hydration and rejuvenation; structural support through deep-plane injections; barrier repair in rosacea and eczema; and scar remodeling. For each, the authors provide suggested treatment protocols based on real-world use, including guidance on injection techniques and anatomical targets. PNs have demonstrated a favorable safety profile, with no reported cases of granuloma or vascular occlusion in the literature to date. Their biocompatibility and tolerability make them a promising option, particularly for sensitive or barrier-compromised skin. However, the current evidence base remains limited, and further studies, including randomized trials and histological validation, are needed. This article provides practical clinical guidance while highlighting areas for future research and standardization in the aesthetic use of PNs.

Keywords: polynucleotides, skin rejuvenation, ligament strengthening, skin structural support, scar remodeling

Introduction

Biostimulatory agents, or "skin boosters", have been a cornerstone of aesthetic procedures for decades.[1] More recently, polynucleotides (PNs) are gaining traction in aesthetic medicine for their skin rejuvenation and anti-aging properties.[2] The popularity of products like PNs, which are produced from salmon or trout DNA,[2,3] may be linked to the growing demand for naturally-derived aesthetic treatments that are also evidence-based and effective, minimizing downtime and lifestyle disruption.[2] PNs are made up of long-chain nucleotides. Therefore, they are more resistant to enzymatic degradation and remain active in the skin for longer periods for enhanced stimulation.[4]

Several physiological and biomechanical mechanisms may contribute to the demonstrated effects of PN-based products in a range of aesthetic rejuvenation applications (Figure 1). The hydrophilic nature of PNs promotes skin hydration, translating to improved skin elasticity and texture, reduced fine lines and wrinkles, enhanced moisture retention, reduced skin dryness, and improvement in skin conditions such as rosacea and eczema.[5,6] Evidence shows that PNs are well tolerated,[5–8] and better tolerated than HA and collagen boosters.[2,9] Most commonly reported reactions were localized side effects such as swelling, discomfort, and slight bruising that are common with injected skin booster treatments.[10] Notably, there have been no reports associating PNs with complications such as granulomas or nodules,

https://doi.org/10.2147/CCID.S557226
Received: 10 September 2025
Accepted: 28 December 2025
Published: 14 January 2026

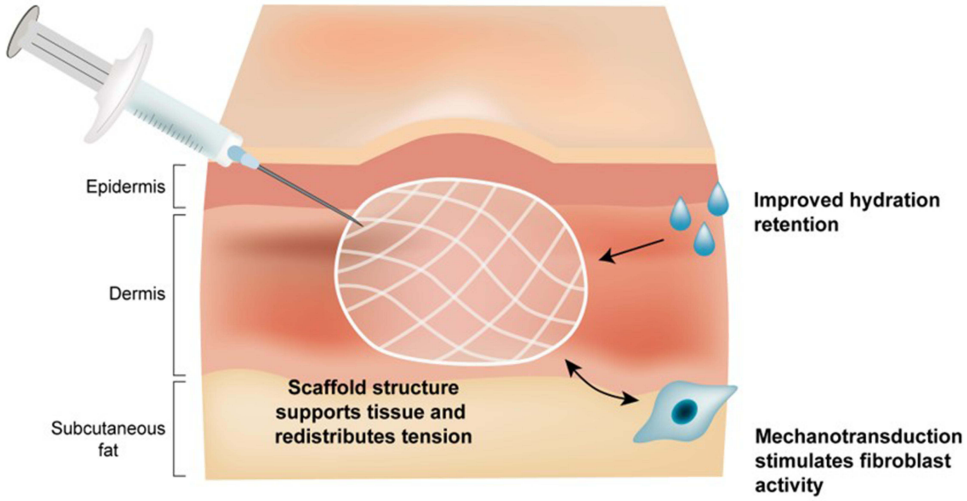

Figure 1 Schematic of Polynucleotides (PNs) Mechanism of Action Figure 1 illustrates the hypothetical biomechanical effects of polynucleotides (PNs). PNs are proposed to form a hydrophilic scaffold that supports the extracellular matrix and may activate fibroblasts via mechanotransduction. These effects are hypothesized to contribute to improved dermal hydration, tissue support, and redistribution of mechanical tension.

prolonged erythema, systemic symptoms, or vascular occlusion, which are well-documented concerns with other injectable fillers.[4,5,11,12] The low incidence of granuloma formation following treatment with PNs may be due to its favorable tolerability profile and minimal immune reactivity.[11] While the possibility of rare events cannot be fully excluded, the available clinical evidence supports a low risk of serious adverse outcomes associated with PN use. However, long-term safety data from multicenter registries or post-market surveillance remain limited, and further longitudinal studies are warranted.

