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REVIEW ARTICLE

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# Noninvasive skin imaging in esthetic medicine—Why do we need useful tools for evaluation of the esthetic procedures

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## Abstract

**Background:** Despite the constant development of aesthetic medicine, there is still a lack of objective methods to assess the effectiveness of antiaging treatments and their impact on the skin. Histopathological examination of the skin section provides most of the key information about the condition of the skin, but it is an invasive procedure that requires a skin biopsy, which may be associated with the formation of a scar that is considered to be an aesthetic defect. Non-invasive imaging methods of the skin like dermoscopy, skin ultrasonography and reflectance confocal microscopy may be a useful solution.

**Aims and Methods:** In this systematic review, we present the possible application of noninvasive skin imaging methods in esthetic medicine. The literature search was conducted via medical database (PubMed, Google Scholar).

**Results:** The research suggests the use of dermoscopy during laser therapy, for the targeted treatment of vascular lesions and appropriate adjustment of laser parameters. Skin ultrasonography, especially high-frequency ultrasonography, has been widely used in aesthetic medicine-during and after volumetric treatments and in the assessment of the effects of anti-cellulite therapies, treatments that correct discolorations and improve skin quality. Publications also highlight the importance of reflexive confocal microscopy in the evaluation of the results of anti-aging treatments using the fractional laser, moisturizing preparations or micro puncturing combined with hyaluronic acid injections.

**Conclusion:** Non-invasive skin imaging methods are useful tools for pre- and postoperative assessment in aesthetic medicine and their wide application may help to objectively assess the impact of anti-aging procedures on the skin.

KEYWORDS
dermoscopy, esthetic medicine, high-frequency ultrasonography, reflectance confocal microscopy, ultrasonography

  

## 1 | INTRODUCTION

With the increasing frequency of esthetic medicine treatments and the development of new procedures, it becomes necessary to evaluate their effectiveness with objective research meta-data. Nowadays, skin biopsy with a histopathological examination still remains the most reliable and relevant source of information about the skin condition. It is an invasive procedure, sometimes associated with complications and the formation of scars, which for some patients are associated with a significant esthetic defect.

Difficulties in the objective assessment of postoperative effects in esthetic medicine may be solved by noninvasive skin imaging methods, which allow for painless assessment of skin condition before, during, and after the procedure. Publications emphasize the use of dermoscopy, skin ultrasound imaging, and reflectance confocal microscopy in pre- and postoperative evaluations, but so far it was not possible to develop a gold standard for the evaluation of the effectiveness of anti-aging procedures.

## 2 | DERMOSCOPY

Dermoscopy, also known as dermatoscopy, skin surface microscopy, or epiluminescence microscopy, is a simple, noninvasive in vivo diagnostic method, which has been widely used in dermatology. It allows for a more accurate assessment of skin lesions compared to the naked eye and analysis of detailed morphological and vascular structures, thus increasing diagnostic sensitivity. Apart from enlarging the image, dermoscopy also makes it possible to visualize the color and structure of the epidermis, the dermal-epidermal border, and the superficial layer of dermis (papillary layer). It is often called a "bridge" between the unarmed eye and the histopathological examination—the structures visible in dermoscopy correlate with the changes in the histopathological image.[1-3]

There are reports about the application of dermoscopy during laser therapy. This method may be helpful in the targeted treatment of vascular lesions, appropriate selection of laser parameters, which enhances the effectiveness of therapy. Dermoscopy proves to be useful during vascular laser therapy, used to treat erythema, telangiectasias, or port wine stain vascular lesions. In the case of large vascular lesions, macroscopic evaluation is usually sufficient, while in subtle erythema/ telangiectasias on the skin with significant photo damaged or melasma, dermoscopy facilitates proper pre-operative diagnosis, selection of the place and parameters of laser therapy and accurate assessment of the effectiveness of the treatment. Also in the case of melasma treatment, dermoscopy may prove to be a useful supplementary tool, which allows the detection of sometimes hardly noticeable vascular components. In the cases of identification of vascular lesions, better effects can be achieved by adding a vascular laser to the therapy.[4] Furthermore, scientific publications suggest the potentially important role of dermoscopy in the evaluation of the usefulness of port wine stains treatment using the Pulsed Dye Laser. Several dermoscopic features and patterns correlate with vessel depth and response to laser therapy. Dot and glomerular vessels are characteristic of superficial dilatation of blood vessels and most often respond better to treatment, while reticular or linear vessels correspond to deeper vascular plexuses and the response to treatment is usually worse. The diameter of a vessel may also have significant predictive value—elongated vessels with small diameters show inferior response to pulsed dye laser therapy.[4-7]

