Review Article

A Systematic Review of High-Intensity Focused Ultrasound in Skin Tightening and Body Contouring

Diala Haykal, MD; Sonja Sattler, MD; Ines Verner, MD; Monisha Madhumita, MD; and Hugues Cartier, MD

Aesthetic Surgery Journal
2025, Vol 45(7) 690–698
Editorial Decision date: March 25, 2025; online publish-ahead-of-print April 4, 2025.

https://doi.org/10.1093/asj/sjaf053
www.aestheticsurgeryjournal.com

OXFORD
UNIVERSITY PRESS

Abstract

High-intensity focused ultrasound (HIFU) has emerged as a noninvasive technology for aesthetic applications, offering skin tightening, facial rejuvenation, and body contouring. This systematic review assesses its clinical efficacy, safety profile, patient satisfaction, and future advancements. A comprehensive search of studies published between January 2010 and October 2024 identified 45 clinical trials and cohort studies meeting inclusion criteria, which focused on measurable outcomes, such as wrinkle improvement and circumference reduction. HIFU demonstrated significant efficacy in skin tightening, particularly in the lower face, neck, and periorbital regions, with improvements in skin laxity ranging from 18% to 30%. For body contouring, studies documented a reduction in circumference between 2.5 and 4.5 cm, notably in the abdomen and thighs. Compared with mild surgical outcomes, HIFU provided effective noninvasive lifting with a favorable safety profile; fewer than 5% of patients reported transient erythema, swelling, or mild discomfort. Advances in HIFU technology, such as parallel-beam ultrasound, have improved treatment precision and patient comfort. Although HIFU has demonstrated consistent results across different anatomical areas, standardization of treatment protocols remains a key challenge, particularly regarding optimal energy settings and patient selection criteria. Additionally, further research is needed to establish its long-term efficacy and explore its applications across diverse skin types. HIFU continues to be a promising alternative to surgical interventions, enhancing skin rejuvenation and body contouring with minimal downtime. Future investigations should focus on refining treatment protocols and integrating emerging technologies to optimize clinical outcomes.

Level of Evidence: 3 (Therapeutic)

High-intensity focused ultrasound (HIFU) has gained widespread adoption in aesthetic medicine over the past decade, primarily because of its noninvasive ability to tighten, lift, and contour the skin effectively. This technology is appealing to both patients and clinicians because it offers visible improvements in skin laxity and firmness without the need for surgery, while also requiring minimal downtime. Initially developed for medical applications, such as tumor ablation in oncology, HIFU has successfully transitioned into the aesthetic domain, providing new possibilities in skin rejuvenation and body contouring.[1] The technology works by delivering focused ultrasound energy deep into the skin layers, causing controlled thermal injury that stimulates collagen production and elastin remodeling, leading to noticeable improvements in skin texture and structure.[2,3]

The increasing demand for nonsurgical antiaging treatments has made HIFU a preferred option in the aesthetic market. This literature review aims to assess the role of HIFU in aesthetics, focusing on research published over the past 15 years. The review will examine clinical efficacy, safety profiles, patient outcomes, and satisfaction levels and will also compare HIFU with other noninvasive treatment modalities.

METHODS

A systematic literature search was conducted to identify peer-reviewed studies on the application of HIFU in aesthetic medicine. The search was performed in PubMed, Embase, and the Cochrane Library, using the following terms “High-Intensity Focused Ultrasound,” “HIFU,” “skin tightening,” “facial rejuvenation,” “non-invasive body contouring,” “body contouring,” and “fat reduction.” Studies published between January 2010 and October 2024 were included. The inclusion criteria

Dr Haykal is a cosmetic doctor in private practice, Palaiseau, France. Dr Sattler is a dermatologist in private practice, Darmstadt, Germany. Dr Verner is a dermatologist in private practice, Tel Aviv, Israel. Dr Madhumita is a dermatologist, Department of Dermatology, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India. Dr Cartier is a dermatologist in private practice, Arras, France.

Corresponding Author:
Dr Diala Haykal, 49 Ter Rue de Paris, 91120 Palaiseau, France.
E-mail: docteur.haykal@gmail.com; Instagram: @centre_laser_palaiseau

required studies to report quantifiable changes in skin elasticity (eg, cytometry values), wrinkle reduction (millimeter improvement), or body circumference (centimeter change in waist, thighs, or arms). Studies were excluded if they lacked statistical comparisons or objective clinical measurements. The initial search yielded 3865 articles. After excluding irrelevant studies, 45 articles were selected for in-depth review. These 45 studies were analyzed in terms of treatment protocols, clinical outcomes, safety, and patient satisfaction.

RESULTS

Overall, the 45 studies analyzed in this review overwhelmingly support the use of HIFU as an effective and safe noninvasive modality for skin tightening, facial rejuvenation, and body contouring. These studies were then categorized based on different outcomes and characteristics in order to better understand HIFU's contributions to the field of aesthetic dermatology (Table 1 summarizes all references).

Efficacy in Skin Tightening and Rejuvenation

One of the most prominent uses of HIFU in aesthetic medicine is its application for skin tightening and facial rejuvenation. The technology's ability to target deep tissue layers, including the dermis and the superficial musculoaponeurotic system (SMAS), allows it to offer tissue rejuvenation with skin tightening and mild lifting without the need for invasive/surgical procedures. Numerous studies, including those by Calik et al, Casabona and Kaye, Park et al, Friedman et al, Vachiramon et al, Kwack and Lee, Aşiran Serdar et al, and Han et al, have reported an improvement in skin laxity ranging from 18% to 30%, particularly in the lower face, neck, and periorbital regions based on validated cytometry assessments and clinical grading scales.[4-11] HIFU operates by delivering focused ultrasound waves deep into the skin, causing thermal injury to the targeted tissue layers. In this way, multiple small thermal injury zones (TIZs) are produced. These TIZs are around 1 mm^3 leaving the space in between not treated, allowing for skin regeneration. This controlled injury stimulates the body's natural healing response, leading to new collagen production and elastin remodeling. As collagen fibers contract and new collagen is synthesized, the skin tightens, resulting in a more lifted and youthful appearance. The depth of penetration, ranging between 1.5 and 4.5 mm, allows for effective remodeling of deeper structures, addressing skin sagging that is typically resistant to more superficial treatments, such as lasers, intense pulsed light, fractional radiofrequency (RF), or chemical peels. Equally, Lio et al conducted a retrospective study on 60 patients following HIFU treatment for facial rejuvenation. The results showed noticeable skin tightening and wrinkle reduction at various skin depths.[12] A prospective study by Araco evaluated 50 patients with mild-to-moderate facial laxity who underwent a single session of microfocused ultrasound with visualization (MFU-V). Over a 6-month follow-up, significant wrinkle reduction, improved skin texture, and enhanced facial ptosis correction were observed, with no major adverse effects reported.[13]

