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Efficacy of radiofrequency combined with single-dot ultrasound efficacy for skin rejuvenation: A non-randomized split-face trial with blinded response evaluation

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Abstract

Background: High-intensity focused ultrasound (HIFU) and radiofrequency (RF) are non-invasive modalities for skin rejuvenation, but their combined effects have not been evaluated.

Objective: We evaluated and compared the efficacy of HIFU alone and combined HIFU and bipolar RF using a newly designed probe.

Methods: Twenty-two Korean adults with facial wrinkles and aging underwent treatment on both sides of their face: HIFU-only on the left and HIFU combined with RF on the right. Skin parameters were measured at different time points to evaluate the improvement in skin rejuvenation.

Results: HIFU treatment significantly improved skin parameters, including pore volume and number, skin elasticity, depth of eye wrinkles, degree of sagging in the eye area, nasolabial folds and cheeks, volume of the jawline, skin density, and permittivity. Furthermore, combining bipolar RF with HIFU treatment enhanced efficacy in reducing pore number, improving skin elasticity, diminishing eye wrinkle depth, and increasing skin moisturization. These findings indicate that bipolar RF can synergically improve skin rejuvenation by providing a thermal effect to the upper papillary dermis, which is more superficial than the target area of HIFU.

Conclusion: Combining HIFU with bipolar RF synergistically improves skin rejuvenation, including pore reduction, periorbital wrinkle improvement, skin elasticity, and skin moisturization.

KEYWORDS
bipolar radiofrequency, facial lifting, high intensity focused ultrasound, skin rejuvenation

INTRODUCTION

Various non-ablative modalities have been developed for skin rejuvenation, including High-intensity focused ultrasound (HIFU) and radiofrequency (RF) are non-invasive modalities for skin rejuvenation that selectively induce thermal injury in the dermis while sparing the overlying epidermis.[1,2] These techniques target dermal collagen for remodeling and have been used for lifting eyebrows, nasolabial folds,

and jaw tightening. To date, no split-face trial has investigated the potential synergistic effects of HIFU integrated with bipolar RF for skin rejuvenation.

These techniques induce thermal heating, thus innovating the handpiece for safe, quick, and effective procedures has become imperative. Most recent devices for face and body treatments commonly employ a multipolar handpiece. (1) For example, in the tripolar handpiece of RF, one tip functions as the positive pole while the others serve as negative poles, constantly monitoring the skin's temperature.[3] We used a newly developed HIFU device that combines RF irradiation in one probe with a diameter of 2.5 cm in a circle shape (Figure 1A). The Simultaneous Dual (SD) probe is designed in such a way that ultrasound is emitted as a single dot from the center of the handpiece, and bipolar RF energy is emitted from the edges alternatively irradiating between ultrasound and RF. This SD handpiece can be operated by grasping and rubbing it like a pen, and it is optimized to treat the whole face including curved areas. The conventional linear irradiated energy of HIFU needs a large plane area in contact with the skin, there has been a limitation to treat curved areas.[1] This allows both ultrasound and RF to be irradiated without replacing the handpiece, and the entire face can be precisely treated through rubbing. The rejuvenation effect can be enhanced by simultaneously treating the dermis of the deeper layer irradiated with ultrasound and the superficial layer where RF is irradiated.

In this study, we evaluate the clinical efficacy and synergic effect of HIFU combined with bipolar RF for rejuvenation enhancement.

Key Points

High-intensity focused ultrasound (HIFU) and radiofrequency (RF) are non-invasive methods for skin rejuvenation, but their combined effects have not been studied before. This study compared the efficacy of HIFU alone and HIFU combined with bipolar RF using a new probe. The results showed that combining bipolar RF with HIFU enhanced skin rejuvenation by reducing pore size, improving skin elasticity, diminishing eye wrinkles, and increasing skin moisturization.

1 | MATERIALS AND METHODS

1.1 | Participants

Twenty-two Korean adults with clinical symptoms of facial wrinkles and aging were treated with the HIFU combined bipolar RF device by two dermatologists in this study. Participants were over 30 years old, averaging 42.8 years (ranging from 30 to 65 years old).