Considering the price of the procedures and patients' expectations, dermoscopy as a predictive method to assess the effectiveness of the procedure using pulsed dye laser seems to be useful in clinical practice.[4-7]

The correlation of dermoscopic patterns with histopathological findings could be helpful in qualification for laser procedures, as a useful tool for the differentiation of lentigo simplex and lentigo maligna and the diagnosis of other skin cancer. The exclusion of skin cancer is necessary before laser therapy. There are a lot of advantages of the dermoscopy, but there are also some limitations such us low magnification, subjective assessment depending on the skills and experience of the person performing the examination, difficulties in accessing lesions located on the mucous membranes or in furrows and skin folds. Dermoscopy seems to be of great importance in esthetic medicine. The possible applications of dermoscopy during laser procedures include vascular laser therapy used to treat erythema, telangiectasias, or port wine stain vascular lesions. It is also a predictive method to assess the effectiveness of the procedure using pulsed dye laser, which could be useful in clinical practice, especially considering the price of the procedures and patients' expectations.[4-7]

## 3 | SKIN ULTRASONOGRAPHY

Ultrasonography (USG), used on a large scale in internal organ imaging, has had limited use in dermatology and esthetic medicine in the past. The breakthrough was the construction of high-frequency heads, which allowed for more accurate skin imaging. The development of ultrasonography technology over the last thirty years has contributed to increasingly accurate skin imaging. Nowadays, there are high-frequency ultrasound machines (HF-USG) available on the market with transducers in the 20-100 MHz range, which allow the visualization of epidermis, dermis, the upper part of subcutaneous tissue, as well as appendages (hair follicles, nails) and small blood vessels. The limitation of HF-USG is the maximum depth of 32 MHz, which is up to 6 mm, preventing the imaging of deeper structures of subcutaneous tissue or fascia. In classical ultrasonography, it is not possible to assess the echoes of the epidermis and dermis, but it is effective for the visualization of the entire subcutaneous tissue and fascia. Modern devices are also equipped with the function of measurement of tissue elasticity, which is an important, useful parameter in the assessment of skin condition, and it has found its application in cosmetology and esthetic medicine. During the skin ultrasound examination, the following physical parameters are used: measurement of skin layer thickness, measurement of blood vessel diameter, measurement of the dermis and subcutaneous tissue echogenicity, and evaluation of flow in small venous vessels. Additionally, in devices with active Doppler function, it is possible to assess the blood flow.[8-13]

The ultrasound image in HF-USG of healthy skin is divided into three layers: the entrance echo (highly echogenic, irregular bundle with hyperechoic areas, the keratinized corneous cell of the stratum corneum), the dermis echo (diffuse echo with a variable echogenicity depending on location, amount of collagen fibers and hydration), and subcutaneous tissue with very low or no echogenicity. The higher the number of collagen fibers, the higher the echogenicity of the tissue, while the higher the amount of intercellular substance, the lower the echogenicity. Ultrasound examination should be performed on affected skin compared to healthy skin. In the case of some disease processes, the dermis reveals an unechogenic space caused by the presence of edema in the dermis. Skin diseases occurring with dermal fibrosis (or with thickening of collagen fibers in the course of the disease) cause a significant increase in the echogenicity of the dermis in the ultrasound image. On the other hand, pathologies causing damage to collagen fibers, accumulation of inflammatory or neoplastic cells in the dermis will reduce the echogenicity of the dermis. The image of the skin also changes with age—the thickness of individual layers of skin and the number of appendages change. In the evaluation of the skin using the classic ultrasound, the epidermis and dermis form a common, hyperechogenic layer, without the possibility of analysis of the individual layers, and is used mainly for the evaluation of subcutaneous tissue and fascia. As in the case of the dermis, inflammatory states causing swelling of the subcutaneous tissue result in a reduction of its echogenicity, while conditions associated with fibrous connective tissue hypertrophy cause an increase in echogenicity. During the imaging of the fascia, the analysis of its structure, evaluation of inequalities and boundaries are necessary.[8-13]