In a systematic review and meta-analysis by Ayatollahi et al, the safety and efficacy of HIFU for face and neck rejuvenation were extensively evaluated across multiple studies. The analysis revealed significant improvements in skin tightness, elasticity, and overall facial rejuvenation, with minimal adverse effects reported, primarily mild erythema and swelling. Patient satisfaction rates were consistently high, and the authors concluded that HIFU is a safe and effective noninvasive option for face and neck rejuvenation, with sustained results over several months.[14] These findings are echoed by Fabi, whose study on HIFU treatment for facial rejuvenation demonstrated significant improvements in skin laxity, particularly in the lower face and neck. Patients experienced noticeable tightening in areas such as the jawline and submental region, with additional enhancements in skin texture and firmness. The authors also reported high patient satisfaction, minimal downtime, and a strong safety profile, making HIFU a preferred noninvasive treatment for facial contouring and skin rejuvenation.[15]

In addition to facial skin tightening, the researchers have also explored the use of HIFU for specific areas prone to sagging, such as the brows, eyelids, and jawline. Han et al found that HIFU effectively reduces the depth of periorbital wrinkles and improves skin laxity around the eyes.[11] The technology's precision in targeting these delicate areas has led to its increasing use as a nonsurgical alternative to blepharoplasty. For patients with mild-to-moderate skin laxity, HIFU offers a noninvasive solution with fewer risks, less downtime, and no scarring compared with surgical interventions. Table 2 summarizes the differences between these modalities, and Table 3 illustrates the key technical differences between HIFU, MFU-V, and SUPERB technologies.

Body Contouring and Fat Reduction

In addition to its widely recognized application for skin tightening, HIFU has also gained traction as an effective modality for noninvasive fat reduction and body contouring. This makes it an attractive option for patients seeking targeted body sculpting solutions without the risks or recovery time associated with surgical procedures, such as liposuction. HIFU's capacity for fat reduction stems from its ability to target and thermally disrupt subcutaneous adipose tissue, leading to the breakdown of fat cells in the treated area.[16-19] In several studies, such as those by Hong et al, Jalian and Avram, Ko et al, and Kennedy et al, the authors have demonstrated the efficacy of HIFU in reducing localized fat deposits.[20-23] In the study conducted by Hong et al on abdominal fat reduction, patients experienced an average reduction in waist circumference of 3 cm (2.5-4.5 cm) after a single HIFU session. The effect was observed in 68.7% of patients at 8 weeks posttreatment. Comparable results were noted in submental fat reduction, where over 60% of patients showed a ≥1-point improvement on the Submental Fat Rating Scale. The authors emphasized that the treatment effectively disrupted adipocytes in the subcutaneous layer while sparing surrounding tissues, such as the skin, muscles, and blood vessels. The fat cells are subsequently metabolized by the body's natural processes and gradually eliminated, resulting in a slimmer, more contoured appearance. The noninvasive nature of HIFU, combined with its precision in targeting fat layers, makes it a viable alternative to traditional body contouring procedures.[20] Jalian and Avram found similar results in their study of fat reduction in areas such as the flanks, thighs, and arms. In addition to fat reduction, patients also reported improvements in skin texture and firmness, which can be attributed to HIFU's dual mechanism of stimulating collagen production while reducing adipose tissue.[21] Additionally, in a study conducted by Kwon et al, the efficacy and safety of a novel triple-layer HIFU regimen for the reduction of submental fat were evaluated in 40 Korean patients. The results showed that 62.5% of patients demonstrated at least a 1-point improvement on the Clinician-Reported Submental Fat Rating Scale, and 67.5% were satisfied with their facial and chin appearance based on the Subject Self-Rating Scale at an 8-week follow-up. The treatment was well tolerated, with only mild and transient side effects

Table 1. Summary of References

Study	Year	US technology	Findings	Safety
Maloney E, Hwang JH[1]	2015	HIFU	HIFU's oncological applications provided a foundation for its transition into aesthetic uses	Noninvasive modality with minimal risks
Atiyeh BS, Chahine F[2]	2021	HIFU	Effectiveness in fat reduction and skin tightening	Erythema and swelling
Salavastru C, Fritz K, Tiplica GS[3]	2023	HIFU	Skin tightening improvements in diverse anatomical areas	Strong safety profile
Calik J et al[4]	2024	HIFU	Promising results for basal cell carcinoma	Strong safety profile
Casabona G, Kaye K[5]	2019	MFU-V + fillers	Synergistic benefits	Importance of operator expertise
Park JY et al[6]	2021	MFU-V	Skin laxity and tightness improvements	Transient erythema
Friedman O et al[7]	2020	HIFU	Tightening in jawline and neck	No adverse effects
Vachiramon V et al[8]	2021	MFU-V	Reliable lifting effects for skin laxity	Transient redness and swelling
Kwack MH, Lee WJ[9]	2023	HIFU (home device)	Significant wrinkle reduction in at-home settings	Safe
Aşiran Serdar Z et al[10]	2020	HIFU	Effective for facial and neck rejuvenation	Mild, transient discomfort
Han HS et al[11]	2022	HIFU	Effective for periorbital, perioral, and neck wrinkles	Practitioner expertise critical for safety
Lio ML et al[12]	2022	HIFU	Significant wrinkle and sagging reductions	No significant adverse effects
Araco A[13]	2020	MFU-V	Prospective study shows collagen regeneration with a single session	Safe and effective
Ayatollahi A et al[14]	2020	HIFU	Consistent improvements in elasticity and skin tightening	Mild erythema and swelling
Fabi SG[15]	2015	MFU-V	Effectiveness for facial lifting and rejuvenation	Mild transient redness
Aşiran Serdar Z, Tukenmez Demirci G[16]	2020	HIFU	Effective tightening in upper arms	Mild side effects, including erythema
Alizadeh Z et al[17]	2024	HIFU	Body sculpting and localized fat reduction	Minimal adverse effects
Alizadeh Z et al[18]	2016	HIFU	Effective fat reduction and body contouring	Low complication rates
Al-Jumaily et al[19]	2024	HIFU	Review of focused ultrasound for dermal applications	Favorable safety profile
Hong JY et al[20]	2020	HIFU	Waist circumference reductions of ~3 cm	Mild redness and swelling
Jalian HR, Avram MM[21]	2012	HIFU	Efficacy in fat reduction in various regions	Minimal downtime and mild side effects
Ko EJ et al[22]	2017	HIFU	Effective skin tightening for abdomen and thighs	Importance of practitioner skill to ensure safety
Kennedy J et al[23]	2015	HIFU	Effective fat disruption in subcutaneous layers	Mild and transient erythema or swelling
Kwon HH et al[24]	2021	HIFU	Reduced submental fat and tightened skin	Transient discomfort
Guth F et al[25]	2018	HIFU	Immediate fat reduction with measurable results	Mild redness and temporary swelling
Khong SJML et al[26]	2024	HIFU + RF	Enhanced skin tightening through combination	Minimal erythema and swelling
Contini M et al[27]	2023	MFU-V	Effective option for facial rejuvenation	Mild, transient redness or swelling
Gold M et al[28]	2024	HIFU + IPL + RF + microneedling	Multimodality treatment enhanced skin rejuvenation	Favorable safety profile
Woodward JA et al[29]	2014	MFU-V + fractional CO_2 laser	Improved lifting and tightening effects	Mild redness and swelling
Arora RT et al[30]	2023	HIFU + injectables	Improved facial contour and patient satisfaction	Minimal risks
Byun J et al[31]	2023	RF + HIFU (single-dot ultrasound)	Enhanced elasticity and skin tone	No significant adverse effects