Given this broad spectrum of favorable effects on cells and tissues, PNs are indicated for skin rejuvenation, anti-aging concerns, including facial skin sagging and wrinkles, and scar treatment. This versatility makes PNs an appealing option for improving overall skin health and appearance. This article synthesizes expert clinical perspectives on PNs, including a discussion of evidence-based indications, techniques, dosage considerations, and treatment protocols. Real-world clinical use of PNs will be illustrated through a discussion of four key indications: skin hydration and rejuvenation; retaining ligament strength and structural support; rosacea and eczema management; and scar remodeling and wound healing.

Main Body And Discussion

Mechanism of Action

While the precise mechanism of action of PNs remains under investigation, emerging evidence points to PNs supporting skin restorative effects through physiological and biomechanical processes (Figure 1). One proposed mechanism involves the formation of a temporary scaffold within the dermis, which may contribute to dermal stability and cellular activation, as seen in high-resolution scanning electron microscopy.[13] This study has shown that PNs natively adopt a highly ordered tessellated polyhedron structure.[13] The microstructure of PNs, composed primarily of pentagons and hexagons, appears to form a highly ordered matrix with uniform wall thickness and empty internal spaces.[13] This structural organization is hypothesized to facilitate the formation of a three-dimensional structural matrix within the dermis, providing physical support and redistributing dermal tension for stability.[6,13,14]

The size of the polyhedral compartments is significantly smaller than that of the average fibroblast, suggesting a physical surface conducive to cellular interaction and attachment.[13] The unique morphology of PNs may provide mechanical cues to dermal fibroblasts, facilitating their binding to these cells.[6,13] The forces generated in the presence of PNs scaffolds, in turn, exert mechanical cues on dermal fibroblasts to stimulate collagen synthesis and tissue remodeling,[6,13] improving skin firmness and contour over time.[9] These structural characteristics have been likened to

biotensegrity principles observed in natural tissues, in which scaffold geometry contributes to the regulation of cellular behavior through mechanotransduction.[13]

Finally, PNs have strong hydrating effects, with hydrophilic, long-chain PNs effectively attracting and retaining water molecules in the extracellular matrix (ECM).[3] Collectively, these effects of PNs may help support a favorable environment for skin restoration.

Treatment Indications

Emerging evidence has demonstrated clinical applications for PNs across a range of aesthetic concerns. We discuss evidence and provide practical guidance for the utility of sterile injectable DNA fragment optimized PNs (Rejuran®, PharmaResearch, South Korea) in skin hydration and rejuvenation, retaining ligament strength, rosacea and eczema, and scar remodeling and wound healing. Table 1 summarizes the dosage, route of administration, technique, and treatment protocol for pertinent skin concerns for which PNs are indicated. Figure 2 illustrates recommended techniques for treatment with PNs for different zones of the face and neck.

Skin Hydration and Rejuvenation

Ageing has a profound impact on the skin, leading to laxity, dryness, and the formation of fine lines and wrinkles, along with a loss of overall radiance.[9] To address these age-related changes, PNs are widely used by dermatologists in South Korea to improve skin texture, reduce pore size, address wrinkles, and alleviate skin redness resulting from inflammation or laser therapy.[5,11,15]

In the authors' experience, PNs may be used to enhance skin hydration and rejuvenation. Recommended techniques and injection parameters are listed in Table 1a. Typically, intradermal injections of PNs are administered using a 34G, 4 mm needle, covering areas such as the forehead, temples, cheeks, periorbital, perioral, and lip areas. A volume of 0.02–0.04 mL is injected per site, spaced 3–5 mm apart, with a total of 2–4 mL used per session. The recommended protocol includes three sessions at four-week intervals.

