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The Application of Red Light-Near Infrared Light and Radio Frequency Synergy in Cosmetic Dermatology

Guanghua Lin[1], Michel E. Pfulg[2]

[1]SWISS GEMO TECHNOLOGY GmbH;

[2]Laclinic-Montreux (Switzerland)

ABSTRACT

This paper reviews the role and application of Red Light (RED), Near-Infrared (NIR) light, and Radio Frequency (RF) in skincare and beauty treatments, and points out the limitations of single light therapy and RF, such as limited penetration depth, pigmentation risk, and thermal burns. The paper then underlines the benefits of the combination of RF and NIR/Red Light therapy in electro-optical synergy, e. g., to enhance energy penetration, improve treatment, and reduce side effects. These benefits are evidenced by a case study on home beauty devices incorporating NIR-RF. The paper concludes that this technique has a broad prospect in the beauty and skincare industry.

KEYWORDS

RED-NIR; RF; NIR-RF Electro-Optical Synergy; NIR; Skin Rejuvenation

1 Introduction

Research has shown that both intrinsic skin aging and photoaging are progressive processes. The extracellular matrix (ECM), which is the central hub for repair and regeneration of the skin, becomes less effective due to aging and UV exposure, leading to declines in collagen and elastin production and thus resulting in the appearance of wrinkles and sagging skin. From a genetic engineering perspective, skin aging and damage are characterized by decreased collagen synthesis and increased expression of matrix metalloproteinases (MMPs). In this light, therapies that use physical stimuli, such as light, RF, and ultrasound, to facilitate the regeneration of collagen and elastin through ECM regulation while inhibiting MMP expression, can ultimately promote skin rejuvenation.

The demand for non-invasive skincare technologies has driven up the popularity of non-invasive light therapy and RF treatments in the beauty industry. RF works with electrical currency in an efficient and safe manner to cause vibrations between molecules and ions and generate heat in the tissues, thus stimulating collagen regeneration. Red light has been shown to reverse the downregulation of collagen and the upregulation of MMP-1, while NIR, which allows for deeper penetration and minimal photodamage, stimulates collagen regeneration by heating the water molecules in the skin. These technologies are therefore widely used in skincare.

However, therapies that use a single-wavelength light source or a single source of energy are distinctly limited. For example, single-wavelength light therapy devices offer limited therapeutic effects and may cause pigmentation or skin burns with excessive energy. Similarly, RF has side effects such as erythema or burns. To address these limitations, therapies that combine Red Light with NIR, or NIR with RF, have emerged as promising alternatives. By integrating the benefits of NIR/Red Light and RF, the synergy can realize greater depth and effect of treatment and a wider

applicability.

2 Application of Light in Beauty and Skincare

2.1 Mechanisms of Red and Near-Infrared Light in Beauty Treatments

Red and Near-Infrared (RED-NIR) light are found in the visible and invisible electromagnetic spectrum between 630 nm and 2500 nm. Due to its superior tissue penetration, red light has found widespread use in biomedical applications. Low-energy red light promotes skin rejuvenation through photobiomodulation (PBM), a process that enhances cellular metabolism, repair, and the regulation of physiological functions. Research suggests that PBM produces its beneficial biological effects by triggering the release of endogenous reactive oxygen species (ROS) and nitric oxide (NO), and modulating calcium ion flux and restoring redox balance. ATP, the primary source of cellular energy, facilitates proliferation and repair, while moderate ROS levels activate antioxidant pathways, enhancing the ability of the cells to resist oxidative stress. With similarly superior penetration, NIR light can reach the epidermis, dermis, and even deeper layers of the skin, and stimulate collagen and elastin regeneration by heating the deeper layers of the skin, which helps to reduce wrinkles.

The unique photobiomodulatory effects of RED-NIR light, coupled with its strong thermal penetration, make it particularly effective for skin rejuvenation. In clinical trials using a 660 nm red light device, over 90% of participants showed improvement in both wrinkle depth and surface roughness, while 87% experienced a noticeable reduction in Fitzpatrick wrinkle scores. This suggests that light therapy can reverse the downregulation of collagen and upregulation of MMP-1, making it a safe and effective method for collagen enhancement. Supporting research by B. A. Rassell et al. found that 51.6% of participants showed a 25%-50% improvement in their photoaging scores, while 12.9% had improvements between 50%-75%.

