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Monopolar Radiofrequency for Dermal Prejuvenation: Scientific Rationale and Mechanisms of Action

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ABSTRACT

Objectives: To summarize the scientific rationale for the use of the monopolar radiofrequency tissue tightening system (monoRF) for the prevention of dermal aging (termed rejuvenation).

Materials and Methods: This narrative review summarizes the basic science of dermal aging and monoRF-induced collagen remodeling and neocollagenesis. Studies supporting the mechanism of action of monoRF treatment and its use for rejuvenation are reviewed.

Results: Dermal aging is largely attributed to the accumulation of fragmented collagen and depleted collagen levels. Collagen remodeling and neocollagenesis may be induced by monoRF treatment, resulting in immediate tissue tightening and subsequent collagen production, respectively. Preliminary data and expert opinion suggest that early and repeated intervention with monoRF may prevent progressive skin laxity via synergistic and cumulative effects.

Conclusions: MonoRF treatment shows potential as a rejuvenation strategy, with preliminary evidence supporting that it induces collagen remodeling and neocollagenesis. Future research should focus on long-term, prospective studies to determine the preventive benefits of consistent annual treatment for aging.

1 | Introduction

Intrinsic and extrinsic aging contributes to reduced collagen levels and fibroblast activity in the dermis, culminating in physical changes such as wrinkling and skin laxity [1, 2]. Corrective rejuvenation treatments may retroactively mitigate these changes; however, younger generations are proactively seeking antiaging treatments before the emergence of discernable dermal aging [3–5]. Popularity of preventive treatments to delay aging, or “rejuvenation,” is driven largely by social media and, by extension, a desire for unrealistic, flawless perfection. Rejuvenation encompasses multiple noninvasive treatments, including dermal fillers, neurotoxins, skin resurfacing procedures, and consistent skincare routines [3–5]. Additionally,

individuals may prefer treatments that do not alter their physical traits to maintain a natural appearance [3, 4]. Although the primary goal of rejuvenation is to maintain a youthful skin appearance, biological benefits include increased collagen formation, reduced cellular senescence, and sustained skin health [4].

The monopolar radiofrequency tissue tightening system (monoRF; Thermage® FLX; Solta Medical) is indicated for the noninvasive treatment of rhytids including those of the periorbital region [6]. The 4th-generation (4th-gen) device utilizes specialized tips to treat multiple body areas, including 3- or 4-cm² tips for the face and small body areas, a 0.25-cm² tip for the periorbital area and eyelids, and a 16-cm² tip for large body areas [6]. Unlike devices that create fractional injury patterns or discrete focal points (eg,

[Correction added on 17 January 2026, after first online publication: The author requested their name be corrected to Mathew Avram in the article.]

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radiofrequency microneedling, fractional lasers, high-intensity focused ultrasound), or devices that rely on inflammatory cascades (eg, injectable biostimulators) [7–10], monoRF treats an area uniformly and noninvasively to reduce skin laxity and may be an effective option for those interested in prejuvenation. Furthermore, its mechanism of action may optimize the inherent architecture of the skin and addresses laxity from a preventive standpoint.

To provide a scientific basis for monoRF treatment for prejuvenation, this narrative review summarizes the basic science of dermal aging, the mechanism of monoRF-induced tissue tightening, histological studies of monoRF treatment, and clinical data that support monoRF treatment as a preventive strategy against skin aging.

2 | Mechanisms of Dermal Aging

2.1 | Changes in Collagen Structure With Advanced Age

At approximately 40 years of age, collagen occupies nearly 70% of the papillary and reticular dermis and diminishes with advancing age to as low as 43% and 57% by the age of 90 years and older, respectively [11]. Type I collagen is the most abundant type of collagen in the dermis and is almost entirely made up of polypeptide chains containing a repeating amino acid pattern that form a unique triple helix structure largely stabilized by hydrogen bonds [12]. The triple helices self-align to create collagen microfibrils, which are crosslinked to form macrofibers and a collagen network that mechanically supports skin [12]. Young skin has a network of organized, elongated, and highly functional collagen fibers, whereas aged skin contains clumped, fragmented, and rigid fibers [1].

Between the ages of 20–30 years and > 80 years, the amount of fragmented collagen can increase by 400% [13]. Collagen fragmentation is closely linked to changes in crosslinking patterns [1, 13]. Although collagen crosslinks initially facilitate structure and organization to the collagen network, over time, these crosslinks are replaced by extremely stable covalent bonds, leading to increased collagen rigidity [1, 13]. As the collagen network becomes clumped and disorganized, fibroblasts experience less mechanical tension resulting in decreased fibroblast activity, including diminished collagen production, prompting a cycle of collagen depletion [14]. Because the bonds that form fragmented collagen are not easily remodeled, preventing its accumulation may be a key mechanism underlying prejuvenation.