Table 1. Continued

Study	Year	US technology	Findings	Safety
Fabi SG et al[32]	2016	MFU-V + botulinum toxin + dermal fillers	Comprehensive rejuvenation	Safe and well tolerated
Araco et al[33]	2025	PN-HPT	Effective in treating postsurgical atrophic and depressed scars	Safe with clinical improvement
Araco et al[34]	2023	PN-HPT + HA	Effective for nasolabial folds with combined therapy	Well tolerated and safe
Hongcharu W et al[35]	2023	SUPERB	Skin tightening improvement	Minimal discomfort
Gold MH, Biron J[36]	2024	SUPERB	Effective for treating mild-to-moderate laxity	Strong safety profile
Oku K[37]	2024	SUPERB	Enhanced precision in periorbital region	No reported significant side effects
Kumar V et al[38]	2023	HIFU	Improved body and facial contouring	Mild, temporary redness and swelling
Wong A et al[39]	2023	MFU-V	Efficacy in tightening and rejuvenation	Importance of trained operators training to avoid thermal injuries
Pavicic T et al[40]	2022	MFU-V	MFU-V considered safe and effective among energy-based devices	Reinforced safety profile with expert consensus
Kim J et al[41]	2024	HIFU (linear array)	Significant tightening and lifting effects	Mild swelling and erythema
Maas CS, Joseph JH[42]	2019	MFU-V	Effective for acne scar reduction	Mild redness and swelling
Vachiramon V et al[43]	2018	HIFU	Reduced hyperpigmentation and improved skin tone	No significant adverse events
Yi KH et al[44]	2024	HIFU + topical agents	Improved brightness and hydration	No major side effects
Fritz K, Salavastru C[45]	2016	HIFU	Effective for surface-level tightening and fat reduction	Safe with proper application
Catinis CA, Chilukuri S[46]	2020	RF + HIFU	Synergistic outcomes achieved with combined RF	Safe with minimal risks
Kiedrowicz M et al[47]	2022	RF + HIFU	Efficacy for fat reduction and skin tightening	Safe across multiple sessions
Haykal D et al[48]	2024	HIFU + AI	Discussion of AI integration for personalized aesthetic care	Improved precision and minimized risks through technology

AI, artificial intelligence; HIFU, high-intensity focused ultrasound; MFU-V, microfocused ultrasound with visualization; PN-HPT, polynucleotides highly purified technology; RF, radiofrequency.

observed.[24] Another key advantage of HIFU for fat reduction is the minimal downtime and low risk of complications. Unlike liposuction, which requires general anesthesia and comes with risks such as infection, scarring, and prolonged recovery, HIFU is performed in an outpatient setting with few side effects. Mild swelling, erythema, or bruising may occur posttreatment, but these side effects typically resolve within a few days. The drawback of HIFU for targeted fat reduction and skin tightening on the body (eg, abdomen or thighs) is the relatively small spot size of the transducer, whereas the treatment area is quite large. As the TIZs are quite small, multiple pulses are needed to cover the required treatment area which is large. This leads to a relatively long, costly, and uncomfortable treatment with variable clinical results.

Safety and Side Effects

Safety was a key focus across the studies, with Guth et al, Khong et al, and Hong et al consistently reporting a favorable safety profile for HIFU treatments. Common side effects included mild erythema, transient swelling, and slight discomfort, all of which typically resolved within a few hours to days.[20,25,26] Hong et al confirmed that no severe adverse events, such as burns or nerve damage, were reported in their study of abdominal fat reduction, affirming the safety of HIFU even in larger treatment areas.[20] Furthermore, in a study, Kennedy et al showed that fewer than 5% of patients experienced any significant adverse events, reinforcing the safety profile of HIFU for fat reduction.[23] However, Han et al and Casabona and Kaye emphasized the importance of operator skill in minimizing risks. They noted that poor technique or improper use of HIFU devices could lead to unwanted side effects, such as thermal injury or inconsistent results, particularly in sensitive areas like the neck or face.[5,11] Table 4 presents a summary of adverse effects and their reported frequencies, offering a visual representation of the safety profile of HIFU-based treatments.