Exclusion criteria included pregnancy, skin ulceration, coagulation disorders, use of anticoagulation medications, history of skin rejuvenation and laser therapies 1 year before the study, and history of cardiovascular disease, epilepsy, or active vitiligo. Informed consent forms were obtained from all participants before treatment. This study was approved by the Institutional Review Board (HM-IRB-P22-0270-MD) and completed in accordance with the Declaration of Helsinki as revised in 2013.

1.2 | Treatment

The HIFU-combined bipolar RF device (V-RO (NEW DOUBLO), Hironic Corp., Ltd., South Korea) was applied to the participants' faces using the SD handpiece. Bipolar RF was irradiated at a 2 MHz frequency with an 80 ms pulse duration, while HIFU was alternatively emitted at a 7 Hz frequency (Figure 1B). The pulse duration ranges from 50 to 450 ms, and the output frequency is 2 MHz. The power of bipolar RF system can be adjusted from 1.35 W to 13.70 W, with 1.35 W as the minimum unit and a non-inductive resistance of 500 Ω. When using a non-inductive 500Ω resistance, the system's maximum voltage is 80.4 V, and the maximum current is 156 mA.

Topical anesthetics were applied to the treatment area 30 min before the procedure. Participants received HIFU-only treatment on the left and combined HIFU and RF on the right side of their faces. Parameters were as follows: 1.5 mm depth with 0.15 J power (1.5 tips), 3.0 mm depth with 0.35 J power (3.0 tips), and 4.5 mm depth with 1.1 J power (4.5 tips) for HIFU; and 12.00~13.70 W power, 2 MHz, and 80 ms pulse duration for bipolar RF. HIFU is emitted in a dot shape from the probe's center, and RF is irradiated in the outer area around the center. The entire face was irradiated with 1500 dots using a 4.5 tip, followed by 1500 dots on the lower face with a 3.0 tip, and 1000 dots on the upper, periorbital, and midface pore-rich areas with a 1.5 tip. The 4.5 and 3.0 tips were used on the lower face for their deeper penetration depth, while a 1.5 tip was used on the forehead, periorbital, and midface pore areas. HIFU was used to irradiate both sides of the face equally with 4000 dots per side, and only the right side of the face was treated with RF simultaneously.

1.3 | Assessment

This study evaluated changes in skin rejuvenation, specifically focusing on the 7-fold pore, skin elasticity, eye wrinkles, nasolabial folds, eye lifting, cheek lifting, jawline lifting, skin density, and skin moisturization. Measurements were taken at baseline, immediately after treatment, and 4–8 weeks post-treatment. Parameter changes were quantified by the evaluation index, detailed with measuring device specifics in Table S1–S3.

1.4 | Satisfaction and adverse skin reactions assessment

All participants were asked to fill out questionnaire surveys. In addition, investigators examined adverse skin reactions and concomitant drug use that may affect the test.

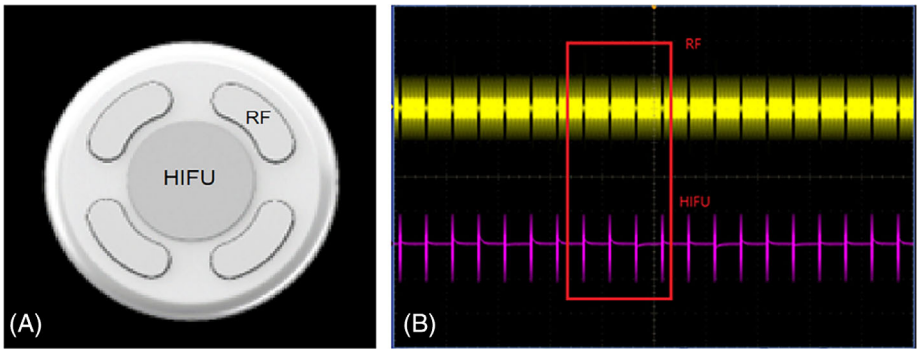

FIGURE 1 A high-intensity focused ultrasound device that combines RF irradiation into a circular probe with a 2.5 cm diameter. (A) The Simultaneous Dual (SD) probe of the device. Ultrasound is emitted as a single dot from the center of the handpiece, and RF energy is emitted from the edges. (B) When bipolar RF is irradiated with a 2 MHz frequency and an 80 ms pulse duration, HIFU is alternatively irradiated using a frequency of 7 Hz.