2.2 | Impaired Fibroblast Activity With Aging

Fibroblasts in older skin produce less type I collagen and more extracellular matrix (ECM) proteases than younger fibroblasts and are more likely to enter senescence, during which they release fewer growth factors and promote an inflammatory environment [14–18]. These age-related changes in fibroblast function represent a loss of specialized identity and are accompanied by changes in fibroblast shape, reduced proliferative capacity, and decreased mechanical tension [18, 19]. Reduced mechanical tension is associated with the release of matrix metalloproteinases that further contribute to dermal

aging [14, 15]. The compromised activity of aged fibroblasts, combined with increased matrix degradation, results in a progressive decline in dermal structural integrity [15]. Procedures that promote the production of new collagen and fibroblast activity may assist in ameliorating skin aging.

3 | Thermally Induced Collagen Remodeling

3.1 | Collagen Remodeling

The primary mechanism behind tissue tightening is thermally induced collagen remodeling. The concept of applying energy to heat collagen and induce remodeling was established by early in vitro and in vivo studies of animal joint tissues [20–22]. Heating collagen to ~65°C breaks intramolecular crosslinks (eg, hydrogen bonds) while retaining the intermolecular crosslinks of the collagen network, causing collagen to thicken in diameter and shorten in length [12, 20]. However, because fragmented collagen that accumulates with age is held together by heat-stable covalent crosslinks, treatment in aged skin may be less effective than in younger skin. Therefore, prejuvenation-based approaches such as monoRF may be more efficient than treating tissue that has aged substantially (Figure 1) [1, 12, 14, 15, 20, 23–27].

For clinical applications, both laser and radiofrequency energy sources may be used to induce collagen remodeling [22]. However, radiofrequency offers a distinct advantage because its energy is not absorbed by melanin and therefore is appropriate for use in individuals of any skin type [28]. Additionally, monoRF does not disrupt the epidermis, resulting in virtually no posttreatment downtime and low risk of serious adverse events. These mechanistic characteristics position monoRF therapy as an ideal prejuvenation strategy aimed at preventing age-related skin changes before they become established.

3.2 | Thermal Wound Healing Response

In addition to direct collagen remodeling, monoRF treatment stimulates the body's natural repair mechanisms. Controlled thermal damage, such as that induced by monoRF treatment, triggers a wound healing response [24]. Importantly, skin wound healing mechanisms overlap with key antiaging processes (eg, growth factor secretion, increased fibroblast activity, and increased ECM [including collagen] production), enabling monoRF treatment to foster skin health through intercellular signaling and ECM revitalization [29]. Therefore, monoRF therapy results in both immediate and sustained effects: while skin tightening happens instantaneously after monoRF treatment, the wound healing process continues for 2–6 months [25].

4 | Histological Validation of the MOA of MonoRF

Early studies demonstrated collagen remodeling with radiofrequency treatment in preclinical models of nondermal collagen-dense tissues [20, 22]. The ability of monoRF treatment to remodel collagen and induce neocollagenesis in human skin has been validated by multiple histological and ultrastructural studies [24, 30–32]. Additionally, other changes in