RED-NIR light also offers notable anti-inflammatory and antioxidant effects. By modulating cell function, proliferation, and repair, RED-NIR light therapy is particularly suitable for inflammatory skin conditions like acne and rosacea. PBM has been shown to inhibit the growth of acne-causing bacteria, a process that involves the generation of ROS and free radicals by photosensitive molecules under RED-NIR exposure. A study by Kui Young Park et al. found that 91% of acne treatment areas showed significant improvement after three sessions of 1550 nm light therapy. One study demonstrated that treatment with 1064 nm light significantly reduced the average count of inflammatory acne lesions, as well as the severity of acne erythema and the erythema index. In addition, light therapy has been shown to regulate sebaceous gland activity, leading to a reduction in lipid production. Another study found that after three sessions of 785 nm light treatment, patients experienced a significant decrease in lipid levels on their cheeks, with notable improvements in pustules and papules (Figure 1).

Figure 1 (a) Comparison before and two weeks after treatment

Figure 1 (b) Comparison before and two weeks after treatment

2.2 Limitation Analysis

While RED-NIR light is a very promising and effective option in skincare and beauty treatments, there are some technical and device-related limitations. At-home RED-NIR therapy devices use much lower energy levels and cannot penetrate deep into the skin, which suggests reduced effectiveness for deeper skin concerns. By comparison, high-power in-office RED-NIR devices may lead to issues such as pigmentation due to risks of overexposure. Therefore, it is important to develop effective and safe RED-NIR therapy devices.

3 Application of Radio Frequency in Beauty and Skincare

3.1 Principles of Radio Frequency Beauty Technology

RF technology has long been used clinically. Since 1868, when Darsonval first used RF current in living tissues, various RF-based therapeutic methods have been developed. The RF energy promotes collagen regeneration, providing aesthetic benefits like reduced wrinkles. In 2002, the FDA approved the first RF device for facial beauty (ThermaCool; Thermage, Inc.), which led to the rapid adoption of RF technology in the beauty industry.

At-home RF devices, which typically operate within a frequency range of 300 kHz to 10 MHz, generate heat by driving the oscillation of ions and polar molecules within tissues, and therefore promote skin tightening, wrinkle reduction, pore shrinkage, or even fat breakdown for weight loss purposes. Unlike laser technology, RF energy targets water rather than pigment and delivers uniform heat to the dermis, making this technology safe for all skin types.

Studies have shown that when the epidermal temperature reaches 40°C to 43°C and the dermal temperature reaches 44°C to 45°C, collagen undergoes conformational changes. RF treatments can induce a mild thermal injury, causing macrophages to migrate to the treated area and secrete cytokines and growth factors. Fibroblasts are stimulated to synthesize new collagen and elastin. This process can lead to an increase in dermal thickness by up to 49%. Research also indicates that RF treatments increase the synthesis of type I and III collagen, mainly in the superficial layers. After 12 weeks, the newly formed collagen and elastin fibers are more organized and replace the original tissue. However, it is essential to avoid exceeding the critical thermal threshold to prevent the destruction of collagen and deeper skin layers.

RF devices can be classified as monopolar, bipolar, multipolar, and phase-controlled. Most at-home RF devices are multipolar. The multiple electrodes create alternating electric currents in a

uniform field, allowing for more precise heating in the same area. As compared to monopolar RF, multipolar RF confines energy within the area between positive and negative electrodes, reducing energy dispersion and allowing for better control. A study demonstrated that multipolar RF devices successfully reduced facial wrinkles, highlighting the potential of multipolar RF technology in home-based beauty devices.

Figure 2 Schematic Diagram of Multipolar RF Interaction

3.2 Limitation Analysis

Despite its significant effectiveness and the absence of side effects like pigmentation, RF technology in beauty treatments still faces some technical limitations. On one hand, at-home RF devices typically use metal electrodes to conduct high-frequency currents into the skin. However, the metal electrodes heat up slowly due to their high specific heat capacity, which in turn makes cosmetic treatment less effective. On the other hand, monopolar RF devices often require higher energy outputs to penetrate deeper into dermis, which may increase the risk of side effects. Thus, developing effective, safe, and comfortable RF technology and products is of considerable importance.