1.5 | Statistical analysis

Data analysis was performed using the SPSS Statistics 19.0 software program (IBM Corp., Armonk, New York). Significance probability determined statistical significance within a 95% confidence interval ($p < 0.05$) and a more stringent threshold at $p < 0.01$ and $p < 0.001$. Before analysis, homogeneity tests were administered for each intergroup data. Data normality was then assessed using the Shapiro-Wilk test. If normality was satisfied by three or more values, a parametric *t*-ANOVA test was used, followed by a Bonferroni correction. If normality was not satisfied, a non-parametric Friedman test was conducted, followed by a Bonferroni correction. Post hoc analysis was conducted using the Wilcoxon signed-rank test.

2 | RESULTS

2.1 | Characteristics of participants

A total of 22 Korean participants were recruited for this study based on the inclusion criteria. One participant (No.18) dropped out due to missing follow-up during the eighth week, resulting in 21 participants being included for the final analysis. Participant ages averaged 42.8 years, ranging from 30 to 65.

2.2 | Assessment of improvement of 7-fold pore

On the left cheek, the values of mean pore volume and pore number improved significantly while the values of the mean pore area, pore density, maximum depth of pores, total pore volume, and roughness average (Ra) did not improve significantly after the HIFU treatment. On the right cheek, all the values of mean pore volume, mean pore area, pore density, pore number, maximum depth, total pore volume, and Ra values all significantly improved after RF treatment.

The combined HIFU and RF treatment exhibited considerable synergic improvements in the mean pore number of the right cheek at the fourth week compared to the baseline; however, there was no statistically significant change in the eighth week (Figure 2A, Table 1). These results indicate that the combined HIFU and RF treatment refined pores by tightening the deep and superficial dermis around hair follicles, but the effects were not statistically significant.

2.3 | Assessment of improvement of skin elasticity

We evaluated the improvement of skin elasticity of 2 mm and 8 mm depths using the R2 and the R8 probes of DUB® SkinScanner. The results indicated significant elasticity improvement in both cheeks after treatment, with the right cheek showing a greater improvement than the left cheek after 8 weeks (Table 2). Furthermore, we found that skin elasticity at a depth of 2 mm was enhanced after 4 weeks and continued improving until the end of the eighth week. Notably, the skin elasticity at a depth of 8 mm on the right cheek was significantly higher than that on the left cheek after 8 weeks.

Elasticity was significantly refined after the HIFU combined with RF treatment, indicating that this combined treatment is more effective in improving skin elasticity than HIFU alone. These results also signify that the combined treatment had a synergistic effect, resulting in an improvement of skin elasticity not only in the superficial but also in the deep layer of the dermis, which continued to improve over time.

2.4 | Assessment of improvement of eye wrinkles

We assessed the improvement of eye wrinkle depth, and the results indicated a significant reduction in the average depth of wrinkles around both eyes following treatment. Both treatments on either side of the face improved depth of eye wrinkles, and, even maintaining this effect 4 and 8 weeks after treatment (Figure 2B). Notably, after the fourth and eighth weeks of combined HIFU and RF treatment, the average depth of eye wrinkles was significantly decreased in the right eye compared to the left eye (Table 2).

TABLE 1 Measurements of 7-fold pore.