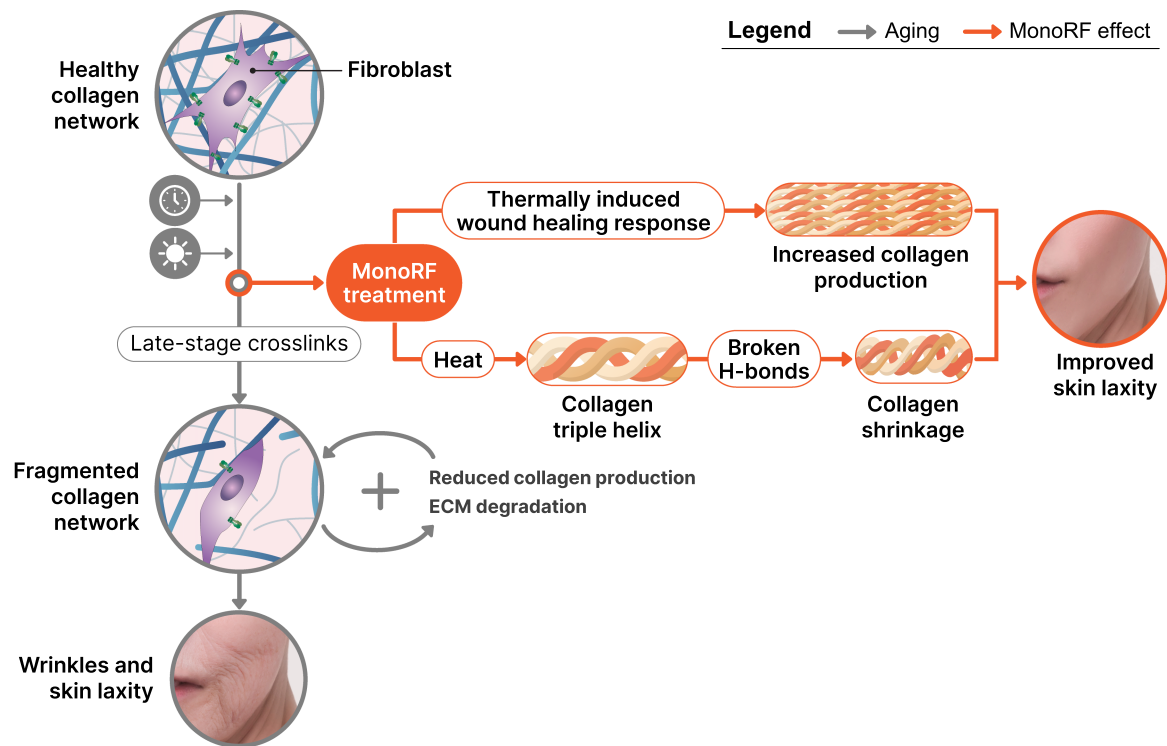


FIGURE 1 | Proposed mechanism of prejuvenation through monoRF-induced collagen remodeling. During skin aging, fragmented collagen fibers (stabilized by thermostable crosslinks) accumulate and contribute to wrinkle formation. Fragmented collagen initiates a positive feedback loop where fibroblasts produce less collagen and more ECM proteases, leading to further collagen fragmentation. Treatment with monoRF may therefore be more effective when applied before significant accumulation of fragmented collagen and establishment of this aging cycle. Two primary mechanisms facilitate dermal prejuvenation: (1) disruption of hydrogen bonds in collagen's triple helix structure, resulting in immediate collagen shrinkage and skin tightening and (2) stimulation of wound healing responses resulting in increased fibroblast activity and neocollagenesis [1, 12, 14, 15, 20, 23–27]. ECM, extracellular matrix; monoRF, monopolar radiofrequency tissue tightening system.

dermal content such as increased dermal thickness have been reported [24, 30, 31].

4.1 | Collagen Remodeling in Human Skin

Clinical studies have provided direct evidence of monoRF's effects on collagen structure in human skin. Abdominal skin from two volunteers treated with 1st-gen monoRF exhibited interspersed areas of merged collagen fibrils with increased diameter immediately after treatment [24]. Additionally, facial biopsy samples from six individuals with Fitzpatrick skin type (FST) III to IV and Glogau class I to II wrinkles were treated with a monopolar radiofrequency device (Biorad, Shenzhen GSD Tech Co) that has identical properties to 1st-gen monoRF [30]. Samples exhibited an increase in a collagen band at the dermoepidermal junction (grenz zone, before treatment: $9.8 \pm 3 \mu\text{m}$; at the end of treatment: $11 \pm 2.3 \mu\text{m}$ [$p = 0.573$]; at 3-month follow-up: $15.6 \pm 2.3 \mu\text{m}$ [$p = 0.004$]). These data confirm that upon treatment with monoRF, human collagen is remodeled to form thick fibrils.

4.2 | Neocollagenesis

Beyond structural changes in existing collagen, monoRF treatment stimulates the production of new collagen. The increase in collagen fibrils observed in abdominal skin after treatment with 1st-gen monoRF was accompanied by increased type I collagen

mRNA expression (2.4-fold at 2 days and 1.7-fold at 1 week posttreatment) [24]. Supporting these molecular findings, the study that evaluated six facial biopsy samples reported significantly increased percentages of dermis-positive collagen from baseline to immediately after treatment and at the 3-month follow-up for type I and type III collagen ($p \leq 0.05$ for all posttreatment assessments; Figure 2A) [30]. Increase of collagen content coincided with significant emergence of newly synthesized collagen ($p < 0.05$ for each time point), suggesting the presence of active neocollagenesis after treatment (Figure 2B) [30].

