Topography of the skin surface as well as melanin and hemoglobin concentration and distribution are a mirror of the functional skin status. Changes in these features not only are a tool for early-stage diagnosis of diseases but also give an indication of the response to medical and cosmetic treatment. Therefore, their evaluation is of great interest for dermatologic research. However, although physicians can apply classification rules to visual diagnosis, the overall clinical approach is subjective and qualitative, with a critical dependence on training and experience. Over the past 20 years, several noninvasive techniques for measuring the skin’s properties have been developed and tested to extend the accuracy of visual assessment alone. Many of them were not only very precise but also very complicated; others were very simple but approximations.

In this article, a new optical, precise, user-friendly measuring system is presented to demonstrate the effectiveness of the most common laser treatments on photodamaged skin. Many of the skin changes commonly associated with aging, changes in pigmentation, telangiectasia, sallowness, and wrinkling are actually the result of sun exposure. Changes in pigmentation (blotchy brown freckles and age spots), dryness, areas of redness, thinning of the dermis, loss of elasticity, fine lines, and deep wrinkles are all signs of chronic UV exposure. Excluding injectables, surgery, and peelings, the most common procedures to improve these changes in the skin appearance are the IPL treatments and, more recently, the fractional resurfacings. Preoperative and postoperative images of patients treated with these procedures and analyzed using this new three-dimensional (D) in vivo optical skin imaging system are shown.
THE SKIN IMAGING DEVICE

The Antera 3D (Miravex, Ireland) imaging system consists of a handheld imaging device connected through a long firewire cable to a computer. The system is completed by proprietary software running on a Windows-based standard laptop or desktop personal computer. The imaging technique of Antera 3D is based on the acquisition of a number of images under varying but strictly controlled illumination conditions. Several light-emitting diodes are used to illuminate the skin with different colors and different illumination directions (Fig. 1). The acquired image data are then used for spatial and spectral analysis for reconstruction of the texture of the skin and analysis of skin constituents.

Skin texture reconstruction is achieved using a technique based on shape from shading, substantially modified to eliminate skin glare and vastly improve the accuracy of measured data. The texture reconstructed in this way is then used for quantitative skin analysis, such as depth and width of wrinkles, lesions of the skin, and overall skin roughness.

The acquired spectral data are used to map the distribution and concentration of melanin and hemoglobin. Unlike traditional imaging techniques, in which only 3 color channels (red, green, and blue) are used, the Antera 3D uses reflectance mapping of 7 different light wavelengths spanning the entire visible spectrum. This mapping allows for a much more precise analysis of the skin colorimetric properties, which are mostly determined by 2 dominant chromophores: melanin and hemoglobin. Acquired spectral images are transformed into skin spectral reflectance maps, and the skin surface shape is used to compensate for light
intensity variation due to the varying direction of incident illumination. The reflectance data are transformed into skin absorption coefficients and used to quantify melanin and hemoglobin concentrations using mathematical correlation with known spectral absorption data of these chromophores.\textsuperscript{3}

The images acquired with the Antera 3D can be visualized in several different modes: standard color skin, texture elevation map, and melanin and hemoglobin concentration maps with 2D and 3D perspective representation. The clinician can select specific skin areas for quantitative analysis and carry out before and after analyses with previously acquired images. Spot-On, the automatic matching technique that registers two or more images to one another is used to compensate for relative shifts and rotations between images, ensuring accurate data analysis. The measurement data can be presented by quickly creating a report that shows the analyzed images together with the measured values and comparison charts. Data can be stored on the computer or included in other document processing applications such as Microsoft Word or Microsoft PowerPoint.

Numeric data collected from one image must not be considered as absolute values but 2 or more images must be compared. The percentage modification of these data (data on melanin distribution, hemoglobin distribution, and surface topography) is very useful to demonstrate the effectiveness of a treatment.

**INTENSE PULSED LIGHT TREATMENT OF FACIAL AGING SKIN**

Current trends in aesthetic treatment of facial skin call for an effective adjunct to injectables or surgery. Patients look for treatment that offers a return to a more youthful appearance through restoration of even color and smoothness, relief from pigmentary sun damage, and the redness associated with ectatic vessels. In addition, this patient group requires treatments that are short and pain free and allow immediate return to all social activities.