Clinical results from both real-world experience and published studies confirm the value of these techniques. PNs have demonstrated effectiveness in improving skin hydration, skin barrier, elasticity, and texture.[8,9] Patients in a randomized, double-blind, active-controlled trial (N=27) showed improved elasticity and skin tone with PNs on one side and HA treatment on the opposite side of the face for crow's feet and infraorbital rejuvenation.[9] A case series reported that five patients treated with four injections of PNs in two-week intervals showed considerable improvement in skin tone and reduced wrinkles and pore size at week 12 compared to week 2 of the study period.[8]

Retaining Ligament Strength and Structural Support

Age-related facial skin sagging results from a combination of loosening of the retaining ligaments and loss of facial volume and bone density.[16,17] PNs support dermal structure and hydration, improving firmness and elasticity through extracellular matrix (ECM) remodeling. The author's recommended techniques and injection parameters for structural support are listed in Table 1b. Deep injections along true and false retaining ligaments are performed using a 30G, 12 mm needle to address facial laxity, asymmetry, and mid-to-lower face aging. Target areas may include the forehead, temples, cheeks, and mandibular region, with 0.02–0.03 mL delivered per site and a total volume of 2–4 mL per session. For support of the temporal region, injections are made into the superficial subcutaneous plane using a 22G or 25G cannula, or intradermally near the preauricular area. The recommended protocol is three sessions at four-week intervals, followed by maintenance every three months.

While PNs are not volumizing agents, they may have some volumizing effects through tissue-supporting mechanisms for example fibroblast activation, collagen synthesis and ECM organization, which help address skin sagging by compensating for age-related facial volume loss.[12] Additionally, deep injections along true and false retaining ligaments using the tower technique can contribute to improved soft-tissue support along these ligaments.[18] True ligaments, such as the zygomatic ligament, anchor directly to both bone and skin, while false or fascio-SMAS ligaments, like the masseteric and mandibular ligaments, connect fascial layers without direct dermal insertion.[19] The tower technique, originally described in filler-based approaches, involves vertical injection of product into the deep tissue layer while progressively

Table 1 Treatment Protocols for Various Indications with Polynucleotides (PNs) with Practical Treatment Guidance Based on the Authors' Clinical Experience

Indications	Needle	Administration Route	Administration Areas	Dosage and Technique	Treatment Protocol
a. Treatment protocols for skin hydration and rejuvenation					
Skin hydration and rejuvenation	34G, 4 mm	Intradermal	• Forehead • Temples • Cheeks • Periorbital area • Lip • Perioral	• 0.02–0.04 mL per injection site • 2–4 mL whole face • 3–5 mm apart.	3 sessions at 4-week intervals.
b. Treatment protocols for facial laxity and structural support					
Skin laxity, mid/lower face ageing, facial asymmetry	30G, 12 mm	Deep injections along true and false retaining ligaments	• Forehead • Temples • Cheeks • Mandibular area	• 0.02–0.03 mL per injection site • 2–4 mL per treatment	3 sessions at 4-week intervals, then every 3 months.
Temple structural support	Blunt cannula (22G or 25G)	Superficial subcutaneous plane (cannula)	• Anterior temple • Posterior temple behind hairline	• 1.0–2.0 mL per injection site • 1–2 mL per side or 2–4 mL per treatment	
		Intradermal (needle)	• Pre-auricular area in front of hairline		
c. Treatment protocols for eczema and rosacea					
Eczema (atopic and seborrheic)	34G, 4 mm	Intradermal	• Forehead • Under eye • Cheeks	• 0.02–0.04 mL per injection site • 2 mL • 3–5 mm apart.	3 sessions at 3-week intervals.
Rosacea	34G, 4 mm or blunt cannula (25G or 27G)	Intradermal (needle) Subdermal (cannula)	• Cheeks	• 0.02–0.04 mL per injection site • 2 mL for both cheeks • 3–5 mm apart.	3 sessions at 3-week intervals.
d. Treatment protocols for scar remodeling and wound healing					
Early wound[a]	Not applicable	Topical application following EBD[c]	• Face • Neck	• 0.5–2 mL, depending on scar length. • Reapply every 30 minutes for 4 hours, then twice daily for 3 days.	2–6 sessions at 4-week intervals.
Late wound[b]	Not applicable				3–6 sessions at 4-week intervals.
Late scar (beyond 1 year)	Not applicable			• 0.5–2 mL, depending on scar length • Apply immediately following EBD. • 2 applications spaced 10 minutes apart • Reapply twice daily for 1 week.	Session 2 within 2 weeks of the first treatment, then 3–6 sessions at 4-week intervals (for face and neck) or 6-week intervals (for body).

Note: [a] 4–12 weeks after surgery [b] 3–12 months after surgery [c] Examples include 1927 nm thulium, erbium-doped yttrium aluminum garnet (YAG) laser, CO_2 laser, microneedling, and radio frequency microneedling.
Abbreviation: EBD, energy-based devices.