Additional clinical evidence further strengthens these observations. A study that analyzed cheek biopsy samples from 11 individuals treated with 3rd-gen monoRF reported significant increases in collagen density throughout the reticular and papillary dermis (12.6%–17.9% increase, $p < 0.05$) 2 months posttreatment [31]. Similarly, another histometric study of 11 individuals with FST III and IV treated with 4th-gen monoRF reported significantly increased collagen fiber density in the papillary and lower reticular dermis compared to that before treatment (0.736 ± 0.06 and 0.652 ± 0.063 , respectively) to 6 months after treatment (0.773 ± 0.044 and 0.686 ± 0.05 , respectively; $p < 0.05$ for each) [32].

Collectively, these studies demonstrate increased collagen production after monoRF treatment. Because collagen-fibroblast contacts activate the production of ECM components [14], monoRF-induced neocollagenesis may also contribute to a positive cycle of collagen production. These studies demonstrate

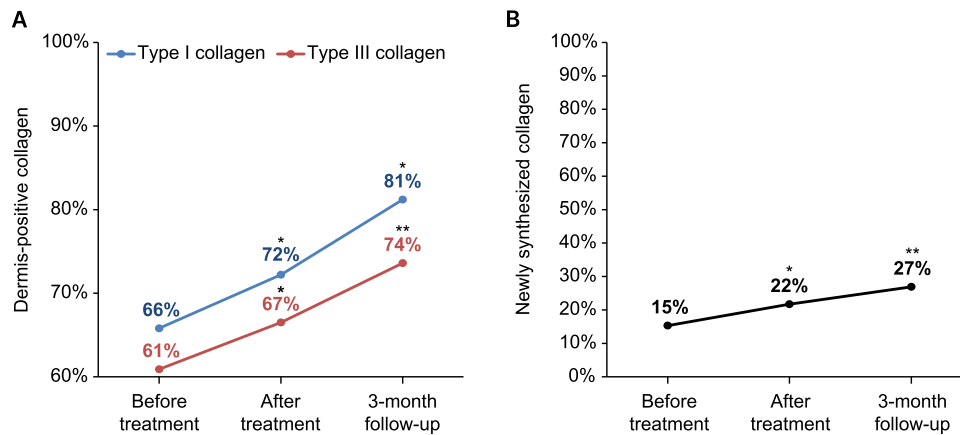


FIGURE 2 | Changes in dermal collagen after treatment with a device with identical properties to those of 1st-gen monoRF as measured by (A) percentage of dermis-positive collagen and (B) percentage of newly synthesized collagen [30]. Biopsy samples were taken from six individuals with FST III to IV and Glogau class I to II wrinkles who underwent six sessions of monopolar radiofrequency treatment at 2-week intervals. The percentage of dermis-positive collagen was determined by immunohistochemistry. The percentage of newly synthesized collagen was determined by histological staining (picrosirius red staining). * $p \leq 0.05$, ** $p = 0.001$. gen, generation; monoRF, monopolar radiofrequency tissue tightening system; FST, Fitzpatrick skin type.

that neocollagenesis begins within days posttreatment, with measurable peaks continuing 2 to 6 months after treatment. Additionally, studies enrolled participants with a mean age of 49 to 51 years and predominantly FST III to IV [30–32]. However, future studies are warranted to include a more diverse patient population, as younger patients demonstrate dermal resilience owing to higher collagen and elastin activity, whereas older patients (40s–50s) experience decreased collagen synthesis and increased disorganization of skin structure [33] but still benefit from treatment, as demonstrated by the studies listed above.

4.3 | Dermal Thickness

In addition to ECM remodeling, studies report increases in dermal thickness with monopolar radiofrequency treatment. Significant increases in epidermal thickness have been reported immediately after treatment with a device similar to 1st-gen monoRF ($67 \pm 3.9 \mu\text{M}$, $p = 0.044$) and at 3 months posttreatment ($79.5 \pm 9.8 \mu\text{M}$, $p = 0.002$) compared to baseline ($62.7 \pm 2.4 \mu\text{M}$) [30]. Consistent with these findings, similar increases were seen in granular layer thickness from baseline ($6.4 \pm 1.1 \mu\text{M}$) to immediately after treatment ($9.9 \pm 1.5 \mu\text{M}$, $p = 0.001$) and 3 months posttreatment ($17.7 \pm 3.1 \mu\text{M}$, $p = 0.0001$). These changes were accompanied by epidermal hyperplasia that increased through the 3-month follow-up. Similarly, a 6.49% ($p = 0.042$) increase in dermal thickness has been reported 2 months after 3rd-gen monoRF treatment [31]. Taken together, these findings demonstrate that monoRF therapy increases dermal thickness, potentially because of a monoRF-induced wound healing response that causes hyperplasia.

