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A Review of Research on Radiofrequency Technology for Delaying Skin Aging

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Abstract. Skin aging is an external manifestation of aging that occurs with increasing age, triggered by multiple mechanisms. Its main characteristics include skin laxity, increased wrinkles, and volume loss. Maintaining or improving youthful skin has become an increasingly important focus. With ongoing research, various anti-aging technologies have emerged. Radiofrequency (RF) technology, due to its ease of operation, high safety, and relatively long-lasting effects in facial rejuvenation treatments, has become an important cosmetic treatment method. Studies show that various RF technologies, ranging from monopolar to multipolar, can effectively reduce wrinkles, improve sagging skin, and enhance skin texture. However, there are limitations, including insufficient efficacy in some cases. This article aims to systematically review the latest developments in the appli cation of RF technology for skin anti-aging, providing a reference for enhancing its clinical efficacy.

Keywords: Radiofrequency technology, skin aging, facial rejuvenation

1. Introduction

Radio Frequency (RF) is a high-frequency, alternating electromagnetic wave, and it is a new non-invasive cosmetic technology, following lasers and photonics. As we age, changes in facial fat aging lead to deep facial fat atrophy and sagging, superficial fat expansion, and loosening of fat septa. At the same time, the skin also ages, resulting in sagging and a decrease in elasticity. The accumulation of subcutaneous fat in the lower face, combined with sagging skin and reduced elasticity, creates a bulky appearance, a rounded jawline, the formation of jowls, and ultimately, an aged appearance in the lower face [1].With the rapid development of the medical aesthetics field, radiofrequency skin tightening technology has become increasingly popular among beauty seekers. It has become a key option in anti-aging treatments. Skin aging is mainly caused by natural aging and prolonged exposure to ultraviolet rays, often manifesting as wrinkles, skin laxity, and changes in skin texture. As a non-invasive facial rejuvenation method, monopolar radiofrequency has demonstrated good safety and feasibility in clinical applications; however, a potential risk of complications remains, requiring careful attention during the procedure. To ensure treatment safety, care should be taken to maintain complete and even contact between the treatment head and the skin, and the integrity of the treatment head should be regularly checked during the process. The mechanism of this technology

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relies on the electrical properties of biological tissues themselves, without relying on specific pigments. Therefore, radiofrequency is safe for all skin types [2].

2. The principles of radio fre quency technology

2.1. Mechanism of RF energy action

By virtue of the electromagnetic induction and electromagnetic wave radiation, radio frequency energy transmission is widely used in wireless charging, IoT (the Internet of Things), smart home etc. In particular, when the current flows through a conductor, an EMF is produced surrounding the same and if this current is applied by the RF signal at least having a specific frequency it produces propagating electromagnetic waves. Once a receiver captures these electromagnetic waves, they can be further converted into usable electrical energy.

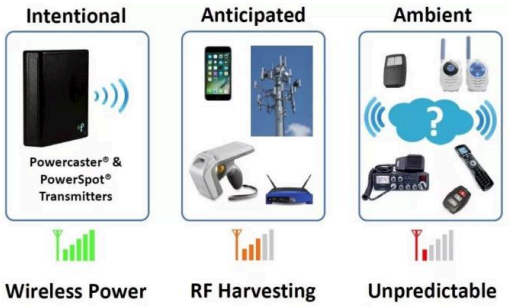

Figure 1. RF energy harvesting

2.2. The mechanism of action of radiofrequency technology on the skin

The basic mechanism of conventional contact-type non-invasive radiofrequency technology is based on the Joule heating effect. Radiofrequency electromagnetic waves alternate at extremely high frequencies, often reaching tens of millions of times per second, causing polar water molecules in biological tissues to rotate rapidly and rub against each other under the influence of the alternating electric field, thereby generating heat. This thermal energy acts on collagen, causing it to undergo thermal denaturation, which triggers the tissue's wound repair response and promotes the synthesis and remodeling of new collagen, thereby improving mild to moderate skin laxity. The clinical efficacy of radiofrequency treatment primarily depends on its intensity, which is directly related to the electrical resistance characteristics of the target tissue. The higher the local impedance, the more significant the heat accumulation, and the deeper the energy penetrates the tissue. Within safe limits, appropriately increasing the duration of a single treatment, raising the output energy, or increasing the treatment frequency can all further enhance the treatment effect(Figure 2).