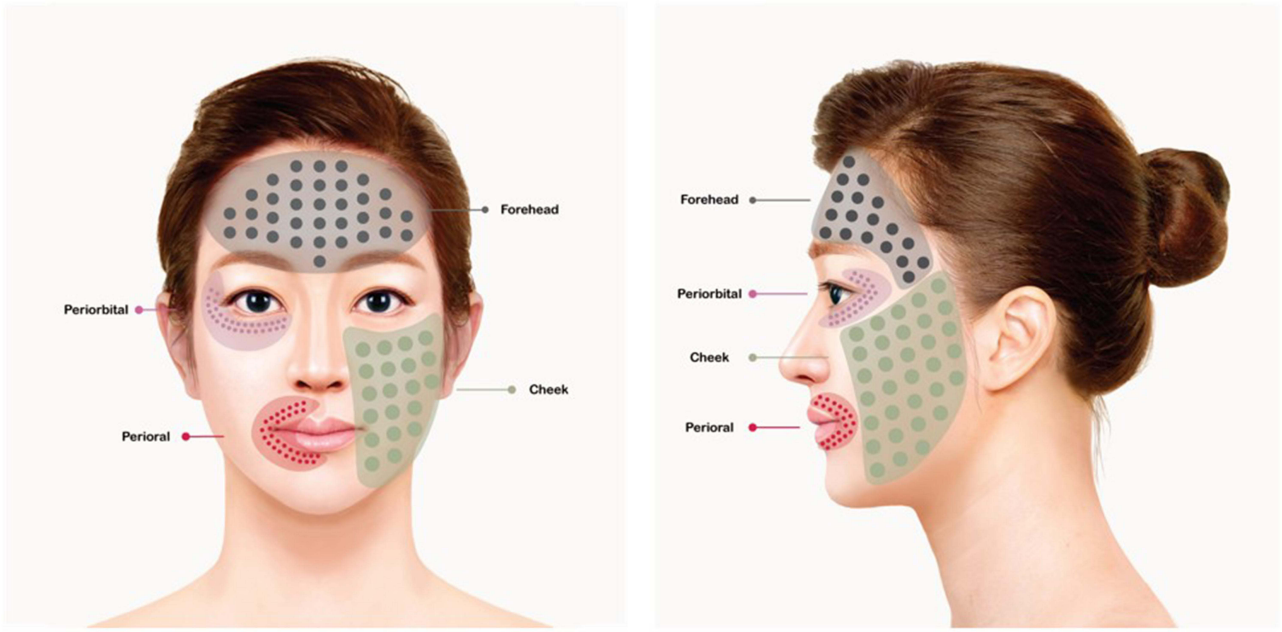

Figure 2 Recommended injection points for PNs treatment Figure 2 illustrates the recommended injection points for treatment with PNs. Treatment points for PNs application across different facial regions (left: front view, right: side view). PNs are recommended for the forehead (black) and cheeks (green), with suggested volumes of 0.02–0.03 mL and 0.03–0.05 mL per point, respectively. PNs are recommended for the periorbital (purple) and perioral (red) areas, with a suggested volume of 0.01–0.02 mL per point.

reducing the amount of filler injected during needle retraction.[18] This method may create a scaffold-like effect that supports overlying tissues. When applied to PNs administration, this technique is hypothesized to improve structural stability and enhance facial contouring.

Other techniques targeting true retaining ligaments and the superficial musculoaponeurotic system (SMAS) have been shown to be effective for facial support and contour. Injection of high G fillers into the base of the true retaining ligaments using a minimally invasive ligament retightening technique improved skin sagging and wrinkling in two patients.[20] Another minimally invasive lifting technique originally described by Suwanchinda et al[21] involved administering soft tissue fillers to the posterior temporal supra-SMAS to effectively address temporal volume loss and facial sagging due to age-related changes in the middle and lower face,[21] as demonstrated by a case report using this technique, that showed facial contouring effects beyond six months following HA treatment.[22]

While these techniques have traditionally been performed using HA or other volumizing agents, PNs may also be suitable due to their biophysical properties, such as scaffold support and improvements in skin quality. Evidence shows that PNs improve skin quality, texture, wrinkles, elasticity, and brightness,[8,23] suggesting they could be a valuable addition to a practitioner's toolkit for non-surgical facial rejuvenation.