Parameter		Left	Right	Intergroup
Mean pore volume (mm^3)	Baseline	0.00119 ± 0.00093	0.00130 ± 0.00092	
	Immediate	0.00107 ± 0.00082	0.00114 ± 0.00088 **	0.496
	4 weeks	0.00100 ± 0.00069 *	0.00109 ± 0.00083 **	0.266
	8 weeks	0.00100 ± 0.00081 *	0.00110 ± 0.00090 **	0.687
Mean pore area (mm^2)	Baseline	0.0859 ± 0.0575	0.0936 ± 0.0546	
	Immediate	0.0785 ± 0.0500	0.0828 ± 0.0524 *	0.505
	4 weeks	0.0747 ± 0.0454	0.0794 ± 0.0519 **	0.204
	8 weeks	0.0742 ± 0.0509	0.0838 ± 0.0521 *	0.920
Pore Density (ea/cm^2)	Baseline	23.78 ± 16.14	30.57 ± 18.48	
	Immediate	23.29 ± 16.85	24.91 ± 18.63 ***	0.199
	4 weeks	19.23 ± 13.67	23.19 ± 18.22 ***	0.092
	8 weeks	20.04 ± 15.53	23.10 ± 16.98 ***	0.191
Pore number (ea)	Baseline	107.90 ± 76.54	148.76 ± 89.89	
	Immediate	106.41 ± 81.64	121.52 ± 90.59 ***	0.166
	4 weeks	88.46 ± 67.08 *	112.71 ± 88.64 ***	0.044*
	8 weeks	92.24 ± 76.32 *	112.38 ± 82.61 ***	0.107
Maximum depth (mm)	Baseline	0.0222 ± 0.0088	0.0229 ± 0.0068	
	Immediate	0.0212 ± 0.0080	0.0209 ± 0.0068 ***	0.275
	4 weeks	0.0209 ± 0.0089	0.0206 ± 0.0061 *	0.457
	8 weeks	0.0202 ± 0.0086	0.0199 ± 0.0062 **	0.339
Total pore *volume* (mm^3)	Baseline	0.2004 ± 0.3023	0.2703 ± 0.3366	
	Immediate	0.1716 ± 0.2594	0.1993 ± 0.3213	0.232
	4 weeks	0.1354 ± 0.1750	0.1858 ± 0.2880 **	0.072
	8 weeks	0.1509 ± 0.2560	0.1872 ± 0.3232 *	0.155
Ra (μm)	Baseline	5.73 ± 2.03	6.05 ± 1.86	
	Immediate	5.76 ± 1.93	5.91 ± 1.78	0.306
	4 weeks	5.58 ± 1.82	5.74 ± 1.78 *	0.337
	8 weeks	5.58 ± 2.01	5.69 ± 1.84 *	0.352

Baseline, immediately, 4 weeks after, and 8 weeks after treatment comparisons. Roughness average, Ra; *p-value < 0.05, **p < 0.01, ***p < 0.001.

TABLE 2 Measurement of skin elasticity and eye wrinkles.

Parameter		Left	Right	Intergroup
Skin elasticity at *2 mm depth*	Baseline	0.5767 ± 0.0652	0.5963 ± 0.0555	
	Immediate	0.6146 ± 0.0701 ***	0.6447 ± 0.0516 ***	0.505
	4 weeks	0.6702 ± 0.0720 ***	0.7186 ± 0.0418 ***	**0.048** *
	8 weeks	0.6736 ± 0.0798 ***	0.7479 ± 0.0340 ***	**0.008** **
Skin elasticity at *8 mm depth*	Baseline	0.7060 ± 0.0596	0.7303 ± 0.0503	
	Immediate	0.7294 ± 0.0499 ***	0.7545 ± 0.0499 ***	0.864
	4 weeks	0.7699 ± 0.0574 ***	0.8130 ± 0.0404 ***	0.086
	8 weeks	0.7923 ± 0.0498 ***	0.8577 ± 0.0399 ***	**0.003** **
Average depth of eye wrinkles	Baseline	0.0465 ± 0.0126	0.0536 ± 0.0133	
	Immediate	0.0428 ± 0.0119 ***	0.0492 ± 0.0124 ***	0.512
	4 weeks	0.0429 ± 0.0120 ***	0.0468 ± 0.0113 ***	**0.010***
	8 weeks	0.0435 ± 0.0113 ***	0.0481 ± 0.0128 ***	**0.008****

Baseline, immediately, 4 weeks after, and 8 weeks after treatment comparisons. *p-value < 0.05, **p < 0.01, ***p < 0.001.