Currently, both classical ultrasound and high-frequency ultrasound are successfully implemented in dermatology, cosmetology, and esthetic medicine. Based on the analysis of the parameters obtained during the examination, including the thickness and echogenicity of individual skin layers, it becomes possible to draw conclusions useful in the diagnosis of a specific skin condition. Research on skin imaging using ultrasonography focuses on two pillars—the assessment of healthy skin and factors affecting changes in its structure and the diagnosis and the monitoring of skin diseases. Alterations in the thickness and echogenicity of each skin layer are related to the processes of endogenous skin aging associated with biological aging and the impact of ultraviolet radiation on the skin (photoaging). Many researchers emphasize that as a result of the skin aging process, a subepidermal low echogenic band (SLEB) forms in the dermis (Table 1).

Thanks to HF-USG, it is possible to assess and classify skin deterioration. Histological changes over the course of the passing years such as thinning of the dermis, reduction of the collagen fibers, degeneration of elastin fibers, and loss of moisture all affect the echogenicity during HF-USG testing. Many researchers emphasize that as a result of the skin aging process, a subepidermal low echogenic band (SLEB) forms in the dermis. Photoaging, solar elastosis, changes in collagen fiber weave architecture and glycosaminoglycans aggregation result in skin imaging changes and SLEB formation. The changes in the thickness and echogenicity of individual layers of skin are related to the process of aging of the skin associated with age and the impact of ultraviolet radiation on the skin (photoaging). The changes in the skin echogenicity and SLEB also depend on individual's predispositions and anatomical location; therefore, the use of HF-USG as an objective tool for the assessment of skin aging requires further studies.[8-13]

With the development of ultrasonography, as well as the popularity of esthetic medicine, the number of publications on applications of ultrasonography in this field of medicine is constantly growing. Based on the literature review, the potential applications of classical ultrasound and HF-USG include.

- evaluation of the course and effects of anti-cellulite therapies (anti-cellulite treatments and preparations),
- accurate assessment of the location and volume of filling preparations during volumetric procedures,
- differentiation of the complications after the filling procedures (eg, differentiation of hyaluronic acid deposits from granulomas around the foreign body),
- evaluation of vascular flow during or after volumetric procedures,
- visualization of the vessel and selection of the laser beam during the closure of small telangiectasias,
- the corrective treatment of the results after the hyperpigmentation correction procedures, evaluation of the efficacy of skin quality improvement and anti-aging treatments (eg, microdermabrasion or fractional laser treatments).[8-13]

### 3.1 | Ultrasonography in anti-cellulite therapies

In the evaluation of cellulite severity and monitoring of anti-cellulite therapies, so far no objective, repeatable method has been clearly defined, and this evaluation is usually based on physical examination. According to the published papers, there have been attempts to assess the severity of cellulite using computed tomography and magnetic resonance imaging, which were not applicable in everyday practice due to the availability, time, and costs of such studies. The safety and availability of ultrasound examination make it a potentially objective method for the assessment of cellulite, as it is visible in ultrasound as ingrown strands of subcutaneous tissue in the dermis. The key features evaluated in HF-USG to assess the severity of cellulite are as follows: thickness of dermis, length and area of subcutaneous tissue bands growing into the dermis, occurrence/absence of edema, and echogenicity of dermis. In case of classical ultrasonography, the parameters measured are as follows: thickness of subcutaneous tissue and elasticity. The study by Mlosek analyzed the efficacy of anti-cellulite therapies (Body Wrapping, anti-cellulite cream, dietary supplement, and RF radio waves) using high-frequency ultrasound—after the treatment the length and area