5 | MonoRF for Prejuvenation

The therapeutic efficacy of monoRF to tighten skin, including that of the periorbital region, has been established in key clinical studies with none-to-few reported adverse events

[26, 34–40]. One study has evaluated the use of multiple monoRF sessions over time, providing preliminary data for its potential role in prejuvenation [41]. This key retrospective study by Suh et al observed eight Asian patients over 6 to 7 years. The patients, aged 34 to 65 years (mean 46 years) with Glogau class I to III wrinkles, underwent three to seven sessions (mean four sessions) at intervals ranging from 4 to 45 months (mean 19 months). Treatment was performed using 2nd- and 3rd-gen devices, with early sessions utilizing the 1-cm² 150-pulse tip and later sessions using the 3-cm² tip (300–400 shots) at an energy of 2 to 3.5 J. The results showed that seven of eight patients exhibited no change in the severity of their wrinkles over the course of the study as measured by Glogau Classification, indicating a preventive effect of treatment (Figure 3A) [41]. Furthermore, 100% of patients and nontreating blinded dermatologists ranked their satisfaction with treatment as satisfied or highly satisfied (Figure 3B and C) [41], with the highest satisfaction reported in patients in their 30s and early 40s who received the most treatments. Although this study was preliminary and limited by a small sample size and heterogeneous treatment regimens, the data support that repeated treatments over time may maintain skin tightness.

The preventive benefits of monoRF treatment are supported by both expert consensus and evidence from clinical studies [42, 43]. A Delphi consensus panel of eight international esthetic dermatology experts asserted that “Patients who are treated with [4th-gen monoRF] every 1 to 2 years may experience prolonged, consistent skin tightening that could help to prevent future sagging.” [42] The importance of early intervention is further supported by evidence that monoRF treatment is more effective in younger patients. For example, in a study of 50 participants (mean age 53.3 years; FST I–IV) with mild-to-moderate cheek or neck laxity, 45 experienced clinical improvement after 1st-gen monoRF treatment (cheek settings: mean fluence 130 J/cm², level 13.5–16; neck settings: mean fluence 110 J/cm², level 12–15.5) [43]. Notably, all five participants who did not experience improvement were above 62 years of age and were the oldest enrolled in the study. This finding, combined with histological data, supports the proposed

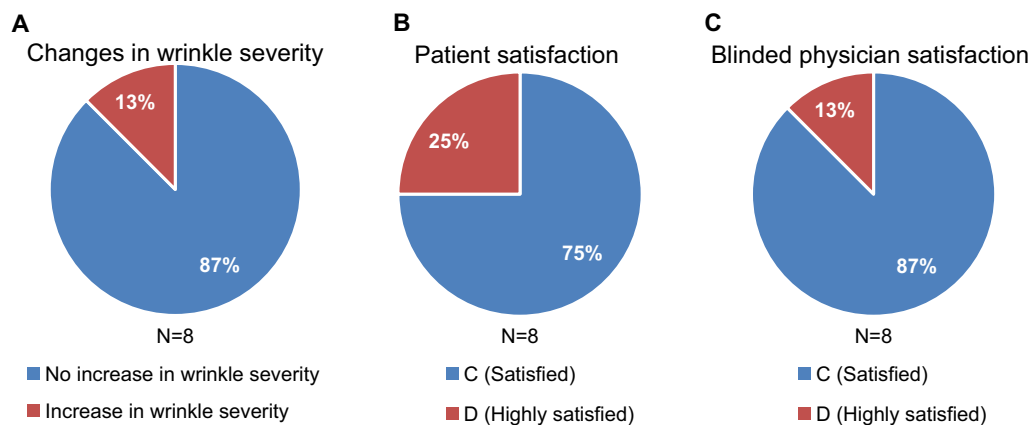


FIGURE 3 | (A) Wrinkle severity assessment, (B) patient satisfaction rating, and (C) physician satisfaction rating with long-term use of 2nd- or 3rd-gen monoRF therapy among eight patients. Changes in wrinkle severity were measured by Glogau Classification. Patient and physician satisfaction were measured on a 4-point scale (A = not satisfied; B = somewhat satisfied; C = satisfied; D = highly satisfied). Physician satisfaction scores were based on photographic evaluation by nontreating blinded dermatologists (sample size not reported) [41]. gen, generation; monoRF, monopolar radiofrequency tissue tightening system.