Rosacea, Atopic Eczema, and Epidermal Barrier Recovery

Recurrent skin redness and sensitivity are common concerns among individuals with conditions associated with impaired skin barrier function, such as acne, rosacea, atopic eczema, and seborrheic eczema.[5] These conditions are often associated with compromised epidermal barrier function, which plays a key role in maintaining skin integrity, regulating hydration, and defending against environmental stressors.[24,25] In rosacea, for example, a study has shown increased transepidermal water loss (TEWL), reduced lipid content, and lower hydration levels compared to healthy skin.[26] Restoring this damaged barrier and improving hydration, therefore, represents a fundamental therapeutic strategy for improving these conditions.

PNs may support skin barrier recovery through their hydrophilic properties,[3] and the ability to improve skin moisture retention.[8] Dry skin has been identified as an indication of PNs.[15] In a preclinical model of mechanically disrupted skin,

a combination of PNs and HA significantly reduced TEWL and inflammation while increasing filaggrin levels.[27] Elevated levels of filaggrin, a pivotal structural protein that is inversely affected by inflammation, demonstrated the ability of PNs to influence moisture loss for optimal skin barrier repair.[27] A recent multicenter study evaluated the use of PNs for dry and chapped lips and reported significant improvements in wrinkle severity and surface roughness after three treatments, with most adverse events being mild and transient.[28] These findings further support the potential of PNs for restoring skin quality in areas prone to barrier disruption and moisture loss.

PNs have demonstrated effectiveness in reducing facial redness that is commonly associated with rosacea and eczema.[5,29] About 25% of dermatologists surveyed indicated rosacea as an indication that would benefit from treatment with PNs.[15] Collectively, the multiple mechanisms of action of PNs translate to increased skin hydration to aid epidermal barrier recovery, reduction in symptoms including redness and scaling, and long-term skin stability.

The authors have used PNs to treat eczema and rosacea with successful patient outcomes. Table 1c outlines suggested treatment protocols. In both conditions, intradermal injections are typically administered using a 34G, 4 mm needle, with 0.02–0.04 mL delivered per site, spaced 3–5 mm apart. A volume of approximately 2 mL is used per session. For rosacea, subdermal administration with a 25G or 27G blunt cannula may be considered in addition to intradermal injections. Eczema may be treated either across the full face or in a lesion-specific manner, whereas rosacea treatment typically targets only the cheeks. The recommended protocol consists of three sessions at three-week intervals.

Scar Remodeling and Wound Healing

The wound healing effects of PNs are well established.,[8,30,31] PNs are therefore considered a suitable choice to address scarring concerns.[5–7] Accumulating evidence points to PN's versatility for treating a variety of scars, such as post-injury facial scars,[32] moderate-to-severe atrophic acne scars,[33] post-surgery scars,[7,32] war injury and burns,[32,34] and facial scars following radiofrequency microneedling treatment.[32] In eight patients treated with PNs, either alone or in combination with platelet-rich plasma, incobotulinumtoxinA, or HA, the appearance of early and late scars and burns faded, and overall skin tone and quality improved.[32]

PN's effectiveness for scar and burn management stems from its combined physiological and biomechanical actions. PNs promote tissue restoration and repair by stimulating the production of fibroblasts and structural proteins, including collagen,[32] which is also a key player in scar remodelling.[3,32] By reducing hyperpigmentation, reducing the local oxidative state, improving skin texture, and promoting angiogenesis, PNs also enhance healing and reduce scarring.[3,6,32] Collectively, these attributes support the role of PNs in facilitating scar remodeling and wound healing.

Recommended treatment parameters for scar remodeling and wound healing are summarized in Table 1d. For early and late wounds, the skin is first permeabilized using an energy-based device (EBD), and PNs are then applied topically at a dose of 0.5–2 mL, depending on scar length. In early wounds, application is repeated every 30 minutes for 4 hours, then twice daily for 3 days. For late wounds, treatment involves 3–6 sessions at 4-week intervals. For mature scars, PNs may be applied immediately following EBD treatments, with two applications spaced 10 minutes apart and reapplication twice daily for one week. Follow-up sessions are recommended every 4–6 weeks.