Following more than 20 years of treatment of vascular lesions using the pulsed dye laser, new laserlike intense pulsed light (IPL) devices were...
Fig. 4. The mathematical hemoglobin variation analysis of the area of the tip of the nose of the patient in Fig. 2 clarifies an improvement of more than 33%.
Fig. 5. A 56-year-old patient before and after 4 sessions of IPL treatment. The coloured square shows the area subjected to the 3D analysis.

Fig. 6. Three-dimensional images of the patient in Fig. 5. It is visually evident that after the treatment the amount of melanin and its variation are improved.
Fig. 7. The mathematical analysis of the result implies that the melanin level is reduced by more than 25% and that its variation is improved by 15%.
Fig. 8. A 52-year-old man with a facial photoaging with prevalent vascular component. On the right, the outcome obtained after 4 sessions of treatment with IPL.

Fig. 9. The 3D aspect of the patient before and after the IPL treatment.
Fig. 10. The mathematical analysis of the hemoglobin implies that the improvement after the IPL treatment is not around 15%. 
developed at the end of the last century. These IPL devices treat these UV exposure–correlated conditions with success and provide a solution for the essential lifestyle criteria when used in a carefully administered program. This new IPL skin rejuvenation technique now has a clinical history of more than 300,000 treatments with excellent patient acceptance. IPL differs from laser light in that, rather than monochromatic single wavelength, IPL emits a noncoherent broad-spectrum light. The IPL devices used in the rejuvenation procedure emit a spectrum extending from 500 nm to 1200 nm. To customize the light energy delivery for a given procedure, the operator uses a cutoff filter, or light guide, of designated wavelength, below which the spectrum is selectively eliminated. The IPL system conforms to the principle of selective photothermolysis. For dilated vessels, as seen in patients with sun damage and rosacea, the light energy with high absorption by hemoglobin and oxyhemoglobin reaches the dermal capillary bed and selectively destroys the abnormal vessels. For sun spots and lentigos, as seen in patients with sun damage, the light crumbles the granules of melanin distributed at the dermoepidermal junction. Macrophages can then therefore remove these smaller granules of melanin. The operator controls all aspects of the light pulse, including cutoff wavelength (nm), energy level (J/cm²), pulse duration (milliseconds), pulse pattern (single, double, or triple), and delay time between pulses (milliseconds). This allows for precise control of light energy, which in this procedure is used for customization for skin type, procedure progress, and other variables.

Big vessels of the nose can be treated (Fig. 2) with few sessions of treatment combining different cutoff (590 and 560 nm), different energy (22 and 19 J/cm²), and different pulse duration and delay time. The 3D images (Fig. 3) visually clarify the effectiveness of the treatment while the report that mathematically analyses the prepictures and postpictures presents the percentage of improvement (Fig. 4).

Sunspots and irregularities of the skin color can be treated with a few sessions of treatment (Fig. 5).
Fig. 12. The mathematical analysis of the melanin variation of the patient in Figs. 8 and 11. The improvement of melanin variation was 14%.
crumbling the pigment granules at different depth. Clinical images show a change that is less easy to discern, while using the 3D system, the improvement can be better appreciated (Fig. 6) and quantified (Fig. 7).

A complete IPL treatment should result in an improvement of telangiectasia, a global reduction of the melanin amount, fewer irregularities in melanin distribution, and a smoother skin. The vascular improvement is often clinically evident (Fig. 8), whereas other features are usually not so noticeable. The 3D system can highlight the vascular improvement as well as calculate the percentage change (Figs. 9 and 10), but more benefits can be seen from the device on melanin variation (Figs. 11 and 12) and skin surface analysis (Figs. 13 and 14).