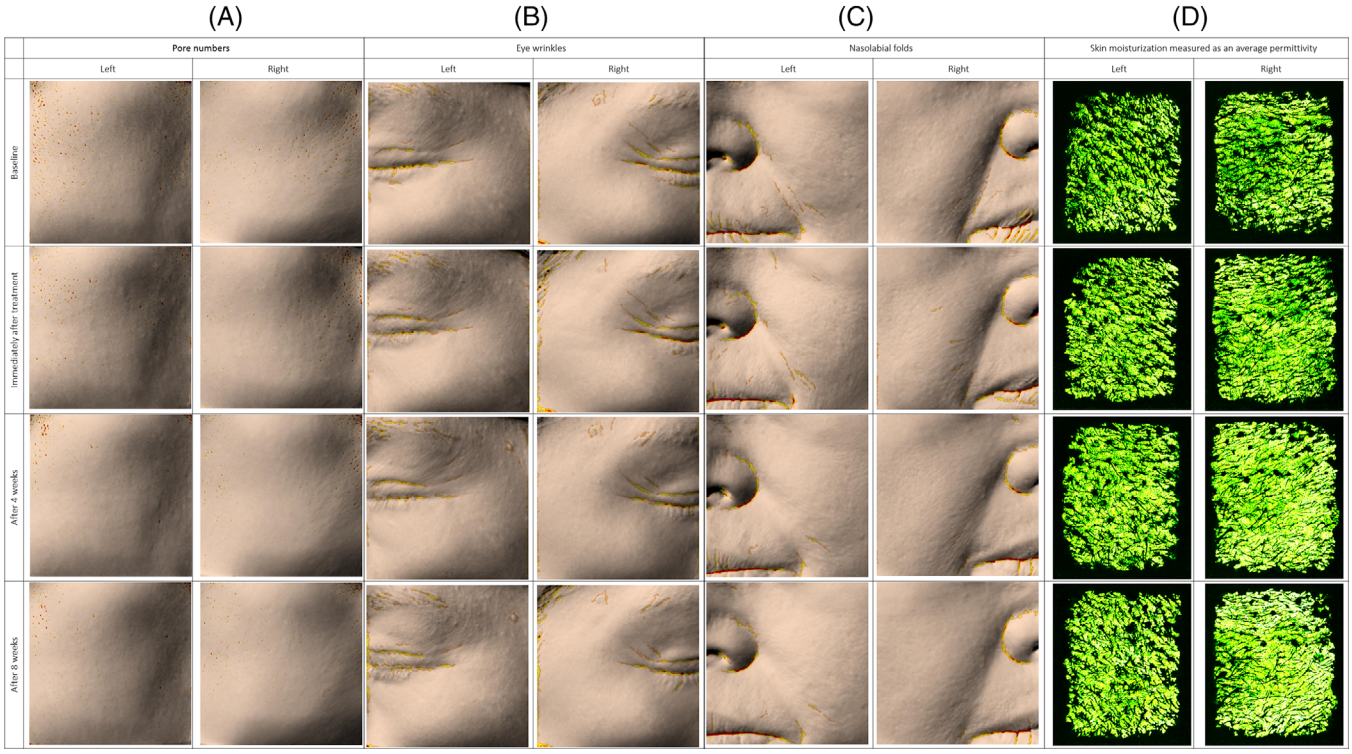

FIGURE 2 (A) Improvement of pore numbers of the left face treated with HIFU alone and the right face treated with a combination of HIFU and RF (Case 14). (B) Improvement of eye wrinkles of the left face treated with HIFU alone and the right face treated with a combination of HIFU and RF (Case 19). (C) Improvement of nasolabial folds of the left face treated with HIFU alone and the right face treated with a combination of HIFU and RF (Case 17). (D) Improvement of skin moisturization was measured as an average permittivity of the left face treated with HIFU alone and the right face treated with a combination of HIFU and RF (Case 15).

2.5 | Assessment improvement of the face lifting

We evaluated changes in the sagging angle of the eye, the average depth of the nasolabial fold, the sagging angle of the cheeks, and the volume of the jawline to assess the effectiveness of facial lifting. Our results demonstrate that both treatments on either side of the face exhibited markedly improved facial lifting compared to baseline after the fourth and eighth weeks. All face-lifting parameters significantly decreased after treatment (Figure 2C, Table 3).

No significant intergroup face-lifting difference was observed in face lifting between the left cheek treated with HIFU only and the right cheek treated with a combination of HIFU and RF. HIFU improved sagging angles of the eye, nasolabial folds, cheeks, and the volume of the jawline. When HIFU is combined with bipolar RF, there is no additional improvement in these outcomes.