Injection Techniques and Treatment Considerations

As PNs are increasingly used in aesthetic practice, there is a paucity of information on injection tools, techniques, and formulations for the best treatment outcomes.[6] Treatment planning and product selection should be customized based on individual patient needs and practitioner preferences. Between needles and cannulas, an expert consensus report recommended finer needles of 30 to 32 gauge for precise and uniform injections to the intradermal layer but recognized that treatment with cannulas targets a wider area with less injury.[23,35] A range of injection techniques may be employed and customized according to each patient's treatment goals and unique facial anatomy to maximize satisfaction and outcomes.[23] For dermal delivery, microdroplet and linear retrograde techniques have been identified as preferred techniques,[23,35] while the serial puncture technique may be appropriate for intradermal injections.[12] For example, these concepts have been demonstrated in a patient who received PNs via an intradermal puncture technique with a 30 gauge needle and reported improved appearance of depressions in the temple region.[12]

Formulation choice may also influence treatment outcomes. The use of low-strength, single-agent formulations of PNs would mitigate the likelihood of wheal formation in sensitive areas such as the periocular area.[35] By contrast, PN-HA combination formulations may be beneficial for extensively damaged skin due to the synergistic effects of PNs and HA.[27,35]

Beyond the indications discussed in this paper, PNs are also being investigated for a growing range of therapeutic applications, including androgenetic alopecia[36,37] and melasma,[38] reflecting emerging evidence and a rapidly growing research landscape for PNs.

Conclusion

Polynucleotides (PNs) are a promising class of bio-rejuvenation agents in aesthetic medicine. The unique biomolecular properties of PNs, including their hydrophilicity and structural scaffold-forming propensity, distinguish them from other injectables. Diverse physiological and biomechanical mechanisms contribute to the multifaceted benefits of PNs, offering significant clinical utility across a range of aesthetic concerns.

Expert perspectives and emerging evidence reinforce PN's effectiveness in improving skin hydration and texture, retaining ligament strength and structural support, reducing recurrent skin redness and sensitivity (rosacea and eczema), and facilitating scar remodeling and wound healing. Real-world treatment protocols reflect the versatility of PNs across indications, administration techniques, and target treatment areas. Furthermore, treatment with PNs is minimally invasive with a favorable tolerability profile, making PNs an attractive option for both patients and practitioners.

This perspective is based primarily on clinical experience and selected published data on PNs. Further research, including randomized controlled trials, mechanistic studies, and histological validation of treatment outcomes, is needed to establish and validate the proposed mechanisms of action and optimal treatment protocols and explore the role of PNs in other indications or in combination therapies. Long-term data on effectiveness are also needed to strengthen the evidence base and inform its optimal use in aesthetic and dermatological practice. Given the increasing demand for natural, minimally invasive, and evidence-based aesthetic solutions, PNs are emerging as a compelling next-generation technology in aesthetic medicine.

Abbreviations

AE, Adverse Event; DNA, Deoxyribonucleic Acid; EBD, Energy-Based Device; ECM, Extracellular Matrix; HA, Hyaluronic Acid; PNs, Polynucleotides; SEM, Scanning Electron Microscopy; SMAS, Superficial Musculoaponeurotic System; TEWL, Transepidermal Water Loss.

Acknowledgments

Medical writing and editorial support were provided by Tech Observer Asia Pacific, funded by PharmaResearch Co., Ltd.

Disclosure

NKR, SC, GC and AS serve as advisory board members for PharmaResearch Co., Ltd. SC also reports personal fees and/or non-financial support from Allergan, Benev, BTL, Galderma, Merz, Revance, PharmaResearch, Skin Medica, Revision, outside the submitted work. AS also reports personal fees from Merz Aesthetics, outside the submitted work. MJK and JS are employed by PharmaResearch Co., Ltd. The authors report no other conflicts of interest in this work.

References

1. Choi SY, Koh YG, Yoo KH, Han HS, Seok J, Randomized KBJA. Participant- and evaluator-blinded, matched-pair, prospective study comparing the safety and efficacy between polycaprolactone and polynucleotide fillers in the correction of crow's feet. *J Cosmet Dermatol*. 2025;24(1):e16576. doi:10.1111/jocd.16576
2. Lampridou S, Bassett S, Cavallini M, Christopoulos G. The effectiveness of polynucleotides in esthetic medicine: a systematic review. *J Cosmet Dermatol*. 2025;24(2):e16721. doi:10.1111/jocd.16721
3. Marques C, Porcello A, Cerrano M, et al. From Polydeoxyribonucleotides (PDRNs) to Polynucleotides (PNs): bridging the gap between scientific definitions, molecular insights, and clinical applications of multifunctional biomolecules. *Biomolecules*. 2025;15(1). doi:10.3390/biom15010148
4. Yi KH, Winayanuwattikun W, Kim SY, et al. Skin boosters: definitions and varied classifications. *Skin Res Technol*. 2024;30(3):e13627. doi:10.1111/srt.13627