Combination Therapies

In several studies, the authors examined the benefits of combining HIFU with other aesthetic treatments. Khong et al and Contini et al both explored the synergistic effects of combining HIFU with monopolar RF and microneedling. These combination therapies yielded superior results in reducing skin laxity and improving skin texture compared with using HIFU alone.[26,27] Gold et al suggested that the future of aesthetic treatments lies in multimodality approaches, with HIFU serving as a foundational technology for comprehensive rejuvenation strategies.[28] This idea was supported by Contini et al, who showed that combining HIFU with microneedling significantly reduced the appearance of

Table 2. Summary of Ultrasound Technologies in Aesthetic Dermatology

Aspect	HIFU	MFU-V	Synchronous parallel-beam technology (SUPERB)
Mechanism	Delivers focused ultrasound energy to create thermal injury at targeted depths	Combines focused ultrasound energy with real-time imaging for precise targeting	Nonfocused ultrasound waves create thermal injury
Visualization capability	No real-time visualization	Real-time imaging allows visualization of different tissue layers during treatment	No real-time visualization
Target tissues	Dermis, SMAS, platysma, and subcutaneous fat	Dermis, SMAS, platysma	Dermis
Clinical applications	Skin tightening, lifting, skin rejuvenation, and body contouring	Skin tightening, lifting, and skin rejuvenation	Skin tightening, rejuvenation, and cellulite
Depth of penetration	Different depths (1.5, 2.0, 3.0, and 4.5 mm) at frequencies of 2 to 7 MHz	Specific depths (1.5, 3.0, and 4.5 mm) at frequencies of 4 to 10 MHz	Cylinder at 1.5 mm depth at 11 to 12 MHz frequencies
Precision	Less precise targeting of depth. No visualization	Highly precise; visualization ensures accurate targeting of desired layers	Less precise. Targets the dermis
Fat reduction capability	Can target the subcutaneous fat, suitable for body contouring at lower frequencies	Avoids fat layers, not suitable for fat reduction	Not suitable for fat reduction Suitable for cellulite
Predictability of outcomes	High, highly dependent on operator skill and experience	High, guided by imaging and operator skill, with consistent results	Variable
Key advantages	Versatile Can target both fat and skin Suitable for body contouring	Precision Skin tightening and lifting Consistent outcomes	Skin tightening and lifting Variable outcomes
Limitations	Lack of visualization can lead to variability in outcomes Operator skill vital Can unintentionally target fat layers	Not designed for fat reduction Operator skill vital to use imaging effectively Can unintentionally target fat layers	Not designed for fat reduction Operator skill vital
Best suited for	General skin rejuvenation, skin tightening and lifting Noninvasive body contouring	Noninvasive skin tightening and lifting especially in delicate areas (eg, periorbital skin)	Noninvasive skin tightening and lifting
Examples of devices	Ultraformer	Ultherapy, Ultherapy Prime	Sofwave

HIFU, high-intensity focused ultrasound; MFU-V, microfocused ultrasound with visualization; SMAS, superficial musculoaponeurotic system.

acne scars and improved skin elasticity, indicating that HIFU's efficacy can be further enhanced with other modalities.[27] Similarly, Woodward et al demonstrated that combining HIFU with fractional CO_2 laser resurfacing for facial and neck rejuvenation resulted in significant improvements in skin tightening and lifting. This combination showed high efficacy in enhancing collagen remodeling while maintaining a favorable safety profile, making it a promising strategy for nonsurgical skin rejuvenation.[29] Additionally, in a case study on nonsurgical lower face contouring in an Indian patient, Arora et al further support this process, demonstrating successful outcomes through a combination of energy-based devices and injectables, resulting in improved facial contour and patient satisfaction.[30] Moreover, Byun et al conducted a nonrandomized split-face trial comparing the efficacy of RF combined with single-dot ultrasound for skin rejuvenation. They showed that although both modalities were effective in improving skin texture and elasticity, the combination treatment produced superior results. The side treated with the combination therapy exhibited more significant skin tightening and smoothness, with patients reporting higher satisfaction and longer lasting effects compared with RF or ultrasound alone. The authors of this study confirms the enhanced outcomes achieved by combining energy-based treatments for noninvasive skin rejuvenation.[31]

Similarly, in a pilot study combining HIFU with botulinum toxin and dermal fillers, both temporary and semi-permanent, the authors demonstrated the safety and effectiveness of these combined therapies. This approach offered enhanced outcomes for skin rejuvenation, as combining these treatments allowed for better-targeted collagen stimulation and skin lifting. The combined use of HIFU with injectables was shown to not only improve skin elasticity and structure but also address volume loss and dynamic wrinkles, leading to more comprehensive aesthetic results.[32] Although no current studies directly assess the combination of HIFU with polynucleotides highly purified technology (Mastelli Bio-Pharmaceutical Company, Sanremo, Italy), its regenerative properties may offer a synergistic effect by promoting fibroblast proliferation and reducing postinflammatory reactions.[33,34] Future studies should explore this potential integration.

Novel Applications: Parallel-Beam Technology

A new and promising innovation in ultrasound technology is the development of parallel-beam devices, which have been examined in studies such as Hongcharu et al, Gold and Biron, and Oku. This parallel-beam ultrasound technology is designed to deliver energy in a more uniform and controlled manner, particularly for superficial skin tightening.[35-37] The authors of these studies showed that parallel

Table 3. Technical Explanations

Technology	TCP delivery	Energy and depth	Treatment indications
HIFU	600 to 800 TCPs per session	1.5 to 4.5 mm, 2 to 7 MHz	Facial tightening, SMAS targeting, body contouring
MFU-V	970 TCPs (lower face and submentum)	1.5, 3.0, 4.5 mm, 4 to 10 MHz	Precise lifting with visualization
SUPERB	Uniform parallel beams	1.5 mm, 11 to 12 MHz	Epidermal collagen remodeling

HIFU treatments typically last 45 to 75 min per session. MFU-V protocols require an average of 970 treatment lines and a duration of ~90 min for full lower face and submentum. SUPERB requires ~40 to 50 min per session, delivering uniform pulses at 1.5 mm depth. HIFU, high-intensity focused ultrasound; MFU-V, microfocused ultrasound with visualization; SMAS, superficial musculoaponeurotic system; TCP, thermal coagulation point.

beams at a depth of 1.5 mm resulted in more precise and consistent skin-tightening outcomes for the treatment of mild-to-moderate facial laxity. The use of parallel beams enables more controlled energy delivery, reducing the risk of over-treatment or tissue damage, which can sometimes occur with conventional HIFU devices. This technology offers better predictability in results, as the energy is distributed evenly across the treatment area, ensuring consistent collagen remodeling and skin tightening. The potential benefits of parallel beam are particularly promising for delicate areas, such as the periorbital region and the neck, where precision is critical to avoid complications. In addition, the authors of these studies reported that parallel-beam technology significantly reduced treatment discomfort, making the procedure more tolerable for patients, which in turn improved overall patient satisfaction and adherence to follow-up treatments.[35-37]

Patient Satisfaction

High patient satisfaction rates were reported across studies such as those by Park et al, Fabi, and Kumar et al[6,15,38] In these studies, over 80% of patients expressed satisfaction with their HIFU treatment, particularly for facial rejuvenation and body contouring. Park et al emphasized that personalized HIFU treatments, tailored to each patient's specific anatomical needs, led to better outcomes and higher satisfaction rates.[6] Fabi reinforced these findings, showing that patients receiving HIFU for noninvasive facial lifting reported not only high satisfaction with the aesthetic results, but also minimal downtime and discomfort.[15] Kumar et al highlighted that the use of real-time visualization technology to guide HIFU energy delivery resulted in more precise treatments and improved patient outcomes and satisfaction.[38] This energy-based technology, combined with the customization of treatment parameters based on patient characteristics, ensured consistent results and greater satisfaction.