FRAC TIONAL ABLATIVE RESURFACING

The drive to attain cosmetic facial improvement with rapid recovery and minimal risk has galvanized laser skin rejuvenation. Although traditional ablative carbon dioxide (CO2) laser resurfacing was widely considered, since its emergence in the marketplace in the mid-1990s, as the gold standard, the increased risk of prolonged wound healing, infection, and pigmentary alteration spurred researchers to look for better options. As a result, the market for nonablative techniques grew fast, and many devices claimed to be efficient for wrinkle reduction and photodamaged skin improvement. However, after a critical review of recent literature, it seems clear that none of these nonablative methods are comparable with ablative skin resurfacing in terms of efficacy. At the beginning of 2000, the question was how to bring together good results, low downtime, and low risks of adverse effects. In 2004, Manstein and colleagues proposed to deliver energy, leaving intact skin bridges between one shot and another. The laser effect is located in the exposed tissue column while the healing processes start from these intact skin bridges. Through delivery of microscopic noncontiguous zones of thermal damage, it was observed that nonexposed epidermal cells and dermal tissue facilitated rapid healing. The concept of fractional

![Fig. 13. The topography of the images in Figs. 9 and 11.](image-url)
Fig. 14. The mathematical analysis of the skin roughness implies that the patient obtained an improvement of 12%.
Fig. 15. A 57-year-old woman before and 9 months after an ablative ultrapulsed fractional CO₂ resurfacing.

Fig. 16. The 3D aspect of the melanin distribution in the patient of Fig. 15.
delivery of energy was originally proposed for a nonablative wavelength but very quickly also applied to the ablative lasers. The idea was to incorporate the well-known results of ablative lasers while maintaining a short recovery time and a low incidence of adverse side effects.

Fractional ablative CO₂ resurfacing performed with an ultrapulsed device can yield good outcomes with only one session of treatment and a recovery time of 5 days. The overall appearance of the patient can be appreciated with clinical images (Fig. 15), but, using the Antera 3D device, the improvement of melanin distribution is much more clear. A report of a quantified melanin distribution modification can be easily generated (Figs. 16 and 17).

The analysis of the skin topography is exciting. The device allows not only calculation of the modification of a wide skin area (Fig. 18) but also evaluation of the degree of individual deep wrinkles before and after treatment (Figs. 19 and 20).

The device is also very helpful when a limited anatomic region is treated (Fig. 21). On lower eyelids, for example, not only can the modification of melanin distribution be evaluated and calculated (Figs. 22 and 23) but also the modification of skin topography can give precise indications of wrinkle improvement (Fig. 24). In this case, the hemoglobin concentration analysis can give a correct indication of neovascularization, which means, new collagen production in the case of higher hemoglobin presence after treatment (Fig. 25).

Fig. 17. The mathematical analysis of the area in Fig. 16 shows an improvement of the melanin variation of around 30%.

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Fig. 18. Mathematical analysis of the roughness of the area in Fig. 16. The improvement was 15%.
Fig. 19. Three-dimensional evaluation of a single deep wrinkle of the left cheek of the patient in Fig. 15.

Fig. 20. The mathematical analysis of a single deep wrinkle implies that the fractional resurfacing determined an improvement of length, width, and depth of an average of 33%.
Fig. 21. Before and after 3D images of a lower eyelid treated with an ablative ultrapulsed fractional CO₂ resurfacing.

Fig. 22. Areas of melanin analysis of the previous patient.
DISCUSSION

All aesthetic procedures need an objective evaluation method. Simple visual analog score scales can be used, but their reliability depends on evaluators’ experience. Conventional methods of evaluation have included photographic and clinical assessment, which have inherent limitations. Computerized image analysis of silicone replicas has been shown to be a reproducible objective technique for measuring skin topography, but it is complex and cannot be used during everyday activities. The 3D in vivo imaging system we are using provides a real-time, precise, quick, and objective analysis of patient-specific characteristics potentially enabling clinicians to predict...
Fig. 24. Wrinkles of the lower eyelid improved by 25%.
the limitations and efficacy of various aesthetic procedures.

**SUMMARY**

It is now possible to objectively quantify changes in skin hemoglobin, melanin, and surface contour in 3D.

This tool is useful for revealing the optimal treatment of skin surface in aesthetic facial surgery.

**REFERENCES**


![Fig. 25. Hemoglobin variation of the eyelid shown in Fig. 21. A higher presence of hemoglobin means neovascularization and therefore new collagen formation.](image-url)