4 Red-NIR and RF Synergy

To address the limitations inherent in single-energy and single-wavelength beauty treatments, multi-energy synergy has been the focus in order to optimize the performance of existing single-energy devices, extend their applicability, and minimize adverse effects. Electro-optical synergy technology or NIR-RF synergy technology, which combines the strengths of NIR and RF to enhance therapeutic outcomes, has attracted extensive attention. This approach uses the combination of optical and RF energies at lower energy levels to offer superior energy delivery, significantly reducing pigmentation risk associated with excessive energy use. NIR light works by preheating the dermis, allowing the skin to absorb more RF energy. This accelerated heating process improves the overall cosmetic results. The combination enables multi-layered energy absorption, enhancing the skin's response to treatment. This not only shortens the duration of the procedure but also reduces the risk of overheating and thermal injury. Furthermore, it offers customizable treatments, with adjustments in both wavelength and intensity to address a variety of skin concerns.

In a word, the combined use of optical and RF technologies has shown significant advantages in both safety and efficacy. A study by El-Domyati et al. involving patients with Fitzpatrick skin types IV to VI and Glogau I to II wrinkles demonstrated substantial improvements in both clinical and histological measures after three months of electro-optical synergistic treatment (six sessions, every two weeks). The treatment resulted in a significant increase in type I, III, and VII collagen, as well as newly synthesized collagen, and improvements in elastin levels. Notably, total elastin levels were

reduced by the end of the treatment and remained lower three months later, confirming the effectiveness and safety of electro-optical synergy in improving facial skin laxity. Likewise, Sadick N's research found that combining light and RF energy at lower, safe energy levels yielded significant clinical benefits, with only mild discomfort and minimal adverse reactions. These findings confirm that electro-optical synergy is a safe, reliable, and user-friendly therapy option.

5 Case Study: GEMO Collagen Device for At-Home Beauty Treatment

RED-NIR represents an advanced anti-aging technology as NIR light penetrates deep into the dermis. At specific wavelengths, it stimulates fibroblasts for collagen synthesis, enhancing skin elasticity and firmness and reducing the appearance of fine lines and wrinkles. This gentle therapy can restore skin vitality while preserving the integrity of the epidermis.

As a leader in high-end beauty devices, GEMO has continued to advance the industry with its innovations. In 2024, GEMO introduced an anti-aging product combining RED-NIR with RF, providing an exciting new opportunity for the home beauty market.

This combination of RED-NIR and RF offers advantages over traditional single-energy beauty technologies. First, it provides greater penetration: traditional at-home RF devices typically penetrate only 3.5 mm into the superficial dermis of the skin, while the combination penetrates up to 4.5 mm to stimulate collagen production in the superficial, middle, and deep dermal layers, resulting in more noticeable anti-aging effects. Second, the combination enables a larger treatment area. Traditional devices typically create a small 3 cm^2 treatment zone, while the combined use of RED-NIR and RF and RF doubles the treatment area by generating a larger, seamless, and focused thermal field. Moreover, GEMO's collagen beauty device provides a comprehensive anti-aging solution with two specialized modes. The CC-FILL mode uses RED+NIR light, which boasts excellent penetration and thermal efficiency, to create a large, focused thermal field, thus evenly stimulating collagen regeneration and restoring skin elasticity and firmness. The V-CODES mode utilizes three-frequency microcurrent technology to stimulate deeper facial muscles, thus enhancing facial support and plumpness. This device tightens the skin from the surface to deeper layers and improves facial volume. According to user reports, noticeable improvements are felt after a single session, and after seven treatments, significant reductions in facial wrinkles are observed (as shown in Figure 3). This demonstrates the device's effectiveness in "instant lifting, seven-session wrinkle reduction".

According to the results of the cellular experiment report, the product demonstrates significant

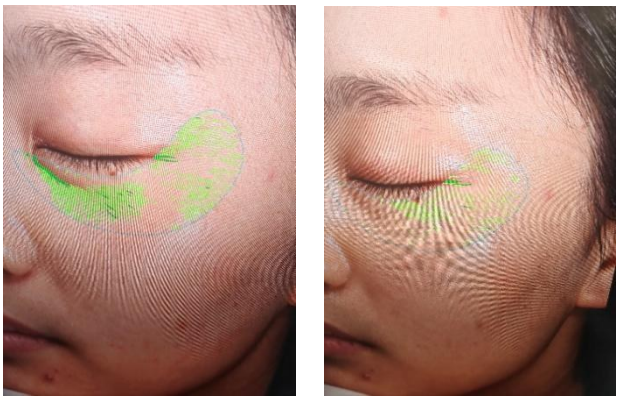

Figure 3 Before and After Treatment with GEMO Cell Collagen Phototherapy for Home Beauty Treatment

effectiveness in anti-aging. The efficacy findings are detailed in Table 1 and Table 2.