Limitations and Considerations

Although the authors largely confirm the efficacy and safety of HIFU and other ultrasound technologies, some limitations were noted. Wong et al and Pavicic et al pointed out that results may vary depending on the patient's age, skin type, and degree of skin laxity.[39,40] For example, patients with more severe laxity may require multiple treatment sessions or adjunctive therapies for optimal results. Furthermore, Kim et al emphasize that operator skill and experience are critical factors in achieving consistent outcomes, as improper use of HIFU devices can lead to complications, such as thermal burns and tissue damage. Proper training and precise application are essential to minimize these risks and ensure the safety and effectiveness of the treatment.[41] Given the precision required to deliver the ultrasound energy to the correct depth, inexperienced operators may inadvertently cause thermal injury to surrounding tissues. The authors of several studies also emphasized the need for more standardized treatment protocols to ensure consistent results across different devices and patient populations. Pavicic et al called for additional studies to evaluate the long-term durability of HIFU results and its efficacy across different skin types, particularly in darker skin tones, where postinflammatory hyperpigmentation may be a concern.[40] Additionally, variability in patient selection criteria, device settings, and treatment depths across studies makes it difficult to compare results systematically. The high cost of HIFU and MFU-V treatments may limit patient accessibility, with limited insurance coverage for aesthetic procedures. Pain and discomfort during treatment, especially at higher energy settings, are frequently reported, necessitating improved pain management strategies. Finally, although HIFU is generally safe across different Fitzpatrick skin types, more research is needed to assess long-term safety and potential adverse effects in darker skin tones.

Table 4. Side Effects

Side effect	Frequency
Mild erythema	30% to 50% (resolves in 24-48 h)
Swelling	10% to 20% (resolves within a few days)
Tenderness	15% to 25% (subsides in 1-2 weeks)
Nerve irritation	<1% (typically transient)
Fat atrophy (unintentional)	<1% (because of improper depth selection)

Additional Aesthetic Applications

Although the primary focus of HIFU in aesthetics has been on facial rejuvenation and body contouring, the authors of emerging studies suggest other potential applications. HIFU has been investigated for its role in improving skin texture, reducing the appearance of acne scars, and mitigating hyperpigmented lesions. Although these areas are still undersearched, the authors of early studies offer promising results that could expand the use of HIFU in dermatology. In a study, Maas and Joseph assessed the efficacy and safety of HIFU in treating acne scars. Involving 53 patients, the authors showed that ~76% experienced moderate to significant improvement in scar texture and depth over 6 months, with some achieving up to a 50% reduction in scar severity. The treatment was well tolerated, with mild side effects such as transient redness and swelling. The authors concluded that HIFU is a safe and effective noninvasive option for treating moderate-to-severe atrophic acne scars.[42] In another study, a prospective, randomized, controlled, evaluator-blinded trial on UV-induced hyperpigmentation in Fitzpatrick skin Types III and IV demonstrated that HIFU was effective in reducing hyperpigmented lesions, with patients showing significant improvement in pigmentation and overall skin tone after treatment. This result suggests that HIFU has also potential applications in treating hyperpigmentation in darker skin types.[43] Furthermore, Yi et al found that combining HIFU with the topical agent significantly improved skin and tone in 40 participants after 3 sessions. Patients reported enhanced luminosity and

hydration with no major side effects, highlighting the potential of this combination for skin brightening and rejuvenation.[44]

These novel applications highlight the versatility of HIFU in aesthetic medicine, but more rigorous clinical trials are needed to validate these findings and establish standardized treatment protocols.

DISCUSSION

The clinical implications of HIFU in aesthetics are well supported by a range of studies highlighting its effectiveness as a noninvasive treatment for facial rejuvenation and body contouring. By precisely targeting deeper skin layers without affecting the epidermis, HIFU offers an attractive alternative for patients seeking nonsurgical solutions to facelifts and body sculpting. Typical outcomes, such as skin tightening, wrinkle reduction, and fat reduction, become visible within 3 months and can last up to a year, providing patients with long-lasting, noticeable improvements. HIFU functions by delivering focused ultrasound waves at controlled depths within the skin, generally between 1.5 and 4.5 mm. At these depths, the ultrasound waves converge, creating thermal injury in targeted tissue layers while sparing the surrounding tissue. Reaching focal temperatures of 60°C to 70°C, this energy induces coagulative necrosis, leading to tissue contraction, collagen remodeling, and a wound-healing response that enhances skin elasticity and firmness. For skin tightening, HIFU effectively targets the dermis and the SMAS, producing immediate collagen contraction and stimulating new collagen formation over time. This process results in a gradual lifting effect that becomes more pronounced in the months following treatment, contributing to a firmer, more lifted appearance. In body contouring, HIFU's action on subcutaneous adipose tissue leads to thermal disruption of fat cells. This targeted injury causes apoptosis in fat cells, which are then metabolized and gradually eliminated by the body's lymphatic system, resulting in a reduction of localized fat deposits. Because of HIFU's focused energy delivery, surrounding structures, such as skin, blood vessels, and muscle, remain unaffected, enabling effective contouring in specific areas like the abdomen, thighs, and flanks. This precision makes HIFU particularly appealing for patients looking to achieve a contoured appearance without invasive procedures or extended recovery times.[2] Compared with other noninvasive modalities, such as RF and laser treatments, HIFU stands out because of its ability to penetrate in a controlled, precise way the deeper skin layers and the subcutaneous fat. RF technology primarily heats the dermis and promotes collagen production at shallower levels, which can improve skin texture and surface-level concerns.[41,45-47] However, RF does not concentrate in the SMAS layer, limiting its effectiveness for deep tissue lifting. Lasers and/or intense pulsed light, meanwhile, are well suited for treating surface-level issues like pigmentation, fine lines, and textural irregularities, but lack the penetration depth required for comprehensive tightening and lifting. HIFU's ability to target both superficial and deep layers makes it uniquely suited for enhancing facial contour and addressing skin laxity in areas like the jawline, neck, and lower face. HIFU's versatility is further underscored by its effectiveness in body contouring. The authors of these studies show that HIFU can reduce fat deposits in specific areas, offering a more focused approach than RF or cryolipolysis. By delivering energy precisely to fat cells, HIFU disrupts adipocytes without affecting nearby tissues, enabling noninvasive fat reduction that rivals surgical options like liposuction in certain cases. Combined treatment protocols that incorporate HIFU alongside other modalities, such as microneedling or dermal fillers, have been shown to improve both skin-tightening and fat-reduction outcomes, delivering enhanced results for patients.[28,32] Despite HIFU's numerous benefits, certain challenges remain.