**TABLE 1** Summary of the possible application of noninvasive skin imaging methods in aesthetic medicine.

| Category | Type | Characteristic | Role in esthetic medicine | Limitations |
|---|---|---|---|---|
| Dermoscopy | | - simple, noninvasive in vivo diagnostic method,<br>- can enlarging the image, visualize the color and structure of the epidermis, the dermal-epidermal border and the superficial layer of dermis (papillary layer), analysis of detailed morphological and vascular structures [1-3] | application of dermoscopy during laser therapy: vascular laser therapy, used to treat erythema, telangiectasias or port wine stain vascular lesions [4] | none, can be useful in clinical practice considering the price of the procedures and patients' expectations [4-7] |
| Skin ultrasonography | Classical | effective for the visualization of the entire subcutaneous tissue and fascia [8-13] | the assessment of healthy skin and factors affecting changes in its structure and the diagnosis and the monitoring of skin diseases [8-13] | not possible to assess the echoes of the epidermis and dermis [8-13] |
| | Classical & High-frequency ultrasonography (HF-USG) | | - evaluation of the course and effects of anti-cellulite therapies (anti-cellulite treatments and preparations),<br>- accurate assessment of the location and volume of filling preparations during volumetric procedures,<br>- Differentiation of the complications after the filling procedures (eg, differentiation of hyaluronic acid deposits from granulomas around the foreign body),<br>- evaluation of vascular flow during or after volumetric procedures,<br>- visualization of the vessel and selection of the laser beam during the closure of small telangiectasias,<br>- the corrective treatment of the results after the hyperpigmentation correction procedures, evaluation of the efficacy of skin quality improvement and anti-aging treatments (eg, microdermabrasion or fractional laser treatments) [8-13] | |
| | High-frequency ultrasonography (HF-USG) | - with transducers in the 20-100 MHz range,<br>- allow the visualization of epidermis, dermis, upper part of subcutaneous tissue, appendages (hair follicles, nails), and small blood vessels<br>- with the function of measurement of tissue elasticity [8-13] | - the assessment of healthy skin and factors affecting changes in its structure and the diagnosis and the monitoring of skin diseases<br>- possible to assess and classify skin deterioration (thinning of the dermis, reduction of collagen fibers, degeneration of elastin fibers, and loss of moisture affect the echogenicity), photoaging, solar elastosis [8-13] | the maximum depth of 32 MHz, which is up to 6 mm, preventing the imaging of deeper structures of subcutaneous tissue or fascia [8-13] |

(Continues)

**TABLE 1** (Continued)

| Category | Type | Characteristic | Role in esthetic medicine | Limitations |
|---|---|---|---|---|
| Elastography | | is an ultrasound technique that allows to quantitatively determine the degree of skin tension, regardles of its acoustic impedance and blood flow [18] | assessing the degree of skin tension by shear wave elastography (SWE), which measures the speed at which a wave generated by the head propagates along the examined tissue [18] | further studies are necessary to broaden the recommendationsfor the use of SWE in other procedures [18] |
| Reflectance confocal microscopy (RCM) | | - a modern diagnostic method that is painless and noninvasive for the patient<br>- enables in vivo tissue imaging with a resolution similar to histopathological examination<br>- allows for imaging of individual layers of the epidermis, dermal-epidermal border, papillary layer of dermis and appendages<br>- allows real time visualization of blood flow (in vascularized skin lesions) [19,20] | - assess the hydration of the epidermis<br>- assess the course and effects of skin aging and the effectiveness of certain products and anti-aging treatments [21-23] | - the extent of the imaged part of the skin (up to the papillary layer of the dermis)<br>- the high price of the apparatus |

of subcutaneous tissue bands growing into the dermis was reduced, the echogenicity of the dermis increased due to the regeneration of collagen, reduction of edema of the dermis, and decrease in the thickness of the subcutaneous tissue was also observed.[10,14]

## 3.2 | Application of ultrasonography in volumetric procedures

Many publications also emphasize the role of HF-USG in filler procedures—it enables better control of the location in which the filler is administered, evaluation of the existing volume, thus improving the quality of the procedure and reducing the risk of complications. Depending on the purpose and plan of the procedure, differences in ultrasound images are observed—after the injection of the filler into the dermis, an increase in echogenicity is visible, and if the substance is placed under the dermis, numerous nonechogenic "pearls" are visible, while the filler in the subcutaneous tissue is visible as a regular, well-defined, hypoechogenic mass. The image in HF-USG also depends on the type of filler, which may be useful in assessing potential complications after certain substances. The image in HF-USG also depends on the type of filler, which may be useful in evaluating potential complications after certain preparations.