Table 1 Product Efficacy Report

Testing Parameter	Time Point	Change Rate (%)	Parameter Description
Skin Elasticity (R2 Value)	After 14 days	14.82%	Increased measurement indicates improved skin elasticity
	After 28 days	18.08%	
Skin Firmness (F4 Value)	After 14 days	-17.34%	Decreased measurement indicates improved skin firmness
	After 28 days	-17.82%	
Skin Thickness	After 14 days	7.42%	Increased measurement indicates enhanced skin thickness
	After 28 days	9.36%	
Skin Density	After 14 days	11.67%	Increased measurement indicates improved skin density
	After 28 days	13.16%	
Chin Angle	Immediate	-1.09%	Decreased measurement indicates a reduction in chin angle
	After 14 days	-2.80%	
	After 28 days	-2.92%	
Wrinkle Volume (Forehead Wrinkles)	After 14 days	-24.30%	Decreased measurement indicates a reduction in wrinkle volume
	After 28 days	-25.03%	
Wrinkle Area	After 14 days	-20.70%	Decreased measurement indicates a reduction in wrinkle area
	After 28 days	-22.80%	
Fibroblasts (Collagen)	After 4 days	158.32%	Increased measurement indicates improved collagen production
	After 14 days	161.82%	
	After 28 days	166.73%	
Facial Volume (Apple cheeks)	After 7 days	5.40%	Increased measurement indicates increased apple cheeks volume
	After 14 days	8.93%	
	After 28 days	14.82%	
Facial Volume (Cheeks)	After 7 days	6.90%	Increased measurement indicates enhanced cheek volume
	After 14 days	9.40%	
	After 28 days	17.03%	
High Point Position (Apple cheeks)	After 7 days	3.91%	Increased measurement indicates elevated apple cheek high point
	After 14 days	6.13%	
	After 28 days	11.23%	
Depression Depth (Nasolabial Folds)	After 7 days	-1.43%	Decreased measurement indicates reduction in nasolabial fold depth
	After 14 days	-2.91%	
	After 28 days	-5.57%	
Facial Volume (Marionette Lines)	After 7 days	-3.31%	Decreased measurement indicates reduction in marionette lines
	After 14 days	-6.79%	
	After 28 days	-11.23%	

Table 2 Cellular Test Report of the Product

Test Item	Test Condition	Rate of Change	Parameter Description
Type I Collagen Content	8 min, 1 intensity, 3 days	269.78%	Indicates anti-wrinkle and skin-firming effectiveness
	10 min, 1 intensity, 3 days	288.12%	
Type III Collagen Content	8 min, 1 intensity, 3 days	180.18%	Indicates anti-wrinkle and skin-firming effectiveness
	10 min, 1 intensity, 3 days	231.78%	
Elastin Content	8 min, 1 intensity, 3 days	109.68%	Indicates anti-wrinkle and skin-firming effectiveness
	10 min, 1 intensity, 3 days	117.05%	
Metalloproteinase Content	8 min, 1 intensity, 3 days	-12.12%	Indicates anti-wrinkle and skin-firming effectiveness
	10 min, 1 intensity, 3 days	-15.46%	
TGF-β Protein Content	8 min, 1 intensity, 3 days	19.03%	Indicates anti-wrinkle and skin-firming effectiveness
	10 min, 1 intensity, 3 days	25.22%	

6 Conclusion and Outlook

RED-NIR technology has garnered significant attention in skincare and beauty treatments for its unique photobiological and photothermal effects. Numerous studies have shown that the RED-NIR and RF synergy shows great potential in boosting collagen production, enhancing metabolism, improving microcirculation, and reducing inflammation. These effects help address skin laxity, reduce wrinkles, improve skin texture, and promote circulation, offering a comprehensive skincare solution.

While RED-NIR and RF synergy has shown promising results, there is still room for further exploration and development. As technology advances, we can expect more advanced NIR-RF devices and possible combinations with other skincare treatments, so users can enjoy more efficient, convenient, and safer solutions. Overall, NIR-RF synergy has great potential for future development and applications. With ongoing innovation, this technology is set to bring more breakthroughs and opportunities to the skincare industry.

About the Author

Guanghua Lin,Master of Electromagnetic Field and Microwave Engineering, SWISS GEMO TECHNOLOGY GmbH;
Michel E. Pfulg, Plastic and Reconstructive Surgeon FMH, MD, Laclinic-Montreux (Switzerland)