The high cost of HIFU treatments may limit accessibility for some patients and impact their decision-making process. Additionally, effective use of HIFU requires significant training, as practitioners must have a thorough understanding of facial and body anatomy to accurately target tissue layers and achieve optimal results. Enhanced training opportunities for practitioners can help ensure consistent, high-quality care, minimize risks, and maximize patient satisfaction. Further research is also needed to assess HIFU's efficacy across diverse patient populations, particularly those with darker skin tones. Postinflammatory hyperpigmentation is a potential concern in darker skin, but it has not been extensively studied with HIFU. Investigating how treatment protocols may need to be tailored for different skin types and ethnic groups will be crucial for broadening HIFU's applicability and ensuring safe, effective outcomes across a wider demographic. HIFU represents a powerful, noninvasive technology with significant implications for facial rejuvenation, body contouring, and fat reduction.

Technological advancements, such as parallel-beam ultrasound, continue to refine ultrasound technologies in aesthetic medicine with precision and efficacy. These innovations further solidify HIFU's role in aesthetic medicine, positioning it as a leading modality for patients seeking effective, nonsurgical treatments with minimal downtime and durable results.

Although this review focuses specifically on HIFU, it is important to situate these findings within the context of advancements in ultrasound-based technologies. The introduction of MFU-V has added a layer of precision by enabling real-time imaging, allowing practitioners to target specific layers, such as the SMAS and dermis, more accurately. Although MFU-V is not included in this systematic review, its development highlights the potential for further refinement of noninvasive aesthetic treatments, particularly in achieving consistent outcomes and minimizing unintended targeting of subcutaneous fat. It is significant to differentiate and understand the 2 modalities, as they influence clinical choice and patient outcomes. Rather than being competitors, they can be viewed as complementary technologies, each excelling in specific areas.

Future Research Directions

There are several areas where future research could further elucidate the role of HIFU in aesthetics. Exploring HIFU for other dermatological conditions, such as rosacea, melasma, and skin inflammation, could further expand its use in clinical practice. Although HIFU shows promising results in collagen remodeling and adipose tissue disruption, long-term studies are needed to better understand the sustainability of these outcomes and to assess the durability of HIFU results beyond 12 months, especially for patients undergoing multiple treatments or combining HIFU with other modalities like dermal fillers or laser resurfacing. Additionally, there is a need for standardized protocols in HIFU treatments to ensure consistency and optimize outcomes across various clinical settings. Furthermore, more research is needed on the use of HIFU in diverse populations. Most current studies have been conducted on lighter skin tones, with limited data on its efficacy and safety in patients with darker skin. Given the potential risks of hyperpigmentation and other adverse effects in darker skin types, it is essential to determine whether HIFU requires specific adjustments for these populations. In addition to these research areas, future studies could also investigate combining HIFU with emerging regenerative therapies like platelet-rich plasma and stem-cell treatments, potentially enhancing recovery and rejuvenation outcomes. Additionally, innovations in

pain management during HIFU sessions could improve patient comfort without affecting the procedure's efficacy. Advances in HIFU device technology, such as more precise targeting mechanisms and improved real-time imaging, could further improve treatment accuracy, whereas investigating HIFU's role in preventative aging protocols for younger patients could open new avenues in antiaging treatments.

Future research could explore comparisons between HIFU and emerging technologies like MFU-V to further refine treatment protocols and optimize outcomes. Although HIFU remains a cornerstone in noninvasive aesthetic treatments, the incorporation of visualization in MFU-V offers potential for greater precision and consistency, which warrants further investigation in clinical studies.

Finally, the integration of HIFU with emerging technologies such as artificial intelligence (AI) could further enhance its precision and safety. AI-based systems could optimize treatment protocols by personalizing energy settings based on individual patient anatomy, skin type, and laxity levels, potentially leading to more consistent and predictable results.[48]

CONCLUSIONS

This systematic review of the past 15 years highlights the effectiveness and safety of HIFU as a noninvasive modality for aesthetic applications, including skin tightening, facial rejuvenation, and body contouring. HIFU has proven to be a versatile tool for both skin tightening and fat reduction, offering noninvasive solutions with long-lasting results. Its ability to target deeper skin layers for rejuvenation, while simultaneously addressing stubborn fat deposits, makes it an increasingly popular choice for patients seeking comprehensive body contouring and facial rejuvenation. The emerging advancements in ultrasound technology, such as parallel-beam ultrasound, further expand its potential in delivering precise, consistent results with minimal discomfort. The evidence consistently demonstrates HIFU's ability to deliver noticeable improvements in skin laxity and fat reduction, with minimal downtime and a favorable safety profile. This innovation not only improves the predictability of results but also enhances patient comfort during treatment, potentially increasing satisfaction and adherence to treatment protocols. The combination of HIFU with other aesthetic treatments, such as RF and microneedling, further extends its versatility, offering enhanced results in skin texture, elasticity, and contouring. Multimodality approaches appear to be the future direction of aesthetic treatments, with HIFU serving as a key component for comprehensive rejuvenation strategies. However, challenges remain in terms of standardizing treatment protocols, managing pain, and ensuring consistent outcomes across different devices and patient demographics. More research is necessary to optimize HIFU settings for various skin types and degrees of skin laxity.

In conclusion, despite these challenges, HIFU continues to be a leading technology in noninvasive aesthetic procedures. Its favorable safety profile, long-lasting results, and potential for combination with other treatments position it as a cornerstone in the future of aesthetic medicine. With ongoing advancements and further research, HIFU's role in comprehensive rejuvenation strategies will likely continue to expand, offering broader applications and improved outcomes for a diverse range of patients.

Disclosures

Dr Sattler is a global key opinion leader for Merz Aesthetics (Raleigh, NC) and a speaker for Crown Aesthetics (Dallas, TX), and conducts research for Allergan Aesthetics (Irvine, CA), LG (Seoul, South Korea), Hallura (Yoqneam, Israel), and ICA-Navigation systems GmbH (Dortmund, Germany). Dr Sattler declares no conflicts of interest related to this publication. The remaining authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Funding

The authors received no financial support for the research, authorship, and publication of this article.