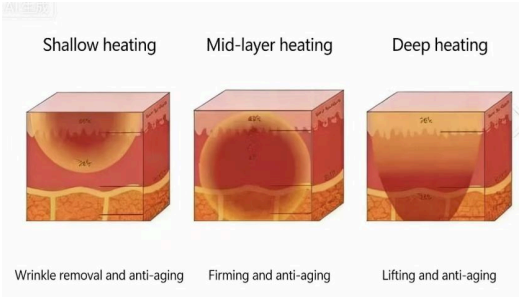

Figure 2. Effects of different levels of heating on the skin

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2.3. Principle of radio frequency heating

Radio frequency (RF) heating relies on dielectric loss in high-frequency electric fields and hysteresis loss in magnetic materials to raise the temperature of objects. This technology acts on charged particles within the material to be heated through a high-frequency electromagnetic field, causing them to oscillate and rub against each other at a high frequency. This effectively converts electromagnetic energy into thermal energy, thereby achieving the purpose of heating. RF heating is suitable for a variety of materials, including solids, liquids, and gases.It has many merits such as fast heating, large energy compression ratio, thermal uniformity, and short response time. The heated material has to be electrically conductive or produce an adequate heat generation through the applied magnetic characterized energy. The conductive material can be heated by a resistive loss effect and the magnetic material is primarily heated through a hysteresis loss effect. Multiple variables influence the output power of this technology, so it is necessary to properly adjust factors such as frequency, output power, and application duration to optimize the heating process and prevent thermal damage to the material due to overheating.

Radio frequency heating technology is applied in various industries, including food processing, chemical engineering, pharmaceuticals, textiles, and the heat treatment of metal materials. It is particularly widely used in the food processing industry. This technology can rapidly raise the temperature of food to the target level, effectively maintaining moisture and nutrients while also providing functions such as sterilization, disinfection, and extending shelf life. Therefore, radio frequency heating equipment has become one of the essential key devices in modern food processing production.

3. The application of radio frequency technology in slowing skin aging

3.1. Application principle

As we age, the content of collagen and elastin in the skin gradually decreases, leading to reduced skin elasticity and the gradual appearance of sagging, wrinkles, and diminished firmness. Radiofrequency (RF) technology delivers controlled energy waves to the deeper layers of the skin, generating precise thermal effects that address these issues. This thermal effect can cause existing collagen fibers to contract and activate fibroblasts, promoting the production of new collagen. Skin aging often manifests as sagging, wrinkle formation, and volume loss, resulting from a combination of internal and external mechanisms that act together as we age. Maintaining or restoring youthful skin has become a growing concern, and with the advancement of related research, anti-aging technologies continue to develop. Among them, radiofrequency technology has become an important method in the field of cosmetic dermatology due to its relatively simple operation, high safety, and lasting effects in facial rejuvenation. Multiple studies have confirmed that various RF technologies, from monopolar to multipolar, can effectively improve wrinkles, skin laxity, and skin texture issues. However, there are also clinical cases where the improvements are limited or the results are not significant.

Radiofrequency (RF) technology is gaining popularity in the global beauty industry, particularly in South Korea, which is closely linked to the high demand for non-invasive cosmetic procedures. Its main advantages are reflected in several aspects:

First, the technology is non-invasive and requires no downtime. Unlike traditional facelift surgeries or other surgical procedures, RF treatment does not involve incisions, injections, or sutures, meaning it has minimal impact on the patient's daily work and life. This makes the

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technology particularly appealing to those seeking cosmetic results without interrupting their normal routines.

Second, RF treatment is widely compatible with different skin types. It is generally suitable for various skin types and tones, reducing concerns for those who cannot undergo other anti-aging treatments due to sensitive skin or the risk of pigmentation. Thus, it is a safe option suitable for most people.

Third, its effects are natural and long-lasting. Although the results are not as immediate as those from Botox or fillers, RF stimulates continuous collagen regeneration, gradually improving skin firmness and texture over time. Patients who complete the recommended treatment course typically enjoy rejuvenating effects that last for several months.

Finally, this technology has received certification from authoritative institutions. Currently, standard radiofrequency devices on the market, such as Venus Legacy and Exilis Ultra, have been approved by the U.S. Food and Drug Administration (FDA) and the Korea Food and Drug Administration (KFDA). These approvals indicate that the safety and effectiveness of the devices have been rigorously verified, providing clinical institutions with a scientific basis and increasing patients' confidence when undergoing treatment.