HF-USG is sometimes also used during the procedure to assess the exact location of the preparation. In classical ultrasound, the deposits of preparations with hyaluronic acid are visible as round or oval nonechogenic pseudocysts. Thanks to the visualization of the local blood flow, the existence of inflammation, the size and location of the material, and the evaluation of the tissue around the filling preparation, HF-USG is a useful method in the assessment of immediate and late postoperative complications, as well as in the determination whether the preparation has been absorbed, repositioned or fragmented. The method may also be useful in determining the location during the dissolution of hyaluronic acid preparations using hyaluronidase.[15]

In the case of late complications occurring several months or years after surgery, the differentiation between nodular deposits of the filler and granulomatous reactions around the foreign body may be clinically very difficult. The studies confirm the potential use of ultrasound to differentiate these states—the deposits of the filler can be seen as hypoechogenic, well delimited from the environment, whereas the granules formed after the injection of hyaluronic acid form hyperechogenic structures with peripheral reflections.[16,17]

## 3.3 | Additional potential applications of ultrasonography in esthetic medicine

Another practical application of HF-USG is sclerotherapy/ microsclerotherapy of small vessels. Ultrasound is very useful during the puncture and in the evaluation of the postoperative diameter of the vessels. HF-USG also allows for greater control during the procedure of closure of the telangiectasias using laser or IPL—it allows to visualize the vessels and assess their size and morphology, estimating the thickness of the dermis, so that the penetration of the laser beam can be selected. HF-USG improves the quality and effectiveness of vessel closure treatments using a laser or IPL.[8-13]

Thanks to the ability to evaluate certain epidermal and dermis parameters, HF-USG has also been used in studies on the effectiveness of certain anti-aging treatments such as microdermabrasion or fractional laser. As a result of the physical effect of diamond crystals on the surface of the epidermis, after the microdermabrasion procedure in HF-USG a decrease in its thickness is visible. Microdermabrasion, by stimulating microcirculation in the skin, causes better hydration of the dermis, visible in HF-USG as a decrease in dermis echogenicity. Skin imaging through HF-USG is also an objective method to assess changes in the skin after treatment with fractional laser ($CO_2$). In the HF-USG examination, a significant increase in dermis echogenicity can be observed as a result of collagen remodeling.[8-13]

## 4 | ELASTOGRAPHY

Ultrasound elastography is an ultrasound technique that allows to quantitatively determine the degree of skin tension, regardless of its acoustic impedance and blood flow. A very popular technique nowadays is tension elastography (eng. strain elastography, SE), which assesses susceptibility to deformation of the examined tissue during controlled compression of the ultrasound head on it. The result of SE is then expressed by a semi-quantitative colored scale or by a strain ratio (SR) calculated by dividing the susceptibility to strain of the tested tissue by the predetermined reference area. Another elastographic technique is shear wave elastography (SWE), which measures the speed at which a wave generated by the head propagates along the examined tissue. The results of the SWE are expressed as Young's coefficient (in kPa) or as the velocity of the displacement wave (in m/s), which in the tests performed were found to be more accurate and more repeatable than those obtained by the SE method.

The use of elastography in assessing the degree of skin tension was for a long time considered unreasonable due to difficulties resulting from the technical aspects of ultrasonography—the examined tissue was too close to the head. This limitation was eliminated with the introduction of HF-USG, dedicated to small, superficially located areas of interest (eng. regions of interest, ROIs).

SWE as an objective method of skin tone evaluation was applied to assess the effectiveness of HIFU (eng. high-intensity focused ultrasound) treatment performed on the face for esthetic purposes. It was shown that 60 days after the procedure, facial skin tension improved in all participants (57 women).[18] This confirms the validity of this method in the assessment of the efficacy of esthetic medicine procedures, and further studies are necessary to broaden the recommendations for the use of SWE in other procedures.

## 5 | REFLECTANCE CONFOCAL MICROSCOPY

Reflectance confocal microscopy (RCM) is a modern diagnostic method that is painless and noninvasive for the patient, which enables in vivo tissue imaging with a resolution similar to histopathological examination. It is increasingly popular and widely used in dermatology and esthetic medicine. This method employs a confocal laser microscope, in which the light source is a diode laser, filling the image with the appropriate resolution and contrast.