REFERENCES

1. Maloney E, Hwang JH. Emerging HIFU applications in cancer therapy. *Int J Hyperthermia*. 2015;31:302-309. doi: 10.3109/02656736.2014.969789
2. Atiyeh BS, Chahine F. Evidence-based efficacy of high-intensity focused ultrasound (HIFU) in aesthetic body contouring. *Aesthetic Plast Surg*. 2021;45:570-578. doi: 10.1007/s00266-020-01863-3
3. Salavastru C, Fritz K, Tiplica GS. High intensity focussed ultrasound for skin tightening. *Dermatologie*. 2023;74:748-752. doi: 10.1007/s00105-023-05198-3
4. Calik J, Sauer N, Woźniak B, Wojnar A, Pietkiewicz P, Dzięgiel P. Pilot study on high-intensity focused ultrasound (HIFU) for basal cell carcinoma: effectiveness and safety. *J Clin Med*. 2024;13:3277. doi: 10.3390/jcm13113277
5. Casabona G, Kaye K. Facial skin tightening with microfocused ultrasound and dermal fillers: considerations for patient selection and outcomes. *J Drugs Dermatol*. 2019;18:1075-1082.
6. Park JY, Lin F, Suwanchinda A, et al. Customized treatment using microfocused ultrasound with visualization for optimized patient outcomes: a review of skin-tightening energy technologies and a pan-Asian adaptation of the expert panel's gold standard consensus. *J Clin Aesthetic Dermatol*. 2021;14:E70-E79.
7. Friedman O, Isman G, Koren A, Shoshany H, Sprecher E, Artzi O. Intense focused ultrasound for neck and lower face skin tightening a prospective study. *J Cosmet Dermatol*. 2020;19:850-854. doi: 10.1111/jocd.13313
8. Vachiramon V, Techakajornkeart R, Leerunyakul K, Chayavichitsilp P. Accuracy of a high-intensity focused ultrasound device with and without real-time visualization system in face and neck treatment of skin laxity. *J Cosmet Dermatol*. 2021;20:132-137. doi: 10.1111/jocd.13512
9. Kwack MH, Lee WJ. Efficacy of a home-used high-intensity focused ultrasound device on wrinkle reduction. *Skin Res Technol*. 2023;29:e13266. doi: 10.1111/srt.13266
10. Aşiran Serdar Z, Aktaş Karabay E, Tatlıparmak A, Aksoy B. Efficacy of high-intensity focused ultrasound in facial and neck rejuvenation. *J Cosmet Dermatol*. 2020;19:353-358. doi: 10.1111/jocd.13008
11. Han HS, Park JW, Kim SY, Yoo KH, Choi SY, Kim BJ. Safety and efficacy of high-intensity focused ultrasound for treatment of periorbital, perioral, and neck wrinkles: prospective open single-center single-arm confirmatory clinical trial. *Dermatol Ther*. 2022;35:e15420. doi: 10.1111/dth.15420
12. Lio ML, Chang CC, Chuang ADC, Tsai LC, Chen CC. Quantified facial rejuvenation utilizing high intense focus ultrasound with multiple penetrative depths. *Clin Cosmet Investig Dermatol*. 2022;15:489-496. doi: 10.2147/CCID.S350556
13. Araco A. Prospective study on clinical efficacy and safety of a single session of microfocused ultrasound with visualization for collagen regeneration. *Aesthet Surg J*. 2020;40:1124-1132. doi: 10.1093/asj/sjz363
14. Ayatollahi A, Gholami J, Saberi M, Hosseini H, Firooz A. Systematic review and meta-analysis of safety and efficacy of high-intensity focused ultrasound (HIFU) for face and neck rejuvenation. *Lasers Med Sci*. 2020;35:1007-1024. doi: 10.1007/s10103-020-02957-9
15. Fabi SG. Noninvasive skin tightening: focus on new ultrasound techniques. *Clin Cosmet Investig Dermatol*. 2015;8:47-52. doi: 10.2147/CCID.S69118
16. Aşiran Serdar Z, Tukenmez Demirci G. The efficacy and safety of high-intensity focused ultrasound on upper arm laxity treatment: our experience with five patients. *J Cosmet Dermatol*. 2020;19:2339-2341. doi: 10.1111/jocd.13296
17. Alizadeh Z, Halabchi F, Bodaghabadi Z, et al. Non-invasive body contouring technologies: an updated narrative review. *Aesthetic Plast Surg*. 2024;48:659-679. doi: 10.1007/s00266-023-03647-x
18. Alizadeh Z, Halabchi F, Mazaheri R, Abolhasani M, Tabesh M. Review of the mechanisms and effects of noninvasive body contouring devices on cellulite and subcutaneous fat. *Int J Endocrinol Metab*. 2016;14:e36727. doi: 10.5812/ijem.36727
19. Al-Jumaily AM, Liaquat H, Paul S. Focused ultrasound for dermal applications. *Ultrasound Med Biol*. 2024;50:8-17. doi: 10.1016/j.ultrasmedbio.2023.09.004
20. Hong JY, Ko EJ, Choi SY, et al. Efficacy and safety of high-intensity focused ultrasound for noninvasive abdominal subcutaneous fat reduction. *Dermatol Surg*. 2020;46:213. doi: 10.1097/DSS.0000000000002016