3.2. Radio frequency classification

3.2.1. Fractional radiofrequency

Fractional radiofrequency is a relatively advanced technology that works by precisely focusing radiofrequency energy on small, localized areas of the skin. Its principle is similar to laser resurfacing, but without obvious side effects such as redness or peeling. It makes use of the laser in a matrix pattern over the skin, thus interposing areas of untreated skin between the needles or electrodes. This results in a mesh of thermally injured areas in the dermis. Fractional radiofrequency versus other multipolar radiofrequency in the treatment of cutaneous laxity: a randomized controlled trial Summary Compared to other multifocal/multipinhole radiofrequencies, fractioned pinhole-blind('matrix RF') does not provide superiority in efficacy. The non-continuous micro-heated zones generated through fractional radiofrequency allow the healthy surrounding tissue to assist in repair; and promote rapid healing causing less adverse reactions, make it a technique that deserves further investigation [4]. Fractional radiofrequency technology is suitable for improving various skin issues, including scars, acne marks, and deep wrinkles. Clinical observations show that most participants experience noticeable improvements in skin texture and overall complexion after completing the corresponding treatment course.

3.2.2. Monopolar RF and bipolar RF

'Monopolar' and 'bipolar' refer to the design of RF devices and the manner in which energy is delivered to the skin. Monopolar RF devices are equipped with a single electrode and have stronger penetration capabilities, allowing the energy to reach deeper skin tissues, making them more suitable for facial contouring and deep tightening. In contrast, bipolar RF mainly affects the more superficial layers of the skin. Since it targets the upper dermis, it is commonly used to enhance skin texture and minimize fine lines.

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3.2.3. Radiofrequency microneedling

Radiofrequency microneedling technology combines the dual effects of mechanical stimulation from microneedles and thermal energy from radiofrequency. This technology creates controlled injuries at the micron level on the skin surface through microneedles, and radiofrequency energy is delivered directly to the dermis through these tiny channels, thereby synergistically promoting the regeneration and remodeling of collagen. This therapy is highly effective in enhancing skin firmness, improving radiance, and optimizing skin texture, and is especially suitable for addressing localized issues such as wrinkles and acne scars.

4. Effect evaluation

Radiofrequency treatment has become a mainstream method in the field of skin rejuvenation due to its short recovery period, high safety, and mild postoperative reactions. Studies have shown that both monopolar and multipolar radiofrequency technologies can effectively reduce wrinkles, improve skin laxity, and enhance skin texture, making them valuable cosmetic techniques in facial rejuvenation, with good clinical results and application potential. However, this technology also has limitations, including individual variations in efficacy and limited improvement in some instances. As reported by Jaffary [5] and others, patient satisfaction was significantly higher at 6 months than at 1 month after treatment, as compared. However, satisfaction with any facial area did not exceed 75%, and the efficacy and safety of these treatments still require further evidence from more randomized trials.

Kassim [6]and others found that bipolar radiofrequency treatment can be set to different frequencies to target each layer of the dermis precisely. The multi-level radiofrequency mode can reach the target tissue temperature more quickly, thereby providing higher efficiency. Additionally, using negative pressure suction can increase the depth of radiofrequency penetration, allowing faster and more precise temperature control. These factors make bipolar radiofrequency more effective than monopolar radiofrequency treatment. The dual-level radiofrequency technology not only has significant therapeutic effects but also demonstrates clinical advantages in multiple aspects: its operation process is relatively simple, patients tolerate it well, and anesthesia is usually not required. This technology has higher treatment safety for individuals with darker skin tones, and the postoperative recovery time is shorter, making the overall treatment experience more convenient and comfortable.

Huang Lüping and others used radiofrequency treatment (AccentXL) for skin tightening in 60 patients with facial aging. Using both patient and physician evaluations, they found that the physician-assessed significant improvement rate was 42%, and the overall effective rate was 92%, similar to most reports in the literature [7]. According to patient feedback, the apparent efficiency after treatment is 33%, and the total effective rate reaches 75%. However, there are certain differences in the evaluations of doctors and patients. This difference may stem from the fact that facial rejuvenation is a gradual process, and patients themselves are less sensitive to subtle changes than clinical observers. It was found that the efficacy of radiofrequency was affected by multiple factors, including operating energy parameters, treatment plan design, patient age, facial contour, and basic skin texture. In addition, if the epidermal temperature is below 41°C or the temperature distribution in the treated area is uneven, the final effect will also be limited. Professor Huang Luping noted in the study that radiofrequency therapy should be performed over the entire area, and the wider the treatment range, the higher the patient satisfaction. However, for people who are overweight or thin, the treatment effect is often unsatisfactory. Radiofrequency therapy may also be