mechanism of action of monoRF treatment for prejuvenation, wherein treatment is most beneficial before the accumulation of fragmented collagen. Collectively, expert opinion, clinical evidence, and histological data signal that future studies monitoring the benefit of repeated treatments before advanced aging are likely to confirm that monoRF treatment contributes to prejuvenation. However, it should be noted that aging is multifactorial and influenced by various extrinsic and intrinsic factors including physiological stressors, environmental factors, and genetic predisposition [44]. Additional prospective studies examining these variables would contribute significantly to our understanding of treatment efficacy across diverse populations.

With the uptick of trending esthetic products and the pressure of “FOMO,” or fear of missing out, on social media, younger generations are increasingly embracing early interventions [3–5]. In a 2018 survey, almost 75% of plastic surgeons reported seeing an increase in patients aged younger than 30 years [45]. This shift has led to esthetic treatments—injectables, facials, and lasers—being introduced at an earlier age, reinforcing the idea that prevention is key. The concept of prejuvenation is redefining the language around esthetic treatments, moving beyond the outdated debate of nonsurgical options versus plastic surgery. Instead, the focus is now on preserving and optimizing youthful features to delay or even eliminate the need for invasive procedures. In this space, monoRF plays a critical role, with data supporting its ability to slow down the aging process by stimulating collagen production and optimizing the skin’s inherent structure. Unlike treatments that simply address concerns, monoRF works beneath the surface to maintain skin integrity, making it a potentially valuable addition to the prejuvenation movement. As the industry pivots toward proactive care, dermatologists must lead this conversation, ensuring that patients receive safe, effective, and evidence-based treatments rather than allowing trends driven by social media influencers to dictate esthetic decisions.

6 | Conclusion

Basic science, clinical evidence, and expert opinion support monoRF treatment as an effective procedure to include in

Clinician Quotes About MonoRF Treatment and Prejuvenation

Fulfilling patient needs

“We have many Asian patients in Boston. They come in asking for monoRF; it is a huge trend. We are seeing a younger and more diverse demographic”

Trends in esthetics

“[Energy-based treatment is] crossing over to skin care. Younger generations are thinking about [esthetics] differently than before”

Natural esthetics with energy-based devices

[I tell my patients,] “You will never look like a different person”

FIGURE 4 | Clinician insights regarding monoRF and prejuvenation trends. Quotes gathered from authors from an advisory board held on October 28, 2024. monoRF, monopolar radiofrequency tissue tightening system.

prejuvenation skin regimens. Treatment with monoRF induces immediate collagen remodeling through thermal denaturation and subsequent neocollagenesis via a wound healing response. Histological studies demonstrate increases in collagen content and dermal thickness after monoRF treatment. Although clinical evidence on prejuvenation remains limited, existing studies have demonstrated that non-ablative radiofrequency induces controlled dermal heating, resulting in fibroblast activation, neocollagenesis, and improved ECM organization [24, 31, 32, 46]. Early and consistent monoRF treatments may help maintain

collagen integrity and dermal elasticity by promoting balanced remodeling before significant age-related collagen fragmentation occurs. In consumer terminology, this concept has been referred to as “collagen banking,” although further longitudinal studies are warranted to substantiate its long-term preventive potential. Because monoRF treatment does not alter appearance to the degree of other esthetic procedures (eg, neuromodulators or corrective surgery), use in individuals who desire a natural effect is recommended (Figure 4).

A key limitation of the available literature is that most clinical studies on proprietary esthetic devices are funded by manufacturers, which may introduce bias in study design, outcome reporting, and interpretation of results. Future research should focus on establishing optimal treatment intervals for prejuvenation, examining long-term safety and durability, identifying ideal patient age for treatment initiation, and conducting larger long-term studies to quantify the preventive benefits of regular monoRF treatment.

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Conflicts of Interest

Suzanne L. Kilmer and Mathew Avram are consultants for Solta Medical, a division of Bausch Health Companies Inc. Ashish C. Bhatia is a speaker and consultant for Solta Medical, a division of Bausch Health Companies Inc. Nicole Y. Lee is a speaker for Solta Medical, a division of Bausch Health Companies Inc, and Galderma RX/Aesthetics. Abby Jacobson is an employee of Bausch Health Companies Inc.

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