2.6 | Assessment result of improvement in skin density

We evaluated skin density using the skin scanner, determining that skin density on both sides significantly increased immediately after treatment, 4 and 8 weeks after treatment. A comparison of the left and right faces revealed a significantly higher increase in skin density in the right cheek after fourth week, but this difference was not significant in the eighth (Table 4).

2.7 | Assessment of improvement in skin moisturization

To evaluate the improvement of skin moisturization, we measured the permittivity and tissue dielectric constant (TDC) of the skin. The results indicated a significant increase in permittivity of both cheeks immediately after, 4 and 8 weeks after treatment. Furthermore, the HIFU and RF combined treatment on the right cheek significantly improved permittivity and TDC compared to the left, proposing that the combination treatment was more effective in improving skin moisturization when the RF treatment was added (Figure 2D).

When measuring the TDC at a depth of 2.5 mm on both sides of the face, only the right side treated with HIFU combined with bipolar RF showed improvement in TDC (Table 5). This improvement was statistically significant immediately, 4 and 8 weeks after treatment, verifying that bipolar RF can significantly improve skin moisture at a depth of 2.5 mm.

TABLE 3 Measurement of the face lifting.

Parameter		Left	Right	Intergroup
Eye, sagging angle (°)	Baseline	50.81 ± 1.92	50.72 ± 1.88	
	Immediate	51.25 ± 1.88 ***	51.22 ± 1.83 ***	0.405
	4 weeks	51.32 ± 1.80 ***	51.28 ± 1.81 ***	0.546
	8 weeks	51.39 ± 1.82 ***	51.27 ± 1.88 ***	0.990
Nasolabial fold, average depth (mm)	Baseline	0.0326 ± 0.0055	0.0323 ± 0.0054	
	Immediate	0.0294 ± 0.0036 ***	0.0284 ± 0.0073 ***	0.880
	4 weeks	0.0143 ± 0.0156 ***	0.0067 ± 0.0124 ***	0.107
	8 weeks	0.0113 ± 0.0149 ***	0.0056 ± 0.0119 ***	0.208
Cheek lifting, sagging angle(°)	Baseline	32.94 ± 3.92	33.29 ± 3.95	
	Immediate	32.33 ± 3.81 ***	32.64 ± 3.54 **	0.821
	4 weeks	32.40 ± 3.84 **	32.71 ± 3.65 ***	0.606
	8 weeks	32.40 ± 3.78 **	32.66 ± 3.69 ***	0.263
Jawline lifting, volume (ml)	Baseline	1.1830 ± 0.5399	1.0914 ± 0.5576	
	Immediate	1.1093 ± 0.4997 *	1.0018 ± 0.5317 ***	0.406
	4 weeks	0.9539 ± 0.4783 **	0.7586 ± 0.4055 **	0.336
	8 weeks	0.9200 ± 0.4406 **	0.7738 ± 0.3507 **	0.772

Baseline, immediately, 4 weeks after, and 8 weeks after treatment comparisons. *p-value < 0.05, **p < 0.01, ***p < 0.001.

TABLE 4 Measurement of the skin density.

Parameter		Left	Right	Intergroup
Density	Baseline	37.93 ± 7.06	37.03 ± 8.58	
	Immediate	41.52 ± 6.88 ***	43.78 ± 6.71 ***	0.052
	4 weeks	41.79 ± 6.64 ***	45.68 ± 6.31 ***	0.003 **
	8 weeks	44.55 ± 7.62 ***	46.29 ± 5.48 ***	0.090

Baseline, immediately, 4 weeks after, and 8 weeks after treatment comparisons. *p-value < 0.05, **p < 0.01, ***p < 0.001.

TABLE 5 Measurement of the skin moisturization.

Parameter		Left	Right	Intergroup
Average permittivity(ε)	Baseline	23.02 ± 7.50	23.12 ± 6.60	
	Immediate	26.61 ± 7.13 ***	28.67 ± 6.54 ***	0.017 *
	4 weeks	27.84 ± 6.44 ***	30.79 ± 6.21 ***	0.008 **
	8 weeks	27.46 ± 6.50 ***	31.18 ± 5.46 ***	0.001 **
TDC 2.5 mm depth	Baseline	40.09 ± 2.60	39.70 ± 2.57	
	Immediate	40.29 ± 2.76	40.34 ± 2.72 ***	0.002 **
	4 weeks	40.37 ± 2.62	40.78 ± 2.57 ***	<0.001 ***
	8 weeks	40.15 ± 2.53	40.51 ± 2.39 ***	<0.001 ***

TDC, tissue dielectric constant.
Baseline, immediately, 4 weeks after, and 8 weeks after treatment comparisons. *p-value < 0.05, **p < 0.01, ***p < 0.001.