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accompanied by certain adverse reactions, mainly including pain during treatment, as well as local erythema and edema after surgery. At the same time, pigmentation and scarring are relatively rare. The number and severity of complications of radiofrequency therapy mostly depend on the natural aging of the practitioner and ultraviolet radiation, or the combined effect of the two, which can reduce the collagen fibers and structural changes in the skin, disrupt the structure of fibrous tissue, and reduce elasticity, resulting in a decrease in volume, changes in bone quality, aggravation of volume loss, and sagging caused by volume reduction than gravity have a greater impact on facial aging. Enlarged pores, etc. [8]

When RF technology is combined with vacuum devices, the skin is locally lifted through vacuum suction, allowing precise matching of treatment depth and RF energy. Compared to the inherent variability in energy transmission within the dermis when traditional electrodes directly contact the skin surface, this combined method restricts the volume of the treatment area. It accurately positions the dual electrodes, enabling the energy density to be precisely focused on the target skin layer—whether superficial or deep—resulting in more efficient treatment outcomes and higher safety. Another advantage of this combined technology is its adjustable penetration depth, which helps avoid unnecessary effects on non-target deep tissues, such as fascia, muscles, fat, and bones. This significantly reduces treatment pain and adverse reactions, often eliminating the need for anesthesia during the procedure. This method can also increase tissue perfusion in the target area and enhance the comfort of cosmetic patients [9].

5. Application effect: evaluation of anti-aging effects of frequency technology

Research indicates that both monopolar and multipolar radiofrequency technologies have applications in wrinkle removal, improving skin laxity, and enhancing skin texture, demonstrating significant clinical effects and broad application prospects. However, this technology still has certain limitations in practical application, such as some patients experiencing less noticeable improvement after treatment.

Researchers, such as Jaffary, found that patient satisfaction was significantly higher at 6 months than at 1 month after treatment. However, across various facial evaluation dimensions, satisfaction did not exceed 75%. This result indicates that its long-term efficacy and safety still require further validation through more randomized controlled trials.

Studies by scholars like Kassim have shown that bipolar radiofrequency treatment can achieve targeted effects on different layers of the dermis by adjusting various frequencies. In contrast, multi-level radiofrequency modes can bring tissues to the preset temperature more quickly, thereby improving treatment efficiency. At the same time, combining this technology with negative pressure suction can enhance the depth of radiofrequency energy penetration, enabling faster and more precise temperature control. These characteristics collectively contribute to the superior clinical performance of bipolar radiofrequency compared to monopolar radiofrequency. Additionally, multi-level radiofrequency also shows significant advantages in terms of operational convenience, patient tolerance, anesthesia requirements, safety for treating darker skin, and postoperative recovery speed.

Safety: The mechanism of radiofrequency skincare is based on the body's own repair potential, and its protection is primarily achieved through non-invasive physical means. This method delivers specific energy to the skin tissue, stimulating the skin's natural renewal and repair functions, rather than relying on chemical reactions or the implantation of foreign materials. Therefore, this technology serves as a beauty strategy that activates intrinsic physiological responses through externally controllable stimulation, without involving chemical changes or invasive procedures, thereby providing corresponding safety advantages.

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Temperature protection of radio frequency devices: In clinical applications, radio frequency (RF) beauty devices face a central challenge: the inherent tension between efficacy and safety. Higher operating temperatures can enhance treatment effectiveness, but they also significantly increase the risk of thermal injury. To overcome this contradiction, it is necessary to move beyond traditional balancing approaches and innovate from a technical perspective—by increasing the RF frequency, the current can penetrate deeper into the dermal reticular layer, achieving a shift from 'surface area heating' to 'deep volume heating.' This mechanism not only improves treatment efficiency but also significantly reduces the likelihood of epidermal burns. The key to achieving deep dermal heating rather than epidermal burning lies in having sufficient frequency parameters to ensure that the energy can effectively reach and act on the dermal reticular structure. Under these conditions, the safety of RF equipment can be reliably guaranteed. Therefore, frequency is the fundamental prerequisite for whether this technology can balance both efficacy and safety.

6. Conclusion

As a therapeutic approach, radiofrequency technology is driving innovation in the field of anti-aging toward non-surgical methods. This technology promotes the regeneration of dermal collagen through thermal stimulation, thereby achieving clinical effects such as improving skin firmness and reducing fine lines and wrinkles. Its mechanism of action is safe and controllable, and its efficacy is long-lasting, making it a reliable cosmetic intervention. In addition to showing significant results in facial rejuvenation, this technology also demonstrates broad potential in body contouring and overall improvement of skin quality.

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