The equipment generates a black and white horizontal cross-section of skin layers with a resolution of about 0.5-1.0 μm in the horizontal plane and 4-5 μm in the axial plane. The range reaches the depth of 200 - 300 μm, which allows for imaging of individual layers of the epidermis, dermal-epidermal border, papillary layer of dermis, and appendages. The device currently available on the market allows visualization of a 500x500 μm skin fragment. During the examination, a mosaic of about 100 images is created, creating an image with an area of 8 × 8 mm. Due to the sequential imaging function at specific skin depths, it is also possible to obtain a three-dimensional image of the marked field. In RCM, a black and white image is generated, in which individual structures are characterized by different contrast generation potential—the largest source of contrast (elements are shown as the brightest) is melanin and melanosomes, as well as keratin (present in the stratum corneum, hair stem), for structures indirect refractive properties include the cytoplasm of granulocytes, the cytoplasm of keratinocytes of the spinous layer of the epidermis, keratohyalin grains, and nucleolus, while low refraction (elements visible as darker) is characterized by collagen fibers, lymphocytes, and red blood cells. Air, cell nuclei, and blood serum cannot generate contrast in RCM, so they are the darkest elements of the resulting image. The currently used confocal microscopes also allow real-time visualization of blood flow (in vascularized skin lesions).[19,20]

The most frequently used application of RCM is the differentiation between mild and malignant pigmented changes. Reflectance confocal microscopy is also used in esthetic medicine, anti-aging, and cosmetic industry. Thanks to RCM, it is possible to objectively assess the hydration of the epidermis, thereby evaluating the effectiveness of treatments or cosmetics with a moisturizing effect. In the case of dry skin, RCM shows an uneven surface of the epidermis, caused by the presence of scales and dilated epidermis fissures with irregular edges. The circular and grainy layer shows a honeycomb pattern, but with less marked boundaries between individual keratinocytes. The application of the moisturizer induces a significant reduction of the skin scaling and size of the epidermis fissures and reduces the irregularity of the surface and structure. Properly moisturized skin in reflectance confocal microscopy has a much more prominent regularity of epidermis architecture. Moisturizing substances also affect the space between keratinocytes. Water-in-oil preparations reach the lower layers of the epidermis very quickly; however, they are characterized by a shorter duration of the moisturizing effect. Thanks to RCM, it is possible to effectively and objectively assess the effects of preparations or moisturizing treatments, both in short- and long-term observation.[21-23]

Reflectance confocal microscopy can also be used to assess the course and effects of skin aging and the effectiveness of certain products and anti-aging treatments such as laser skin resurfacing. The changes occurring in the epidermis during the aging process, visible in the RCM, include a reduction in the thickness of the epidermis (in the late stage of skin aging visible atrophy of the epidermis), focal increase in the amount of melanin (visible in the RCM as mottled pigmentation—often clinically invisible), dyskeratosis of the epidermis cells, irregularity in the spherical, and granular layer of the epidermis (honeycomb pattern disorder), epidermis hyperplasia, polycyclic skin warts. Also, changes in the dermis that take place during the aging process are very well visible in RCM—thickened, compact collagen fibers and elastosis can be seen (collagen and elastin fibers cannot be distinguished by RCM). With the possibility to observe changes in the course of skin aging, reflectance confocal microscopy enables the monitoring of the effectiveness of anti-aging therapies with the resolution similar to histopathological examination, without the need for skin biopsy.[22,23] In Longo et al patients, RCM was used to assess the efficacy of anti-aging treatments using fractional CO2 laser. In the study group, before the procedure, using RCM skin aging was observed, mainly disseminated foci of hyperpigmentation (corresponding to numerous pigmented keratinocytes) and various degrees of collagen fibers degeneration. After 3 weeks, at the level of the epidermis in the RCM, the reduction of pigmentation foci was visible with the substitution of pigmented keratinocytes by normal epidermal cells. Additionally, in the RCM, microholes in the stratum corneum (clinically invisible) and numerous dendritic cells, spread in the epidermis, corresponding to the Langerhans cell, as well as accumulation of leukocytes in the laser-treated areas were visible. Most of the changes were observed in the RCM at the level of dermis, where the remodeling of collagen fibers has been observed. After three months, newly formed collagen fibers were visible in the RCM. In the study by Richtig et al (2011), apart from the pre-treatment evaluation (distinction of benign lentigo stains from malignant lentigo stains), the changes in the skin after lentigo stains removal with the use of Q-switch ruby laser were also observed. After 10 days following the procedure, migration of bright cells to the superficial layers of epidermis corresponding to melanin was observed which at a later stage exfoliated with the epidermal cells.[24,25] Changes in the skin after photorejuvenation using IPL (intense pulsed light) were also studied. In RCM, a statistically significant thickening of the epidermal layer, an increase in skin papillary density, and a decrease in capillary diameter were observed.[26]