2.8 | Self-report questionnaire

All participants completed a self-administered questionnaire that assessed their satisfaction with skin improvement on the left and right sides of their faces and any side effects. The questionnaire was conducted 8 weeks after treatment, and participants were instructed to report any adverse skin events during each visit or to contact the examiner if they experienced: erythema, edema, scaling, itching, tingling

sensations, burning sensations, pain, or blisters. No side effects were reported by any participants or observed by the examiners during the study.

3 | DISCUSSION

Energy-based modalities for facial rejuvenation have rapidly evolved over the past decade, including lasers, light-based devices, and non-light-based thermal tightening devices such as RF and ultrasound. In particular, HIFU causes the deep dermal layer and superficial muscular aponeurotic system (SMAS) to contract, remodelling the targeted collagen fibres and subsequently tightening and lifting the skin.[1] Alternatively, RF emits an electrical current that converts into thermal energy due to the natural electrical resistance of molecules in the tissue.[2] Notably, collagen coagulation from RF heating the dermis from 40°C to 48°C while the epidermis remains cool can induce an immediate dermal contraction.

Histologic analyses have revealed that HIFU and RF both induce neocollagenesis and neoelastogenesis in the dermis and HIFU treatment induces dermal collagen thickening and straightening of elastic fibers in the mid-to-deep dermis and SMAS.[1] Furthermore, histologic analyses have revealed that RF caused neocollagenesis and neoelastogenesis more diffusely including the upper papillary dermis, while HIFU is sharply focused on the mid-to-deep dermis.[4] HIFU can produce focused, microthermal lesions at precise depths in the mid-to-deep dermis up to 6∼7.8 mm deep while RF can deliver uniform heat up to 2∼4 mm deep within the dermis,[5] suggesting that combining these two devices may exert synergistic effects in different skin layers by compensating for the different depth.

We conducted a split-face comparison study to evaluate and compare the efficacy of combining bipolar RF with HIFU and HIFU alone for skin rejuvenation. Our results showed that HIFU treatment significantly improved various skin parameters, including pore volume and number, skin elasticity, depth of eye wrinkles, degree of sagging in the eye area, nasolabial folds and cheeks, volume of the jawline, skin density, and permittivity. These results are consistent with previous studies and indicate that HIFU not only penetrates the dermis but also reaches the SMAS layer to induce neocollagenesis and neoelastogenesis, thereby increasing elasticity, improving density, and providing facial lifting effects.

We found that the HIFU device used in our study was effective in skin rejuvenation and facial lifting. Furthermore, we investigated whether combining bipolar RF and HIFU treatments could produce more effective and synergistic results. As a result, when HIFU was combined with bipolar RF, it significantly reduced pore number, enhanced skin elasticity, reduced depth of eye wrinkles, and an increase in skin moisturization measured as TDC at a 2.5 mm depth. These findings suggest that bipolar RF improves skin rejuvenation by providing a thermal effect that diffuses to the papillary dermis, which is more superficial than the target area of HIFU. Moreover, combining HIFU with bipolar RF can produce additional benefits for improving upper dermal skin parameters, such as pore reduction, wrinkle improvement, and skin moisturization. There was no significant intergroup difference observed in face lifting between the left cheek treated with HIFU only and the right cheek treated with a combination of HIFU and RF. These results can be explained by that HIFU improved sagging angles of the eye, nasolabial folds, cheeks, and the volume of the jawline because improvement of facial sagging can be achieved by targeting the deeper layers of the skin. Due to the significant differences in lifting effects observed before and after treatment with HIFU alone, it appears that HIFU alone is sufficient to produce significant lifting effect. However, further research is needed to fully understand the synergistic effects of RF, as its potential additional effects cannot be ruled out.