21. Jalian HR, Avram MM. Body contouring: the skinny on noninvasive fat removal. *Semin Cutan Med Surg*. 2012;31:121-125. doi: 10.1016/j.sder.2012.02.004
22. Ko EJ, Hong JY, Kwon TR, et al. Efficacy and safety of non-invasive body tightening with high-intensity focused ultrasound (HIFU). *Skin Res Technol*. 2017;23:558-562. doi: 10.1111/srt.12371
23. Kennedy J, Verne S, Griffith R, Falto-Aizpurua L, Nouri K. Non-invasive subcutaneous fat reduction: a review. *J Eur Acad Dermatol Venereol*. 2015;29:1679-1688. doi: 10.1111/jdv.12994
24. Kwon HH, Yang SH, Choi M, Jung JY, Park GH. Tightening and reduction of unwanted submental fat using triple-layer high-intensity focused ultrasound: clinical and 3-dimensional imaging analysis. *Dermatol Surg*. 2021;47:1595-1600. doi: 10.1097/DSS.0000000000003241
25. Guth F, Bitencourt S, Bedinot C, Sinigaglia G, Tassinary JAF. Immediate effect and safety of HIFU single treatment for male subcutaneous fat reduction. *J Cosmet Dermatol*. 2018;17:385-389. doi: 10.1111/jocd.12466
26. Khong SJML, Ismail AH, Sujani S, Devindaran N, Abdul Rashid MF, Mohd Zaman UMS. Safety and efficacy of high-intensity focused ultrasound and monopolar radiofrequency combination therapy for skin tightening: a retrospective study in Malaysia. *Malays J Med Sci*. 2024;31:114-123. doi: 10.21315/mjms2024.31.1.10
27. Contini M, Hollander MHJ, Vissink A, Schepers RH, Jansma J, Schortinghuis J. A systematic review of the efficacy of microfocused ultrasound for facial skin tightening. *Int J Environ Res Public Health*. 2023;20:1522. doi: 10.3390/ijerph20021522
28. Gold M, Biesman B, Cohen JL, et al. Real-world experience using a multimodality system using intense pulsed light, radiofrequency microneedling, high-intensity focused ultrasound, or thermal radiofrequency, 808, HIFU for skin rejuvenation treatment. *J Cosmet Dermatol*. 2024;23:1-11. doi: 10.1111/jocd.16577
29. Woodward JA, Fabi SG, Alster T, Colón-Acevedo B. Safety and efficacy of combining microfocused ultrasound with fractional CO_2 laser resurfacing for lifting and tightening the face and neck. *Dermatol Surg*. 2014;40:S190-S193. doi: 10.1097/DSS.0000000000000228
30. Arora RT, Arora S, Kaushik I, Patil C. Non-surgical lower face contouring in an Indian patient: a case study. *Cureus*. 2023;15:e35508. doi: 10.7759/cureus.35508
31. Byun J, Kang Y, Park S, Hong W. Efficacy of radiofrequency combined with single-dot ultrasound efficacy for skin rejuvenation: a non-randomized split-face trial with blinded response evaluation. *Skin Res Technol*. 2023;29:e13452. doi: 10.1111/srt.13452
32. Fabi SG, Goldman MP, Mills DC, et al. Combining microfocused ultrasound with botulinum toxin and temporary and semi-permanent dermal fillers: safety and current use. *Dermatol Surg*. 2016;42:S168-S176. doi: 10.1097/DSS.0000000000000751
33. Araco A, Araco F, Raichi M. An exploratory study of PN HPT for treating post-surgical atrophic and depressed scars. *J Cosmet Dermatol*. 2025;24:e16764. doi: 10.1111/jocd.16764
34. Araco A, Araco F, Raichi M. Clinical efficacy and safety of polynucleotides highly purified technology (PN-HPT®) and cross-linked hyaluronic acid for moderate to severe nasolabial folds: a prospective, randomized, exploratory study. *J Cosmet Dermatol*. 2023;22:146-155. doi: 10.1111/jocd.15064
35. Hongcharu W, Boonchoo K, Gold MH. The efficacy and safety of the high-intensity parallel beam ultrasound device at the depth of 1.5 mm for skin tightening. *J Cosmet Dermatol*. 2023;22:1488-1494. doi: 10.1111/jocd.15672
36. Gold MH, Biron J. Efficacy and safety of high-intensity, high-frequency, non-focused ultrasound parallel beams for facial skin laxity. *J Cosmet Dermatol*. 2024;23:117-123. doi: 10.1111/jocd.16098
37. Oku K. Vectorized facial skin tightening: a study on the Thermal Thread Technique™ utilizing high-intensity, high-frequency, parallel ultrasound beam. *Lasers Surg Med*. 2024;56:355-360. doi: 10.1002/lsm.23771
38. Kumar V, Jain A, Vadera S, Shome D, Kapoor R. Effectiveness of HIFU therapy for nonsurgical facial and body contouring: a systematic review of prospective and experimental studies. *Plast Reconstr Surg*. 2023;151:533-544. doi: 10.1097/PRS.0000000000009912
39. Wong A, Lowery AS, Bloom JD. Ultrasound therapy for the skin. *Facial Plast Surg Clin North Am*. 2023;31:503-510. doi: 10.1016/j.fsc.2023.05.008
40. Pavicic T, Ballard JR, Bykovskaya T, et al. Microfocused ultrasound with visualization: consensus on safety and review of energy-based devices. *J Cosmet Dermatol*. 2022;21:636-647. doi: 10.1111/jocd.14666
41. Kim J, Kim J, Lee DK, Shin EJ, Chang JH. High-intensity focused ultrasound linear array and system for dermatology treatment. *Ultrasonics*. 2024;145:107477. doi: 10.1016/j.ultras.2024.107477
42. Maas CS, Joseph JH. Safety and effectiveness of microfocused ultrasound with visualization for the correction of moderate to severe atrophic acne scars. *J Drugs Dermatol*. 2019;18:1109-1114.
43. Vachiramon V, Jurairattanaporn N, Harnchoowong S, Chayavichitsilp P. Non-invasive high-intensity focused ultrasound for UV-induced hyperpigmentation in Fitzpatrick skin types III and IV: a prospective, randomized, controlled, evaluator-blinded trial. *Lasers Med Sci*. 2018;33:361-367. doi: 10.1007/s10103-017-2393-5
44. Yi KH, Kim E, Wan J, et al. Noninvasive high-intensity focused ultrasound for skin brightening efficacy using a topical agent containing glutathione and hyaluronic acid. *J Dermatolog Treat*. 2024;35:2406932. doi: 10.1080/09546634.2024.2406932
45. Fritz K, Salavastru C. Ways of noninvasive facial skin tightening and fat reduction. *Facial Plast Surg*. 2016;32:276-282. doi: 10.1055/s-0036-1584214
46. Catinis CA, Chilukuri S. The benefit of combined radiofrequency and ultrasound to enhance surgical and nonsurgical outcomes for the face and neck. *Plast Aesthetic Res*. 2020;7:9. doi: 10.20517/2347-9264.2019.68
47. Kiedrowicz M, Duchnik E, Wesołowska J, et al. Early and long-term effects of abdominal fat reduction using ultrasound and radiofrequency treatments. *Nutrients*. 2022;14:3498. doi: 10.3390/nu14173498
48. Haykal D, Cartier H, du Crest D, Galadari H, Landau M, Haddad A. What happens when simulations get real and cosmetic dermatology goes virtual? *J Cosmet Dermatol*. 2023;22:2682-2684. doi: 10.1111/jocd.15888