Reflective confocal microscopy was also used in the assessment of postoperative stretch mark therapy using microneedling combined with hyaluronic acid injection. Before treatment, collagen fibers arranged in parallel were visible, running along the skin's tight lines, opposite to the direction of stretch marks. 60 days after therapy, intersecting, numerous collagen fibers with a high degree of refraction were observed.[27] Using RCM, the effectiveness of non-surgical blepharoplasty using Plasma Exeresis technology was also assessed—improvement in skin flaccidity and collagen quality in the dermis were examined within 30-45 days after surgery. Before the surgery, RCM had thick, collagenous fibers arranged in clusters, while after the surgery, numerous long, straight, regular fibers were observed.[28]

As the melanin is distinctly visible in skin examination in RCM, both in melanocytes producing it and the deposits of melanin in keratinocytes or melanophages, the treatment's effects of pigmentary disorders (ie, melasma, solar lentigo, postinflammatory hypo- or hyperpigmentation, and vitiligo) can be easily controlled by this tool. This was confirmed in numerous studies, showing the changes in the intensity of brightness correlating with melanin in the epidermis or upper dermis.[29-31] RCM allows to assess very precisely the depth of melanin localization in the dermis. The great advantage of this imagining technic is the fact that with one device it can be diagnosed if the lesion is either benign (melasma, solar lentigo, hyperpigmentation, and seborrheic keratosis) and can be managed by the means of esthetic medicine or cosmetological procedures, or malignant (melanoma, pigmented actinic keratosis, and basal or squamous cell carcinoma) where more radical and invasive treatment is required.

In summary, the reflectance confocal microscopy characterizes many advantages, according to its use in esthetic medicine:

- the noninvasive, rapid, painless imagining method of skin examination,
- the possibility of obtaining an image with a very high resolution similar to histopathological examination—differential diagnosis of benign and malignant lesions and thus safe and appropriate management can be introduced,
- useful method for assessing the effects of different anti-aging and cosmetic therapies, which enables dynamic in time visualizations of regions of interest.

The limitations of this method are as follows:

- the extent of the imaged part of the skin (up to the papillary layer of the dermis),
- the black and white imaging requiring special training and experience,
- the high price of the device,
- relatively smaller field of vision in comparison with other imaging techniques,
- there are still no protocols of RCM use in esthetic medicine available (more studies are needed).

## 6 | SUMMARY

Given the constant development of esthetic medicine, it seems essential to develop a comprehensive, noninvasive method for the evaluation of the effects of individual treatments and substances. Very often, the promotion of the therapies that do not have any recognized clinical trials are observed, and information about the new products is often provided only by the manufacturers. This is a very disadvantageous situation, both from the perspective of the patient and the physician, because working with such preparations or using untested equipment is not predictable, and may result in serious consequences and numerous adverse effects.

The development of objective methods of assessment before and after esthetic medicine procedures seems crucial for any further developments in this field of medicine. Noninvasive methods of skin imaging, which currently prove to be useful both in dermatology and esthetic medicine, include dermoscopy and videodermoscopy, skin ultrasonography, and reflectance confocal microscopy (Table 1).

Dermoscopy, in addition to the diagnosis of skin cancers, has also found its application in treatments using vascular lasers and also as a predictive method to assess the effectiveness of treatments involving pulsed dye laser which has proven to be useful in clinical practice. Ultrasonography is widely used in esthetic medicine to assess the effects of anti-cellulite therapies, during and after volumetric procedures and in cases of complications. Reflectance confocal microscopy is also a very promising diagnostic tool, which can be used to evaluate numerous anti-aging procedures.

## DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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