5. Lee D, Kim MJ, Park HJ, et al. Current practices and perceived effectiveness of polynucleotides for treatment of facial erythema by cosmetic physicians. *Skin Res Technol*. 2023;29(9):e13466. doi:10.1111/srt.13466
6. Lee KWA, Chan KWL, Lee A, et al. Polynucleotides in aesthetic medicine: a review of current practices and perceived effectiveness. *Int J Mol Sci*. 25(15). doi:10.3390/ijms25158224
7. Kim JH, Jeong JJ, Lee YI, et al. Preventive effect of polynucleotide on post-thyroidectomy scars: a randomized, double-blinded, controlled trial. *Lasers Surg Med*. 2018;50:755–762. doi:10.1002/lsm.22812
8. Park KY, Seok J, Rho NK, Kim BJ, Kim MN. Long-chain polynucleotide filler for skin rejuvenation: efficacy and complications in five patients. *Dermatol Ther*. 2016;29(1):37–40. doi:10.1111/dth.12299
9. Lee YJ, Kim HT, Lee YJ, et al. Comparison of the effects of polynucleotide and hyaluronic acid fillers on periocular rejuvenation: a randomized, double-blind, split-face trial. *J DermatolTreat*. 2022;33(1):254–260. doi:10.1080/09546634.2020.1748857
10. 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
11. Rho NK, Kim HS, Kim SY, Lee W. Injectable "skin boosters" in aging skin rejuvenation: a current overview. *Arch Plast Surg*. 2024;51(6):528–541. doi:10.1055/a-2366-3436
12. Kim MJ, Park HJ, Oh SM, Yi KH. Polynucleotide injection treatment for iatrogenic fat atrophy in two patients: potential for safe volumization in aesthetic medicine. *Skin Res Technol*. 2023;29(8):e13439. doi:10.1111/srt.13439
13. Kim MJ, Park HJ, Jung RJ, et al. High-resolution 3-D scanning electron microscopy (SEM) images of DOT(TM) polynucleotides (PN): unique scaffold characteristics and potential applications in biomedicine. *Skin Res Technol*. 2024;30(4):e13667. doi:10.1111/srt.13667
14. Hayashi K, Yanagisawa T, Kishida R, Ishikawa K. Effects of scaffold shape on bone regeneration: tiny shape differences affect the entire system. *ACS Nano*. 2022;16(8):11755–11768. doi:10.1021/acsnano.2c03776
15. Rho NK, Han KH, Cho M, Kim HS. A survey on the cosmetic use of injectable polynucleotide: the pattern of practice among Korean Dermatologists. *J Cosmet Dermatol*. 2024;23(4):1243–1252. doi:10.1111/jocd.16125
16. Araghi F, Dadkhahfar S, Pourani MR, Gheisari M. The importance of facial retaining ligaments' preservation during the subcision. *Aesthet Surg J*. 2022;42(1):NP87–NP88. doi:10.1093/asj/sjab332
17. Ryu MH, Khoo LS, Lee JO, Li D. Reframing the etiology of facial sagging from a facelift perspective. *Plast Reconstr Surg Glob Open*. 2018;6(7): e1831. doi:10.1097/GOX.0000000000001831
18. Bartus CL, Sattler G, Hanke CW. The tower technique: a novel technique for the injection of hyaluronic acid fillers. *J Drugs Dermatol*. 2011;10 (11):1277–1280.
19. Mirontsev A, Andruschenko O, Vasil'ev Y, et al. Clinical anatomy of the ligaments of the face and their fundamental distinguishing features. *Medicina*. 2024;60(5). doi:10.3390/medicina60050681
20. Huang P, Li CW, Yan YQ. Efficacy evaluation of True Lift ® a nonsurgical facial ligament retightening injection technique: two case reports. *World J Clin Cases*. 2022;10(27):9783–9789. doi:10.12998/wjcc.v10.i27.9783
21. Suwanchinda A, Webb KL, Rudolph C, et al. The posterior temporal supraSMAS minimally invasive lifting technique using soft-tissue fillers. *J Cosmet Dermatol*. 2018;17(4):617–624. doi:10.1111/jocd.12722
22. Sahawatwong S, Sirithanabadeekul P, Patanajareet V, Wattanakrai P, Thanasarnaksorn W. A novel technique of supra superficial musculoaponeurotic system hyaluronic acid injection for lower face lifting. *J Clin Aesthet Dermatol*. 2016;9(2):58–62.