Skin density and moisturization on both right and left sides continued to increase immediately after the treatment, 4 and 8 weeks after treatment. Notably, the right side of the face, which received the combined treatment, showed a significant increase in skin density in the fourth week compared to the left side, which only received HIFU treatment. According to previous studies, RF stimulated an immediate wound-healing process and an immediate increase in IL-1β and TNF-α, and edema.[6] These contribute to the immediate increase in skin density and moisturization of our results. In addition, it was found that reticular dermal volume, cellularity, and the induction of tropoelastin, fibrillin, and procollagen 1 and 3 increased markedly by Day 28 post-treatment.[6] Our results also demonstrated a significant increase in skin density in the fourth week post-combined RF treatment. From 4–10 weeks post-treatment, the treated skin was replaced by new dermal tissue, and histological studies revealed evidence of new collagen and elastin deposition highlighted by increased cellularity and hyaluronic deposition.[6] Our result also showed that the skin density and moisturization increased and continued up to 8 weeks after treatment.

4 | CONCLUSION

In this study, we used the SD probe that combines HIFU and RF irradiations in a single handpiece. The SD probe has several advantages that it is precise to treat curved areas of the face. It produces the energy in a single dot rather than a conventional line composed of dots of ultrasound. It also enables simultaneous and safe irradiation of HIFU up to the deep dermis and RF up to the superficial dermis of the skin, without changing the probe. Therefore, this SD probe offers more comprehensive and effective treatments for various skin conditions, including skin laxity and wrinkles, by simultaneously stimulating collagen production in different layers of the skin.

The study's main limitation is the short follow-up period of 8 weeks, which may not be sufficient to demonstrate long-term efficacy in skin rejuvenation. However, the study's findings are still significant as they provide evidence for the synergistic effects of combining HIFU and bipolar RF in improving various skin parameters, including pore reduction, wrinkle improvement, and skin moisturization. These

results suggest that the SD probe has the potential to offer a more comprehensive and effective treatment for various skin conditions.

AUTHOR CONTRIBUTIONS

Ji Won Byun: Conceptualization (equal); writing—review and editing (lead); writing—original draft (lead). Yoo Ri Kang: Conceptualization (equal); formal analysis (lead); writing—review and editing (equal). Kyel Ko: Software (lead); writing—review and editing (equal). Soo-jung Park: Methodology (lead); writing—review and editing (equal). Wonkyu Hong: Conceptualization (leading); Writing—original draft (supporting); Writing—review and editing (equal).

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CONFLICT OF INTEREST STATEMENT

The authors have no relevant financial or non-financial interests to disclose.

DATA AVAILABILITY STATEMENT

The authors did not receive support from any organization for the submitted work.

REFERENCES

1. Suh DH, Shin MK, Lee SJ et al. Intense focused ultrasound tightening in asian skin: clinical and pathologic results. *Dermatol Surg*. 2011;37(11):1595-1602. https://doi.org/10.1111/j.1524-4725.2011.02094.x
2. Gentile RD, Kinney BM, Sadick NS. Radiofrequency technology in face and neck rejuvenation. *Facial Plast Surg Clin North Am*. 2018;26(2):123-134. https://doi.org/10.1016/j.fsc.2017.12.003
3. Alvaro P, Alberto O, Matia F, Beatrice Marina P. An innovative temperature-controlling handpiece for face and body skin laxity and tightening treatment with radiofrequency. *Skin Res Technol*. 2023;29(6):e13385. https://doi.org/10.1111/srt.13385
4. Suh DH, Choi JH, Lee SJ, Jeong KH, Song KY, Shin MK. Comparative histometric analysis of the effects of high-intensity focused ultrasound and radiofrequency on skin. *J Cosmet Laser Ther*. 2015;17(5):230-236. https://doi.org/10.3109/14764172.2015.1022189
5. Dierickx CC. The role of deep heating for noninvasive skin rejuvenation. *Lasers Surg Med*. 2006;38(9):799-807. https://doi.org/10.1002/lsm.20446
6. Hantash BM, Ubeid AA, Chang H, Kafi R, Renton B. Bipolar fractional radiofrequency treatment induces neoelastogenesis and neocollagenesis. *Lasers Surg Med*. 2009;41(1):1-9. https://doi.org/10.1002/lsm.20731

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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