23. Cavallini M, Bartoletti E, Maioli L, et al. Consensus report on the use of PN-HPT (polynucleotides highly purified technology) in aesthetic medicine. *J Cosmet Dermatol*. 2021;20(3):922–928. doi:10.1111/jocd.13679
24. Darlenski R, Kazandjieva J, Tsankov N, Fluhr JW. Acute irritant threshold correlates with barrier function, skin hydration and contact hypersensitivity in atopic dermatitis and rosacea. *Exp Dermatol*. 2013;22(11):752–753. doi:10.1111/exd.12251
25. Addor FA. Skin barrier in rosacea. *Anais brasileiros de dermatologia*. 2016;91(1):59–63. doi:10.1590/abd1806-4841.20163541
26. Zhou M, Xie H, Cheng L, Li J. Clinical characteristics and epidermal barrier function of papulopustular rosacea: a comparison study with acne vulgaris. *Pak J Med Sci*. 2016;32(6):1344–1348. doi:10.12669/pjms.326.11236
27. Ha YJ, Tak KH, Jung JM, et al. The effect of polynucleotide-hyaluronic acid hydrogel in the recovery after mechanical skin barrier disruption. *Skin Res Technol*. 2024;30(9):e70068. doi:10.1111/srt.70068
28. Rho NK, Park HJ, Kim HS. Clinical efficacy and safety of a highly purified polynucleotide for dry and chapped lips: a prospective, multicenter study. *J Cosmet Dermatol*. 2025;24(5):e70224. doi:10.1111/jocd.70224
29. Lee DK, Oh M, Kim MJ, Oh SM. Clinical effects of polynucleotide with hyaluronic acid intradermal injections on facial erythema: effective redness treatment using polynucleotides. *Skin Res Technol*. 2024;30(9):e70034. doi:10.1111/srt.70034
30. Galeano M, Bitto A, Altavilla D, et al. Polydeoxyribonucleotide stimulates angiogenesis and wound healing in the genetically diabetic mouse. *Wound Repair Regen*. 2008;16(2):208–217. doi:10.1111/j.1524-475X.2008.00361.x
31. Jin H, Seo J, Eun SY, et al. P2Y2 R activation by nucleotides promotes skin wound-healing process. *Exp Dermatol*. 2014;23(7):480–485. doi:10.1111/exd.12440
32. Kim MJ, Wan J, Oksana L, et al. Polynucleotide-based treatments for various facial scars including combat injuries. *J DermatolTreat*. 2024;35 (1):2426626. doi:10.1080/09546634.2024.2426626
33. Araco A, Araco F. Preliminary prospective and randomized study of highly purified polynucleotide vs placebo in treatment of moderate to severe acne scars. *Aesthet Surg J*. 2021;41(7):NP866–NP874. doi:10.1093/asj/sjab125
34. Rho N-K, Chung S. Treatment of a full-thickness laceration scar on the forehead using a 1,064-nm fractional picosecond laser and polynucleotide gel injection. *Med Lasers*. 2018;7:88–90. doi:10.25289/ML.2018.7.2.88
35. Cavallini MB, Maioli E, Palmieri L, Papagni M, Priori M, Trocchi G. Value and benefits of the polynucleotides HPT™ dermal priming paradigm a consensus on practice guidance for aesthetic medicine practitioners and future research. *Clin Exp Dermatol or Clin. Exp. Dermatol*. 2024;9.doi: 10.29011/2575-8268.100224.
36. Thanasarnaksorn W, Limsuchaiwat N, Sirithanabadeekul P, Charoensuksira S, Suwanchinda A, Meephansan J. Polynucleotides as a novel therapeutic approach in androgenetic alopecia: an analysis of effectiveness and safety. *Arch Dermatol Res*. 317(1):399. doi:10.1007/s00403-025-03908-6

37. Leone A. Polynucleotides versus platelet-rich plasma for androgenetic alopecia: a case series. *JOJ Dermatol Cosmet*. 2025;6.doi: 10.19080/JOJDC.2025.06.555699.
38. Gulfan MCB, Wanitphakdeedecha R, Wongdama S, Jantanapornchai N, Yan C, Rakchart S. Efficacy and Safety of Using noninsulated microneedle radiofrequency alone versus in combination with polynucleotides for the treatment of melasma: a pilot study. *Dermatol Ther*. 2022;12(6):1325–1336. doi:10.1007/s13555-022-00728-8